# BINDERS

**WHAT MATERIALS CAN BE USED AS BINDERS ?**

The binder is the part of the mortar that holds all the different sized particles of aggregate together. Without a binder the aggregate would simply be a pile of sand.

## Kimbada cha makuta

In Zanzibar three types of binder are used. In the simple 'kimbada cha makuta' of the shamba, heavy clay soil is often used to bind together pieces of coral to make infill between the sticks of the frame. This kind of clay binder and mortar is not very good as it will easily wash out in the rains, although it is simple enough to mix up more and replace the loss. Simple clay bound soil mortars in Zanzibar are suitable only for crude buildings.

## Portland Cement

Another kind of binder very widely used is Portland Cement. Cement is supplied as a grey, dry, and very fine powder. It is added to the aggregate dry and then mixed in with water to produce a wet mass, CEMENT MORTAR. These mortars are now used with coral stone, concrete block, bricks and as renders.

## Lime

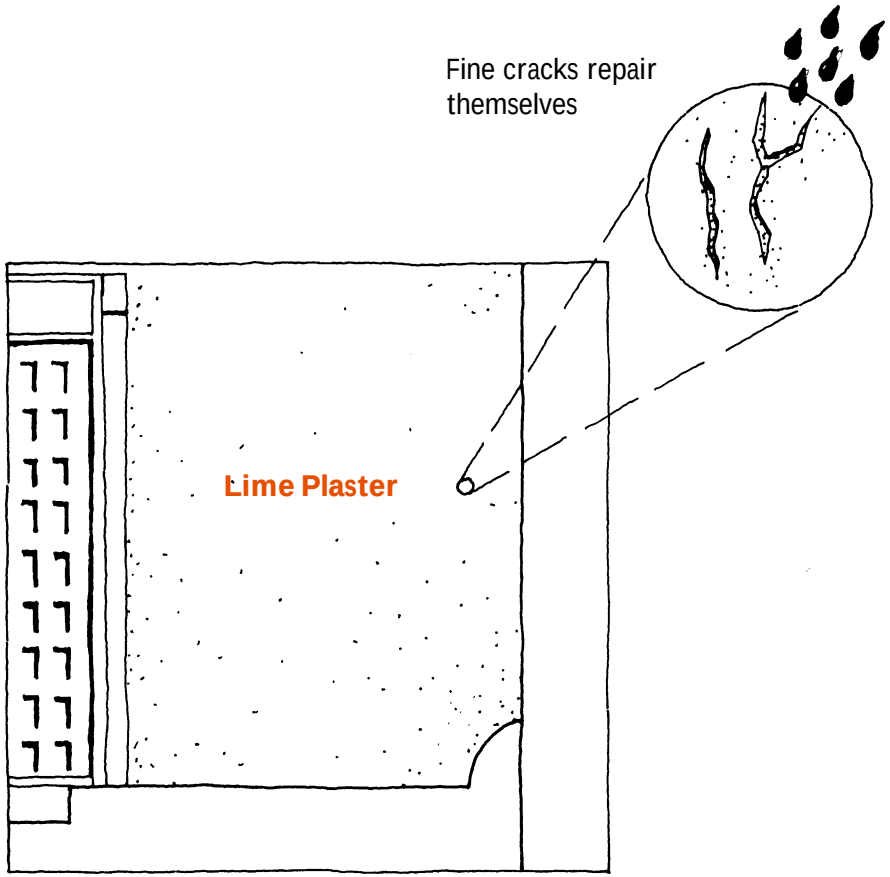
To build the higher quality coral stone Swahili house, and many years ago to build the Stone Town, a third kind of binder was used, lime. Lime is today supplied as a fine white powder called HYDRATED LIME or as a thick white paste called PUTTY. Hydrated lime is generally only used as a component of cement/sand/lime mortars and is not of sufficiently high quality to specify for use as a traditional lime mortar. Lime putty is the binder originally used in the construction of the Stone Town. Lime in this form has been used to make mortar for thousands of years in many parts of the world.

## WHICH BINDER IS BEST ?

Before looking at the very different mortars produced by cement and lime binders, it is important to understand how crucial mortars and renders are in the life of a stone building.

When used in a building, stones are encased in mortar. The mortar fills the spaces between the stones and is often applied to their faces as a plaster or render. Mortar makes the environment in which stones must live. If stones, and the buildings made from them, are to remain healthy, mortars and renders MUST be as similar as possible to the stones they live with.

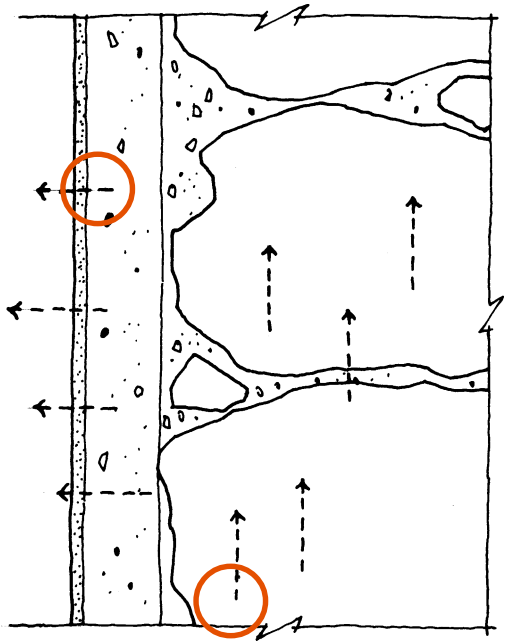
Many old houses were built with poor foundations. This often leads to cracks forming in the walls as heavier parts of the house start to sink. Mortar made with a lime binder remains slightly flexible even when set and will let walls move without cracking too much. Furthermore, lime mortars repair fine cracks themselves as rainwater slowly deposits fresh calcium carbonate taken into solution from the surrounding mortar.



## LIME PLASTER

Old buildings were built without damp proof courses which stop rising damp inside the walls and it is very important that mortars are porous so moisture can pass through them and evaporate. This helps to keep houses dry and makes a healthy atmosphere inside.

