S·P·A·B

BRIEFING

Lime

THE BUILDING LIMES FORUM

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Contents

Cover: New lime work is vulnerable to rapid drying on warm or windy days so is protected with hessian.
Image: Ralph Hodgson

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Introduction

Douglas Kent, technical and research director, Society for the Protection of Ancient Buildings and Building Limes Forum member.

An understanding of lime is fundamental to the repair and long-term protection of our precious stock of historic buildings. Lime-based materials are also emerging into the mainstream within low carbon construction systems. This is a timely moment for two of lime's leading advocates - the SPAB in association with the Building Limes Forum (BLF) - to consider the material's value and potential.

Lime is a versatile natural material which was employed in the construction of nearly all surviving old buildings in Britain. The word 'lime' refers to quicklime or slaked lime, widely used to form the binder for mortars, plasters, renders and washes - a lime-based building system that often began with lime being burnt in small-scale local kilns.

To understand why the use of lime is not as prevalent as it once was we need to look back to the period around the First World War. This was a time of huge change to the structure of British society, including the loss of skills, the demise of the country house and an era, also, when we saw a not unrelated change in construction methods and materials.

The move from 'traditional' solid to 'modern' cavity wall construction is generally taken as pre- and post-1919. This shift included a change away from time-honoured approaches employing lime to the use of Portand cement and, gradually, other materials such as plastic paints and pre-mixed gypsum plaster.

By the mid-20th century, the use of lime had all but died out in the UK, other than as an additive or 'plasticiser' in cement; the past tradition reflected simply in local street names that allude to where old lime kilns once stood. Unfortunately, the new 'wonder' materials that replaced lime were not to be the panacea once believed – especially when used on traditionally constructed buildings.

Importantly, unlike numerous modern products, lime-based materials let structures 'breathe' and move gently – essential properties with old buildings. The breathable nature of lime helps maintain the building's equilibrium, controlling moisture and dampness, and thereby offering health benefits, internal comfort and protecting the building's fabric from damage. Lime-based materials contribute characteristic soft textures, weather gracefully and avoid the bland uniformity often associated with modern products. Lime can also bring environmental benefits and, from structural and aesthetic perspectives, avoids the necessity of regular expansion joints to compensate for thermal movement as required with cement mortars.

As with any craft, working with lime demands skill but it is not a mysterious material or, necessarily, a particularly difficult one to use. Indeed, many would say they prefer working with lime to modern materials. The SPAB held its first *Lime Day* back in 1976 while the BLF was founded in 1992 to promote the development of expertise and understanding in the use of lime in building.

Lime is not a relic technology as some would claim. Far from it, lime has real, practical benefits and is at the forefront of a number of exciting developments in both conservation and sustainable construction. This *SPAB Briefing* aims, through the words of some of the leading practitioners in the field, to explain the exciting role lime has to play in the future of our built environment and we are delighted to come together with the BLF to offer this insight.

IMAGE: DOUGLAS KENT/DAVID GIBSONE

The generic families of limes and cements (simplified chemistry).

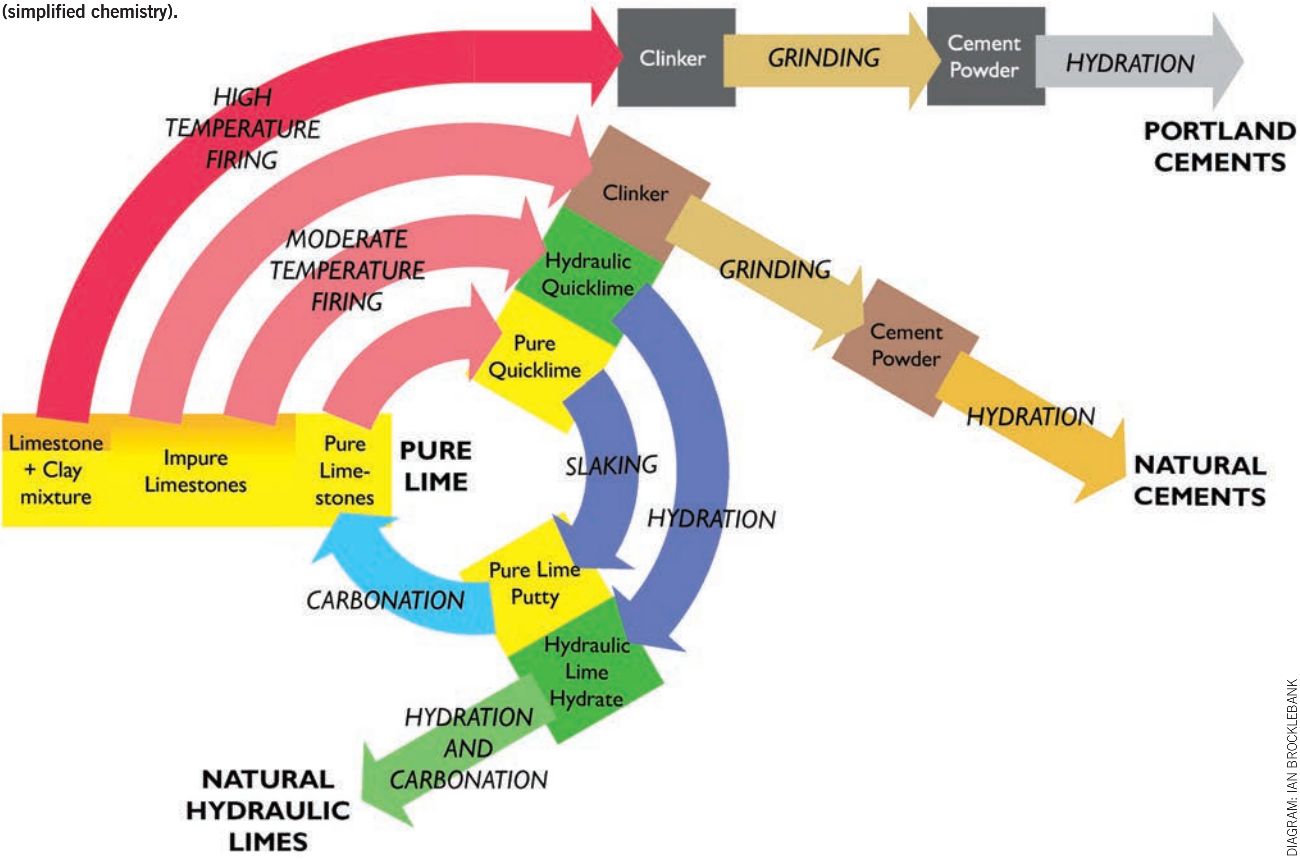

DIAGRAM: IAN BROCKLEBANK

Understanding limes and cements

A knowledge of lime is essential when repairing old buildings. Carsten Hermann, building conservation advisor at Historic Scotland, explains the basics.

Lime is a calcium-rich material, used as a binder in mortars to bed bricks and stones, point masonry joints, and plaster and render surfaces. To make mortar, lime is mixed with aggregate and water into a pliable material which, when exposed to air, loses its pliability (sets) and hardens over time.

