Society for the Protection of Ancient Buildings: Information Sheet 9
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AN INTRODUCTION TO BUILDING LIMES

by Michael Wingate

Anyone working on historic buildings should be thoroughly familiar with lime as it is central to good conservation practice. Though lime is no longer as easily available as it once was, and many contractors may initially need persuading to use it, it is successfully employed on many building sites without difficulty. It need not be the preserve of the specialist nor of the large scale project. It does not require rare and complicated skills.

Lime for use in building repairs comes in various forms, each of which has rather different properties. The purpose of this Information Sheet is to explain briefly the principal characteristics of the different sorts of lime. The practical use of lime in mortars, plasters, limewash, and so on, will be dealt with in separate publications.

Introduction

The binder for mortars and plasters in most forms of old building was lime. This gave soft textures and allowed the buildings to breathe freely. In recent times cements have been used with hard new materials in the hope of producing more durable buildings, though this approach has not been particularly successful. Serious problems arise when the less permeable modern cement mortars and plasters are used in the repair of old buildings where the general aim should be to choose mortars and plasters which breathe more freely than the materials they protect. For this lime is still essential.

The lime used in building is prepared from chalk or limestone burnt in a kiln and then hydrated or slaked with water. The resultant powder, cream or "putty" will be mixed with sand for mortars and plasters or diluted for limewash.

Lime-burning

Limestone, chalks, seashells and corals are all formed of calcium carbonate. When they are heated in a limekiln this dissociates to form *quicklime* (calcium oxide) and carbon dioxide gas. The temperature in the kiln affects the ability of the quicklime to react freely and the best, most *reactive*, quicklimes are formed at the flame temperatures produced historically by wood firing. Most modern commercial limes are produced at rather higher temperatures and so the limes we use today will not be exactly the same as those found in historic buildings.

Quicklime

Quicklime is calcium oxide, also known as "*lump lime*" and "*unslaked lime*". When the lumps of quicklime are taken from the limekiln they have the same shape as the original pieces of mineral from which they were formed, though slightly shrunken. Some of the lumps will be *underburnt* and will have a core of unconverted carbonate. When these are slaked the core remains and can be removed by sieving.

Fresh, hand-picked lump lime: the poorer material feels heavier.

More serious defects arise through exposure to excessively high temperatures in the kiln. In extreme cases the lumps become *over-burned*, they shrivel and look wizened. Instead of slaking quickly they may never slake or, worse, may slake after many months and spoil finished plasterwork, pitting the surface as the stress around the over-burned grains make the face explode. This is called *pitting and popping*.

The old method of avoiding this was to *hand pick* the lumps of quicklime (rejecting the ugly lumps!), to sieve the slaked lime carefully and to store the lime as *putty* (see below) for very long periods before using it for plastering. This allowed extra time for any over-burned particles to slake.

Less dramatic defects occur when quicklime is *hard-burned*. These rather dense lumps react slowly and may cause *unsoundness* in plasterwork when late hydration of many fine particles causes a general expansion and hence a loss of bond to the backing.

The most reactive quicklimes are formed at the lowest possible temperatures, just above 900°C. In commercial lime-works it is more economical to produce lime at rather higher temperatures, but new techniques may become available to enable excellent limes to be produced economically.

Quicklime which is left for any length of time in a moist atmosphere absorbs water and carbon dioxide from the air. The lumps develop loose dusty surfaces and eventually fall apart. This process is called *air slaking* or *wind slaking* and the degraded lime is called *fallen lime*. It should be discarded.

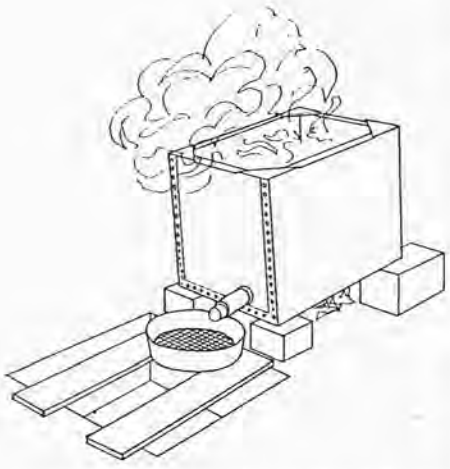
Slaking

A good, reactive, quicklime will combine vigorously with water to form slaked or hydrated lime. This is calcium hydroxide. As it slakes a lot of heat is generated and the material may double in volume (hence the stresses causing pitting and popping described above). The heat makes the process dangerous and quicklime in the eyes can cause very serious damage. Slaking must be organised with great care and further advice is given below.

