Stucco Conservation

Chapter 6

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Project Goals

The stated goals of the project were to identify the early original stuccoes; develop consolidation treatment methods for strengthening weakened original stucco; remove all inappropriate stucco in-fill and patches without damaging the adjacent original material; develop a formula for a new lime and sand stucco, for use as in-fill, that imitated the best of the early original material; and finally, create a simple durable whitewash or limewash to apply over the finish coat of stucco, which would provide protection and create a pleasing and uniform appearance.

I was asked to assist in moving the stucco portion of this project from research and testing to implementation. Rob Fitzgerald and I reviewed what was known about the various stuccos on the building and his recommendations for repairs. I then had to find ways to extend removal and application techniques developed in the laboratory to the scale of a construction site, at the same time coordinating and integrating them into the existing budget and schedule.

Preparation

I needed to be able to predict conditions beneath the stucco's exterior by examining its outer surface. To understand the range of possible conditions present, I spent several days tapping, scraping, and drilling the stucco and then examining the loosened stucco by picking it apart. One thing I learned was that the hollow sound I heard when tapping some places rarely meant that the stucco was in any danger of coming loose. Usually it was mechanically well attached. The real problem areas were the fields of original stucco found underneath the crust of Portland cement. This early lime stucco, though usually relatively intact in appearance, crumbled easily on contact. These areas were identified as prime candidates for consolidation.

The plan called for me to move ahead of the mason's assistant, classifying the stucco and marking it with chalk to indicate course of action. Three types of stucco were identified: Portland cement patches, which were to be removed; sound original stucco, which was to be left untouched; and weakened original stucco, which was to be consolidated. For the first few days I marked the stucco ahead of Chris Hamilton, a local craftsperson who worked as the mason's assistant. Chris was responsible for removing most of the stucco patches. I marked the border between the original stucco in good condition and the stucco that needed removal; using a diamond blade on a grinder, I cut grooves in the Portland cement several inches beyond the borders of the areas of the sound stucco. These grooves isolated the early stucco from potentially damaging vibrations of hammer blows. Chris followed after me, cutting away inferior stucco and cement patches using a small sledge hammer and various chisels. The following week one of the project managers I had trained took over the marking process. As the time for applying new stucco drew near, we still had no clear candidate for a cosolidant. Rather than hold up the progress of the project, we decided to limit our consolidation efforts to an area of weakened stucco on the garden-side wall. The rest of the unstable stucco was removed.

Joe Forrest was selected as mason for the project because of his prior experience with lime mortar. He was trained in England shortly after World War II when some traditional building techniques including slaked lime for mortars, stuccoes, and plasters were still in use. He has been a practicing mason builder for over forty years. Rob Fitzgerald located him through his contacts with the National Park Service. Joe had recently completed a successful stucco project on a historic house at Valley Forge, Pennsylvania. Rob interviewed Joe and put me in touch with him. Even more than his cost estimate, I was looking for certain qualities and attitudes. Foremost of these was experience with and enthusiasm for traditional lime and sand stuccoes. Equally important was Joe's ability to understand the conservation goals of the whole project and to use his talents toward that aim (not an easy thing for many artisans). Finally, he had to have the patience and curiosity to try new techniques, experiment with formulations, and share his knowledge with us.

Charles Phillips, Rob, and I met with Joe to go over our plans for stucco removal, repair, and replacement. Joe was encouraged to help us further plan the work, which he did. We reviewed formulas developed by Rob and compared them to traditional mixes that Joe was familiar with. Joe was asked to develop a work plan and make an estimate of quantities and supplies he would need. We agreed to supply all materials and labor to Joe. In preparation for the application of the stucco Joe was to supervise the removal of the Portland cement and failed early stucco and make final adjustments to the remaining stucco to ensure a good bond. The old stucco areas had to have strong, clean edges, clear of crumbling bits. These edges then had to be stepped up in layers and back cut to avoid thin and feathered edges where new stucco covered old. He was also asked to prepare sample areas with skim coats and limewash for review.