Lime is produced by firing limestone (calcium carbonate) in kilns, driving off carbon dioxide. The resulting lumps of 'quicklime' (calcium oxide) can be ground into powder. Adding water (slaking) turns quicklime into hydrated lime (calcium hydroxide). If the added amount of water is controlled to the minimum required for this chemical reaction to occur, the resulting product remains a dry material. The addition of excess water produces lime putty.

Mortar can be made from quicklime, dry hydrated lime or putty. The lime reacts with the carbon dioxide in the air (carbonation), binding the mortar eventually into a hard material, chemically similar to the limestone it was made from. The processes of firing, slaking and carbonation are therefore referred to as the 'lime cycle'. This cycle, however, only applies to relatively pure limes, also termed air limes as they set and harden through air exposure.

Many limestones contain impurities, such as aluminates, ferrites and silicates. These mineral types, often found in clay, allow mortar to set and harden through chemical reactions with water (hydration). Lime with sufficient quantities of such minerals is termed hydraulic or water lime. If exposed to air, it sets through a combination of carbonation and hydration. Available as hydrated powder, hydraulic lime sets faster than air lime and is of higher strength and lower permeability. If made from limestone without additions during production, the lime is called 'natural hydraulic lime' (NHL), a material commonly used today.

Hydraulic lime mortars can achieve different strengths, depending on the lime's impurities and additions made during its production or mixing; site workmanship also plays a role. Stronger mortars tend to be less permeable, but exact predictions of permeability and strength are often difficult. This can be problematic, as mortars with low permeability and high strength can cause accelerated deterioration of, and damage to, adjacent building fabric, by inhibiting water transport and due to their inability to accommodate small-scale movements.

Today, lime mortar is generally produced by either adding water to a mix of hydraulic lime and aggregate, or by mixing lime putty with aggregate without additional water. Premixes are available, where aggregate has been mixed off-site with either hydraulic lime or putty. Products sold as 'hydrated lime' are commonly air lime. They result in lime mortars inferior to those made from putty, but are used as additive in cement mortar.

Making mortar with hydraulic lime or putty results in chemical reactions which only heat the mortar gently, if at all, as the slaking during the lime production has reduced the lime's reactivity. Mortars can also be mixed from quicklime, aggregate and water, resulting in a stronger chemical reaction with significant heat generation. These 'hot mixes' are thought to have better bonding properties and be more permeable. Also, hot lime mortar expands in volume, as the quicklime slakes, which, if applied hot, helps fill masonry joints, but can cause cracking of brickwork.

The transition from limes to cements

The influence of clay minerals in lime mortars was only understood systematically in the 18th century. Their hydration occurs chiefly due to the presence of belite (dicalcium silicate), a mineral produced when firing clay-rich limestones. The ratio of belite to lime determines a mortar's hydraulicity.

At the turn of the 19th century, clay-rich, calcium-containing depositions from the coast around Harwich in Essex and the Thames estuary were kiln-fired. Due to their specific mineral mix, these depositions could not be slaked, but were ground to a powder, forming a hydraulic binder which allows mortars to set much faster than the lime mortars used to that date. First patented in 1796 as 'Roman cement', this binder had a high belite content and also contained aluminates and ferrites. It was fashionable at the time to name new binders 'cements' to distinguish them from traditional limes. Various so-called cements were developed at the time, but not all of them were rich enough in belite to be actually classed as cement by modern standards. Roman cement was produced from a single material without additions during production, making it a 'natural cement'. Mostly used for rendering, natural cement produced mortars significantly stronger than the weak lime mortars used at the time, yet their permeabilities were surprisingly similar.

These early cements are different from the Portland cements so commonly used today. Patented in 1824, 'Portland cement' is produced by firing limestone with clay additives. Unlike today's Portland cements, their forebears were relatively weak and permeable materials, as they were fired, like limes, at around 900 °C. During the 19th century, firing at higher temperatures became possible. Firing impure limestone at increased temperatures, up to 1250 °C, results in a greater proportion of belite. Above this temperature a new mineral forms: alite (tricalcium silicate). It gives today's Portland cement mortars their rapid set and makes them extremely hard and impermeable, compared to mortars made from limes, natural cements and early Portland cements.

Conservation challenges

By the mid-20th century, Portland cement had replaced lime in building construction. Due to its limited use, only a small selection of limes remained commercially available. Over time, it became apparent that today's Portland cement is far too hard and impermeable for use with many historical materials. In building conservation, this led to cement being unilaterally identified as bad, regardless of its type, whereas all forms of lime were seen universally as good. Although our understanding of limes and natural cements has become more nuanced over the last decades and their supply greatly improved, choosing the most appropriate mortar for a specific repair situation can still be challenging.

Training is a vital part of the SPAB's work.

IMAGE: RALPH HODGSON

A beautiful material

Architect Tim Ratcliffe, of Tim Ratcliffe Associates, sets out some of the qualities that make lime special.

We know the ancient Egyptians were using lime in the construction of pyramids by 4000 BC, but the clearest ancient description of the use of lime mortars and plasters appears in Vitruvius's *Ten Books of Architecture* in the first century BC.

Subsequently, the fall of the Roman Empire saw the lime methods that had developed decline, although the material remained in use through the Dark Ages. We know, for example, from archaeological evidence, that Norman builders sometimes used mortar mills to mix their mortars. The fact that many large churches, castles and cathedrals from the Gothic period are still standing bears witness to the amazing qualities of the lime mortars used. A revival in the use of more sophisticated uses for lime came with the Renaissance and the Italian plasterers who brought decorative plaster methods to Britain.

In the 17th century, Joseph Moxon's book *Mechanick Exercises* explained that different limestones produced different types of lime; an understanding that developed in the 18th and 19th centuries. Yet, as the building industry became more concerned with speed and efficiency, it was almost inevitable that harder setting cement binders would be developed and favoured, often with disastrous consequences when used in the repair of older buildings.

The beauty of lime mortars, plasters and paints is their 'breathability'. They are the Gore-Tex of the building world, allowing water vapour out of a structure, rather than trapping it. In addition, their ability to wick moisture away from stones or bricks, and then release it by evaporation, further helps the drying of a structure.

In some circumstances, as well as drawing moisture out, they can act as a poultice to salts. In extreme cases this can cause them to degrade, but this sacrificial decay is part of what helps protect vulnerable historic fabric.

Most lime mortars are relatively soft and are able to accommodate a certain amount of movement. Consequently an old structure can lean or bend slightly without failing. Interestingly, even if the face of mortar cracks, this can expose uncarbonated lime behind, which sets, so the lime effectively self-heals.

Unlike modern materials that tend to look hard, angular and shiny, lime mortars, lime plasters and limewash are soft on the eye. They have a natural, mellow appearance and improve with age, even weathering gracefully. The way soft lime plasters and renders behave, when exposed to wetting and drying cycles, is fascinating. Squirl patterns appear when free-lime (uncarbonated material) is drawn across the face of the coating, and then deposits around the edge of a patch that has dried more quickly. The layers of squirls that form over decades show us where there are shallower and deeper features behind. This phenomenon can be beautiful.


IMAGE: ROGER HUNT

The inbuilt flexibility of lime accommodates a degree of movement.

