



Over the past ten years there has been an increased interest in traditional lime mortars for restoring historic masonry. Lime Putties, Lime Mortars, Hydrated Limes, and Hydraulic Limes, are now “buzz” words in the preservation industry. The issues that are involved in making traditional mortars have been argued and debated. This introduction will attempt to illustrate some of our experiences and knowledge in working with traditional lime mortars.

The Lime Cycle

The easiest way to explain how lime mortars are made and how they work is illustrated through the “lime cycle.” The lime cycle effectively demonstrates what takes place during the burning, slaking, and use of lime mortars.

Lime Burning

It all begins with limestone. This limestone can be hydraulic (see An Introduction to Natural Hydraulic Limes) or non-hydraulic, high calcium, magnesian, or dolomitic. High calcium limes are those that are 95-100% pure calcium carbonate. Magnesian limes contain calcium carbonate with a 5-40% content of magnesium carbonate in the limestone, and dolomitic limes contain over 40% magnesium carbonate. Traditionally, all of these limes were produced for building limes. Virginia Lime Works traditional mortars are produced with high-calcium lime.



The limestone is placed in a kiln and burned at temperatures (over 1650° F) sufficient to drive off the carbon dioxide and moisture from the stone. Many different fuels can be used for this process. Michael Wingate discusses the various fuels employed in lime burning in his book, Small-scale Lime-burning a practical introduction, available from Stylus Publishing:



“The traditional fuels are wood, coal, and sometimes peat. In many ways wood is one of the best fuels and when other fuels are used attempts are made to imitate the best flame characteristics of wood.

The most expensive coals burn best in lime-kilns and some lime-burners keep down costs by burning high quality coals in the least popular size gradings.

Oils and gases can be efficient and convenient but the balance is offset by the need for the more sophisticated types of kiln with higher capital and maintenance costs.” – Small Scale Lime Burning pg. 42

When burning limes, it is important to maintain the temperature just above the calcining point to ensure that the limestone is neither over nor under burnt. From Small-scale Lime-burning A practical introduction pg 9-10 (Section 2.2)

“Just as the carbonate has several structural forms, so has the oxide. The most reactive forms of lime are produced when the burning is kept to as low a temperature as possible. This is achieved without effort when wood is used as the temperatures barely exceed 900°. For lime to be produced at these low temperatures and the partial pressure of the carbon dioxide must be kept low and the steam produced by burning wood helps achieve this...”

“In normal commercial practice kiln temperatures are kept high to speed up decomposition. Temperatures around 1250°C are quite normal. ‘Solidburned’ quicklime formed at this temperature has a more formal structure and is less reactive than the loosely structured ‘lightburned’ lime produced at low temperatures.





Above perhaps 1250°C there is a danger that slight impurities in the raw material can form fusible products which close the pores of the lumps. The lime is then said to be 'overburned' and will have a wizened appearance. The closed structure makes the overburnt quicklime very slow to slake and this can cause serious problems in some uses."



For more information about traditional lime burning, kilns, fuels, and limes in general, we recommend reading [Small-scale Lime-burning a practical introduction](#) by Michael Wingate.

The purpose of burning lime for building mortars is to effectively drive off all carbon dioxide and moisture from the limestone. This is to produce a calcium oxide (also known as quicklime).

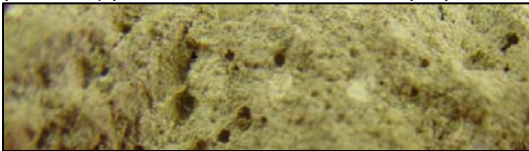
Lime Slaking

Once the quicklime has been taken from the kiln, it must be slaked, which is the action of combining moisture with the quicklime. When quicklime and water are combined, an exothermic reaction takes place as the quicklime begins to swell and crumble away, producing a calcium hydroxide. If slaking is done with a minimum amount of water (steam or air), the quicklime breaks down to a powder, or a hydrated lime. If slaking is done with an excess of water, the material can be worked down to form milk of lime. This milk of



lime, over time, will settle out and a lime putty will be formed. Also, when lime is made into lime putty, the material continues to slake, and the particles break down, dissolve, and then precipitate, causing the particle sizes to become finer and richer. Lime putties that are run directly from quicklime are considered better when applications require superior plasticity and carbonation. Also, as it is in a wet state there is a greatly reduced risk of the material carbonating. It is argued that if one adds water to hydrated lime it forms a lime putty, but this is both true and misleading. Since the material has previously been slaked, as in a "hydrated lime", when one adds water, it forms a lime paste. Basically this is just an extension of hydrated lime, unlike true lime putties that are made by slaking quicklime with an excess of water.

