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Architects + Engineers

COMMON DEFECTS AND FAILURE MODES IN CEMENT PLASTER

by

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Abstract

While improvements in construction methodology and our knowledge base in the building envelope industry have grown by leaps and bounds over the past few decades, very little has changed in the cement plaster (CP) industry. Today the methods for the building shell construction have grown in number and CP is being used in many different applications, yet very little has changed in the design and application methods of CP in over 100 years. As a result of the changes in construction methods, inappropriate use of Cement Plaster and lack of understanding of the fundamental principles of CP, there has been a dramatic increase in water intrusion and other failures.

This paper will discuss modes of failure in cement plaster that include cracking in plaster caused by mix design, improper placement and fastening of lath, improper curing, and structural flexibility of the wall. Common sources of water intrusion in plaster also include improper flashing of wall penetrations and openings, large cracks; and improper termination of plaster. Aesthetic issues with plaster include, staining due to moisture absorption and mold, chimney soot, patching stucco and coating/painting.

This paper will also discuss design of the CP system primarily in exterior applications. Issues discussed include mix design of cement plaster and stucco finishes, role and function of lathing and plaster stops and accessories, methods to improve perimeter conditions and penetration flashing; common modes of failure in cement plaster including cement plaster used as a mortar base for tile and stone, and how to avoid them; and methods to repair leaking or failing plaster.

The paper will include actual case studies and real life examples, including photographs of buildings with cement plaster problems and causes and effects of the deficiencies as well as exploration of various methods and level of repair.

HISTORY

Cement Plaster has been used as an exterior finishing material for literally thousands of years, first as a crude method of sealing out the elements and providing rudimentary sanitation and protection, then later as a more refined method of providing functionality and even ornamentation in Roman and Greek times. In the Bible's Old Testament, Leviticus 14:42 details re-plastering a house for sanitation and purging of a plague. As a sanitary coating it was used to keep out vermin and insects.

According to the "Plaster and Drywall Systems Manual" Third Edition, written by J. R. Gorman, Sam Jaffe, Walter F. Pruter and James J. Rose, "Cement Plaster" is a cementitious, that is, containing cement, material or a combination of materials and aggregates which, when mixed with a suitable amount of water (plus, in some cases, other liquids), forms a plastic or moldable mass which, when applied to a surface, adheres to it and subsequently sets or hardens, preserving in a rigid state the form or texture imposed during the period of plasticity. The term "plaster" is used with regard to the specific composition of the material and in the construction industry does not explicitly denote either interior or exterior usage.

There are three generic types of plaster – gypsum, lime and portland cement. The focus of this paper is on the exterior cement plaster type, that being the most common type of material.

Generically, plaster is a weatherproofing element to protect against wind, rain and sun and is also a leveling coat to make walls and ceilings level or smooth either for aesthetic appeal or the base to which coatings, covering, frescoes or other ornamentation may be applied.

The terms "Portland Cement Stucco," "Portland Cement Plaster," "cement plaster" and "stucco" are often used interchangeably. In this paper, some of the differences will be discussed although the focus is on generic cement plaster as an exterior building material.

Cement plaster is usually applied in three coats over metal reinforcement with or without solid backing. The methods and standards of installation will be discussed.

TECHICAL DEFINITIONS

Mix design

The components of cement plaster such as sand, water, admixtures, portland concrete cement and other components are usually expressed as a relationship to each other, in parts. According to Table 25-F of the 1997 Uniform Building Code, the required ratio is 4 parts sand and one part portland cement for the first coat, five parts sand and one part portland cement for the second coat, and three parts sand and one part portland cement for the finish coat. Plasticizers and other admixtures should be specified by the designer and not be left to chance or the decision of the craftsman.

Adhesion

The capability of cement plaster to stick or adhere to the underlying surface or sub-strate. This is important because in order to remain effective, adhesion must be maintained over the service life of the cement plaster.

Cohesion

The ability of a material to bond or cling to itself and not disintegrate. After adhesion of CP to metal lath reinforcement, the cohesion of subsequent coats of CP governs the ability of the assembly to remain fixed in place after the plaster envelops the metal reinforcement. A cohesive plaster remains where it is placed. This is important especially in situations where CP may be used as a structural element.

Brown Coat

In three coat work, the second coat applied over the first, or scratch, coat. In two-coat work, brown coat refers to the doubled up base coat. In either use, the brown coat is the coat directly beneath the finish coat.

Base Coat

All plaster applied before the application of the finish coat.

Finish Coat

Final coat, which could include integral color and coarse or fine texture. Finish coat can consist of acrylic based elastomeric material for greater flexibility and crack resistance.

Coat

A thickness of plaster applied in a single operation.

Workability

The ease or ability of CP to flow or be moved, usually expressed as an amount of time. Gorman, et al, op. cit., have described this in some detail: workability involves adhesion and cohesion as well as unit weight and spreadability. During application, the plasterer judges the degree of workability based primarily on experience in similar conditions including ambient air temperature and humidity. In the laboratory, degree of workability can be measured by numerous tests, including tests for flow, slump; unit weight and penetrability. To give plaster the best workability requires use of aggregate with consistent and favorable shape and gradation, consistent mix of cement, and optimum amounts of air, water and plasticizers that are properly combined and proportioned during mixing. Any ingredient incopororated into the mix design, outside of optimum amounts will lessen the workability of plaster. This can result in failures.

Building Flexibility and L ratio

Building walls shall not flex beyond the limits of ASTM standards and the Uniform Building Code. Wall flexibility is measured as a ratio between the length of the wall – "L" – versus the flex. The maximum recommended ratio CP is L/360, for thin set tile L/480.

Weather resistance

Ability to withstand rain penetration, resistance wind, thermal and moisture changes, resistance to the impacts of the atmosphere including air pollution

Seismic conditions

Ability of CP to provide sheer value to seismic loading. Depending on geographic location Code allows use of CP as a sheer wall, with very specific conditions related to embedment of the CP in the metal lath, as well as nailing. During lateral loading and seismic events, CP can develop cracks, reducing its ability to act as a shear wall. Many buildings, during the Northridge, California earthquake, were severely damaged due to this type of failure. Due to the limited nature of stucco's ability to perform as a seismic restraint, most structural engineers don't use stucco as a shear seismic wall element.

Sheer strength

The ability of stucco to act as a sheer, or load bearing element in building design.

Tensile strength

The ability of plaster to resist tensile stresses. Proper curing and lath embedment is mandatory.

Compressive Strength

The ability of CP to carry its own weight and compressive loads imposed during flexure and lateral loading.

MATERIALS

Lathing or Metal Reinforcement

Metal lath reinforcement should be used whenever CP is applied over wood frame open construction, wood framed sheathed construction, metal framing, flashings, surfaces providing unsatisfactory adhesion, and chimneys. Metal reinforcement should properly positioned and fastened securely to the supporting structure. The reinforcement needs to be properly "furred" or embedded in CP.

Plaster stops

A transitional metal or other mechanical method that properly terminates CP at locations such as windows, doors or transitions to other types of building materials. Plaster stops should be designed in order to not leak, and provide proper means of terminating stucco to adjoining construction. They should be applied integrally with application of the stucco, not as an after thought.

Plasticizers

The function of a plasticizer is to improve workability. The plasticizer must meet the requirements of the appropriate ASTM standard. Lime is the most common plasticizer used for CP application.

Water

Mixing water must be clean and fit to drink. It should be free of harmful amounts of any mineral or organic substance that would affect the setting time, workability or color.

Aggregate

According to Gorman, the quality and size of aggregates and sand affect the quality and performance of CP and the skills required for application. Aggregate should be consistent in its gradation, clean and free from organic materials, and free from clay, loam and fines. Consistent gradation is important because the voids remaining after all sand particles have assumed their final position will be filled with portland cement paste. The best matrix is obtained when the sand grain particles are almost in contact with each other and the remaining voids are filled with cement paste. The volume of void space can be measured in the laboratory. The gradation of aggregate can also be measured by numerous tests.

Flashing

Flashing is usually constructed of metal or self adhesive membranes and is used to redirect water away from the building cladding, to building exteriors. Flashing is vital to the longevity of the plaster substrate and the prevention of water seepage into the building. Flashings must be designed and installed so that water getting behind the plaster will be channeled downward and outward towards the exterior of the building. Retention of water within the wall will result in deterioration of paper, rot, biological growth, mechanical decomposition of the CP and other problems. This could lead to rusting of any metal lathing fasteners and flashing and penetration of water into the building. Water collected within the CP my also lead to disruptive expansion and deterioration of the plaster in a freeze-thaw environment.

Admixtures

Admixtures are special chemicals or other materials other than water, aggregate, portland cement that add necessary and desirable qualities to the finished product. Admixtures are used to entrain air, accelerating the rate of cure, prevent freezing, repel water, increase the adhesion or cohesion, increase tensile strength or act as a color pigment. Admixtures can include acrylic materials and synthetic or natural fibers.

Bases

CP can be applied to a wide array of bases, including brick, concrete or concrete blocks. Special means of adhesion apply.

Use as a substrate

CP can be used in a wide variety of application of other topping materials such as ceramic tile or brick veneer. Each time CP is used as a substrate, special conditions of use or application must be followed.

CONVENTIONAL DESIGN DETAILS

Typical design details – what the designer should include

1. Don't rely on building paper as a means of waterproofing. Typical methods of handling this detail can be seen in Drawings 1 and 2 attached.
2. Design all flashings, openings and intersection to disallow water intrusion through plaster. Typical methods of handling this detail can be seen in Drawings 3 through 7 attached.
3. Terminate edges of CP with flexible sealant joints where movement is expected, and at large openings. Typical methods of handling this detail can be seen in Drawings 8 and 9 attached.

Mix design of material

1. Acrylic admixtures improve hydration and reduce cracking
2. Polypropylene and polyethylene fibers reduce cracking by increasing CP's tensile strength
3. Reducing water by adding plasticizers reduces shrinkage cracks.

Underlayment design for waterproofing

1. Use rot resistant materials such as breathable polypropylene materials (such as Dupont Stucco Wrap).
2. Seal penetrations and openings with self adhesive type flashings such as Ice and Water Shield. Typical methods of handling this detail can be seen in Drawing 10 attached.

Weep design

1. Stucco is an imperfect barrier system.
2. Despite good mix design, admixtures and proper flashing design, some cracks will occur and water will penetrate
3. Allow for incidental water to weep out. Typical methods of handling this detail can be seen in Drawings 11 and 12, attached.
4. Flash weep screeds with self adhered flashings. Typical methods of handling this detail can be seen in Drawing 13, attached.

Lathing Design and application including sheer walls

1. Fasten lath on studs, 6" on center. Typical methods of handling this detail can be found in Drawing 14, attached.
2. Perimeter flashing is critical in shear wall application
3. Expanded metal lath is better than wire mesh
4. Furring fasteners are better than self furring lath.

Application techniques

1. Spray applied base coats creates difficulties in controlling thickness and lath furring.
2. Troweling allows CP to be worked into expanded metal lath.
3. Cure time: 24 to 48 hours between scratch and brown coats, 14 days between brown and finish coats.
4. Moisture cure reduces shrinkage cracks.

Metal vs. Wood framing

1. Metal framing is more flexible than wood.
2. Metal framed buildings have more thermal movement.
3. Make sure building flexibility is maximum L/360.
4. Use solid sheathing where possible, especially over metal studs.
5. Screws and too many fasteners can prevent furring of lath at studs.

Plaster Stops and Accessories

1. Use expansion at floor level.
2. Reveal Intersections – how they are sealed, soldered or welded, is important.
3. Different types of weep screeds are available in the market.
4. Use corner aids.

Perimeter conditions including nailing

1. Follow the ASTM standards – See Drawing 14 attached.
2. Field Monitor the construction.

APPLICATION METHODS

According to the Uniform Building Code, Section 2508, CP shall not be less than three coats when applied over metal lath or wire fabric lath and shall not be less than two coats when applied over masonry, concrete or gypsum backing.

CP can be applied either by hand or machine to the thickness specified in Table 1 ASTM Standard C926-98a, and Table 25-F of the Uniform Building Code, and embedded within metal lath as required, to a depth of at least ¼ inch. Each coat must be applied to an entire wall or panel without interruption to avoid or preferably eliminate cold joints and abrupt changes. This will assure uniformity of application and continuity of thickness and structural strength. Wet plaster should abut set plaster only at naturally occurring interruptions in the plane of the plaster, such as corners aids and stucco stops. Joinings where necessary shall be cut square and straight, also in accordance with ASTM C926-98A.