In a world where speed and efficiency are key, it is easy to see why lime mortars and plasters fell out of favour for a while. Modern alternatives, though, are proving too destructive. The fact an old wall will suffer more damage in 20 years than in the previous 200 years, if pointed with Portland cement, and will need to be repaired and repointed again, is not efficient. Similarly, environmental damage caused by hard-setting materials and risks to human health from modern impervious coatings, are beginning to be recognised as significant problems.

Whilst lime building materials require some care, and consequently cost slightly more in the short term, they have a proven track record of over 6,000 years, and have been used successfully for centuries by people with very limited resources. Using lime is not rocket science, and the craft skill required is small compared with the benefits it brings.

www.timratcliffe.co.uk

Left: Tile and mortar repair to window jamb.
Below: Jamb before repair.
Opposite: Stonework at Temple Church, Bristol, after conservation.

IMAGES: PHILIP HUGHES ASSOCIATES

Repair and conservation

Chartered building surveyor Philip Hughes, chairman of the SPAB technical panel, examines the role of lime in the care of old buildings.

The use of lime in conservation reflects the historic use of the material but, due to developments from the latter part of the 20th century, also extends that use in ways that would probably not have been considered in earlier times. The resulting range of lime-based techniques allows repair and conservation methods conceived as being compatible with the existing historic fabric.

Conservation of limestone

Groundbreaking work using lime for the repair and conservation of limestone figure sculpture on the west front of Wells Cathedral was undertaken in the early 1980s and was generally referred to as the 'lime method' (see *Lime today*, page 15). These techniques continue to be refined and developed and are now in widespread use.

Currently lime conservation techniques include: initial temporary support of the stonework (where necessary); cleaning of stonework (if needed); removal of previous unsuitable repairs such as iron cramps or dowels and cement repairs; careful cleaning back of decayed stonework whist retaining the original face; packing voids with a carefully prepared mortar; grouting fine cracks using fine lime mortars; the use of micro-pins to secure loose or fractured elements; surface repairs using lime mortar and the use of sheltercoat. Sheltercoat is a fine blend of lime and stonedusts selected to match the colours of the stone. This needs to be well worked into the surface of the stone, allowing high points of the stone to 'grin' through - a thick surface layer is rarely successful aesthetically.

The micro-pinning technique was developed by English Heritage at Temple Church in Bristol *c*1995 to conserve severely fractured stonework which had suffered from fire damage during the Second Word War and subsequent weathering.

The micro-pins generally consisted of two or three strands of approximately 1 mm diameter copper wire twisted together and encapsulated in resin. These were cut to length and set into pre-drilled holes. Resin was used to secure the pins in several windows but hydraulic lime was used in one window. All have performed equally well to date.

Surface repair of stonework and brickwork

There are historic examples of the use of lime for the surface repair of stonework. William Weir and other early SPAB architects also used lime mortar widely in the repair of external stonework, often in conjunction with other techniques such as the use of tiles.

One of the most important elements of the surface repair of decayed stonework is the matching of mortars to the colour and texture of the existing stone and of making these weak enough to act sacrificially. That is to be more porous than the original stonework, encouraging moisture to evaporate from these new repaired surfaces more than from other areas of the stone which, in turn, will concentrate any salt deposition and decay in the areas of repair thus helping to protect the stonework. This concept of repairs being sacrificial was quite novel in the 1980s - although accepted earlier in wall painting conservation work - but has now become widely adopted in the techniques used for the repair of historic buildings.

Lime mortar and sandstones

The techniques comprising the lime method were developed specifically for the conservation of limestones. The use of lime mortar for the repair of sandstones has a long history but there are potential risks as some sandstones are not tolerant of lime and its use can result in surface decay. Careful examination of the stone and any changes due to initial use of lime bedding or pointing mortars will usually indicate whether stone repair with lime mortar is safe. Lime mortar can be used on calcareous sandstones.

Grouts for structural repair of masonry

Grout, based on hydraulic limes or on pure lime with pozzolanic additives (see *Lime today*, page 15), has been used for filling voids in masonry. The intention is to bind in loose particles and help to prevent the 'jacking' or bulging of a wall that occurs when small movements - such as thermal movement - allow material to drop further within voids. Grouting is normally combined with the introduction of 'stitching' or 'tying' of the masonry.

Mortar for pointing and bedding

Careful selection of materials is crucial for all repair work but particularly so with mortars as they have a large range of functions to perform, even in the same building or wall. For example, pointing at low level may need to be particularly soft and open textured to act sacrificially to protect adjacent historic stonework, possibly using an air lime mortar. However, at the top of the wall, the pointing of coping or parapet stones may need to be much more weather-resistant in order to shield the building fabric below, probably using a hydraulic lime mortar. The limes and aggregates have to be chosen for each application with thought for their function and appearance.

Renders and plasters

Clearly it is possible to patch areas of loss to plaster or render using matching material. It is less common, but can be relatively straightforward, to use lime to consolidate plasters and renders that are becoming detached from their background or which are delaminating with one layer separating from another. When the plaster or render is on a solid wall but delaminating, its conservation usually involves the use of lime grouts or fluid lime mortars, often known as slurry mortar, injected into the plaster or render before the original surface is 'squeezed' back into position. There are many ways in which the technique can be adapted to suit particular circumstances. Lime water can be used to consolidate friable plaster surfaces on solid backgrounds while limewash, applied over the surface of plaster or render, will provide protection of the surface.

Old repairs in cement-based materials

The general aim of using lime mortar wherever possible does not mean that every piece of cement mortar, plaster or render on a historic building should be removed. As with lime, the term 'cement' covers a range of materials and their strengths have varied over time (see *Understanding limes and cements*, page 6). Any work to a historic building is likely to involve some loss of historic fabric and there is a high risk of damage when cutting out cement pointing or removing a cement render. Such operations should only be undertaken if there is significant ongoing deterioration occurring as a result of the presence of these materials, using skill and care to minimise damage.

Analysis before intervention

Although vitally important to the conservation and 'breathability' of old buildings, lime does not cure everything! Before embarking on any repair to historic fabric it is important to analyse the problem. This means understanding as much as possible about the existing materials, their condition, the causes of decay and the extent to which this is ongoing. A certain amount of scientific analysis may be necessary but it is often difficult to interpret the results due to the enormous number of factors affecting any building. One of the most important tools available is the use of senses, particularly sight and touch, as well as careful thought about what one is looking at. Research into previous repairs undertaken or materials used can also be invaluable. Above all, with any intervention, including repairs, it is important to remember that it may have a beneficial or detrimental effect. It is essential to guard against causing harm.

www.pha-building-conservation.co.uk

IMAGE: TŶ-MAWR LIME/LIMECRETE COMPANY

Highly efficient mixers mean limecrete is suitable for large projects.

Can lime be commercial?

With a growing number of lime products available, Nigel Gervis, a director at Tŷ-Mawr Lime, explores the material's commercial potential.

Natural hydraulic lime is now offered by virtually every builders' merchant and even DIY superstores, although only a few will keep stock and not all will be able to advise on the use of lime in any meaningful way. Specialist companies support a network of independent merchants expanding the market to include not only the default NHL 3.5 but a range of air ('fat') lime mortars, plasters and limewashes, while mortars are available in bulk bags and even silos.

