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Further reading

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An Introduction to Building Limes (Information Sheet No.9) (SPAB) - Michael Wingate

Practical Building Conservation Volume 3 - Nicola and John Ashurst - English Heritage

BS6270 : Part 1 : 1982 ; BS CP 111 : Part 2 : 1970 for mortar designations which include lime mortars

The Control of Damp in Old Buildings (SPAB) - Thomas, Williams & Ashurst

Pointing Stone and Brick Walling (SPAB) - GBA Williams

EAST ANGLIAN SUPPLIERS	PRODUCTS SUPPLIED	
Ashfield Traditional, Cricketers, Forward Green, STOWMARKET, Suffolk IP14 5HP - Tel: (01449) 711273	All types of limewash Hair for plaster	
Hendry and Sons Limited, Station Road, Foulsham, DEREHAM, Norfolk NR20 5RE - Tel: (01362) 683249	Lime putty in tubs Hydraulic Lime Hair	Limewash Chestnut Laths Readymixed Mortars/Plasters
Hirst Construction Materials Limited, Laughton, SLEAFORD, Lincolnshire NG34 OHE - Tel: (01529) 497517	Limewash Hydraulic Lime Hair	Lime putty in tubs and bulk Readymixed Mortars/Plasters
Mascot Traditional Materials, Owls House, Frieston Road, Caythorpe, GRANTHAM, Lincolnshire NG32 3BX - Tel: (01400) 272724	All Lime Products	
Farrow and Ball, 11 Hellesdon Park Ind. Estate, Drayton Road, NORWICH, Norfolk NR6 5DR - Tel (01603) 400777	Manufacturers and suppliers of traditional paints including limewash	
Auro Organic Paints, Unit 1, Goldstone Farms, Ashdown, SAFFRON WALDON, Essex CB10 2LZ - Tel (01799) 584888	Plant based organic oils, wax, stains and paints	

OTHER PRODUCERS/ SUPPLIERS/CONSULTANTS	PRODUCT/SERVICE	
Bleaklow Industries Limited, Hassop Avenue, HASSOP, Derbyshire DE9 3LH Tel: (01246) 582284	Lime putty	Readymixed mortars
Hydraulic Lias Limes Limited, Melmoth House, Abbey Close, SHERBORNE, Dorset DT9 3LH Tel: (01935) 817220	Blue lias hydraulic lime	
The Lime Centre, Long Barn, Morestead, WINCHESTER, Hampshire SO21 1LZ Tel: (01962) 713636	Lime putty Hydraulic Lime Consultancy	Limewash Readymixed Mortars/Plasters Practical Training

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GREEN BUILD

INFORMATION SHEET 1

Building With Lime

NORTH NORFOLK DISTRICT COUNCIL

Disadvantages

(a) Non-hydraulic lime is slow to harden. This problem can be overcome with a pozzolanic additive or by switching to hydraulic lime.

(b) Lower crushing strengths than cement. This is unlikely to cause a problem in traditionally constructed low rise buildings, except when using non-hydraulic lime mortar under concentrated loads. The typical strength of a Type 3 cement mortar (1:1:5 - 6) cement/lime/sand is $2.5N/mm^2$.[7] Lime putty mortar has a 28 day strength typically around 0.3 - 0.5 N/mm^2.[9,4] This can be doubled by the addition of a suitable pozzolan. However the higher strengths of cement are easily matched by an NHL3.5 hydraulic lime mortar and could be matched by an NHL2 mix.

Paddle Mixer

(c) Cost. Mortar made with lime can cost twice that of cement. This cost differential seems to be the result of small scale production, since the manufacturing process is simpler, uses less energy and is therefore potentially cheaper. As volume sales increase, this price differential is likely to reduce. Material selection is never straightforward. We do not always specify the cheapest bricks, and where quality bricks or flints are used, a better quality mortar can often be justified.

(d) Familiarity. Most craftsmen will not be familiar with the different techniques applicable to lime use, nor the differing characteristics of lime. As lime use increases this problem should gradually reduce. Short courses for craftsmen are available, but an open mind and willingness to embrace new ideas are a must.

(e) Equipment. Special equipment is generally unnecessary for hydraulic limes but it is difficult to mix lime putty mortars in a standard drum mixer. Paddle mixers or roller pan mixers are preferred.