On the same subject of slaking, it should be noted that the Romans had legislation saying that the lime used for buildings must be aged for at least three years. It should be noted that this was due to the fact that the lime that they were burning was dolomitic. The magnesium carbonate found in dolomitic limes converts to magnesium oxide at a lower temperature than calcium carbonate converts to calcium oxide; therefore, it was often the case that the magnesium oxide was overburnt. This is why it was so important to allow the lime as much time as possible to slake. In modern production, dolomitic limes are slaked by an autoclave (under pressure) process, which ensures the proper slaking of the magnesium oxide.



While discussing slaking and mixing aggregates to form a mortar, an alternative but historically common method should be brought to attention. Many people are under the common misconception that most historic mortars were made as a combination of lime putty and sand. Although this method was practiced, it was primarily a mix designed for plasters or extremely fine "finishing" mortars. For a large part, traditional masonry was built using "hot" lime mortars. These mortars were easy and quick to make, and were often a better performing mortar than lime putty mortars. There are a few ways to make hot lime mortars. One method is measuring out volumetric proportions of sand and lime (often three or four parts sand to one portion of lime). The sand is then mounded up around the quicklime to cover it. The quicklime will then begin to slake by drawing the moisture



from the sand. Over a short period of time (overnight), the quicklime will be reduced to a hydrate and the dried sand and lime would then be punched through a sieve to remove any coarse or large unslaked or underburnt particles of lime. This mixture would then be added with water to form a finish mortar. Alternatively, a mixture of sand and lime can be combined with water immediately and the mixture will slake the lime and make a building mortar at the same time. Both of these methods were often used in traditional building construction, and a common indicator for the presence of these types of mortar are the small inclusions of lime that are found in many historic mixes. If these mixes were made from lime putty, the inclusions would often appear flattened and “smeared” throughout the mortar.

Making Lime Mortars

Now that the various types of slaking have been discussed (and examples of traditional hot mixed mortars), the methods of making



mortar with lime putty should also be discussed. The first and foremost issue when making lime putty mortar is understanding the amount of water retention in lime putties. Although the lime putty may have fattened and aged to the consistency of a cheese, the more that it is beaten and worked, the more workable and pliable it becomes. Therefore, when making lime putty mortar it is important that the mix is both mixed and beaten. The mixing will blend the particles of sand and lime together, but the compaction of the sand and lime will bring the mortar about to a dense, workable, cohesive, and rich mixture. This can be achieved by hand, by mixing with a hoe and shovel, followed with beating it with a pestle or it can be achieved mechanically through the use of a roller pan mixer. Roller pan (or Mortar Mill) mixers are built with both blades that blend and mix the material and large steel wheels that compress the lime and sand together. Lime putty mortars should never be initially mixed in a standard drum or paddle mixer. They must be mixed **AND** beaten, and then if the need arises to rework lime putty mortars, then a paddle mixer can be utilized.



Using Lime Mortars

Now after the mortar has been prepared, it can be used right away or it can be stored and aged until ready



for use. Non-hydraulic lime mortars set due to the re-absorption of carbon dioxide (known as carbonation). Natural Hydraulic Lime mortars set due to both their hydraulic properties and carbonation (the amount of hydraulic set versus carbonation is dependant on the degree of hydraulicity), whereas the set of traditional non-hydraulic lime mortars is dependant solely on carbonation. If the mortar is kept from air (either stored in pails, or mounded up and covered with damp burlap and plastic), it can be stored for extended periods of time. Over time, the alkaline nature of the lime will begin to etch the particles of sand making a tighter and more cohesive mix. After the lime mortar has been applied (through repointing, laying, plastering, or other uses), carbon dioxide dissolves into water vapor to form carbonic acid. This carbonic acid combines with the

dissolved calcium hydroxide to form calcium carbonate. It is very important that the mortar does not dry too quickly, which could inhibit the absorption of this carbonic acid, but it is also important that the mortar is not oversaturated with water, which could also inhibit carbonation. It is also very important to ensure the mortar is protected from freezing temperatures, harsh direct sunlight, strong winds, and heavy rain until the mortar has properly cured. Through controlling the rate of absorption of your substrate combined with the protected curing of the mortar, proper carbonation can take place, resulting in a long lasting and durable lime mortar.