The ubiquitous use of NHL 3.5 and NHL 5 in situations where an air lime would function adequately, if not better, is commonplace as these products have a faster set and higher final compressive strength. As such, poor working practice can be disguised by the strength of the binder. Even so, failure of lime work occurs mainly due to lack of knowledge. The response of many lime manufacturers has been to produce dry pre-mixed, all in the bag, hydraulic limes which have been modified to make their use easier and their performance better by improving flexibility, breathability, workability and frost resistance.

Hydraulic limes definitely have a role to play and are extremely useful, especially in new-build. This is reflected by the fact that, in 2008, the NHBC Foundation, in partnership with the BRE Trust, published *The Use of Lime-based Mortars in New Build.* Indeed, hydraulic lime mortars have been used in many high-profile new build projects including at St Pancras Station and the Royal Hospital Chelsea.

Lime variants, that can be applied to plasterboard, cast concrete or even water-proofed surfaces, now give immense range to the pallet of materials available. So-called 'hybrid mixes' or 'improved mixes', where lime is used in conjunction with other modern binders and additives, are designed for specific functions. It would be wrong to dismiss this range of materials because they are not 'traditional'. In reality, when repairing, renovating and converting buildings, we are frequently dealing with situations that are not traditional because of previous interventions. There are also situations where time constraints on a job will be such that air limes and hydraulics will struggle to perform in a limited time scale, or when work cannot be carried out at a more suitable time of year. Sometimes compromises have to be made whilst gaining maximum benefit for the building.

Portland cement is firmly entrenched and extremely well marketed so modern hydraulic limes - laboratory tested, CE marked and EN 459 compliant - have been developed to be as user-friendly as possible without comprising their qualities. What should be remembered is that there are dangers in de-skilling an industry that needs a greater understanding of an ever expanding number of materials and how they perform together.

Although lime mortars are never going to be used on the same scale as cement mortars for new construction, the use of developed products containing lime, such as hempcrete walling, have experienced popularity with large-scale projects. Limecrete floors, a straightforward alternative to concrete floors, are becoming ever more popular and are now the default specification for many projects, especially in the conservation and re-ordering of ecclesiastical buildings.

The development of internal and external insulation systems has further increased lime sales as they are promoted with their own proprietary renders. Meanwhile the drive for insulation and energy efficiency has brought new products to the market. These products and systems have the potential to be at the forefront of new sustainable buildings where the specification not only looks at the projected energy savings but, importantly, the embodied carbon in materials, their lifespan and ability to be recycled rather than left for landfill.

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Lime today

The lime revival was a turning point in building conservation. Eoin Madigan, an Irish stonemason and recent SPAB William Morris Craft Fellow, brings the story up to date.

Sadly in the last 100 years we have managed to lose and forget our close bond with lime in favour of more modern materials. As a result, we are now playing a game of catch-up using science where once there was skill and knowledge handed down from generation to generation.

While natural and Portland cements have been around for a long time, it was really at the turn of the 20th century that the latter took hold. In the early 1900s cement started to replace lime mortars due to its quicker setting times and because it requires little or no aftercare. If we couple these facts with the onset of the First and Second World Wars, where countless numbers of skilled working men were sent off to war never to return, we start to see a bigger picture of how our knowledge of lime was lost. For, if there are no lime workers there can be no lime work - it only takes one generation to forget before skills and knowledge are lost.

The lime revival

Those who were there say that the 1950s, 1960s and early 1970s were dark times when it came to the use of lime mortars. This is not to say that lime was not being produced but the knowledge of how to use it was lost. Lime was actually removed from the building code of practice in 1976. Luckily, in 1974, Professor Robert Baker and his wife Eve, the leading conservators of English wall paintings and stone sculptures in their day, came to inspect the figures on the western front of Wells Cathedral. It was decided that the west front must be seen as a whole and that all of it, including the stonework and carved ornaments, as well as the figures of sculpture, deserved to be conserved. The conservation of the figures of sculpture on the west front of Wells Cathedral was widely talked about and seems to be the moment when people started to rediscover the importance of using lime and lime mortars in the conservation of historic limestone structures.

The work lasted twelve years and, while there, the Bakers helped develop, through trial and error, many different techniques in lime-based conservation that are often referred to as the ‘Bakers’ technique’ or sometimes the ‘lime method’. Some of these techniques and repair methods are not only in use today but also can still be seen in situ 35 years later.

What we should really thank the Bakers for is the legacy of their work which was the spark that re-ignited the knowledge and use of lime in conservation today. They made people aware of the skill of the practitioner and advised that those who work with these materials everyday should be consulted, listened to and involved when decisions are being made about conservation. They also highlighted the importance of training programmes for conservators and that conservation does not and cannot follow modern contract timeframes. Finally, and most importantly, they prompted people to talk about the importance and benefits of using lime in conservation and even its place in modern construction.

Purity and pozzolans

Historically we not only used lime for building but we spread it on the land to raise the alkalinity of the soil or ‘sweeten the grass’.

IMAGE: LIMETEC

Previous page: Lime is slaked to produce lime putty.
Left: Lime mortar was used for the new build work at St Pancras, London.
Below: Calcium carbonate, here in the form of limestone, forms the basis of all lime building products.
Opposite page top: One of the Wells sculptures in the 1980s.
Opposite page bottom: Hot lime mortar mixing is demonstrated at a joint SPAB Scotland BLF event.

We whitewashed our farms and stables to stop the spread of bacteria, put it in wells to purify the water and, even for a short time, used it to illuminate our theatres, hence the saying 'in the limelight'.

Today most of the lime that is produced is for use in power stations, chemical factories, sugar and steel works and water treatment plants. The lime that is produced for such works has to be very pure and this has had a knock-on effect on limes produced for the building trade, resulting in very pure lime putties being sold for making lime mortars. Historically we burnt less pure limestone than we do today with these impurities aiding the hydraulic setting capabilities of the mortar. Also, wood, peat and coal were used to burn lime in kilns which left behind impure pozzolanic materials which undoubtedly ended up being mixed with the quicklime and further helped the mix have a hydraulic set. Today most kilns used to burn lime were developed for the cement industry and use clean gas and coke to fuel them. In most parts of the country we traditionally used, whether deliberately or unbeknownst to ourselves, feebly if not eminently hydraulic mortars which have stood the test of time; it seems likely that many of the problems and failures we see today when using lime putties are because the lime is now so pure.

IMAGE: ROGER HUNT

Pozzolans, in a nut shell, allow calcium oxide, when mixed with water and aggregate, to hold its set underwater or, in other words, have a hydraulic set. We have most of our historic knowledge of pozzolans from the Roman empire, and one man in particular - Vitruvius - who documented his experiments with volcanic ashes to create hydraulic sets in his *Ten Books of Architecture*. Natural pozzolans are silicates and aluminates commonly found in volcanic ashes and pumices and, when you add these to the mix, they enable it to set without carbonation.

Natural hydraulic lime is said to be used in Scotland due to the harsher climate. Indeed, unmodified modern putty limes would not last long as an external render in places like the Scottish Highlands and Islands. So how do we still see traces of historic mortars and renders? Historically most, if not all, Scottish limes were at least feebly hydraulic because they burnt oyster shell on the west coast and bioclastic limestone in the east. Both shell and bioclastic limestone, which is derived from seashells, contain very small amounts of clays that build up between the layers of shell as it grows. When burnt to produce quicklime, this clay is enough to create a feebly hydraulic set.

