THORHELICAL® AUSTRALIA

GUIDE TO LIME

...AND IT'S APPLICATION IN THE CONSERVATION AND RESTORATION OF BUILDINGS

EDITION 3



ROUNDTOWER quality building limes

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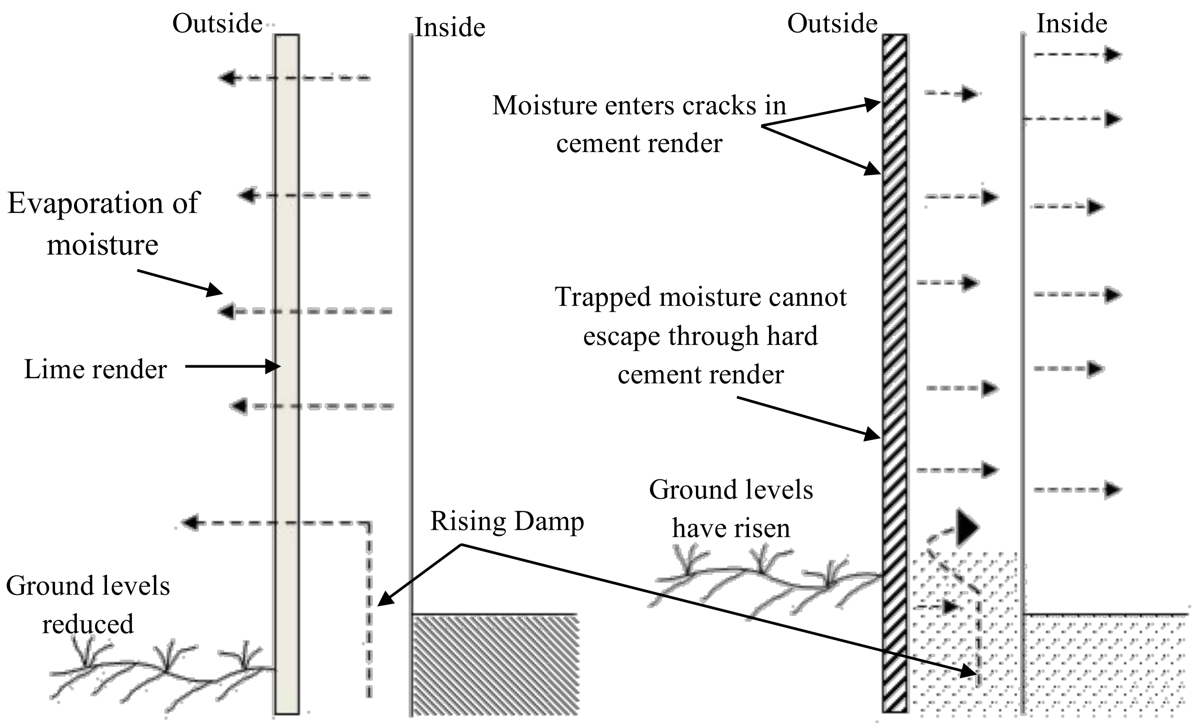
Why Lime?

For the past 150 years modern artificial cements have slowly been replacing traditional lime based mortars and plasters, to such a degree that now virtually all construction is carried out using only modern materials. Whilst many of these materials are perfectly suitable for modern buildings they have been found to be incompatible with the construction of old buildings.

The need to understand the different technology involved in historic and modern structures is essential if successful repair and maintenance programmes are to be carried out.

Lime has been the primary binder used in mortars and plasters for a thousands of years and the vast majority of all buildings constructed before 1900 made use of lime. Despite this, in many cases today lime is ignored, so why Lime?

Modern cements are harder and less permeable than lime mortars, the general aim when selecting a traditional mortar or plaster is that it should breathe more freely than the material which it is applied to and that it should have less composite strength than the substrate with which it is used. This is essential if you are to prolong the life of the historic fabric.



Solid wall of porous material with external lime render

Solid wall of porous material with external cement render

Example of damage caused due to cement pointing.

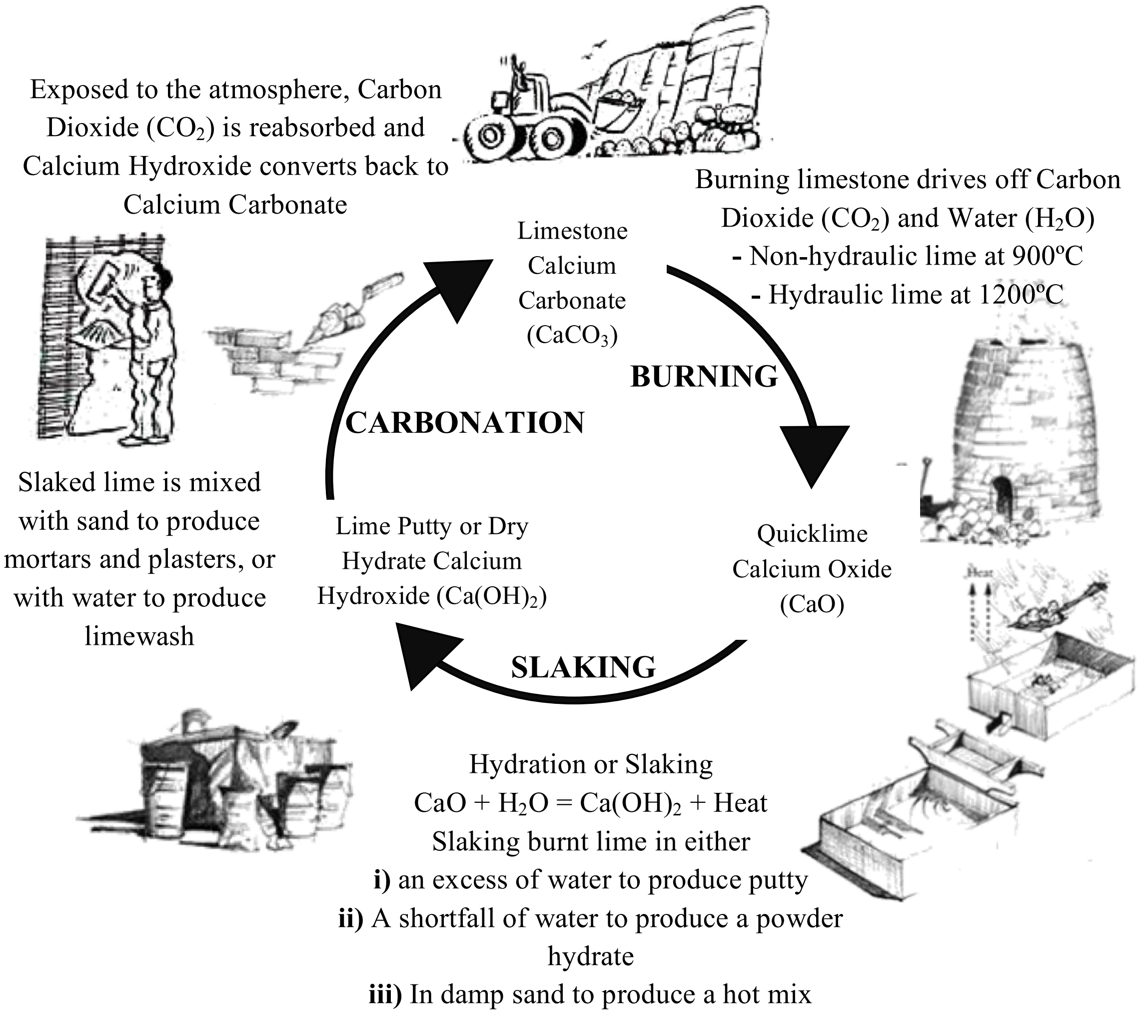
Modern buildings generally rely on an outer layer to prevent moisture penetrating the walls, whereas buildings constructed before 1900 generally rely on allowing the moisture which has been absorbed by the fabric to evaporate from the surface. In essence old buildings exposed to the elements are continually absorbing moisture and the ability for the moisture to evaporate again is crucial to the well being of the structure. Using cement based mortars and plasters in traditional buildings runs the risk of locking-in moisture which could result in dampness internally and general building fabric decay. Problems generally arise when the building has been “repaired” with inappropriate materials through lack of knowledge.

