GENERAL GUIDELINES for WORKING WITH LIME PUTTY FOR MORTAR, PLASTER and LIMEWASH

Understanding water – suction and evaporation – is crucial to the successful application *and* durability of lime mortars, plasters, stuccoes, and limewash. It is impossible to overstate the importance of working with as dry a mortar as possible while adequately dampening the substrate. This is the opposite of standard working procedures for portland cement mortars. Without the benefit of a wet substrate the bond of lime to the substrate will be limited. Because lime mortar sets more slowly than portland cements and yet curing of the mortar requires a *slow* loss of water, it is important to ensure the substrate is wet for an extended period before beginning work to ensure water loss will be slow. Too-wet mortar leads to shrinkage as the water is drawn off leaving voids.

It is best to think of the water needs of lime as a cross-fade between scenes in a movie with the water slowly disappearing as the carbon dioxide is moving in. Lime mortars will not gain strength, in fact may turn to powder, if starved of water too early. Lime mortars do not set hydraulically from reaction with water as portland cement (a huge benefit that allows premixed lime mortar to be stored and reused indefinitely as long as it is kept wet). Rather lime sets, or carbonates, through absorption of CO_2 in the air (and dissolved in rainwater.

Lime putty-sand mortars are more plastic and better accommodate settling or movement in walls partly because of their slower setting rate and as a result of "autogenous healing," where cracks are resealed (especially outdoors) as acidic rainwater enters and partially dissolves some of the calcium carbonate. This temporarily creates calcium bicarbonate that re-deposits into the crack where it subsequently recarbonates. This means that in addition to being more "breathable" (doesn't trap water behind as portland cement does), lime mortars are also better at shedding water than portland. With its quick and rigid set, portland stucco is likely to crack under stress or movement and those cracks allow water infiltration and finally water trapping within the wall. In contrast, lime stucco can better adjust to settlement common in new construction as well as to subsequent cracks *because* it sets more slowly. This means the slow set is a bonus to builders rather than a drawback – once the different characteristics of working with lime are understood.

Although it may seem that "stopping water" is a good idea, many of our modern building methods and materials are designed to act in conflict with the nature of water. Water will get into walls both from the exterior and interior (bathrooms, kitchens, people and plants respiring). It is better to accept this and plan for quick evaporation. Good design directs water away from walls with a good roof overhang and foundations that extend out of the ground several feet. Annual mulching increases the grade around a building rapidly, so foundations should rise above the splash line of any yard or bedding materials.

Only the calcium proportion of a lime carbonates quickly, so purpose-made high-calcium architectural lime putty can be expected to set rapidly and provide a very durable work in all climates. While S-type and other hydrated limes work well in conjunction with portland cements (as this is the product they were design for), they are not manufactured with the high surface area and small particle size that speed carbonation for a lime-sand only mortar.

Mortar Components

Sand. The quality of sand is of primary importance to achieving a high quality lime mortar. It is the job of the sand to provide structural strength with the lime putty coating and cementing the particles together.

Sand should be clean and free of silts or organic material. Sand containing silt should be washed until all silt or organic materials have been rinsed away. (In cases where on-site sand is being used to match an original mortar in an historic building and obtained by washing soil from the site to the appropriate degree, it is advisable to mix the mortar a month in advance to give the lime an opportunity to stabilize the clays fully).

Sand should be as sharp or angular as possible. Rounder sands are less structural because they do not lock together as well.

Sand should be comprised of various size particles from fine to coarse. Graphed, a well-graded sand for mortar would chart to a bell curve, meaning that the majority of particles are in the mid-range of sizes with the quantity of larger and smaller particles decreasing as you move to the particle size extremes. A good range of sizes allows the sand grains optimal packing and with it a reduction in shrinkage and cracking.

Particle Size Distribution of Aggregates.

Sand used for building should ideally be clean and sharp (angular, not rounded) with a range of particle sizes as these will pack together more tightly, providing a more structural matrix. The strongest mortar would come from a sand with the bell-curve range of sizes ensuring that every surface of each sand particle would be touching another sand grain with only a thin film of lime gluing them together. (Imagine golf balls, marbles, bb pellets and table salt mixed together, with the smaller aggregates filling voids between the larger ones.)

Determining the Lime:Sand Ratio:

There needs to be enough lime to coat each sand particle and bind it to neighboring particles without being in excess. Too much lime and the sand particles are pushed apart, weakening the mortar because the sand particles cannot pack tightly together. Different sands have different lime:aggregate ratios based on the void space between the particles of sand.

Determining the Lime:Sand Ratio: A Simple Test. Alcohol (such as Everclear from the liquor store) provides a better void reading than water and the sand should be very dry for this test. If necessary, the sand can be dried in an oven at 200ºF for half an hour or put in a microwave oven until it stops steaming up the interior, then cooled. Two equivalent dimensioned containers are needed for testing (ideally milliliter beakers, not glasses from the kitchen cabinet.)

Ideal sand proportions are determined by comparing the ratio of dry sand to the amount of alcohol required to just wet the top of that sand. For example, if a container with 100ml of sand takes 30ml of alcohol, then the approximate 3:1 sand:lime ratio often used for estimating is correct. If on the other hand that same 100ml of sand takes only 20ml of alcohol, the ratio is 5:1.