Current production

Sadly, we now seem to import all our hydraulic lime from abroad. This is not because the UK does not have sources of clay-rich stone (eg Blue Lias) to burn or the knowledge to do so; the story seems to be a lot more complicated than that. Until recently the UK did produce hydraulic limes but sadly, for various reasons, production has ceased. Consistency of material is very important when producing lime and continual testing of product and raw material before sale is vital. When carrying out this work, practitioner skills and techniques must be unified to ensure best results from the product. Government objections to existing quarry expansions are another reason why hydraulic lime is not being produced in the UK.

Modern hydraulic lime v historic hydraulic lime

Modern bagged natural hydraulic limes (NHLs) are not to be confused with historic hydraulic limes. Today modern hydraulic lime has to conform with specifications which refer to the compressive strength of mortar at specified curing intervals, usually at two, seven and 28 days. These testing times were developed for the cement industry. With lime mortar, durability and strength comes with age due to the carbonation process. The classes of NHLs sold (2, 3.5 and 5) refer to the compressive strength in megapascals of a 1:3 lime:sand mix by mass after 28 days. Users should be aware, though, that the strength continues to grow considerably over the first couple of years so the result may be a much stronger and less breathable mortar.

Hot mixes

Quicklime or calcium oxide mixed with aggregate and water is the purest form of lime mortar we have. When the water is added to the dry mix of quicklime and aggregate a chemical reaction occurs between the water and the quicklime creating calcium hydroxide. This reaction gives off great heat, reaching 160 ˚C to 190 ˚C in less than 30 seconds. As the reaction is taking place, the lime in the mix expands up to two and a half times its original volume. When the lime, water and aggregate have been thoroughly mixed one ends up with a very sticky and 'plastic' mortar which is warm to the touch. This is known as a hot mix.

Hot mixes appear to have been used on many vernacular and historic structures in the UK in the construction of random and squared rubble walls. A tell-tell sign of this will be 3 mm to 5 mm white inclusions in the mortar. It therefore seems logical that, when conserving these structures, we should insist, where possible, on using hot mixes as the favoured choice of mortar.

Conservation aside, there are many advantages to using hot mixes. As the chemical reaction occurs, the alkalinity of the mix increases causing the mix to become very caustic. This enables the lime to etch into the sand, creating a very good bond between binder and aggregate. As previously mentioned, when water is added to quicklime it expands so, when the mix is used hot, the mortar will expand, filling up any cracks or voids in the wall. This is a great advantage when bedding masonry or undertaking deep pointing, especially vertical pointing as these joints can be hard to fill and compact which may lead to major water ingress. The expansion also provides a good, open pore structure in the long-term, although in the short-term increases susceptibility to frost damage.

The white inclusions in the hot mix can be two things. Firstly, they may be slaked but uncarbonated lime or, secondly, unburned calcium carbonate, which is the raw material used to make quicklime. They are advantageous because they can improve the physical structure of the mortar and help its autogenous (self-healing) properties take place.

A mortar which showed even one of these beneficial traits would be a good mortar to use but to have all of them together in one mix makes hot mixes the mortar of mortars in my eyes.

IMAGE: SPAB

IMAGE: JESSICA SNOW

PROTECT LIKE PAINT, BREATHE LIKE LIME

KEIM MINERAL PAINTS

Mineral paints are an ideal alternative to traditional lime washes and unsuitable modern masonry paints, for the decoration and preservation of historic buildings.

First invented and used in 1878 in Bavaria, Germany, Keim Mineral Paints utilise natural materials to create extremely durable protective and integral decorative coatings.

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•Available in a wide range of colours

•Resistant to mould and fungal growth

Mineral paints, unlike conventional acrylic paints, form a permanent crystalline bond with the underlying substrate, rather than a purely adhesive bond. This retains the breathability of the substrate and ensures that moisture vapour continues to pass through the substrate unimpeded, with no risk of blistering and cracking of the paint finish. Mineral paints provide an extremely long term decorative solution which works in harmony with buildings and lime components.

Think lime
Think breathability
Think KEIM

IMAGES: CLIVEDEN CONSERVATION

Consolidating Tewkesbury Abbey

Highly commended by the SPAB's John Betjeman Award judges, a repair project at Tewkesbury Abbey employed the latest lime technology. The abbey architect, Andrew Townsend of Andrew Townsend Architects, explains.

As with most medieval and earlier masonry buildings, lime was a fundamental part of Tewkesbury Abbey's construction and later alterations, only being supplanted in the late 19th century by materials based on Portland cement. Although cement-based repair methods were on the face of it easier to use – providing faster setting time and requiring less 'tending' – in due course they often led to decay in the surrounding stonework.

One of the principal causes of decay in stonework is soluble salt which, as the term implies, requires the presence of moisture to be transported through masonry. Problems of decay usually occur at or near the surface of masonry as the moisture dries out and the salts crystallise and expand, causing disruption of the surface. When salt-laden moisture moves to the surface of the stonework, it takes the path of least resistance, moving through the most permeable material which, in traditional masonry construction, is often the lime mortar bedding and pointing. Cement-based materials have much lower permeability than lime-based mortars and renders and, where the former is used, this can lead to accelerated decay in the individual stones and any surviving lime-based mortars.

The benefits of lime

The ability of lime-based technology to deliver, in most circumstances, an equilibrium which ensured - with reasonable maintenance - the survival of masonry structures for many centuries appears to have been well understood by the builders at Tewkesbury Abbey. After a period during which Portland cement was the repair material employed by those charged with the care of the abbey, lime technology made a successful return under the stewardship of Neil Birdsall, my predecessor as abbey architect and a SPAB Scholar. Having observed the benefits of lime during my own time on the SPAB Scholarship, and afterwards in architectural practice caring for masonry structures, it was an easy decision to use lime-based methods of repair to tackle areas of decaying and threatened stonework.

Understanding the building

The walls on the south side of the abbey are rich in historical and archaeological significance; much of what survives dates to the original construction of the abbey in the early 12th century with the re-working of the building in the 14th century expressed in the design of the aisle and clerestory windows. The remains of the cloister, in the form of blank decorative panels, is also a significant feature of the south side of the abbey, appearing to be the

IMAGE: CLIVEDEN CONSERVATION

Previous page top: South side of Tewkesbury Abbey after repair. Previous page bottom: Initial treatment of severely decaying stone using nanolime allowed for subsequent consolidation with mortar repairs and lime-based sheltercoat. Left: A band of badly decayed greensand was repaired using a combination of clay roofing tiles and lime mortar repair.

vestige of a 15th-century reconstruction of an earlier cloister.

Documentary evidence indicates the building was affected by a number of major fires in the medieval period and, during an inspection of the stonework in 2012, much of the fire-affected stone was found to be fractured and loose. Softer areas of greensand and lias stone, set among the generally more robust limestone, had also decayed severely. Concern was raised about the condition of the fragments of surviving plasterwork - originally internal finishes but long-exposed to the weather - and the severe decay of stonework to the surviving cloister.