It is interesting to note that many structures built using lime technology 500+ years ago and maintained correctly are still in excellent condition today. It remains to be seen how modern structures will fare in 500 years!

Brief Chronological History of Lime Use

Prehistoric use Mesolithic Period 9000 - 4500BC	Jericho, Mesopotamia - Polished lime plaster floor
2500BC	Ancient Egypt - Lime and gypsum wall plasters
500BC	Mycenae, Greece - Fine lime stucco in Temples
300BC	Roman Italy - Lime concrete, a mixture of sand, lime, and pozzolans used in the Appian Aqueduct.
98BC	Germany - Waterworks of Gaul using pozzolanic lime mortar.
122 - 130AD	Hadrian wall, constructed with lime concrete.
600 - 1200AD	Early Christian. Lime probably first introduced into Ireland (maybe through Irish monks)
700AD	Britain, three Saxon mortar mills excavated in Northampton.
c1250AD	Gypsum introduced into Britain.
c1500	Decorative plasterwork known as pargetting in lime and gypsum.
1600 onwards	Lime plastering on wooden laths and solid backgrounds.
c1756	John Smeaton's research for the correct mortar for the Eddystone Lighthouse rediscovered hydraulic properties in certain limes such as Dorking Grey Limes, Barrow Limes, Blue Lias.
1774 - 1796	Natural Cements (Roman). Made by James Parker by calcining nodules of argillaceous limestone and grinding down. Similar cements where made and the names of Sheppy, Medina and Atkinsons were all known as Roman cement.
1824	Joseph Aspdin patented Portland cement, but it was another 100 years before it started to replace lime on a large scale.

Lime Cycle


Exposed to the atmosphere, Carbon Dioxide (CO_2) is reabsorbed and Calcium Hydroxide converts back to Calcium Carbonate
Limestone Calcium Carbonate ($CaCO_3$)
Burning limestone drives off Carbon Dioxide (CO_2) and Water (H_2O)
- Non-hydraulic lime at 900ºC
- Hydraulic lime at 1200ºC
BURNING
CARBONATION
Slaked lime is mixed with sand to produce mortars and plasters, or with water to produce limewash
Lime Putty or Dry Hydrate Calcium Hydroxide ($Ca(OH)_2$)
Quicklime Calcium Oxide (CaO)
Heat
SLAKING
Hydration or Slaking
$CaO + H_2O = Ca(OH)_2 + Heat$
Slaking burnt lime in either
i) an excess of water to produce putty
ii) A shortfall of water to produce a powder hydrate
iii) In damp sand to produce a hot mix

Non-Hydraulic Lime

Non-Hydraulic Lime Putty	Although traditionally this type of mortar was used internally and externally, today it is generally used for internal plasterwork & cornice etc, pointing, bedding and renders in sheltered areas.
Non-Hydraulic With pozzolan	All of the above plus the ability to withstand more exposure to the elements.

Production

Limestone is burnt in a kiln using temperatures of around 900^{o}C to produce lump lime, Calcium Oxide (CaO).

The production of lime putty is a hazardous procedure and should only be carried out by suitably trained personnel. This is not a procedure to be carried out on site where the work cannot be monitored and controlled.

The lump lime/burnt limestone (calcium oxide) is immersed in water. The mix is raked vigorously to aid the breakdown of the lump lime. When the resulting mix is the consistency of milk, the lime is then sieved to remove any un-slaked particles. The operatives should take great care as the mix reaches a very high temperature due to the chemical reaction taking place. The resulting material is called lime putty (calcium hydroxide).

This material is left to de-water/mature for at least three months in a bulk container known as an ark. The material will take on the appearance and consistency of a cream cheese. Lime putty can be stored indefinitely in this state provided it is not exposed to air. When Carbon Dioxide, which was burnt off in the kiln, is reabsorbed back into the mortar/lime, this causes it to return to its original state, calcium carbonate.

Storing the lime putty in airtight containers allows the putty to mature and any un-slaked particles will have sufficient time to slake. The longer the putty is allowed to mature the better the finished product. Traditionally in Italy the best quality work was carried out using lime putty allowed to mature for generations.

Having manufactured and left the lime putty to mature for at least three months then this material can be used for mixing with suitable aggregate to make mortar. The best method of manufacturing a lime putty based mortar is to mix the ingredients in a mortar mill. The resulting mortar is of a high quality and very workable. No extra water should be necessary during the mixing process.

The amount of lime putty needed to bind the aggregate is determined by the amount of void space between the grains of sand, which needs to be filled. Most mixes use a ratio of two and a half parts aggregate to one part lime putty. This can vary slightly depending on the aggregate selected.

Health and Safety *– Lump lime (calcium oxide) is a caustic alkaline. When it comes in contact with eyes or skin, it will cause a chemical burn. Wash the affected area with a solution of sugar water immediately and seek medical assistance. When working with lime the operative needs to wear personal protective equipment (eye protection, gloves, overalls and dust mask).*

Mortars

Non-hydraulic lime mortars were generally speaking the most common type of mortar used in the construction of historic buildings, these mortars were often a mixture of lime, earth, shells, crushed stone, pit or beach sand. The aggregate used basically depended on what was available locally and was often the direct result of years of local knowledge being passed down from generation to generation, as opposed to formal teaching techniques. These mortars performed and do perform in a very different way from modern cement or gypsum based mortars.

Non-hydraulic limes, sometimes called “fat limes” are limes which are very pure with regard to their calcium carbonate ($CaCo_3$) content, the purest forms of this material can have upwards of 95% $CaCo_3$, these “fat limes” have no or little chemical set in the way that modern materials harden, they harden by a process called carbonation i.e. reaction with the air.

The carbonation process is a slow ongoing reaction which can take weeks, months and to a degree years to complete. The mortars and renders therefore need good protection from the elements whilst carbonation is taking place.

Hot Lime Mix

This is the most traditional method of preparing mortar in Ireland. This process combines slaking and the mixing of the aggregate in one operation. This method was most commonly used in the preparation of mortar for the construction of rubble stone walling. The mixing took place on or very close to the construction site.

The aggregate was normally spread in a circle and the lump lime was added to the centre of the heap, water was added and the mixture was turned a number of times. The end product is a very workable and “plastic” mortar that is ideal for rubble wall construction. You can use this fresh or it can be stored and reworked at a later date. Traditionally the mixing of mortars was carried out in the winter and they were left to sour out in pits until the building season started in the spring.