During the reaction the lumps break down to a fine powder (*dry hydrate*) and if an excess of water is used the mixture of slaked lime and water will form a suspension known as *milk of lime*. If the milk is left to stand a clear solution (*lime-water*) stands above the coagulated mass of *lime-putty*. The lime putty will continue to swell as it absorbs more water physically into its mass.

Dry hydrate is available in paper sacks from builder's merchants. It is known simpy as *hydrate* or *hydrated lime* or just as *bag lime*. Lime putty is widely available on the continent, but only available in England from a few suppliers.

There are several ways in which lime can be slaked by hand. One of the most useful is to add lumps of quicklime to hot water, initially about twelve inches deep in a metal tank—perhaps an old gal-



Lime slaked in the tank will be run through the sieve into the pit.

vanised water tank. This may be set up over a fire to preheat the water. It should be fitted with a wide spout near the bottom and this should be stopped with a tapered bung. The tank should be slightly tilted so that the spout discharges over the traditional wood lined pit in the ground or over a convenient storage vessel.

Wear goggles, barrier cream, waterproof overclothes and gloves and Wellington boots. Have an assistant ready with fresh water and eye irrigation equipment and ensure that people who are not wearing protective clothing and equipment stand well away from the slaking tank. This work is dangerous.

Lump by lump add about one volume of quicklime for every eight or ten volumes of water in the tank (the proportions can be adjusted for different limes). Do not use suspiciously dense or discoloured lumps. It is important to get quickly to a state where the water boils vigorously and to do this the first few lumps may be broken to pebble sized pieces to increase the surface area for the chemical reaction and put in by the shovelful. As an alternative the water may be brought right up to the boil on the fire. Further water and quicklime may be added, always maintaining the temperature high and keeping an excess of water. Stir the tank initially and then from time to time with a long handled paddle. Use a rake or hoe to churn up lumps on the bottom until all movement stops. Cover with a well fitting lid and leave until the milk cools.

The vigorous agitation is to stop the formation of a skin of slaked lime around lumps of quicklime as this can prevent further water from reaching the quicklime surface. This mishap, known as *drowning*, can bring the whole process to a standstill.

Extremely reactive quicklimes will slake in cold water—the process starting slowly and accelerating as heat is generated. There is a danger that drowning of the lime will occur unless it is constantly agitated—a process greatly assisted by boiling water.

When the milk is cool release the bung and pour the lime into the pit or drum through a fine sieve (say 2.36 mm or evern finer for highest quality plaster work). Any large hard-burned lumps and large pieces of core will remain in the bottom of the tank and the sieve will catch finer pieces of unwanted material. Gentle pressure may be used to press the mass through the sieve, though not for the very finest work. Discard any grit on the sieve and the lumps at the bottom of the slaking tank. Keep the pit covered to keep out dirt and to reduce evaporation. As the milk of lime in the pit (or storage vessel) settles out to a lime putty the lime water above will develop a crystalline skin. Make sure that putty remains covered with water.

Lime Putty

With good fresh quicklime the method described above produces very good putties because of the hand picking, the heat, the stirring and the sieving. Good putties may also be bought. Dry hydrated lime will be greatly improved if it is mixed with water to fatten up as a putty.

The longer a putty (from a *pure* lime) is kept covered by water the better it becomes. This is partly because extra time is given for the late slaking of any quicklime which may have passed the sieve, but also because the lime continues to absorb water into a fatter physical structure. The longer the putty is left the more tenaciously it will retain the water is has absorbed. The plasticity also increases so the lime can be spread more intimately around the sand grains when it is mixed in a mortar. The water retention improves the bonding between mortar and masonry. A fair guide is to keep the putty for at least two weeks for general use and preferably for several months. Keep it much longer, ev years, for the finest work.

