COMMON SOURCES OF DISTRESS
IN STUCCO FAÇADES

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Abstract

In the past several years, the authors have evaluated several buildings throughout the United States that were clad with Portland cement plaster (stucco) anchored to the wall using metal lath. Water leakage and distress in the form of cracking and delaminations were frequent concerns with these buildings. Several conditions were identified as the causes of these issues, including poor installation of weather-resistive barriers and flashings, poor installation of lath and stucco accessories, improper stucco mixes, improper sand gradation, improper placement of the stucco, and improper curing. Evaluation of these conditions revealed a significant failure on the part of both designers and contractors in understanding and applying the requirements for stucco and lath installation provided by ASTM C926, Standard Specification for Application of Portland Cement-Based Plaster, and ASTM C1063, Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster. Therefore, this paper will discuss the typical conditions responsible for the defects observed in the field and clarify the requirements presented in the ASTM standards. This paper will also discuss common long-term repairs that can be performed to address these issues.

Speakers


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INTRODUCTION

Over the past 15 years, the authors have investigated defects in exterior Portland cement plaster (stucco) cladding on hundreds of buildings throughout the southeastern United States. The investigations have been performed for a variety of reasons, including resolving issues noted during construction, storm damage claims, water leakage, and litigation arising from recent construction. The construction of the buildings under investigation has included stucco applied to solid bases, such as concrete or concrete masonry units (i.e., directly applied stucco) and stucco applied to metal plaster bases (metal lath). An adequate understanding of the properties of the various components in stucco cladding, the interaction among the stucco cladding and other building elements, and how the cladding resists rainwater penetration are critical to the initial design and installation of a stucco cladding system, proper diagnosis of any stucco defects that may arise, and the development of long-term repairs to address these deficiencies.

The focus of this paper is on those defects noted in buildings with exterior stucco cladding applied to metal lath. In metal lath supported systems, the stucco encapsulates a metal lath, which is attached to the building structure. Attachment of the metal lath to the building structure in these systems is critical to the integrity of the stucco cladding. The attachment methods must be able to transfer vertical loads—primarily the weight of the stucco cladding system—and horizontal loads—primarily from wind forces—into the building structure without resulting in damage to the stucco. Failure to adequately attach the metal lath can result in cracks, displacement, or detachment of the stucco from the building. The metal lath should also divide the stucco into discrete areas to enable initial drying shrinkage and subsequent expansion and contraction in response to temperature changes and other environmental factors to occur without damaging the stucco. Continuity of the lath within these discrete areas is important to reduce the risk of isolated cracks forming. The initial scratch coat must fully encapsulate the metal lath to provide an adequate bond and protect the metal lath from deterioration. The remaining stucco coats, the brown coat and finish coat, must be adhered to each other and to the scratch coat to prevent delamination of the stucco between coats. In addition, the stucco components—including cementitious materials, aggregate (sand), and water—must be properly proportioned, mixed, applied, and cured for metal lath-supported systems to function properly and to endure.

For water leakage issues in stucco systems, it is important to understand how the stucco cladding resists water penetration. The primary method of resisting water penetration through stucco cladding is at the exterior face of the assembly. However, water should be expected to penetrate the stucco, either by absorption through the stucco, through cracks or separations within the stucco system, or failed sealants at stucco terminations. Therefore, stucco systems supported by metal lath provide a drainage system consisting of a weather-resistant barrier (WRB) and flashings to collect and drain incidental water that penetrates the exterior surface back to the exterior of the building, as well as prevent the water from reaching the interior of the building. Reducing the avenues that enable water to penetrate the stucco through proper design and installation of these drainage components is critical to the success of stucco applied to metal lath.

Two documents, both of which have been incorporated by reference into the model building codes, have been developed by ASTM International, Inc. (ASTM) to provide designers and installers with the minimum requirements for metal lath and exterior stucco cladding. These documents are ASTM C926, Standard Specification for Application of Portland Cement-Based Plaster, and ASTM C1063, Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster. Unfortunately, ASTM C926 and ASTM C1063 are fairly complex standards, and the authors’ evaluations of defects in stucco-clad buildings have revealed significant failures of the various parties involved, including design architects, waterproofing consultants, contractors, and subcontracts, in understanding and applying the requirements for stucco and lath installation provided by these documents. The common failures noted include poor design and installation of flashings and WRBs; inadequate or incorrect layout and installation of control/expansion joints and other stucco accessories; and improper stucco mixes, sand gradation, placement of the stucco, and curing. These conditions have led to significant deficiencies in the completed stucco cladding, including cracking, separations, delaminations, and water leakage.

In this paper, the authors will describe several of the defects commonly noted in exterior stucco cladding. The primary cause(s) of these defects and the relationship of these causes with ASTM C926 and ASTM C1063 will be explored. Failures of the exterior stucco cladding and concealed drainage systems leading to water leakage into the building will also be discussed. In addition, the authors will provide several long-term repair options to address defects in the stucco cladding and failures of the drainage systems.

