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Considerations For The Use Of Exterior Insulation & Finish Systems (EIFS) On U.S. Army Facilities

U.S. ARMY CORPS OF ENGINEERS
CENACTT
NATIONAL ALTERNATE CONSTRUCTION TECHNOLOGY TEAM

DEPARTMENT OF THE ARMY
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Numerous U.S. Army and Air Force buildings clad with exterior insulation and finish systems (EIFS) have recently experienced maintenance problems, localized deterioration, and outright failure. In cases of major failures, remedial work may cost more than $1 million.

This report provides technical information and guidance for specifying, reviewing, and/or inspecting EIFS claddings. It also contains a brief history of EIFS, describes EIFS components and different types of EIFS claddings, lists considerations for EIFS selection, and details typical EIFS failure modes. Figures show successful and unsuccessful EIFS condition on military and private sector buildings.

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FOREWORD

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Over the course of this effort, the USACE Omaha District Project Managers were Jennifer Young and Jeff Skog. Richard Lampo from USACERL was the project technical coordinator. The Headquarters, USACE Technical Monitor was Rodger Seeman, CEMP-ES. Leo A. Daly, c/o Raymond Madsen, Omaha, Nebraska. and Kenney, Williams and Williams, Inc. (KWW), c/o Mark Williams, Maple Glen, Pennsylvania, were contractors in this effort.

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1 INTRODUCTION

Background

In recent years, exterior insulation and finish systems (EIFS) have been used as a cladding on U.S. Army and Air Force buildings. Field feedback indicated numerous EIFS-clad buildings were experiencing maintenance problems, localized deterioration, and outright failure. In a couple of cases of major failures, remedial work may cost more than $1 million. Consequently, the U.S. Army Corps of Engineers undertook a material properties and performance investigation to understand how EIFS is best utilized.

Objectives

The objective of this effort was to provide technical information and guidance to Corps personnel responsible for specifying, reviewing, and/or inspecting EIFS claddings.

Approach

To meet the project objective, the following data collection approaches were used:

- Field survey of nearly 50 EIFS clad buildings from various military posts to assess and document conditions

- Compilation of information on EIFS definition, classification, and material performance

- Survey of EIFS manufacturers in the United States for additional input on system composition and performance.

Report Overview

Chapter 2 contains a brief history of EIFS. Chapter 3 describes EIFS components. Chapter 4 identifies different types of EIFS claddings and their respective advantages and disadvantages. Chapter 5 discusses considerations for EIFS selection. Chapter 6 lists typical EIFS failure modes. Photographs are included that document successful and unsuccessful EIFS conditions on military and private sector buildings. Chapter 7 presents summary and recommendations.

2 HISTORY

Overview

Exterior insulation and finish systems (EIFS) are exterior wall claddings consisting of insulation and wet-applied finishes. Finishes are composed of cementitious and/or synthetic materials. EIFS function as a building skin, protecting the building structure from moisture and thermal changes. These systems are "barrier type" claddings. By design, "barrier" walls must shed water and prevent moisture from penetrating into the building itself. Hence, all EIFS must perform as waterproofing systems. Moisture protection is attained by providing an integrated system of EIFS layers in which each component serves specific and unique functions.

Different terms have been used to refer to EIFS, including "synthetic stucco," and "soft" and "hard" coat systems. As these systems gained acceptance in the construction industry, the need for a clear terminology to describe types of EIFS and their related components became apparent. Manufacturers, distributors, and users, under the auspices of the Exterior Insulation Manufacturers Association (EIMA), designated "exterior insulation and finish systems" as the official name for these cladding systems. EIMA also classified various types of EIFS (see Chapter 4).

The benefits of EIFS for both retrofit and new construction are many. Moisture and weather protection as well as insulating properties are obtained in one integrated system. EIFS is less expensive than many conventional building materials. Structurally lightweight, EIFS places only slight additional loads on the building foundation and structural supports. Retrofit work can be completed without disturbing occupants because the cladding is attached to the outside of the building. Optimal floor space is realized in all types of construction, and exteriors are relatively maintenance-free. With ongoing manufacturers' refinements, EIFS offers an increasing range of colors and finishes as well as pre-fabrication options.

Europe

EIFS originated in Europe as an outgrowth of the painting and plastering trades more than 30 years ago. Following World War II, building professionals began to use a combination of remedial coatings and rigid insulation to upgrade existing building facades. With the success of retrofit use, Europeans also applied these systems to new construction projects. To date, however, retrofit application represents the predominant use of EIFS in Europe.

Interested manufacturers "formalized" the practices of building contractors by supporting research and development efforts. Manufacturers and professionals in West Germany led in the development of EIFS technology. Manufacturing advances enhanced the basic notion of combining synthetic/cementitious coatings and rigid insulation, and fostered widespread acceptance of EIFS.

United States

EIFS were first introduced in the United States in 1969. The Dryvit Corporation is generally credited with being the first to import the system concepts from West Germany and adapt them for use in the United States. Estimates indicate that EIFS have been used in over 100,000 major projects—both new and renovated–since their introduction to North America. According to EIMA, the EIFS industry is growing more than 25 percent a year. To date, applications have primarily involved nonresidential buildings: office and retail developments, hotels, schools, and hospitals. However, residential use is reportedly increasing.

Although U.S. systems retained the basic components of European systems, certain modifications were made to reduce costs and accommodate the practices of the North American construction industry. Significant modifications were made in the kinds of substrate material used, and the methods of system application and detailing. These differences are discussed in greater depth throughout this report.

3 SYSTEM COMPONENTS

Overview

EIMA defines EIFS as nonload bearing exterior cladding systems and classifies these systems as Class PB (polymer based) or Class PM (polymer modified). EIFS chemical formulation varies by class as well as manufacturer. The current EIMA classification differentiates system types largely by base coat thickness and the method of installing system reinforcement. The EIMA classification is endorsed by virtually all EIFS manufacturers.

EIMA describes these systems as generally consisting of an insulation board, an adhesive and/or mechanical attachment of the insulation board to the substrate, an integrally reinforced base coat on the face of the insulation board, and a textured, protective finish. Each EIFS component serves specific functions integral to the overall performance of the exterior wall. A brief discussion of each system component as well as related materials is provided below.

Lamina

Lamina is a composite layer consisting of three parts: finish coat, base coat, and reinforcement. Finish coat is the system's outermost surface and provides color and texture to the building. Base coat is the foundation for the finish coat, holds the system reinforcement, and most importantly, serves as the wall assembly's primary barrier against water penetration. EIFS reinforcement can be external, either fiberglass mesh or metal lath, which may be combined with internal fiber reinforcement mixed in the base coat.

Rigid Insulation Board

Rigid insulation board provides thermal resistance and reduces potential for system cracking by isolating the lamina from the substrate. Typical kinds of insulation used in EIFS include molded expanded polystyrene (MEPS), extruded expanded polystyrene (XEPS), semi-rigid fiberglass, and mineral/rock wool. The type and density of insulation used vary by individual manufacturer.

Attachment

EIFS is attached to the building substrate by adhesives, mechanical fasteners, or a combination of both. For adhesively attached systems, base coat material or a special adhesive compound is used to adhere insulation board to the substrate.

Substrate

Although not a component of EIFS, substrate is integral to system performance because it is the innermost point of contact between the system and building. Gypsum sheathing with steel studs is used most often in U.S. commercial installations. Masonry and cementitious board are alternate substrates.

For reference, Figure 1 presents the components of a typical Class PB system.

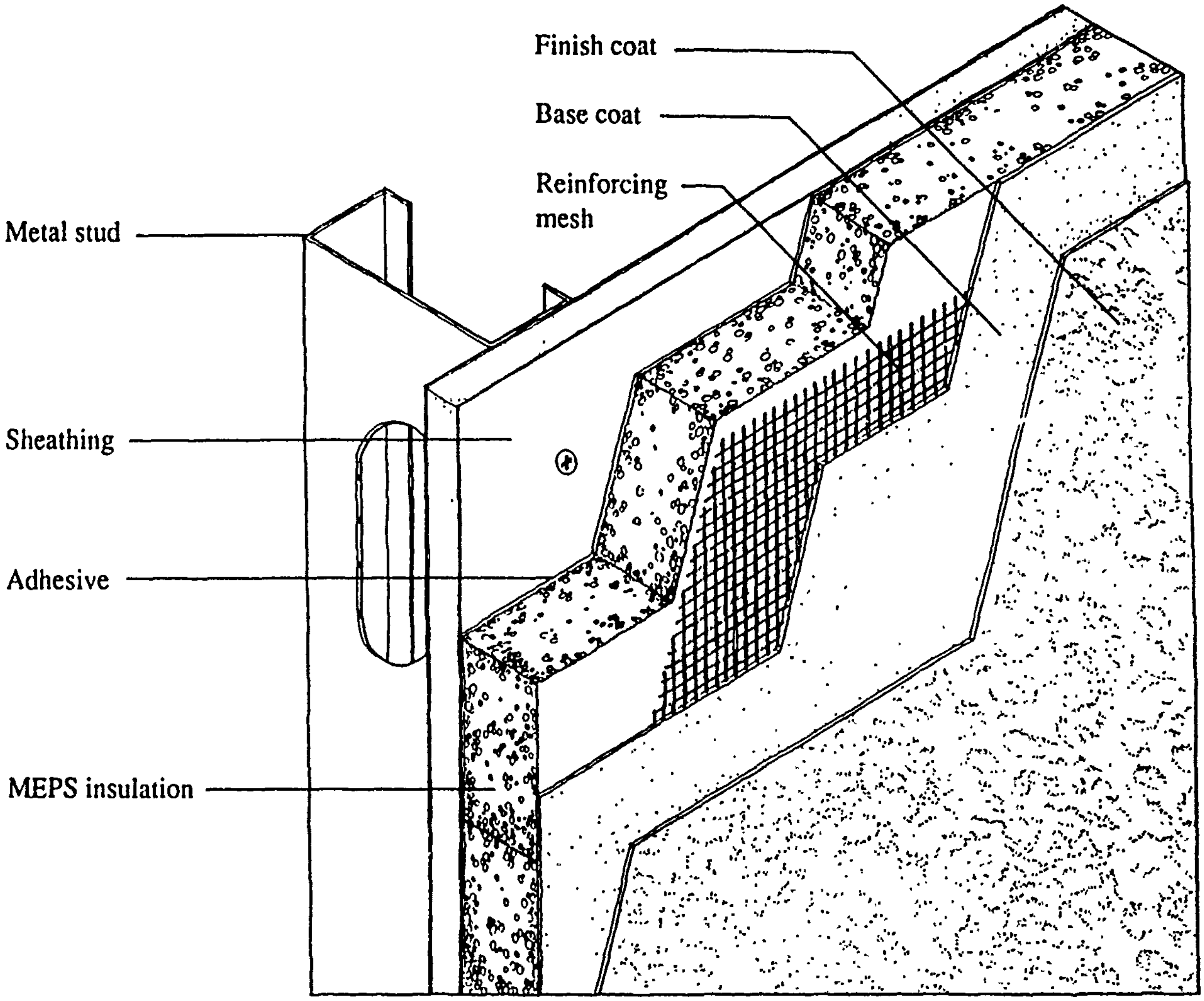

Figure 1. Typical Class PB System.

Finish Coat

Finish coats typically contain some percent of polymer compound together with silica sand or other aggregate, antifungicides, and additives to enhance workability and resistance to freeze-thaw cycles. Depending on the manufacturer, the finish coat can also contain portland cement. As the outermost EIFS surface, the finish coat provides a weathering surface, color, and texture for the exterior wall.

Weathering Surface

EIFS must serve as a moisture and weather barrier, since a durable weathering surface is necessary for overall system performance. The finish coat is the initial surface of contact for elements of moisture and weather. To ensure the system's success, the finish coat must be thick enough to adequately cover the underlying base coat. In practice, the actual thickness of finish coats varies according to the chemical and physical properties of particular products. Cementitious material or stone aggregates in the finish coat increase the specified thickness.

Although primarily used in retrofit situations, elastomeric coatings are occasionally applied over the finish coat to enhance weather resistance. However, these coatings are generally unnecessary if the system is properly installed. As with all system components, adherence to the manufacturer's recommendations for finish coat selection and application is important.

As the outermost surface of the system, the finish coat "telegraphs" imperfections in underlying layers, specifically imperfections in the substrate, insulation, or base coat. Fissures or micro-cracks in the finish coat signal a potential threat to the "moisture security" of EIFS. Regular inspection and expeditious maintenance of small cracks prevent minor defects from developing into major problems.

One characteristic of noncementitious finish coats is their tendency to soften when exposed to moisture for an extended time. This softening leads to delamination such that the finish coat pulls away from the base coat and reinforcing mesh. Class PB sealant joints are particularly vulnerable to delamination since most systems rely on the finish coat as the sealant substrate. With moisture-induced softening, it appears that the bond between the finish coat and sealant material is stronger than the bond between the finish and base coats. Cohesive EIFS lamina failure at sealant joints is the result. Use of open-cell back-up rod aggravates this condition by absorbing moisture which enters the joint.

An added factor in the delamination process is the presence of voids within the finish coat. These microscopic pockets serve as "conduits" that carry unwanted moisture into the EIFS finish coat and bring about softening. Finish coat softening and voids help explain why the base coat is the primary barrier against moisture in EIFS claddings.

Color and Texture

Aside from its function as a weathering surface, the finish coat also provides the exterior wall with an aesthetically pleasing appearance of lasting color and texture. A wide range of colors, from light to dark, are available. Some manufacturers offer more than 350 standard colors from which to choose. Custom colors are also available from virtually every manufacturer.

Most manufacturers state that unlike some traditional stuccos which require periodic repainting, EIFS do not. EIFS colors are integral to the system finish and usually are not affected by sun or mildew. However, there is some evidence that dark colors tend to fade and chalk with time, and that some finish coats tend to support mildew growth, particularly on north-facing facades. Periodic recoating of dark colors or mildew removal may be required to maintain the original facade appearance. In addition, impurities in finish coat materials—small particles of iron, for example—can oxidize and appear as rust colored streaks on the facade. Removing these impurities and recoating the finish surface is the remedial action of choice.

Color has a direct effect on thermal joint movement. Light and heat are reflected by pale colors and absorbed by dark ones. The absorption properties of dark colors increase thermally induced movement which, in turn, strains sealant joints. Sealant joint design should take into consideration the reflection value of the selected color. The higher the reflectivity, the less a particular color is affected by thermal factors. For this reason, pale or light colors are preferred. If dark colors are used, it may be necessary to limit panel size, increase the number of joints, or enlarge joint width.

Finish coat texture ranges from relatively smooth to coarse, depending on the type and size of aggregate used. For example, natural stone finishes containing colored aggregates of marble or quartz are available. These finishes emulate the appearance of exposed granite, marble, or building stone.

The aggregate composition has a direct bearing on finish coat porosity and compaction, both of which influence moisture retention. Aggregate composition is a factor of particle size and gradation as reflected in the granulometric curve (proportion and distribution of different-sized aggregate particles). Some EIFS finish coats are "gap graded"—predominantly large and small aggregate particles; others are continuously graded with a complete range of large-medium-small particles. "Gap graded" materials do not compact well, resulting in an open finish coat with voids. In addition, the tooling of sealant against a "gap graded" material is more difficult.

Aside from a wide range of available colors, manufacturers typically offer texture and pattern choices similar to those of traditional portland cement stucco—sand finish and swirls, among others. The use of three-dimensional shapes to enhance the appearance of doors, windows, and facade details further expands the aesthetic possibilities of EIFS. The design flexibility inherent in the many colors, textures, and finish options of EIFS is a major reason for the increasing use of these claddings.

Reinforcement

EIFS reinforcement is classified as external and internal. External reinforcement includes fiberglass mesh and metal lath; internal reinforcement is incorporated in the base coat, usually by the manufacturer.

Whatever the reinforcement used, this component is central to EIFS performance because it increases durability, tensile strength, and impact resistance. For all types of EIFS, not only must the reinforcement be compatible with other materials in the system, but it must also meet the building's usage needs. Manufacturers provide recommendations and guidelines for reinforcement selection and use. The particulars of any given end use must be assessed by building professionals before reinforcement selection and installation.

External Reinforcement

This is the most popular kind of EIFS reinforcement. Typically, it is a balanced, open fiberglass mesh fabric coated with a polymeric finish for compatibility with other system materials. Class PB systems always incorporate fiberglass mesh, while Class PM systems sometimes use this kind of reinforcement.

Usually fiberglass mesh is adhesively attached in Class PB systems by working and completely embedding the mesh into the wet base coat during the application process. Exposed or partially embedded mesh is especially problematic. Such conditions could allow water to enter this reinforced base coat layer. Retained water leads to finish coat softening by keeping finish coat surfaces moist. Retained water may also lead to chemical attack and weakening of the fiberglass mesh. Furthermore, partially embedded mesh diminishes the system's integrity by simply weakening system fortification. Class PB systems must be "backwrapped" at all exposed edges of the insulation board; that is, the lamina is returned from the system face, over the edge and to the back of the insulation board. Backwrapping helps prevent moisture from entering EIFS layers by eliminating lamina discontinuities at areas exposed to the weather.

Fiberglass mesh is generally available in three weights: regular, intermediate, and heavy. Regular or "standard grade" mesh serves as the basic system reinforcement and weighs about 4.5 ounces per square yard. Intermediate weight mesh has threads up to three times heavier than regular grade and weighs about 12 ounces per square yard. Heavy mesh offers the most impact resistance and weighs about 20 ounces per square yard. Fiberglass detail mesh is another type of reinforcement, one which is usually specified in Class PB systems for application around openings and at terminations.

In broad terms, standard grade fiberglass mesh is typically used for wall areas which have limited exposure to impact. Heavyweight mesh, on the other hand, may be needed at high impact areas such as the base of buildings or entrance areas. The edges of heavy mesh are usually abutted and embedded in the base coat. Standard reinforcing mesh, also embedded in the base coat, is applied over the top to cover the seam. This procedure ensures that system coatings function as one cohesive unit.