When producing hot lime mixes judging the correct ratio of lime-aggregate is rather difficult. Lump lime increases in volume when it slakes. In general a useful rule of thumb is to use four parts aggregate to one part lump lime.

This type of mortar is unsuitable for plastering as it may contain un-slaked particles. These un-slaked particles tend to blow and give the plastered surface a pock marked appearance.

There are many health and safety issues to be addressed when working with hot lime mixes and great care should be taken. Skilled operatives who understand the process and the dangers are essential when working with hot lime mixes.

Mixing

Today, non-hydraulic lime mortars are mixed from high calcium non-hydraulic lime putty and aggregates. Lime putties for these mortars should be at least 3 months old and wherever possible older, in fact the older the better, as the lime putty improves with age. The aggregates required for the lime mortar will of course vary from job to job, particularly where mortars are being matched, in the past generally speaking the nearest local aggregate to the job would be used, whether this was sand, crushed stone or even plain earth, clay earth being the oldest known mortar used in Ireland. Today good quality sands and aggregates are easily available, therefore when selecting your sand you should wherever possible use washed sharp gritty sand, well graded with the minimum amount of silt in the sample. Of course certain tasks will call for certain sands, a fine internal lime plastering finish would call for fine silica sand, whereas pointing on ancient rubble stone masonry would in all likelihood call for a mixture of aggregate from fine silica sand up to small pieces of crushed stone.

Wherever possible, non-hydraulic lime mortars or plasters should be mixed in a mortar mill. The action of the mortar mill, using a combination of revolving cast iron wheels and scrapers cuts and squeezes the lime putty and aggregates together, and by doing so there is no need for extra water to be added, other than the moisture within the putty itself. The great benefits of this are that mortars made this way are far less prone to shrinkage as the correct amount of water is within the mix.

Another method of mixing lime mortars is to use a pan mixer. It is in many ways very similar to a baker’s dough mixer, using a mixture of paddles and scrapers to combine the components together, again the moisture within the lime putty should be adequate for making the mortar, but if more water is needed, it should be kept to the minimum.

If the use of this equipment is not available then the possibility of purchasing readymade mortars should be considered, but should this option not be available, then mixing by drum mixer and further mixing by hand will be the only option.

When using a drum mixer, add the components in small amounts and keep the drum at a more horizontal angle, almost certainly more water will need to be added to stop balling and the only way to counter this is to stop the mixer at different times and ram the mortar with a timber rammer. The mix will need further hand mixing on a banker board and should be chopped and rammed as well as turned by shovel until the putty and aggregates are well blended and mixed together. Should hair be required in a mix, this should be added no more than two weeks before use, as the lime mortar in its wet state may rot the hair.

Storage

In the past lime mortar was heaped up and allowed to stand with little more protection than a sheet thrown over it, and in many cases no protection at all, the outer skin hardened and the mortar underneath remained moist with just occasional wetting down. The reason for allowing the mortar to stand or mature is to allow a better bond to take place between lime and sand. When using large amounts of mortar the best way of storage is to construct large timber mortar bins, three sided, which will allow the mortar to drain off any excess water and with little more than a polythene sheet keep the mortar air tight, wetting the top in warm weather. When using small amounts, sealed plastic tubs offer the best way of storage.

Additives

Pozzolanic Additives

The word pozzolanic is derived from the word Pozzuoli. This is the name of an area on the Italian coast near Vesuvius. This is where the Romans sourced pozzolanic additives, they mined the ashes deposited by the occasional eruptions of this volcano, and they then used these additives in mortars.

A "pozzolan" is defined as *"a siliceous or siliceous and aluminous material, which in itself possesses little or no cementing property, but will in a finely divided form - and in the presence of moisture - chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties."* Definition taken from **"Pozzolanic and Cementitious Materials"** by Malhotra and Mehta (Gordon and Breach Publishers, 1996)

Hydraulic reactions similar to those which occur in a hydraulic lime can be achieved in non-hydraulic lime by adding pozzolans. These finely powdered materials are added to lime mortar to increase the durability, performance, and to provide a quick chemical set, independent of carbonation, which also occurs in due course. For best results the pozzolans need to be 70 microns or less, pozzolans any larger only act as an aggregate.

The following list contains the most commonly used pozzolans:

Inorganic Additives

Metastar - A fine white ceramic powder from burnt English china clay (kaolin). This product is produced under a strict quality control environment. Add 10% Metastar by volume of mortar.

Brick dust - Crushed low-fired brick tile. It ranges in colour from red to buff. Add one part brick dust to four parts mortar. Brick dust also acts as a particulate and may colour the mortar.

PFA - Pulverised Fuel Ash. Dark grey coloured powder, suitable for grouting.

Trass - A khaki coloured volcanic powder sourced in Germany.

Volcanic dust - Original material used by the Romans as a pozzolan and still used in certain parts of Italy.

Organic Additives

Hair - Traditionally ox hair was the most commonly used although horse and goat was also used. The hair was mostly used for internal plaster to give tensile strength particularly when used for plastering onto laths. Today hair is sourced from goat, yak, horse, and less commonly cattle.

Tallow - This product is derived from the rendering of livestock. It is added for increased water resistance, particularly in limewashes and greater flexibility. It is added to slaking quicklime to achieve an even distribution throughout the limewash. The mix is allowed to cool and is then sieved. However, if used inside in humid conditions it may promote mould growth.

Raw linseed oil - This plant based additive is useful to inhibit the ingress of moisture through limewashes (weather resistance). It also reduces the dusting effect of limewash. It is usually added to the last two coats to help in the shedding of moisture.

Casein (or Skimmed Milk) – Casein is a protein in milk. This is added to limewash and the substances combine to form Calcium Caseinate, giving good resistance to dusting and improved weathering.

Other Additives

Plaster of Paris - This gypsum material is only to be gauged with mortar for internal use. This accelerates the initial set when mixed with fat lime mortars and is normally used for internal decorative plaster work.

Marble Dust – Used in the making of traditional plasters, and hand moulded work.

Common salt - Traditionally added to limewash to help with carbonation because of its hydroscopic effect. BEWARE adding salts to the building may damage the fabric.

Pigments - Traditionally earth based pigments common to the particular locality were added to limewash for aesthetic reasons.

Hydraulic Lime

Feebly Hydraulic Lime NHL 2	Some internal/external work, pointing, bedding, rendering on soft brick or stone backgrounds in sheltered locations, grouts.
Moderately Hydraulic NHL 3.5	External rendering, pointing, bedding, some moulded work in normal exposure conditions.
Eminently Hydraulic NHL 5	Areas of extreme exposure on hard dense stonework, sea defences, canal work, coping, pointing (very strong mortar).
Natural Cements	Run stucco work, casting, and underwater works.

Production

Hydraulic limes differ from non-hydraulic limes in that they have a chemical set as well as the process of carbonation. The limestones from which hydraulic limes are formed naturally contain a varied range of minerals of which silica and alumina are the main ones for creating hydraulic lime. When these limestones are heated in the kiln at temperatures of around 1200^{o}C, the resulting lime has different properties. From the pure limestone, the silica and alumina combine with the lime to form active compounds. These compounds combine in water to create a chemical set. The percentage of silica and alumina contained in the limestone will determine the main characteristics of the lime and of course the resulting mortar or plaster.