Lime plaster allows moisture to evaporate



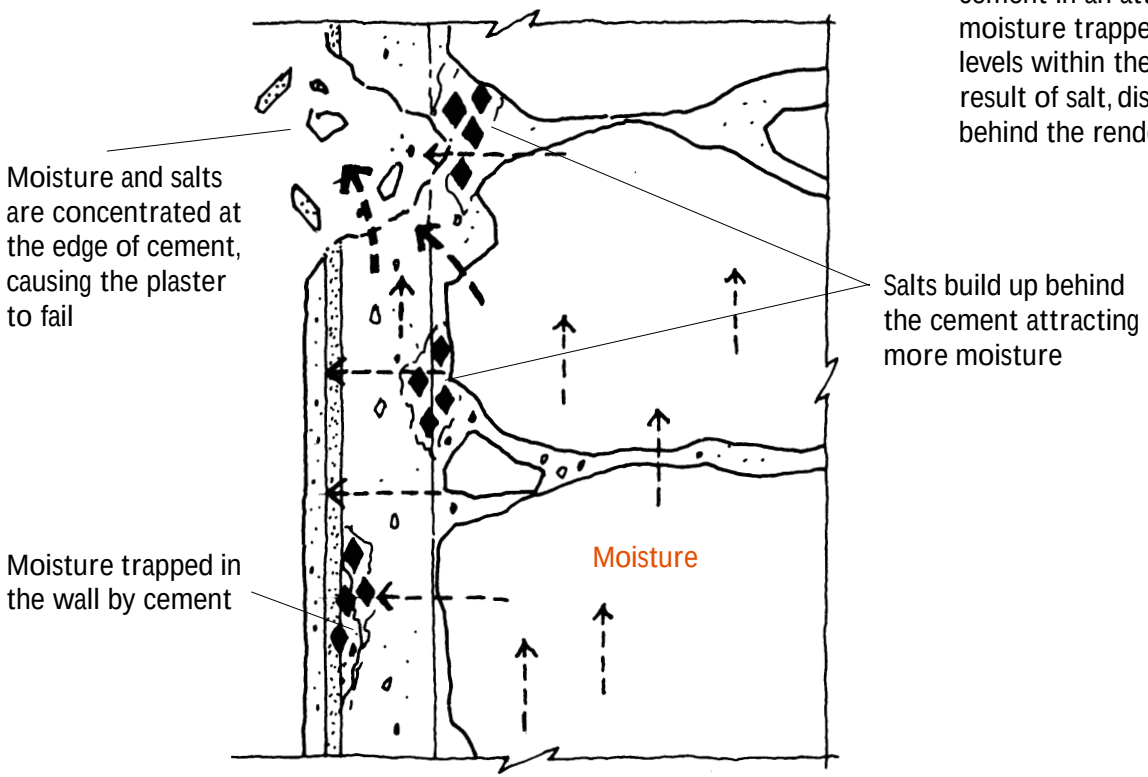
Moisture rises in the wall

## CEMENT MORTARS

Cement mortars are very useful to modern builders but potentially disasterous when used for traditional construction and restoration work. When cement sets it is strong, hard, waterproof and can be used in almost any circumstances. Cement is also very easy to use and of known quality and reliability. All of this makes them ideal for many MODERN building processes but not recommended for use in old buildings.

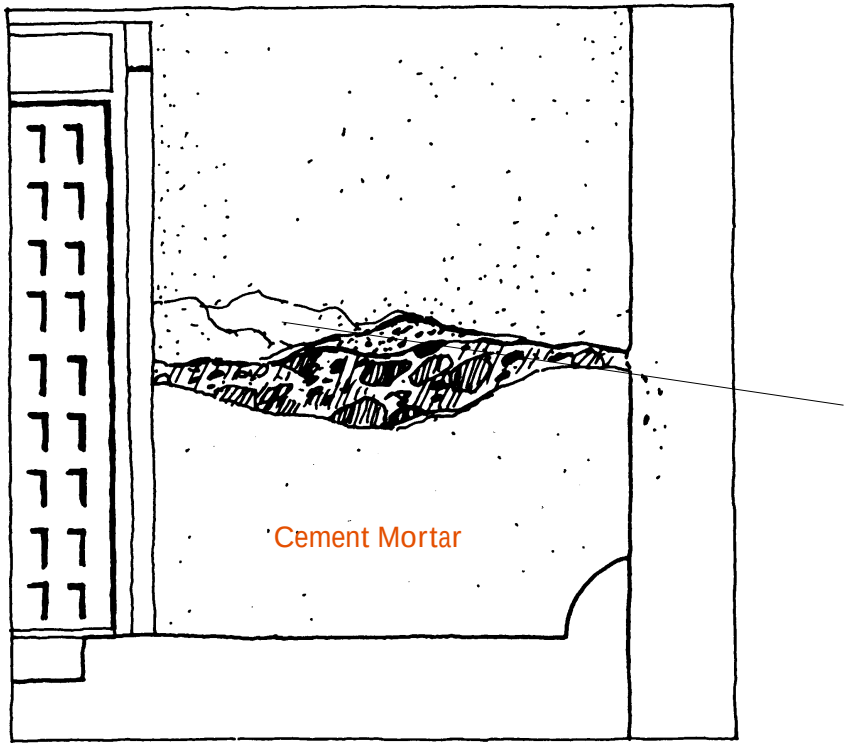
When preparing a mortar for use with historic masonry, it is important to think of the building not as a rigid structure, with all of its parts set fast as though cast in steel, but as a living animal that MUST move and breathe. Cement-based mortars do not have the ELASTICITY to allow the building to move without cracking.

## Cement inhibits moisture evaporation




The waterproof nature of the cement mortar inhibits evaporation of rising moisture and often helps to encourage a damp and humid atmosphere in the house. Damp walls that have been rendered in waterproof cement in an attempt to cure the problem will become wetter because moisture trapped behind the render will naturally rise to new and higher levels within the wall. This action can also damage and weaken walls as a result of salt, dissolved in rising moisture, crystallising in the mortar behind the render and breaking it up.