A second kind of external reinforcement is metal lath. It is fabricated in expanded, wire-woven and wire-welded forms. Metal lath is the traditional reinforcement for portland cement stucco. It can be used in certain Class PM systems, but is never used in Class PB systems. Metal lath is always mechanically attached and is generally available in various configurations to accommodate finish situations.

Internal Reinforcement

This reinforcement is internally incorporated in the base coat compound during manufacture. Internal fiber strands such as chopped random fibers are one kind of internal reinforcement. Compared to external reinforcement, internal EIFS reinforcement is less common. Its use is limited largely to Class PM systems, which usually incorporate a chopped random fiber form in conjunction with external reinforcement.

Base Coat

Base coat composition varies from manufacturer to manufacturer. Most base coats contain polymer, portland cement, and fillers. A few manufacturers offer a 100 percent polymer-based product. "Pure" polymer base coats come ready-mixed, whereas cementitious base coats are generally mixed in the field. The polymer and fillers of cementitious base coats are typically combined by the manufacturer and shipped in 5-gallon containers to the site, where portland cement and a small amount of water are added.

Some products are intended to be used as a base coat only; others are designed to serve two purposes: to adhere the insulation to the substrate and to provide the system's base or "ground" coat. This kind of dual purpose product is incorporated in many Class PB systems available in the United States today.

The base coat serves multiple, interrelated functions within EIFS. First, it is the primary barrier for stopping water from penetrating into other wall components. Second, it holds or "embeds" the external reinforcing mesh and/or actually contains the internal reinforcement material. Third, the base coat receives the finish coat and is thus the foundation for the system's outermost layer.

Since the base coat is the system's primary defense against moisture penetration, its application and detailing are critical aspects of the installation process. Application and detailing are especially important in Class PB systems which require the base coat to be applied in the correct thickness for proper performance. In the United States, a nominal base coat thickness of 1/16 to 1/4 inch is the standard requirement for many Class PB systems. Class PM systems in the United States use a thicker base coat, ranging between a nominal 1/4 to 3/8 inch.

Deviations from the recommended base coat thickness can lead to EIFS deterioration. An insufficient applicatio, of base coat will not protect and/or hold the reinforcement. A base coat that is too thin or too thick will result in cracking and exposure of the reinforcing mesh to moisture. With time, the exposure of fiberglass mesh to moisture and alkalinity from the system matrix (especially with cementitious base coats) could diminish i's reinforcing strength.

In Class PB systems with fiberglass mesh, the base coat should fully encapsulate the reinforcing mesh so that the mesh is free from contact with the insulation on the bottom and the finish coat on the top. It is interesting to note that European systems typically incorporate a skim or "key coat" of base material on top of an initial base coat layer. This double base coat is applied in two layers, a procedure which facilitates the correct positioning of the reinforcing mesh in the base coat. Applicators are able to focus on the placement of mesh during the initial base coat, and attend to possible inconsistencies in base coat coverage on the top of the mesh when the skim coat is applied. By contrast, the one-step base coat procedure generally employed in the United States requires greater skill in order to fully embed or encapsulate the reinforcing mesh.

The specified mixing proportions for the base coat are intended to promote the best possible performance of the exterior wall. The manufacturer's recommended ratio of components should be strictly followed. Deviation from these proportions can jeopardize the success of the system. For example, if the amount of cement in the base mix is increased, or the polymer decreased, the resulting material will be stiff and prone to cracking.

The correct degree of mixing is equally important. Over-mixing yields unsatisfactory results. Such practices introduce unwanted air into the formulation, creating air voids or "pockets." These pockets permit moisture to pass through the base coat layer and increase the likelihood of exterior wall problems. Again, manufacturers provide specific mixing instructions for base coat preparation. Climatic conditions are also significant factors in a successful base coat installation. Temperatures or humidity levels outside the range sanctioned by the product manufacturer can adversely affect the base coat. Applied in a wet, workable state, the base coat undergoes a series of chemical and physical changes to achieve a solid, rigid state. Should the outside temperature fall below prescribed limits before a solid state is fully attained (typically 40 °F), the overall integrity of the system is endangered.

Less than prescribed climatic conditions can slow the reaction between polymers and portland cement, extending the setting time or causing incomplete setting altogether. For "pure" polymer base coats, application in other than manufacturer-specified conditions can lead to curing problems. Whether the base coat is cementitious or pure polymer, it must be fully cured prior to the application of finish coat.

Some system manufacturers recommend a primer on top of the base coat. Primers function as adhesion intermediaries and eliminate the adverse effect of efflorescence due to base coat cement content. To facilitate application, a wet primer is often applied before finish coats with large aggregates.

Insulation

Insulation is an essential component of EIFS. Rigid insulation board provides thermal resistance and isolates the base coat from the substrate. Where applicable, insulation also provides a surface for the system's adhesive attachment to the substrate. The specific type and density of insulation vary in accordance with the requirements of proprietary systems.

Typical kinds of insulation used in EIFS include MEPS, XEPS, semi-rigid fiberglass, and mineral/rock wool. Polyisocyanurate and polyurethane boards are additional types of insulation. MEPS is the insulation used most often in U.S. EIFS applications; XEPS is second in frequency of use. Both MEPS and XEPS are discussed below. Semi-rigid fiberglass is used in European systems, with only limited use in this country. Mineral/rock wool, a traditional insulation material also used in Europe, is not typically used in the United States. Some U.S. manufacturers are assessing mineral/rock wool insulation for domestic application because of its high fire resistant and low smoke generation properties. Polyisocyanurate and polyurethane boards are used primarily in Europe and infrequently in the United States.

MEPS Insulation

Compared to XEPS, MEPS insulation offers a lower initial cost. Virtually all Class PB systems use MEPS insulation and adhesive attachment, although adhesive and mechanical attachment may be combined. MEPS is installed in 2 x 4 foot panels, using a running bond pattern with staggered vertical joints.

MEPS insulation boards must be a minimum of 1-pound per cubic foot in density. Higher densities are available and specified for some applications. Throughout the United States, the average thickness of installed MEPS insulation is about 1.5 inches. Depending on the R-value desired, it can be installed in thicknesses of up to 4 inches for 1-pound density board. Building codes generally allow a maximum MEPS thickness of 4 inches.

As a result of manufacturers' production methods and quality control procedures, MEPS boards can vary significantly in their physical and performance characteristics. The actual density of boards and their dimensional characteristics (length, width, thickness, squareness, and planar flatness) significantly affect EIFS performance. Poor quality MEPS board allows moisture to percolate freely between beads, lessening the insulation value of the board. MEPS boards must be tightly butted to avoid gaps. Gaps between boards represent a lapse in the system's support and result in cracking of the overlying finish and/or base coats. Where gaps exist, slivers of insulation should be inserted. Gaps should never be filled with adhesive or other non-insulating material.

Before applying the base coat, the surface of the MEPS insulation must be properly prepared. Site dirt, ultra-violet (UV) degradation and unevenness should be corrected by rasping the surface. Yellowed surfaces damaged by UV exposure should be rasped until the surface is 100 percent white.

XEPS Insulation

Most Class PM systems use XEPS insulation. Compared to MEPS, XEPS insulation typically has a higher density, a greater compressive strength, and—because of its closed-cell construction—less vapor permeability. Overall, XEPS insulation is manufactured in accordance with tighter dimensional tolerances. A tongue and groove is provided on two edges of the board for alignment purposes. The cost of this insulation is about double that of MEPS.

The minimum density for XEPS insulation in U.S. EIFS applications is 1.6 pounds per cubic foot, although the densities of many products are closer to 2.0 pounds. XEPS insulation has excellent water resistant properties because of its closed-cell construction and continuous skin. As discussed in Section IV, this closed-cell XEPS construction influences the vapor transmission process within EIFS claddings and requires special design consideration.

Attachment

Attachment is the means by which EIFS, specifically its insulation component, is held to the building structure or substrate. Attachment may be adhesive, mechanical, or a combination of the two. The type and method of attachment is determined by specific system requirements, manufacturer guidelines and, to some extent, user discretion.

Adhesive Attachment

Since EIFS was introduced to the U.S. market in the late 1960s, the majority of installations have used adhesive attachment only. As noted earlier, a single product may be used for both adhesive attachment and base coat application, depending on the proprietary system selected. Similar to base coat compounds, adhesive materials are either ready-mixed by the manufacturer or prepared on-site by the applicator. Adhesive attachment entails the placement of base coat material or a special 100 percent polymer-based mixture on insulation boards, which are then pressed to the substrate. Adhesives are typically applied by one of two methods, as discussed below.

The first method is termed "ribbon-and-dab" application. Ribbons of adhesive are placed around the perimeter of the insulation board, and dabs of adhesive are placed within. This method is particularly useful in cases of uneven substrate such as existing masonry or concrete surfaces. Not all manufacturers officially endorse this method of application. There is concern that a consistent application of adhesive is more difficult to achieve with the "ribbon-and-dab" method. An added concern is that this method provides less protection for the substrate should water penetrate the system. Moisture can run between dabs of adhesive and have direct contact with the substrate, heightening the potential for deterioration.

For the above reasons, an alternative method of application known as "notched trowel" is specified by some manufacturers. This method involves use of a notched trowel to cover the entire back of the insulation board with adhesive in an evenly distributed layer. Notched trowels of various sizes are recommended by manufacturers to control the dimensions of adhesive ribbon. The notched trowel method works well on even substrates such as sheathing boards. Depending on the adhesive used, notched trowel application is preferred by some manufacturers because it offers water resistant qualities. Should moisture penetrate the system barrier, the overall coat of adhesive applied by the notched trowel method provides an additional layer of protection.

Mechanical Attachment

Mechanical fasteners are available in a range of shapes and sizes, and vary by manufacturer. In general, fasteners are nail-like forms which are driven into the substrate/framing. A recent report[1] noted that the use of mechanical fasteners—alone or in combination with adhesives—is increasing. Mechanical fasteners are reportedly being added to manufacturers' standard lines of adhesively attached EIFS. Specifiers now have the option of using mechanical fasteners in combination with adhesives, an option which provides additional security with respect to system attachment.

When mechanical fasteners are used in Class PM systems, the insulation is typically spot fastened to the substrate. Then, the system reinforcement is attached using the remaining fasteners. Spacing of

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[1]Doyle, M. "Trends in Specifying EIFS," *Building Design and Construction* (August 1988), pp 60-61.

the fasteners is important and is generally specified by the manufacturers. When mechanical fasteners are used in Class PB systems, they are typically countersunk and plugged with insulation board to avoid telegraphing the presence of the fastener through the base/finish coats.

Mechanical fasteners are available in a wide variety of pull-out strengths depending on substrate material, fastener material, and depth of fastener penetration. Advantages of mechanical fastener installation include secure attachment to questionable substrates and ease of construction.

Substrate

The substrate represents the innermost point of contact between the cladding and the building. Although not a component of EIFS as such, the substrate is nonetheless significant simply because it is the foundation for EIFS attachment.

While EIFS can be applied over almost any sound substrate, surface preparation and the proposed method of attachment are important considerations. The preparation of existing substrate surfaces with cleaners, sand blasting, or other measures may be necessary. Some EIFS claddings use primers which serve as adhesion intermediaries between the system and the substrate. Generally, any surface contamination that might interfere with adhesive bonding must be removed.

The selection of substrate material for new construction must be coordinated with the requirements of specific EIFS claddings. Retrofit projects seeking to use EIFS should be examined for overall wall integrity. Where adhesive attachment is to be used, consideration of the existing substrate is critical. EIFS should not be adhesively installed over substrates of questionable integrity unless bond tests are first undertaken. In questionable cases, mechanical fasteners may be the only means of attachment. An alternative for extremely poor substrates is the use of mechanically attached metal lath over a bond breaker such as building paper. The lath and bond breaker form a physical link between the existing substrate and the EIFS system. Lath reinforces the cladding while mechanical fasteners assure attachment. The bond breaker also provides a second barrier against moisture penetration.

For most U.S. commercial installations—both Class PB and Class PM—exterior grade gypsum board on steel studs serves as the substrate. Low cost, good workability, and high fire resistant properties account for the prevalent use of this substrate material. Gypsum board is easily installed, carries minimal deadweight, allows stud space for wiring or additional insulation, and accommodates framing for interior finishes. Other substrates include cementitious-based sheathing, calcium silicate boards, and masonry.

Gypsum sheathing usually consists of a gypsum core and a water-repellent paper surface. The standard U.S. practice is to secure the gypsum board to light gauge steel stud framing. Either adhesive or mechanical attachment can fix the insulation to the gypsum board. Because of the board's laminated paper surface, moisture represents a threat to board integrity. In the presence of moisture, the paper facing of the board can loosen from the gypsum core, jeopardizing adhesive attachment. Weakened adhesive attachment may not sufficiently resist positive and negative wind loads acting upon the building facade. Over time, the continued presence of moisture together with the pressures of wind loads can cause EIFS failure.

Recommendations differ on the type of attachment suitable for use on gypsum substrate. Most EIFS manufacturers approve adhesive attachment. However, concerns about delamination have led certain U.S. gypsum board manufacturers to endorse only the mechanical attachment of any exterior wall system, including EIFS, to their paper-faced gypsum sheathing. For any proposed use of EIFS over gypsum sheathing, the manufacturer's most current installation procedure/details as well as Corps of Engineers Guide Specification requirements must be strictly followed. (The December 1988 CEGS-07240[2] requires the system to be mechanically attached when used over gypsum sheathing boards)[3].

A gypsum board composed of a fiberglass surface over a gypsum core is available. This product is specifically designed to address concerns about the delamination of paper-faced gypsum boards. Fiberglass surfaced gypsum costs from 40 to 50 cents more per square foot than paper-faced gypsum. Currently, paper-faced gypsum is approximately 80 cents per square foot.

Sealant Joints

Materials

EIFS sealant joints typically use polyurethane sealant, an elastomeric material capable of maintaining a good seal when completely cured. A multicomponent sealant consisting of a base compound, a curing agent and an optional coloring compound is generally specified. Multicomponent sealants are mixed at the site just prior to application. Careful attention must be given to the complete dispersion of curing and coloring agents in the base compound.

Back-up rods, correctly specified and installed, are critical to good sealant joints. Joint depth on EIFS should not exceed joint width, with a maximum depth of 1/2 inch stipulated. To control the depth of joints deeper than this, joint back-up rods are used. Importantly, back-up rods vary in their material composition. Open-cell rods retain moisture which can cause deterioration of sealant joints from the inside out. Closed-cell polyethylene rods, with their smoother surface, are less likely to hold moisture; hence, only closed-cell rods should be used.

Since rod shape determines the cross-sectional contour of the installed sealant, only round rods should be used. Correctly installed, round back-up rods allow the sealant to bond only at the joint interfaces, creating an hourglass shaped cross section for the sealant bead. This shape reduces cohesive strain within the sealant material and increases contact at the bonding surfaces.

Some manufacturers offer a line of accessories to ensure the proper installation of their EIFS. The basic accessories include corner aids, stop beads for termination, starter tracks and joints, all made of plastic and/or metal. In the U.S. today, accessories are primarily specified for Class PM systems, with only minor use in Class PB systems.

Design and Application

Careful attention must be given to sealant design and application at all EIFS building terminations—places where EIFS begin, end, or join other portions of the building construction. Joints are needed at two basic conditions: where EIFS meet EIFS; and where EIFS meet dissimilar materials.

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[2] CEGS-07240, *Exterior Insulation and Finish System* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], December 1988).

[3] R.G. Lampo, J.C. Trovillion, *Exterio · Insulation and Finish Systems (EIFS) on U.S. Army Facilities: Lessons Learned*, Technical Report M-91/02/ADA228572 (U.S. Army Construction Engineering Research Laboratory [USACERL], October 1990), p 16.

EIFS-to-EIFS conditions require horizontal or vertical expansion and control joints at changes in substrate; major changes in wall or plane direction; and at any change in height, configuration, or system. Expansion joints control composite and/or widespread building movement and provide relief for the entire wall system, while control joints control localized movement and penetrate only the EIFS cladding. Conditions in which EIFS meet dissimilar materials include places where EIFS meet other building materials such as masonry; where EIFS meet building penetrations such as windows, doors, pipes, railings, or fixtures; and where EIFS meet the roof or ground.

Sealant joints should be neatly tooled to compact the sealant and eliminate air pockets or voids. Tooling also provides a smooth finished appearance to sealant joints. Poorly tooled joints or those lacking tooling altogether can precipitate sealant joint failure. This underscores the importance of tooling as well as quality workmanship in achieving a proper adhesion between the sealant and the sealant substrate.

Sealant Joint Failure

Most systems rely on the finish coat as the sealant substrate. Since certain noncementitious finish coats tend to soften with exposure to moisture, there is concern that the finish coat may not be the best substrate for sealant. Sealing to the base coat or sealing to accessories are alternative approaches recommended by some manufacturers.

Concerns about sealant joint failure have led some manufacturers to recommend double seals on sealant joints. The installation specifications of these manufacturers vary, but typically one seal is placed in the wall cavity construction, separate from the EIFS cladding; the other is detailed to the EIFS finish coat. Another approach consists of a primary seal detailed to the base coat and backed up by a secondary seal placed either in the EIFS component layers or in the wall cavity construction. Of course, the actual detailing of any double seal requires a thorough assessment of specific project conditions and construction allowances.

4 COMPARISON OF EIFS TYPES

Overview

As reported earlier, EIFS are classified by EIMA according to typical system components. The EIMA classification is considered a standard reference terminology for EIFS. In the U.S. today, the product lines of many EIFS manufacturers encompass both Class PB and Class PM systems. Differences in materials, application, and attributes characterize each system. The unique as well as shared features of each system type, its advantages, disadvantages, and recommended usage situations, are discussed below.