The main characteristics:

1) Strength
2) Setting time
3) Durability
4) Frost resistance
5) Workability
6) Colour

Different Types

There are three recognised types of Natural Hydraulic Limes (NHL's):

1) Feebly Hydraulic - NHL 2 - Approx 12% - 18% active clay minerals
2) Moderately Hydraulic - NHL 3.5 - Approx 18% - 25% active clay minerals
3) Eminently hydraulic - NHL 5 - Approx 30% - 40% active clay minerals

"Active clay minerals" refer to silica and alumina impurities in the original limestone

A further classification, NHL-Z indicates a hydraulic lime which contains other additives, of which Portland cement or white cement may be one. Therefore it is important when selecting a hydraulic lime that you fully understand the class of lime you are buying.

Mixing

A conventional cement mixer can be used although for larger projects a paddle mixer is preferable. The mix is typically 1 part lime : 2.5 parts sand. Measuring the material must always be with a gauging box or bucket. A shovel is not acceptable since quantities are too inconsistent.

Lime mortars mixed in drum mixers can be prone to balling. Use of particular mixing techniques can reduce this. We recommend the following procedure:

1. Start with an empty mixer
2. Add 1 part sand
3. Mix in 1 part lime
4. Followed by 1.5 parts sand
5. Mix dry for at least 5 minutes
6. After 5 minutes **slowly** add water until the desired consistency is reached, it is very important not to drown the mix by adding too much water
7. Once the desired consistency is reached, mix for a further 20 minutes

The mix, to begin with, should appear rather dry but as mixing time increases the render will become much 'fattier'. If too much water is added the risk of shrinkage will increase and the final strength reduced. Do not use any Plasticisers/water proofers.

If the walls are dry, damp down to reduce the effects of suction.

Sand Selection

Sand and larger sized aggregates make up the larger proportion of most mortars. Colour, texture and overall strength are all strongly affected by the choice of aggregate.

The aggregates most commonly used with hydraulic lime are sand and grit, although for the purpose of matching historic mortars various impurities may have to be added. A good sand should be a washed sharp sand with angular grains to ensure good bonding qualities. Soft building sands should be avoided as their rounded grain shape can result in excessive shrinkage.

Sands used should be well graded with a range of grain sizes, which for most plaster, render and mortar work will range from 5mm down to 75 micron. Larger sized aggregates may be used in some mortar or pointing work. As a rule of thumb for pointing, the maximum size of aggregate should be no bigger than one third of the joint width. Sands, which contain a clay or silt content of more than 4% should be avoided, as these will inhibit the contact between lime binder and aggregate.

Sands which have a high fines content should also be avoided as the larger surface area of these will require more water in the mixing. This higher water content will induce shrinkage and can affect flexural and compressive strengths. Monogranular sands should be avoided as they will possess poor workability qualities and will inhibit good vapour exchange i.e. the ability to breathe.

Water

Use clean water. The addition of water should be considered carefully, as it will directly affect the ultimate strength and durability of a mortar. The more water introduced into the mortar mix, the weaker will be the final result. However too little water will prevent the chemical processes taking place and weaken the material. Generally, water should be added sparingly, until a useable consistency is achieved. Adjust quantities to give a workability suitable for the application. It is important to use the minimum amount of water necessary so as to reduce shrinkage.

Application

Application		NHL	Typical Mix	Approx Coverage (Per 25kg bag)
Internal Plastering	Backing Coats (10mm)	NHL2	2.5 sand : 1 Lime	$8m^2$
	Finishing Coat (3mm)	NHL2	1.5 Fine Silica sand : 1 Lime	$26.5m^2$
	Finishing Coat (3mm)	Lime Putty	1 Fine Silica sand : 1 Putty	$26.5m^2$
External Rendering	Coat (10mm)	NHL2	2.5 sand : 1 Lime	$8m^2$
		NHL3.5	2.5 sand : 1 Lime	$8m^2$
Pointing Rubble Stone		NHL2	2.5 sand : 1 Lime	$10m^2$
		NHL3.5	2.5 sand : 1 Lime	$10m^2$
Pointing Brickwork		NHL2	2.5 sand : 1 Lime	$16m^2$
		NHL3.5	2.5 sand : 1 Lime	$16m^2$
Harling/Wet Dash/Roughcast		NHL3.5	2.5 sand/Aggregate : 1 Lime	$7.5m^2$
Slurry Coats		NHL2	2.5 sand : 1 Lime	Refer to supplier
		NHL3.5	2.5 sand : 1 Lime	Refer to supplier
Bedding Mortar (Standard Block)	On Edge	NHL3.5	2.5 sand : 1 Lime	64 Blocks
	On Flat	NHL3.5	2.5 sand : 1 Lime	36 Blocks
Lime Concrete	(50mm)	NHL5	2 Mixed Aggregate* : 1 Lime	$1m^2$

* 2 Parts blended aggregate – 33% Washed Sharp Sand 66% Aggregate 10-18mm

Lime Works

Background Preparation

Raking Out and Pre Pointing Operations

The purpose of this operation is to remove either old and deteriorated pointing/bedding mortar or modern cementious mortars that are causing damage to the building fabric.

- Always carefully survey the masonry to be re-pointed and check if the whole elevation needs re-pointing or can it be patch pointed.

- Before general cutting out proceeds, protect windows and cover drains, vegetation etc. which may need protecting.

- Cutting out of decayed mortar is best carried out in the context of conservation with hand tools. A 2.5lb lump hammer and plugging chisel are best. Cold chisels should not be used because they may wedge in the joints and split the stone or brick. Impact should be at an oblique angle to the face of the joint.

- Power tools are to be discouraged as they can cause serious damage to the adjoining masonry particularly in unskilled hands. In certain situations, power tools, such as small power or air chisels, can be effective for removal from larger flat areas, as their percussive action can loosen large flat sheets without the loss or even, potentially, destabilisation of masonry that may result from hacking by hand. Removal must always be undertaken with care and common sense.

- Cement pointing should be picked out with care. Narrow joints can often be cleaned out using hand held hacksaw blades. For other joints suitably narrow chisels that will not damage adjacent stones may be used. Where wide joints exist, a series of small holes, carefully drilled along the exact centre line of a joint may allow the cement mortar to break inward when tapped. This technique should not be used where there is a risk of damaging masonry behind the cement, for example in finely jointed ashlar walls.

- The work should begin at the highest point and continue downwards.

- As a general rule joints are cut out to a depth of twice the width of the joint, quite clearly this rule applies to brickwork, but in the case of rubble masonry this could result in overly deep joints, which may de-stabilise sections of masonry. Therefore a minimum depth of 25mm will allow a good body of re-pointing mortar. Deep joints must be built up in consecutive layers with a minimum of 4 days between coats. Where joints are very wide due to pinnings becoming dislodged then these need to be re-used during pointing. Pinnings are shards of stone that are inserted into wide joints between larger stones in rubble masonry.

- During raking out, any pinnings which become loose should be collected and reused.

- During raking out, each joint should be squared off to form a suitable recess to take the new pointing mortar.

- The raked out joints need to be brushed thoroughly with a soft bristle brush to remove any loose material working from top to bottom.
- Use a water hose to flush out the joints starting at the top and working downwards. This serves a number of purposes:
    a. It removes any dust etc. left after brushing.
    b. It dampens the bedding mortar and masonry. This reduces the rapid loss of moisture from the pointing mortar due to background suction.