CRACKS, SEPARATIONS, AND DELAMINATIONS

Cracks form in stucco when forces or stresses within the stucco exceed its tensile strength. Although these stresses can be the result of external forces such as building displacement, wind, seismic movements, impact, etc., our experience is that cracks are more frequently caused by deficiencies in the design and installation
of metal lath and stucco stemming from an inadequate or inaccurate understanding of ASTM C926 and ASTM C1063.

For discussion purposes, we have divided the types of cracks commonly observed into two separate categories: extensive cracking and isolated cracking.

Extensive cracking can be defined as map or pattern cracks that occur throughout an individual stucco panel or are widespread throughout the stucco façade. These cracks may be fine crazing cracks as illustrated in Figure 1 or wider pattern cracks as shown in Figure 2.

Isolated cracking includes individual cracks or widely spaced cracks within an individual stucco panel. These cracks can be hairline width or very wide and may extend across an entire stucco panel or only a limited portion of the panel. In addition, isolated cracks may occur on multiple stucco panels throughout a building. Figure 3 illustrates an example of an isolated crack.

From a distance, separations often appear similar to isolated cracks. However, whereas cracks are fractures within the stucco, with stucco on each side of the crack, separations consist of gaps between the stucco and stucco accessories, such as expansion and control joints and casing beads. Separations often appear alongside isolated cracks and frequently have similar causes.

Delaminations occur when the stucco separates into individual layers or coats, or develops a separation within a layer. Delaminations can be difficult to detect in the early stages, as the defects are generally in a plane parallel with the exterior face of the building. However, over time, delaminations often lead to extensive cracking.

The following sections identify common causes of excessive and isolated cracking, separations, and delaminations and discuss the relationships between these conditions and ASTM C926 and ASTM C1063. Since delaminations often lead to excessive cracking and have similar causes, delaminations and excessive cracking are discussed together. Similarly, separations are presented in a subsequent section along with isolated cracking.
The most common conditions resulting in delaminations and excessive cracking identified through our field investigations of metal-lath-supported stucco systems include the following:

- Incorrect stucco mix proportions
- Improper gradation of sand
- Poor curing
- Delamination between stucco coats
- Corroded lath

Incorrect Stucco Mix Proportions

Stucco consists of cementitious materials—frequently Portland cement and lime mixed with aggregate (usually sand) and water. Correctly proportioning the various components and properly mixing the components are critical to the long-term success of the stucco cladding. Incorrectly proportioned stucco mixes that frequently lead to excessive cracking include mixes with high cement contents (undersanded), low water-to-cement ratios, or high water-to-cement ratios. Stucco prepared from these poorly proportioned mixes is often weak and can suffer from early drying shrinkage and high porosity.

For a traditional stucco mix, Tables 2 and 3 in ASTM C926 provide mix proportions for the base coats (both scratch coat and brown coat) and finish coat. The tables are given by volume and specify the proportions of cement, lime, and sand that shall be included for a specific stucco mix. Based on discussions with designers and installers over the years, it has been our experience that the tables are often interpreted improperly, resulting in undersanded or cement-rich stucco mixes. Table 2 specifies that the volume of sand be between 2½ and 4 for the first coat and 3 to 5 for the second coat. Table 3 specifies that the volume of sand for the finish coat be between 1½ and 3. However, the table also includes “Volume of Aggregate per Sum of Separate Volumes of Cementitious Materials.” This requires adding the separate volumes for cementitious materials (cement plus lime) and then multiplying the sum of these materials by the volume of sand (2½ to 4 for the first coat, 3 to 5 for the second coat, and 1½ to 3 for the finish coat) to obtain the total volume of the aggregate to be included in the mix. For example, to obtain a “CL” plaster mix with 1 part Portland cement, 1 part lime, and 3 parts sand for the first coat, and 3 parts sand for the second coat—the actual amount of sand to be used in the mix should be calculated as follows: (1 part Portland cement + 1 part lime) X (3 parts sand) = 6 parts sand. Frequently, this requirement is misinterpreted and installers and designers often fail to multiply the volume of sand by the sum of the cementitious materials when mixing stucco. Mixtures of this type have relatively high cement contents, which are typically prone to increased shrinkage, resulting in a higher probability of the formation of excessive cracking.

It should be noted that a significant amount of current stucco installation on buildings uses preblended bag mixes rather than site mixing in accordance with the tables provided by ASTM C926. Assuming that adequate quality control measures are followed by the manufacturer, these preblended bag mixes provide the correct proportions of lime and cement—and, in some cases, sand—leaving only water and/or sand to be added at the project site. Instructions on the bagged mix typically specify the amount of sand and water to be added. Therefore, it is important to follow the manufacturer’s instructions during the mix process.

