

WB4-2: Best Practices® and Quality Issues in Residential Stucco Application

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Abstract

In the Western U.S., three-coat and one-coat stucco are the dominant exterior finishes for residential construction. Still, stucco is present in almost every market. While the use of stucco is widespread, it has performed poorly in recent years due to the improper execution of key details. This paper closely examines what has been learned from extensive on-site inspections and lab tests of both durable and failed stucco systems. In particular, it looks in detail at:

- Installing the drainage plane, bond break, and lath
- Selecting and storing the raw materials
- Mixing and applying cementitious stucco
- Applying the scratch coat or base coat, including the similarities and differences when applying one-coat and three-coat stucco
- Executing and testing hydration
- Applying the finish coat

Best Practices®³ for applying stucco have been developed by extensively studying each of these components. In addition, important details have been created for key areas like horizontal surfaces, architectural accents, and transitions to other exterior finishes. By having a shared knowledge base, designers, specifiers, trades, and site supervisors can work together to produce a durable stucco finish.

Keywords: stucco, brown coat, scratch coat, weep screed, lath, fasteners, hydration, mixing, sand, details, issues, solutions

Introduction

While there are longstanding Best Practices for applying stucco, the increased production pace brought on by the residential building boom in the early-to-middle 2000's resulted in a number of quality issues. This paper summarizes the Best Practices for three-coat and one-coat stucco and includes commentary on the sheathing, drainage plane, raw materials, mixing, application techniques, hydration, and paint. Also, this paper provides two case studies that present a couple of the major quality issues that IBACOS has addressed for homebuilders—stucco cracking and paint burning.

The Basics: Stucco Best Practices

A three-coat stucco system consists of a scratch coat, brown coat, and finish coat. The scratch coat is applied first to provide a strong base for the system. It is embedded in metal lath such that the lath is in the middle of the coat in order to strengthen and secure the coat. The scratch coat is the strongest coat in a three coat system. The brown coat is applied next to bridge any shrinkage cracks developed during the curing and drying period of the scratch coat and to create an even surface for the finish coat. The finish coat is applied last, creating a decorative finish on the wall surface.

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Despite its name, a one-coat system typically consists of two coats—a base coat which is often applied in two passes to ensure the reinforcing lath is embedded in the middle of the coat, and a finish coat which creates the desired decorative effect over the wall surface. In the Southwestern United States a continuous layer of expanded polystyrene (EPS) board that is installed on top of the drainage plane is often used behind a one-coat system.

Below are the major components of a stucco system. It is crucial to properly install each one in order to ensure the durability of the system.

Wall sheathing

When wood sheathing is installed continuously and fastened correctly, it provides shear strength for the home and creates a good foundation for the stucco. If sheathing is installed only at corners of the building or above and below windows, as seen in **Figure 1**, it creates an uneven surface for applying the stucco. It is difficult to apply stucco at a uniform thickness across an uneven surface. Ideally for a stucco installer, sheathing should be continuous as seen in **Figure 2**. A 1/8" space should be left between the edges of the boards to allow for moisture expansion of the OSB. Sheathing should be the proper moisture content and grade to help prevent unnecessary dimensional changes, possibly leading to cracking.



Figure 1: Sheathing only at shear locations



Figure 2: Continuous sheathing

If one uses open-frame construction, line wires should be installed in the place of sheathing to support the stucco system. Line wires should be spaced 6" apart and stretched tight. However, as the first case study discussed later demonstrates, a lack of continuous sheathing can still result in places where the cross section of the stucco changes and creates opportunities for significant cracking.

Drainage plane

A quality drainage plane installation is crucial to a quality stucco system, because stucco is not impervious to water. When moisture penetrates the exterior finish, it should be able to move down the drainage plane and back out to the exterior. In production homebuilding, housewrap is often the material of choice for creating the drainage plane. After the sheathing is installed, housewrap should be applied shingle style, starting at the foundation and using the manufacturer's recommended fasteners. The housewrap should extend past the wall-to-foundation intersection a minimum of 1". All horizontal and vertical seams should be overlapped a minimum of 6". All vertical seams should be taped using the manufacturer's recommended construction tape. There should be no gaps or tears in the housewrap.