Application

The formulation and consistency of each layer of stucco, its thickness, care, and protection after application, are always under the control of the mason. The mason endeavors to mix the lime putty and sand so that it can be easily handled and tooled smoothly but not mix it so wet that it falls off the trowel or sags after it is smoothed in place. The layers are kept thin, not only to reduce sag and creep but also to allow the stucco to begin its curing process. An initial firmness and set comes as soon as the water begins to evaporate. The mason has to adjust the mixtures and maintain just the right amount of moisture for days and weeks after laying up the stucco. This ensures that each layer is allowed time to set up and begin the process of carbonation before a new one is applied. If the underlying layer of stucco is not maintained properly, it will have dried out so much that it rapidly sucks water out of a fresh layer applied above it. At minimum, it may prevent the two layers from bonding, and it is very likely that the new layer will be soft and crumbly. If this condition occurs and is not remedied, the two layers will separate.

The basic ratio we used for the stucco was one part lime putty to three parts sand. This was used for both the pointing mix and the scratch coats. (The pointing mix is mortar for filling voids between the stones in the substrate, the scratch coat and the brown coats are the first few layers of stucco.)

Each day Joe oversaw the mixing of the stucco and, for the most part, applied all of the new stucco by himself. The three to one mix of sand to lime putty was used for the brown coats. Rob Fitzgerald's formula called for the use of sands imported from New Jersey and Connecticut. One of these sands was no longer available. We had decided to avoid importing materials whenever possible, as it caused additional expenses and delays. The project managers from Restoration Group, Inc. (RGI) took a sample of sand from the banks

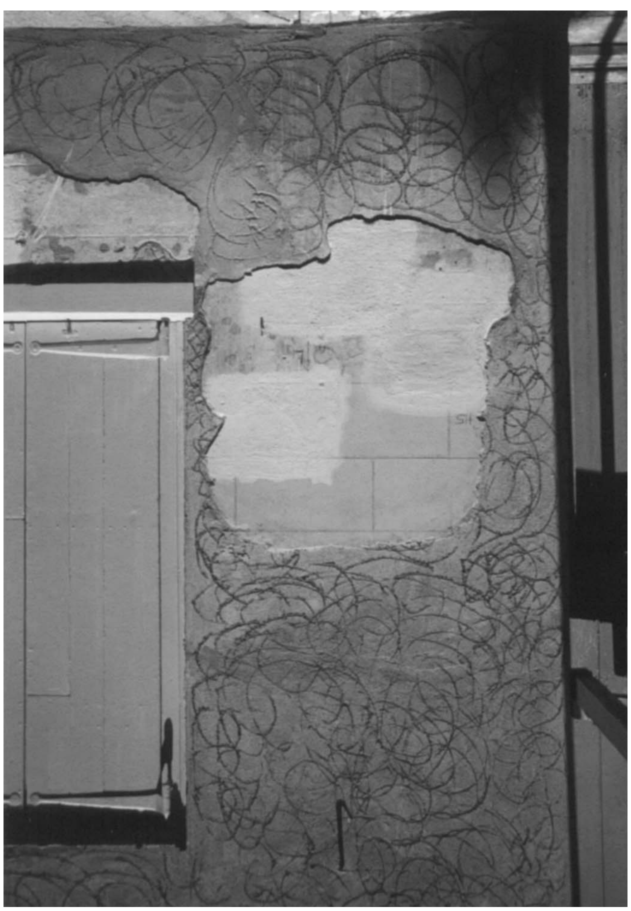
Removal of cement patches.

Mixing stucco.

of the Wissahickon (which runs through Fairmount Park about a mile from Wyck). This sand turned out to be a close match of the sand in the early stucco samples. In all likelihood the creek was the source of the original sand. Unfortunately, we were unable to get permission from Fairmount Park to remove sand for the project. Restoration Group, Inc. located alternative sources of local sand, and they, along with Charles Phillips and Joe Forrest, were able to work out mixes of the appropriate color and grain size for the pointing mortar and stucco. Nolen Company of Germantown supplied the sand; the mixture consisted of fine brown sand (from the Delaware River) and yellow bar sand (from the Schuylkill River).