In some cases, we have determined that the proportions of sand and cementitious components in the cured stucco were incorrect, even though the mix design provided for correct proportions. Further investigation revealed that inadequate mixing of the components resulted in the proportional differences. Guidelines for measuring the components and mixing the stucco are provided in ASTM C926. These requirements include using measuring devices of known volume and mixing the constituents in a mechanical mixer. In addition, Appendix XI of ASTM C926, which is stipulated as nonmandatory information, recommends that the stucco be mixed for three to five minutes after all components are added to the mixer. Following these requirements will help ensure that the stucco is properly blended.

ASTM C926 does not stipulate the specific volume of water to be used in the stucco mix. Instead, the stucco contractor is specifically charged with determining the amount of water to be included. Several factors are identified in Appendix XI, including the suction of the base or the previous coat, water content of the aggregate, drying conditions, and finishing operations. Because of these factors, including curing, the final water-to-cement ratio is very difficult to control. However, in our experience, the final effective water-to-cement ratio should be less than 0.55.

To help ensure that the stucco to be used on a project is properly mixed and is of good quality, petrographic and chemical analysis in accordance with ASTM C1324, Standard Test Method for Examination and Analysis of Hardened Mortar, can be performed during the mock-up phase of a project. The results of the analysis can be used to determine the final mix proportions.

Improper Gradation of Sand

Another common issue that leads to excessive cracking of installed stucco is the use of sand that fails to comply with the requirements of ASTM C926, which specifies that the sand be in accordance with ASTM C897, Standard Specification for Aggregate for Job-Mixed Portland Cement-Based Plasters. In our experience, it is often difficult for contractors to obtain sand that matches the gradation requirements specified in ASTM C897. Therefore, sand that does not meet the ASTM C897 requirements is often substituted. In most cases, the substituted sand is much finer than that required by ASTM C897. Using fine sand often results in the installer using too much water due to the increase in total surface area of the sand, resulting in a stucco mix that has a high water-to-cement ratio. A mix with a high water-to-cement ratio would result in a weak stucco mix, which could result in excessive cracking.

Poor Curing

Good curing practices, which maintain sufficient moisture in the stucco mix to permit continuous hydration of the cementitious materials, can help prevent or reduce the risk of excessive shrinkage cracking. The premature loss of water from the stucco caused by high temperatures and exposure to wind and sun can result in early hydration and excessive cracking if good curing practices are not employed.

It should be noted that stucco can actually dry out faster in cool weather when exposed to direct sunlight and wind than it will on hot days when not exposed to direct sunlight and wind. ASTM C926 requires curing of the stucco with three different methods:

1. Moist curing by applying a fine fog spray of water as frequently as required, generally twice a day in the
morning and evening. Care must be exercised to avoid erosion damage to Portland cement-based plaster surfaces. Except for severe drying conditions, the wetting of the finish coat should be avoided; that is, wet the base coat prior to the application of the finish coat.

(2) Plastic film, when taped or weighted down around the perimeter of the plastered area, can provide a vapor barrier to retain moisture between the membrane and plaster. Care must be exercised in placing the film. If placed too soon, the film may damage surface texture; if placed too late, the moisture may have already escaped.

(3) Canvas, cloth, or sheet material barriers can be erected to deflect sunlight and wind, both of which will reduce the rate of evaporation. If the humidity is very low, this option alone may not provide adequate protection.

The amount of water or the length of time the curing should be performed is not defined in ASTM C926; however, the Portland Cement Association (PCA) recommends maintaining 80% relative humidity for at least 24 hours and, in some cases, up to seven days. The method that has proven to be most successful in curing stucco, in our experience, is to tent the stucco to prevent exposure to sunlight and wind, and maintain at least 70% relative humidity inside the tent for seven days; or to cover the stucco with wet burlap and maintain the moisture in the burlap for seven days.

After the initial seven days of curing, we also recommend that the stucco continue to cure for an additional 23 days to help ensure all of the initial shrinkage has taken place prior to placing the finish over the stucco. While this is not often performed, most coating manufacturers recommend this as well. Allowing the stucco to fully cure prior to placing the finish will allow the contractor to repair cracks and deficiencies in the stucco prior to placing the finish.

**Delamination Between Stucco Coats**

If the stucco is not properly placed, properly scratched, or properly prewetted between coats, a poor bond can develop between the various stucco layers, leading to delaminations between the stucco coats. Delaminations between stucco coats can lead to excessive cracking. Requirements for applying each stucco coat are provided in ASTM C926.

The first or scratch coat must be applied so that the metal lath is fully embedded in the stucco and the stucco forms full keys through the lath. The thickness of the stucco in the scratch coat over the metal lath must be thick enough to enable the entire surface to be scored. The scratch coat is required to be scored in one direction only (horizontally for wall surfaces) as soon as it becomes firm, as indicated in ASTM C926.