Salts

This cloister area appeared to be suffering from the effects of soluble salts and analysis of samples of the stone revealed high levels of sulfate- and nitrate-based salts. The former is usually linked to atmospheric pollution and the sheltered areas of cloister masonry had the characteristic darkening and hard surface skin associated with this form of attack. Nitrate-based salts occur as a result of, amongst other things, the breakdown of organic material including animal waste. Documentary research revealed that the ground levels on the south side of the abbey from the post-Reformation period until the late 19th century had been several feet higher than at present. Old photographs show orchards running right up to the abbey walls and it is assumed livestock grazed here, perhaps sheltering against the walls, thus leading to a build up of nitrates in the cloister stonework.

Although it is not generally possible to reduce significantly the salt content in building masonry, measures were taken to reduce the effects of the moisture needed to move the salts around and, in this way, to minimise future damage. Lime-based techniques and materials were also used which act 'sacrificially', decaying in preference to the original material in situations where salts and moisture are present and continue to cause problems.

Nanotechnology

We were keen to retain as much as possible of the surface of the cloister stonework, which in many areas was so friable the physical effects of wind and rain beating on it led to frequent loss of material, accumulating in powdery mounds at the foot of the wall. Consolidation of this crumbly material presented a particular challenge and, following the preparation of a trial area of work, the use of recently-developed 'nanolime' was agreed (see *Innovation*, page 22). This appeared to provide initial consolidation of the most unstable areas as a base for the other lime-based techniques.

Nanolime consists of very fine particles of lime (calcium hydroxide) suspended in different alcohols (such as ethanol) and the theory is that it is able to penetrate decayed limestone before the ethanol evaporates leaving the lime to 'bind' the unstable grains of stone. Testing of masonry before, during and after the application of nanolime to the decayed cloister stonework at Tewkesbury was carried out by stone conservation consultant David Odgers, using a resistance measurement drill. The results of testing to date appear to indicate the nanolime is effective at consolidating the top 2-3 mm of decayed stone but that there is no evidence the depth of consolidated material increases over time. Despite the apparently limited effect of the nanolime, this depth of consolidation of previously extremely fragile stonework proved sufficient to allow for further consolidation and protection of the stonework using a palette of other lime-based techniques:

- Lime/aggregate slurry used to fill cracks and voids
- Pinning of fractured stones using fine threaded stainless steel rod
- Lime-based mortars used to fill larger voids and to 'weather' the surface of the stones
- Lime-based sheltercoat applied to the surface of the stone and worked into the smaller voids to help protect the stone surface

Practical solutions

Further protection of the cloister masonry was afforded by a small, lead-covered timber 'pentice' fitted at the head of this area at some time in the past but mostly missing by the time the works were undertaken. This was re-introduced to help direct rainwater clear of the vulnerable areas of stonework.

Elsewhere to the south wall of the abbey, localised decay had occurred in several areas, leading to concern about the structural or constructional performance of the nearby masonry. Where this was the case, repairs were carried out in situ in traditional SPAB fashion using clay roofing tiles bedded in lime mortar, ensuring only the minimum amount of existing material was cut out. A mullion of a high-level clerestory window was one area where this technique was used, illustrating the degree to which subtle variations in the line of the repair can be achieved, perhaps comparing favourably with an alternative method of repair using new sawn stone.

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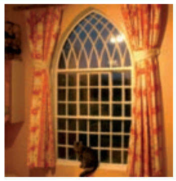

Hempcrete is used in conjunction with a timber frame and shuttering.

IMAGE: LIMECRETE COMPANY

Innovation

Although lime is a traditional building material, new products that make the most of its benefits are emerging, says historic buildings consultant Joe Orsi.

'Fit for purpose' is an expectation we have for all products and services that we procure; this applies not only to innovative solutions but also to materials that are sold as 'traditional'. It is a reasonable expectation that, if we re-render a wall using lime and animal hair as a reinforcement, we should not have to shovel sheets of failed render off the lawn the following spring.

Three years ago it was noticed that there was a pattern of render failure caused by the degradation of the animal hair within it. This concern was raised with the Building Limes Forum which asked one of its members to examine some samples. It was found that animal hair imported from outside the EU, which required treatment against anthrax spores, had been so aggressively treated that the hair was compromised before it was even used. Studies revealed that keratin proteins (the glue that binds hair together) can be severely damaged by these acid treatments. Many of us are now aware of the problems related to imported hair but further tests with some locally-sourced, untreated hair have found similar patterns of failure. Historically, hair degradation has been a problem and there is evidence that hair in the past has failed. It has also been found that other hair has been unaffected and it is unclear why this is the case.

Alternatives to hair

If there is uncertainty about how fit for purpose hair is for reinforcement, then what are the alternatives? Plant fibres such as straw, hemp or sisal do not degrade in the same way as hair. Indeed, sisal fibres put into a tub of wet lime putty to test their resilience have still been strong enough to use nine months later. Sisal is a cactus fibre which has been successfully used in Latin America as a plaster reinforcement for many years. Modern polypropylene, cellulose, PVA and fibreglass fibres are now widely used in premixed limes and provide better distribution than hair or plant fibres; they extend the life of the plaster without affecting other performance characteristics such as flexibility or vapour open qualities. This is a good example of how alternative and innovative materials can offer an improvement over the traditional.

Chalk lime

Fibre reinforcement is essential to chalk lime plasters and renders. Traditionally, copious quantities of hair were used, particularly in some Georgian plasterwork, most of which still remains flexible enough to roll up like a carpet. Timber-framed properties, which go through dimensional changes throughout the year, benefit from this highly flexible plaster. On examination, chalk plasters can vary in aggregate composition; some are lime and virtually pure chalk with a range of particle size from 5 mm down, others have inclusions of harder aggregate such as sand and flint. The traditional versions of this plaster are very prone to high shrinkage, which can cause unsightly cracks.

Modern versions of chalk plaster do not have the same shrinkage problems because they use much finer chalk powder and very fine polypropylene fibres, both of which have excellent distribution. The resulting product is much more flexible and adhesive and has a better tensile strength than traditional chalk lime. Chalk lime plasters should remain one coat, which is a benefit for speed of application, but can be problematic if future over-skimming is required because chalk forms a weak bond to itself. In situations such as these, primers are used to control the underlying plaster.

Chalk lime is a better insulator than sand limes, will work on most substrates and is particularly good when used on traditional lath or modern insulating wood wool boards.

Hempcrete

Hemp is a natural plant fibre and, when its woody core is bound with a hydraulic lime, water and small amounts of other additives, it may be used to form a material known as hempcrete which offers excellent thermal insulation, thermal inertia and humidity control. This composite can be sprayed or placed inside a shuttered frame and, more recently, has been made available as high-tech prefabricated panel or cladding systems. These products have been used to construct a number of high profile commercial buildings as well as for new homes and extensions.

Hempcrete may be used to provide thermal insulation during the retrofit of older structures. One situation where the product has proved its worth is where the infill panels of timber frame buildings have been replaced with inappropriate materials. Hempcrete offers many of the same characteristics as wattle and daub, and can be cast in situ within the timber frame to fit the space perfectly, while providing breathability and potentially improved thermal insulation and airtightness.