For lime, Joe first used the Corson's hydrated dolomite lime left from both the original and test drops. When that supply was exhausted, at least another twenty bags were purchased and used, mostly for pointing and scratch coats. Riverton hydraulic lime, which

Building up stucco layers.



Joe Forrest cleaning masonary before stucco was applied.

had been called for in Rob Fitzgerald's formulae, had to be imported from Virginia. Because mixtures containing Riverton hydraulic lime set up much faster than traditional stuccoes, these were found to be most suitable for areas where the stucco needed to be built up in thicker layers, such as the jack arches over the windows. Andrew Ladygo, an architectural conservator, visited the site in late spring 1995 while we were running whitewash tests on the drops. The lime we were using created a whitewash that was too bright. He suggested that we consider Corson's quicklime to achieve a more accurate color matching. Quicklime required more effort in slaking than the hydrated bag lime did; however, once introduced to the project, quicklime was found to have many uses. Joe came to prefer its working properties and used it for most of the remainder of the job.

There was a difference in views about the appropriate mix ratio for the final layer. Charles Phillips, Rob, and I understood that each succeeding layer, including the final layer, should be slightly weaker and more porous than the last. To accomplish this, the amount of sand in each layer would have to be increased. Joe held to the idea that the sand amount should be decreased in the final coat, which because of its higher lime content would then create a tougher, less porous outer surface that was also easier to tool. A two to one mix with 1/6 inch sieved sand "borrowed" from the Wissahickon Creek was used for the finish coat. Rob had acquired red sand in an attempt to reproduce a red component he had found in the oldest final coats. This was used in the early finish mix until it ran out. After that, no more red sand was available from the supplier, George Schofield. It may be that the red component was not sand after all but rather crushed brick, a traditional pozzalanic additive. The Wissahickon Creek sand also ran out, and when we could not get permission from Fairmount Park to get more, we were forced to approximate it by adding handfuls of Carolina mica to the sand mixture.

One-half of Wyck's front side was completed using lime putty made from powdered hydrate. The other half of the front wall and all of both sides and the back were finished using Corson's quicklime. The quicklime had to be slaked on site. The chemical reaction that takes place when water is added to lime creates a lot of heat. The lime therefore had to be slaked in a proper container, either metal or wood. Slaking the quicklime also produced lime putty for the stucco, milk of lime for limewash, and lime water. Both the milk of lime and lime water were used as consolidants on the area of weak, friable stucco on the garden-side wall.

Joe Forrest applied between three and five layers of stucco, depending on the thickness required to bring it flush with the finished surface. The layers were kept to no more than ½ inch in thickness and were allowed to dry slowly, with alternating wet and dry cycles, for between three days and a week before the next layer was added. Joe's original estimate for the stucco removal and replacement was ten weeks. It took about fourteen weeks.

Consolidants

We were looking for a consolidant that would strengthen (i.e., bind the individual particles of sand together) while not appreciably decreasing the porosity of the stucco. Rob had developed a system that called for using dilute ElRey 200 as a consolidant to strengthen weakened stucco and for using full-strength ElRey 200 as an adhesive. ElRey 200 is an acrylic emulsion used an an admixture in making adobe structures in the southwest. When included in the stucco mixture it increases strength and improves resistance to water. The suspended acrylic particles in the ElRey 200 solution—as with most acrylics—are very large. My tests showed that the acrylic particles could not penetrate the interstices of the stucco and therefore were unable to consolidate. Particles collected on the surface while the capillary action of the stucco sucked water out of the emulsion down into its core. Tests showed ElRey 200 was also unsuccessful as an adhesive. The acrylic stuck to the loose outer surface of the weakened stucco. Adhesion between pieces may have been possible if the substrate (i.e., the weakened stucco) had already been strengthened by a consolidant. Some tests using a water/lime grout with a small amount of ElRey 200 acrylic showed promise. These tests were made on areas of the second drop where fissures had opened between dinner plate–sized chunks of loose stucco.