Class PB Systems

Class PB systems, with their polymer-based finish coats, are sometimes called "thin coat," "soft coat" or "flexible" systems. Class PB systems dominate the industry, with Class PM systems second in usage. Proprietary Class PB systems generally share the same basic components, as discussed in Chapter 3. Despite this, the actual material composition and application techniques of individual Class PB systems vary from manufacturer to manufacturer. The most common Class PB system configuration includes a polymer-based finish coat, a base coat composed of portland cement and polymer, and external fiberglass mesh reinforcement embedded in the base coat. A diagram of Class PB system components is shown in Figure 1. The following summarizes the distinguishing features of Class PB systems:

- Most Class PB systems use a noncementitious finish coat.

- All Class PB systems specify a thin base coat, roughly 1/16 to 1/4 inch.

- All Class PB systems use external reinforcement in the form of fiberglass mesh and applied in one or two layers. Some Class PB base coats contain internal fiber reinforcement in conjunction with external reinforcement.

- Most Class PB systems use base coats which incorporate cementitious materials. However, a few manufacturers of Class PB systems specify a noncementitious or "all polymer" base coat.

- Virtually all Class PB systems specify MEPS insulation, although depending on the Class PB system, other types of insulation can be used.

- All Class PB systems can accommodate adhesive attachment; some Class PB systems use a combination of adhesive and mechanical attachment. As discussed in Chapter 3, optional mechanical fasteners are now offered by most manufacturers.

- Exterior grade gypsum board is the most frequently used EIFS substrate, but there are other recommended substrates. Reliance on gypsum sheathing reflects an independent preference in the construction industry. Most Class PB systems can be used with other substrates, including masonry, concrete, and cementitious board.

A number of advantages explain the wide use of Class PB systems in the United States today. One principal advantage is that Class PB systems are typically less expensive than Class PM systems and represent cost savings over other types of exterior wall treatment. The lower cost of Class PB systems is related in part to material composition: the MEPS insulation is less expensive than the XEPS used in Class PM systems.

Another advantage of Class PB systems is a high polymer content, which requires fewer control joints to resist cracking that can occur in more cementitious systems. A proportionally greater reliance on polymers together with a thinner application results in a more flexible, less rigid exterior wall. However, like all EIFS, Class PB systems require joints when abutting dissimilar materials. As noted earlier, this typically occurs at large and small penetrations (window or door openings and pipes, railings, fixtures, etc.) and at major changes in plane or wall direction.

Class PB systems are the most lightweight of all EIFS. Exterior walls clad with Class PB systems are significantly lighter than those using traditional exterior materials. While EIFS claddings generally place less structural load on buildings than traditional materials, Class PB systems, with their high polymer content and fiberglass reinforcing mesh, place the least load.

Theoretically, Class PB systems should have better impact resistance because of their inherent flexibility. To some degree, this is true. Specifically, when Class PB systems are struck with a blunt object, they may simply dent, not crack. However, insufficient base coat thickness will lessen impact resistance. While Class PB coatings are more flexible, their thin application provides less protection when compared to the thicker Class PM systems.

Class PB systems possess certain disadvantages. First, they are prone to puncture damage from sharp objects. Since both the base and finish coats are thinner, the overall protective layer is also thinner. For this reason, virtually all Class PB systems offer a heavier mesh to reinforce these wall areas which are anticipated to have high contact.

Second, Class PB systems usually incorporate MEPS insulation, a material which is less dense than the XEPS boards used in Class PM systems. MEPS consists of molded polystyrene beads fused together to create insulation board. This fused-bead construction results in a more "breathable" insulation material than the closed-cell construction of XEPS. The capacity of MEPS to allow water in its gaseous (vapor) state to pass through the insulation layer has some benefit; however, with respect to insulating properties, this capacity contributes to the lower thermal resistance of MEPS.

Third, the finish coats of Class PB systems rely on polymers in emulsion to provide moisture and weather protection. These polymers tend to soften when continuously exposed to moisture. As previously noted, constant water exposure can cause the finish coats of some Class PB systems to lose cohesion and delaminate, causing sealant joint failure. While no EIFS system can tolerate moisture intrusion, Class PB systems which are adhesively attached are particularly susceptible to the adverse effects of moisture penetration.

Class PM Systems

Class PM systems are sometimes called "thick coat," "hard coat," or "rigid" systems. This type of EIFS usually contains higher proportions of portland cement in the base coat compound. The higher cementitious content of Class PM system coatings results in a thicker, more rigid system than Class PB systems.

Like Class PB systems, Class PM systems vary widely with respect to material composition and application techniques. The most common Class PM configurations include the following: (1) a cementitious finish coat with polymer modification, a base coat of polymer and portland cement, mechanically attached external fiberglass mesh or metal lath reinforcement, and XEPS insulation, and (2) a cementitious finish coat with polymer modification, a base coat with chopped glass fiber reinforcement (internal), mechanically attached fiberglass mesh (external), and XEPS insulation. Figure 2 illustrates typical Class PM system components. The following summarizes the distinguishing features of Class PM systems:

- Most Class PM systems use a polymer-modified cementitious finish coat, although a noncementitious finish coat can also be used.

- All Class PM systems specify a "thick" base coat, ranging between a nominal 1/4 to 3/8 inch.

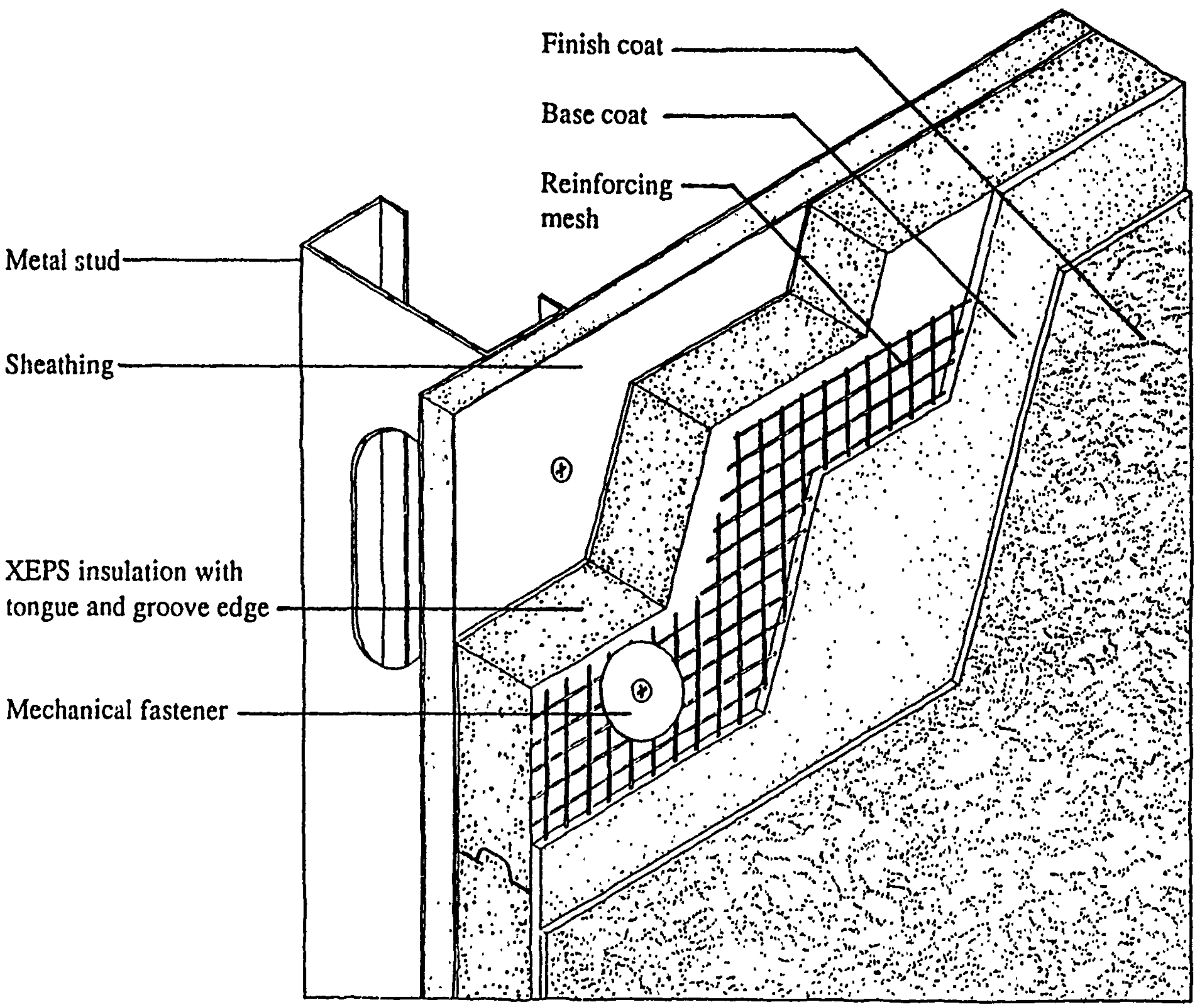

Figure 2. Typical Class PM System.

• For Class PM systems, a metal lath or fiberglass mesh reinforcement is commonly used.

• All Class PM systems use mechanical as opposed to adhesive attachment. This method of attachment is used because of the weight of Class PM cementitious materials. In addition, the smooth surface of XEPS cannot provide an adequate surface for lamina adherence.

• Class PM systems usually use XEPS insulation, which is always mechanically attached to the substrate.

• Exterior grade gypsum sheathing is the most frequently used substrate material. Others substrates include cementitious-based sheathing, calcium silicate boards, and masonry.

Class PM systems offer several advantages. Because of their cementitious content, they are more resistant to puncture from sharp objects. The thicker base and finish coats provide a greater total protective layer than Class PB systems. Under heavy use, Class PM systems tend to hold up better than Class PB systems with standard reinforcement. If frequent contact or high impact is anticipated because of intended building use or proposed occupancy, Class PM systems may provide the best protection against damage to the exterior wall.

The insulating value of Class PM systems is typically better than that of Class PB systems because the closed-cell construction and material properties of XEPS insulation provide better thermal resistance. At the same time, because XEPS insulation is less vapor permeable, condensed vapor may collect within Class PM systems, causing deterioration from the inside out. Accurate vapor transmission analysis is critical for overall system performance.

Mechanical attachment is a distinct advantage of Class PM systems. It allows for the inclusion of a weather barrier membrane such as building paper to protect the insulation and/or substrate from deterioration should water penetrate the system. Compared to adhesively attached Class PB systems, mechanically attached Class PM systems are less sensitive to substrate conditions. The mechanical attachment of Class PM systems makes this type of EIFS a potentially better choice for retrofit projects with questionable substrates.

Finally, Class PM systems can incorporate natural stone aggregates of a larger size because of their thicker finish coats. While both types of EIFS offer aggregate finishes of quartz, granite, or other stone, Class PM systems can provide finishes that are aesthetically closer to nonsynthetic materials.

Class PM systems are not used as often as Class PB systems. Major reasons for this appear to be cost and a limited number of manufacturers. As previously noted, one factor in the higher cost of Class PM systems is XEPS insulation, which is about twice the cost of MEPS board. Often, cost appears to be the decisive factor in EIFS selection. The greater initial expense entailed in a Class PM system leads many building specifiers to choose a less costly Class PB system. However, when appropriate, the selection of a Class PM system can minimize maintenance and repair costs once the system has been installed.

Class PM systems are thicker by design and typically rely on polymer-modified cementitious material, resulting in a more rigid, less flexible cladding. Class PM systems require more control and expansion joints than do Class PB systems. Careful adherence to square footage and proportion requirements is necessary in order to minimize cracking. The attendant placement and detailing of joints is also important in order to avoid cracking due to movement.

Typically, Class PM panels should not exceed 150 square feet or be longer than 20 feet in any dimension. The application of Class PM materials must be contained within control joints that are in a proportion of no more than 2.5 to 1.0. This requirement avoids long panel applications and eliminates cold joints, meaning the juncture of wet finishes with set material. Of course, adherence to the manufacturer's recommendations for climatic conditions and mixing is necessary for a successful installation.

5 EIFS SELECTION

The great majority of EIFS use to date by the U.S. Army Corps of Engineers has been for retrofit projects. It appears that this trend will hold for the near future. To achieve a retrofit project's full potential, careful consideration must be given to existing conditions and project goals. The decision to use EIFS should be made within the context of a project's program of requirements.

Economic factors should be considered along with less tangible concerns such as the existing building context and the desired architectural expression for the finished retrofit. Depending on project needs, quantifiable and nonquantifiable criteria assume varying degrees of importance. For instance, there may be a need to bring design unity to a group of military buildings which possess different exterior wall treatments. In this case, nonquantifiable factors may have precedence over other concerns. The relative weight of these factors can only be determined by project particulars.

The possibilities presented by the combination of rigid insulation and synthetic coatings are many. However, an understanding of the limitations as well as possibilities of EIFS is necessary for successful use. EIFS limitations relate largely to the unique material properties and behavior of these claddings. When correctly specified, installed and maintained, EIFS can be a thermally efficient, moisture-protective and cost-effective cladding for buildings.

Once it is established that EIFS will be used on a project, the type of EIFS to be specified—Class PB or Class PM—must be determined. This determination is influenced by building use, substrate type, proposed occupancy, site, climate, and exposure, among other factors. When choosing a system type, one important principle which should guide selection is that while Class PB systems are inherently more flexible, Class PM systems offer greater puncture resistance. For example, a Class PB system with standard reinforcement may be well-suited to an office building that is anticipated to have ordinary impact exposure. However, for barracks or retail stores that may be exposed to repeated impact, either a Class PB system with heavy-weight mesh or a Class PM system may be best.

Based on the authors' survey of nearly 50 EIFS-clad facilities at seven Army and Air Force installations, the U.S. Army Corps of Engineers has generally specified these systems appropriately. In most cases, the type of EIFS specified—Class PB or Class PM—is suitable to building use and occupancy. The EIFS buildings surveyed were relatively new installations in good to excellent condition at the time. Nonetheless, circumscribed signs of failure were found, including varying degrees of cracking, impact damage, and inadequate closure. These are discussed in Chapter 6. While it is difficult to single out any one cause, application deficiencies as opposed to improper specification and maintenance appear to account for the most problems. Tighter monitoring of application procedures during installation would undoubtedly diminish application inadequacies.

Even though a couple of major problems were noted in the field survey, overall the Army's and Air Force's use of the systems is still considered successful. This success is largely because the predominant application has been retrofit use on existing low-rise masonry structures. This use is consistent with the original intent of these systems. In many respects, this type of application carries a diminished risk of failure. Not only has the original construction had ample time to settle, thereby providing a stable substrate, but also most of the military buildings surveyed had masonry or concrete substrates. These are highly durable substrates that carry a low risk of deterioration even if moisture penetrates the system. Related to this, the low height of the buildings is advantageous because exposure to positive and negative wind pressures is minimized.

As the Army continues to upgrade and replace aging facilities, EIFS use will no doubt expand. Successful use on a wide range of project types is possible, given knowledgeable EIFS specification, design, and installation, along with careful attention to the particular needs of a given project.

6 TYPICAL EIFS FAILURE MODES

Overview

Because Class PB systems are the most frequently installed type of EIFS in the United States today, the failure modes discussed in this report generally relate to Class PB systems. However, certain failures are especially common in Class PM systems; these are also discussed. Table 1 is an overview of failure modes, the areas of origin, and contributing factors. The following text discusses these factors in detail.

Table 1

Failure Modes

Failure Mode	Area of Origin	Contributing Factors
Cracking	Insulation boards	Failure to abut boards Varying quality insulation board Adhesive beyond board edges Incorrect backwrapping Omission of insulation slivers Failure to interlock corners Omission of running bond pattern
	System articulations	Configuration Improper installation - uneven base coat -failure to embed mesh Incorrect backwrapping Improper alignment with windows Articulation corresponds to board joints
	Window and door corners	Omission of diagonal mesh Improper board installation at windows
	Control joints	Omission of Class PM control joints Poor joint design Poor control joint installation Premature joint termination Accessories failure
	Expansion joints	Failure to provide as needed - height - substrate - plane/wall - system - configuration Poor joint installation

Table 1 (Cont'd)

Failure Mode	Area of Origin	Contributing Factors
Spalling/Cracking	EIFS lamina	Excessively thick/thin application Improper mixing of coatings Materials deterioration Inappropriate substrate
Impact Damage	External influences	Thin, poorly applied lamina Improper mesh embedment Mesh deterioration EIFS unsuitable for building Lack of provision for penetrations
Inadequate Closure	Through-wall openings	Inadequate seal - windows - fixtures - doors Inadequate maintenance/repair
	EIFS terminations	Poor detailing at roof line - parapets - downspouts - gutters Improper backwrapping Poor detailing at ground - granular drainage - raised EIFS line
	Sealant joints	Improper joint design Improper installation Cohesive EIFS lamina failure Cohesive sealant failure Adhesive sealant failure
System Detachment	Insulation/substrate	Adhesive attachment - incorrect material - incorrect application - ribbon-and-dab method Mechanical attachment - incorrect application Unsound substrate
Surface Degradation	Finish coat	Fading Staining Mildew Iron spots

CRACKING

INSULATION BOARDS

Contributing Factors

Failure to abut boards – Insulation boards must be tightly butted to avoid gaps between boards. Poor abutment can be attributed to a number of factors, among them varying quality board and incorrect application practices. Gaps represent breaks in the insulation surface. This surface serves to support the overlying lamina. Gaps cause cracking of the lamina along board lines (Figure 3); this in turn allows moisture to intrude. Unwanted moisture inside the system can pass through board gaps and cause further deterioration of system components. Aside from cracking, the outline of board gaps can be detected through the finish coat at the system's surface, a condition which detracts from building appearance (Figure 4).