The first coat, or scratch coat, should be applied with sufficient material and pressure to form full keys through, and to embed the metal base. This is especially important when dealing with expanded metal lath because the openings are so small that plaster does not key-in with spray application. There shall be sufficient thickness of material over the metal to also allow for scoring the surface. In our experience, lack of following this methodology is one of the leading causes of CP cracking and failure. We have noticed in our forensic investigations a significant change in the craftsmanship of work crews in the last ten years, such that the CP is not always properly embedded within the metal lath, and often is not embedded at all.

After the first coat has reached sufficient stiffness (usually 24 hours), the second or brown coat shall be applied with sufficient material and pressure to ensure tight contact with the first coat and to bring the combined thickness in line with ASTM C926-98a. This is another area where we have seen problems occurring – not allowing enough cure time and not providing moist cure. Between the brown coat and finish coat, ASTM C926-98a also recommends 14 days cure time. Long cure time and moisture cure improve strength and decreases shrinkage.

It is not the purpose of this paper to discuss the finite details of cure time, as this is more adequately discussed in ASTM C926-98a that indicates that the timing between coats will vary with climatic conditions and types of underlying base material. In general, cold or wet weather lengthens and hot or dry weather shortens the cure time. We strongly recommend that the CP be water fog moistened at least once and perhaps twice a day.

The Uniform Building Code, 1997 edition calls for a minimum of 48 hours between the first and second coat and a minimum of seven days between the second and finish coat. We generally like to see longer periods of time between brown and finish coats, with application of a water fog each day. However between scratch and brown coats we have had good success with cure time of 24 hours or as long as it takes for scratch coat to stiffen prior to base coat application. Following these techniques will improve strength adhesion and reduce cracks during

NON-CONVENTIONAL DESIGN ISSUES

EIFS

Exterior Insulation Finish Systems (EIFS) is relatively new to the United States. EIFS was originally developed and used throughout Europe as aesthetic improvements to older and war damaged buildings. They were used as an exterior cladding over masonry and concrete walls. Conventional EIFS has no back up such as building paper and self adhered flashing, and is therefore more prone to damage due to water intrusion.

THE MOST COMMON MODES OF FAILURE

In our experience on the west Coast, cracking and failure of CP is caused primarily because of:

Mix design:

Not following proper mix design leads to problems such as lack of water, rapid drying due to lack of hydrating agents in hot climates, improper gradation of aggregate and poor quality control, will lead to failure.

Improper installation of lathing

This is a relatively common, but not often reported, means of failure in CP. Lathing must be properly nailed to ASTM standards, furred, not stretched too tightly, not over fastened and not under fastened. The type of lath is also important, because in our experience expanded metal lath provides the best reinforcing, provided the scratch coat is worked-in with a trowel.

Improper curing

In rapid, piece work construction, there is often not enough time for curing between the various coats. Wet cure or fog cure helps in proper hydration of cement and reduces shrinkage cracks.

Wall flexibility

Inability to distribute load properly during seismic and other activity

If the wall flexes too much during seismic, wind or thermal loads, it causes cracking in CP and subsequent water intrusion (CP requires a "breathable" paper such as grade "D"). Paper longevity is measured by ASTM standards such as 20 minute and 60 minute paper.

Improper underlayment

Improper application of paper, i.e. reverse lapping, holes, tears, etc., improper or lack of flexible self adhering flashings.

Water

Intrusion caused by improper flashing of wall penetrations and opening such as pipes, windows and doors, large cracks, improper termination.

Stains

Aesthetic issues such as staining caused by moisture absorption, mold, chimney soot patching, coating/painting

CASE STUDY 1 Major Medical Center

Allana-Lippert Inc. was retained by a major medical center in California to perform a building condition survey as related to moisture intrusion, condensation, sub-slab water intrusion, roof leaks chilled water condensation and subsequent development of mold. There had been reports of mold on the interior face of some exterior walls and pipe wrap insulation in the ceiling space. Condensation and wet insulation was also reported on the underside of the roof deck. There were reports of roof leaks and possible wall leaks. The case study as presented here only focuses on the water intrusion through the exterior walls of the building. This case study also includes a review of the methodology of data gathering, review of available drawings, field observations and destructive and water testing employed in the project.

EXECUTIVE SUMMARY

Our observation and testing shows that several components of the building envelope were allowing water to enter the building, elevating the levels of humidity. The water intrusion was occurring mainly through exterior cement plaster (stucco) and brick veneer. Water intrusion was also occurring through the roof metal coping, augmenting the stucco leaks at the exterior wall cavity. The exterior stucco and brick veneer was failing due to improper attachment of the stucco lath, which had caused excessive movement of the stucco, leading to large cracks and twisting and severe deformation of stucco expansion screeds and stops.

CONDENSATION:

Water intrusion through the exterior wall also led to higher than normal humidity levels in the building, increasing the condensation buildup on the chilled water lines and also causing condensation between the exterior wall and vinyl wall covering.

Some of the interior faces of the exterior walls were covered with vinyl wall covering. Vinyl is a vapor barrier and does not allow moisture to permeate through it. We observed that in isolated areas, mold was forming on some surfaces between the vinyl and sheetrock due to condensation.

SOLUTION:

To correct the leaks through the stucco and brick, the entire exterior skin of the building will need to be torn out and re-done. The exterior wall can be reinstalled with new stucco and mortar bed/thin-set brick similar to existing construction or Exterior Insulation and Finish System (EIFS).

METHODOLOGY OF SURVEY:

Our firm initiated this project with a review of project drawings and a cursory inspection of all 3rd floor rooms. Drawings were reviewed in order to become familiar with construction details and areas of potential concern. We also performed a visual inspection of all the exterior façade of the building. We also performed destructive testing of the cement plaster system, mortar bed and brick veneer, and interior portions of the exterior wall. In addition, we performed water testing of the exterior wall to ascertain and pinpoint the specific point of the source of leaks.

During the course of the investigation, we directed air quality samples of all three floors of the building and potential mold sampling of the interior sheet rock from the exterior walls.

INVESTIGATION:

Allana – Lippert performed both visual and intrusive analysis of certain components of the building to ascertain information and make recommendations. The areas included in this case study include:

1. **Interior/Exterior Construction**
2. **Investigation of Stucco and Brick Veneer and storefronts**
3. **Humidity levels and Condensation**
4. **Laboratory Analysis of Building Components**
5. **Discussion with Various Personnel**

1. Interior/Exterior Construction

The building is a three story metal framed structure with 15/16" cement plaster over lath and paper over gypsum sheathing over 18 Gauge steel studs 16" on center. The studs span anywhere from 11 feet to 13 feet, from floor to floor or floor to roof. According to the structural drawings, the wind loads for this project are assumed to be 15 lbs per square foot under 30 feet and 20 lbs per square foot over 30 feet high. At 15 lbs wind loading, studs spanning 11', the deflection of the studs is L/360, which is within acceptable tolerance for stucco. At 20 lbs wind loading and 13 feet on center (Roof to floor) the deflection is greater than

L/240, which is more than the minimum required for stucco. Portions of the exterior wall consist of ¾" mortar bed with ¼" brick veneer in lieu of cement plaster. For thin set brick or tile over mortar bed, manufacturers require a maximum deflection of L/480, which the existing construction does not have. The windows are storefront style operable and non-operable windows with a sealant joint between the mullions and stucco stop. Windows do not have the traditional "fin" used with cement plaster type construction.

Interior finish materials include textured and painted sheetrock and vinyl wall covering, carpeting and vinyl flooring.

2. Investigation of Stucco and Brick Veneer & Exterior Storefronts

The stucco and brick veneer were closely observed and tested on a large section of the south side of the building. With the use of scaffolding we were able to conduct both water tests and intrusive analysis. We were also able to have the interior sheet rock removed on the 3rd floor exterior wall to observe the water damage and mold, water intrusion during testing and sheathing and lath fastening pattern.

Water testing was carefully conducted by masking off portions of the wall to enable us to isolate the various components of the wall. Water tests were conducted with an AAMA 501 nozzle to simulate heavy rain and provide quick results. We started the tests at the low point and moved up until leaks were observed. With water testing we were able create several leaks at stucco expansion joints between stucco and brick panels and in the field of the stucco where we observed extensive cracking had occurred.

During intrusive testing it was observed and determined that the expanded metal lath for both stucco and mortar (for brick veneer) were very poorly attached to framing members. In most areas (more than 90%) the fasteners for the lath were only screwed through gypsum board sheathing and not the metal studs. The fasteners appeared to be installed horizontally 16" at head leaps in the lath; no fasteners were installed vertically on studs. Industry standard practice requires fasteners vertically on studs 6" on center, for studs that are 16" on center. This lack of proper fastening had allowed excessive movement of the stucco and mortar and subsequently had distorted and bent the horizontal and vertical expansion joints and has resulted in very wide cracks in the stucco. Mainly the movement in the exterior skin appeared to be occurring due to thermal changes. We observed that while the entire building is fastened poorly, the south and west exposures are in much worse condition than the north and east exposure due to the sun.

We also observed that the expansion reveal used for this project is a two-piece and the two pieces are overlapped incorrectly and the overlap is only 1/8". We also observed that the architect had detailed two horizontal metal studs 1" apart at the reveal joints so that the lath and expansion joint could be fastened properly. These horizontal studs were omitted in the actual construction. These main factors have combined to distort and damage the reveal and expansion joints and create large cracks in the stucco.

We also observed that the window/storefront frames did not have backer rod installed in conjunction with the sealants and therefore have failed in several areas.

3. Humidity Levels and Condensation.

Humidity levels throughout the building were checked with a "Psychro-Dyne" wet/dry bulb gauge and found to be 34% at the first floor laundry room; 32% at the first floor lobby; 42% at the 2nd floor exercise room (south side of building) and 36% in the 2nd floor patient lounge. These readings at these areas were not outside the range of typical levels expected however, we do not know the humidity levels when it was occupied and during the winter rainy periods.

Condensation: Condensation behind the vinyl would likely occur in the fall/spring climate, during the cooling cycle when the interior temperatures are low and exterior wall cavity is saturated due to wall leaks, sun heats up the wet exterior wall cavity creating a plume of humidity. However, condensation in the chilled water lines could likely occur anytime during the year when the chilled water lines are circulating and interior humidity levels are high enough. The ceiling/roof assembly does not have a vapor barrier on the warm side and is susceptible to condensation forming during periods of low exterior temperature and high interior humidity. Condensation in the ceiling would likely only occur in the winter, when the roof deck is cold and interior humidity levels are high.

4. Laboratory Analysis of Building Components

Several samples of building drywall, insulation and air were collected for testing for mold. Elevated levels of mold were found in the interior air samples on the 3rd floor which resulted in shutting down and evacuating the entire floor.

5. Discussions with Associated Personnel

Throughout the course of the investigation, Allana – Lippert had several conversations with people involved with this project. The information obtained from these people was used in the preparation of this case study.

CONCLUSIONS AND RECOMMENDATIONS

The building is exhibiting excessive leaking and interior moisture levels due to deficient construction of the exterior skin. Building stucco and brick veneers are moving excessively due to inadequate attachment and poor flashings.

Long-term corrections may include some or all of the following:

a) Replacement of all stucco and brick veneers to correct inadequate attachment
b) Depending on laboratory results, partial replacement of interior drywall

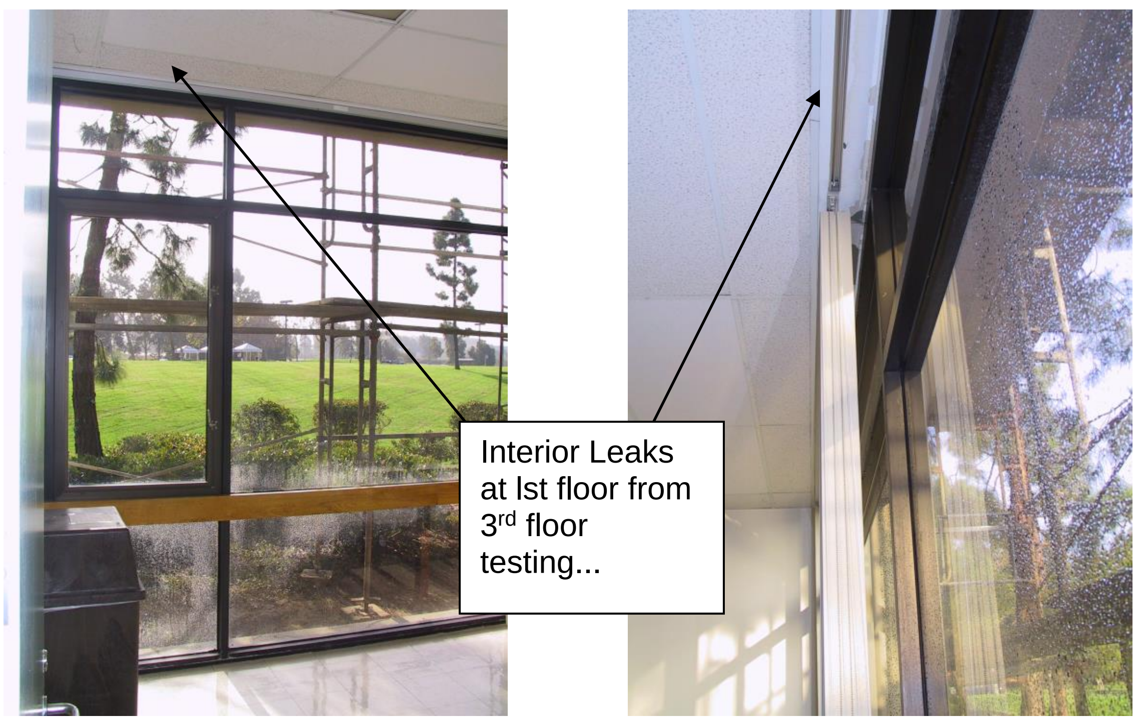
Allana-Lippert designed a hydrid CP system with stucco wrap, flexible flashings, traditional scratch and brown coats. However for the finish coat, we designed a highly flexible slam coat to bridge over potential cracks due to higher flexibility of the wall.