ElRey 400 is a microacrylic emulsion used on adobe as a surface consolidant and sealer. In tests it seemed to penetrate and strengthen stucco samples. Further testing was not pursued, as architectural conservators Morgan Phillips and Norman Weiss were skeptical about the use of acrylics on exterior stucco. In the long-term, they felt there was a risk that acrylic films inside the wall might significantly decrease vapor permeability.

One of the earliest consolidants to be considered was Consavare OH (ethyl silicate). It appeared to work well but was quickly ruled out because of its cost. Looking back, it might have been better to have used it, especially in light of the reduced number of square feet of stucco that actually needed consolidation. The ideal consolidant for lime/sand stucco appears to be a penetrating solution of calcium hydroxide. In fact studies in England have shown that lime water and milk of lime can be used successfully to strengthen weakened or sugaring lime stucco. Both milk of lime and lime water are produced when lime is slaked. Milk of lime is the earlier of the two products. Shortly after water is added to fresh lime or lime putty, the slaking lime is stirred, suspending particles of lime in the water. The resulting solution of lime and water is like a dilute whitewash and has the consistency of two percent milk. Lime water is produced a couple of days to weeks into the slaking process. It is the clear unagitated water that lies over the slaking lime, with a thin translucent crust formed at its surface.

Rob's early testing showed some improvement in strength to test samples in the laboratory after many—forty to sixty—applications of lime water. As work commenced on the stucco at Wyck, we had only anecdotal information about these tests and could not justify working the long treatment times into the budget. Toward the end of the project, Tom McDowell, of RGI, determined that the lime water that stands over freshly slaked Corson's quicklime worked very well as a stucco consolidant. Every day over a three-to-four-week period he sprayed lime water from the slaked lime onto a 12-by-5-foot section of the garden-side wall, just past the jog where the buildings join, which showed a lot of damage from a leaking downspout and gutters. The lime water from the slaked quicklime appeared to harden the friable stucco in that area. Joe Forrest ran his own tests on a 2-by-3-foot section of very crumbly stucco nearby. He applied multiple coats of milk of lime by brush. Not only did this lime milk consolidant return internal strength to the stucco but also when portions were cut away for examination, they were found to have adhered to the stone behind with a fresh layer of calcium carbonate. This process worked so well that after one or two applications, the strengthened stucco began to inhibit the intake of more milk of lime. This can cause problems where the weakened stucco is more than an inch thick. Perhaps these areas should be saturated first without allowing drying cycles. Testing needs to be carried out to determine whether there is a way to combine the lime and water with a wetting agent to increase its penetration.

Whitewash

Wyck was whitewashed during the last week in September 1995. Joe had started stuccoing at the caretaker's end of the building, had moved around to the front of the building, then to the Germantown Avenue end, and finished on the garden side of the house. This meant that the garden facade received its coats of whitewash within weeks of the final coat of stucco, while the other facades had cured for as long as a month and a half. Dorothy Krotzer, a graduate student of architectural conservation at the University of Pennsylvania, and Andrew Palewski, a local craftsperson, applied the whitewash. They applied it with large coarse brushes in three successive coats. The whitewash, or limewash, was made from the slaked lime putty and water. Its composition, texture, and color had been decided during tests made in the drop areas in the spring and summer of 1995. Hydrated lime was found to make a whitewash that was unacceptably bright, as noted previously, while Corson's quicklime produced a suitable color without needing the addition of tints. Viewing the newly whitewashed building was startling. Since then Wyck has begun to take on an aged look as the white color has mellowed and developed subtle variations in tone.