- Damping down the wall may need to be repeated a number of times throughout the day depending on weather conditions. This helps to reduce the background suction.
- Failure to dampen down the wall surface will cause rapid drying of the pointing mortar causing excessive shrinkage and lead to a weak and powdery finish.

Salt Contamination

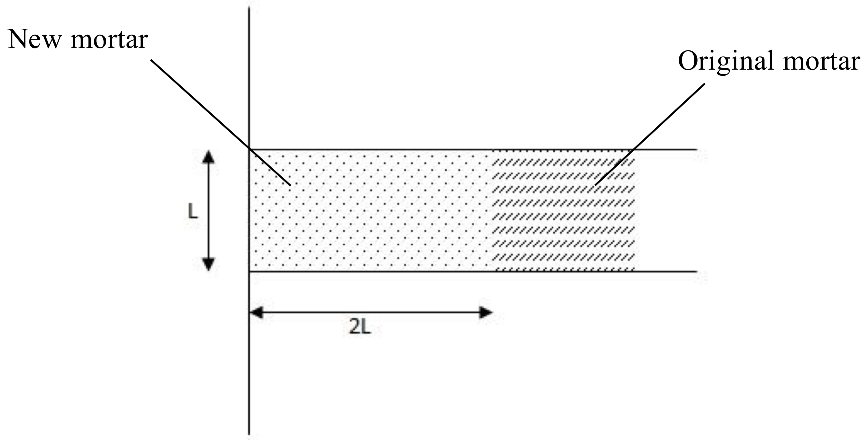
If dealing with a structure or building which may have had a damp problem over the years, the effects of salt-contamination may need to be taken into consideration, as the application of render coatings over salt contaminated masonry can present significant issues. A common cause of salt contamination is from ground water, which may contain sulphates, nitrates and chlorides, ground levels may be too high and therefore may need lowering. Lack of air bricks under-floor, poor guttering and leaking roofs will contribute to continued high levels of moisture within the core of a masonry wall. Other common sources are flue gases and contamination from road salts. In coastal locations sea winds or sea spray can result in a significant salt content in the masonry. Storage of fertiliser, gunpowder and other substances can also result in the presence of chemical salts in masonry.

Where the source of salt contamination can be removed, or the masonry isolated from the source, then a process of sacrificial poulticing, using clay and/or lime renders, might be considered before application of a new lime based coating.

In most instances removal of the source of contamination is not possible, and the only course of action may be to attempt to reduce the movement of moisture through the contaminated masonry. In the case of rising ground water (rising damp), measures to be considered may include lowering of external ground levels, introduction of ground drainage to lower the water table, removal of hard ground finishes and provision of an evaporation zone adjacent to the base of the wall, etc. Where effective remedial measures are not possible, a new lime coating will act as a poultice, drawing salts into itself, and may require frequent renewal. If salts remain in masonry which is subject to movement and evaporation of moisture then this process of renewal of the lime coating will be an ongoing requirement.

Pointing

This is the process where new mortar is inserted into prepared joints between brick or masonry. By carrying out this work the brick/masonry will continue to retain its stability. Good quality pointing also has great aesthetic value.



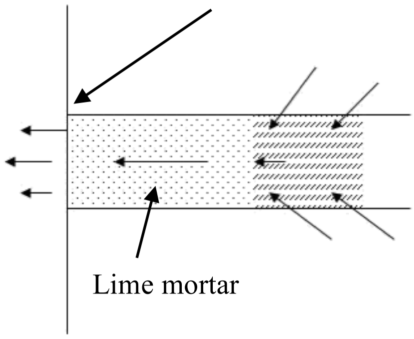
Correct pointing finished with flush with the masonry.

- The selection of the most appropriate mortar is essential before work commences. Analysis of the original mortar may be required to formulate the correct match.

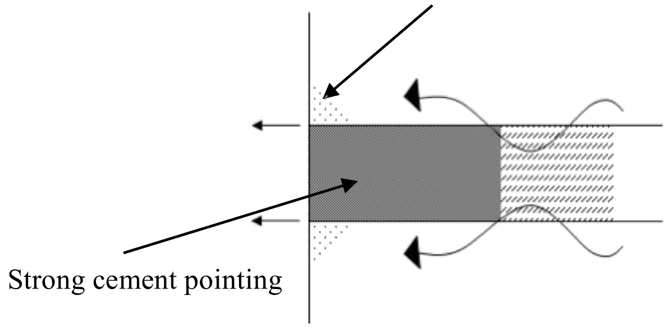
- The selected mortar needs to be slightly weaker than the stone or brick substrate. The pointing acts as a conduit where moisture that enters the building is allowed to pass back to the surface. If a very hard and dense mortar is selected then the moisture tends to pass out through the interface between the stone and pointing. This in turn causes damage to the face of the stone or brick.

Usual pattern of decay when mortar is softer and more porous than walling material

Usual decay pattern when masonry is more porous/harder than pointing



Wall built of porous material.



Wall built of impervious material.

- Matching the colour/texture of the original mortar can be achieved by adjusting the various ratios of aggregate used.
- Point a trial area before the job commences for approval by the client/architect.
- Before pointing commences, dampen down the masonry joints using a pump sprayer.
- Having selected the most appropriate mortar, this needs to be mixed to a relatively stiff consistency, using the absolute minimum of water to avoid later shrinkage.
- The new mortar should be placed into the joint using a pointing iron. A standard trowel should not be used, as they cannot fill the back of the joint (a range of pointing tools should be available to deal with different joint sizes).
- The mortar needs to be pushed firmly into the dampened joints.
- The joints should be finished in accordance with the original form where evidence exists.
- On large joints, pinnings need to be inserted into the mortared joint. This reduces the volume of mortar used, aids carbonation and helps reduce shrinkage during setting.
- A flush finish, fractionally recessed is a very acceptable finish giving both the masonry and the pointing the best possible weathering surface. See pictures below.

Example of external pointing

- Mortar should not be smeared over the face of the stone/brick if the masonry/brick is to be exposed.

- The finished mortar should be compacted into the joint when a partial set is evident using a stiff bristle/churn brush. The brush should be struck at the joints and not dragged across the joint. This gives an even and textured finish, which aids evaporation of moisture from the joints. Various other techniques can be employed to give the appearance of age and weathering.

- Keep damping down the newly pointed work for at least ten days to aid carbonation and avoid shrinkage.

- Protect the finished work from frost, sun, wind and rain by using a combination of hessian sacking and plastic until fully cured.

Plastering

- Before commencing plastering, ensure that all loose dust and debris has been well brushed off and the background is clean and tight. All loose pointing should be raked out and re-pointed.

- Thoroughly wet the background to control the suction i.e. to ensure that the water is not drawn out of the wet plaster into the dry masonry too rapidly.

- If the background has excessive hollows or unacceptable unevenness, dubbing out coats may be needed. Maximum build up should be 10mm per coat.

- Once dubbing out coats have stiffened, give them a good scratch key in preparation for the next coat.

- Apply the first backing coat evenly over the masonry at a maximum of 10mm thickness; do not overwork with the trowel. If a "flat even surface" is required, lightly drag a straight rule or plasterer's featheredge over the surface to remove the high points. If a vernacular or "old world" style is preferred just lay evenly over the surface following the contours of the wall.