(f) Need for Protection. Non-hydraulic limes should only be used during the "growing season", April to September, to allow time for the carbonation process to develop before the first frost. In mild weather, it may be possible to extend this period by a week or two. The use of hydraulic lime can extend this period still further, particularly the eminently hydraulic limes, but manufacturers' advice should always be sought. Covers to protect the completed work from rain and frosts must always be available on site. In summer, protection is equally important to prevent rapid drying by wind and sun. Damping down will be needed in hot weather and once again the recommendations of the manufacturers should be followed.

Buildings with solid walls

Lime mortars, plasters and renders are indispensable in the repair and alteration of older buildings. To fully appreciate the central role of lime, we need to understand the fundamental difference between modern (20th Century) forms of construction and those that preceded them.

A principal function of all buildings is to exclude unwanted moisture. Today, this is largely achieved by the use of impervious outer layers, or a system of barriers as with DPC's, floor membranes, cavity walls, waterproof paints and cement renders. These barriers to moisture are effective when applied to the whole building and may be described as the "raincoat approach". Rain is not absorbed by the structure but runs off in torrents. Inside our raincoats we are protected from the rain but can at times become almost as wet through condensation.

Problems arise when we try to apply this approach to older buildings with solid walls. Before the 20th Century almost all buildings had solid walls constructed using local materials. Soft local bricks, carstone and chalk clunch have one thing in common, they all absorb moisture. Walls constructed using these materials will absorb and hold driven rain until it stops and the moisture can slowly evaporate back into the atmosphere. The solid wall therefore, acts not as a raincoat, but as an "overcoat". A thin overcoat, may withstand a light shower before it becomes saturated and the user starts to feel damp. The thicker the overcoat the more rain it will hold before showing wet patches on the inside. Solid walls act in exactly this way.

This crack pattern is typical of cement mortar pointing into flint. The pointing is no longer excluding water but trapping it, raising the moisture level within the wall

Repointing

With solid walls the mortar has a key role in providing a vapour permeable matrix to wick moisture away. Lime mortars fulfil this function but not so cement which is relatively impermeable.

Repointing an old building with a cement mortar will have two possible effects. The first, is to concentrate moisture movements within the masonry units, resulting in long term damage from frost and salt crystallization (see technical advantages (e) overleaf). The second, is to reduce the rate of evaporation, increasing the risk of dampness inside and the likelihood of timber decay where joists are built in.

Solid walls should always be repointed with a suitable lime mortar to protect the building fabric and to guard against moisture entrapment.

Impermeable wall coatings

If walls are absorbent, the modern approach is to cover them with an impermeable film or render. Waterproof paints, silicone washes and water repellent cement renders are often erroneously used as methods of reducing dampness and may for a short time appear to be successful. But the changing seasons and temperatures will cause movements in all walls and cracks will soon develop in the membrane. These cracks are now subject to vastly increased water flows. The wall surface will be non absorbent and rain driven onto the wall will cascade down the face in streams. This wind driven rain will soon find cracks developed over the summer months, concentrating water penetration at these points. If the membrane has limited vapour permeance, moisture will be slow to evaporate away and may accelerate damage to the fabric through salt crystallization and frost, or present as damp patches inside.

Just as damaging is the effect of interstitial condensation. Vapour pressure is normally higher inside buildings than out, so there is a natural migration of moisture vapour through the wall to the outside air. When a membrane of limited vapour permeance has been applied to the outside, evaporation is reduced. Eventually, the build up of moisture within the wall can cause the paint to blister or the render to spall as the "raincoat" breaks down, usually with consequent damage to the building fabric.

Lime wash reduces rain penetration whilst allowing the wall to breathe. It is a traditional, low cost and frequently successful method of improving weather resistance where decorative films have already been applied to the external surface. If penetrating damp is persistent, a lime render will usually prove successful, (where render is a visually acceptable finish).

The downpipe has been repaired, but repairs to the wall with cement pointing will not last and form an ugly patch. Below the eaves, ancient lime wash is still evident with the brickwork substrate it once covered, completely undamaged.

Flint walls

It may be thought that flint is the exception - a local material that is completely non absorbent. What objection could there be to waterproof membranes and cement pointing with a material that is itself impermeable and virtually indestructible?