Varying quality insulation board – Depending on the manufacturer's production methods and quality control procedures, insulation boards can vary in their dimensions: length, width, thickness, squareness, and planar flatness. Varying quality boards are difficult if not impossible to abut. Boards which are out of square or those which vary in thickness are especially likely to cause lamina cracks. Differences in board thickness create step-in board faces and variations in lamina thickness. The lamina at such locations inevitably cracks. The insertion of insulation slivers to fill gaps and the rasping of board edges to level variations in thickness are recommended installation practices.

Adhesive beyond board edges – If applied improperly, excess adhesive can overrun the perimeter of insulation boards. Adhesive between boards obstructs tight abutment (Figure 5). Manufacturers recommend that board edges be wiped clean of excess adhesive prior to installing adjacent boards.

Incorrect backwrapping – Backwrapping is typically required at all exposed edges of the insulation board. This recommended procedure is sometimes misconstrued by applicators as meaning backwrap all insulation board edges (Figure 6). This practice thwarts tight abutment and creates gaps.

Omission of insulation slivers – Where gaps between insulation boards exist, slivers of insulation should be inserted. The omission of insulation slivers is one of the most common reasons for lamina cracking.

Failure to interlock corners – MEPS boards should be interlocked at corner terminations. The use of an interlocking board pattern results in a staggered joint configuration. The stacking of board courses without interlocking corners creates continuous joints. This incorrect method of installation results in cracks along the corners of Class PB claddings (Figure 7).

Omission of running bond pattern – Insulation boards should be applied in a running bond pattern with staggered vertical joints. Gaps left between boards caused the cracking (Figure 8). Boards should not be installed in a stacked pattern such that the vertical edges of boards are in line with one another. This creates continuous vertical joints which can run the entire height of the building and precipitate lamina cracking along joint lines.

Figure 3. Crack in EIFS lamina due to a failure to abut the insulation boards.

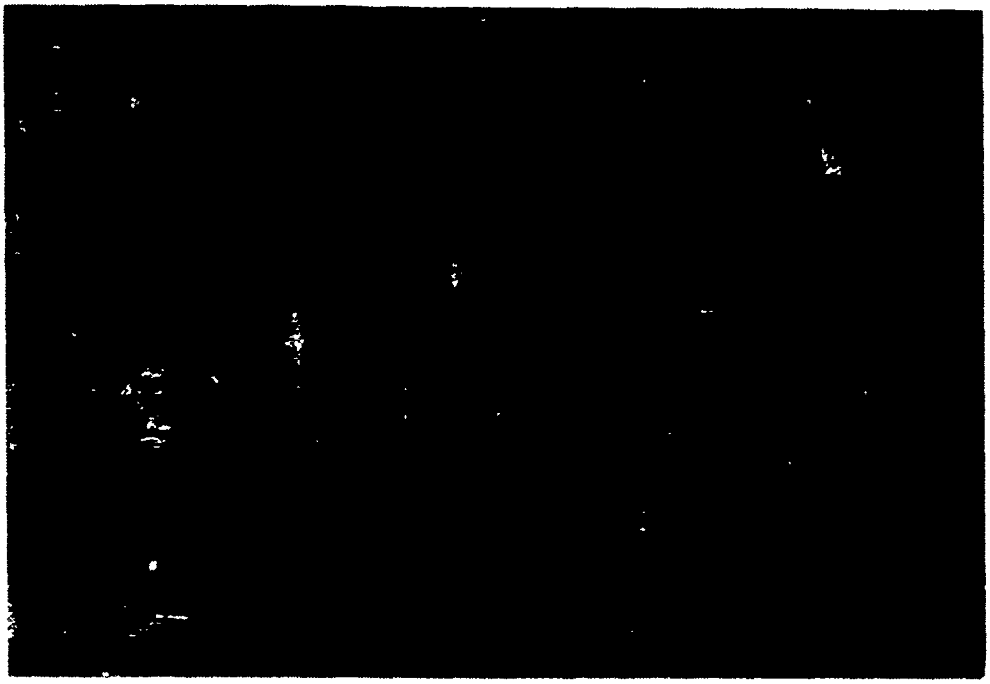

Figure 4a. Cracking which follows the outline of the insulation boards is a sign of failure to abut boards.

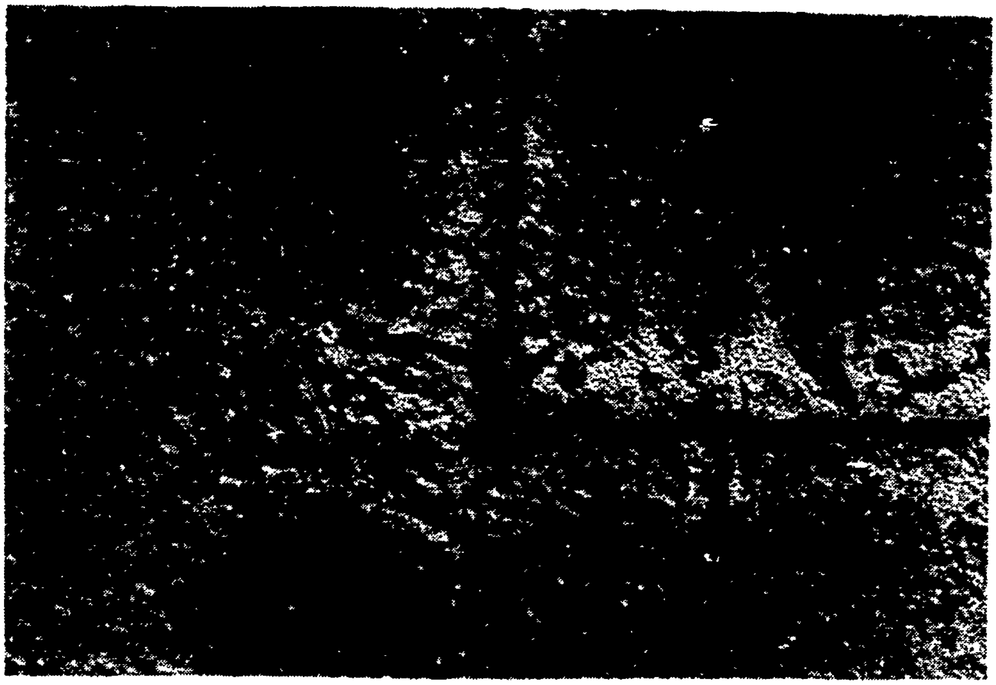

Figure 4b. Closeup of cracking in Figure 4a.

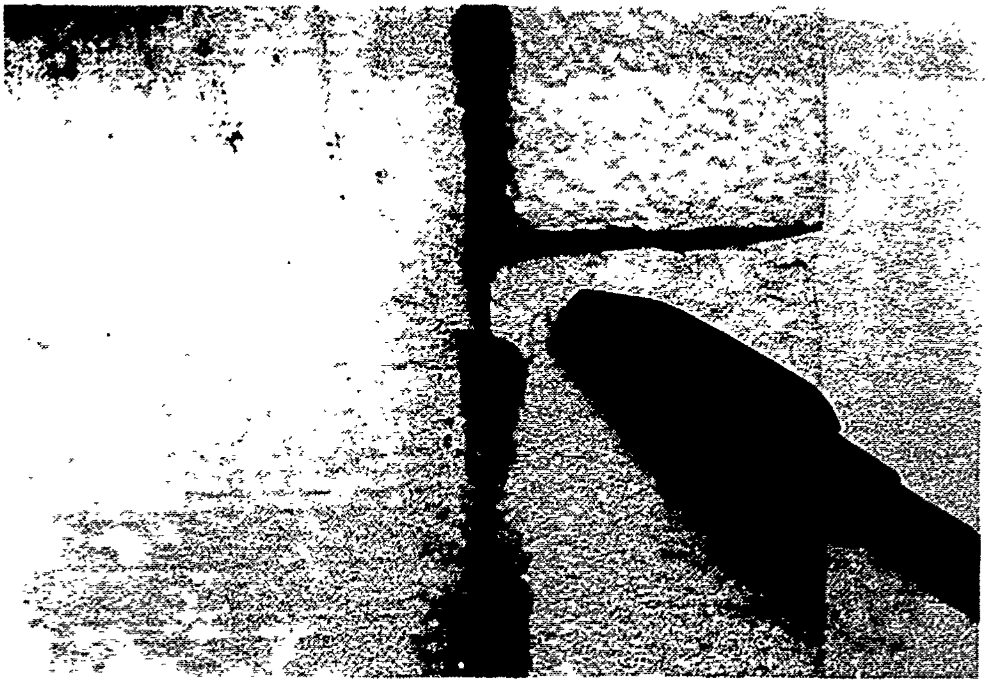

Figure 5. Adhesive between EPS boards - improper.

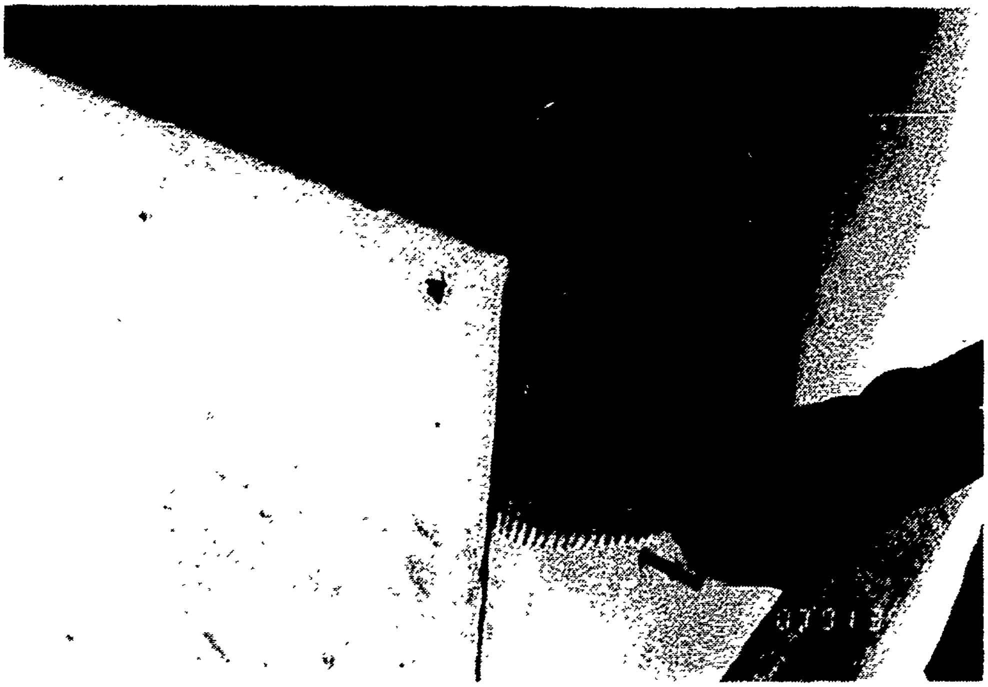

Figure 6. Incorrect backwrap between EPS boards.

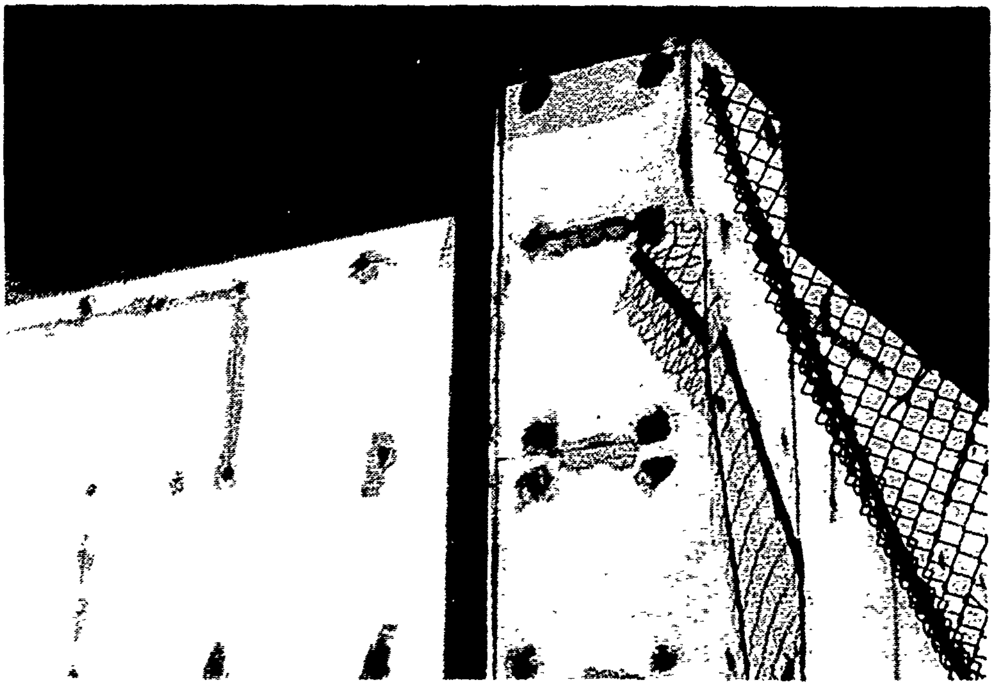

Figure 7. EPS outside corner - interlock omitted.

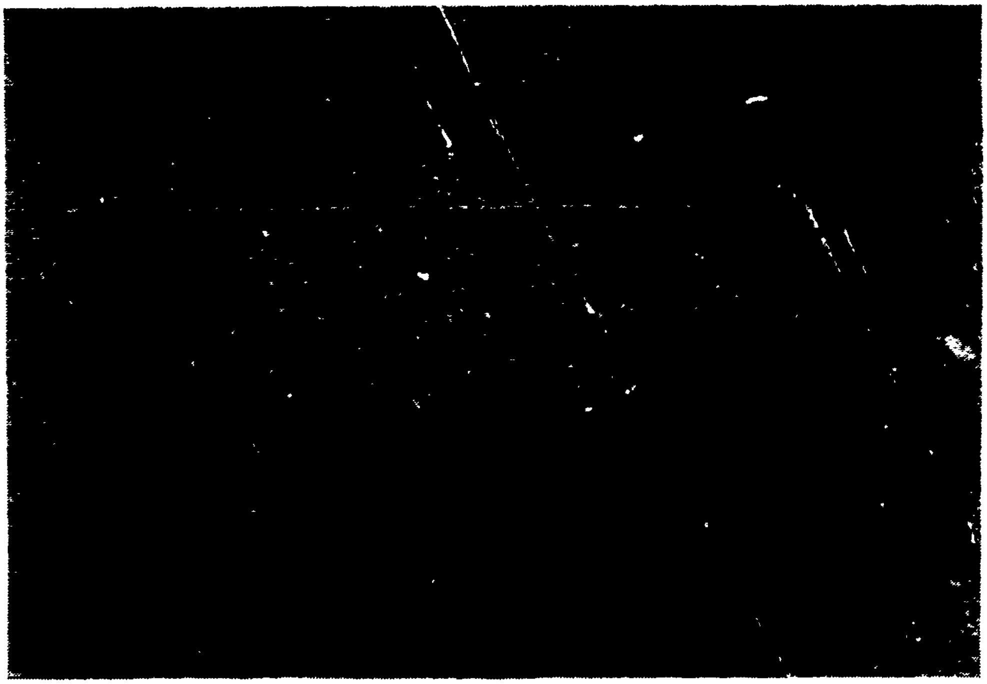

Figure 8. Vertical and horizontal crack intersection shows the omission of a running bond pattern.

SYSTEM ARTICULATIONS

Contributing Factors

Configuration — System articulations include aesthetic joints which serve to enhance building design and character. Unlike joints which accommodate movement, aesthetic joints are surface details. The configuration of these details weakens the structure of EIFS cladding. Specifically, the removal of insulation board to create aesthetic joints diminishes system integrity. In addition, mesh in recessed grooves changes plane which reduces tensile strength. During joint installation, tools such as trowels can cut the mesh in system articulations. This interrupts the continuity of system reinforcement and results in cracking of the lamina (Figure 9).

Improper installation — System articulations require that EIFS lamina be applied on either a protruded or recessed (U- and V-groove) insulation surface. Careful workmanship is required to properly install these details. The risk of uneven base coat application and partially embedded mesh is heightened because of the limited working space available at system articulations. A base coat that is too thick or too thin is prone to cracking. Likewise, mesh which is not fully embedded weakens the lamina composite and increases the chance of cracking (Figure 10).

Incorrect backwrapping — Backwrapping is typically required at all exposed edges of insulation board. System articulations do not require backwrapping; they are continuations as opposed to terminations, of the cladding. Where board joints are incorrectly aligned with grooves, and where insulation boards are unnecessarily backwrapped, system cracking is extremely likely.

Improper alignment with windows — The alignment of system articulations with window heads, jambs, or sills can cause cracking (Figures 11 and 12). Proper design should isolate these articulations from other system details.

Articulation corresponds to board joints — The alignment of system articulations with underlying insulation joints is an incorrect installation practice. Cracking typically occurs at these alignments. Planning and foresight on the part of the applicator ensures that system articulations do not correspond to underlying board joints.