The product can be purchased in pre-mix bags for small onsite applications and is lightweight and flexible. Hempcrete's eco credentials are good because the hemp plant absorbs CO_2 during its growth with a carbon capture of 130kg CO_2/m^3 and a potential thermal conductivity as low as 0.6 W/m^2K, which is comparable with cork or sheep's wool.

Limecrete

Lime concrete, or limecrete, floors were developed in the late 1990s and, when properly specified, do not require a damp-proof membrane (DPM). They offer a practical alternative to concrete where a structural floor slab that is vapour permeable is required. For example, where the walls of an old building have no physical damp-proof course and where a concrete slab and DPM would risk pushing dampness up the walls. Some systems are LABC-approved, complying with Building Regulations Parts A, C and L, while still meeting conservators' needs.

The principle of a limecrete floor is to select a layer of material that prevents the capillary rise of ground source moisture and which will also serve as an insulator. This insulating material can vary from lightweight aggregate consisting of clay balls, which resemble Maltesers, to more recent developments in recycled foamed glass products and cork. Most of these systems are able to accommodate underfloor heating pipes or electric heating cables.

Limecrete floors may help resolve problems of dampness in an old building where a solid floor has previously been removed and

IMAGES: LEFT, LIMECRETE COMPANY; RIGHT, MIKE WYE & ASSOCIATES

Cork insulating render during application. Left: A limecrete floor, incorporating underfloor heating, is laid.

replaced with concrete. Generally though, the installation of a limecrete floor, or indeed any other type of floor, is not appropriate where an original pamment, clay tile, limestone, slate or wooden floor still exists. Even if the earlier material is reused, there will be a loss in terms of natural character and historic information which lies on the surface of and beneath these floors. The depth available for installing a limecrete floor should also be considered to ensure it does not affect the building's structure.

Nanotechnology

Friable masonry and plasters have always been challenging for conservators and various consolidates have been employed, with mixed results.

One approach has been the use of limewater, which consists of tiny particles of lime (calcium hydroxide) suspended in water; this was brushed onto the surface of the plaster or masonry to add more binder below the surface. Typically, limewater would contain around 1.7 g of lime per litre of water and penetration was limited to how far the suspended particles could be transported. With this method the risk of water saturation had to be considered, as this could attract damaging expansive salts or further degrade associated timber or the hair reinforcement.

A solution to this problem is to replace the water with an alcohol such as ethanol which will not cause a salt or degradation risk and, moreover, will transport a greater quantity of nano-size particles of lime much deeper into the building fabric, thereby significantly improving the outcome and the conservation costs. (See *Consolidating Tewkesbury Abbey*, page 19)

This so-called nanotechnology can also help by transporting nanobubbles of CO_2 for carbonating limes in general; these bubbles erupt alongside the calcium hydroxide to form a carbonated lime. Both nanolime and nanobubble technology are currently being investigated by Dr Richard Ball and Prof Wang Wang at the University of Bath. Investigations into nanolime are supported by Alison Henry at English Heritage and nanobubble carbonation studies by Singleton Birch and the EPSRC Centre for Doctoral Training in Decarbonisation of the Built Environment (dCarb).

Insulating plasters and renders

We are now seeing more modified building limes such as thermally insulating plasters and renders that are made by mixing in an insulating 'aggregate'. Although not offering the significant increase in thermal efficiency of insulating boards or other similar products, insulating renders can, if used appropriately, have the potential to improve the thermal performance of buildings with minimum impact on the internal or external character. For example, if an original lime plaster or render has failed beyond repair and requires renewal, this could be the opportunity to consider an insulating lime render. These materials can also be useful in areas such as window and door reveals where dimensions preclude the use of other, bulkier, insulation materials. In these instances, insulating render or plaster can contribute to a reduction of thermal bridging.

A consideration with insulating plasters and renders is potential shrinkage rates as there is little point using any insulation system if shrinkage is creating an air leakage problem. One new insulating plaster is made with 55 per cent recycled foamed glass. This is not only efficient (0.2 W/m^2K) but has a low shrink rate.

Hemp can be used to good effect in an insulating plaster. Cork is another material now being used as an aggregate in insulating lime render. The cellular structure of cork means it is an ideal thermal and acoustic insulation material. It is obtained from the cork oak (*Quercus suber*), a tree which allows itself to be stripped of its outer casing which it then regenerates.

A more high-tech aggregate that is being used in insulating lime renders is aerogel. Another nanotechnology, this was originally developed for space applications and the raw material used in its manufacture is silicate. Aerogel consists almost entirely - 90 to 98 per cent - of air so has extremely low thermal conductivity and is claimed to be the lightest solid in existence.

Together with their thermal value, insulating renders and plasters that incorporate lightweight aggregates have the advantage of exerting less shear stresses on the substrate while their lightness is also of benefit to those applying them. The downside with some is that they can be more fragile than conventional lime renders.

As with all products and materials, both new and old, we should always carefully examine claims that are made and then make a conservative prediction about their performance and what loss or impact the methods might have on our buildings. What we should not do is dismiss them because they are new, or rely on them simply because they are traditional materials or methods.

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Hempcrete panels being installed during the construction of Marks & Spencer's Cheshire Oaks store.

IMAGE: HEMBUILD

The eco question

Jeremy Blake, an architect and partner at Purcell and convener of the Building Limes Forum, explores the environmental benefits of lime.

A building material that has been used from the time of the earliest civilisations, lime is not only important in the repair of old buildings; it is also an exceptionally virtuous material in the construction of new buildings in the 21st century, when environmental responsibility has become a critical issue. Properly used and applied, its performance can be outstanding, whilst its material qualities are timeless and enduring – the ideal eco solution.

Manufacture and supply footprint

The burning of calcium carbonate, most commonly in the form of limestone or chalk, in order to produce lime, has an environmental impact through emissions of carbon dioxide. It is sometimes contended that, because the burning temperature required to produce lime is lower than that required to produce cement, producing lime results in lower carbon dioxide emissions. But it is not as simple as this; factors such as the efficiency of the kilns, the fuel employed and the bulk density of the product must be taken into account. This can mean in practice that there is little difference in the residual embodied carbon for different masonry mortar types whether they are pure lime, hydraulic lime or cement. For the sake of comparison, therefore, it is best to assume that there are currently no environmental benefits to lime in its manufacture and supply; its substantial advantages lie in the other areas detailed below.

Carbonation

Carbonation is the process that takes place during curing and drying, whereby carbon dioxide is reabsorbed from the air, effectively completing the cycle back to calcium carbonate. This cycle can carry on indefinitely and is an embedded environmental advantage in using lime.

Reduced waste

Plasticisers or rapid curing additives may be added to cement to help extend a mix's workability. At the end of a day, however, any unused cement mortar becomes unusable waste. Hydraulic lime mixes can remain usable the day following mixing, and pure lime putty mixes can be stored indefinitely, provided they are kept in airtight bags or containers. The quantity of waste from lime-based binders and coatings is therefore minimal if they are handled well and kept free from impurities in their mixing and storing.