For the second or brown coat, sufficient pressure to ensure tight contact with the previous coat is required by ASTM C926. The brown coat can be installed as soon as the scratch coat is rigid enough to support it without damaging the continuity of the scratch coat or the keys between the scratch coat and metal lath. The brown coat surface has to be in a true, even plane, and any defects must be filled with plaster, after which the surface must be uniformly floated. The purpose of floating the brown coat is to increase the density of the coat and to provide a better bonding surface for the finish coat. Similar to the application of the brown coat, the finish coat is required to be applied with enough pressure to ensure tight contact with the brown coat.

ASTM C926 permits the second and third coats to be applied as soon as the underlying layer becomes rigid enough to support the application of the next layer without damage. This eliminates the need to prewet the prior coat before the application of the next coat. If the application of the second coat or finish is delayed after the underlying stucco has reached its initial set, the underlying layer of stucco should be dampened by prewetting the surface.

We have observed three primary defects in the application of the stucco coats that violate the requirements of ASTM C926 and often cause delaminations to occur. Delaminations frequently occur when the scratch coat or subsequent coats are not applied with enough pressure to—in the case of the scratch coat—form full keys through the lath or—in the case of the brown and finish coats—ensure tight contact between the coats. Small voids or discontinuities form between the coats or within the coats due to this lack of pressure. Over time, these conditions can cause larger-scale delaminations between the stucco coats. Failure to score the entire surface of the scratch coat is another common condition that results in delaminations. The third defect we have commonly observed is the failure to prewet the underlying layer when applying a subsequent coat after initial set of the support layer.

**Corroded Metal Lath**

Corroded metal lath can also result in excessive cracking. Corroded metal lath is typically the result of poor keying between the first layer of stucco and the lath, improper stucco mix, poor maintenance, aged stucco, and water traveling through unsealed cracks and separations in the stucco.

One of the reasons ASTM C926 requires the first coat of stucco to encapsulate the metal lath is to protect the lath from corrosion. Embedment of the metal lath in the stucco provides protection in a number of ways. First, if the stucco is relatively impervious, the stucco reduces the exposure of the metal lath to oxygen and water. Both elements are necessary for the corrosion reaction to occur, and the absence of either element brings the corrosion to a halt. The second (and probably most significant) way in which stucco can protect embedded metal lath is by creating an environment that is favorable to the formation of a metal oxide surface coating on the lath, thereby “passivating” it from further corrosion, similar to the manner in which concrete protects embedded reinforcing steel. The alkalinity of the stucco is considered the most important quality of the matrix in creating a passivating environment. The passive metal oxide layer can be broken down by reactive ions (such as chlorides), which decrease the alkalinity of the stucco. Carbonation of the stucco can also create an environment that does not favor passivation. Relatively impermeable stucco not only reduces exposure of the steel to oxygen and water, but also slows the intrusion of chloride ions and the propagation of the carbonation reaction, relative to the more-pervious stucco.

**Isolated Cracking and Separations**

Isolated cracking and separations are primarily the result of improper design and installation of metal lath, or poor practices in the application of the stucco. Based on our investigations, the most common defects resulting in isolated cracking and separations include the following:
Improper Design and Placement of Control Joints

The failure to follow the design and installation requirements provided in ASTM C926 and ASTM C1063 for control and expansion joints is perhaps the most frequent cause of isolated cracking observed in our investigations. The purpose of control joints, as defined in ASTM C1063, is to minimize stresses in the stucco induced by drying shrinkage and minor movement of the building or stucco. In addition, ASTM C1063 indicates that control joints are required to accommodate both expansion and contraction. If control joints are not designed or installed in a manner that allows the joint to accomplish this purpose, isolated cracking frequently occurs.

Control joints must be installed to separate the stucco into areas of less than 144 square feet on walls, as required by ASTM C1063. The distance between control joints is further limited to 18 feet. We have observed that adherence to these two criteria has become more common in recent years, resulting in fewer isolated cracks occurring due to oversized stucco panels. However, ASTM C1063 also limits the length-to-width ratio of the stucco areas delineated by control joints. The maximum length-to-width ratio of any stucco panel is 2½ to 1. The stucco panels adjacent to windows, particularly along the jambs, frequently exceed this ratio. Often, these relatively tall, narrow stucco panels contain isolated cracks. The cracks generally form at locations that would enable the stucco panel to meet the required ratio. For example, panels that are 9 ft. tall and 18 in. wide commonly form two horizontal, isolated cracks. These cracks typically break the panels into segments that are 3 ft. tall by 18 in. wide, for a length-to-width ratio of 2 to 1. Figure 4 illustrates an example where the stucco panels exceed the 2½ to 1 ratio.

One of the common arguments regarding improper installation of control joints relates to the party responsible for determining their location. Annex A1 of ASTM C926 provides clear direction that the designer is responsible for illustrating the type, depth, and location of all accessories (which include control joints) in the contract documents. The requirement for the designer to provide control joint locations is even more clearly stipulated in the Appendix to ASTM C926. This appendix states that the intent of the standard is “to have the type, location, depth, and orientation of control and expansion joints both stated in the project specifications as well as shown and detailed on the contract drawings.”