## Damage caused by cement patch repairs



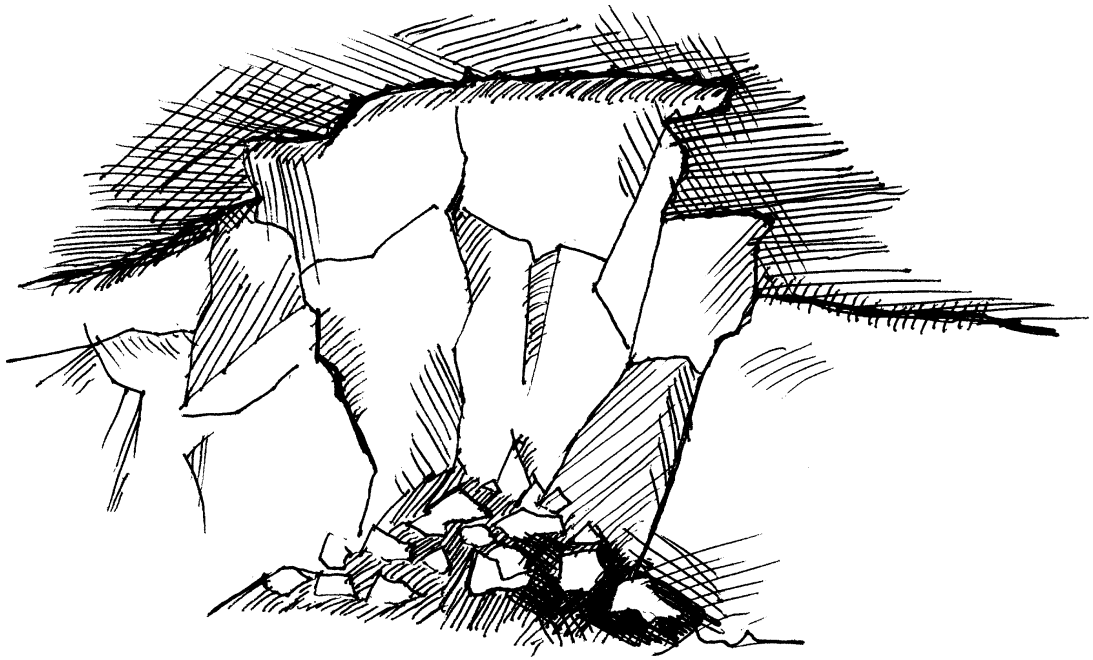

It is common practice in the Stone Town to replace lime renders with cement because it is thought to be stronger and less likely to suffer damage in the future. Areas of cement patching can often be seen surrounded by scars eaten deep into the wall. Cement mortars will also expand and contract up to twice as much as limestone or brick. This means that stones and bricks are constantly fighting against the mortar that surrounds them, which eventually leads to the formation of many small cracks that allow more rainwater into the wall.

Moisture and salts are concentrated at the edge of cement, causing the plaster to fail

# LIME MORTAR

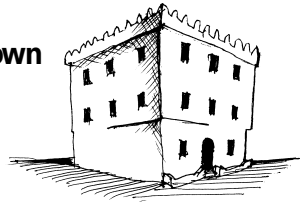
**LIME**

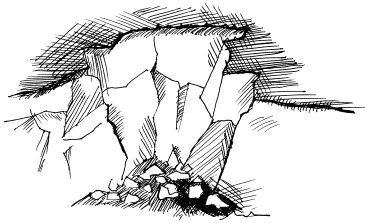
Lime mortars are always to be preferred for use with stone or brick and especially in old houses built with lime mortar originally. If it is possible during the course of repair work, it is good to remove as much cement repair as possible and replace it with lime mortar. This will allow the stones to breath and move. Cement renders in particular should be removed and replaced with lime-based plaster. It is always better to use lime based mortars with coral stone, because lime is made from coral stone and re-mains chemically compatible. Lime and coral stone will bond together better. In order to understand this, we must look at the way lime is made and how it works as a binder.



## THE LIME CYCLE

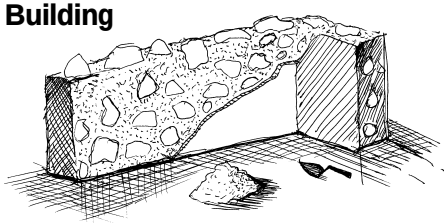
Stone Town



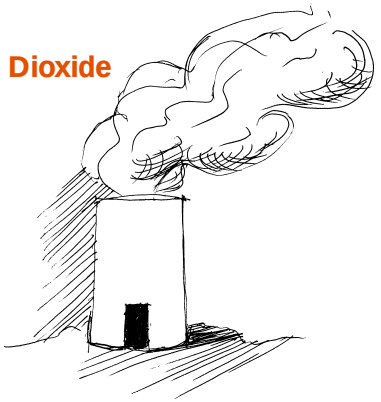


Lime Stone

Building



Lime Burning



Carbon Dioxide

Calcium Carbonate

Carbon Dioxide

Water

Calcium Oxide

Mixing Mortar



Carbon Hydroxide

Quick Lime



Lime Putty

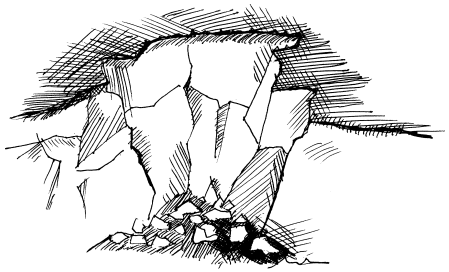



Water

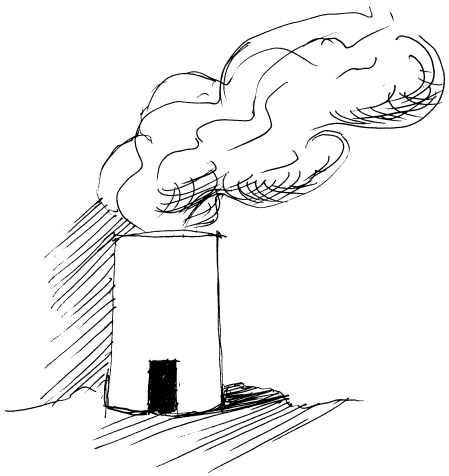


Slaking

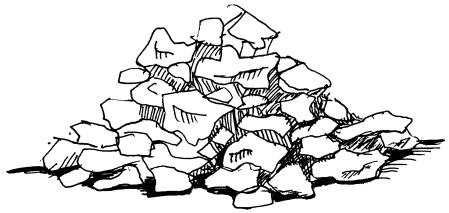
## MANUFACTURING LIME



Lime Stone



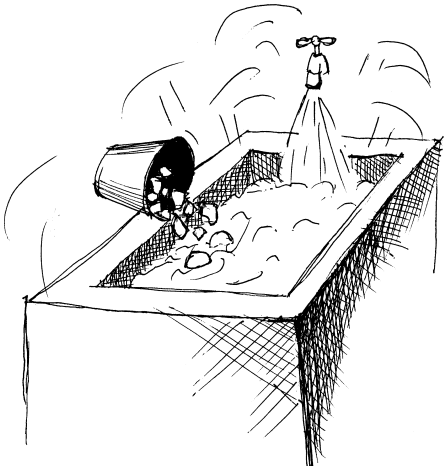
Lime Burning



Quick Lime

**1.** The raw material of lime is limestone, which must first be burnt in a KILN or CLAMP. In Zanzibar it does not matter which kind of limestone is used, the procedure is the same.