For the thin set tile, we specified a traditional 2 coat mortar bed ¾" thick, an antifracture membrane and a flexible thin set adhesive with a shear bond strength exceeding 500 psi. The antifracture membrane aids in isolating and bridging cracks in mortar bid and flexible thin set mortar allows for a little more flexibility.

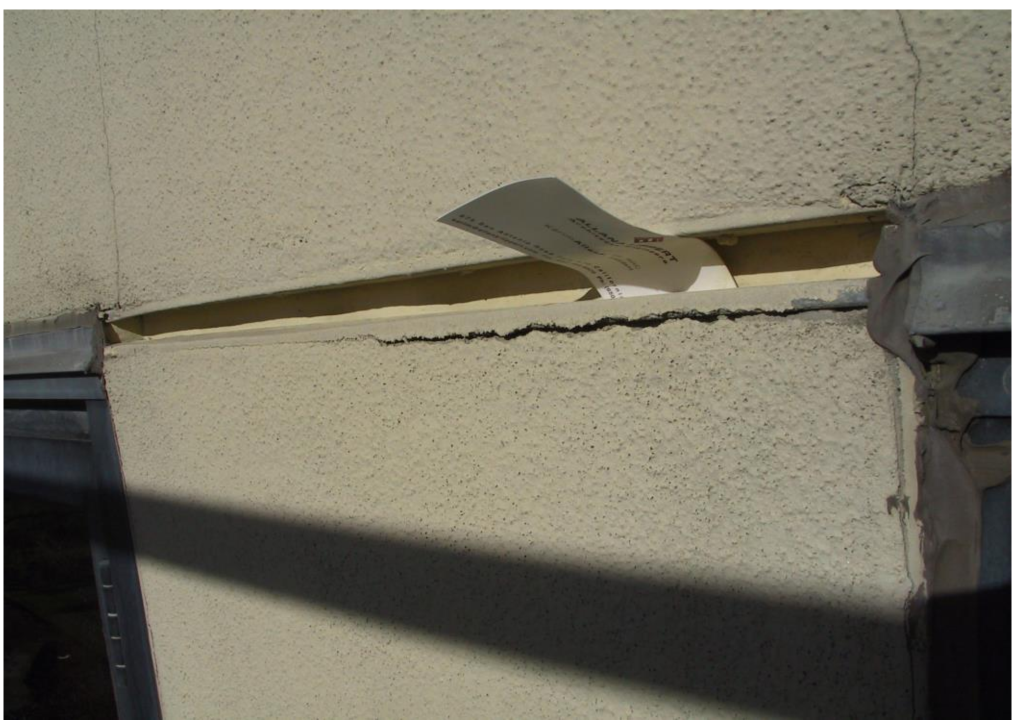
BUDGETS AND COST ESTIMATES

Budget and cost estimates are being developed.

TOP: Water testing and destructive testing of the exterior wall was conducted on the south side of the building. The area selected for testing included, brick veneer, cement plaster and typical windows. **BOTTOM:** Water sprayed on third floor leaked through storefront head condition on 1st floor. Water intrusion through the exterior wall is traveling through 3 floors in the wall cavity.



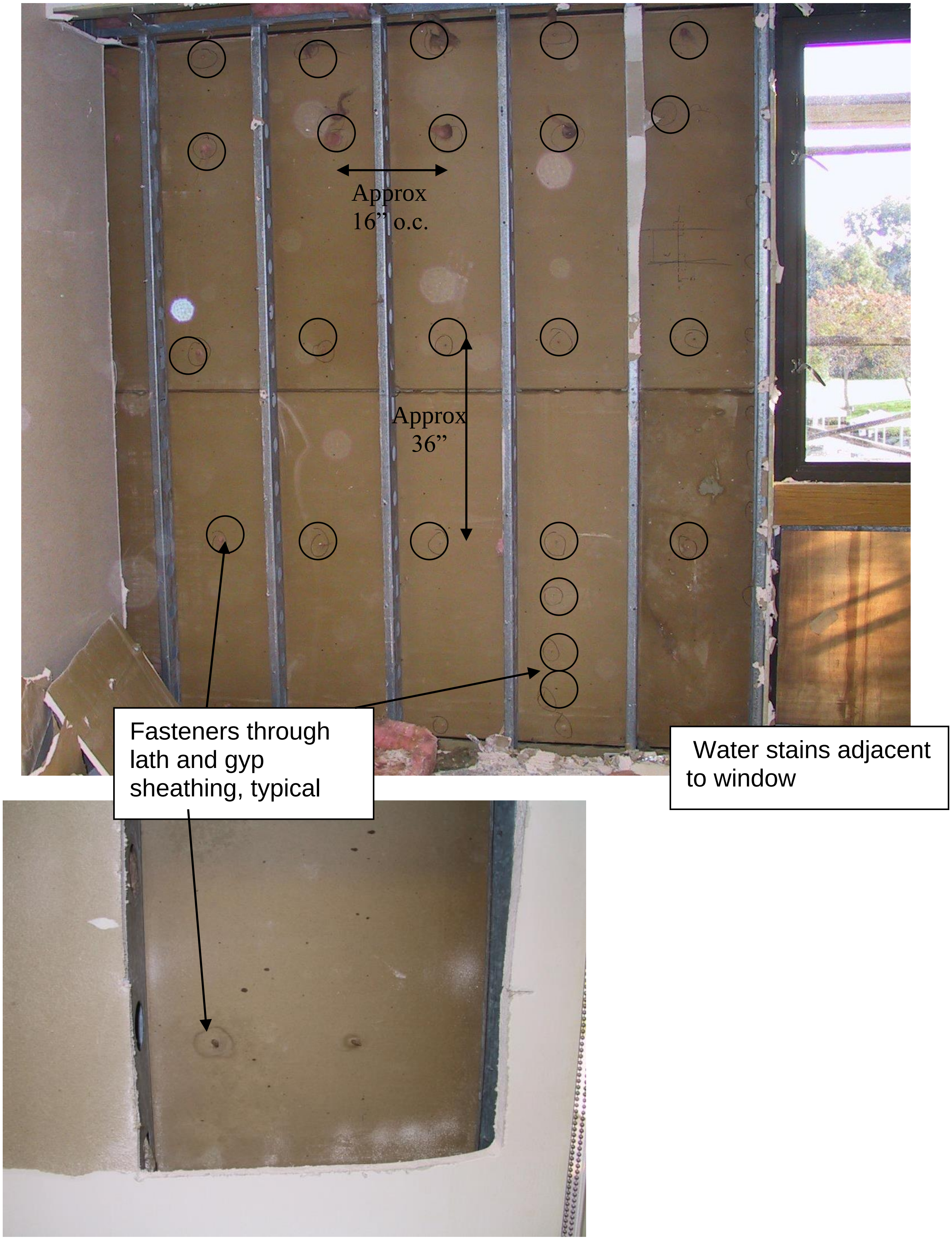
TOP: Stucco/Mortar expansion screeds are twisted and distorted due to movement
BOTTOM: Large cracks at expansion joint. Also, this type of expansion joint collects water and directs it at the sides causing water to leak down the sides.



TOP: This 2 piece expansion joint has a very small overlap between the top and bottom piece. Wind driven rain can direct water behind the joint.
BOTTOM: Exploded view of the two-piece expansion screed.

TOP: The vertical stucco expansion joint has split in fatigue, due to cyclical movement back and forth movement.

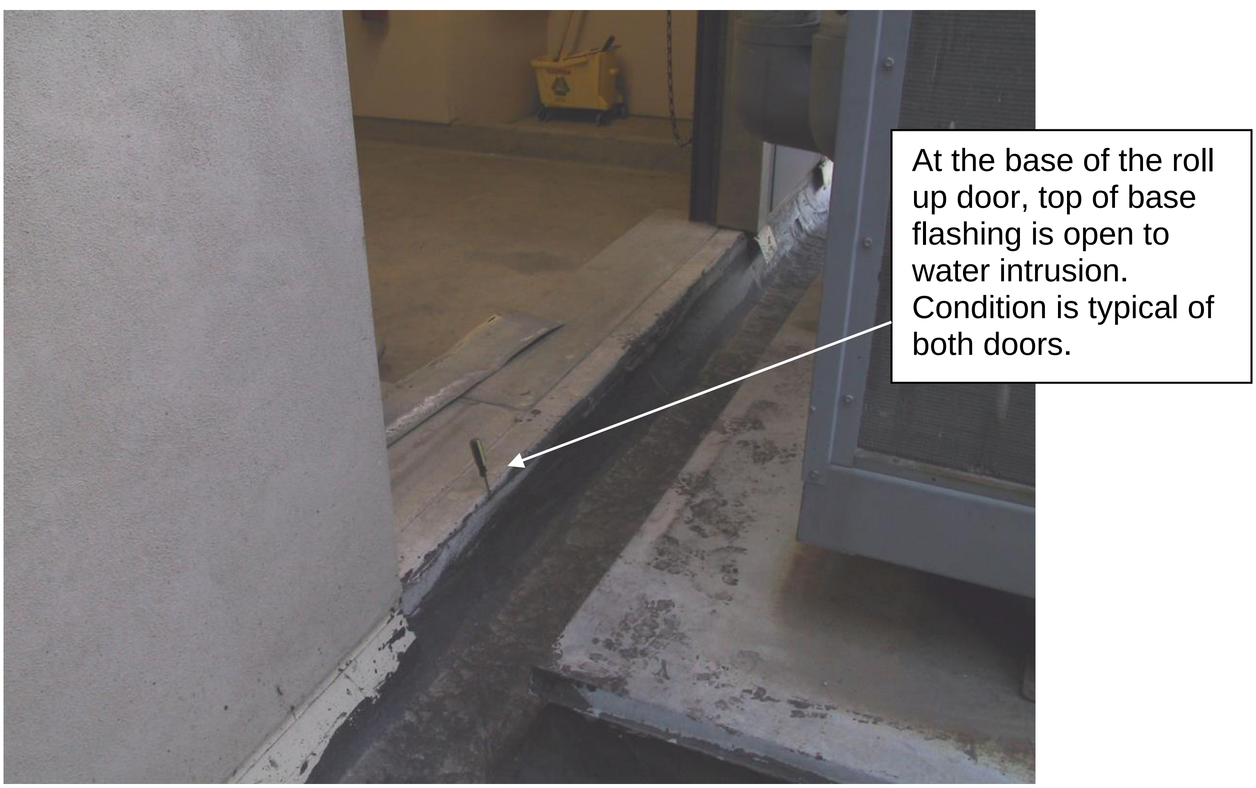
BOTTOM: Surface of the stucco is cracked throughout. Cracks range from 10 mils to 50 mils (over ¼" thick). This level and type of cracking is not typical.


Approx
16" o.c.
Approx
36"
Fasteners through lath and gyp sheathing, typical
Water stains adjacent to window

TOP & BOTTOM: Typical exterior wall framing, 18 gauge metal studs 16” on center, spot-welded to steel framing at each floor. Since the exterior wall framing is continuous from floor to floor, water can travel down the exterior wall cavity from 3rd to 1st floor.