Pigments. Not all pigments are stable in the high alkalinity of lime putty. This is less of a concern if mixed as a limewash and used immediately since the lime will rapidly return to a neutral pH as it carbonates, but for stored limewash or for pigmented mortars, pay attention to the alkaline stability of any purchased pigments. All natural iron oxide pigments and most earth pigments are alkaline stable. Your pigment supplier should be able to differentiate.

Clean Water. Chlorine or high iron content in the water used for mortar-making or limewash can produce staining and efflorescence. It is highly recommended that municipal water supplies using chlorine for water purification be allowed to sit out in sunlight for no less than 24 hours before use in masonry work to off-gas the chlorine, especially in the hottest summer months when excess amounts of chlorine are often added. In-line reverse osmosis treatment is another alternative for removing chlorine from municipal water.

Working Conditions and Methods

Lime Putty cannot carbonate as long as it is kept in a sealed container with at least an inch of water over top to protect it from any contact with carbon dioxide. As lime or mixed mortar is removed from containers, it should be reconsolidated into a tight pile at the end of the day that can be tightly secured and covered with water to stop carbonation.

Mixing Lime Mortar

Lime mortar or plaster must maintain a consistent proportional mixture of lime and sand (and fiber, if used).

1. Mix lime plaster thoroughly prior to use. *(Mixing makes lime more plastic and workable, so keep this in mind if the stucco on your hawk begins to get stiff: if it is picked up and dropped on your hawk a few times, it will instantly become more workable, or pound it in a bucket or on your plaster stand a few times with a 2x4 cutoff.)*

a) Vertical shaft mixers should be used. Avoid false economy: The cost of a new mixer will save time and money while providing a thorough, consistent mix. Common masonry drum and barrel mixers do not adequately mix lime mortar.

b) Add sand and lime alternately to the mixer while it is running, never allowing the sand proportion in the mixer to be greater than the ratio to lime. Unless sand is extremely dry, added water is most likely not needed. If water appears to be needed, add slowly. Rarely is more than a gallon of water needed for pointing mortars even with the driest sand.

c) Remember excess water leads to shrinkage; the more you add now, the harder you will have to work to compress the mortar later.

d) Mix for a minimum of 20 minutes. Do not worry about over-mixing the mortar. (Motor heat or mixing in direct sunlight for long periods however may cause the mortar to dry out). Cover the mixer with an impermeable membrane such as roofing membrane to limit evaporation and CO2 uptake during mixing.

e) When thoroughly mixed, lime mortar should look dry in the mixer, but work nicely on the trowel or hawk. Stop the mixer and test the mortar before continuing to add water. Again we want “dry” mortar applied to a “wet” substrate.

f) Mortar is ready for most activities when a trowelful tapped twice against the side of the mixer achieves enough of a bond that the trowel can be held upside down without the mortar dropping off.

g) Fiber may be added to the fully mixed mortar in the last few minutes of mixing. Cut and tease hair into a separate container before adding to mortar to limit clumping. Once the fiber has been blended in, stop the mixer promptly so that the hair or fiber does not begin clumping around the mixer paddles. Hair to be added at a rate of about a gallon to five gallons of lime putty so that hairs are on about a ¾” spacing with each troweful.

h) If the mortar is made too wet, spread it out on a piece of plywood placed at an incline to allow water to run off and be soaked into the plywood as well as evaporate slowly. Do not leave the mortar like this unchecked for more than an hour or carbonation may begin. (However, when temperatures drop below 40 degrees, the water will be too tightly bound and evaporation will not occur until warmed.)

Plaster may be allowed to rest overnight in the mixer if it is tightly covered and mixed again before use the next morning. Un-haired mortar can be mixed in advance and stored indefinitely in airtight containers with a 1” water barrier on top. Haired mortar will not store as long due to the high alkalinity that dissolves organic materials such as hair (six months maximum).

General Mortar Ratios by Coat for Exterior Applications (Stucco)

**** Do not apply lime mortars or limewash when risk of freezing is present during application or curing process (for up to a month after applying exterior stucco). ••**

First Coat (Harled Coat) = a "soupy" wet mix of mortar that can be thrown or sprayed on the wall with considerable force to achieve both a mechanical and chemical key.

- Mixed dry and apply to dampened masonry, lath, or bales. Wet when you arrive at work, 30 minutes before starting, and, as needed, just before application. Surface is ready when it feels cool to touch indicating that it is damp.
- Ratio = coarse aggregate to lime ratio as derived from void-space test.
- Do not add fibrous materials to the harled coat.
- Apply harled coat about 1/4" thick.
- On very uneven substrates such as strawbales, fill deep voids with mortar a day in advance.

Intermediate Coats - second through third coats depending on specified final stucco thickness. Sometimes called "scratch coats" or "base coats" with the mortar referred to as "coarse stuff."