Solid flint walls behave in just the same way as any other solid wall except that the mortar forms a much larger proportion of the wall material. This is fortuitous, as the absorbent lime mortar matrix must hold and later release all rain driven moisture. The flints will not assist in this function. Often, flint walls will have a soft brick or chalk backing and this increases the walls ability to hold moisture. The greater volume of lime mortar will also assist in providing a path for moisture vapour originating within the building to evaporate harmlessly away.

Damp Proof Courses

There is a wide range of options here and many old buildings have had damp proof courses successfully installed. Some walls are more difficult to treat, for example, where voids have developed, whilst others may be composed largely of non absorbent material, e.g. flints.

Where it is considered inappropriate to install a modern DPC, or where there is no evidence of dampness, the ability of the wall to evaporate moisture rising from the ground becomes critical. Wall surfaces both inside and out must retain the vapour permeance of the original material. Lime should always be used for repointing as well as for any external render or internal plaster. Cement renders and plasters applied to any wall not containing a DPC can only exacerbate problems in the long term.

Without a DPC, the need to maintain vapour permeance to the external surface becomes critical.

As a general rule, dampness in the walls of older buildings is usually the result of a defect in some other part of the structure, or of inappropriate repairs. We can be fairly certain these buildings were not troubled with persistent or chronic dampness when first constructed. Leaking gutters, downpipes and drains, dripping taps, blocked roof valleys and the build up of earth outside, are prime suspects, with the inappropriate use of cement and impervious membranes causing trouble in the longer term. Given adequate heat and ventilation, natural moisture movements should not become troublesome in well constructed older buildings.

Building Regulations

It is sometimes said modern regulations prevent lime use. This is certainly not true. Although current British Standards[7] refer only to cement mortars, recent research by English Heritage[4] and others have given us the basic data to once more specify lime mortars and renders with confidence.

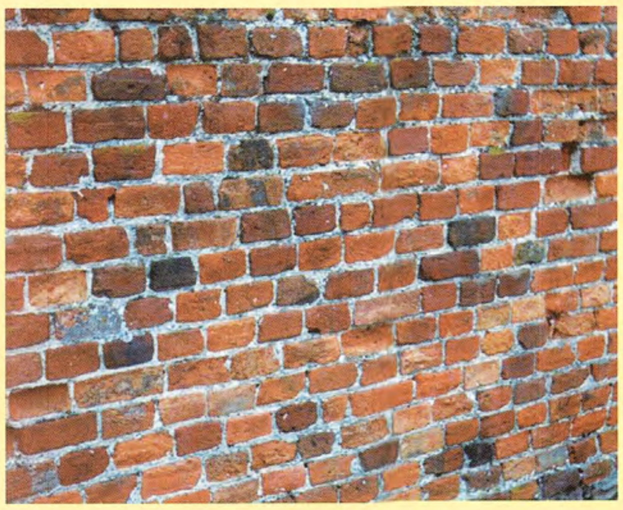
Introduction

This leaflet is intended to give a brief introduction to building limes, their uses, the types of lime commonly available, and where they may be obtained.

What is Lime ?

Lime is produced from lime stone (calcium carbonate) and in past times from chalk. It is calcinated (burnt) to produce quicklime (calcium oxide) and then "slaked" (added to water) to produce calcium hydroxide. This is the lime putty used mainly in conservation work as well as hydrate or builders' lime commonly available at the builders' merchant.

Non-hydraulic limes, (Putty & Hydrate) harden by exposure to carbon dioxide in the atmosphere. Through the evaporation of water and the reabsorption of carbon driven off during the burning process, lime mortar laid between bricks or applied as plaster becomes calcium carbonate once more and so the lime cycle is complete.



Local soft red bricks in lime mortar

NORTH NORFOLK DISTRICT COUNCIL

History

Evidence exists that suggests lime has been used as a binder in building mortars and plasters for at least 7000 years.[1] From 2000 year old Roman remains we know that lime technology had become surprisingly sophisticated. So it is astonishing to realise that in the late 20th century, we had all but lost the skills and knowledge gained through countless generations of lime use. The reason ? Cement.