The contractor and subcontractor are not completely absolved of responsibility in this area. However, Annex A1 also requires the contractor or subcontractor to evaluate the surfaces to receive stucco, notify the proper authorities, and correct any unsatisfactory conditions.

Another common issue observed in our investigations related to installation of control joints is the failure to cut the metal lath at the control joint locations. Some groups have promulgated the concept that extending the metal lath continuously through the control joints is appropriate.

The first argument against this concept is that the engineering mechanics involved do not support continuous metal lath. The stucco, if properly installed, is keyed into the metal lath, which restricts the ability of the stucco to freely shrink unless the lath is cut. If the metal lath is not cut, the stucco will likely either shrink away from the control joint, developing a separation between the control joint accessory and the stucco; or cracks will develop between control joints because the accessories can’t function as intended. Our research into this condition has not revealed any documentation based on engineering mechanics that would support forgoing the cutting of the metal lath at control joints.

A second argument is that ASTM C1063, which has been adopted by reference into the model building codes, requires the metal lath to be discontinuous at the control joints and tied to each side of the control joint accessory. Although isolated cracks do not always occur at locations where the metal lath is continuous through the control joints, we have investigated numerous cracks that were the result of the inability of the stucco to accommodate movements and/or drying shrinkage.

Overfastening of the Metal Lath

ASTM C1063 requires the metal lath to be fastened to the building framing members by screws, staples, or nails, depending on the framing material. The primary purpose of the requirement is to ensure that the metal lath is attached to an adequate support. However, the requirement to attach the metal lath to framing members also has the effect of limiting the number of fasteners installed in a given area. We have observed isolated cracking caused by metal lath installations containing several
fasteners installed in a relatively small area. The profuse fastener installation limits the ability of the metal lath to move laterally, thereby causing excessive stresses in the stucco as a result of drying, shrinkage, or other movements. In addition, overfastening the stucco prevents the stucco from forming a full key with the metal lath and fully embedding the lath, the ramifications of which were discussed previously.

Overfastening can also refer to installing fasteners too tightly. Staples used in lath installation are required to be crowned and driven flush with the metal lath per ASTM C1063. For screws, the standard requires the screw to “pass through, but not deform” the metal lath. Overdriving the fasteners also restricts the ability of the metal lath to accommodate movements without damaging the stucco. The use of guides on drill drivers and adequate location of structural members can reduce the risk of overdriving fasteners. Figure 5 illustrates an example of an overdriven screw.

Incorrect Lapping of Metal Lath Segments

According to ASTM C1063, the side laps of metal lath segments must be attached to framing members or wire-tied together. The failure to follow these criteria frequently causes isolated cracking. If the segments are not connected at the side laps, adjacent segments can move independently, particularly if the stucco scratch coat is not applied with enough force to form full keys with the lath. These independent movements result in isolated cracks in the stucco.

Another common issue occurs in stucco installed with paper-backed metal lath. Metal lath with backing is specifically required by ASTM C1063 to be installed such that metal abuts metal at the laps. If the paper is placed between the metal laths at the laps as illustrated in Figure 6, the stucco cannot achieve full keys through both sections of lath at the laps. This installation also permits differential movement between adjacent portions of the stucco, which causes isolated cracks to occur, as illustrated in Figure 7. Sometimes, isolated cracks will form at about 3 ft. on center vertically (i.e., at each lap) when these conditions occur.
Poor Integration of Stucco Accessories

Poor integration of the stucco accessories with the field metal lath often causes separations to occur between the stucco and the accessory. Several controls are provided in ASTM C1063 to ensure that the accessories are integrated with the field metal lath. Where paper-backed metal lath is employed, the standard forbids placing the paper backing between the lath and the accessory flanges. In addition, the accessory flanges are required to be fully embedded in the stucco. Basically, the accessories should be integrated with the field metal lath and treated similarly to laps in the lath discussed previously. Failure to comply with these constraints enables the stucco to shrink away from the accessory, resulting in a separation between the stucco and accessory. Figures 8 through 12 illustrate examples of improper connection between the metal lath and stucco accessories.
Another common deficiency related to the integration of the accessories into the stucco is inadequate placement or keying of the stucco at accessories. ASTM C926 requires that the stucco be applied with sufficient pressure to fully embed the metal lath and form full keys with the lath. We have identified many instances in which the stucco was not fully keyed with the accessory, enabling the stucco to separate from the accessory. Figure 13 illustrates an example where the scratch coat is poorly keyed into a stucco accessory. Figures 14 and 15 illustrate examples of a separation between the stucco and a stucco accessory.