**2.** As limestone is burnt, water and CARBON DIOXIDE are driven off, which changes the stone into QUICKLIME which still looks very much the same as limestone but is lighter in both colour and weight.



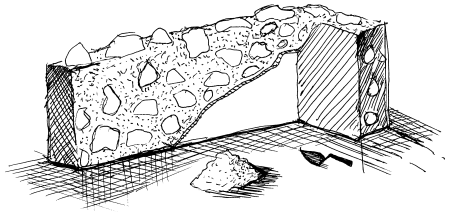
## Slaking

**3.** When cool, the quicklime is put in a tank and covered with water. As soon as it comes into contact with the water it will expand very quickly and get very hot, occasionally the water may boil. This process is called SLAKING and the mixture of slaked lime and water is called PUTTY.



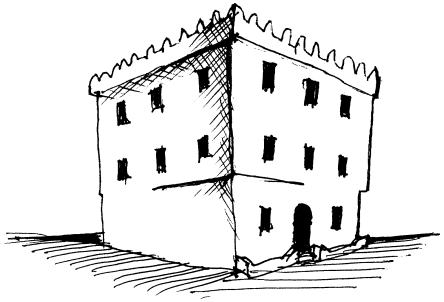
## Mixing Mortar

**4.** To make mortar it is necessary to mix the putty, which will become the binder, with suitable aggregates.



## Building

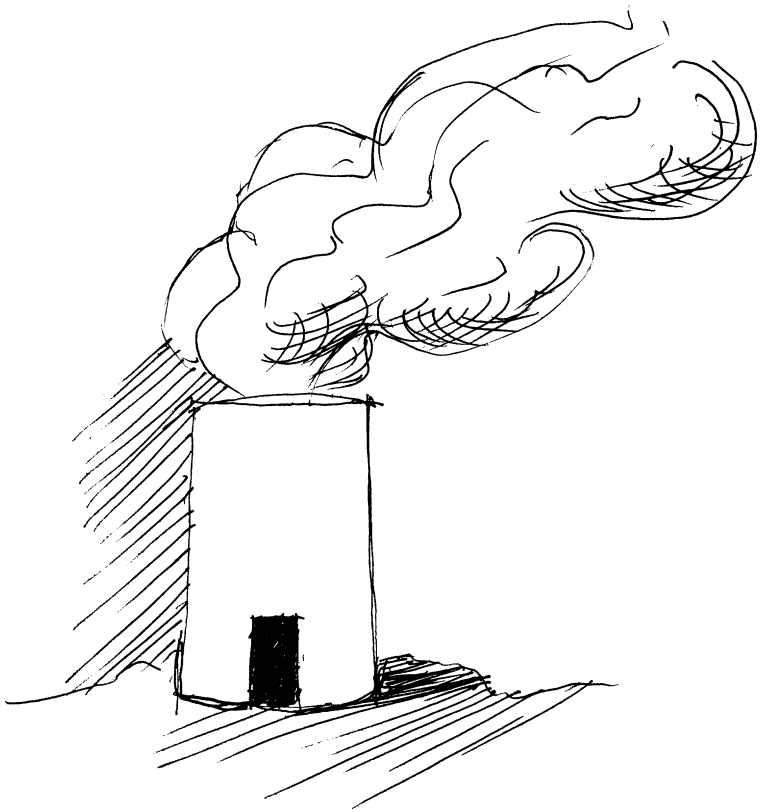
**5.** Once the mortar is used in the wall or as a render, the water will start to evaporate and CARBON DIOXIDE, from the air, will be absorbed. This process is very slow and is called CARBONATION. As the lime in the mortar takes in carbon dioxide, it replaces that lost when the stone was burnt and slowly turns the putty back into a form limestone.



## Stone Town

**6.** So lime mortars, when CARBONATED, are chemically the same as limestone and will act in a very similar way. Although the manufacture of lime and lime bound mortar is very simple, to get the best quality product and good working results great skill and detailed knowledge is needed.

## LIME BURNING OR CALCINATION



The use of lime as a binder is very ancient and has been practiced world-wide. There are many different methods of making quicklime from lime-stone. In Zanzibar the most common way of making quicklime involves the use of a CLAMP (in Swahili, 'tanu'). This is the oldest and most basic way of burning limestone.

### Burning Limestone

Several layers of coconut logs are arranged on the ground in a large circle. On top of these are stacked coral stones, followed by more logs and more stones, the stones becoming smaller towards the top of the dome shaped heap. The logs are then set alight and will burn for many hours. Although some of the lime produced in this way will be of excellent quality, there will be much that is UNDER-BURNT and a little that may be OVER-BURNT. This is because a great deal of the heat produced by the burning logs is lost and many of the corals never actually get hot enough to be fully converted into quicklime. For this change to take place a minimum temperature of 880° C is needed. To ensure that stones are burnt right through a slightly higher temperature is best. The very best quality and most reactive quicklime is produced in the lower temperature range. The higher the temperature the more the lime is OVERBURNT and the quality decreases. Fortunately, the temperature at which coconut burns is just about that which is needed to produce good quality lime so there is not too much danger of over-burning.

### Difficulties using the Clamp

The biggest problem with the clamp is that so much fuel is needed to produce a small amount of quicklime. Under-burnt lime, which has not quite reached the minimum temperature, will contain a core of unchanged lime-stone and only the outer skin will be of any value. Over-burnt lime is often wizened and shrunken in appearance and it is also very slow to SLAKE, taking weeks. If lime like this is used to make plaster before it has fully slaked, the process will continue on the wall, resulting in fragments peeling off as the particles slowly expand.

## Improving Kilns and Better Lime

The clamp is such an ancient and crude method of production that it is not difficult to improve. The most important thing is to retain much more of the heat and so change more coral into quicklime and use the fuel more efficiently. A very simple way of doing this is to cover the outside of the clamp with a thick layer of wet mud containing palm leaves or reeds as reinforcement. Holes should be left in the mud at various points to provide ventilation. Although the clay covered clamp is more efficient, eventually the heat of combustion causes the clay to fall away and the advantage is lost.

