

HOME AND DRY

Developing a non-hydraulic setting air lime for the insulation and repair of traditional buildings

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ALMOST ONE in four buildings in the UK are traditionally constructed using lime rather than cement. If well maintained, solid walls of brick or stone set in a lime mortar work well, drying rapidly after a rain shower so damp never penetrates far into the wall. Condensation inside the building also dries quickly, so the walls act as a buffer for both humidity and heat, moderating extremes in the building.

By the end of the first world war lime technology had largely been abandoned in favour of faster-setting mortars. It was only in the late 20th century that conservationists began to realise that these cementitious mortars were actually damaging traditionally constructed buildings. Traditional mortars were softer and tolerated the natural expansion and contraction of solid masonry without failing. And they were highly permeable. It was discovered that problems occurred when old masonry was repointed, as this introduced just a thin layer of hard cement at the surface alone. As the core remained flexible, even modest thermal movement could cause the surface to spall, as pressure is exerted across the face of the wall. Being relatively impermeable, cement also prevented the mortar from wicking moisture to the surface. In particular, the cement renders used tended to trap moisture, and if cracked, more moisture is drawn in by capillarity, making the walls cold and damp.

Over the course of 60 years or so prior to the lime revival, traditional methods of making and using mortars were forgotten. Text book descriptions were often ambiguous, and a new generation of conservators had to rely on trial and error and on the analysis of old mortars. Today, new discoveries are still being made.

For the retrofit sector these developments are important because because damp walls are known to leak up to 30 per cent more heat than dry walls, and in some cases the actual figure can be far higher. Simply by getting all our



A traditional roughcast lime render on a solid masonry wall

traditionally constructed buildings up to a sound condition would help reduce the UK's carbon emissions substantially.

The types of lime used generally fall into two categories: non-hydraulic or 'air' limes which set very slowly by a chemical reaction with carbon dioxide alone; and hydraulic limes which stiffen more quickly due to a partial crystallisation set. One area of great interest is in the development of non-hydraulic hot-mixed mortars, because they seem to be producing mortars which are much closer in nature to those found historically and there is a growing consensus that these mortars can provide the best performance in use.

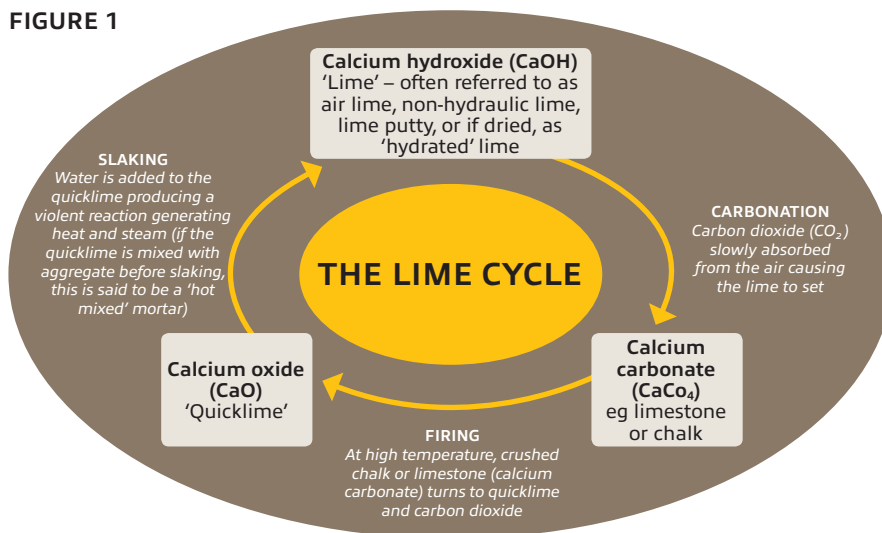
While their slow set means that air limes require more care and skill in use, they tend to be more permeable, and some hydraulic limes have been shown to become almost as hard and as impermeable as cementitious mortars when aged. Mortars made with air limes also offer lower conductivity and are therefore a good insulant, all of which make these mortars ideally suitable for older solid wall buildings. These properties are also significantly enhanced when used with appropriate aggregates,

and the final result is akin to most pre-industrial mortars found in the UK and on the continent.