The whitewashed lattice of the trellis did not fare as well. Most of the horizontal trellis pieces and those verticals that had been removed at the beginning of the project were whitewashed before they were reinstalled. The wood was wet down before receiving two coats of unamended whitewash. By spring 1996 the whitewash was flaking severely. It was then decided to remove the failed whitewash and start over, this time using an acrylic additive. The lattice members were left in place and the scaling whitewash was scrubbed off with a wire brush. The wood was then prepped with a prewash of ElRey and water and allowed to dry for forty-eight hours before it was whitewashed with a mixture of slaked lime, water, and the acrylics Embond and ElRey 200. There have been no further failures of this sort on the lattice. Over time, brown patches have bloomed. This is probably owing to natural tannins leaching out of the wood, but there is also a possibility that bacteria have begun to grow. When first applied, whitewash acts as a biocide, but it gradually loses its bacteriocidal properties. Paints are not a substitute for whitewash or limewash. Limewash feeds fresh calcium carbonate into the stucco's surface. It is a sacrificial layer. The whitewash surface takes the brunt of the stresses of weathering, thermal shock, evaporation and recrystallization of waterborne salts. It helps to keep these processes from occurring within and on the surface of the stucco. Ideally, every year to three years the whitewash should be renewed. The frequency of refresher coats will lessen as the whitewash accumulates. After awhile it may need only reapplication in spots.

Results

Joe applied the last of the finish coat of stucco on September 1, 1995. Winter came early, allowing the stucco just two months to cure. The winter was severe, with cold temperatures and record-breaking snowfall; a blizzard early in 1996 left three feet of snow on the ground. In the spring the stucco was found to have failed in irregular patches in a band along the base of the wall—starting at the brick level and extending upward for about two feet—on both the front and garden sides. Above this two foot band the stucco was in excellent condition and the entire gable end remained sound. The stucco failed for two main reasons, primary being that some areas were still wet beneath the surface when freezing temperatures hit. This happened because either the stucco remained wet from the work in the fall or the band above the bricks became waterlogged during its prolonged contact with water and ice. About half of the failures on the front and all of the failures on the garden side were of this type. The stucco in these patches was crumbly and soft. The secondary reason was a failure of bonding between coats. This happened in limited places on the terrace side. The stucco had formed into crumbly plates; when hit with a chisel, the upper layers came off cleanly, exposing an intact underlayer with visible tool marks and scraffito (a clear sign of a failure to bond). Paradoxically, this separation occurred owing to lack of sufficient water; inadequate wetting of underlying layers prior to the new application. This resulted in a dramatic suction of moisture out of the new stucco causing it to dry too quickly. As these failures occurred only on the front of the house, they may have resulted from the basal coats of stucco being applied on a very hot day and drying too rapidly. In some areas we believe the prior stucco layers had carbonated too thoroughly and, coupled with heavy suction, did not allow bonding of the subsequent layers.

There was a third kind of failure found in only a few places near the ground. Here mushy wet stucco lay directly beneath a thick layer of whitewash. This may have been the result of our attempt to replicate the texture of the original whitewash left on the building. Its thickness was from multiple coats applied over many years. The new whitewash may have been applied too soon and too heavily, helping to retard the setting and carbonation of the stucco. Or, our tooling may have overworked the surface to a degree that most of the lime binder was sucked to the surface leaving a weakened layer of mostly sand just beneath the surface.

Repairs to the stucco were made by Dorothy Krotzer beginning with the front wall in April 1996. Repairs to the garden wall began mid summer, ending in late August. Failed patches were removed with hammer and chisel. Before stuccoing failures at the sidewalk level, a strip of 3⁄8-inch dense foam was laid to create an air space between the ground and the stucco's bottom-most edge. This gasket was meant to prevent moisture from wicking upward into the stucco. The formulae used for the repairs were the same as for the project (two to one ratio of sand to lime for the basal and middle coats and a three to one ratio for the finish coat). Unamended whitewash was applied over the finish coat.

The front and garden sides of Wyck differ in their exposure to sun and run-off, the front side having the advantage of facing south onto a wide lawn with trees planted at a distance from the house. The only significant exception to this has been two large

American hollies, which because they lacked historical significance had been removed the previous fall. With the hollies gone, the front wall has sun for the better part of the day. The garden side is in shade continuously during the summer months. Its grape arbor, which runs the full length, acts as an awning for the first floor.