The putty will become slightly rigid during a long period of storage but this is lost when the putty from a pure lime is *knocked up*.

A lime putty called "Lamotex" is sold by Tilcon Ltd at some of their depots. It is not derived from quicklime but is a by product in the production of acetylene gas from calcium carbide. It is, however, calcium hydroxide and is used in the preparation of ready mixed mortars for new building work.

Dry Hydrate

The most readily available lime is the dry hydrate sold in paper sacks through builder's merchants. This is prepared to the standards set out in BS 890 (the requirements for test methods have been replaced by parts 1–4 of BS 6463). The quicklime will have been slaked in a mechanical hydrator and harmful den particles will have been removed by air separation. They will then probably have been ground finely in a ball mill and, unfortunately, blended back into the hydrate. One of the principal measures of quality of the dry hydrates is their fineness which is a guard against unsoundness.

If used carefully dry hydrate can give acceptable results, though it is unlikely to be used in the best quality plasterwork.

Hydrated lime should never be used straight from the bag. Its performance (particularly its plasticity) increases markedly if it is allowed to soak for twenty four hours and (for *pure* limes) much longer if possible. A putty may be prepared by mixing with water to a creamy consistency and leaving it to stand in a covered container.

Hydraulic Limes

Pure limes will not set under water. They take an initial very weak set just by drying out and they only develop strength by the very slow process of "induration" at the exposed surface. The calcium hydroxide absorbs carbon dioxide from the atmosphere when there is water present and calcium carbonate is reformed. This induration may continue over hundreds of years. Throughout the Middle Ages and well into modern times this was accepted as normal, but there are ways in which lime mortars can be prepared to achieve a firm set throughout the whole mass. One is by using "hydraulic" limes, so called because they were suitable for use in hydraulic engineering works.

Hydraulic lime mortars were known from Roman times but the first thorough investigations of them were made by John Smeaton in the mid 18th century when he was searching for suitable materials for the third Eddystone Light-

house. He found that limestones with a clay content of about 16% produced limes which were best able to set under water.

Many deposits of limestone and chalk contain clay impurities in the carbonate. When they are heated in a limekiln the clayey matter becomes activated and forms compounds with lime. These have a chemical affinity for water with which they form further compounds with setting properties. These *cementitious* compounds have structures analagous to teasels and can interlock to give high compressive and shear strength to mortars. If the clay content exceeds 16% the material might still be useful as a *natural cement* but it would have to be ground finely before use as the lumps of quicklime could no longer break up on slaking. (The lime and clay compounds in Portland Cements are rather similar but are formed at much higher temperatures).

There is, or perhaps there was, a wide range of limes. At one extreme are the *fat lime* which, in a reactive state, will slake vigorously but cannot set under water. At the other extreme are the *natural cements* which set rapidly even under water, but which cannot slake in lump form. In between are the *hydraulic limes* which can be grouped into three loose categories on the basis of their setting times, though this can vary greatly with temperature:

Eminently hydraulic . . . . . setting in 1–4 days
Moderately hydraulic . . . . . setting in 5–15 days
Feebly hydraulic . . . . . setting in 15–21 days

Totternhoe in Bedfordshire is the only site in the UK where hydraulic lime is still produced for use in building. The feebly hydraulic *grey lime* is widely specified for repairs to ancient buildings and is available as a dry hydrate. A semi-hydraulic quicklime is prepared for agricultural use at Shillingstone in Dorset where quicklime is also available at the limeworks by arrangement. There used to be famous sources along the Blue Lias belt in Aberthaw, Watchet, Barrow and Rugby. Other hydraulic limes came from Lyme Regis, Arden (near Glasgow), Whitby and Flintshire. Grey chalk limes were produced in Surrey and Sussex. At the quarries at Amberley in Sussex both white and grey chalks were used for limeburning.

Hydraulic lime production in the UK seems to have collapsed because of the failure to agree British Standards to cover such wide-ranging and variable materials. Standards were agreed in France where the difficulties of natural variation were overcome by encouraging the mixture of natural hydraulic limes with natural cements and pozzolans. The Homologous French Standard NF P15–310 specifies three grades by the strength of standard mortar cubes after maturing for 28 days:

XHN 30 . . . . . 30 Bars
XHN 60 . . . . . 60 Bars
XHN 100 . . . . . 100 Bars

Sources of French hydraulic limes are given at the end of this information sheet.