**Water Leakage**

As discussed previously, stucco cladding assemblies supported by metal lath are drainage systems. As described in Annex A2 of ASTM C926, proper installation and curing can greatly increase the water resistance of stucco cladding. However, ASTM C926 goes on to state that stucco should not be considered waterproof. Water can penetrate the stucco in a variety of ways, including absorption through the stucco, via cracks within the stucco or separations between the stucco and stucco accessories, and through failed or missing sealants at stucco terminations or penetrations. As with any drainage system, WRBs and flashings are required to prevent water that penetrates the stucco from passing into the interior of the building. For water to infiltrate into the building, either the WRB or flashings must have failed or been incorrectly installed.

Neither ASTM C926 nor ASTM C1063 provides extensive requirements for installation of flashings and WRBs other than indicating that these components are required for stucco supported by metal lath. In particular, ASTM C926 requires the stucco designer to specify and describe flashings for openings, terminations, and perimeters of the stucco system. In addition, both ASTM C926 and ASTM C1063 discuss installation of weep screeds at the bases of walls and the integration of the WRB with the weep screed. Sloping of horizontal surfaces and appropriate methods of construction at the interface of vertical and horizontal surfaces are also discussed in the standards. The following paragraphs discuss several defects identified during our field investigations of water leakage in stucco systems supported by metal lath.

**Flashings**

Generally, designers specify through-wall flashings at heads of windows, as required by ASTM C926. This flashing typically terminates above the window jambs and does not extend beyond the jambs, as illustrated in Figure 16. Formed end dams are not normally installed in this instance due to the propensity for cracking at the end dam locations, amongst other concerns. These conditions create several difficulties regarding integration of the flashings with the WRB and the windows and enur-
The integrity of these systems. Due to these difficulties, small holes often occur at the interfaces of these materials, enabling water to bypass the flashings and WRB and penetrate the building. One way to resolve these concerns is to install sealant on the through-wall flashing when accessory casing bead (J-mold) is installed above the flashing in an effort to create an end dam. However, in our experience, the placement of the sealant is often not watertight or fails prematurely, and water continues to bypass these sealant end dams. Our recommendation is to install continuous flashing around the building at the elevation of the window heads. The authors have successfully employed this method in major stucco repair and reclad projects on a variety of facilities.

Another concern relating to flashings occurs at the base of walls, where flashings or weep screeeds are required. Through-wall flashings or “other effective means to drain away any water” are required by ASTM C926 to be provided at the bottom of any stucco wall supported by a floor or foundation. We have investigated numerous buildings that lack appropriate flashings, particularly at balcony locations or other interruptions above grade. The lack of flashings at these locations enables water that penetrates the stucco to enter the building and often causes significant issues.

Weather-Resistive Barriers
As discussed previously, ASTM C926 and C1063 provide very little guidance with regards to WRB installation. The fact that the standards remain fairly silent on the installation of WRBs should not minimize the importance of the WRB in stucco construction. As discussed previously, water can penetrate stucco through a variety of means. Once water gets behind the stucco, any defect in the WRB provides a potential avenue for water leakage into the building.

The primary defect we have observed in WRBs that has led to water leakage into buildings has been unsealed screw holes through the WRB as illustrated in Figures 17 and 18. This typically occurs because the locations of the framing members are not readily identifiable after installation of the WRB, and the lath installer installs screws through the exterior sheathing that don’t penetrate framing members as required by the ASTM standards. Usually, the installer either leaves the screw in the wall, providing an avenue for water to follow the screw penetration, or removes the screw, leaving a hole through the wall for water to penetrate. Rather than trying to guess the location of the framing after the WRB is installed, we recommend marking the framing locations.
on the WRB using chalk lines. This will help the metal lath installer to accurately install screws through the framing members. If a screw misses the framing, we recommend that the metal lath and WRB be cut to seal the hole in the sheathing. Once the hole in the sheathing is sealed, the WRB can be sealed and the metal lath can be wire-tied back together.

Other common WRB issues unique to stucco construction include degradation of a sheet WRB by the stucco and metal lath adhering to the sheet WRB. Many investigations have revealed that the stucco adhered to the WRB, decreasing or eliminating the drainage plane behind the stucco. In some cases, the stucco had damaged the WRB, resulting in holes in the WRB. To avoid these problems, we recommend installation of an outer, intervening layer between the stucco and WRB. This layer can comprise a paper backing on the metal lath or a second layer of WRB and is generally considered a sacrificial layer. All flashings should be incorporated into the inner WRB rather than the outer layer. The model building codes typically require similar installations for stucco cladding with wood-based sheathing; however, we recommend this double layer for all framed construction.

LONG-TERM REPAIRS

In order to develop long-term repairs for stucco defects, it is critical to determine the root cause or causes of the defects. Only after the problem has been defined should design of the repair begin. As mentioned above, numerous deficiencies in the design and installation of stucco and/or metal lath can result in excessive cracking, isolated cracking, interior water leakage, or some combination of these three conditions. We have developed several repairs, ranging from recladding to coating, which can function as long-term repairs if they are appropriate for the defects identified during an in-depth investigation of the stucco. The following paragraphs briefly describe some of these repairs and conditions in which the repairs may be appropriate.