In summer and fall 1996 Philadelphia broke all records for rainfall. Tarps were used on both walls to prevent pools of water from forming at the base of the repairs and to protect repair patches from washing off in heavy rains. The stucco on the terrace side, having been applied late in an unusually wet season, may never have been able to dry adequately. The winter was wet but mild, with dramatic swings in temperature. In January seventeen-degree nights were followed by fifty-degree days. All repairs held on the front side. When failures began to appear in late winter and early spring, they were restricted to the garden side. The stucco failed in the same way as it had in the previous year. The dolomitic lime used in the stucco formula may have been susceptible to run-off from the garden, but for the most part the failures were due to constant dampness. A combination of conditions caused this second set of failures: The repairs to the garden side were done late (in August and September), in damp weather and in a damp place shaded by plant growth; these conditions have incurred water-laden stucco, which was then susceptible to freezing. It is possible that if the stucco had been applied earlier in the summer, the outcome might have been different.

The second round of repairs began in late July 1997. The stucco was removed in the failing areas, and in many places it was taken back to the stone. An area of soggy stucco was found just to the right of the conservatory doors. This was puzzling, since we were in the midst of a drought. Rainfall was so low that the staff at Wyck was planning an intervention to save smaller trees on the grounds. This situation seemed to indicate that some of the moisture problems might have origins below ground level.

Charles Phillips and I decided to use this second round of repairs to discover if high calcium lime or Jahn Restoration Mortar might be better able to withstand the destructive forces found at the base of the garden-side wall. Each failure area was divided into three equal vertical sections. In the middle section, dolomitic lime-based stucco was applied as a control in the same mixtures as had been used during the exterior conservation project and repairs of 1995 and 1996. In the right-hand section, high-calcium lime replaced the dolomitic lime in the control mixture (as was recommended by Norman Weiss)—high-calcium lime is far less susceptible to sulfate attack from pollution (acid rain) and therefore much more stable in urban environments. In the left-hand section we decided to test a Jahn Restoration Mortar, specifically their stucco mix; it has been formulated using natural cement mortars, specially designed for areas with high water and salt exposure, and is made to outlast traditional stucco mixes.

Dorothy Krotzer returned to make the repairs. Lime water was sprayed twice a day for two days on selected areas before the mortars were applied. Strips of gasketing material were placed on a single layer of small stones at the base of the repair areas in order to separate the mortar patches from the walkway. Dorothy noticed that the Jahn mortar had a tendency to suck water out of adjoining patches. For this reason, the Jahn mortar was put down first and allowed to set up for a day or two before another stucco type was put beside it. It was applied in a ration of four to one, mortar mix to water. Unlike high-calcium and dolomitic stuccos, whose mortars can be kept for a few days if the proper moisture is maintained, the Jahn mortar stiffens in less than an hour. This meant that it had to be mixed in smaller batches and that additional time had to be factored into the application process to allow for mixing several batches a day. The surface of Jahn mortar tends to be smoother than traditional stuccoes, and we added aggregate to the topcoat in an attempt to match surrounding stucco. Its quick setup time presented difficulties when giving the topcoat its final finish.

The dolomitic lime putty mortar was applied using the same mixtures as in previous repairs. Of the three mortar types it is the slowest to set, remaining damp weeks after application. The high-calcium lime putty mortar was easiest to apply and finish, and in some areas it appeared to set and begin to harden after one to two weeks.

On September 23, 1997, when I observed the repairs, the dolomitic and high-calcium stuccos did not seem to be drying properly. In particular the area to the right of the conservatory doors had stayed very damp throughout the course of the repairs. The stucco was drying too slowly for the conditions we had already identified and seemed to suggest that something else was causing the dampness. The first thought was that water was rising up through the foundations, but generally accepted theories of rising damp did not explain the situation at Wyck. It does not have really porous monolithic foundations, it has a foundation in which stones have been laid up. Additionally, if there were rising damp, there should have been other symptoms, and this was not the case. The inside basement walls remained dry. So we returned to an earlier hypothesis that there was a lot of water in the ground. Wyck sits on a slope whose highest point is at the property's northern-most corner. Runoff from the garden would follow the slope downward, damming up against the garden side of the house.

