# Building Materials

## LIME

Lime used in building is made from chalk or limestone (calcium carbonate) burned in a lime kiln to form quicklime. The quicklime is added to water in a process known as slaking to form a creamy lime putty. Lime putty is mixed with sand to form lime mortar, or with water and pigments to make limewash. Lime mortar and limewash harden by a chemical process called carbonation as water evaporates and the lime reacts with carbon dioxide in the air. During each of these processes the lime undergoes a chemical change but the final stage, carbonation, converts it back to calcium carbonate which is chemically and physically similar to the original limestone. This is known as the "lime cycle".

There are two basic types of lime; hydraulic lime and non-hydraulic lime:

The term "hydrated" is often used when referring to lime and there is sometimes confusion about the differences between hydraulic lime and hydrated lime. "Hydraulic" refers to types of lime which set partly due to a chemical reaction with water. They can therefore harden even underwater.(The setting of hydraulic lime is much more complicated than is shown in the lime cycle above). Non-hydraulic limes require the presence of air in order to set and will not harden underwater. The term "hydrated" simply refers to any type of lime, hydraulic or non-hydraulic, which has been slaked. The terms "hydrated lime" and "slaked lime" mean exactly the same thing. However, many people use the term "hydrated lime" to describe only the dry, powdered non-hydraulic lime sold in bags at builders merchants. This is misleading since non-hydraulic lime putty and dry powdered hydraulic lime are also hydrated limes. It is less confusing to learn and use the correct terminology which describes the material more precisely.

## NON-HYDRAULIC LIME

The lime most commonly used for conservation work today is non-hydraulic lime, which may also be referred to as high calcium lime, pure lime or fat lime. It is available either as a dry powder or as a sticky lime putty. Both are chemically the same (calcium hydroxide) and are made by slaking quicklime (calcium oxide) in water. The dry powder is made under carefully controlled conditions which ensure that there is no excess water once slaking is complete, whereas lime putty contains more water than is necessary for complete slaking.

The excess water protects the lime putty from reacting with the air so it can be stored indefinitely without hardening. In fact the longer it is stored the better it becomes. This is because storage ensures thorough slaking and because the lime continues to absorb water into its structure. This increases the plasticity of the lime allowing a closer contact with the sand grains when it is used for mortar, enabling a better bond between mortar and masonry. Lime putty should be stored for at least one month before use, and ideally for at least three months. The longer it is stored the better, and for the best work use putty which is six months or one year old. Lime putty should be stored in airtight conditions.

Dried lime on the other hand starts to deteriorate from the moment it is made. As a powder it has a large surface area which, when exposed to the air, results in partial carbonation of the lime even before it is used for making mortar. Therefore it cannot create such an effective bond with the sand or masonry. Its properties improve a bit if it is mixed with water and stored for at least 24 hours before use, but for best results use good quality, mature lime putty not hydrated lime powder.

Non-hydraulic lime is suitable for use with traditional building materials such as stone, clay brick and earth, in a variety of situations.

## HYDRAULIC LIME

Hydraulic limes are made by burning limestones which contain impurities, particularly minerals such as silica, alumina and iron oxides, to form hydraulic quicklime, which is slaked in a similar way to non-hydraulic lime. Hydraulic limes undergo partial hardening by reaction with water so, unlike non-hydraulic limes, they are capable of setting underwater. This setting property derives from the presence of the impurities which, once slaked, react with the lime in the presence of water forming solid crystals. The proportion of these minerals occurring in the limestone and combined during the burning affect the strength of the lime and the speed with which it will harden. A low proportion of impurities will produce a feebly hydraulic lime whereas a higher proportion will yield a moderately or an eminently hydraulic lime. Some hydraulic limes are so strong and quick setting that they are referred to as natural cements. A recent European standard for classifying hydraulic limes is rapidly replacing the old classification. Natural hydraulic limes are now designated as NHL with the terms ‘feebly’, ‘moderately’ and ‘eminently’ replaced by the suffixes ‘2’, ‘3.5’ and ‘5’. So, for example, a feebly hydraulic lime would be designated NHL2.

Because hydraulic lime starts to harden by reacting with water, hydraulic lime if made into a putty must be used soon after slaking and cannot be stored for long periods. However hydraulic lime is usually supplied in powder form which, if kept airtight and dry, has a longer shelf life.

Blue Lias limestone was historically an important source of hydraulic lime for building mortars. Its use declined and eventually ceased during the twentieth century but it is now manufactured in Somerset once again. Hydraulic limes are also imported from France, Switzerland and Italy.

Hydraulic lime is suitable for use with moderately durable stone and brick, especially in exposed conditions. As it may be stronger than non-hydraulic lime it may not be suitable for use with very soft, weak materials such as cob and decayed stone or brick.