Flashing

Flashing is an essential part of water management on a wall. Flashing should be installed at all vulnerable areas, such as windows, doors, intersections, and penetrations, and properly integrated with the drainage plane.

Weep screeds

Weep screeds act as a stop for the stucco and allow water to exit the wall system and drain away from the home. They should be installed at wall-to-foundation and roof-to-wall intersections. It is important to make sure weep screeds are installed over the housewrap and the bond break material is layered shingle style over the weep screeds' flange.

Bond break

Because water can dissolve chemical compounds from stucco that can react with the drainage plane causing deterioration, a bond break should be installed over the housewrap. For three-coat stucco, a second layer of building paper applied separately from the first often acts as the bond break, preserving the housewrap or underlying layer of building paper to effectively shed water from the home.

Metal lath

Self-furring metal lath acts as reinforcement and anchorage for the scratch or base coat. The lath has to be installed in the middle of the layer to make sure that the scratch coat will mechanically bond to the substrate. If the lath isn't double-sided, the side with the stand-offs must be installed against the wall surface. The stand-offs hold the lath about 1/8" off the wall, allowing the stucco to fully encase it. The fasteners that secure the lath to the wall should be attached to the framing. The lath should be continuous across the entire wall. The lath should also be applied to all architectural features. The alternative to using self-furring lath is to use lathing stand-offs.

Control and expansion joints

Control and expansion joints are designed to relieve stresses on stucco walls to prevent extensive cracking from occurring where the material expands and contracts or where the house experiences framing movement. Control joints should be installed at least every 144 square feet. When possible, control joints should align with window and door openings to protect against cracks and to create a look that is more aesthetically pleasing to the homeowner. Expansion joints should be installed between floors and between changes in mass, such as the house-to-garage intersection.

Stucco coats

In a three-coat system, the scratch coat is the first coat of stucco applied to the wall. It is important to ensure that the proper proportions of cement, stucco-grade sand, and water are used in the mix. It is particularly important to have the correct amount of sand, as too much sand can weaken the system and too little can increase the likelihood that it will crack. The scratch coat should then be applied to the wall at a uniform thickness of 3/8" to a maximum of 1/2", completely encasing the metal lath, and leveled with a darby. If the scratch coat is spray-applied, it must be allowed to firm-up first or too much of its intended thickness will be removed. The scratch coat should be scratched horizontally to promote both a mechanical and chemical bond between it and the brown coat, which is applied next. Scratching this coat promotes a good mechanical bond between the scratch and brown coats and helps the scratch coat retain water during hydration. The brown coat is applied in a similar manner to the scratch coat, but it should be mixed with slightly more sand and applied at a thickness of no more than 3/8". The application of the base coat in a one-coat system is similar to that of the brown coat in a three-coat system. It should not be scratched and should be level in preparation for the finish coat. The finish coat is the final coat of stucco applied to the wall. Out of all the coats, it is the thinnest and is meant to provide a decorative finish. The finish coat should be applied to the wall at a thickness of 1/16" to 1/8".

Hydration

Stucco hydration is one of the most important aspects of creating a durable system. Hotter, drier climates will require that the hydration process begin earlier. To hydrate each coat, the wall surface should be flooded with a gentle stream of water, working from the bottom to the top until the water runs off in sheets. Applying water from top to bottom will cause the water to run down in rivulets, potentially eroding the stucco. Once the water has been absorbed by the surface of the scratch coat, it is ready for another cycle of wetting. Each exterior wall should be wetted at least once, but up to as many as three times, if the wall continues to soak up water. The stucco should retain moisture for the first 48 to 72 hours after it is applied in order to gain the strength needed to fully support the next coat.

In one-coat systems, the base coat is more like a brown coat in that it must establish the final shape of the stucco system. This coat should be wet for a minimum of 48 to 72 hours, but it can benefit from additional wettings to advance the hydration of the system.

In both one-coat systems and three-coat systems, fully hydrated first layers will exhibit cracks but will be firm and strong. Under-hydrated first layers can create too much suction when the finish coat is applied. This suction can reduce the strength of the finish bond and limit the strength of the total system.