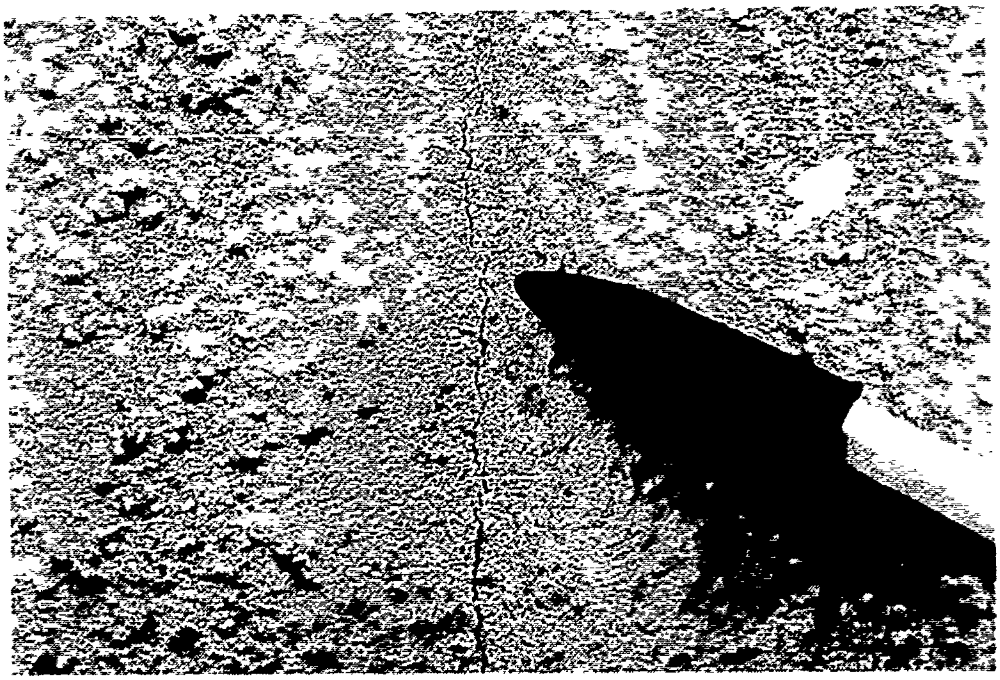

Figure 9. Cracking in "V" groove articulation.

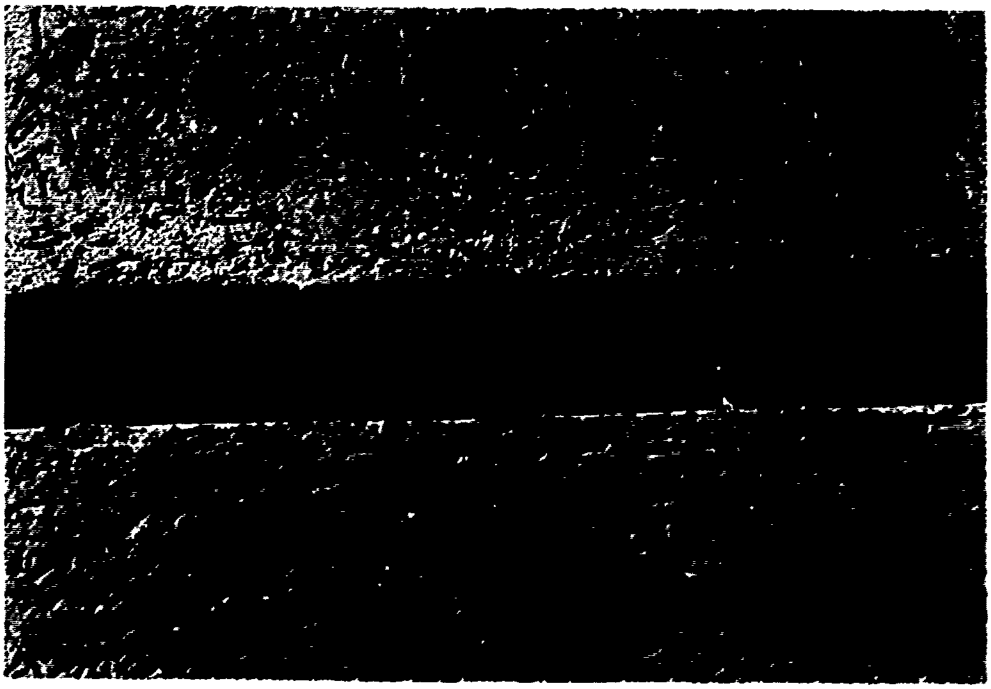

Figure 10. Exposed mesh in "U" groove articulation.

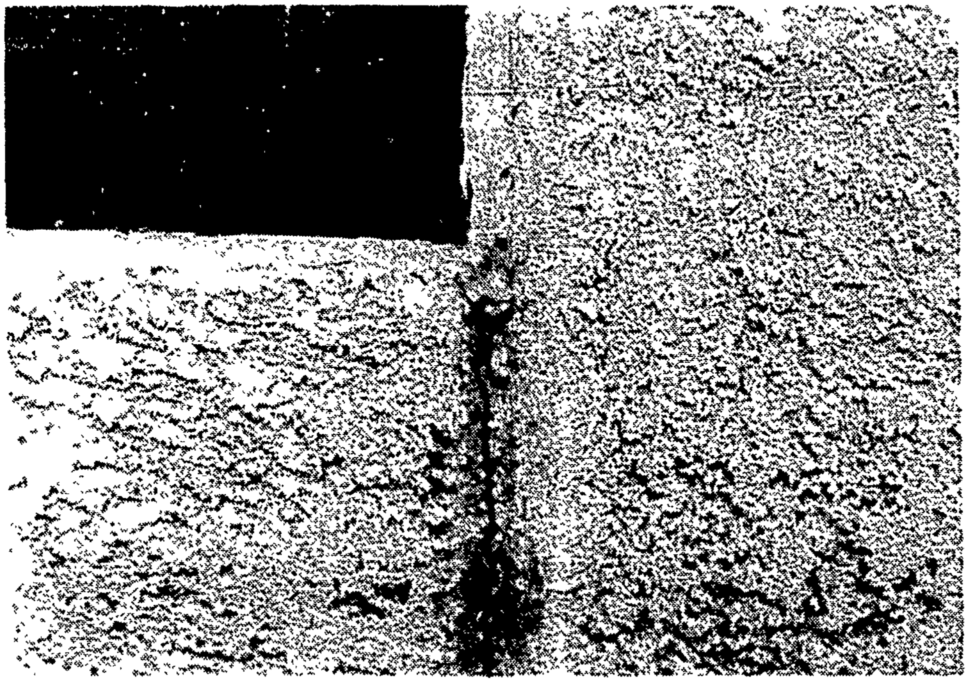

Figure 11. Cracking in "V" groove articulation.

Figure 12. Cracking in "U" groove articulation.

WINDOW AND DOOR CORNERS

Contributing Factors

Omission of diagonal mesh — Doors and windows are the most common kind of building opening. Other system penetrations include openings for building equipment such as air conditioning units and fixtures. Because the corners of openings are points of concentrated stress, additional reinforcement is necessary. Diagonal mesh is required at the corners of all EIFS openings. The omission of diagonal mesh at corners leads to cracking (Figures 13 and 14).

Improper board installation at windows — An incorrect practice is to install insulation boards against door and window openings so that board joints align with window heads, sills, and jambs. When board joints coincide with corners, horizontal and vertical cracking typically occur (Figure 15). L- or saddle-shaped boards should be installed around all openings to diminish the number of board joints at corners (Figure 16).

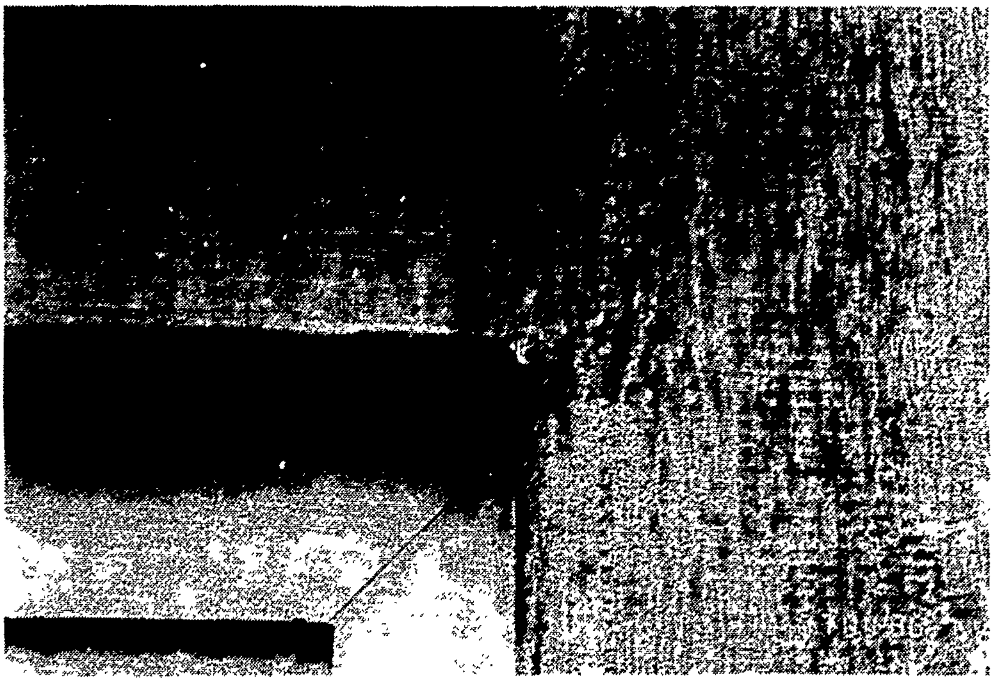

Figure 13. Crack at window head; diagonal mesh omitted.

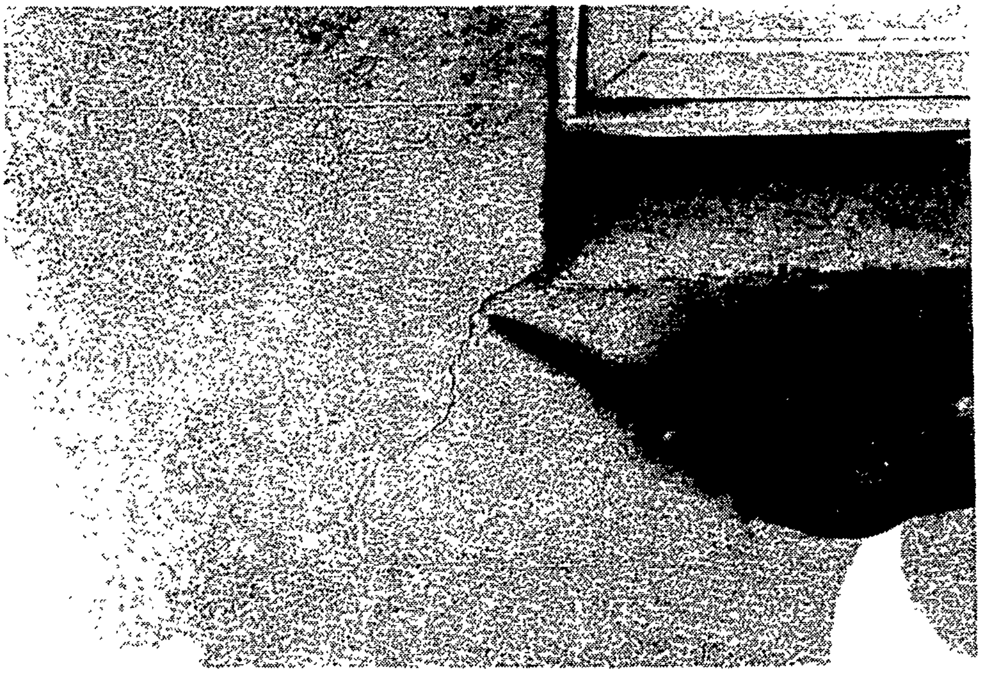

Figure 14. Diagonal crack at window sill.

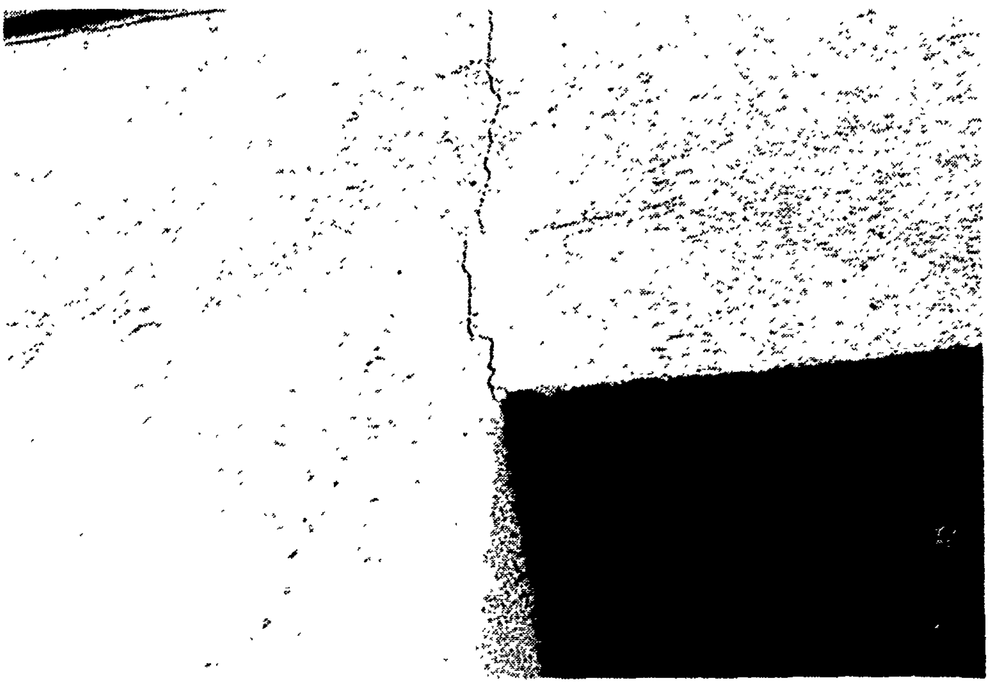

Figure 15. Vertical crack at window head showing improper alignment of insulation board joint at window head.

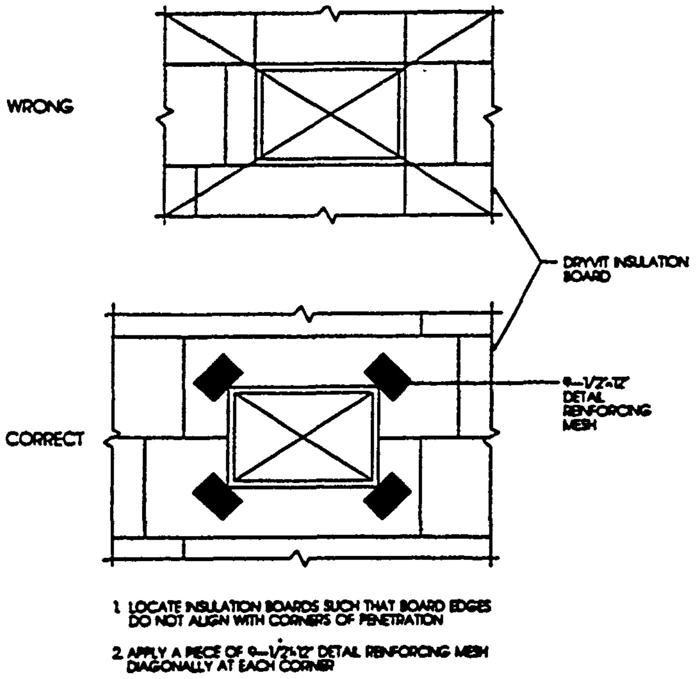

Figure 16. Dryvit: Wall Penetration Details. (Source: Dryvit Systems, Inc. Used with permission.)

CONTROL JOINTS

Contributing Factors

Omission of control joints — Control joints accommodate movement by limiting EIFS application to areas of specific proportions. Unlike expansion joints, control joints do not traverse the building structure; rather, they are detailed to the EIFS substrate. Class PM systems with their typically higher cementitious content require a greater number of control joints. The omission of control joints on EIFS installations can cause horizontal, vertical, or diagonal cracking (Figures 17 and 18).

Poor joint design — For Class PM systems, control joints should be placed between areas which are in a length to width ratio no greater than 2.5 to 1.0. Class PM joint placement which does not adhere to this ratio reflects inadequate joint design. In addition, structural needs should guide design decisions regarding joint placement. A joint which is consistent with building design and detailing but does not successfully accommodate movement can crack, thereby undermining both the integrity and appearance of the cladding.

Poor control joint installation — Numerous application factors contribute to poor joint installation. One of the most significant is the failure to remove coating material from inside control joint profiles. This inside space should be cleaned of all coating material. If allowed to remain, this material can limit the joint's capacity to accommodate movement, resulting in cracking (Figure 19).

Premature joint termination — Horizontal and vertical control joints that are terminated prematurely lead to cracking at the ends of joints (Figures 20 through 23). Control joints should extend the full width and height of the detailed area. For instance, vertical joints should run the full height of the building from roof line to ground. Vertical and horizontal joints which intersect should permit the vertical member to continue through the intersection (Figure 24). If terminated at the intersection, the joint is prone to horizontal, vertical, and diagonal cracking.

Accessories failure — Class PM systems typically use accessories at joints. Successful installation depends on the material composition of accessories as well as proper installation. Vinyl accessories are more likely to result in failed or broken joints than metal accessories (Figures 25 and 26).

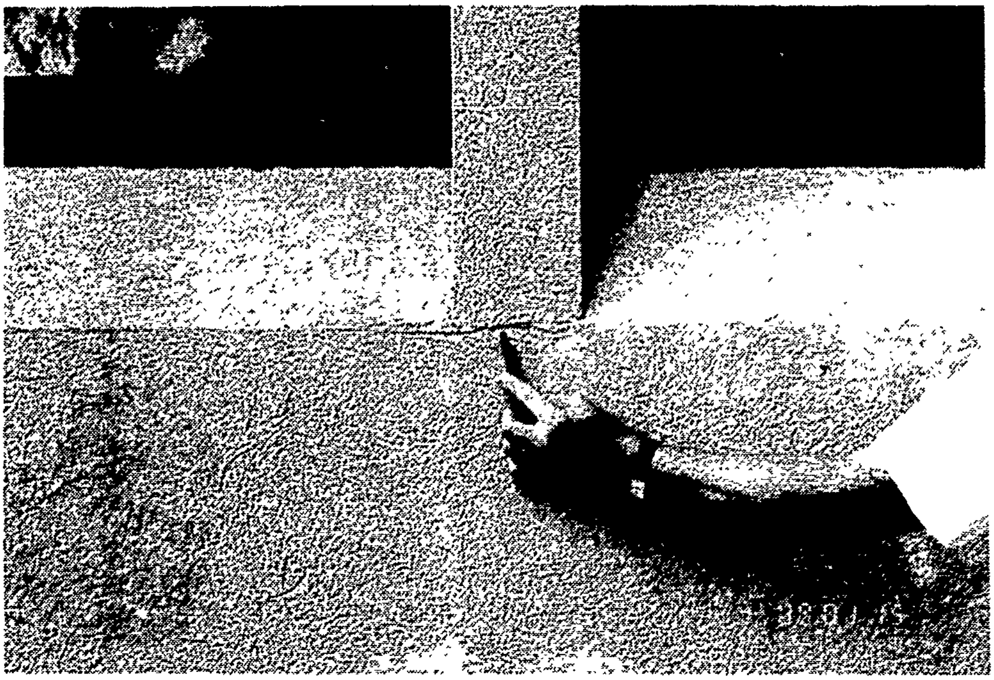

Figure 17. Crack due to control joint omission.