## SUPPLIERS

If you ask for lime at a builders’ merchant you will almost certainly be offered dried non-hydraulic lime sold in bags. However good quality non-hydraulic lime putty is superior and should be used wherever possible. Non-hydraulic lime putty and dried hydraulic lime are available from an increasing number of specialist suppliers, but they are rarely available from builders’ merchants. Lime putty is usually supplied in plastic bags or tubs in which it can be stored indefinitely. It should be matured by the supplier for at least one month before sale, and most suppliers also stock three month old putty. Check the age before buying. Lime putty can be stored for years, improving all the time. Here at **Old House Store** we can supply putties from 3 months to 5 years old.

## AGGREGATES

The choice of aggregate is important in determining the appearance and performance of the lime mortar. Aggregate adds bulk to the lime and acts as a filler, helping to reduce shrinkage of the lime as it dries out. This is best achieved using a well-graded, sharp aggregate. This means that the particles are angular rather than rounded and that there is a range of particle sizes, incorporating both fine and coarser particles. Such aggregates will interlock well, the smaller grains filling the spaces between the larger ones. Aggregates where the particles are all

the same size or are soft and rounded do not interlock to the same extent and will form less cohesive mortars. If you scoop up a handful of sharp, well-graded sand and clench your fist you will feel the sand grains interlock forming a solid mass in your hand. If you do the same with a soft or poorly-graded sand it will feel much less solid and still feel liable to "give" in your hand. This is a useful test when buying sand. You can also use a x10 hand lens to look more closely at the angularity of the grains and the range of grain size.

A well-graded aggregate will also impart a stronger texture to the mortar than one with uniform particle sizes. The texture of the mortar should reflect the type of masonry being repointed. Masonry with fine joints should be pointed with a fine aggregate whereas wider jointed masonry usually looks best pointed with a coarser mix. Most historic mortars are composed of whatever aggregate was available locally and many have a higher proportion of fine particles than would be recommended today. Although it is usually desirable to try to match the texture of the original mortar when re-pointing care should be taken to avoid reproducing mortars which are too fine and may not perform well.

The colour of a mortar is influenced by the choice of aggregate. However, lime tends to whiten any aggregate with which it is mixed so that lime mortars are traditionally pale cream or buff. When carrying out re-pointing or re-rendering it is usually best to try to match the colour of the original pointing rather than that of any later work. Only rarely is a strongly coloured mortar appropriate so artificial pigments are very rarely needed.

The most common type of aggregate is sand, sometimes with the addition of grit where a coarse aggregate is needed. The sand should be well washed to remove impurities such as clay, salts and organic matter which could all affect the performance of the mortar. They should then be stored away from possible contamination by soluble salts, and ideally in dry conditions. It is much easier to accurately measure volumes of dry sand than damp or wet sand. This is because most sands swell and increase in volume when damp or wet so if damp sand has to be used this 'bulking' must be taken into account and a greater volume of damp sand will be needed for each volume of lime.

Most builders merchants sell sand of unspecified origin and it is only by looking at it and feeling it that you will be able to assess whether it is suitable for lime mortar.

Crushed limestone or chalk dust is sometimes used as aggregate. Particles of chalk or limestone are more porous than sand grains and can help entrain air into the body of the mix aiding carbonation and producing good, durable mortars. But, although stonedust was often used traditionally, it can be very difficult to use successfully. It is often supplied nowadays as a very fine powder which requires the addition of a great deal of water to make a workable mix and makes the mortar more prone to shrinking and cracking. If stone dust is added it should be crushed and sieved to produce a well graded aggregate. Since most users do not have access to a set of standard mesh sieves, and since most suppliers would charge a small fortune to sieve stone dust for you, it is probably better for DIY users to avoid using it, or at least to use it in small quantities of say no more than 1/2 part stone dust to 21/2 parts of sand.

Occasionally other materials, such as crushed shells, kiln slag and ash were used as aggregate in traditional mortars, and these will often be evident when looking at the old mortar. However they are rarely used nowadays except for very specialised conservation work.

## ADDITIVES

Historic mortars often contain a variety of substances such as milk, blood, linseed oil and tallow, which were added to alter the mortar's properties. However the benefit of some of these additives is questionable and nowadays such additives are only used in exceptional circumstances and following detailed analysis of their effects.

Many modern mortar additives are on the market but most of these are either unnecessary or unsuitable for use with lime mortar. Plasticisers are not needed as lime mortar is naturally extremely workable. Accelerators or antifreeze additives can introduce harmful soluble salts into historic masonry and should not be used in mortar for historic work. If lime mortar must be used during periods of frost-risk the work should be protected from freezing until it has carbonated. Waterproofers are also unsuitable for lime mortars as they reduce the ability of the mortar to breathe and thus reduce one of the greatest advantages of using lime mortar.