Full-Scale Removal and Replacement

Full-scale removal and replacement is generally the most appropriate repair for stucco that is exhibiting excessive cracking due to incorrect stucco mix proportions, improper gradation of sand, poor curing, delamination between stucco coats, and corroded metal lath. In addition, depending on the character of the water leakage being experienced, full-scale removal and replacement can be the most fitting repair for water leakage caused by unsealed holes through the WRB. These conditions are typically indicative of major deficiencies in the design and/or application of the stucco, as described previously. Therefore, long-term repairs should include removal and replacement of the affected stucco.

Depending on the extent of the excessive cracking, the replacement may encompass the entire façade (i.e., recladding) or simply specific affected stucco panels. When removing isolated panels of stucco, it is important to not cut through the metal lath adjacent to the stucco accessory (construction joint) that separates adjacent stucco panels. Therefore, it is recommended that the stucco be cut approximately 4 in. from the stucco accessory. The stucco over the 4 in. margin should be carefully removed, eliminating or minimizing damage to the underlying metal lath. The metal lath in the field of the stucco panel can be cut; however, caution should be used not to cut through the exterior sheathing. Once the stucco and metal lath are removed in the field of the stucco panel, repairs should be made to the exterior sheathing and the WRB, as necessary. At the edges of the stucco panel, the existing metal lath adjacent to the stucco accessory should be bent out to allow for the new WRB to be installed in a shingle fashion with the existing WRB. Laps between the new and existing WRBs must be at least 2 in., or as required by the WRB manufacturer and/or applicable building code. Once the repairs to the exterior sheathing and WRB are made, new metal lath and new stucco can be installed.

Excessive cracking caused by incorrect stucco mix proportions and improper gradation of sand are material defects in the stucco cladding. When premature water loss enabled by poor curing methods results in wide, excessive cracking, the stucco is typically weaker and prone to additional cracking and degradation. Excessive cracking caused by corroded metal lath typically occurs when maintenance efforts have not been performed or have failed. Application of an elastomeric coating over the stucco façade will not address the primary causes of these issues and, therefore, is not recommended as a long-term repair solution for these conditions.

Removal and Replacement of Isolated Stucco Areas

Removal and replacement of isolated stucco areas is often a suitable, long-term repair for isolated cracks caused by incorrect lapping of metal lath segments or overfastening of isolated areas of stucco. Depending on the water leakage experienced, isolated removal and replacement of stucco can be an appropriate long-term method to address water leakage caused by inadequate flashing installation and isolated damage to the WRB.

To repair a crack in the field of the stucco due to underlying conditions such as improperly placed/lapping of paper-backed metal lath, the stucco should be removed to expose underlying conditions. The removal of the stucco should be performed by cutting the undamaged stucco at least 6 in. away from either side of the crack. The saw cut should be at a depth that does not damage the metal lath. The cut should be made with a bevel that will allow the new stucco to be placed under the existing stucco that will remain. The stucco material within the cut area is then carefully removed to avoid damage to the metal lath. Once the stucco is removed, the metal lath should be cut to expose the condition causing the crack. Once the condition is repaired, the metal lath should be restored by using tie wire to connect the new lath to the old so as to cover the damaged area.

When removing and patching small isolated areas of stucco, the type and properties of the existing stucco should be determined so the new stucco will be as similar to the existing as possible and avoid any incompatibilities between materials or differences in strength and thermal expansion. A stucco mix may be composed of Portland cement, blended cement, plastic cement, or masonry cement. The amount of lime may vary between none to twice the amount of cement. The amount of the aggregate may vary between 2½ and 5 times the sum of the cement and lime, and there may or may not be an acrylic-type modifier or bonding agent and fibers in the existing mix. Petrographic and chemical analyses, in accordance with ASTM C1324, of samples of the existing stucco can determine the mix components and relative content by volume.

Coating the stucco with an acrylic paint or an elastomeric coating is often part of isolated replacement of stucco. The decision to paint or coat the stucco is often an
Installation or Replacement of Stucco Accessories

When isolated cracking or separations along stucco accessories are caused by improper design and/or installation of control joints or poor integration of stucco accessories, installation of new stucco accessories or removal and replacement of stucco accessories have proven to be effective long-term repair options. This repair can be effective for water leakage caused by improperly installed flashings or failure to install flashings or weep screeds. The actual removal of the stucco and metal lath, repairs to any damaged sheathing or WRB, and installation of new lath and stucco will be similar to that discussed in the previous section.