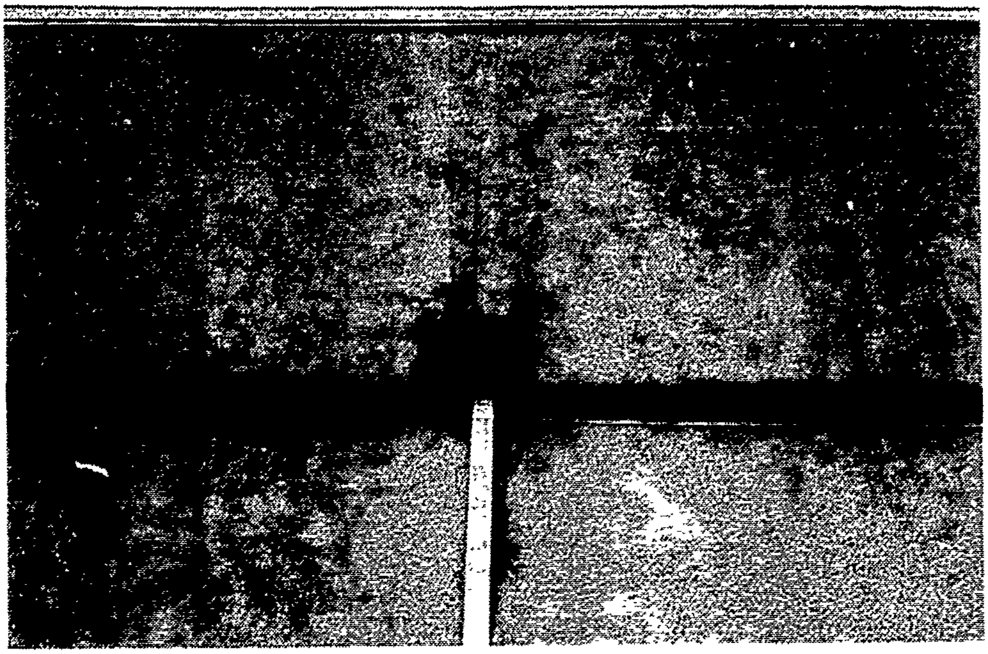

Figure 18. Control joint omission at substrate change.

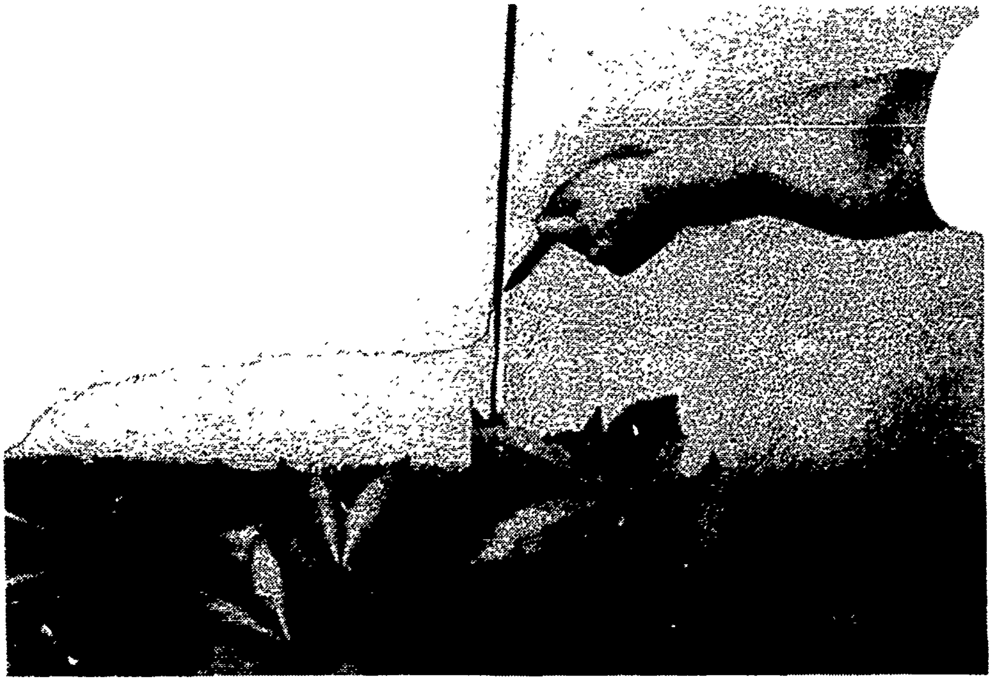

Figure 19. Impingement at control joint - crack.

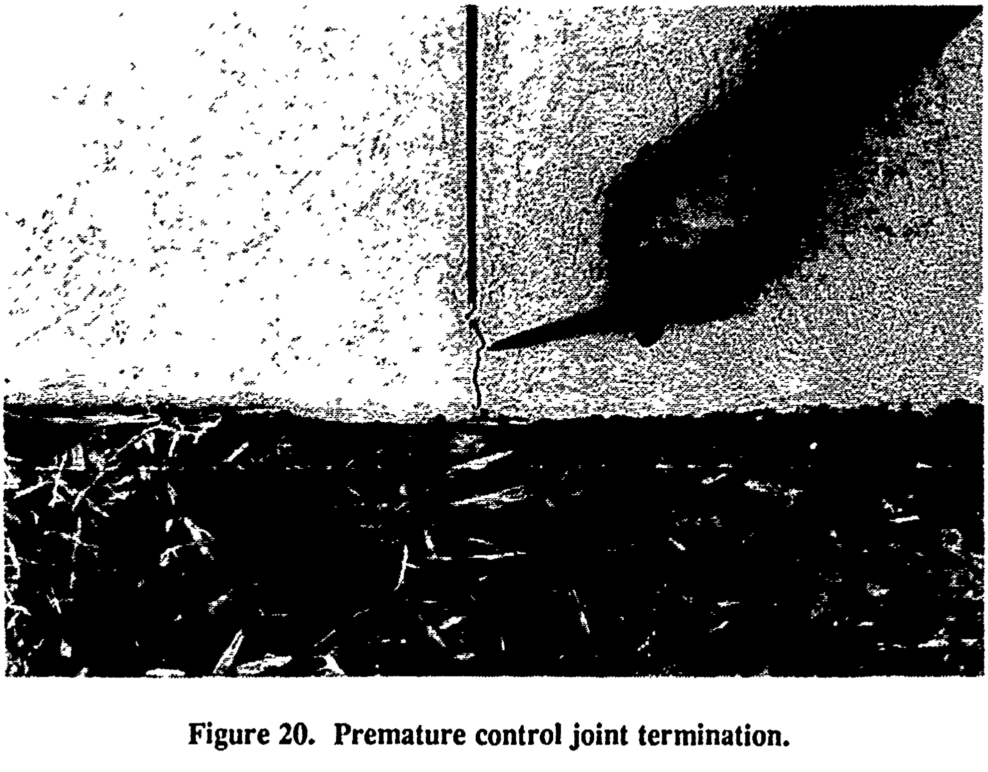

Figure 20. Premature control joint termination.

Figure 21. Premature control joint termination.

Figure 22. Premature control joint termination at sill.

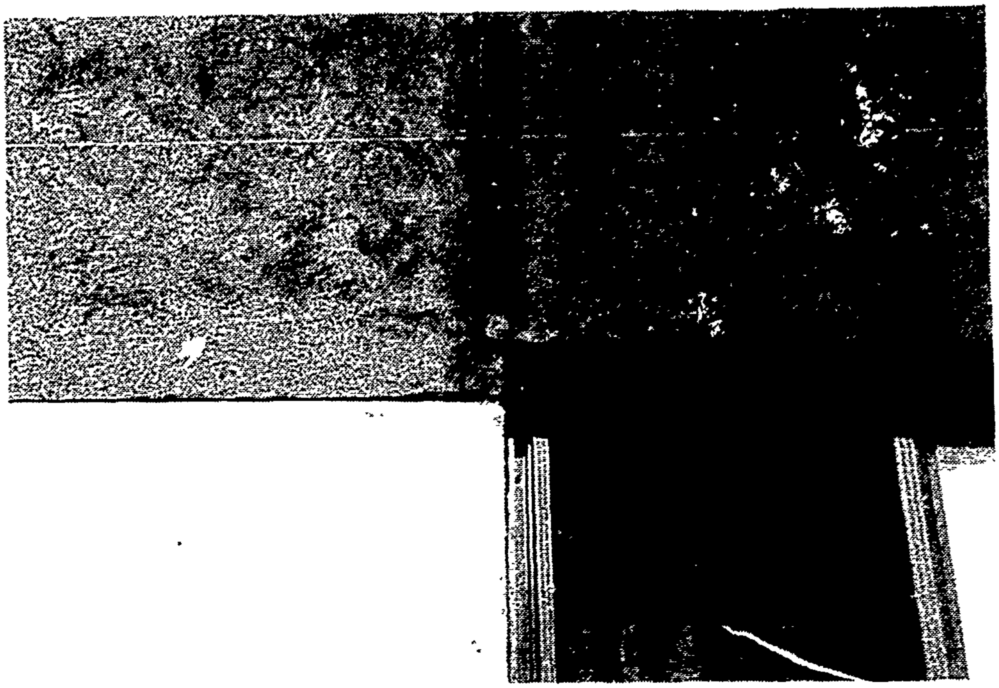

Figure 23. Premature control joint termination.

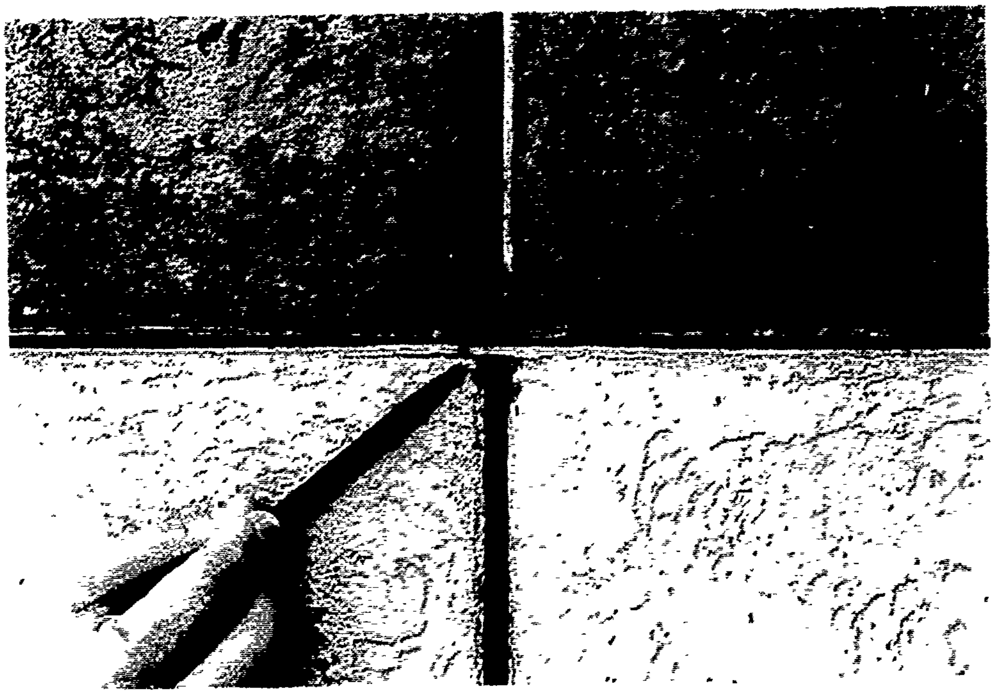

Figure 24. Improper control joint termination.

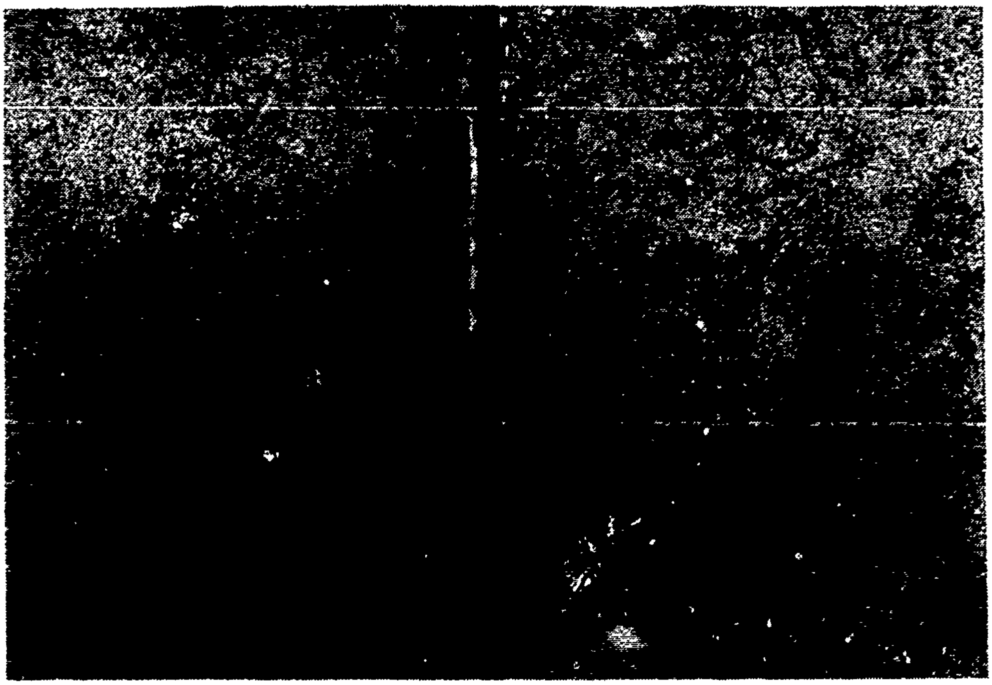

Figure 25. Vinyl control joint failure.

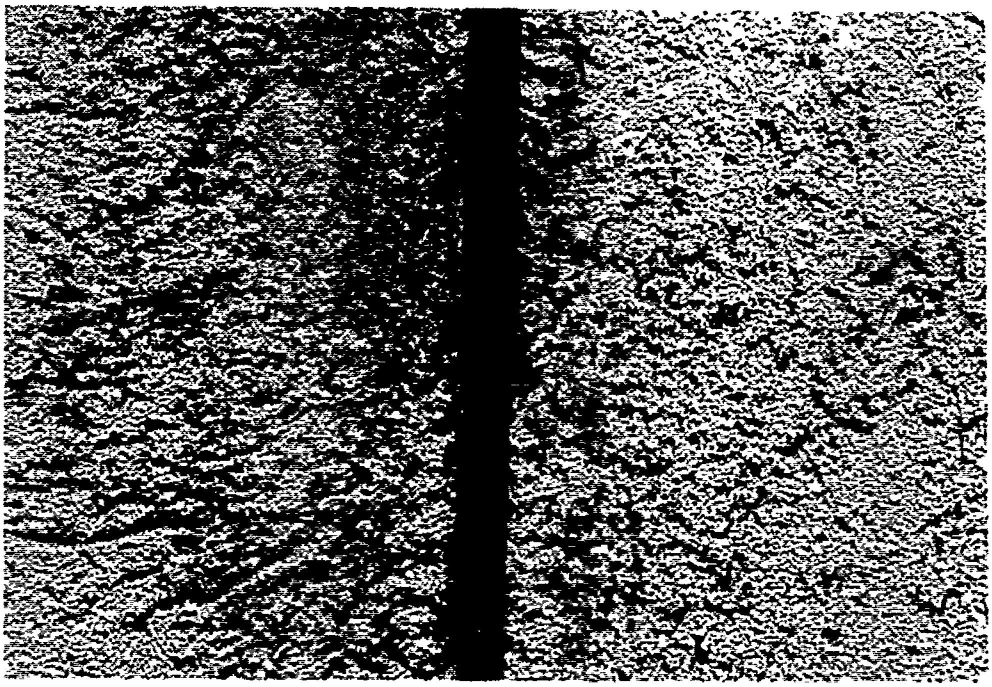

Figure 26. Vinyl control joint failure.

EXPANSION JOINTS

Contributing Factors

Failure to provide as needed — Expansion joints accommodate movement between building segments. They cross through EIFS components to the underlying building structure. Expansion joints are typically required at places where EIFS meets building components of dissimilar material or configuration (Figure 27). They are also required at major changes in building height, plane, or wall. The omission or inadequate provision of necessary expansion joints on EIFS installations can cause cracking (Figures 28 and 29).

Poor joint installation — Among the numerous application factors that contribute to poor joint installation, and thus cracking, are improper joint dimensions, incorrect use of materials, and incorrect finishing. Expansion joints typically incorporate sealant material. The proper application and tooling of sealant material are important aspects of successful joint installation (Figure 30).