Pozzolanic Additives

The setting action of natural hydraulic limes can be imitated by mixing any lime with certain additives known as pozzolans. The Romans knew of two types, but their knowledge was not generally available in the Middle Ages and was only republished in the 16th century.

Natural Pozzolana is a volcanic ash which takes its name from the deposit at Pozzuoli near Naples. Similar materials are found elsewhere and one from Germany was transported down the Rhine to Holland where it was ground to a fine powder and shipped to England in casks. This was known as *Dutch Terass* or *Trass*. In his experiments John Smeaton found it very effective for "water building".

The Romans also used crushed tiles or bricks as an aggregate in their cisterns and conduits. The most effective *artificial pozzolans* are produced from clays with a greasy, unctuous, feel which shows that they are finely divided. A relatively low firing temperature leaves the material in the most reactive state.

In the UK there are two widely used artificial pozzolans, though neither is manufactured for this use. HTI powder is ground down from a fired china clay and is intended for use in a High Temperature Insulation. Its white colour is useful in the conservation of lime plasters and structural lime mortars. PFA is the Pulverised Fly Ash from coal burning power stations and is used as an extender in Portland cement concretes for large scale engineering works. With lime it makes an effective grout for filling fissures in walls although its dark colour may cause problems and the source must be selected to avoid ash which is contaminated with sulphate.

Magnesian Limes and Dolomitic Limes

The metallic element magnesium forms similar compounds to those of calcium and although deposits of pure magnesium carbonate are very rare, the double compound of calcium carbonate and magnesium carbonate, *dolomite*, is quite common. Magnesian limestones contain both dolomite and unattached calcium carbonate.

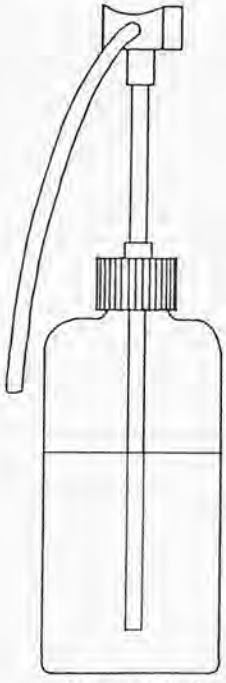
For many chemical and industrial uses the magnesian limes formed from these limestones are perfectly acceptable, but for building use there is a severe disadvantage. Magnesium carbonate gives off its combined carbon dioxide at a much lower temperature than that needed for the dissociation of the calcium carbonate. At normal kiln temperatures the *magnesia* (magnesium oxide—the equivalent of quicklime) becomes hard-burned and so it slaked extremely slowly. There is thus a severe risk of unsoundness in mortars and plasters made with magnesian limes.

Magnesian limes should not be used for building work except in areas where there is a good local tradition. In England they have been widely used in a belt from Mansfield to Boston Spa in the East Midlands; they are common throughout the USA.

Safety and First Aid

Quicklime is a dangerous material and an employer and his agent are legally responsible for ensuring that anyone handling it or working near it follows safe procedures.

A leaflet on safety is available from the Totternhoe Lime and Stone Company Ltd (Lower End, Totternhoe, Dunstable, Bedfordshire, LU6 2BU). It sets out the need to wear goggles (quicklime dust in the eyes is the most serious risk) and protective gloves and clothing. Barrier cream should be used on exposed skin and the mouth and nose should be protected from dust. The leaflet also details first aid treatment and lists suppliers of safety equipment. In case of accident clean water should be available for washing profusely and medical attention should be sought.



An eyewash bottle.

The amount of heat given off during the slaking of quicklime can present a

fire hazard. Quicklime should not be stored on wooden floors and sweepings should not be mixed with wood shavings, sawdust or other combustible materials.

Dry hydrate and putty are much safer to use, but both are caustic and will make skin dry out and crack. Barrier cream is needed and gloves should be worn where possible. Care should be taken to keep lime out of the mouth, lungs and eyes.