Case Study 1: “Monster” Cracks

In January 2007, at the request of a builder, IBACOS began to investigate what became known as “monster” cracks affecting a number of homes in a large community. These were characterized as cracks in the stucco cladding as large as 0.3 inches and in some cases sheared the metal lath supporting the stucco system. The homes affected were large single story homes that were framed with shear panels only at required locations, as opposed continuous sheathing. IBACOS, with the help of a third party lab began to analyze samples of stucco from these homes in order to determine the cause and origin of the issues.

As noted already, a traditional three-coat stucco system begins with the scratch coat being set in the lath. This layer is then hydrated to essentially force cracking to occur. These cracks are small and spread over the entire surface of the wall. The brown coat has to be mixed so it is slightly weaker than the scratch coat. To do this, the brown coat is applied no thicker than the scratch coat and is mixed with slightly more sand in order to change the stress release characteristics. When this coat is hydrated, it cracks in even smaller segments dispersed over the large area of the wall. Finally, the finish coat is thinly applied to complete the system. Due to the amount of air entrainment and the trowel action during the texturing of this layer, the system is pre-stressed through a series of small dispersed drag cracks that result in a decorative and relatively discontinuous surface, which relieves stresses.

The fundamental causes of the “monster crack” in **Figure 3** were the fact that the stucco mix had too little sand and the scratch coat was not hydrated enough before the brown coat was applied. The strength of the stucco mix is controlled by the ratio of sand to cement. Lab analysis showed that the scratch coat contained significantly less sand than specified in the Uniform Building Code (UBC) (**Figure 4**), and the amount of sand scarcely met the proper sand-to-cement proportions. In an effort to make the stucco easier to pump for spray application many applicators will alter the proportions of the scratch coat so it is stickier when it hits the wall. These proportions must be carefully controlled to build a stucco system that, when adequately hydrated, will allow each layer of stucco to relieve stresses within the system through a dispersed pattern of small cracks that are developed prior to the application of the next layer of stucco.

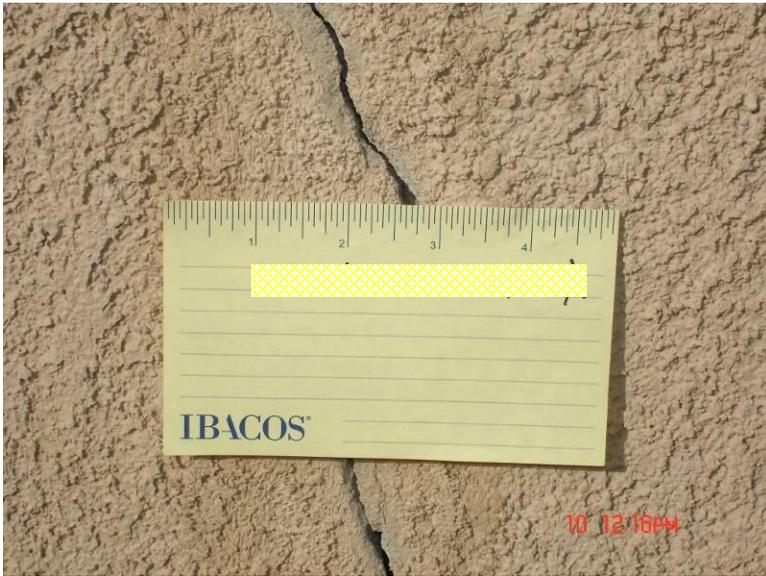


Figure 3: “Monster” crack

Base Coats¹

Plaster mix symbols	Parts by volume ²							
	Cementitious materials					Volume of aggregate per sum of separate volumes of cementitious materials		
	Portland cement or blended cement	Plastic cement	Masonry cement ⁴		Lime	Scratch coat	Brown coat 2nd ³ coat	Finish coat ⁵
N			M or S					
C	1	—	—	—	0 – 3/4	2-1/2-4	3-5	—
CL	1	—	—	—	3/4-1-1/2	2-1/2-4	3-5	—
M	—	—	1	—	—	2-1/2-4	3-5	—
CM	1	—	1	—	—	2-1/2-4	3-5	—
MS	—	—	—	1	—	2-1/2-4	3-5	—
P	—	1	—	—	—	2-1/2-4	3-5	—
CP	1	1	—	—	—	2-1/2-4	3-5	—