There were several possibilities for what was causing the water retention, perhaps there were large flat stones or a buried earlier walkway. To discover the cause, we removed bricks in front of the wet area by the conservatory doors and dug out soil to a depth of nine inches. This excavation served a dual purpose: Whatever connection was supplying the test patches with water would be broken and with adequate air circulation the stucco could dry properly. We could also perhaps find the reason for the underground moisture problems. At nine inches we came upon a dense layer of clay that extended down for at least fifteen more inches. The hole remained open for the month of October, becoming covered only when rain threatened. Once the moisture connection was broken all of the patches began to dry, with the dolomitic lime putty mortar lagging behind the rest. To allow this area to dry to the fullest extent possible hay bales with a covering tarp were placed against the house during periods of freezing temperatures. The discovery of clay may mean that we have finally identified the problem. But without further testing it was not clear whether clay was just in-fill from a stage of Wyck's construction or whether there is a clay layer present throughout the grounds.

The dampness of the stucco delayed whitewashing until 1998. In the short-term whitewashing was not necessary, and an additional layer of dried whitewash would probably have further slowed the drying of the test patches. Two variations of whitewash were applied in the spring. One-half of the repairs received coatings of traditional whitewash, the other half received coatings of whitewash developed by Norman Weiss. This experimental whitewash was made by adding ingredients to traditional whitewash that give it greater hiding power. It should look more opaque and have less chalking. Another anticipated benefit of this second whitewash is that two coats can be applied in twenty-four hours, as opposed to the three coats over the course of a week for traditional whitewash. We also hope it will prove to be more durable and biocidic.

One secret to stucco work may be timing application to early summer weather when dryness and warmth are present to cure stucco thoroughly. It is probably also a good idea to do the work before the peak of summer when temperatures are high, at which point the stucco can dry too fast. If it becomes necessary to apply stucco in mid-to late summer, it should be shielded from strong sun and draughts, kept damp (misted) for three to seven days, and not allowed to dry out rapidly. After the initial set, wet and dry cycles will help the process of carbonation. Even in exposed areas full carbonation can take years.

Addendum, 2001

It was the Wyck project that got me interested in historic masonry and its repair. I decided to devote more time to studying the chemistry of the failure process as well as traditional craft methods. I wanted to develop better and above all practical conservation techniques. I have been lucky over the last five years to work with chemists, conservators, and masons across the county and abroad. Somehow the right projects have come my way, and I have been able to devote most of my time to masonry projects of all types. I am committed to improving our understanding of the causes of masonry failure, developing practical repair techniques, and getting this information to craftsmen, architects, and engineers.

I just read the account of the work at Wyck for the first time in several years. I thought I would add to it some of what I have learned over the last five years. Of course, the most important thing is the lime itself. I now use only high-calcium lime (97% or better) that has been calcined properly and has a high surface area and is therefore highly reactive. Typically limestone is calcined (burned) in a kiln—rotary or vertical—to at least 1650° F for 24 to 72 hours depending on the size of the pieces, the shape of the kiln, the fuel, etc. Even the best high-calcium limestone can be over-fired (producing low surface area and less reactivity) or under-fired (meaning the limestone is still calcium carbonate and only acts as more filler or aggregate). Unfortunately, many commercial limes, readily available at builder's supply houses, manage to be both at once. The exterior of the lump is over-fired, and the process is so short that the center of the lump never reaches the necessary temperature and resulting pressure to drive out the CO^2.

I was convinced for a long time that bagged hydrated lime was unsuitable for making good lime mortar. Instead, I traveled to limestone quarries and took fresh lump lime (calcium oxide) directly from the kilns back to the building site, where I would slake it immediately. I soon discovered that slaking oxide yourself cannot improve the quality of a bad lime or reverse the damage caused by poor calcining practices.