Certain materials, known as pozzolanic additives, may be added to lime mortar to increase its initial set and also to increase its durability in exposed locations. The most commonly used pozzolans are brick dust made by crushing and sieving soft, under-burnt bricks, volcanic ash called trass and calcined china clay sold under the name of Polestar or Metastar. Lime mortars are frequently gauged with ordinary Portland cement or white cement to speed up the initial set. However recent research has suggested that the addition of small quantities of cement may actually weaken the mortar and it is better to avoid the use of cement in lime mortars.

Although pozzolanic additives can be extremely helpful their use is usually best restricted to the more specialised conservation projects. In many circumstances a simple lime mortar will perform perfectly well and be remarkably durable provided it is properly mixed and applied and allowed to dry out slowly and carbonate properly.

Animal hair is traditionally added to lime plasters and renders to reinforce the mortar and reduce shrinkage cracking. It is particularly valuable in strengthening plaster applied to wooden laths but is also frequently found in plasters on a masonry backing. It should be supplied washed and sterilised.

## READY-MIXED MORTARS

A number of specialist suppliers can now provide ready-mixed lime mortars. These are usually sold in bags or plastic tubs which can be stored indefinitely. Provided they have matured for long enough (at least one month) they require only tipping out and knocking up before use. Each supplier will have a selection of standard mortars for different purposes such as pointing, plastering or rendering, but special mixes using a particular sand or incorporating hair can usually be made on request and at extra cost. Mixing your own lime mortar is time consuming and hard work so ready-mixed mortars, which are tried and tested, are ideal. Suppliers will also usually give advice about using the materials.

## MIXES AND PROPORTIONS

When using lime mortar to repoint or re-render an old building care should be taken to ensure that the mortar used is as close a match as possible to the original in terms of colour, texture and composition. The original pointing mortar can often be revealed in the joints behind newer pointing or render, but it must not be confused with mortar used for a previous repointing or with the mortar used for bedding the masonry. Some lime mortar suppliers have facilities for analysing the constituents of old mortars so that they can be accurately matched,

but in most cases mortars can be matched by eye and by making up a few trial mixes. Where it appears that the original mortar contained a high proportion of fine material and that a replica mix may perform poorly then it might be better to use a better graded aggregate rather than to repeat a mistake for the sake of historical accuracy.

Where there is no evidence of the original mortar an appropriate new mix can be made taking into account the type and hardness of the building material and the exposure of the building. In general, soft, porous or severely weathered stone must be treated with a softer, weaker mortar than hard, dense stone.

For pointing and rendering there is the choice between using hydraulic or non-hydraulic lime for the binder. The decision usually depends on the nature of the wall being treated and its degree of exposure. However, this is a subject about which there are strong and varied opinions. English Heritage is undertaking research which it is hoped will sort out some of the controversy, but at the moment it is almost impossible to give hard and fast guidance about which lime should be used in which circumstances. There is general consensus that a hydraulic mix is suitable for use below ground level or in areas subject to prolonged periods of dampness, and that rendering on cob walls and internal plastering should be undertaken using non-hydraulic mixes, but beyond this there is little agreement amongst practitioners. However, for most stone and brick in reasonable condition there is, technically, little to choose between a hydraulic and a non-hydraulic lime and the decision often rests with the personal preference of the person applying it or the architect specifying it. Non-hydraulic lime is very sticky and nice to use, although it is more likely to suffer shrinkage. A non-hydraulic mortar can be given a hydraulic set by adding a pozzolan, but incorporating the pozzolan evenly can be hard work, especially for large volumes of mortar, and it is more expensive than using a hydraulic lime. Hydraulic lime tends to be leaner, or less sticky, and so can be more difficult to use, but tends to set faster and shrink less. Because it can be mixed more easily (see later section) it can work out cheaper to mix your own hydraulic lime mortar in a drum mixer than to buy ready mixed non-hydraulic mortar. In more exposed locations science tends to suggest that hydraulic limes would perform better but there are plenty of practitioners who can point out ancient non-hydraulic lime renders on west facing church towers which are still going strong. The debate is likely to continue for some time.

The most basic lime mortar mix consists of 1 part of lime to 21/2 or 3 parts of sand. In these proportions there is just sufficient lime to thoroughly coat the sand grains and fill the voids between the grains forming a compact cohesive mortar. By varying the type of lime and sand used in such a mix an infinite variety of mortars can be created to suit the requirements for pointing and rendering.

It is not advisable to use a mixture of hydraulic and non-hydraulic lime in the same mix as the behaviour of such hybrid mixes is not properly understood. For a quicker initial set pozzolanic materials may be added to a basic non-hydraulic mix but further advice should be sought before using them.

For repointing very finely jointed ashlar a more lime-rich mix is usually used. A mix of 1 part lime to 1 part fine sand is quite common and for the very finest of joints pure lime putty is used.