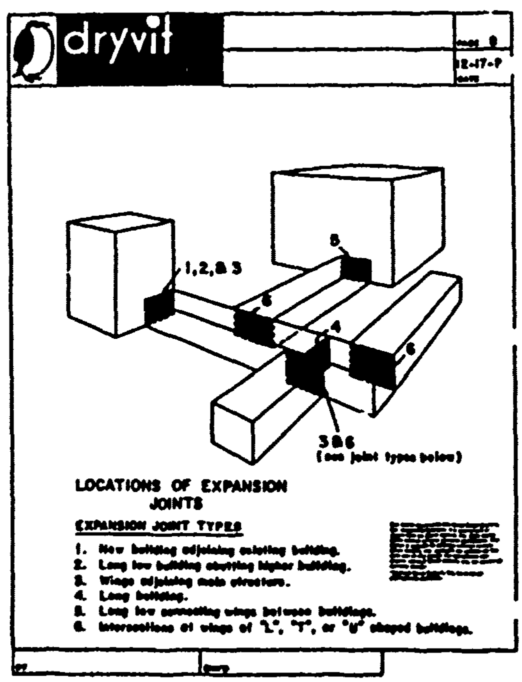

Figure 27. Dryvit: Expansion joint location drawing. (Source: Dryvit Systems, Inc. Used with permission.)

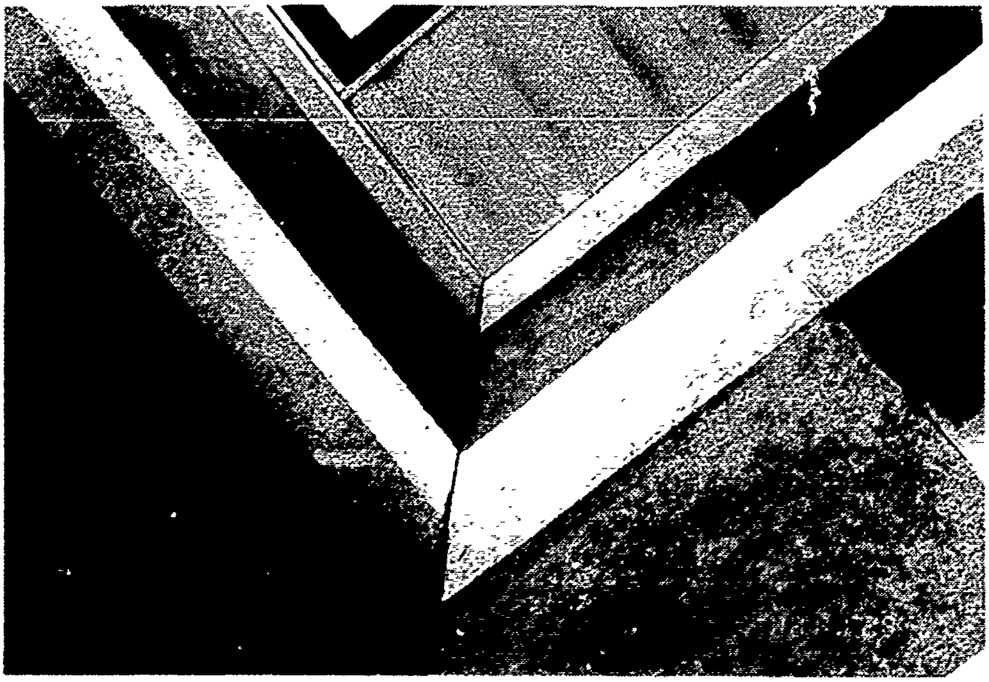

Figure 28. Expansion joint omission at corner.

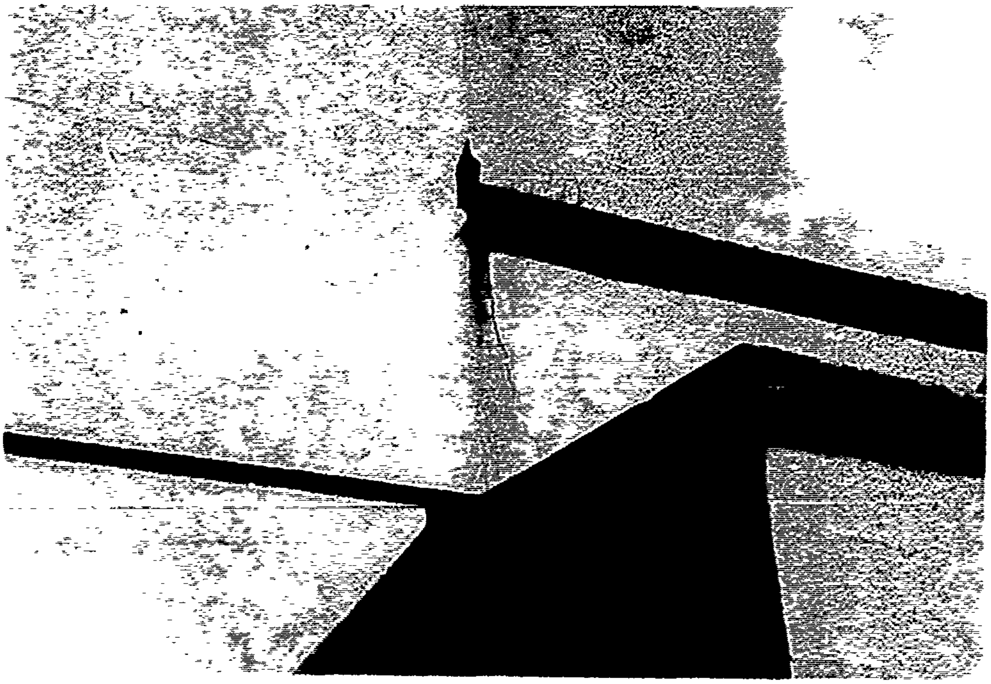

Figure 29. Omission of expansion joint between buildings.

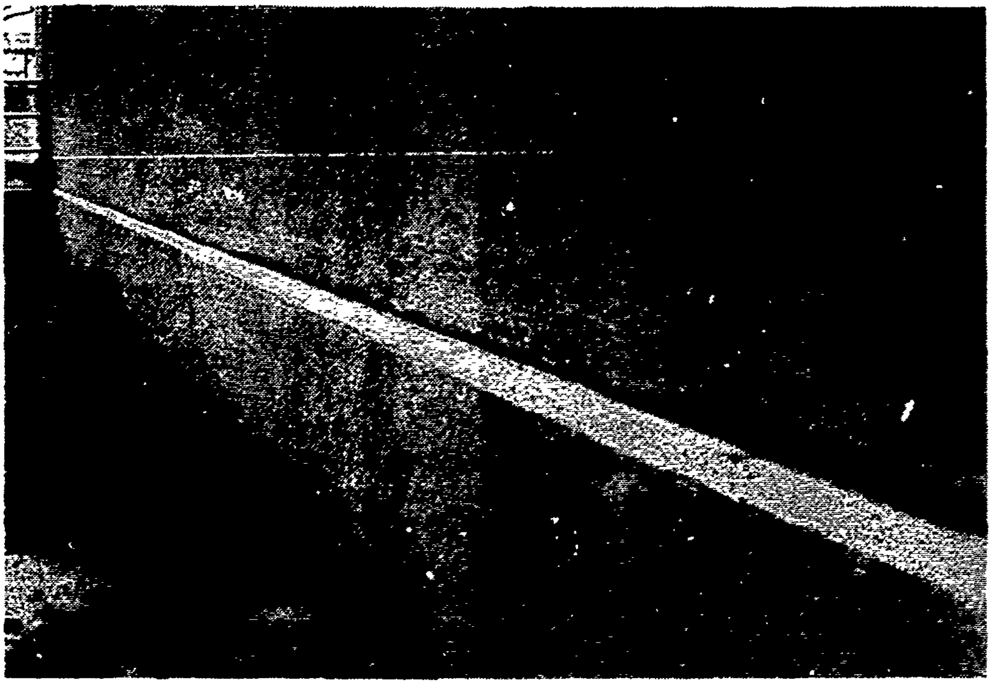

Figure 30. Successful expansion joint at building base.

SPALLING/CRACKING

EIFS LAMINA

Contributing Factors

Excessively thick/thin application — EIFS lamina is intended to function as a composite layer of integrated materials. The installation and detailing of the finish and base coats are critical for lamina integrity. Coatings must be applied to the manufacturer's specified thickness. For instance, base coat material that is applied too thick is likely to crack and spall (Figure 31). Alternatively, a thin base coat provides inadequate protection for system components and is subject to deterioration, cracking, and failure. During application, the reinforcing mesh must be completely encapsulated by the base coat. A visible mesh pattern in the base is a sign that the EIFS lamina has been applied too thin (Figures 32 and 33).

Improper mixing of coatings — Because base coats are typically mixed on site, adherence to the manufacturer's recommended ratio of components is essential. If the amount of cement in the base mix is increased, or the polymer decreased, the resulting material will be stiff and prone to spalling and cracking.

Materials deterioration — Poor preparation of MEPS insulation board can result in the deterioration of insulation and lead to spalling and cracking. Site dirt, UV degradation (Figure 34) and unevenness should be corrected by rasping MEPS board surfaces prior to base coat application. Correct board preparation ensures a good bond between the lamina and insulation board.

Inappropriate substrate — The application of lamina on substrates other than those recommended represents noncompliance with manufacturer's guidelines; for instance, applying lamina directly to plywood or gypsum board is not an approved practice. Some products that have the appearance of EIFS allow for the direct application of coatings over concrete, masonry, and stucco. Additionally, manufacturers offer polymer paints which also resemble EIFS. However, the application of EIFS lamina on inappropriate substrates results in failure (Figures 35 and 36).

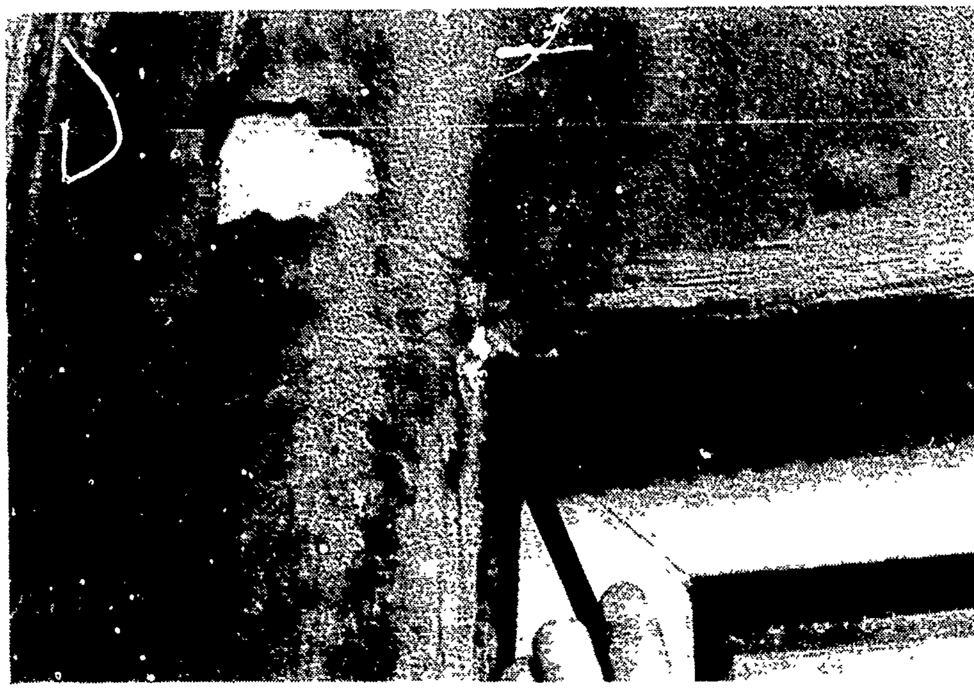

Figure 31. Spalling of base coat due to improper application.

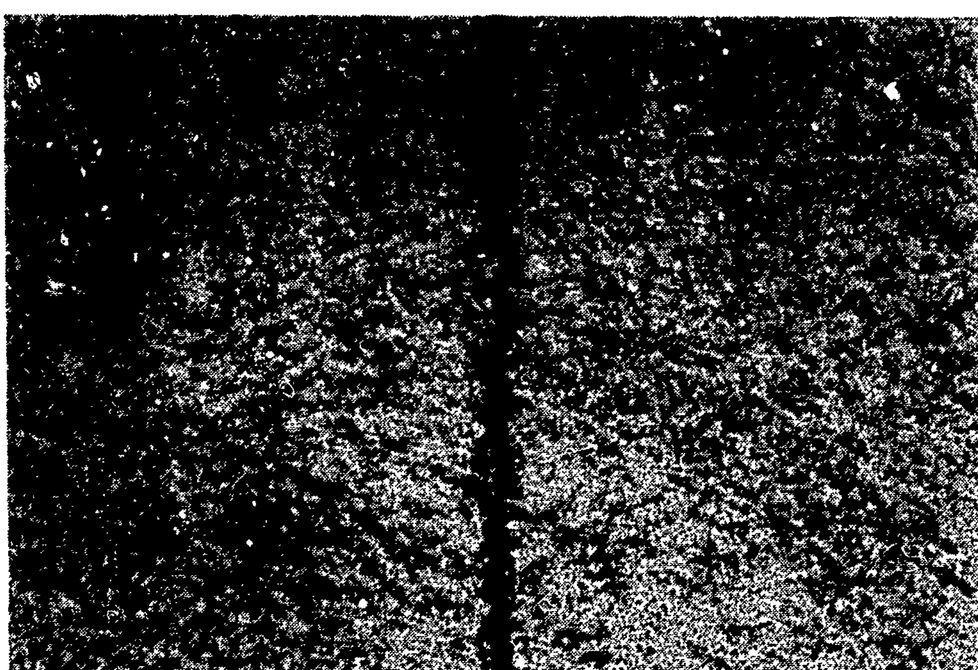

Figure 32. Insufficient mesh embedment.

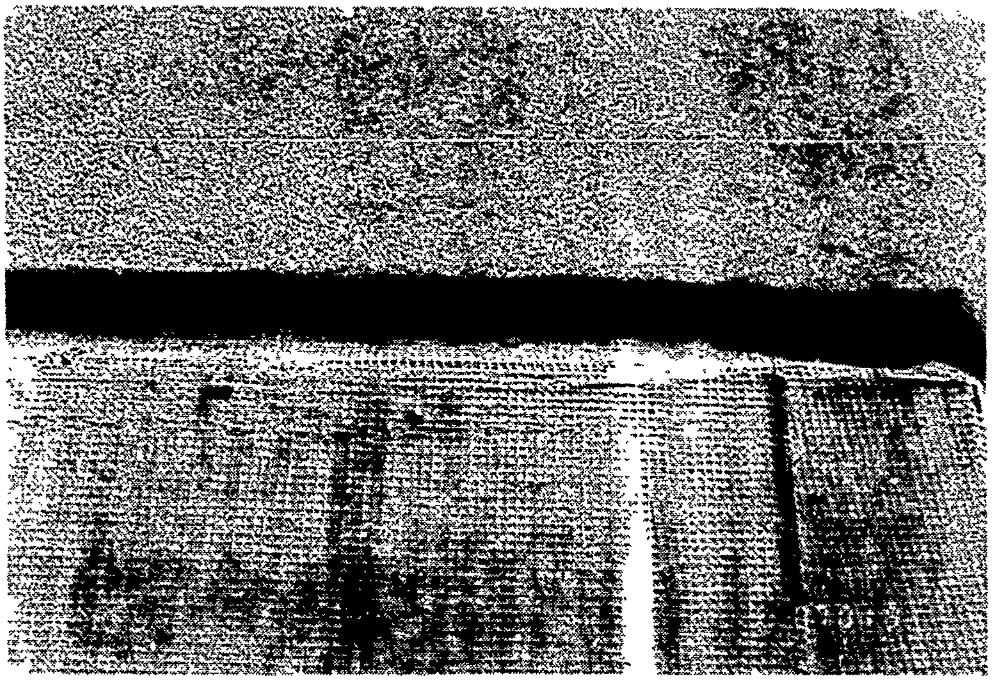

Figure 33. Insufficient mesh embedment.

Figure 34. Ultraviolet EPS board damage.

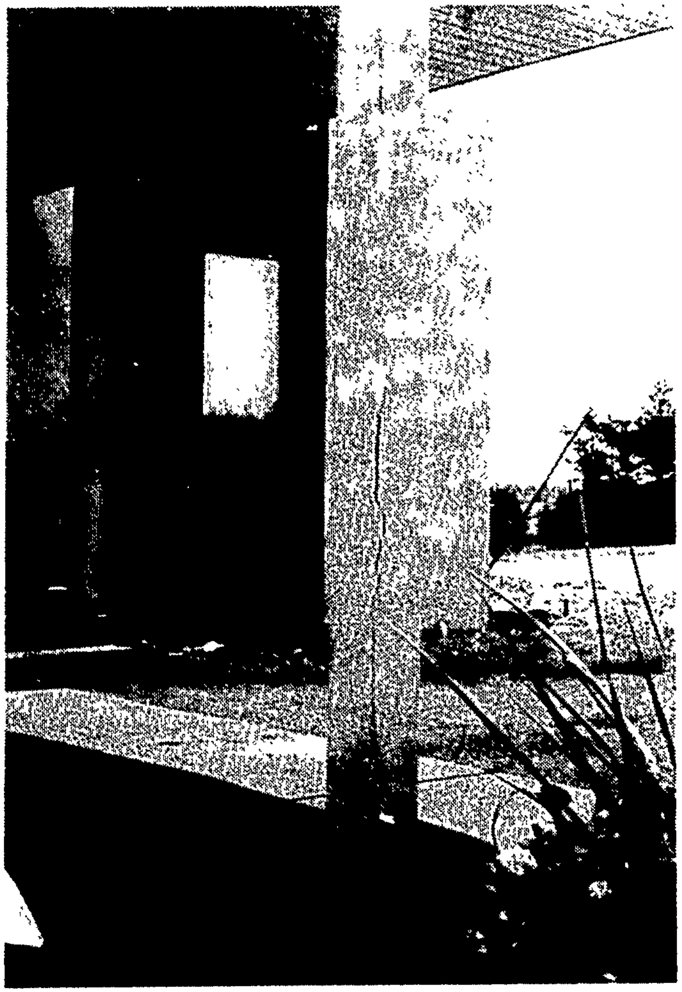

Figure 35. EIFS lamina failure due to application over improper substrate: in this case, a wooden column.