- For a "flat and even surface" this first backing coat will form the surface for the levelling or float coat. Therefore once this coat has stiffened it should be scratch keyed. Any shrinkage cracks that appear should be worked back before the set is established, by wetting and then re-working and scouring with the float. Excessive scouring will weaken the coating. If curing and other conditions are not appropriate, and excessive shrinkage occurs, the mortar should be removed and the work redone.
- For a "flat and even surface" a second coat/float coat is applied to the first coat once the first coat/scratch coat has hardened to such a degree that a slight indentation can be made by pressing with your thumb. With hydraulic lime that is usually 24 to 48 hours depending on weather conditions (i.e. temperature, humidity etc.). If the first/scratch coat has gone very dry, this must be well damped down before applying the second or floating coat. This floating coat is ruled off in good plastering practice, level and true. The second coat is applied to a thickness of approximately 8 – 10mm, but never thicker than the preceding coat. Once this has set or hardened sufficiently, the plaster should be vigorously scoured or compacted with a wooden float, again avoiding overworking of the surface. This process should be completed at least twice to further flatten and compact the plaster as it shrinks on drying. Further scouring should be used if continued shrinkage cracks appear. This process is **very important** if shrinkage cracks are to be avoided.

- Once rubbing up has been carried out, the surface should be lightly keyed using a scratcher for the finishing coat.

- For finishing on "flat and even" work, a third coat is applied, once again the previous coat is wetted down and the finish coat is applied. This coat should be in the region of about 6mm in thickness. This coat needs to be rubbed up to close down the surface.

- The work needs to be protected from the elements for at least 10 days. Periodic wetting down of the surface to aid carbonation will also be necessary.

The above points are for a general approach to lime plastering, and it must be remembered that the best style of plastering on a historic structure would be to follow the evidence, if any remaining plasterwork left on the building is in good enough condition to give a true representation of earlier work.

Example of Lime Plaster Mix:

Coat	Thickness	Mix
First/Scratch Coat	Max 10mm	2.5 Sand : 1 Lime
Second Coat/Floating or Screeding Coat	8 – 10mm	As above
Finishing Coat	6mm approx.	2.5 Sand : 1 Lime

Lime Harling

Harling is a Scottish name for what is often called wet dash or roughcast. This is probably the most traditional finish that is still common today. Like all external finishes, its purpose is to act as a protective outer layer that gives good weathering characteristics. This is mainly due to the combination of large and small aggregate. This combination gives a large surface area, which can shed moisture easily.

- Harling is a textured finish that was traditionally thrown by hand using a large flat trowel.

- Harling comes in many types and textures from very small aggregate to aggregate up to 20mm.

- A new application of lime harling onto a sound, even background should generally be in two coats of approximately 8mm and 6mm thickness respectively. A thin single coat application is also possible but this may be less durable in exposed locations.

- Where a thicker harl is required, the material should be built up in several thin coats. As in modern construction, it is good practice for each subsequent coat to be thinner, weaker and more permeable than the preceding coat.

- Before work commences, the background needs to be cleaned down of any loose material and vegetation. Any moss or lichen must be thoroughly cleaned off and the walls should be sprayed with a moss-controlling agent as per the manufacturer's instructions.

- Having cleaned the background, some localised patch pointing may need to be undertaken.

- Before work commences, mask off and cover exposed windows and stone etc.

- When mixing the dry materials use gauging buckets to ensure consistency of mix otherwise variations could show up in the finished product.

- The harling mortar should be mixed to a rather fluid consistency which when thrown should spread easily but not slump on the wall. The best tool for applying harling is a purpose made 'harling trowel'.

- Before throwing on the dash, damp down the background but do not kill the suction by over wetting.

- Modern methods of mechanical application, although they may be technically sound in some situations, are unlikely to produce an acceptable result in traditional harling work. If spray application is used, it should always be finished with a hand cast top coat.

- The first coat of harl may need to be lightly pressed back with the back of the harling trowel, or with a stiff bristle brush, as it starts to set, to remove any high spots. Care should be taken not to over-work or smooth the surface, but just to push it back. Each layer of lime material should be allowed to cure, normally under protective coverings, and then re-dampened before applying another layer.

- If two or more coats are applied, they should be applied while the previous coat is still fresh/green. This is important for better adhesion between coats.

- On masonry features such as quoins etc. the harling may be feathered out (the material can be cast progressively thinner as it approaches the detail so as to die away to nothing) to expose these features. Where harling stops against dressed stone masonry care must be taken not to form raised edges. These edges are vulnerable to water penetration which may lead in the future to detachment of coating. Details such as raised margins and string courses offer protection, allowing the harl to be tucked behind. Details without a positive edge, such as crow-steps, and external angles, require extra thought and skill in application.

- If patch repairs are to be undertaken, then the surrounding material needs to be analysed to ensure a correct match. With this information it is possible to repair damaged areas of harling quiet successfully. These will have to be built up in wet thin even coats so as not to stand out.

- Continue to dampen down the finished work for up to ten days.

- The final finish should be painted with a breathable paint finish such as limewash or a silicate masonry paint, to provide an extra barrier to the weather and to complement the overall effect.

Protection, Curing and Aftercare

This part of the process does not receive the attention that it deserves particularly if work is carried out in the winter, when frost may be a problem, or in the summer when the mortar dries out too quickly.

Traditionally the time to carry out work using lime products are in the mid to late spring season or in the autumn. This is not very practical in the modern age; therefore we are forced to initiate certain steps to mitigate the negative effects of the weather.

The first measure is to provide suitable scaffold for carrying out the safe and effective operation of harling, pointing or smooth rendering. Drape green mesh or in very exposed situations monoflex on the outside of the scaffolding. This cuts down the harmful effects of wind drying the material too quickly.

On the inside of the scaffold, hessian sacking combined with a plastic sheet provides an excellent barrier against the negative effects of the weather. The use of hessian and polythene close to the wall creates a microclimate that can raise the temperature a few degrees.

This needs to be left in place for at least ten days or longer in adverse weather conditions in the case of non-hydraulic limes. In extreme conditions it may be necessary to use bubble wrap or to install heaters to protect the work against frost attack. Work should never be carried out if the temperature is below $+5^{o}C$.

Fat limes or non-hydraulic limes will need protection for longer than hydraulic limes to ensure they are not damaged, particularly by winter frosts. Therefore timing and material selection are very important ingredients when choosing the correct time of year to commence work.

Rapid drying whether by wind or sun can lead to shrinkage (cracking), separation from background, crumbly and powdery mortar. Proper curing conditions involve the process of gradual drying and should ideally result in no shrinkage.

When lime mortar dries too quickly it results in whitening on the surface. This is the lime being drawn to the surface. As mortar carbonates it needs to dry out slowly. It needs to be kept moist (not wet) for at least 10 days. This aids the process of carbonation. Keeping the work moist can be achieved by the use of a garden pump sprayer.

The second factor to be aware of is to ensure that roof coverings, down pipes etc. are functioning properly before work commences. Water entering the masonry at any level will cause localised saturation within the masonry and this in turn causes problems in the application of the lime finish. Temporary measures may need to be put in place for the disposal of rainwater.