TOP: Roof parapet Coping to wall intersection has no saddle. This condition is leaking in room 314 below. **BELOW:** Edge condition at penthouse, sheet metal coping does not counterflash the stucco adequately.

TOP: Configuration of typical metal coping at roof parapet wall. The overlap between the top and bottom piece is only ½”, which is not adequate to prevent wind driven rain penetration. There is also no secondary protection under the sheet metal.



CASE STUDY 2 Private Residence

BACKGROUND:

Allana-Lippert, Inc. was retained by the owners, to evaluate the conditions of building envelope components at a private residence in California. This case study is based on visual observations, destructive testing, review of existing construction documents, review of the project during reconstruction and review of photographs and historic information provided by the owners. Although there were other problems with the building, this case study only provides a review of the cement plaster, exterior CP ornamentation and balconies, and exterior sheet metal flashings.

LEAK HISTORY

Leaks were found in many locations in the house, including the master bedroom closet, the laundry room, an upstairs mechanical room and the pool house, where leaks were found throughout that building. When the destructive testing was completed and during reconstruction work, a significant number of damaged walls, parapets and balconies were discovered.

There was a lack of appropriate construction details at the top of the parapet wall surrounding the residence. Cap flashings and copings there and elsewhere were improperly installed. These conditions were also present at the chimney. This allowed water to get behind the CP at many locations and create significant damage to the plywood sheer wall and other wooden components of the building structure.

Counterflashing had been improperly installed on most of the cement plaster walls. There is also no counter flashing above the base flashing. The ornamental stucco band around the top of the building was improperly installed, and lacked slope and good water proofing practices.

Ornamental ballistrades were improperly installed in many locations, especially the top of the balcony. Water seeped through the bottom of the ballistrades and created water damage to the balcony rail wall.

In the pool building, roofing was applied over the "L" flashing, with no counterflashing. In standard CP installation, the base of stucco requires a counterflashing. In addition, the gutter was installed before the stucco and the plaster was applied around the gutter. As a result, plaster was missing where the gutter meets the wall. The gutter was removed, shortened, end capped and plaster patched.

CEMENT PLASTER INSTALLATION

The exterior wall surfaces were cement plaster construction, consisting of grade "D" building paper and lath over shear plywood (or open studs), with scratch, brown and an integral color finish coat. Based on visual observation of some of the exterior walls, the following deficiencies were noted:

Water appeared to be penetrating behind the cement plaster in various areas. This was evidenced by darkening of the plaster in various areas due to water penetration during rains. Also visible were rust stains in hairline cracks in plaster, which resulted from water intrusion, plaster was poorly terminated to the ballistrades and around window openings.

Weep screed was missing or blocked on roof level at chimneys. There were no receiver flashings in exterior wall penetrations through stucco. This condition is present at, roof parapet coping, overflow drain penetration, and kitchen duct penetration through plaster.

Our destructive testing revealed there was no adequate flashing at stucco cornices/bands. Although building paper has been wrapped over the wood which created the ornamental stucco bands, it is inadequate at horizontal surface of plaster and resulted in water intrusion, as shown in the photos. The self-furring lath appears to have been poorly fastened (too tight); as a result it is not furred properly. In many areas, the lath does not have minimum 1/4" coverage. There is only one layer of building paper at shear wall; the Building Code requires two plies.

CONCLUSION

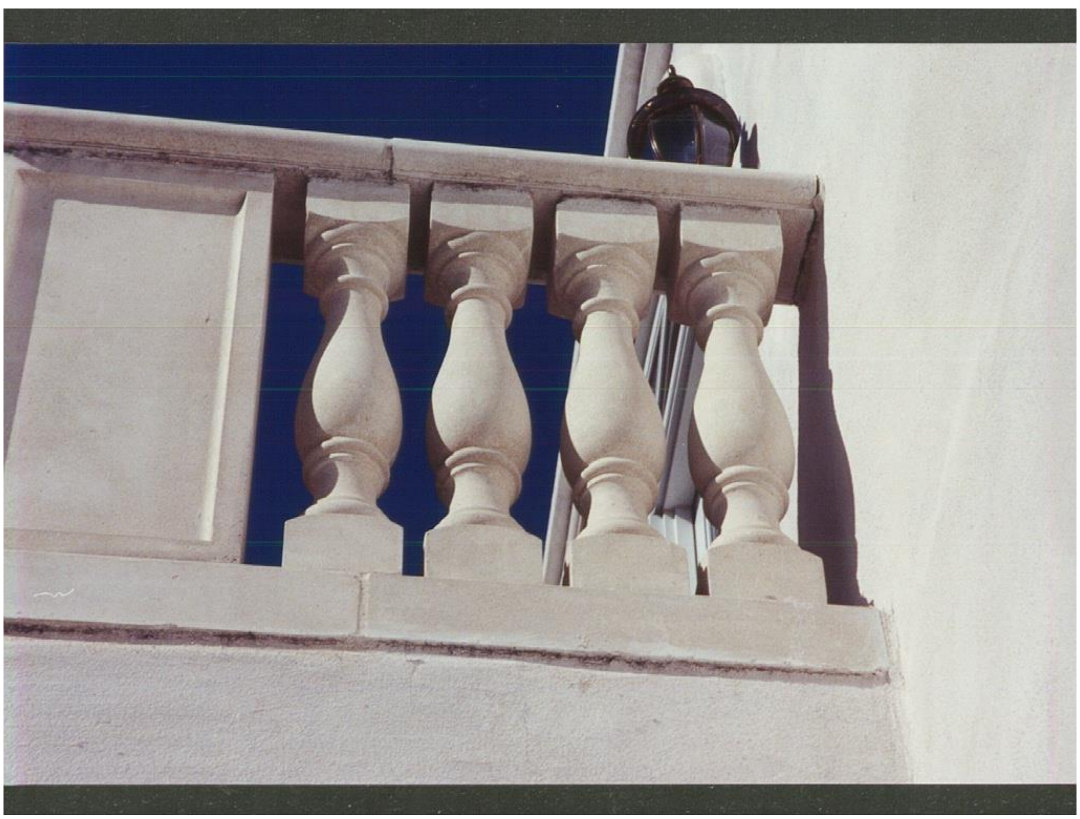
Due to the deficiencies we uncovered during our investigation we recommended to the owner that all the stucco be removed and reinstalled with proper underlayments, flashings and terminations.

Exterior view of residence prior to destructive testing. Note balcony, stucco band, and windows

Stucco band and CP, prior to destructive testing and stucco removal.

prior to testing and stucco removal.

Main source for water intrusion



Leaks through balcony created damage to wall and balcony.

Source of water intrusion below ornamental ballistrades.

Severe damage due to water intrusion at top of hand rail wall.

Severe damage to parapet walls due to lacking proper flashing.

Lack of cap flashing created problems at the hand rail wall.

Severe water damage behind stucco band due to improper design and application.

Improper transition from stucco to down spout. Detail lacks a receiver sleeve

Pipe thru stucco has no sleeve flashing.

Improper flashing at window.

Improper sealant and lack of transition at window

<u>CASE STUDY 3 – CP Used as Mortar Base for Ceramic Tile on An Office Building for a High Tech Firm</u>

Building exterior envelope failures can be much more complex than they first appear, as was discovered by a high tech company in Palo Alto, California. On one of its most important buildings that housing design engineers, serious adhesion problems were occurring with ceramic tiles used to clad the exterior fascade. We identified the underlying problem and recommend a fix.

The Problem

On this almost ten-year old building, ceramic tiles were apparently failing to adhere to the underlying sub-strate of CP which had been used as a bedding mortar applied to metal lath fixed to the steel stud walls of the metal framed building. Although the failure was random, it was very serious, as tiles were falling from many locations, including high up on the three story building, creating danger for pedestrians entering and leaving, and potentially exposing the interior of the building to water intrusion.

Upon first visual inspection, it appeared as if the problem was created by improper mix design, mix application and curing times of the cementitious thin set mortar used to adhere the tiles to the mortar base. The expensive Italian made porcelain tiles could be pulled away from the building by simple hand pressure, with almost no thin set mortar sticking to the backs of the tile. This led to the initial belief that the solution involved removal of the affected tile, applying new thin set to the tile and then reaffixing the tiles to the exterior.

The <u>Apparent</u> Solution

Prior to seeking professional engineering assistance, the high tech firm had removed about 300 square feet of ceramic tile and attempted to reapply it with its own maintenance forces, with mixed results. Five years then passed and more tiles continued to come loose from the building. Rather than just reapplying the tile, it was determined that that more investigation was necessary and the owners retained Allana–Lippert to perform forensic investigation and design a solution.

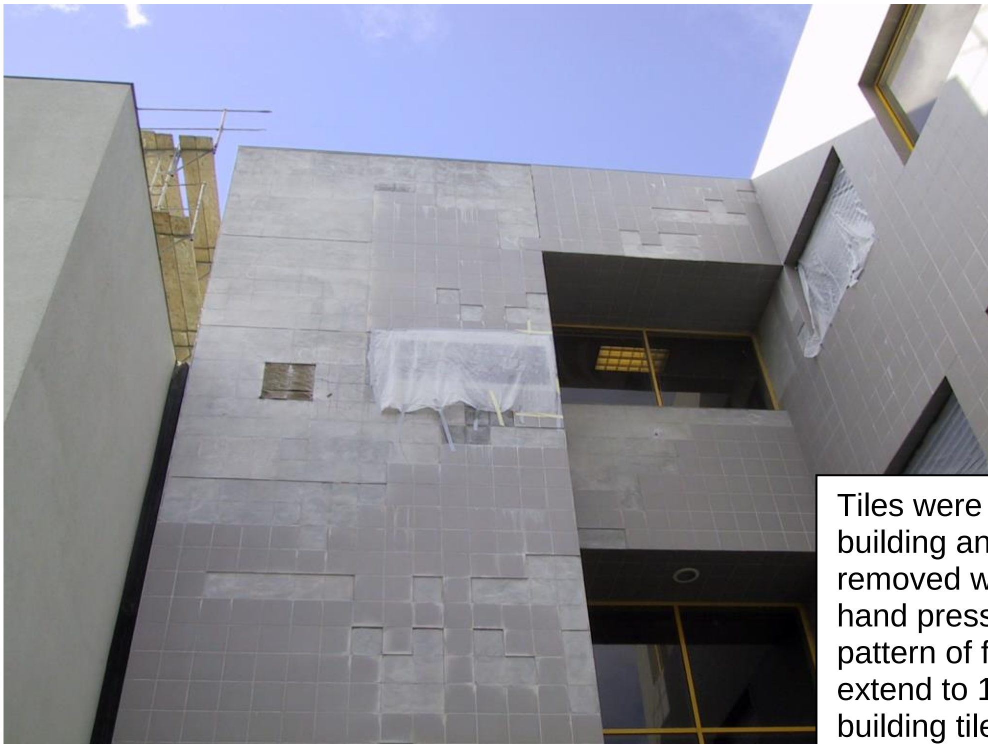
It was discovered that the original thin set mortar had been inappropriately designed and applied in some but not all areas. As originally believed by the client, the thin set mortar was allowed to dry prior to affixing the tile to the mortar bed and, the bedding mortar was allowed to skin before the tiles were set in place. The thin set trowel marks were evident, the tile was not “beaten” in place and the adhesive may have set prior to placement of tile.

Additional Root cause discovered

Upon destructive testing other more serious problems were discovered. The mortar base on the building was seriously cracked in a wide spread pattern. This was due to the improper design of the exterior metal studs which then lacked the proper rigidity. The constant flexing exceeded good design standards and caused the cracking to occur. In some locations, 18 GA studs 16" O.C. were spanning 22 feet. So, even in those areas where the mortar was properly mixed and applied, wide spread cracks in the mortar base had developed leading to shear bond failure of tile. We also discovered that liquid acrylic admixture was not used in the thin set adhesive which is essential for adhesion to porcelain tiles. It was determined that in order to repair this building effectively, we would have to completely remove all tiles, grind-off the old thin set adhesive, apply antifracture membrane and re-install the tiles.

New game plan

It was not feasible to stiffen the exterior metal studs to meet design specifications. This would have required shutting down this building and removal of the entire exterior skin. Instead, Allana – Lippert recommended an alternative solution to the client which included, removing existing tile; grinding off the existing thin set material, applying a base coat with fiberglass mesh reinforcement and a flexible finish coat. The finished project is over a year old and does not exhibit any visible hairline cracks. Since the problem had been discovered and properly "noticed" within the 10 year latent defect period, the original contractor and subcontractors shared most of the burden of the solution.



Tiles were falling from the building and could be removed with slight hand pressure – but the pattern of failure did not extend to 100% of the building tiles – and was random.