This article looks at one proprietary product which has recently been developed. Although a form of non-hydraulic calcium hydroxide, it is supplied as a dry powder and when water is added the mix stiffens to provide a preliminary set without any addition of setting agent or pozzolan. The set is referred to by its manufacturer as a 'Vivus' set, which results from the way that the quicklime is manufactured and slaked. There are no clay impurities in the limestone used to make it, and none are added, so in essence it remains a pure air-lime and within the normal 'lime cycle'. Carbonation is a secondary setting process in that it is unnecessary for construction work to proceed, but adds strength in the long term. Like a hydraulic lime, it will continue to carbonate over the following months and years, depending on the depth of material. In the process carbon dioxide is absorbed from the air, completing the lime cycle (see Figure 1).

This non-hydraulic setting mortar is able to perform in the application stage

FIGURE 1



One of the pre-production insulation panels tested, 62mm (2½") thick

as effectively as hydraulic lime but then delivers the flexibility that is essential for the conservation and repair of old buildings. In one experiment, a piece of carpet was skimmed with a plaster made from this lime and allowed to set. It did so overnight. It was possible to dent the plaster with a thumb without cracking it and even to bend the piece of carpet without damaging the plaster. The remaining mix from the experiment was left in a tub. This same batch is now a hard lump and the carpet plaster is still intact – 2½ years of poking and prodding, later.

DEVELOPING A LIME-BASED INSULATION PRODUCT

In 2014 development of an insulation system based on a non-hydraulic setting mortar was awarded funding under a Small Business Research Initiative (SBRI) established by The City of Cardiff Council, Cadw, Innovate UK (formerly Technology Strategy Board) and Low Carbon Trust with principal

funding from the Welsh Government. The aim of the scheme was to assist the development of 'innovative measures that will improve the energy performance of traditional and historic buildings'.

The first step was to prepare sample insulation panels (left) with a thickness of 62mm (2½"). These contained Vivus lime, mineralised wood chips and various permeable aggregates selected to ensure a very high degree of vapour transfer, ideally suited to traditional solid wall construction. Independent testing confirmed thermal conductivity of 0.1 W/mK in the least efficient sample of Vivus render, in order to establish a base-line, compared to 0.5 W/mK typically found in conventional sand/cement renders. (Thermal conductivity is measured in watts per square metre of surface area for a temperature gradient of one kelvin for every metre thickness – W/mK.) The tester also confirmed that in his view even better results could be expected if different aggregate materials and thicknesses were used.

Currently the insulation systems in common use are all impermeable and are not readily compatible with older building walls. The research confirmed that a suitable insulation panel would be a useful tool in the retrofit armoury.

Testing and experimentation is ongoing to determine exactly how thick the panel or how deep the insulation needs to be, to provide adequate insulation and to buffer humidity, but without being too deep to apply to older walls with existing architectural features. Findings are expected during the course of 2017.

Other materials such as plasters and renders were also developed using the same quick setting non-hydraulic lime and a similar range of aggregates. During workshop trials these were shown to be successful in their ability to set and, once

dry, in their ability to absorb and readily release humidity. Conventional lime sand mortars tend to have a much higher degree of capillarity due to the impervious nature of the mineral aggregate, drawing moisture in and retaining it for longer, offsetting some of the benefits of the lime. The advantage of a premixed product using carefully selected aggregates is that the resulting render, plaster or insulation panel is able to work in a diffusive manner, without capillarity.

The plasters and renders also work in conjunction with the insulation material to create a holistic approach to insulating and finishing historic buildings. The materials are all compatible with those found in older buildings. The panels are best fitted to either internal or external faces of exterior walls by being solid bedded onto the surface using the non-hydraulic setting lime mortar. The reasoning is that the panel will then become an integral part of the wall, thus ensuring the original design is maintained, promoting seamless humidity extraction through the structure. This simple approach contrasts with many modern retrofit solutions which include air-gaps, capillarity and impervious layers.

MANUFACTURING AND TESTING

Following successful completion of the insulation tests, the product was approved for a second phase of SBRI funding. £142,000 was awarded for developing commercial production, for developing variations in the setting time, and for demonstrating the products in a 'whole house project'.

The facilities of a manufacturing company in Derbyshire were used to test production of the material in normal commercial mixing and blending apparatus, and to benchmark a manufacturing process and ability.

Due to the high temperature of the chemical reaction (approaching 200°C during slaking), it very quickly became obvious that specialist machinery would need to be developed in order to manufacture the binders if they were to ever reach the market. Nevertheless, enough materials were produced for demonstrating the product. The first successful prototype machine is now in operation, with basic materials being produced in autumn 2016.