Limecrete

The use of limecrete is desirable in a historic building as it allows naturally occurring moisture to escape through the floor. The use of modern cement floors has caused some problems as moisture is unable to escape through the floor and is pushed towards the walls and can cause damp patches to occur in or around the base of the wall. If additional insulation is needed then recycled foamed glass beads or expanded clay aggregate may be incorporated into the floor slab.

A base of clean hardcore (minimum depth 150mm) may be used. It should be well compacted down by use of a vibrating plate. A limecrete floor requires no D.P.M. (damp proof membrane) as the lime method is to allow moisture to breathe through a structure.

Limecrete is laid in layers of normally no more than 50 mm. Greater thicknesses are achieved by adding subsequent layers to build up the desired thickness.

Limecrete should be mixed to the consistency of a floor screed i.e., a semi-dry state, which will hold together when squeezed by hand, wet traditional concrete type mixes will result in excessive shrinkage. If possible a screed mixer or roller pan mill should be used and drum cement mixers tend to result in the mix balling.

The limecrete can be finished by tamping with a wooden or steel tamper and the surface can be rubbed up using either a timber or polyurethane float.

Limecrete floors are fully compatible with under floor heating. When covering the water pipes then a 75mm layer of limecrete is necessary. It is essential that when the under floor heating is commissioned the amount of heat directed to the pipes within the limecrete is very gradually increased to minimise shrinksge.

Once laid limecrete should be kept damp for 96 hours (minimum). This may call for spraying with water during warm and hot periods. Limecrete must always be protected from freezing conditions for the first 10 days after laying. Traffic should be avoided for 10 days, and thereafter protective boards should cover the work for 3 weeks before exposure to general traffic.

When selecting a floor covering it is important to select a material that continues the ability of the floor to breath such as natural stone or terracotta tiles. Timber floors are also an option but it is best to lay the wooden boards on treated timber battens to allow a air gap and to incorporate vents to allow a degree of air exchange.

A point to keep in mind when installing a limecrete floor is that it should not be used to support masonry walls or chimneys. Suitable foundations need to be planned and put in place before the limecrete floor is laid. Lighter timber stud walls may be acceptable.

Limewashing

Limewash (or other breathable paint finish) is the final part of the protective envelope for structures coated with a lime render either smooth or rough as in the case of harling.

- It provides a protective, permeable and renewable skin of calcium carbonate.
- The best limewash is manufactured from mature lime putty.
- Surfaces to be limewashed must be clean and free from grease. The best results are achieved on porous backgrounds i.e. lime plasters and renders. Surfaces and joints should be brushed free of loose dirt with a natural bristle brush (not a wire brush) to ensure a good bond, and open joints flushed out with water. Previously limewashed surfaces must also be well brushed down and any loose limewash scraped off.
- Any mould should be treated with fungicide and thoroughly washed off with clean water. Do not use fungicides which contain silicon. All lichens, moss and vegetation

should be removed using a compatible biocide and bristle brush, or a steam cleaner. All forms of biological growth will retain moisture and can grow back through the new coating.

- The area to be limewashed needs to be dampened down with clean water prior to application. Dry porous sandstone will normally have excessive suction. Dampening down, to control suction between the background and newly applied materials is essential. Applying limewash to a dry surface will cause excessive dusting and an unpleasant white bloom on the surface. This is due to rapid drying and the lime being brought to the surface. Spray about 3sq/m of the surface to be limewashed with water until the surface is damp but not running with water. Do not try to damp down the whole wall or ceiling at one time, as most of the area will be dry before it can be limewashed.

- Denser, more impervious stones, e.g. whinstone or other metamorphic stones, or some granite have very little natural suction, and lime mortars may not adhere to these stones if there is any surface water present. These low-suction backgrounds need no dampening down.

- Limewash is best applied using a 5 or 6 inch brush working the wash in thoroughly over the surface. It is important to stir the limewash before and regularly during the application.

- Building up a thickness of limewash using many light coats is the most desirable approach. Apply, working the wash well into the surface. The limewash will appear transparent when first applied so care must be taken not to build up the limewash too quickly, as this will craze on drying.

- A period of 24 hours should be given between coats, to allow the wash to dry. It is important to rewet the previous coat before applying the next coat.

- At least 5 – 6 coats are needed on new work, up to 10 can be added if time allows, building up a satisfactory depth of colour.

- For best results lightly buff up the surface when it has “taken up” a little using a dry worn brush.

- As with all operations using lime products, protection will need to be provided before, during and after application. It is very important that there is no danger of frost for several weeks after the limewash application.

- Limewash should be maintained with further coats every 2 – 4 years depending on exposure.

- The application of limewash is a very important part of the structures protective skin yet many specifications either omit it, or not enough resources are channelled towards it.

Limewash serves a very functional purpose yet it is also decorative. Plain un-coloured limewash will take on the colour of the lime used; this can range from pure white through to grey or buff coloured. Generally earth pigments were used to colour the limewashes, most commonly ochres, but also siennas and umbers, which produced a range of yellows, reds and oranges. Broadly speaking these produced pastel shades, although deeper colours are not uncommon. Coal dust, ash, blood and ground stone dust have all been found as additives in historic limewashes to achieve the desired colour. When using pigmented limewashes, it is advisable to calculate the total amount and to mix this in one batch. Slight variations in colour are possible between batches.

Common Mistakes and Solutions

Limewash dry but powdery:	Dried too fast, spray with water and recoat with limewash.
Limewash not absorbed:	Unsuitable non-porous surface remove and use alternative product.
Limewash patchy:	Insufficiently mixed, mix following coat thoroughly. Dampness within masonry or different building material i.e. stone/brick.
Limewash dries too quickly:	Remove flaky limewash and damp down the background.

Silicate Masonry Paint (Mineral Paint)

Silicate masonry paints are another option for the final part of the protective envelope for structures coated with a lime render either smooth or rough as in the case of harling.

The most abundant Elements in the Earth's crust are oxygen (46.6%) and silicon (27.7%). Minerals which combine these two elements are called silicates. Over 90% of the Earth's crust is composed of silicate minerals.

Conventional paints form a layer on the substrate, which tends to become brittle, form cracks and then flake off when exposed to weathering, this is a sign of poor keying with the substrate. Through a process known as silicification, Silicate paints form a micro-crystalline structure, permanently bonding directly with the substrate mineral. Mineral paints offer superior quality to conventional masonry paint as they provide a breathable finish.

The binder (waterglass) contained within the paint is highly resistant to UV light, giving it lightfastness attributes. The special property of silicification means that bronzing caused by weak chalking produces effective self-cleaning. This results in clean facades that are free from dirt deposits and algae and offers diverse possibilities for exterior colour design, for example, in new build work or for the restoration of historical building materials.

Mineral paints offer a healthy and environmentally friendly alternative to the majority of the paint market. Mineral paints have a very low VOC (volatile organic compounds) content, they are non-toxic, and are free of artificial resins, solvents, preservatives, plasticisers and biocides. No toxic gases are released during a fire. The high alkalinity of the coatings has a mould resistant and bactericidal effect.

Silicate Paints have a very low diffusion resistance (S_d value): the thickness that water vapour has to travel to escape, a lower S_d value indicates a lower resistance to water vapour permeability, and this means more moisture is released. Silicate paints ensure unrestricted water-vapour diffusion between the atmosphere and the porous substrate. Permeable systems provide perfect building conditions and protect both plaster and masonry from moisture accumulations.