Cure time of thin set 1/4” notched trowel used for application of thin set motar is evident indicating the material may have skinned or set prior to placement of tile.

Tiles could be removed simply by hand – original thinset pattern over mortar base remained, with no adherence to removed tile.

Mortar base also displayed cracking. In this instance, use of non-acrylic admixture and lack of tile cleaning led to dis-bondment.

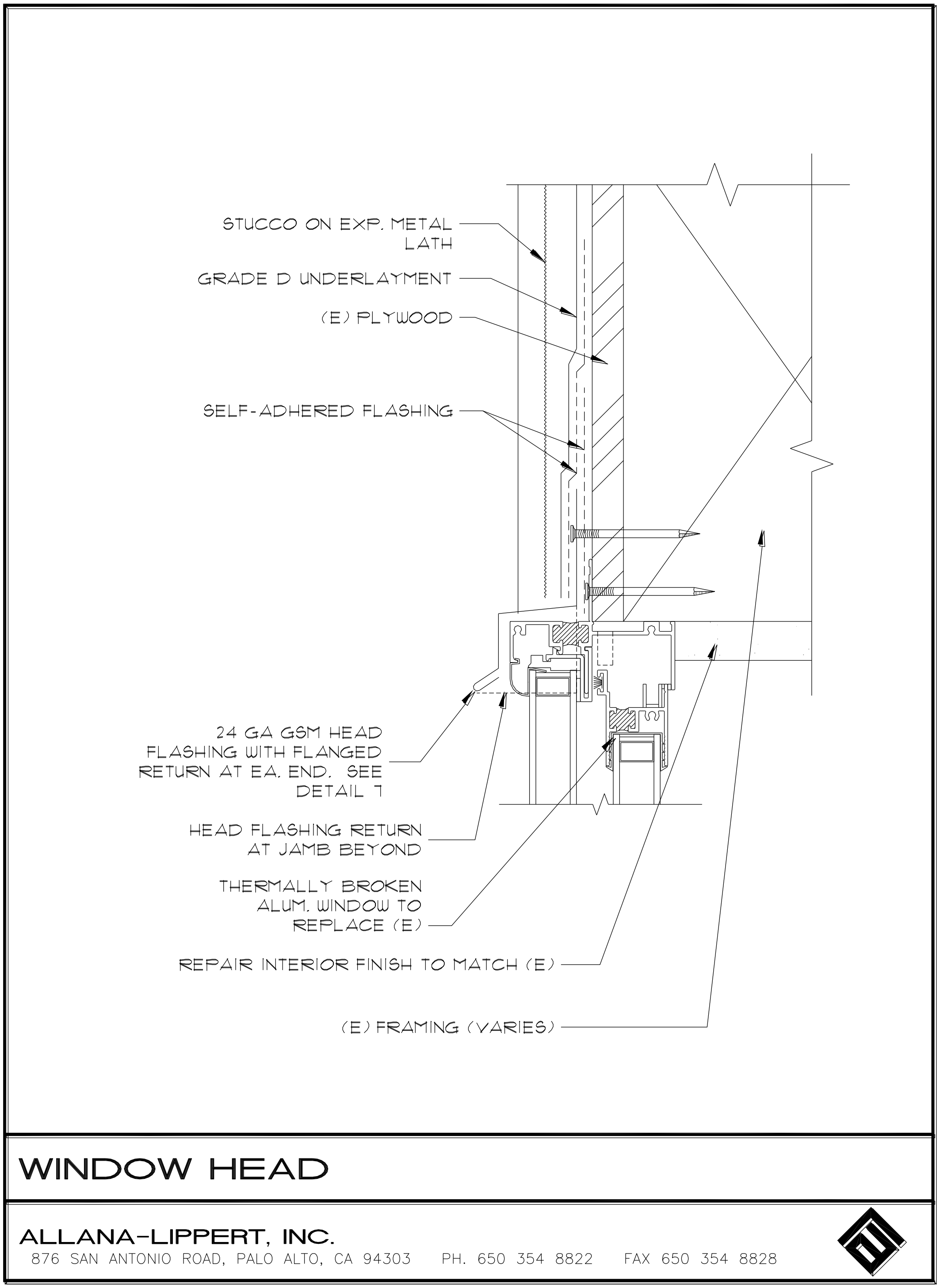

After complete tile removal, webbing embedded in first skim coat, followed by finish coats.
Tiles completely removed, some by hand, some by mechanical means.


The finished product.

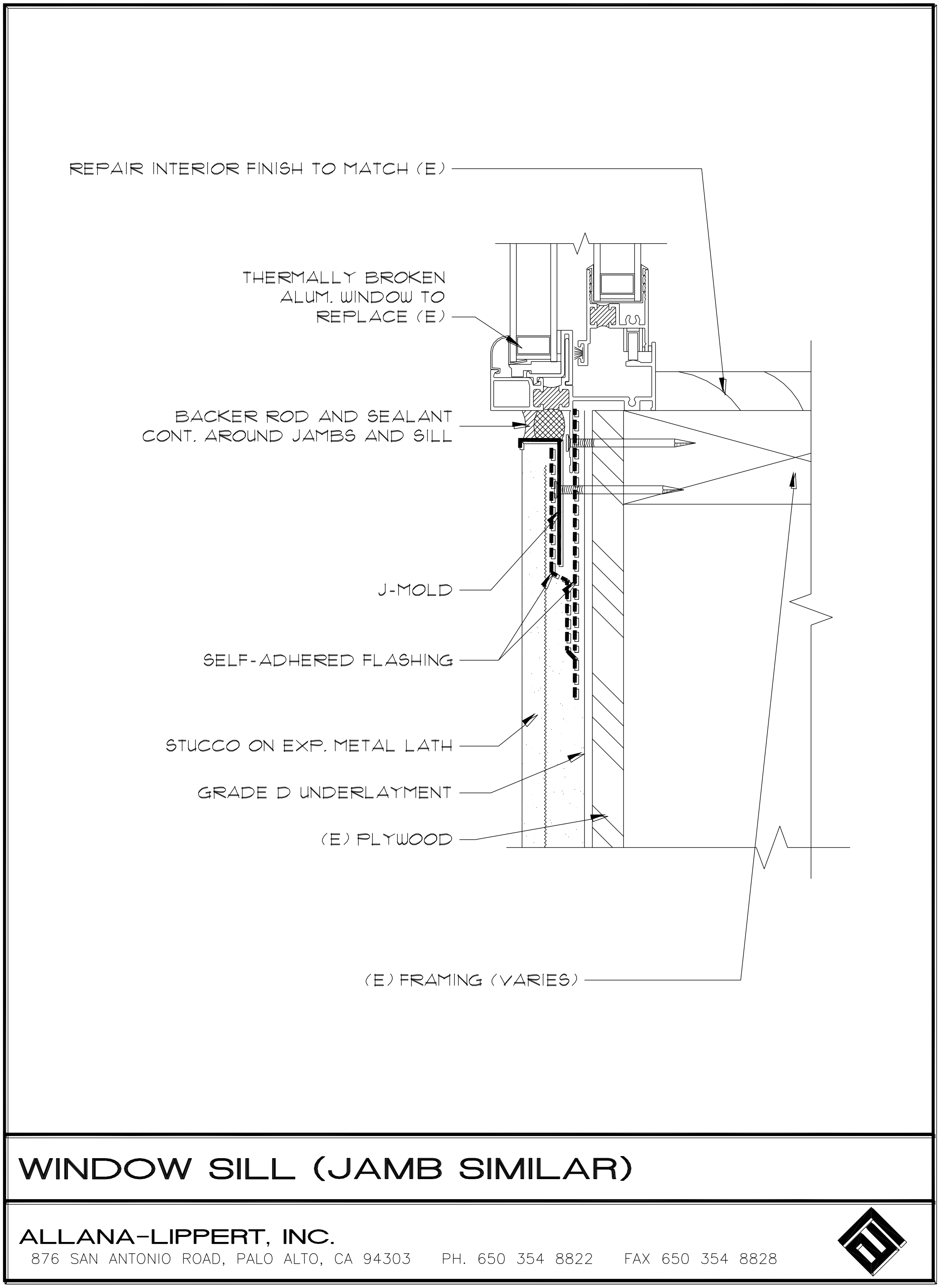
TYPICAL DETAILS

FOR

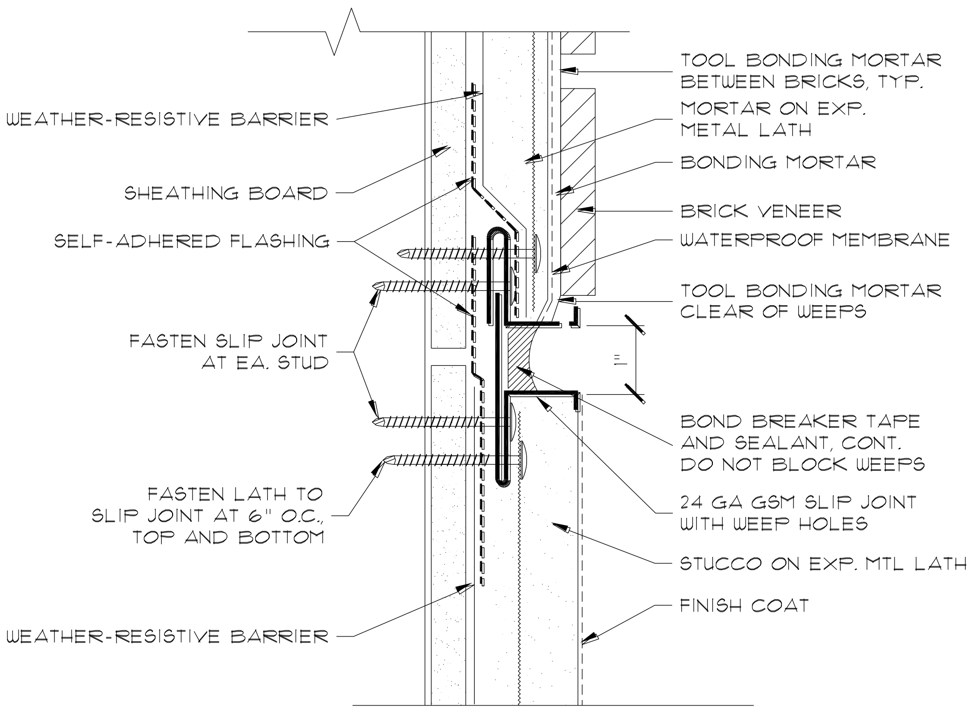
WATERPROOFING CEMENT PLASTER AND WINDOWS



DRAWING 1 – WINDOW HEAD



DRAWING 2 WINDOW SILL



NOTES:

1. HORIZONTAL 2-PIECE EXP. JOINTS ARE CONTINUOUS AROUND BUILDING.
2. VERTICAL EXP. JOINTS STOP AT HORIZONTAL EXP. JOINTS.

HORIZONTAL 2-PIECE EXP. JOINT

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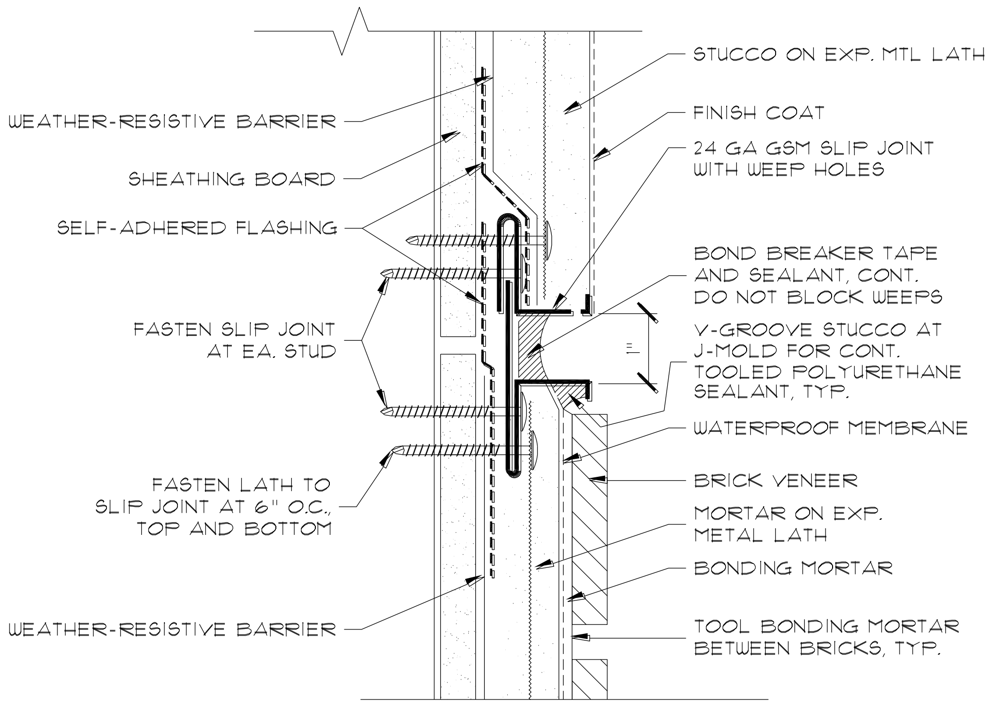
DRAWING 3 HORIZONTAL 2 PIECE EXPANSION JOINT
BRICK VENEER ABOVE EXPANSION JOINT



NOTES:

1. HORIZONTAL 2-PIECE EXP. JOINTS ARE CONTINUOUS AROUND BUILDING.
2. VERTICAL EXP. JOINTS STOP AT HORIZONTAL EXP. JOINTS.