Finish Coat¹

F	1	—	—	—	3/4-1-1/2	—	—	1-1/2-3
FL	1	—	—	—	1-1/2-2	—	—	1-1/2-3
FM	—	—	1	—	—	—	—	1-1/2-3
FCM	1	—	1	—	—	—	—	1-1/2-3
FMS	—	—	—	1	—	—	—	1-1/2-3
FP	—	1	—	—	—	—	—	1-1/2-3

¹The mix proportions for plaster coats to receive ceramic tile shall be in accordance with the applicable requirements of ANSI A108.1 series applicable to specified method of setting time.

²Variations in lime, sand, and perlite contents are allowed due to variation in local sands and insulation and weight requirements. A higher lime content will generally support a higher aggregate content without loss of workability. The workability of the plaster mix will govern the amounts of lime, sand, or perlite.

³The same or greater sand proportion shall be used in the second coat than is used in the first coat.

⁴Additional portland cement is not required when Type S or M masonry cement is used.

⁵In areas not subject to impact, perlite aggregate shall be permitted to be used over base-coat plaster containing perlite aggregate.

Figure 4: UBC Portland Cement Mix Proportions (ASTM C 926)

The scratch coat in this case study contained less sand than required. This lack of sand made the scratch coat stronger, forcing cracks to occur farther apart. Even a properly mixed brown coat would not have been able to overcome the excessive shrinkage that resulted from an incompletely hydrated scratch coat. However, the brown coat contained even less sand than the scratch coat. Also, since the scratch coat was not adequately hydrated before the application of the brown coat, the two layers acted together. When layers act together, it is as if the stucco thickness has doubled and even almost tripled, since the brown coat does not encase any lath. Therefore, the stresses are increased threefold, causing the distance between cracks to increase as well. Since stresses are not released within the system through a series of small cracks, the stucco stores the energy until the forces exceed the tensile quality of the lath-cement combination. This excessive force occurs at locations where the cross section of the stucco is reduced, such as at a window. The presence of a window in a large uninterrupted field of stucco reduces the cross section of the stucco to one half. The cross section is also reduced when the back sheathing layer changes thickness (**Figure 5**), which is why cracks also frequently show up along the edge of an underlying shear panel.

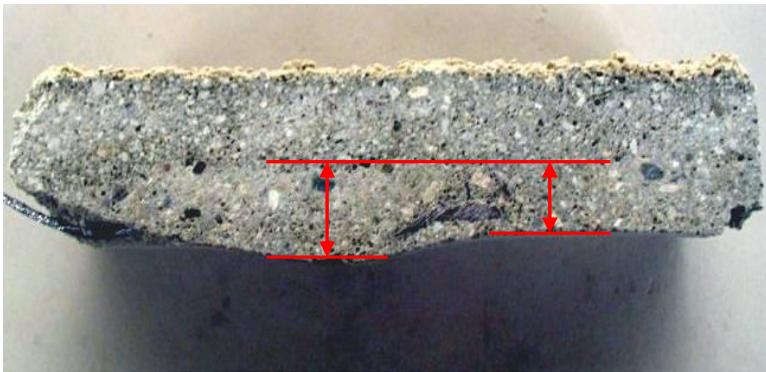


Figure 5: Variable thickness at shear panel locations

Also worth noting is that based on samples taken from the damaged homes, the scratch coat was intermittently applied too thin and its thickness varied from completely absent to more than 3/8". When a brown coat is applied to a scratch coat that is in this state, the stresses now develop in a thickened brown coat. All of the stresses from hydration are being driven by a single hydration event, rather than two separate ones. The strength of this combined coat forces large cracks to occur that are concentrated at the cross section reductions (**Figure 6**).