At locations where the designer and installer failed to provide adequate control joints—either by excessive spacing or failure to abide by the permitted length-to-width ratio established in ASTM C1063—new control joints will be required. As stipulated in ASTM C1063 for new stucco construction, we recommend that the locations, sizing, and installation requirements for new control joint accessories be provided by the designer in the contract documents for the repairs. Similarly, where flashings or weep screeds were not installed, removal of stucco and installation of these accessories should be appropriately detailed by the designer for the repairs. This repair can also be applicable to situations where cracks form due to failure to cut the lath at the control joints. In these conditions, the existing stucco is cut on a straight line at least 3 in. on each side of the existing control joint. The contractor must be careful to restrict the cut to a depth that does not damage the metal lath and WRB. The metal lath is then cut at the control joint location to create a break in the existing lath and allow the new control joint to be installed under the existing lath. The new control joint accessory must be wire-tied to the existing metal lath at a spacing not to exceed 7 in. on center, following which, the new stucco is installed in accordance with the procedure described in the previous section. Similar repairs would be applicable for replacement of flashings or weep screeds that were incorrectly installed and for addressing separations along stucco accessories caused by poor application of the stucco or failure to adequately integrate the stucco accessory with the field metal lath.

As discussed in the previous section, a final step in these repairs is often application of an acrylic paint or elastomeric coating. However, as discussed previously, this decision is largely an aesthetic one.

Routing and Sealing Cracks and Separations

Routing and sealing of isolated cracks in the field of a stucco wall and separations along a stucco accessory can also be appropriate repair options to address cracks caused by inadequate control joints and separations caused by poor integration of the stucco accessories. However, the designer and/or installer of the repair should make it abundantly clear to the owner that this repair does not address the underlying cause of the defect. Therefore, this repair should be considered a short-term repair. Over time, as the sealants age and the stucco continues to move in response to environmental factors, the sealants should be expected to fail and the repairs repeated. In addition, we recommend that mock-up repairs be performed to illustrate the aesthetics of this repair scenario. These repairs—particularly routing and sealing of cracks in the field of the stucco caused by inadequate control joints—can be considered unsightly. The mock-ups would enable the owner to evaluate the aesthetics of the completed repair. This repair is often used to address the deleterious conditions while funding is procured for a larger project that would address the underlying causes of the cracks and separations.

Application of an Elastomeric Coating

Application of an elastomeric coating can be an appropriate repair in a few isolated conditions. For instance, an elastomeric coating can be a very good long-term repair option for addressing excessive fine crazing caused by poor curing. Note that the craze cracks in this case should be no more than hairline width, and no other major defects should be identified in the stucco. The elastomeric coating should have at least 300% elongation to allow the coating to stay watertight as the cracks move due to thermal temperature changes, and the perm rating should exceed at least 5.0 to allow the wall to breathe. If the perm rating of the coating is too low, moisture can be trapped in the stucco system and freeze/thaw or other damage can occur.

However, application of an elastomeric coating is not the panacea that some consultants and contractors have made it out to be. We have performed investigations on numerous buildings that continue to suffer from water leakage after application of an elastomeric coating. These buildings continued to leak because the repair designer and/or contractor failed to understand that the elastomeric coating was an attempt to create a barrier wall system of the stucco cladding, which, as we discussed previously, is intended to perform as a drainage system. In order to develop a barrier system from stucco, every avenue for water penetration—including windows and other penetrations, terminations, etc.—must be addressed and formed into a barrier. This is a very difficult and expensive process and should only be attempted by very experienced designers and contractors. In addition, the owners should be apprised of the need for an extremely diligent maintenance program that monitors and addresses degradation of the various components comprising this barrier system.

CONCLUSIONS

When designed and installed correctly, stucco supported by metal lath can provide a durable, aesthetically pleasing covering for building walls, requiring relatively minimal regular maintenance to continue functioning as intended. In order to assist designers and contractors, ASTM has developed two standards, ASTM C926 and C1063. For a project to be successful, all parties involved in designing or installing stucco walls should have a thorough understanding of these documents. Unfortunately, there is some confusion among both designer and installers regarding the requirements promulgated in these documents and the...
ramifications of the failure to comply with these requirements. This confusion or disregard often results in significant defects in stucco installation, including excessive cracking, delamination, isolated cracking, separations, and water leakage. Because these documents have been incorporated by reference into the model building codes, failure to comply with the stipulations of these documents frequently represents a violation of the building code.

In this paper, we have endeavored to inform the reader of several defects commonly noted in our investigations that have resulted in significant failures or distress in stucco construction. These defects could have been avoided simply by understanding and following the stipulations outlined in ASTM C926 and C1063. We have also described some long-term repair options that can be implemented and the fallacy of expecting application of a coating to the exterior face of the stucco to provide a long-term solution to all of these defects. For long-term repairs to be successful, the repairs should address the root cause(s) of the defects, as determined following a thorough investigation by a competent person, rather than merely attempting to address the symptoms of these defects, such as cracking or separations.