Further reading

Mortars, Plasters and Renders in Conservation—John Ashurst (Ecclesiastical Architects and Surveyors Association).

Chemistry and Technology of Lime and Limestone—R.S. Boynton (New York. Second edition 1980).

Lime and Lime Mortars. Department of Scientific and Industrial Research, Building Research Special Report No. 9—A.D. Cowper (HMSO London 1927).

Information Sheet 4, The Need for Old Buildings to breathe—Philip Hughes (SPAB).

Information Sheet 1, Basic Limewash—Jane Schofield (SPAB).

Technical Pamphlet 5, Pointing Stone and Brick Walling—Gilbert Williams (SAPB).

Small-scale Lime-burning—Michael Wingate (Intermediate Technology Publications 1985).

Line drawings by Tim Ratcliffe, who was a Patrick Plunket Memorial Scholar in 1987.

Sources of Lime

High Calcium Quicklime

Quicklime is available from a very few builder's merchants and is normally only obtainable from the limeworks by arrangement. The British Lime Association, 156 Buckingham Palace Road, London SW1W 9TR (01-730 8194) publishes a list of members who burn lime.

Sources include:
A. R. C. Battscombe Quarry, Cheddar, Somerset (0934) 742733.
R. H. Bennett, Nr. Winchester, Hants (0962) 71336
St. Blaise Builders, Evershot, Dorset (093 583) 662.
Bleaklow Industries Ltd., Hassop, Derbyshire (024688) 2284.
ICI Chemicals & Polymers Ltd., Buxton, Derbyshire (0298) 768468.
R. M. C. Industrial Minerals (Peakstone), Buxton, Derbyshire (0298) 5424.
Hargreaves Quarries Ltd., Hartley Quarries, Kirkby Stephen, Cumbria (0930) 71740.
H. J. Chard & Sons, Feeder Road, Bristol (0272) 777681.
Singleton Birch Ltd., Barnetby, South Humberside (0652) 688386.

Lime is also made at some steelworks and (in the Winter months only) at sugar beet factories. It is sometimes possible to obtain small quantities by arrangement with the works engineers.

Magnesium Quicklime

Dolomitic quicklime is available by special arrangement from: Steetley Quarry Products Ltd., Whitwell, Worksop, Nottinghamshire (0909) 722471.

Lime Putty

Lime putty should be run from quicklime if possible. Before ordering, check to see how the putty is prepared as there is little point in buying a recently prepared putty if it was produced from dry hydrate, and the acetylene byproduct lime (Lamotext) might not be acceptable.

Sources include:
R. H. Bennett, Near Winchester, Hants (0962) 71336.
Bleaklow Industries Ltd., Hassop, Derbyshire (024688) 2284.
Hirst Conservation, Sleaford, Lincs (052 97) 449.
H. J. Chard & Sons, Feeder Road, Bristol (0272) 777681.
Potmolen, Warminster, Wiltshire (0985) 213960.
Rose of Jericho, Kettering, Northamptonshire (0536) 73439.
Severn Valley Stone, Tewksbury, Glos (0684) 297060.
St. Blaise Builders, Evershot, Dorset (093 583) 662.
Tamar Trading Co. Ltd., Holdsworthy, Devon (0409) 253556.
Tilcon Bristol (0272) 541978; Coventry (0203) 303562; Gerrard's Cross, Bucks (0753) 883833.
Rory Young, Cirencester, Glos (0285) 68826.