HORIZONTAL 2-PIECE EXPANSION JOINT

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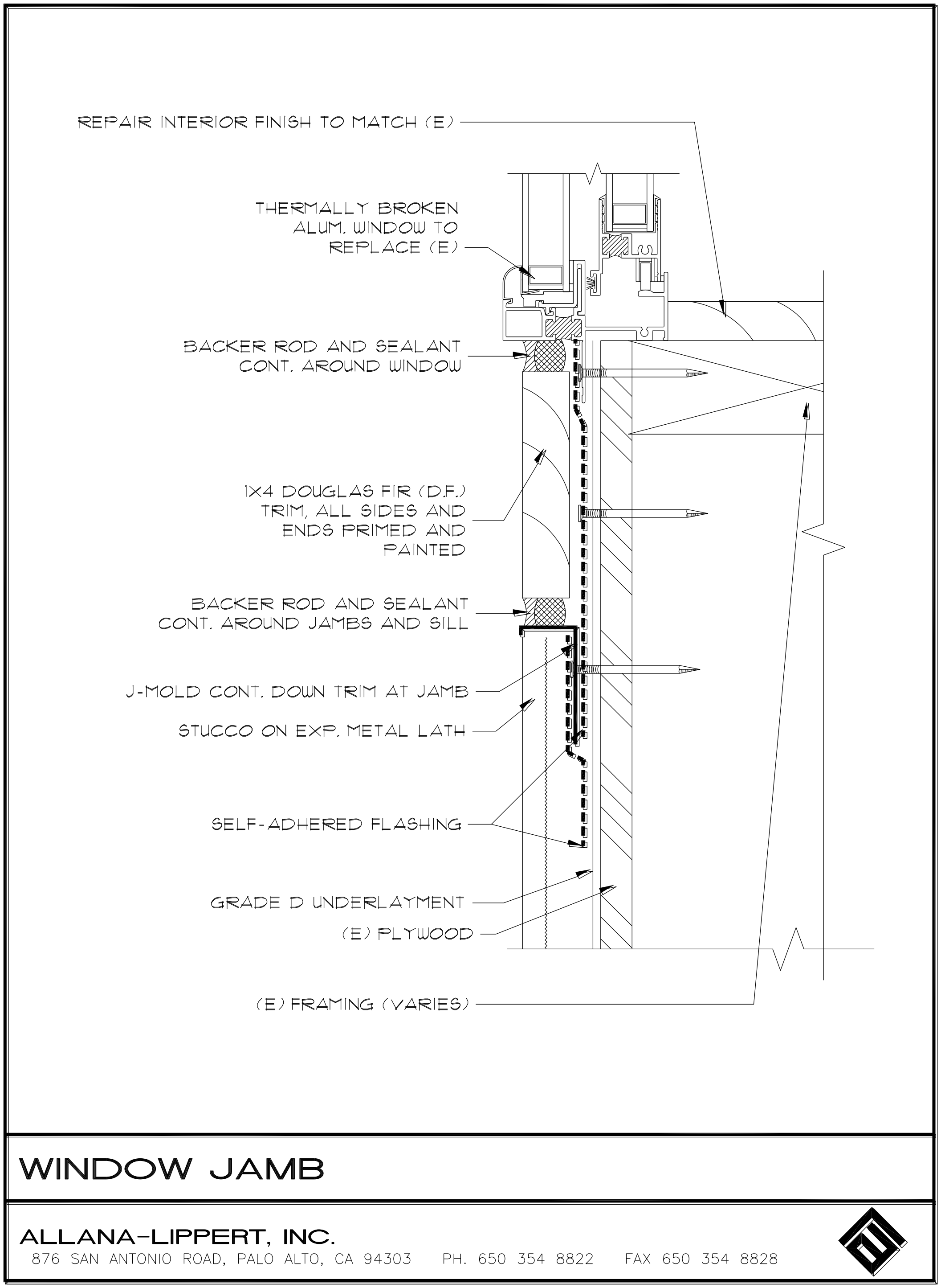
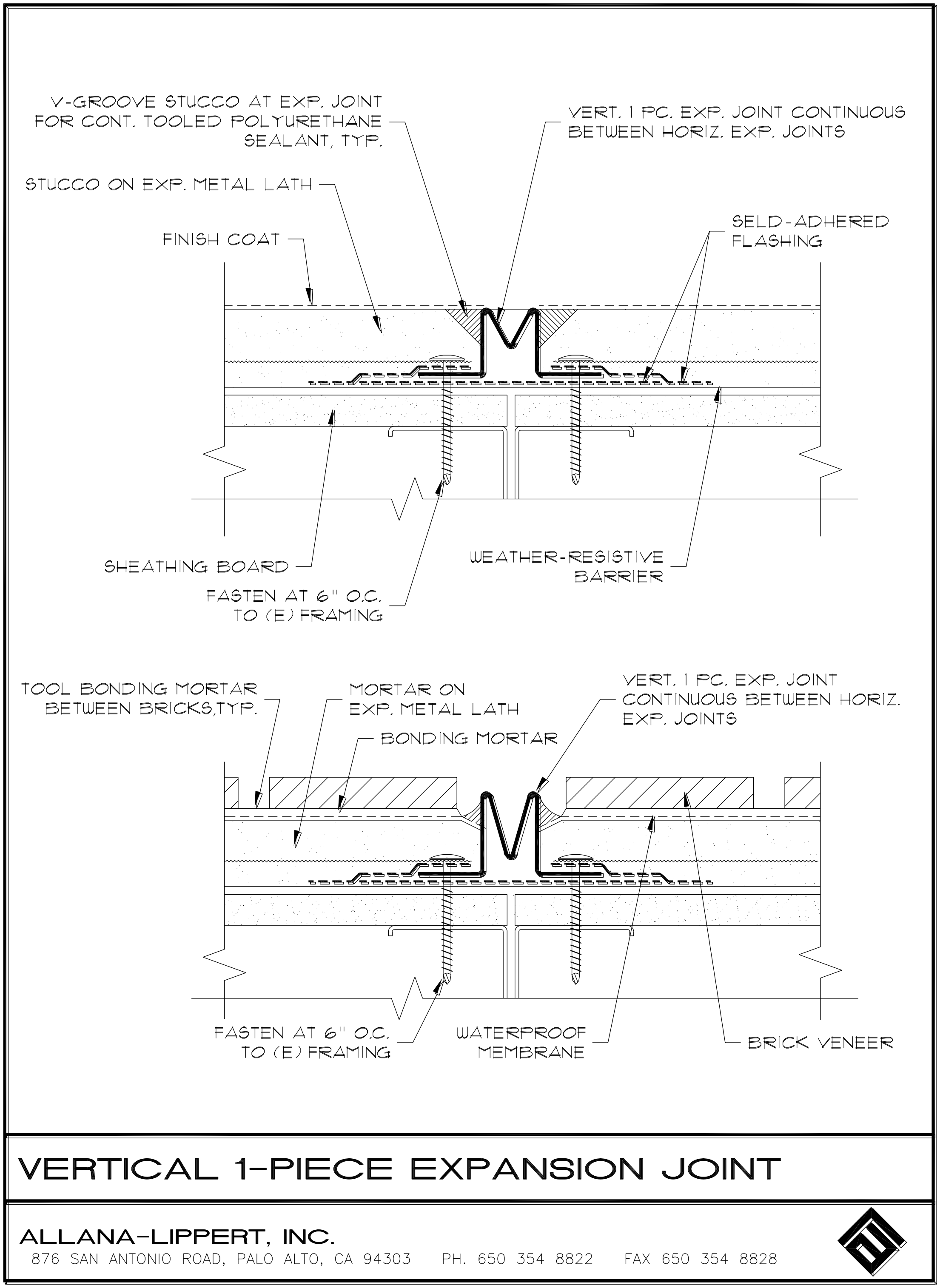
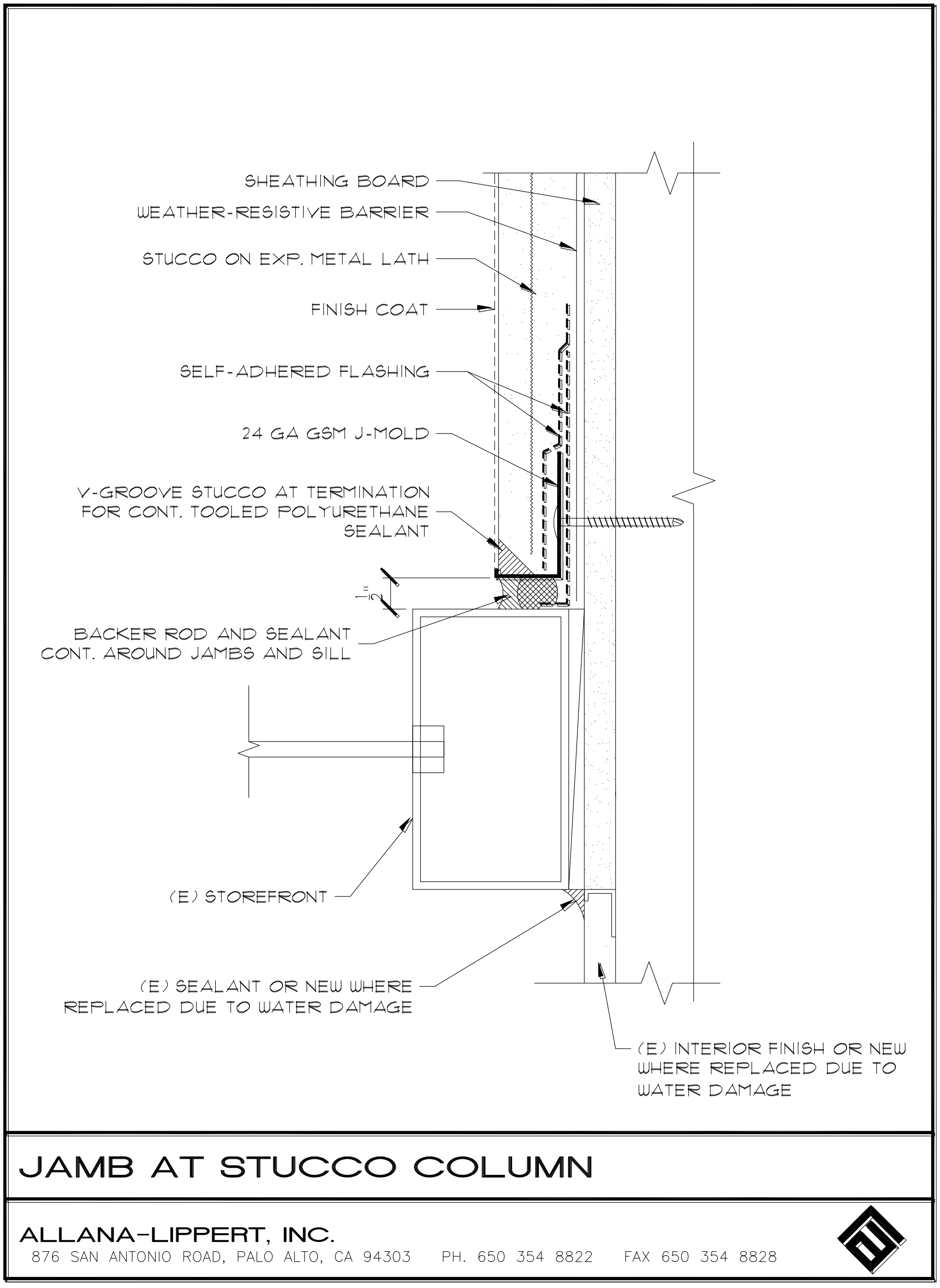
DRAWING 4 - TWO PIECE EXPANSION JOINT
BRICK VENEER BELOW EXPANSION JOINT