Recyclable properties

The contrast between lime and cement when recycling construction materials cannot be more graphically highlighted than by observing the demolition of masonry buildings. The engineering strength of cement mortar applied to brickwork walling is clearly demonstrated in the demolition of post-war brickwork structures, where it is the bricks that fail rather than the mortar. Lime-mortared masonry buildings, on the other hand, fail at the joints and, more strategically, the mortar can be easily removed from the brick or stone to enable its reuse. This results in the materials containing the embodied carbon – the reabsorbed carbon dioxide emissions originally released through the manufacture of the bricks – being reused without any further environmental impact. Cement-mortar masonry, by contrast, is only fit for crushing as hardcore.

Breathability and thermal properties

The permeability and porosity of lime mortars and plasters allow them to shed water through transpiration and evaporation. This fundamental characteristic enables lime to be a breathable mate-

Hempcrete together with hydraulic lime mortar, render and plaster was used to construct the Adnams distribution centre.

IMAGE: LIMETEC

rial, shedding water more rapidly than the surrounding, denser, building materials and drawing water from them. Thus the moisture content in the construction is reduced such that, during frosty weather, the destructive expansion of saturated materials is avoided. This is proving to be a key factor in the overall thermal performance of the solid masonry wall, so consistently used by our forebears with such good effect. This dynamic is often compromised in modern interventions into historic buildings by the inappropriate use of cement renders and pointing, gypsum plaster and concrete floors.

It is well known that dry materials have better thermal properties than damp or wet ones, with up to 40 per cent more heat lost through a wall that is damp than through one that is dry. Masonry walls built with lime are drier than those constructed with cement mortars because of the breathable qualities of lime. Thermal imaging is also now beginning to challenge the perceived benefits of the post-war tradition of cavity wall construction over solid masonry wall construction.

In addition to brick and stone, lime is beneficially used with a number of other building materials, including mud, timber, and straw bales. In straw-bale construction, lime plaster and render, along with limewash, are vital materials for protecting the straw bales from the elements and ensuring the buildings' longer-term thermal qualities.

In 2001 a small housing estate for a local housing association in Haverhill, Suffolk, incorporated two alternative construction methods – most houses were built with brick and block using a cement binder with cavity walls and two with a lime–hemp mix built up within shuttering. The theoretical U-value for the masonry houses was significantly better than for the lime–hemp houses, whereas the actual performance of the masonry houses, substantiated through thermal imaging, was significantly worse than that of the lime–hemp houses. The explanation was thought to be the superior moisture control of the lime, which was not taken into account in the theoretical calculation of U-values. The BRE is currently carrying out research in this area of thermal dynamics in conjunction with Bath University.

IMAGE: DOUGLAS KENT

Lime mortars allow the reuse of bricks following demolition.

The ultimate virtuous circle

As mentioned above, the exceptional qualities of lime as an enduring building material can be further enhanced environmentally with the addition of hemp. Hemp is the second-fastest growing plant on the planet after bamboo, growing 14 ft (4.25 m) in fourteen weeks. It requires no chemicals and only a little fertiliser, and the cellular structure of its woody stem, or shiv, gives exceptional thermal and breathable qualities. Because it grows so quickly, it is especially efficient in absorbing carbon dioxide. Shiv is added to lime to produce lime–hemp (also known as hempcrete), a versatile building material which has a variety of uses (see *Innovation* page 22).

Hempcrete was first used on a large-scale commercial building in the UK to construct the Adnams brewery distribution centre in Suffolk. Since its opening in 2005 the building has needed to be neither heated nor cooled, maintaining a constant temperature of 15° C, thanks in large part to the thermal properties of the material. The energy bills are 50 per cent of those of its conventionally built predecessor whilst the building itself is ten times larger.

An example of the move towards lime–hemp becoming increasingly mainstream is seen in the more recent Marks & Spencer store at Cheshire Oaks in Cheshire. Included in the design specification was the use of 2,600 m² of preformed 2.4 x 4.8 m x 400 mm hempcrete panels, along with numerous other eco features. Early indications are that heating costs are 42 per cent less than equivalent stores with a more standard cavity brick-and-block construction, and overall carbon emissions were 40 per cent lower, a massive saving.

When buildings such as this are finally demolished, the lime–hemp products can be crushed and scattered on the field before sowing the next hemp crop – the ultimate environmental cradle-to-cradle cycle.

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Limewash reflects different moods, ever changing as it becomes wet or dry.

IMAGE: TŶ-MAWR LIME

Limewash

Martin Brown, historic building consultant and director of WarmCote, considers a material that has both aesthetic and practical values.

Timeless and beautiful, the visual softness of a limewashed building touches something deep within us; a subconscious understanding that what we are looking at is 'right'. Its aesthetic charm pleases us, even if we do not immediately know why.

Limewash, in its most basic form - lime putty with the addition of extra water - has been in existence as long as lime has been used in buildings, probably more than 5,000 years.

From the vibrant blue of the houses surrounding the Meherangarh Fort in Jodhpur to the deep earthy pink of cottages in Suffolk, the romance of limewash is very easy to understand but, as with so many of the materials used on our historic buildings, the reasons behind it are far more practical.

The pigment that gives the blue hue in Jodhpur is copper sulphate, a powerful pesticide and herbicide - termites are a major problem and the buildings are predominantly of earth construction. Copper is still used in antifoul paints and it can be regularly found when exposing early paints in Victorian kitchens and sculleries; as a leading paint manufacturer suggests, almost correctly, 'insects don't like blue'.

Suffolk pink has been dumbed down to a vibrant bubblegum colour by modern masonry paint manufacturers, whereas it was a much earthier brown. It is generally supposed that the colour was achieved by the addition of animal blood into the limewash, though this appears to be unlikely. One traditional Suffolk paint manufacturer attempted to tint limewash to the depth of Suffolk pink using pig's blood but, to achieve the colour, the lime was too dilute to function and the whole thing smelled appalling.

The general function of limewash is to add a sacrificial, sterile, protective layer to the surface beneath/substrate, usually lime plaster. It should be remembered that limewash gently wears away - whereas modern masonry paints just become tired and grubby - and will generally need to be reapplied every five years, more regularly in areas of high exposure. Assuming the mix and application are correct, the biggest enemy of lime externally is freeze-thaw action. Historically water shedding materials were added, especially in areas that were particularly prone to saturation. In East Anglia, many of the timber-framed buildings have elevations that lay out of plumb, especially gable ends. It was usual in these circumstances to add a pentice board, a small timber shelf at roof level that throws the water clear of the lower walls. Often linseed was added, or tallow. In the case of tallow, it should be added to quicklime at the point of slaking; the caustic reaction breaks the fat down into soap, an air entrainer and stearate, a water repellant.

We are now able to introduce stearate as a carefully measured powder additive and are also using Teflon to repel water. Whatever is added, it must not be done in a heavy handed way that blocks the pores of the render and restricts breathability. The intention should be to repel water as a liquid, whilst allowing the free movement of water as a vapour.

One of the great joys of limewash is its ability to reflect the mood of the moment. When damp from a downpour, this simple finish will be dull and sombre but, caught in a drying breeze and bathed in the sun, it will radiate life. Such characteristics suit the contemporary aesthetic just as well as the historic, and cannot be matched by modern materials, so it is no surprise that limewash is increasingly embraced in new construction. Here its breathable, natural nature lends itself to eco buildings constructed with straw bale, hempcrete, cob and clay lump.

www.warmcote.co.uk