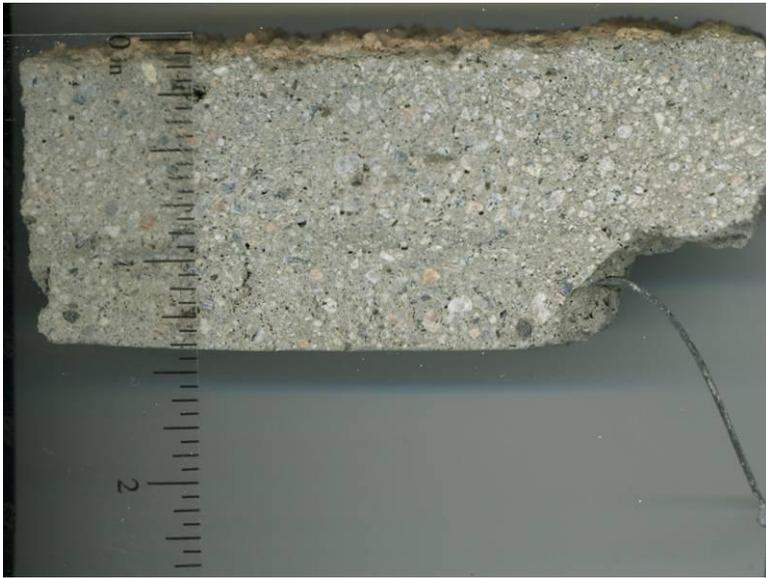


Figure 6: Disproportionately thick brown coat

While IBACOS' analysis of the samples showed that the pH levels were within an acceptable range and the surface was not particularly vulnerable to water intrusion, the in-depth lab analysis indicated clearly that the stucco mix had strongly influenced the development of the large cracks. The mix had too high of a water-to-cement ratio for the scratch coat. This also contributed to the buildup of shrinkage stresses. As the excess water dried, the partially cured cement shrunk and added stress to the stucco system.

Conclusions on the “monster” cracks

Considering the errors that took place, the stucco cracks still took a number of months to manifest. The reason for this is related to the hydration history of stucco. As hydration occurs, the stucco system shrinks. If hydration is delayed or inadequately implemented during construction, then it will occur after the stucco system is applied and will be based on natural cycles of wetting.

Lab analysis indicated that the final layer was fully hydrated and that the deeper layers were marginally hydrated. Therefore, the system hydration was completed by weather events: rain, dew, and humidity. This allowed stresses to build for months after closing and homeowner occupancy. Since the stucco was essentially too strong and under-hydrated, large cracks continued to appear as hydration advanced. However, as time passes, the stresses will be relieved and the frequency of new large cracks will likely decrease. While the inconsistent depth of the scratch coat will provide additional locations for cracking, they will most likely not be “monster” cracks.

In some cases, homeowners reported hearing the metal lath snap as the stucco cracked. The breaking of the lath, while unusual, was consistent with the fact that there was very strong stucco on the side walls where there are no other areas with a reduced cross section, forcing the stresses to concentrate. In these areas of extreme stress, IBACOS recommended a repair which included control joints (**Figure 7**). For the repair of small cracks (1/16” or less) sealing with an elastomeric latex sealant is recommended. Following the required drying period a fog coat of paint can be applied to blend with the existing coat. The builder may have to consider fog coating the entire elevation in order to achieve a uniform color.



Figure 7: Wall area that required control joints

Lessons for the builder

The following are lessons for the builder to prevent these issues from occurring again:

1. Plan for control joints at key cross section reductions and a maximum of 144 square feet between joints.
2. Carefully control the amount of sand in each coat. The scratch coat should have less sand than the brown coat. The ratio for the scratch coat should be 2.5 to 4 parts sand for each part cementitious material. The brown coat should be between 3 and 5 parts sand for each part cement (Refer to the mix proportion chart and bag mixing instructions).
3. Verify the quality of sand. The sand used in the mix must be clean and free of organic materials. It must also be appropriate in size. There are three basic classifications for sand: concrete sand, which is too coarse, stucco sand or plaster sand, which is the proper selection, and masonry sand, which is too fine and will not protect from cracking. Also, protect sands from the native soil on the jobsite to avoid contaminating it with organic material or inappropriately graded sand.
4. Control water-to-cement ratios to minimize dewatering stresses.
5. Apply a uniform 3/8" scratch coat, making sure that the lath is embedded in it and that there is a uniform base for the brown coat. The physical character of the scratches or trowel marks serves as keys for the brown coat to adhere to.
6. Hydrate adequately between each coat to allow hydration stresses to be released in thinner sections, resulting in more but smaller cracks.
7. Make sure the appropriate cement is used in the stucco mix. Masonry cement and plastic cement are blended cements with a proportion of lime and controlled texture to make them workable in stucco applications. Portland cement needs to be blended to provide workability. Pre-mixed material is also available and may be the best solution if clean stucco sand is unavailable.