Portland cement was patented in 1824 by Joseph Aspdin, an English bricklayer. Its use steadily increased throughout the 19th century, but it is probably true to say lime remained the principal binder up to the turn of the century. Throughout the 1920's cement became predominant, helped by the change from solid to cavity wall construction. After the 2nd world war in the massive re-building effort of that period, with a shortage of skilled bricklayers, the use of cheap bricks, blocks and cement mortars, the quality of masonry reached its nadir[2] and lime, as a binder, was consigned to history.

The revived interest in lime in recent times is perhaps a reaction to the poor quality and cheap materials that had become the norm during the 1960's and 70's. How far this revival will go remains to be seen. But today it is possible to build once more with lime putty mortars with or without pozzolans*, or with one of the increasing range of home produced and imported hydraulic limes.

Lime putty in use at Saxlingham

Types of Lime

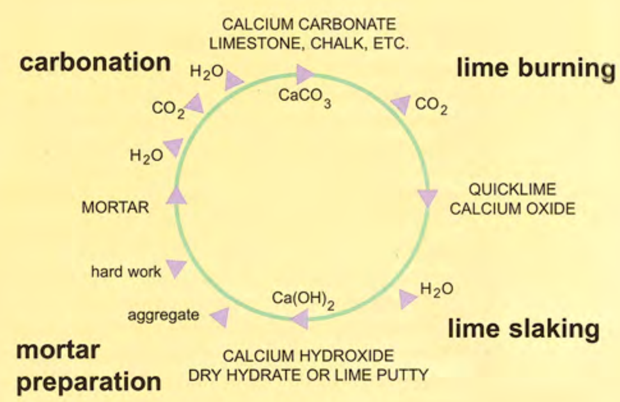
Lime divides into two main types - hydraulic and non-hydraulic.

Non-hydraulic Lime

Non-hydraulic lime is derived from lime stone consisting of almost pure calcium carbonate. It is available in two forms - lime putty and hydrate or bagged lime. Chemically, these two products are identical i.e. calcium hydroxide, but their characteristics can differ markedly.

With hydrate lime, the dry powder is exposed to air from the moment of manufacture. When purchased, it may be days or weeks old and substantial carbonation will already have occurred. It is still a useful plasticiser and will also improve the weather resistance of cement mortars and renders but it should not be used as a sole binder.

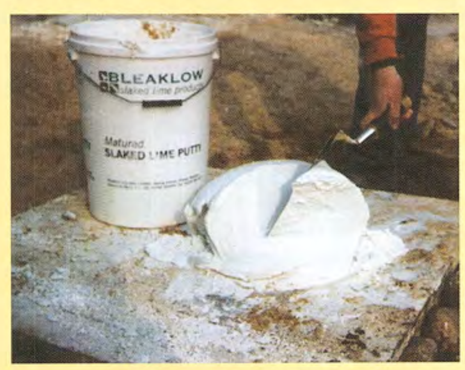
Lime putty differs from hydrate in the method of production. It is "slaked" in water and remains submerged in water in its plastic container. Air is completely excluded so that carbonation cannot begin until it is mixed with sand and allowed to dry. Only then can carbon dioxide be absorbed from the atmosphere converting the calcium hydroxide back into calcium carbonate. With putty there is no chemical "set" as with cement. The mortar hardens through carbonation which may continue for many years.



THE LIME CYCLE

Hydraulic Lime

In Britain, hydraulic lime is produced from an impure limestone (Blue Lias Lime) , one containing a proportion of clay (silica and alumina). They are classified as "natural" hydraulic limes and have the designation NHL. Hydraulic limes may also be produced by adding a pozzolan at production. In this case the lime is designated NHL-P or NHL-Z.[3]



Lime Putty

Bagged Hydraulic Lime

For many years hydraulic lime was classified as feebly, moderately, or eminently hydraulic, according to the proportion of active clay present -

Feebly hydraulic -	less than 12% active clay;
Moderately hydraulic -	12 to 18% active clay;
Eminently hydraulic -	18 to 25% active clay.

These classifications have recently been replaced by the new draft European standard as follows :-[3]

Designation	Compressive Strength at 28 days	
HL2	2 - 5	N/mm²
HL3.5	3.5 - 10	"
HL5	5 - 15	"

These strengths are based on a 1:3 lime sand mix.