Now my partner and I have a laboratory where we can test the limes, I am happy to report that there are several very high-quality limes available. I generally use one of the high-calcium hydrates made by Mississippi Lime, which I slake for at least seven days (longer if possible) before use. An excellent "fat" English lime putty, Buxton lime, with exquisite working properties is now available in the United States, as well.

One thing that we did not do at Wyck that we do now is to pre-mix the stucco and let it sit for 2 to 4 weeks before use. This gives the binder time to be fully absorbed into the sand and allows the alkali-silica reaction that produces calcium silicate to take place. This aging is essential to improving the working properties and greatly reduces shrinkage when the material is applied. As the aged mortar or stucco is needed, it is thrown into a mixer for several minutes, where it develops into a very workable material usually requiring little, if any, additional water.

Also at this time a clay pozzolan can be added. Had we used pozzolan at Wyck, I believe that most of the moisture and freezing problems would not have occerred. The use of pozzolan (developed by the Romans) allows a more rapid setting and hardening of the mortar (generally in 2 to 4 weeks). The pozzolan reacts with some of the lime (calcium hydroxide), producing calcium aluminum silicates. The remaining unreacted lime will continue to carbonate slowly.

Another technique we now use when we apply stucco or plaster to an uneven surface like a stone wall or even strawbales is to harl the wall first. A lime mortar slurry is flung against the wall using a slightly concave harling trowel or even a stiff brush. This splatter coat sets and carbonates rapidly, providing a rough textured surface that really grabs and holds the first trowel-applied layer of stucco.

Selecting the right sand for mortar is extremely important. Generally, coarser sands and a higher sand content (up to 4:1) promote more rapid carbonation. It is important to look at the sand in the original mortar and try to match it. If by particle size analysis you determine that the original is an inferior mix, then you may supplement the blend with other sands accordingly to make a more durable mortar.

I find locating matching sand to be relatively easy. There are many commercial sands available that can be sieved and combined. Often a county or state soil geologist can quickly locate comparable sand deposits in the area that match your sample. The most common problem I see with exterior stuccos is that the causes of deterioration are not determined. Stucco failure on a section of wall may be due to one or more factors, including poor quality work or materials, leaking gutters, and salt carried up from below. Before attempting to preserve or repair the area, it is important to understand why the damage has occurred and to correct the problem.

In "reading" buildings, experience is the most important tool. The aim is to relate the observed physical symptoms to underlying causes. It is important to begin by carefully examining the building inside and out to map the areas and types of deterioration. Conducting simple on-site chemical tests to identify salts or sulfates or examining samples using low-power microscopy can speed up the discovery process and allow one to quickly focus on the most likely causes. Often it is necessary to remove small samples of the original material for testing in the laboratory, where the chemical components of the original materials can be identified as well as the chemical residues that indicate the sequence and path of deterioration.

In our laboratory we regularly examine samples using microscopy, differential thermal analysis, thermogravametric analysis, x-ray diffraction, and elemental analysis. These types of analysis help us understand why the deterioration is occurring so that we can develop solutions that can be taken to the scaffold and applied to the building.

Of course, the biggest problems with lime plasters and stuccos is our lack of experience in working with them. Everyday use of pure lime mortar was on its way out over one hundred years ago, and pure lime plasters have not been common for the last 60 to 80 years. I see many good plaster mechanics working hard to re-learn the proper methods of lime and plaster mortars. Often they get part of it right, but since they continue to think that the working qualities are the same as gypsum and cement plasters, they miss some of the most important aspects of working with lime. Poor quality limes, with improper slaking, no aging of materials, too little working of the lime and mortar before application and the addition of too much water in the mix are just a few typical mistakes. We need to work hard not only at learning these obscure and sometimes difficult craft techniques but also at understanding on a simple, practical level the chemistry that underlies and illuminates the craft process.