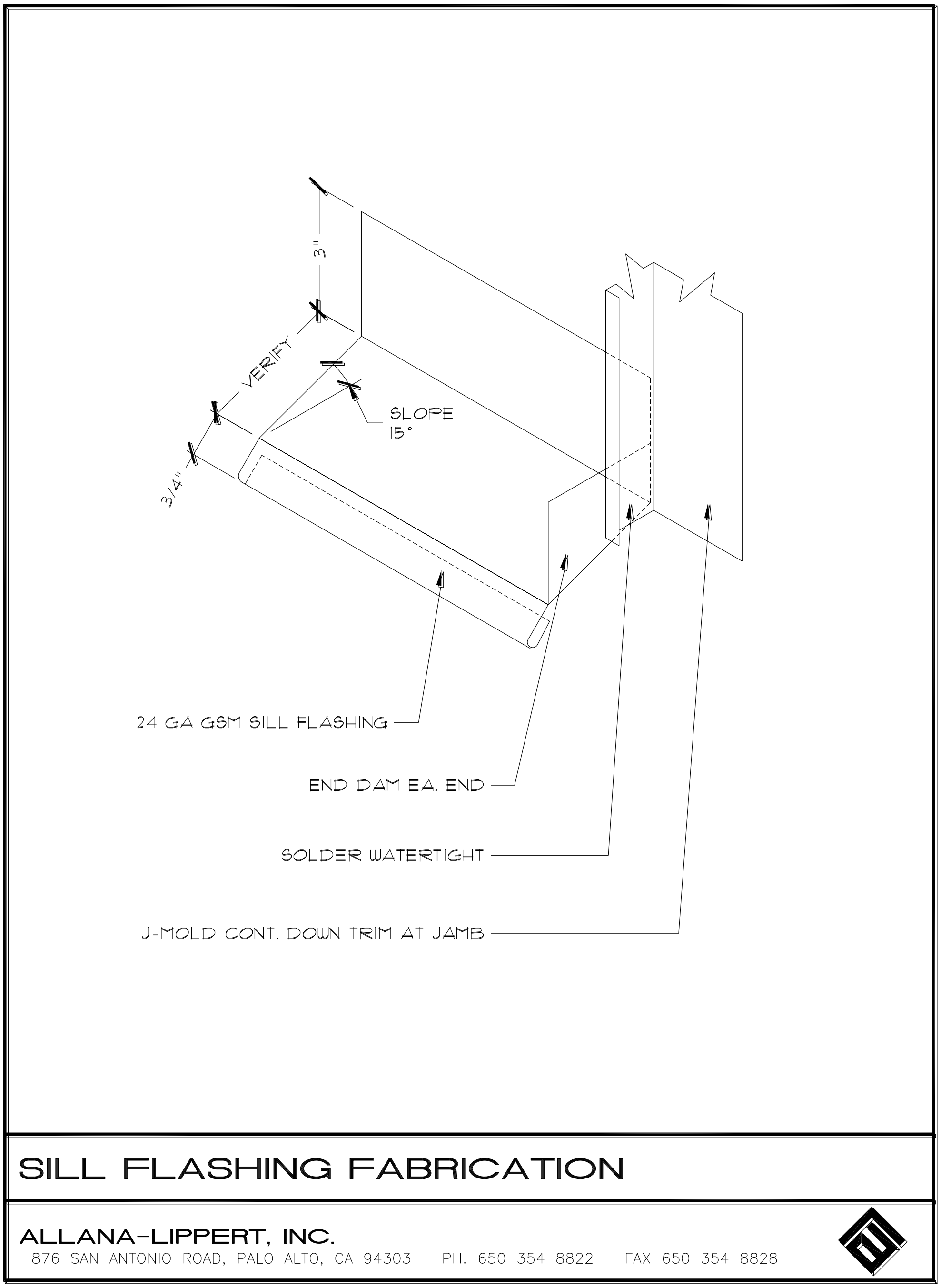
DRAWING 5 ROUND PENETRATION DETAIL



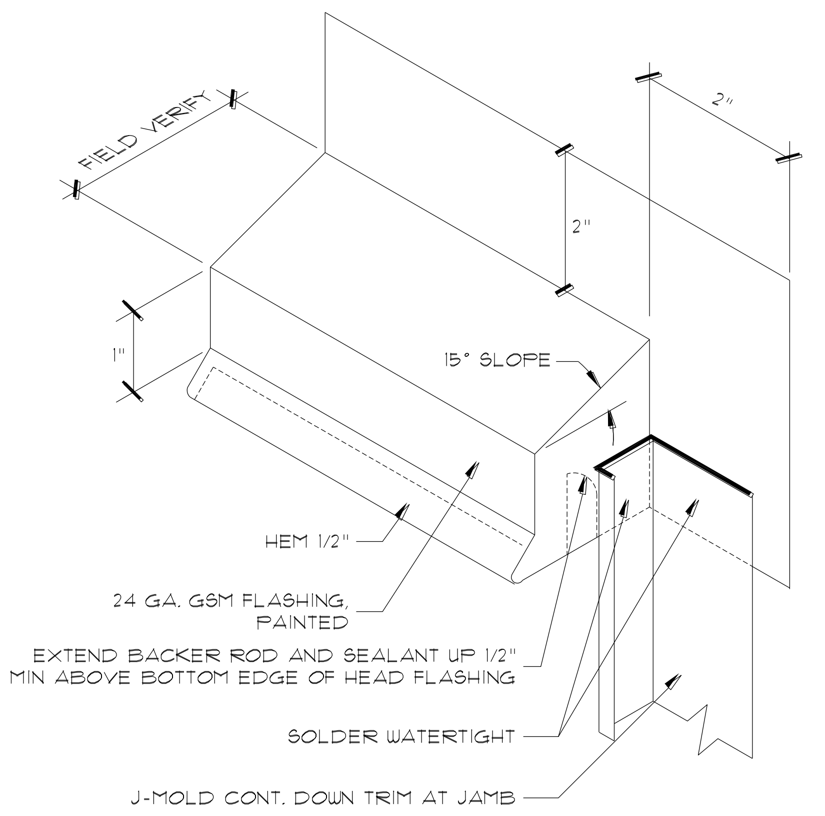
DRAWING 6 VERTICAL 1 PIECE EXPANSION JOINT



DRAWING 7 JAMB AT STUCCO COLUMN



DRAWING 8 SILL FLASHING FABRICATION



HEAD FLASHING FABRICATION

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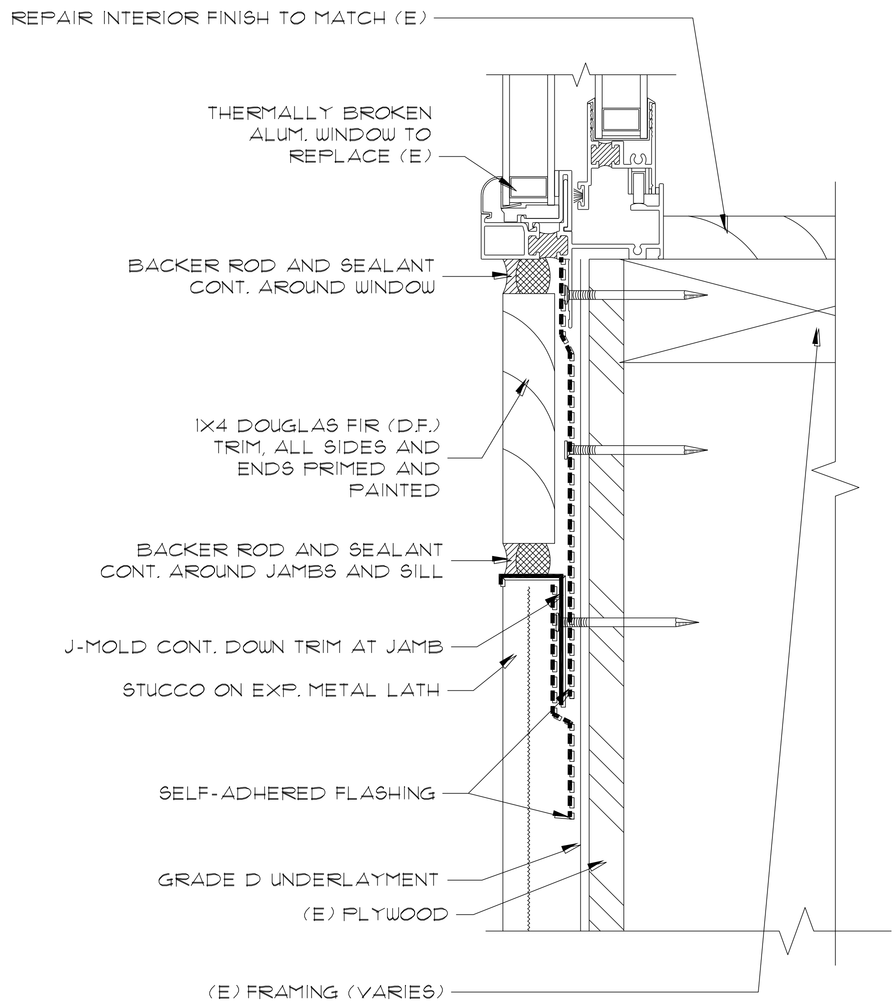
DRAWING 9 HEAD FLASHING FABRICATION