- Ratio = same as harled, coarse aggregate mixed to void-space proportions
- Cut and tease hair into mortar in the final moments of mixing at rate of 1 gallon to 5 gallons of lime in batch.
- Intermediate coats should be applied at approximately 5/8" thickness.
- Intermediate coat mortars will be mixed as dry as possible while achieving the desired consistency: lifted on a trowel, tapped on the side of the mixer three times and inverted, the mortar maintains its bond to the trowel, even when shaken.
- Remember trowelling of plaster and stucco is about compression as much as smoothing the surface. Press hard.

Finish Coat for Stucco.

- For ideal durability, the finish coat would maintain same coarseness as preceding coats. The final appearance can be made smoother with applications of limewash. Coarser coats cure more rapidly and evenly than fine; a plus for exterior work. If finish stucco must be finer – whether using alternate sand or sieving the largest aggregate out of the coarser mortar already being used – maintain a good range of aggregate sizes with an angular sand.
- Mix as dry as possible, do not incorporate hair or fiber
- Apply to no less than 3/8" thickness.

General Mortar Ratios by Coat for Interior Applications (Plaster)

Scratch or base coats

- Reusing wood lath is possible without use of bonding agents if wetting of the lath begins the day before!
- Use aggregates with a good bell-curve range of particle sizes and angularity with the largest aggregates topping out at 3/16". Maintain aggregate:lime ratio determined by void-ratio test.
- Mixed dry and apply to dampened masonry, lath, or bales. Wet when you arrive at work, a half hour before starting, and, as needed, just before application. Surface is ready when it feels cool to touch indicating that it is damp.
- Apply in 3/8" coats. If applying through lath, estimate almost double mortar usage to accommodate mortar pushed through and wrapping through and down over the back of lath to achieve mechanical key.

Finish coat for Plaster

- Aggregates with a good bell-curve range of particle sizes and angularity with the largest aggregates topping out 1/8". Before considering a significantly finer sand that may compromise durability, try a test panel with limewash to soften the appearance.
- Only on the finish coat of interior plaster can the lime content of mortar be slightly increased. Adding too much more lime however will lead to shrinkage and cracking.
- Better to work with slightly drier finish plaster dampening it as needed during troweling. Remember troweling of plaster is about compression as much as smoothing the surface.
- If a more polished surface is desired using a finer aggregate, it can be achieved without admixtures:

  o When plasterwork is firm to touch, scour surface using only as much water as is necessary to moisten the surface and allow a wooden float to glide freely. Continue scouring until a dense, even, and close-grained surface is obtained. (Scouring with a cross-grained wood float leaves a dense open-grained finish; a plastic float leaves a more polished homogeneous appearance.)

  o Plasterwork may be further trowelled using a steel trowel and a broad flat brush, sprinkling water on the surface, followed directly with the trowel.

Plasters and stuccoes should not be applied thinner than ¼" as this can lead to drying out too rapidly. Do not keep reworking lime plaster or stucco once it is well adhered to the wall. This may cause lime to be drawn to the surface where it can form a hard crust over a soft backing and deprive the interior of enough lime to bind the sand.

General Preparation and Use of Limewash from Lime Putty

Mixing Limewash: Limewash is mixed by thinning lime putty to the consistency of whole milk consistency. (If pigments are to be added, keep the limewash thicker, since the pigments will be added in water, further thinning the limewash.) This normally means filling a 5-gallon pail only 1/3 full with putty and then incrementally adding water with mixing in between.

Lime putty should be thoroughly whipped in a five gallon pail using a right angle drill with a masonry mixing paddle **before** adding water. Mix to a consistent creaminess. Cut a whole in the lid of the pail for the spindle of your masonry paddle and secure the bucket lid tightly while mixing to keep limewash from splattering. Remember your safety goggles. Water should be added incrementally a half-gallon at a time. Adding too much water at once will complicate consistent mixing with clumps of putty floating past the paddle.

Pigments should not be added until limewash is thinned.

- Pigments should be mixed with just enough warm water to fully "wet" the particles completely, before adding to limewash. Don't waste money pigmenting every coat of limewash. Build up opacity with white limewash until the last layer or two.

Applying Limewash: As with all lime products, the substrate should be thoroughly dampened before limewash is applied. Do not apply limewash on extremely windy days or in straight summer sunlight. Follow the sun around the building; don't let it follow you. If necessary, mist the limewash over several hours, allowing it to dry slowly. Flash drying will lead to chalking.

- Limewash can be brush-applied, sprayed or even rolled on, although each of these methods is increasingly messy and personal protection as well as protection for surrounding surfaces becomes a greater concern.
- Lime will etch aluminum and can discolor copper under certain conditions, so protect surrounding metalwork.
- Do not apply limewash when risk of freezing is present during application or for two days after.

These guidelines are provided in good faith. They are not a substitute for suitable workforce training.

Safety Precautions When Working With Lime

Lime is an extremely caustic material when wet, with a pH of 12. (Lime becomes pH neutral when carbonated). Protective goggles and gloves should be worn at all times. Additionally, protective clothing should be worn where risk of splatter on to bare skin is present.

Clean water should always be at arms length for flushing eyes or skin. Lime on skin can be neutralized with a very mild acid such as vinegar or lemon juice. Repeatedly flush eyes with fresh water for several minutes and consult medical advice.