Case Study 2: Paint Burning

In June 2006, at the request of a builder, IBACOS began to investigate what appeared to be a paint burning issue affecting a number of homes in a large community. Paint burning is the degradation of paint on a stucco finish appearing as a loss of gloss, whitening, and breakdown in the paint film. The initial condition was described as "snow burn" and was characterized by a paint discoloration and stucco softening in the lower portion of the wall where snow drifted against the home during the winter. The appearance of "snow burn" suggested that the cold weather may have been an issue. It soon became clear that the

damage pattern was related to an advanced reaction of hydration products due to the availability of additional moisture. The additional moisture allowed un-reacted stucco to partially reactivate and create a high alkali, or high pH, environment.

Onsite inspections were made of several completed homes experiencing the issue, as well as several homes still under construction that were in the stucco application or painting stage. It was discovered that the stucco was allowed to dry immediately after application, which halted the hydration process that is required to produce durable stucco. No additional hydration was observed, and this was consistent for both the base layer and texture finish.

The stucco also appeared to be rich in sand and to be potentially contaminated by native soils. Native soils could have been the result of poor material storage, since the specifically graded stucco sand was not always kept separate from the ground. Both excessive sand and dirty sand tend to increase the amount of water needed to produce a workable mix. But too much water reduces the concentration of the cement and reduces the strength of the stucco. It was common to see delamination of the finish wherever the base coat drew water from the newly applied finish coat, allowing the texture to dry rather than fully cure. The base coat should have been kept damp to cure properly and pre-wet prior to the texture coat being applied. This practice will prevent delamination.

Inspections of the paint revealed that it was applied with an airless applicator through a short wand. It appeared that the painter sprayed upwards from a standing position on the ground. Doing so resulted in inconsistent paint thicknesses and little or no coverage on the top of the stucco texture. It was also observed that when primer was present, its coverage was inconsistent and generally under the specified application thickness. Additional thickness of paint does not make up for a lack of primer. The primer is designed to protect the paint layer from exposure to higher pH environments. Latex paint will degrade in alkali environments, causing a loss of gloss and flexibility, which is typically referred to as paint burning. These conditions led to low durability, poor adhesion, and peeling of the paint, and in some cases, delamination of the stucco's texture coat and weakening of its base layers.

In addition, lab testing, which included pH testing and an in-depth microscopic analysis, was used to determine the presence of a primer coat, the continuity of that coat, and the average paint thickness of the color coat. IBACOS also consulted a specialized construction technology lab to test the stucco samples in accordance with ASTM standard C 1324 – Examination and Analysis of Hardened Masonry Mortar and ASTM standard C 856 – Standard Practice for Petrographic Examination of Hardened Concrete.

IBACOS received viable samples of stucco from over 200 different homes in the community, all of which exhibited varying degrees of damage. Viable samples were then photographed from various angles and stored for possible future analysis. Typically, two to four samples were received from each home. Attempts were made in the field to send at least one sample from a section of the home with notable degradation and one sample from a section of the home that appeared to be of sound integrity.

Due in part to the expense of the testing, samples from 12 homes have been analyzed by the construction technology lab using ASTM standard C 856. Of those 12 homes, samples from eight have been further analyzed using ASTM standard C 1324. IBACOS conducted the analysis of the paint thickness. What follows are the findings based on the investigation to-date.

Conclusions on the paint burning

Insufficient priming and painting is what led to the accelerated manifestation of the durability issues on the surface. While these issues were inevitable due to the stucco's quality, there is evidence that shows the homes were not primed and painted according to specifications. Specifications required the painter to apply the primer at a 5 mil wet thickness in order to dry to a 2

mil dry thickness. This was not the case in many situations. In addition, the most important step, backrolling the primer after it is applied in order to achieve a continuous coat, was not followed.