## The Shaft Kiln

The next step up from the clamp or the clay-covered clamp is the simple shaft kiln,The shaft kiln resembles a short fat tower. The outside is often made of concrete, although coralstone and lime mortar will do just as well. To stop the heat inside burning the walls, the kiln is lined with fired clay bricks set in earth mortar and, to retain as much heat as possible, an insulating layer of 15mm to 20mm coral aggregate is provided between the brick-lining and stone walls. Ventilation is provided by brick covered channels in the kiln floor and ports through the walls.

## Suitable Fuel

Although timber burns at about the correct temperature to produce first quality lime, it is expensive and damaging to the environment. It is a good policy to reduce the amount of timber required by adding coconut husks and setting aside areas of land on which to plant new coconut. Coconut logs burn quickly and produce a long flame; this is very useful within the shaft kiln as it helps to produce a good even CALCINATION. Because coconut burns quickly it can be used to encourage other, slower burning fuels such as dung.

## Filling the Kiln

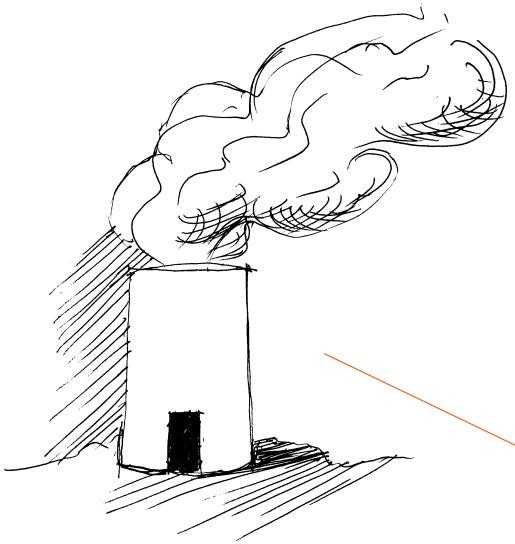
It is very important that the stones within the kiln are more or less the same size, about the size of a fist or a little larger. This ensures that the charge is filled with small gaps or voids, enabling air to enter the mass and flames to work up through it. If it is necessary to burn two or more sizes of stone at the same time they should not be mixed. Each size should be packed together, isolated by fuel layers. The base of the kiln is stacked with logs so as to form a tunnel, which is filled with brushwood. Above are arranged alternate layers of fuel and stone. To fire the kiln it is necessary to ignite the brushwood. If flames come out of the top of the kiln there is too much air getting in and the ventilation holes must blocked with clay or brick. Should black smoke come out, more air is needed and ventilation holes should be enlarged. When the kiln is operating at its most efficient temperature, a very small amount of smoke should be visible. The air above the kiln should 'shimmer' slightly. A rough indication of the temperature inside the kiln can be gained by observing the colour of the combustion through a ventilation hole,

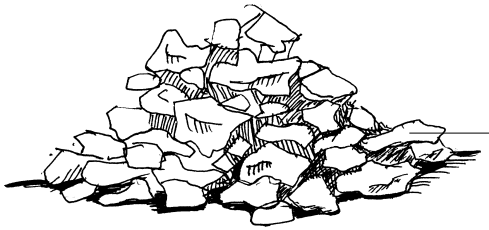
| | |
|---|---|
| 500°C | **slightly visible red glow** |
| 700°C | **dark red** |
| 800°C | **mellow cherry red** |
| 1000°C | **bright red** |
| 1200°C | **bright orange** |

With practice it is possible to judge the working temperature and regulate the firing conditions.

## SLAKING & SIEVING

In order to obtain the best results it is very important that the quicklime is slaked as soon as it is cool enough to move, no time must be lost in submerging it in water. The longer quicklime is exposed to the air, the more the quality of mortar made from it will decrease. This is because moisture contained in the air will very soon begin to slake the lime. The problem with this is that as well as water, air contains carbon dioxide. If left out the quicklime will both slake and carbonate at the same time. This is called AIR SLAKING and means that the quicklime is turned back into limestone dust before it has been used in a mortar. This will make it quite useless as a binder.