The house chosen for the 'whole house' demonstration was Mill Cottage, in Pontcanna, Cardiff, which was saturated and rotting before the works began. The house is of 18th-century origin with 19th-century rebuilds. As with many



Mill Cottage on completion of repointing and lime-washing using Vivus materials



Fireplace and window details, with insulated walls, plastered and finished

such vernacular and humble houses, some terrible 20th-century replastering, painting, patch rebuilds and hard cement pointing had been carried out. There were even areas of glistening moisture on interior wall surfaces and large areas were black with mould. Also, the ground floor skirting boards had rotted through. At this point, some basic humidity readings were taken in June 2015 (Figure 2).

The work began with internal faces of the exterior walls being stripped of their coatings and then relined with insulating and humidity-buffering mineralised woodchip panels created especially for the project, and then plaster finished with a Vivus plaster skim.

Outside, the walls were depointed of cement and repointed with Vivus mortar and lime-washed.

It was clearly demonstrated that the material can be applied quickly. Pure lime skims were applied and finished in the same day. The skims contained no aggregate of any kind nor any other additive – they were pure air lime. In some rooms, purely for the experiment, panels were fitted to the walls and then skimmed and finished on the same day without issue.

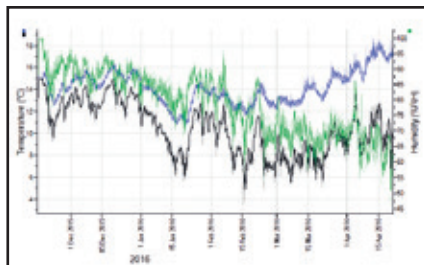
The north- and south-facing external walls were also finished in the same timescale, repointing and initial coat of limewash completed on day one and subsequent coats applied on day two, completing the work, front and back – sunshine with wind (south front) and cold damp shade (north rear). The two walls were completed in the same manner, clearly demonstrating the setting property of the materials used.

Inside, the walls were paper lined and then decorated with a modern 'fully breathable' soft paint. Although this will not affect the insulation per se, it will undoubtedly reduce the ability of the walls to absorb humidity. However, many owners and tenants will expect to be able to use these finishes, so this was added as

FIGURE 2: Humidity readings – June 2015

AREA	POSITION	HUMIDITY(%RH)	
		Ground floor	First floor
Internal west wall	Low level	96.35%	88.50%
	High level	88.99%	88.50%
Internal north wall	Low level	94.89%	79.50%
	High level	78.56%	79.50%
Internal east wall	Low level	93.02%	89.99%
	High level	89.90%	89.55%
Internal south wall	Low level	89.95%	88.70%
	High level	87.05%	88.70%

FIGURE 3



Sample data recorded following the work at Mill Cottage showing a marked fall in dewpoint (black) and relative humidity (green) from December 2015 to April 2016, while temperatures (blue) rose. During this period the house was uninhabited and the weather in this exposed location was particularly cold and wet.

part of the experiment. It is expected that the house will remain humidity free, even with the walls lined with paper.

A key element of the demonstration lay in showing the effect of humidity, contained within a structure, on the insulation performance. This moisture can reduce the effectiveness of any insulation by up to 30 per cent depending on the levels. Successfully dry out a building and maintain that humidity, then it will be warmer. Take an insulation that buffers humidity while also helping to equalise the humidity by being diffusive, and apply it to a wall that because of its manner of construction, acts in the same way,

then we will have achieved many things simultaneously.

The insulation and humidity control abilities are now being monitored with sensors installed at the property. The data taken thus far has shown a very beneficial effect. The average humidity levels recorded in the building had dropped 24 per cent from June 2015 to April 2016, and it is estimated that the energy efficiency of the walls has increased by more than 30 per cent. Empirically, the house is now warm and dry, even though the building was not inhabited all winter following the works. The temperature remains fairly constant, feeling cool on hot summer days and warm and dry on damp cold days.

The monitoring will continue for another two years to show the long term effect over winters and summers with the building being regularly used and inhabited. Feedback from the occupants will also be sought.

HARRY CURSHAM (harry@vivus.solutions) has spent the past 27 years working with, experimenting with and learning about air lime materials. He is a director of Vivus Solutions Ltd (see page 34). The full Welsh Government SBRI report is available from the author on request.