*Pozzolan**

This is a generic term used to describe any material which, when added to non-hydraulic lime, induces a hydraulic set. Clay is the natural pozzolan in hydraulic lime. Some types of brick dust (burnt clay) have been found to work extremely well with lime putty, producing mortars far more durable than cement mortars.[4] The term derives from a volcanic ash called pozzolana found near Naples.

Sands

Any note on lime must contain some words about sand. Indeed, many would argue that sand has a greater effect on the finished mortar than the lime, affecting its colour, texture, durability, strength and vapour permeability. Soft builders' sand is definitely out. Sands should be sharp (angular) and well graded. An example of a suitable well graded sand is given below :- [5]

Percentage retained on BS sieve meshes	
10%	2.36mm
20%	1.18mm
20%	600 micron
20%	300 micron
15%	150 micron
15%	finer than 150 micron

Grading result sheets are available from most gravel pits which will enable comparisons to be made, but in practice it is difficult to achieve the ideal. Most sands tend to have higher concentrations in the 600 and 300 micron ranges than is desirable. Coarse sands for concreting usually contain sufficient of the larger particle sizes but are deficient in the smaller grains, 150 micron and below.

It is these smaller particle sizes which give the sand its colour and improve its workability. In coarse sands these smaller grains and silts are usually washed out, leaving the sand a pale, almost opaque yellow. A sand of this type mixed with lime will produce a stark white mortar which may not be acceptable. To obtain the softer whites and creams of the past a yellow sand will be needed. However, a word of caution - much of this deep yellow could result from the presence of silt. Many old mortars have been found with high levels of silt which appeared not to have been detrimental. Today however, a silt content of over 10% would not be acceptable.[6] Good results can often be obtained with a blend of coarse and soft sands.

Why use Lime ?

For many, cement mortars offer assurance. The strength is guaranteed. One need not be too fussy about the sand. Why bother with this antiquated weak material ? There is no doubt using lime will demand more care and thought than cement. The advantages of lime mortars lie not in their price, nor in their tolerance of misuse, but in their performance over hundreds of years.

As a result of the dense cement pointing, moisture movements are occurring, principally within the bricks, with consequent long term damage

Technical Advantages

(a) Lime mortars and renders are vapour permeable. In solid construction this can often eliminate problems of condensation allowing the wall to "breathe".

(b) It has significantly improved resistance to rain penetration, a fact long acknowledged in British Standard Codes of Practice.[7]

(c) It can reduce and sometimes eliminate the need for movement joints, being far more flexible than cement.

(d) Its strength is appropriate to soft Norfolk red bricks, carstone and chalk clunches.

(e) It protects the masonry units from the damaging effects of salt crystallization and frost. The mortar acts as a sacrificial matrix repairable every 150 to 200 years or so by repointing. Use cement mortars and the evaporation and consequent salt crystallization will occur within the masonry units, accelerating the erosion of soft bricks and stones, often leaving the offending cement mortar standing proud of the degraded bricks. Dense cement mortar concentrates moisture movement within the brick/stone, leading to accelerated deterioration through frost attack. Over time, the effect of these mechanisms leads to an accelerating cycle of brick/stone decay, water entrapment and further decay.[6]

(f) It has improved adhesion and workability and is generally preferred by craftsmen once they become used to its differing properties.

Environmental Advantages

(a) Using lime allows the masonry units to be reclaimed at the end of the buildings' life. Use cement mortar and the bricks and flints become expensive hardcore. Bricks have a high "embodied energy"* and a potentially long life, often longer than the buildings. Reclaiming these bricks at the end of the buildings' life can double their life and in so doing halve the embodied energy.

* The energy consumed in the extraction manufacture, transportation and use.

(b) It facilitates the alteration and repair of older buildings and enables them to be more easily adapted to modern use.

Original lime mortar still performing well after 200 years

Visual Advantages

Mortar represents about 20% of the visible surface area of masonry, up to 30% in flint work. Substituting the dull grey of cement for the soft creamy whites of lime, changing the smooth dense texture of cement to the coarser more open texture of lime, with the larger sand particles visible in the hardened mortar, will transform any masonry facade. Even without the technical and environmental advantages, lime can be justified on this count alone.