When using Silicate Paints, it is extremely important to carefully cover areas that are not being treated, especially glass, ceramics, and window sills, and protect them from splashes; otherwise the paint will form an irreversible chemical bond with the substrate.

Whilst the application of a silicate paint system is by standard methods, they are more demanding than conventional masonry paints, it is therefore important that the person/s carrying out the work follow the manufactures guidelines, and familiarise themselves with the principles along with some ground rules to ensure long lasting results.

Checklist of Good Practice

Select Appropriate Materials:

Investigate any existing lime coatings on the building.

Preserve existing materials wherever possible.

Investigate the characteristics of the masonry, local climate and conditions.

Investigate materials available, using local sources where appropriate.

Lime materials should always be weaker than the host masonry.

Do not compromise lime materials by using them in conjunction with modern materials and technologies.

Be aware of other influences or constraints, particularly in urban or marine locations.

Modern materials that are too strong for the host masonry will trap moisture in the wall leading, potentially, to stone decay and interior damp problems.

Non-Hydraulic mortars cannot harden in wet conditions and are not suitable in situations of continuous saturation.

Non-Hydraulic mortars that remain saturated will be vulnerable to damage by frost action.

Non-Hydraulic mortars in permanently wet situations will be susceptible to leaching of lime.

Appropriate Detailing:

Protect edges of harling and renders as effectively as possible.

Avoid formation of exposed ledges.

Continuously saturated areas, caused by details catching rain, will be prone to staining, frosting and accelerated decay.

Water splash from adjacent hard surfaces can damage lime coating, particularly if road salts are present.

Prepare Materials Correctly:

Lime putty should be well matured.

Natural Hydraulic lime should be fresh.

Ensure materials are stored in conditions which will prevent drying out (mortar and putty) or dampness (dry hydrates).

Use clean, well graded, washed sharp sands.

Ensure ratios of lime to aggregate are correct for the types of lime and aggregate.

Ensure any gauging is accurately measured and thoroughly mixed.

Knock-up materials thoroughly.

Do not add extra water to substitute for knocking-up. Where required, extra water should be added after the initial knocking up.

Inadequate mixing and maturing, or the use of excessive water, will result in lack of cohesion within the mortar, resulting in loose and crumbling materials.

Uneven gauging or measuring of lime/aggregate ratios may result in leaching-out of concentrations of free lime.

Good Working Practices:

Fully prepare walls prior to application of lime coating.

Remove all dust, debris and vegetation.

Dampen down sufficiently to control suction.

On surfaces without adequate suction, provide a mechanical key (e.g. a splatter dash coat).

Allow saturated masonry to dry out before applying new lime coatings.

Insufficient dampening down of dry porous backgrounds, resulting in excessive suction, will cause shrinkage cracking, loss of bond between coats or with substrate, and a weak and friable mortar.

Apply lime harling and renders in thin (max 10mm) even coats.

Excess thickness of material may not fully carbonate and may develop shrinkage cracks.

Leave an open texture to the surface, avoiding excessive working of the material.

Overworking of the material may bring free lime to the surface and cause a skin (laitance) to form. This may lead to loss of bond between coats and to the material being unable to carbonate properly. Excessive overworking will impoverish the lime mix by removing lime in the form of laitance.

Saturated walls will continue to dry out after the lime coating is applied. This may cause continuing dampness in the coating, which may then be vulnerable to frost. Any soluble salts moving into the coating may lead to pitting and spalling of the surface, showing a white 'bloom'. (Sacrificial lime coatings may be applied, for this purpose, as a poultice to draw salts out of the masonry.)

Lichens and vegetation not fully removed may grow back through the new coating.

Appropriate Working Environment and Protection:

Provide appropriately designed scaffolding for the best working access, from which protection may be hung.

Ensure that roof coverings, gutters and down pipes are functioning before work begins; otherwise make temporary provision for rainwater disposal.

Provide adequate protection over the top lift of new work.

During application and curing provide protection against rain, rapid drying by sun or wind, and frost.

Dampen down the surface on new lime materials, as required, to slow the rate of drying.

Where new lime materials are placed after September or before April, protect from frost until fully cured.

Shrinkage cracking or areas of material with an open friable texture will occur in lime coating materials if rapid drying occurs (by sun or strong winds) before proper carbonation.

Rapid drying may also draw lime to the surface making the material appear over-white.

Non-hydraulic lime will not carbonate in situations of continuous saturation.

Hydraulic lime mortars may become friable if insufficient water is available for the hydraulic set to take place.

Rain or other continuous saturation may cause lime leaching and staining on neighbouring components, as free lime is mobilised.

Immature or un-carbonated mortars and non-hydraulic lime materials in continuously wet situations may be damaged by frost action.

Roundtower Natural Hydraulic Lime 2: NHL 2

Feebly Natural Hydraulic Lime

- ✔ Used for internal plastering and externally
- ✔ Where the masonry is made up of a soft material

Roundtower Natural Hydraulic Lime 3.5: NHL 3.5

Moderately Natural Hydraulic Lime

- ✔ Used mainly for masonry and external plaster works
- ✔ The most popular material for new build work.

Roundtower Natural Hydraulic Lime 3.5 White: NHL 3.5

Moderately Natural Hydraulic Lime

- ✔ Another NHL 3.5 with the exception that it has a higher 'whiteness'
- ✔ And is useful when colour matching mortars

Roundtower Natural Hydraulic Lime 5: NHL 5

Eminently Natural Hydraulic Lime

- ✔ This material is used in areas of high exposure such as in marine environments
- ✔ Wall copings, lime concrete, etc.

ROUNDTOWER LIME PUTTY

Used mainly on historic buildings, soft masonry and where exact mortar matches are important.

Roundtower have been manufacturing lime putty (non-hydraulic lime) since 1999, for the restoration of many heritage listed buildings.

Although traditionally this type of mortar was used internally and externally, today it is generally used for internal plasterwork & cornice, pointing, bedding and renders in sheltered areas.

Roundtower lime putty is manufactured in Southern Italy and is extremely high quality with the addition of marble dust mixed through it which makes it an incredibly smooth and workable product. It is perfect for lime washes and finish coat plasters.

Roundtower lime putty has been matured for a minimum twelve months before being transferred into 20kg tubs storing the lime putty in airtight containers to mature and any un-slaked particles will have sufficient time to slake. The longer the putty is allowed to mature the better the finished product. Traditionally in Italy the best quality work was carried out using lime putty allowed to mature for generations.

The best method of manufacturing a lime putty based mortar is to mix the ingredients in a mortar mill. The resulting mortar is of a high quality and very workable. No extra water should be necessary during the mixing process.

Lime putty offers the best flexibility and breathability of any lime mortars.

Roundtower lime putty is used to manufacture lime wash, traditional lime mortars and plasters.

The production of lime putty is a hazardous procedure and should only be carried out by suitably trained personnel. This is not a procedure to be carried out on site where the work cannot be monitored and controlled.

Health and Safety – Lump lime (calcium oxide) is a caustic alkaline. When it comes in contact with eyes or skin, it will cause a chemical burn. Wash the affected area with a solution of sugar water immediately and seek medical assistance. When working with lime the operative needs to wear personal protective equipment (eye protection, gloves, overalls and dust mask).

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