Figures 8 through 15 that follow represent the typical paint and stucco durability issues confronted in the community. Notice the delamination of the paint and finish coat. The stucco base coat below was very sandy and weak to the touch.



Figure 8



Figure 9



Figure 10



Figure 11



Figure 12



Figure 13



Figure 14



Figure 15

In addition, various homes in the community underwent a repair protocol that involved “sounding.” Sounding is a test that checks for weak stucco that pulls away from the wall and leaves voids and pockets behind. Following a power wash at 2000 psi to identify areas susceptible to failure; sounding was conducted by hammering on the stucco in areas that were weak or deteriorated. Weak areas fractured into sandy chips and were removed. The varying extent to which the stucco was found to be weak is illustrated in **Figures 16 through 21**. Areas that resisted the impact of the hammer were judged as adequate in strength.

The paint burning can also be tied to low strength of the stucco. In IBACOS’ opinion, low strength stucco is the result of an excessively sandy mix and too little hydration. Hydration is required to properly cure stucco and lower its pH level. This conclusion is supported by lab results that showed the stucco had an excess of un-hydrated cement particles. Following hydration, cement particles act to bind the stucco together as a system. Hydration immediately after placement is critical to the long-term durability of a stucco system. Also noted in lab testing was a moderately high to excessive sand-to-cement ratio. The specification of this ratio is set by ASTM standard C 926 and should not to exceed 4:1. Tests of certain samples found the ratio to be as high as 5.3:1.



Figure 16



Figure 17



Figure 18



Figure 19



Figure 20



Figure 21

Lessons for the builder

The following are takeaways for the builder in order to avoid these problems in the future.

Stucco issues:

- Poor mix control
 - Too much sand in relation to cement and the introduction of native soil in sand results in a mix that is lean in cement content, reducing the strength of the stucco.
 - Too much sand demands more water to reach equal workability, reducing the strength of the stucco.
- Poor hydration of base coat
 - Lack of consistent and adequate hydration does not allow the cement to properly cure, resulting in reduced strength in the base coat. Instructions on the manufacturer packaging clearly state the need for hydration and protection.
 - Lack of consistent and adequate hydration produces a first coat starved for water, contributing to a weak texture coat.
 - Lack of consistent and adequate hydration of the first coat contributes to high residual alkalinity, contributing to paint burning.
- Poor hydration of texture coat
 - Inadequate and inconsistent wetting of the first coat of stucco results in dehydration of the texture coat, resulting in poor adhesion, poor curing, and delamination.
 - Inadequate and inconsistent hydration of the stucco after the texture coat is applied results in poor strength development of both the first coat and texture coat.
- Poor thickness control
 - Stucco that is too thin does not have enough strength, even if it is properly cured. Some samples from the homes were as thin as 3/16”.
- Poor embedment of lath
 - Though a lesser contributor, poorly embedding the lath in the first coat reduces the strength of the stucco. Since the system was so weak overall, this is a secondary issue.

Paint issues:

- No primer or inadequate primer thickness
 - Without primer, there is nothing to protect the top coat of paint from contact with the stucco.
 - Primer that is too thin or applied inconsistently does not properly prepare the surface and does not protect the top coat of paint.
- Poor coverage or inconsistent application of the top coat of paint
 - Poor coverage or inconsistent application can allow water to enter the stucco system, resulting in higher alkalinity conditions that eventually degrade the paint finish.

- One thick layer of top coat is not equal to a layer of primer and paint.
- Frequent areas of incomplete coverage of the stucco, typically higher on the wall and on top of the texture, create a direct opening for water to enter the stucco.
- Poor thickness control due to a lack of back rolling (or other technique) to achieve uniform coverage can allow rain to enter the stucco system.

Final Thoughts

With respect to the two case studies presented here we have been able to deepen our understanding of potential causes of stucco cracking and paint burning on stucco through on site investigation and the analysis of physical samples. The characteristics of the stucco itself such as sand-to-cementitious ratio, pH level, hydration level, and application techniques go hand in hand with framing, drainage plane, flashing and preparation work to create a durable stucco system. In the residential production environment, close attention must be paid to all of these details in order to avoid costly deficiencies such as those noted in this paper.

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