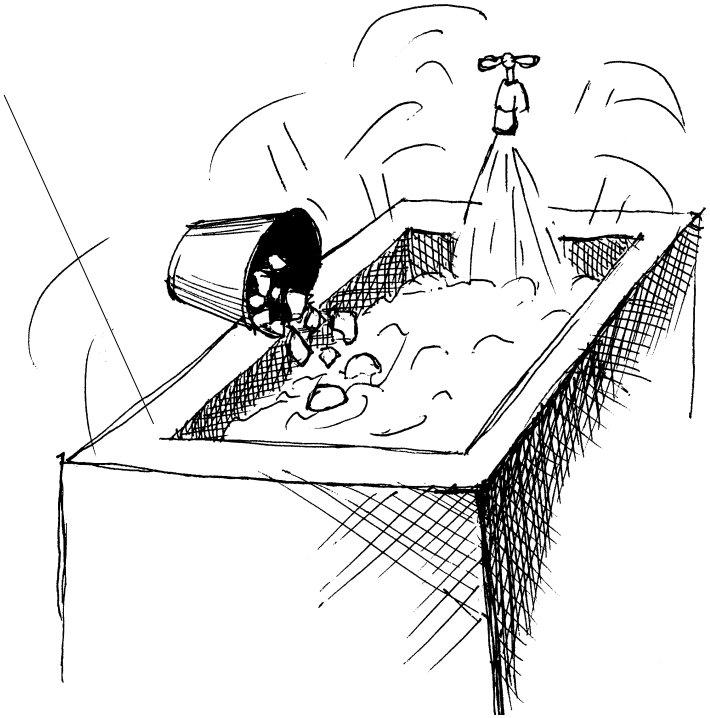
**Maximum 3 days**

**Quick Lime**
Always use lime in lump form not powder

**Slaking**

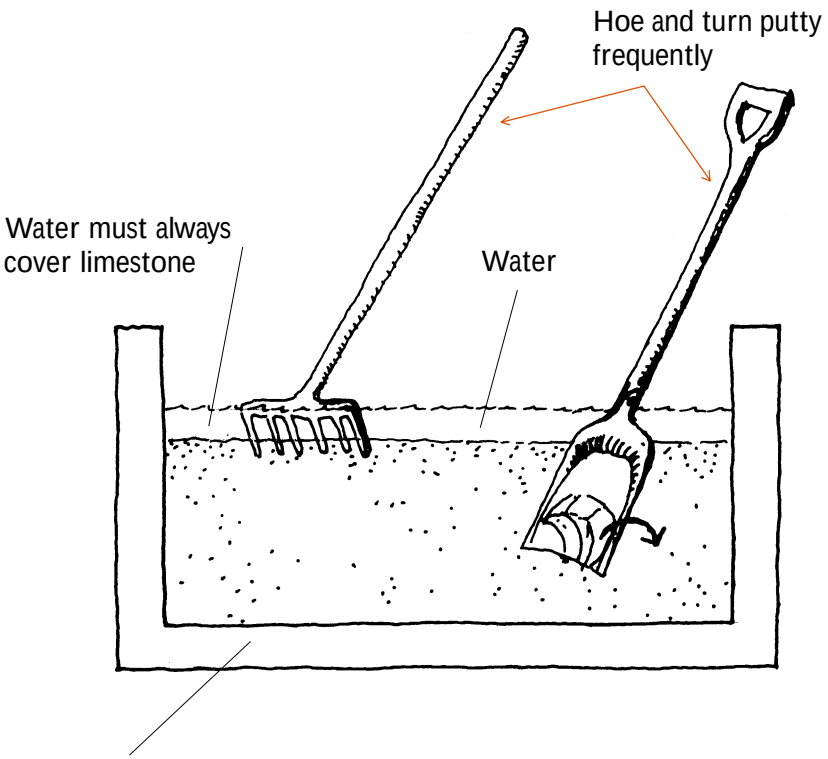
Always put the lime into the water, **never** pour water over the lime

Concrete Tank



## Making Lime Putty

Make sure that the lime putty stays in the pit for a **minimum of 4 days,** or as long as possible

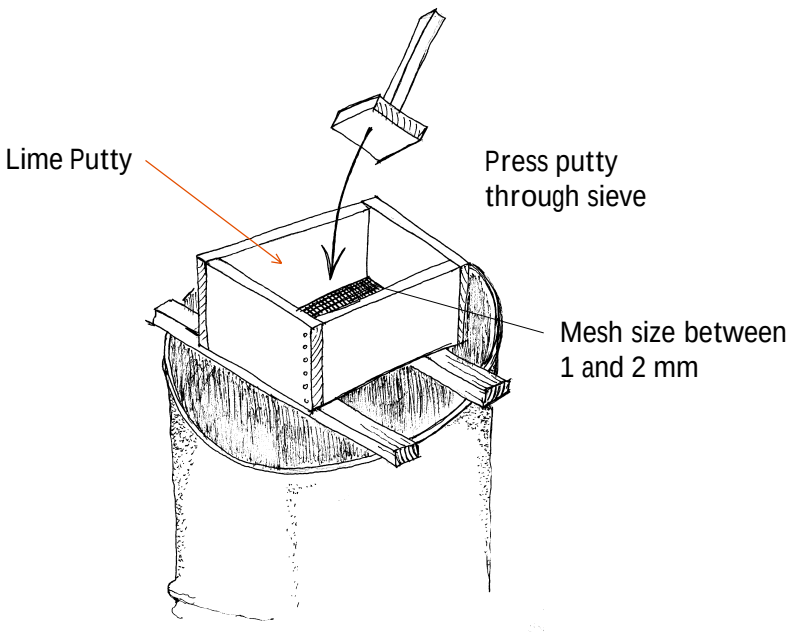



During slaking there must be sufficient water to completely cover the lime. It is important to remember that as slaking proceeds the lumps will swell and get much bigger, so enough room must be left in the tank or pit to allow for this. If possible it is best to slake in a large concrete tank, but if this is not possible slaking can just as easily be carried out in a shallow soil pit. To make such a pit it is necessary to select an area of flat ground about 5m square. It is best if the ground is slightly higher than the land around; this will help stop possible contamination of the lime with salts possibly contained in the soil. A strong earth bank about 1m high is next built around the site. The soil must be well compacted and beaten down with a shovel.

Once the bank is completed the pit is lined with palm leaves and plastic bags to prevent the lime becoming contaminated with soil. When all of this work is done, the pit should be filled with water to depth of about 500mm and the quicklime shovelled in. **Always put the lime into the water, never pour the water over the lime**. As the lime starts to expand, be ready to add more water should it show above the surface. After two or three hours the heat and bubbling caused by slaking will stop but that does not mean slaking is over. The lime will continue to swell and slake for at least two days. It must therefore stay under water, in the pit, for at least four days, during which time it must be hoed and turned frequently.

## SIEVING

After at least four days under water the QUICKLIME has become LIME PUTTY and is now ready for REFINING. This is a simple task involving picking out all the remaining unburned limestone and any other large impurities, followed by sieving. It is best if the sieve has a mesh size of between 1 mm and 2 mm. As with every other part of lime technology, refining is simple but if it is not done well the quality of the putty will suffer. After refining, the putty must again be stored under water until it is required. It is possible to store putty in a number of small pits dug into the ground. The pits must, of course, be lined as before and their tops covered with palm leaves to reduce evaporation and exclude unwanted material.




## FOR WELL-SLAKED PUTTY FOLLOW THE STEPS BELOW:

1. Quicklime must be slaked as soon as it is cool enough to move and must never be left for long periods in the open air.

2. It must be slaked in clean pits or tanks free of soil or vegetable matter.

3. The quicklime must be completely covered by clean water during slaking and sufficient water must be kept on hand to top up the tank when necessary.

4. The quicklime must remain in the tank and fully covered by water for a period of at least 48 hours. This will ensure that all the lime is slaked.

5. Whilst in the slaking tank the mass must be stirred and agitated at regular intervals. This will make sure that water penetrates through the mass and the whole is completely slaked.

6. When slaking is complete the putty must be transferred to clean storage tanks where it must remain under water for as long as possible before use and for a minimum period of six weeks.

7. During in the transfer from slaking to storage tanks, the putty must be refined and unburned fragments of stone and larger pieces of fuel debris removed. The putty must then be forced through a sieve with a mesh size of 1mm to 2mm.