WINDOW JAMB

ALLANA-LIPPERT, INC.
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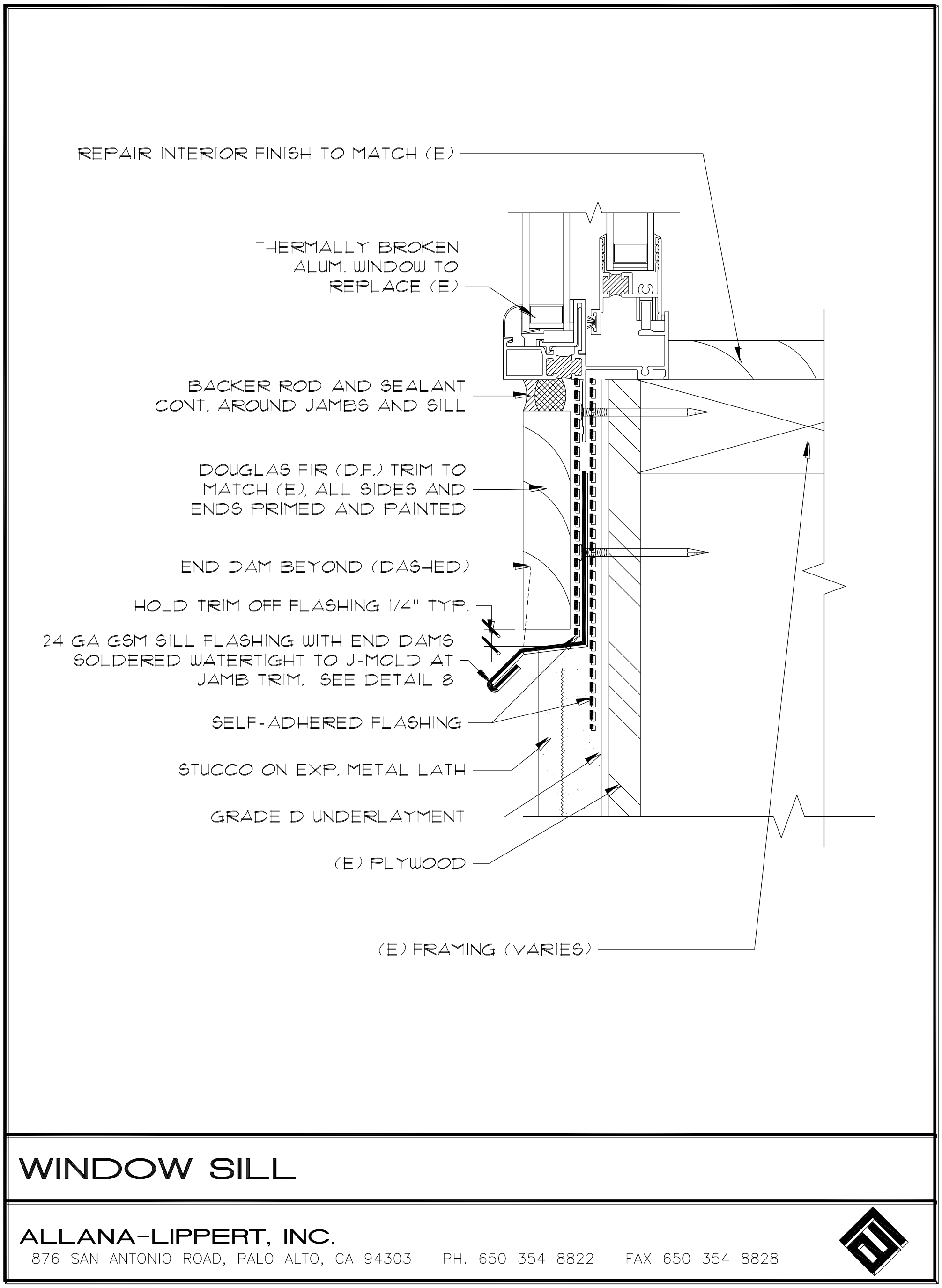
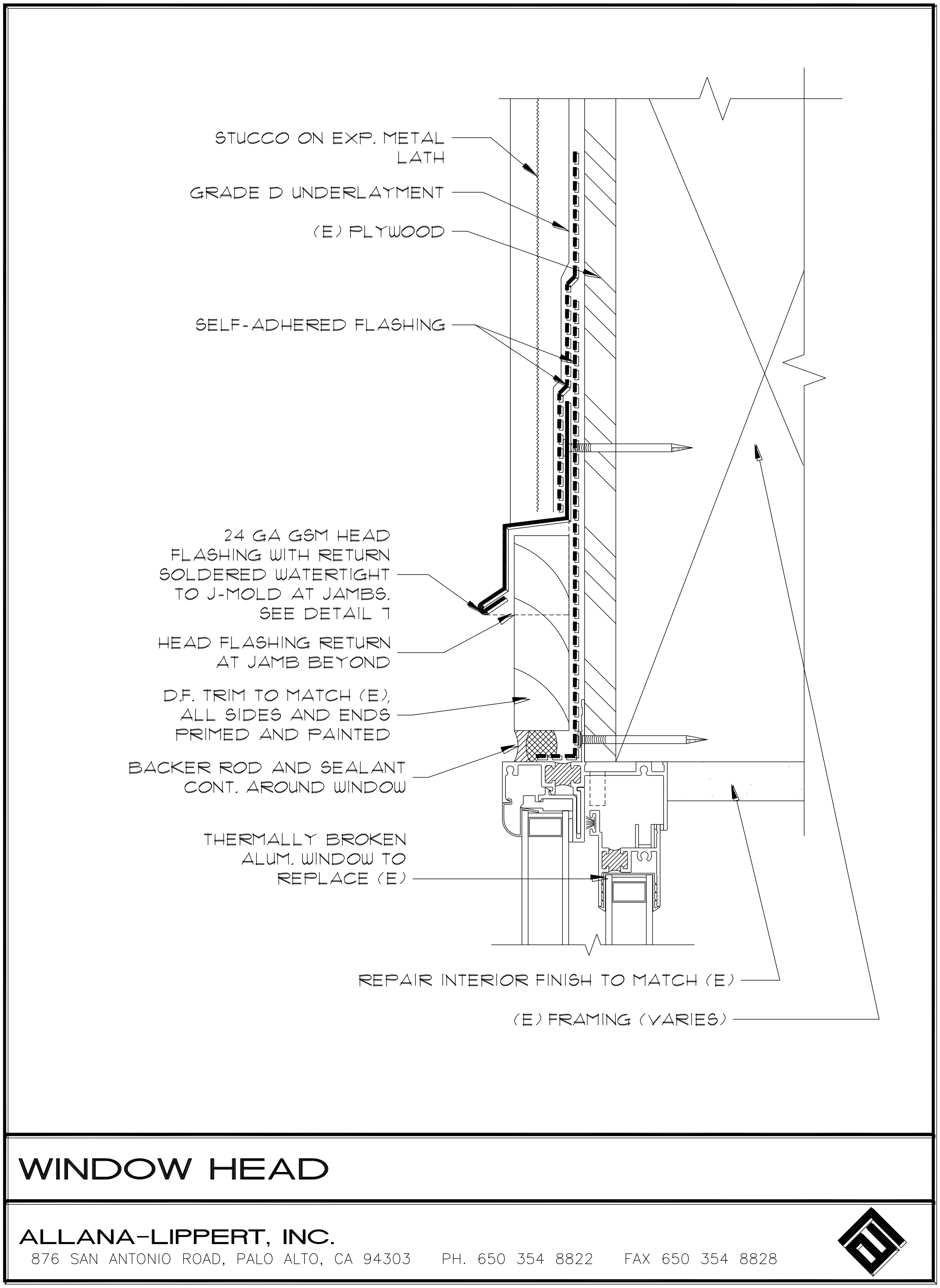
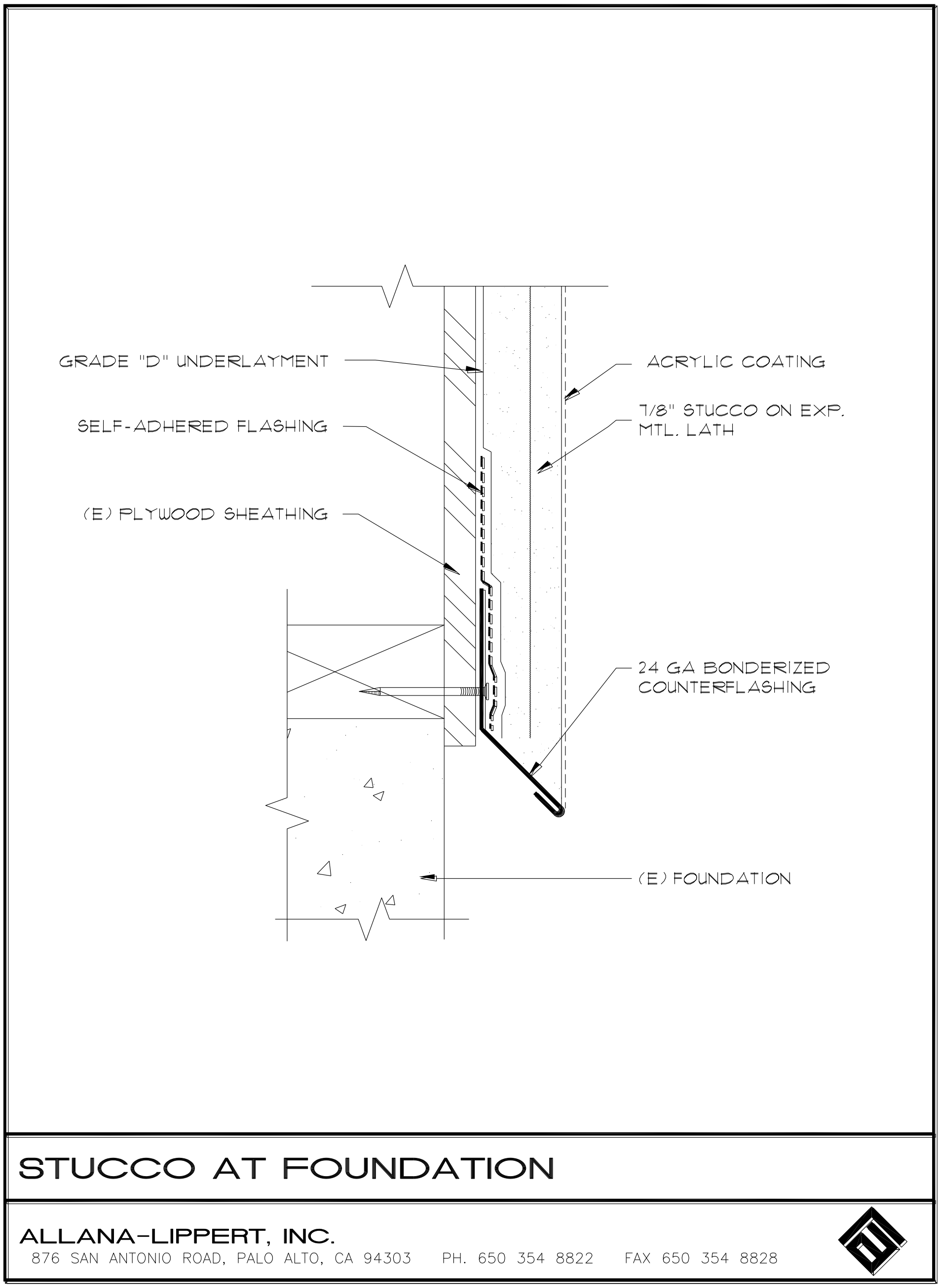
FLASHING 10 WINDOW JAMB



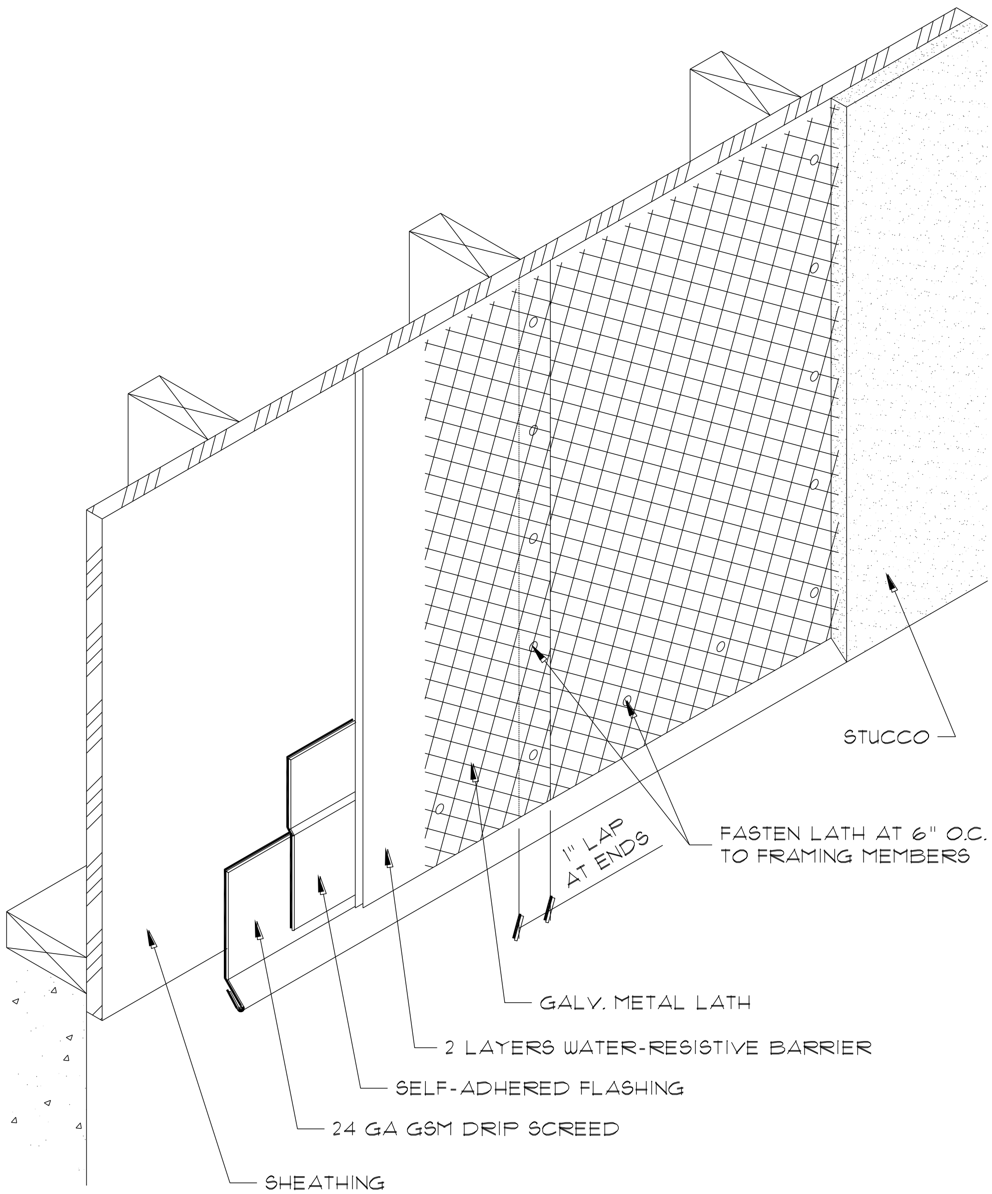
DRAWING 11 WINDOW SILL DETAIL



DRAWING 12 WINDOW HEAD DETAIL



DRAWING 13 STUCCO AT FOUNDATION



TYPICAL STUCCO SYSTEM

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DRAWING 14