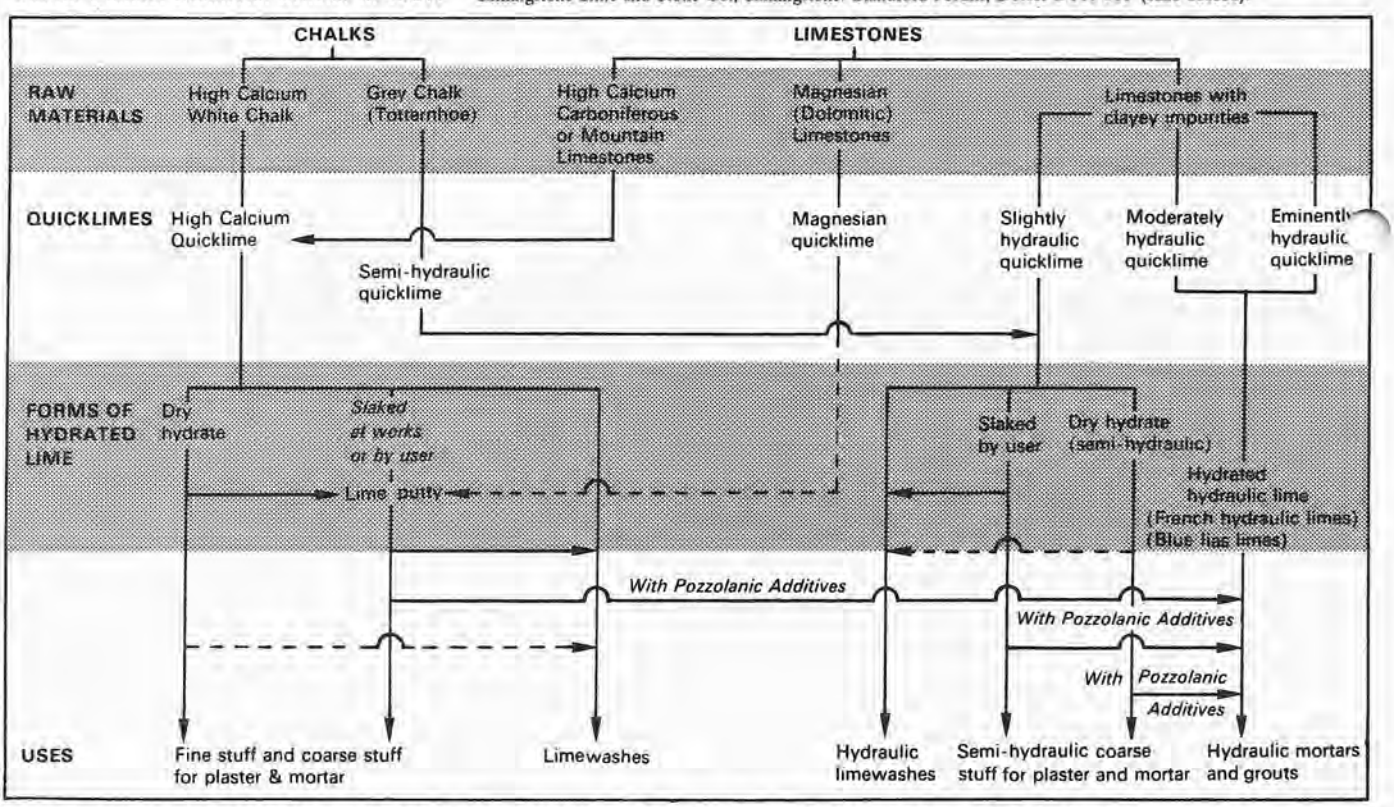
Hydrated Lime

The hydrated lime generally available in the UK is the dry hydrate of a pure (non-hydraulic) lime. This is stocked at nearly all builders merchants. A few merchants also stock the hydrated grey limes from Totternhoe and Shillingstone.

Hydraulic Limes

Eminently hydraulic lime is only available in the UK through The Cathedral Works Organisation, Chichester, West Sussex (0243) 784225 or through William Anelay Limited, Osbaldwick, North Yorkshire (0904) 412624.

Feebly hydraulic limes (a terrible name for one of the most useful materials) are available as quicklime by arrangement from Totternhoe Lime and Stone Co. Ltd., Dunstable, Bedfordshire (0525) 220300. Goodlands Builders Merchants in Tiverton, Devon (0884) 257025 will supply quicklime from Totternhoe by special arrangement and from the Shillingstone Lime and Stone Co., Shillingstone. Blandford Forum, Dorset DT11 0TF (0258 860338).



RELATIONSHIPS AND USES OF DIFFERENT TYPES OF LIME. (Chart after Cowper, BRE Special Report No 9; the chart is intended only to give a general idea of the uses of which the different broad types of lime are best adapted and should not be interpreted too literally).

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