## MIXING LIME MORTARS



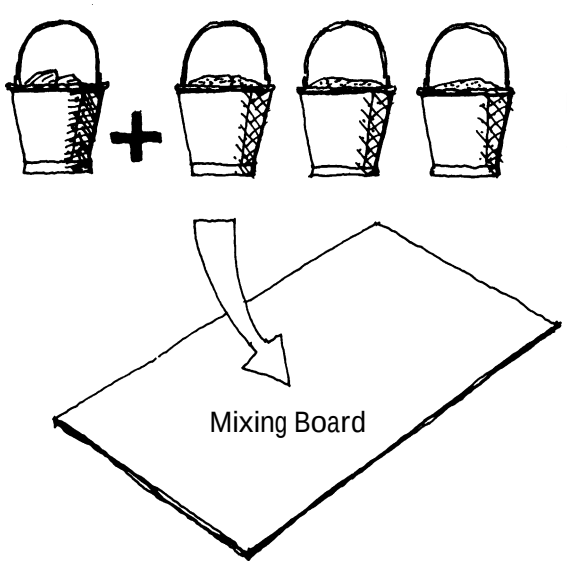
It is not possible to mix lime mortar in the same way as cement mortars, which are simply turned over and over, with occasional chopping.
To make a strong lime mortar it is essential to coat each particle of aggregate with lime paste, this means that the pile of mortar, after initially mixing in the aggregates with a shovel, must be beaten with pick axe handles in addition to chopping and turning. The longer mixing and beating can be prolonged the better and more efficient the mortar will be.

It is also important that only the smallest amount of extra water is added during mixing. The temptation to pour on lots of water in order to make mixing easier must be resisted. Additional water will severely weaken the mix and cause a great deal of shrinkage and cracking on drying.

In addition to all of the above it is also very important that the correct ratio of aggregate to binder is maintained. Once mixed, the mortar should be stored for as long as possible before use. This enables the lime to thoroughly coat every particle of aggregate, ensuring an efficient and well-bound mortar. Lime mortars that have not matured for long enough will not bond well with the aggregate. Lime particles become smaller as they mature and develop closer contact with the aggregate. If lime mortars are used soon after mixing, the lime does not have time to develop a close contact with aggregates that may already be coated with a film of water.

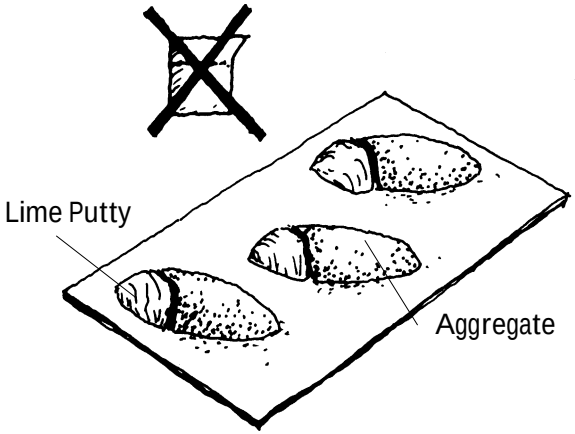
## FOR THE BEST QUALITY MORTAR FOLLOW THESE STEPS:

**Note:** Throughout the whole mixing process, no extra water should be added. However, if some of the aggregate is composed of a very dry and porous stone dust it may be necessary to add a small amount. If this is required a hand held spray should be used in order to avoid swamping the mix.




Lime(1) Aggregates (3)
1:3 ratio

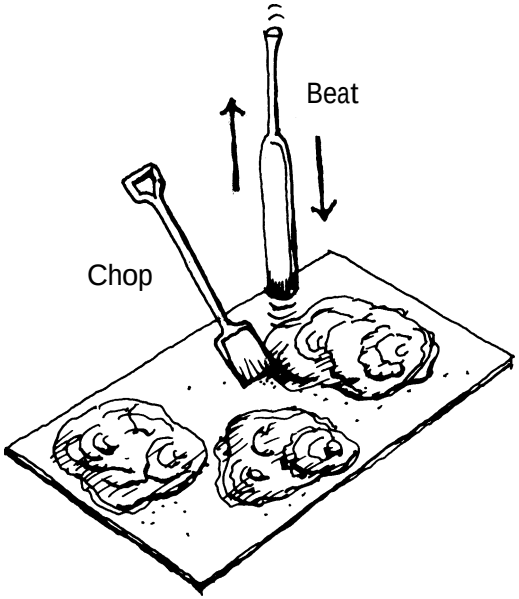
**Do not** add extra water




**1.** Metering is easy to achieve by regarding a suitable bucket as one whole unit of measure. A one to three mix would consist of one bucket of lime to three of aggregate.

**2.** Using the same bucket, measure out the correct amount of aggregate which should be as dry as possible.

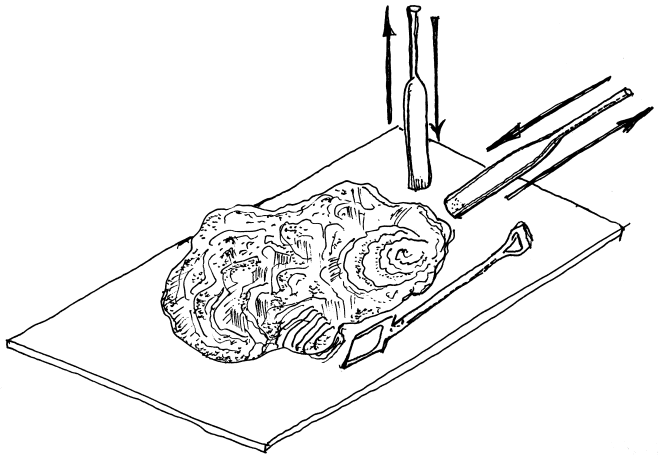
**3.** Using a shovel, divide the lime into a number of small parts spread evenly over the mixing area. Using the same bucket measure out the correct amount of aggregate, adding small quantities to each of the piles of lime.




**4.** Using a shovel, fold and shop the aggregate into each of the piles of lime.

**5.** Each pile must next be firmly beaten with timber paddles and occasionally chopped with a shovel. The longer this process can be maintained the better the quality of mortar will be.

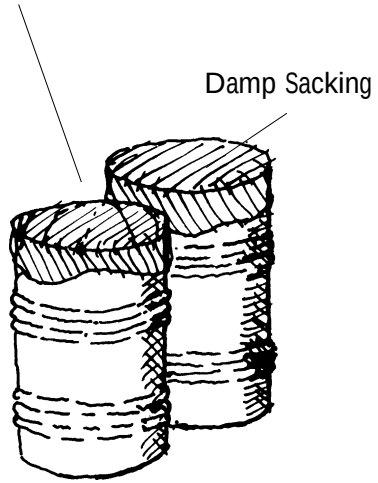
Small piles shovelled togther



**6.** When each of the small piles is thoroughly mixed they should be shovelled together to form a single large pile which should again be chopped and beaten.

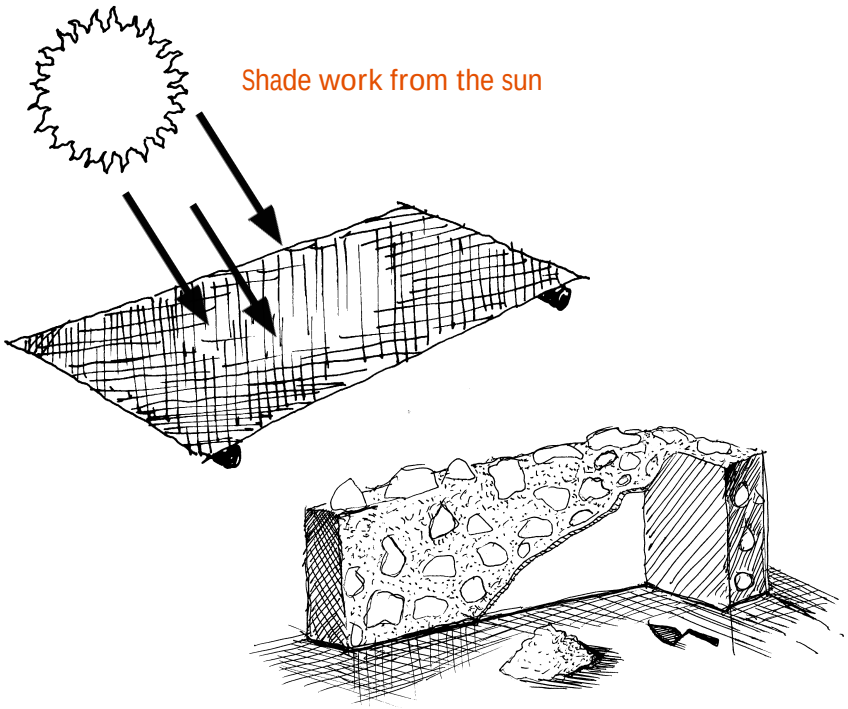
Storage Bins

Damp Sacking



**7.** Once mixed, the mortar should be stored for as long as possible before use and for a minimum period of three months. It should be stored in a clean pit or in a number of plastic or galvanised steel bins. Whilst in storage air must be excluded from the bins or pit. This can be done by covering them with damp sacking and palm leaves.

## THE SETTING OF LIME MORTARS




### Carbonation

Lime mortars set very slowly, as the water required for mixing and preparation evaporates and carbon dioxide from the atmosphere is absorbed. Carbon dioxide works with the lime producing a growth of tiny interlocking limestone crystals, which bond with the aggregates binding them together. Although this reaction may take place quite quickly on the surface, it can take years to spread through the mortar in a thick wall. This slow process of setting as a result of contact with carbon dioxide contained in the atmosphere alone is called CARBONATION.

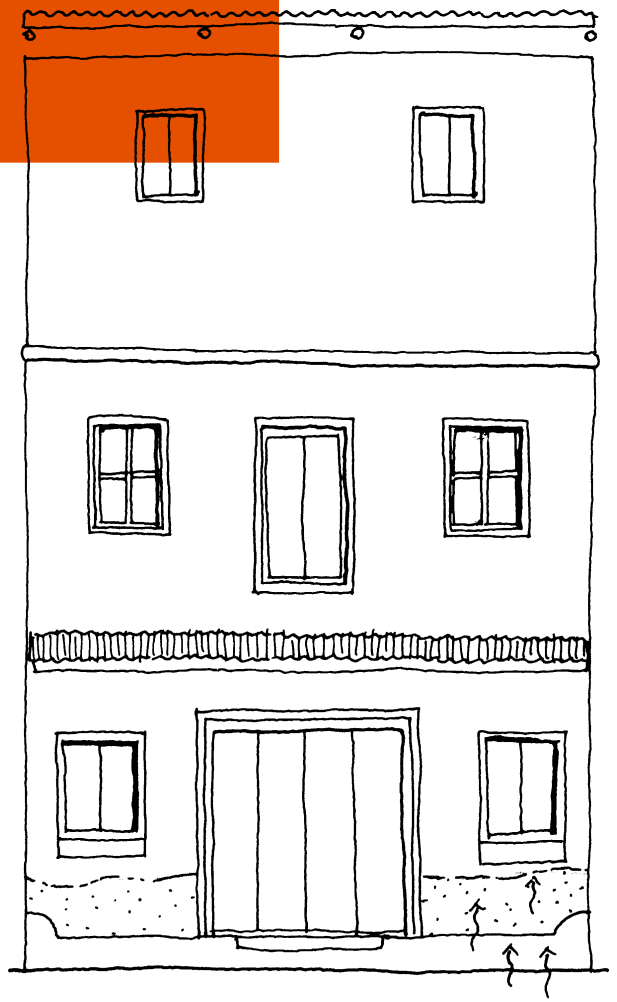
Carbonation is helped if the mortar is encouraged to dry very slowly, making it much easier for carbon dioxide to enter if it is slightly moist. This can be done by gently spraying the surface with a garden spray. A rendered wall MUST also be protected from direct sunlight by hanging sheets of wet sacking in front of it. If renders are allowed to dry very quickly they will crack and will not bond properly with the masonry.

### Setting with Additives

Adding other materials to lime mortar that react chemically, can speed up the setting processs. Set additives are essential if the mortar is to be used in a situation that is constantly wet, as carbonation will not take place if the mortar remains saturated. Lime mortar alone will NOT set under water, to do so, it must have an effective set additive mixed with it. The materials that will work in this way are called POZZOLANAS and contain SILICATES or ALUMINATES or both. A very common building material that makes an excellent pozzolana is brick. To be used in this way, the bricks must first be broken into small pieces and then reduced to dust by sieving through a fine flour screen. The brick dust is added to the mix of lime and aggregate just before use. To one part of lime and three parts of aggregate should be added 1/4 of a part of brick dust. Although it is not best practice, if no other pozzolana is available, a small amount of cement can be added to the mix. This should not exceed 1/2 of a part.

# 5.

# REPAIRS TO HISTORIC RENDER



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