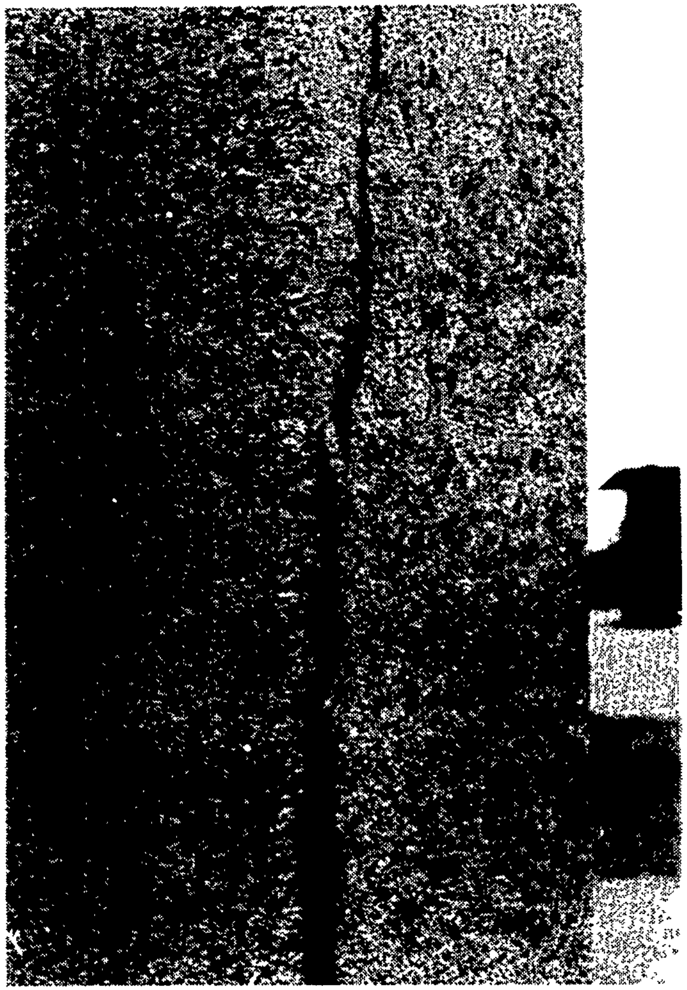

Figure 36. Closeup of EIFS lamina failure shown in Figure 35.

IMPACT DAMAGE

EXTERNAL INFLUENCES

Contributing Factors

Thin, poorly applied lamina — The lamina provides a durable cladding surface and is intended to resist impact from external forces. Coating thicknesses are specified by the manufacturer to achieve optimal durability as well as lamina integrity. Thinly applied coatings or those varying in thickness lack durability. Aside from the risk of spalling and cracking, a thin or inconsistent lamina is less likely to sustain impact without damage.

Improper mesh embedment — Fiberglass mesh must be fully embedded in the base coat during application. Partially embedded mesh weakens the impact resistance of EIFS systems (Figure 37).

EIFS unsuitable for building — EIFS claddings are not appropriate for all buildings or building areas. The selection of EIFS cladding should take into account the intended building use and proposed occupancy. Areas such as loading docks (Figure 38) or ground floors (Figure 39) are typically subjected to frequent and repeated impact. These areas may require a wall cladding other than EIFS or additional reinforcement. Cladding selection should be guided by individual project conditions.

Lack of provision for penetrations — Building penetrations (doors or windows) and fixtures (door hardware or HVAC equipment) should be detailed and installed in a manner consistent with use (Figure 40). For example, an incorrectly positioned doorstop can subject the cladding to repeated impact from the door knob and puncture the lamina (Figure 41). Design professionals and EIFS applicators must work together to ensure adequate provision for such details.

Lack of provision for maintenance equipment — Lawn mowers and other lawn maintenance equipment can cause impact damage to EIFS (Figure 42). This type of impact damage can be prevented by changing the EIFS base detail (Figure 43) or by adding a gravel boarder around the base of the building (Figure 44).

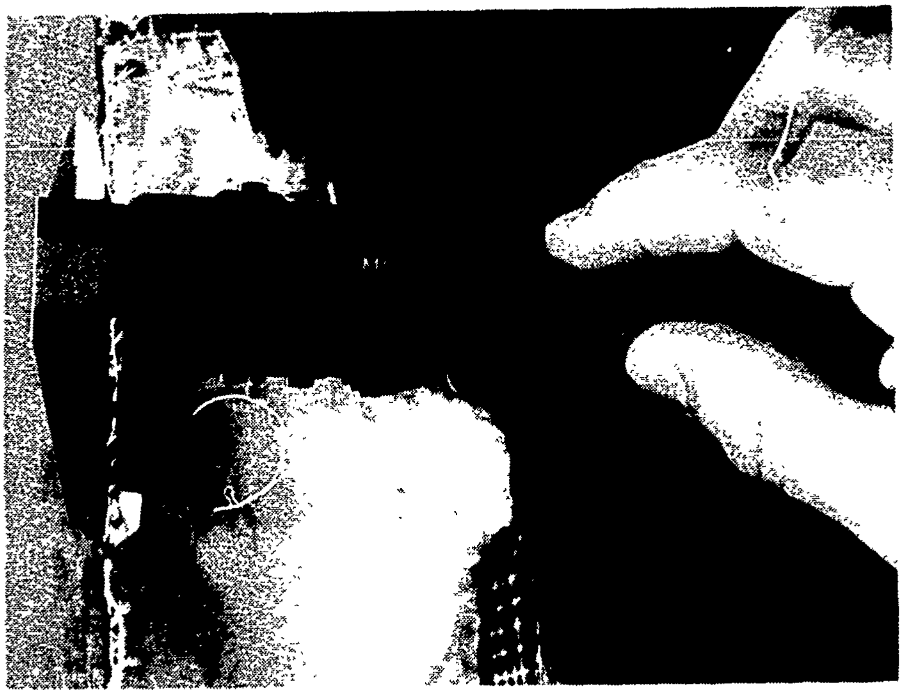

Figure 37. Inadequate material application.

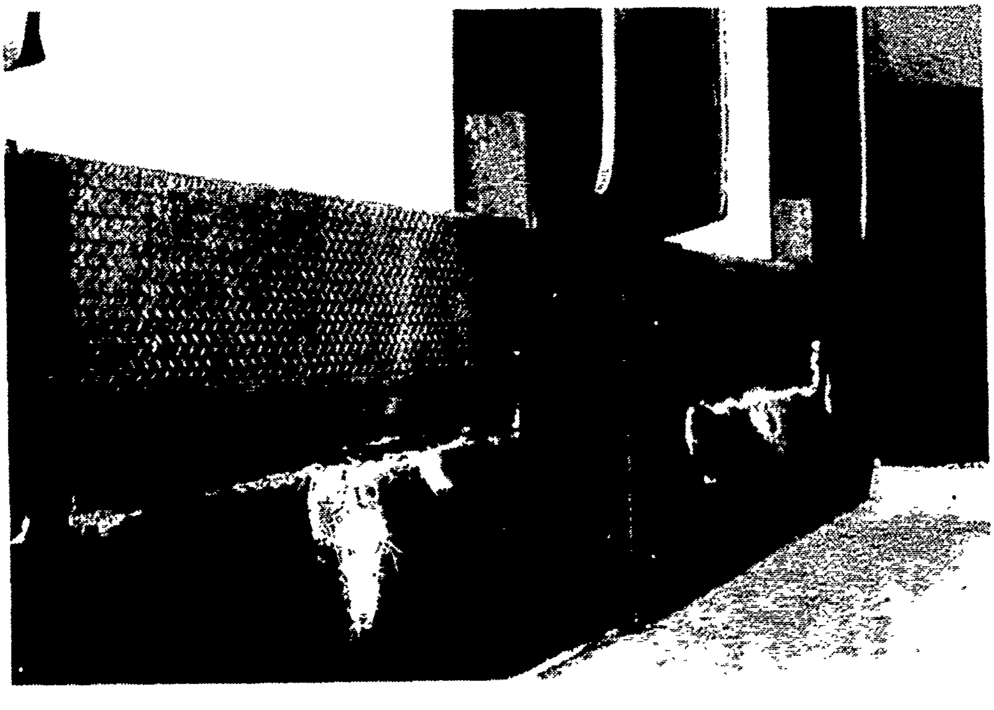

Figure 38. Impact damage at loading area.

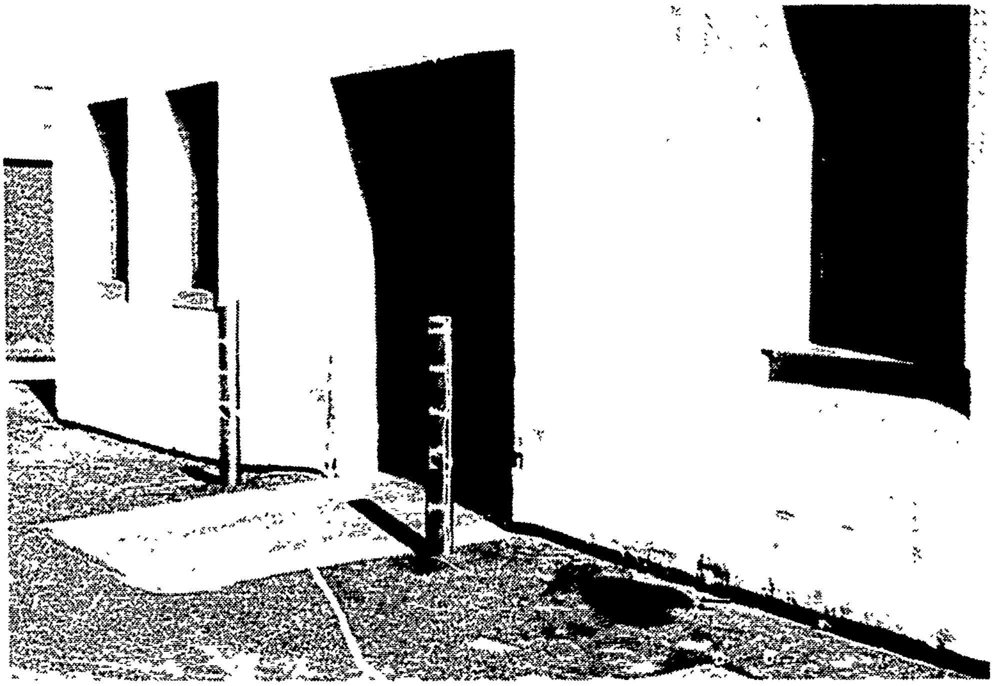

Figure 39. Impact damage at service area.

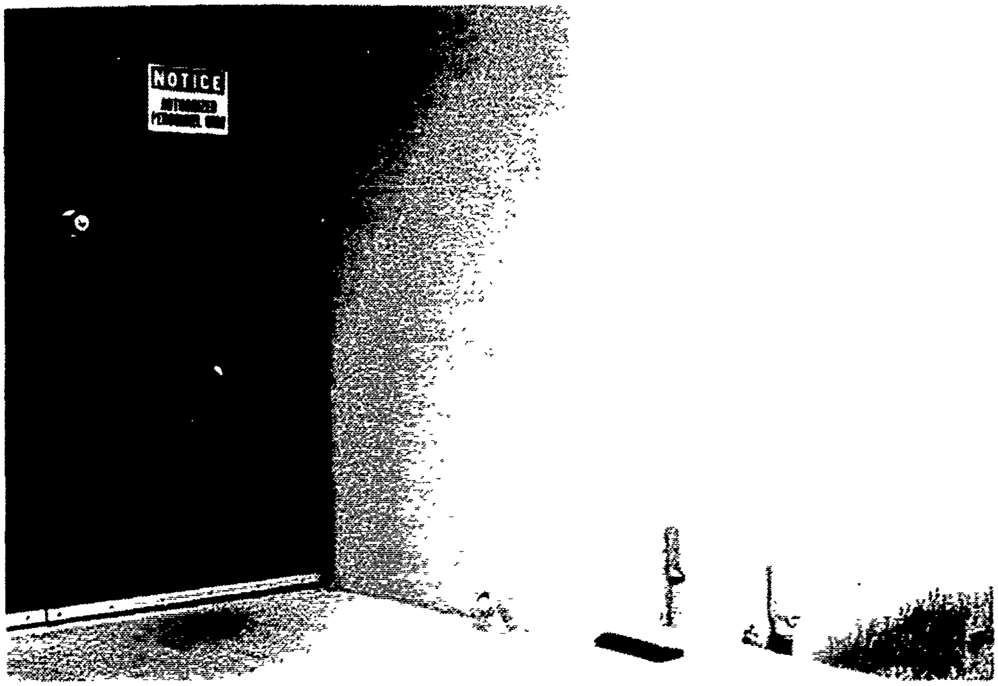

Figure 40. Doorstop prevents impact damage.

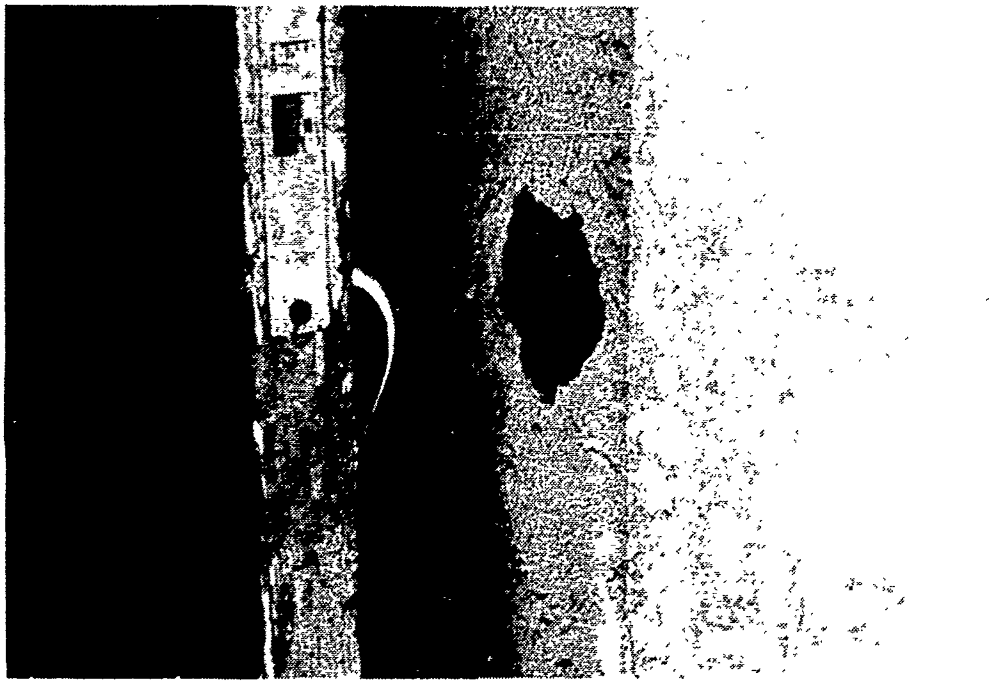

Figure 41. Impact damage due to door hardware.

Figure 42. Impact damage due to lawn maintenance.

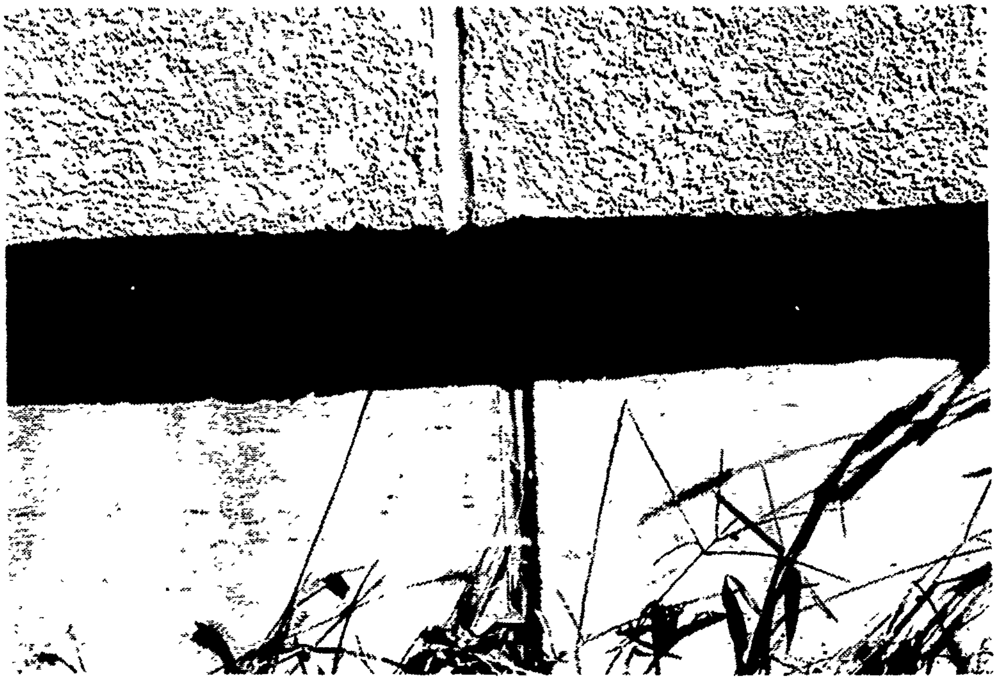

Figure 43. Base detail to accommodate lawn equipment.

Figure 44. Gravel border around building perimeter.

INADEQUATE CLOSURE

THROUGH-WALL OPENINGS

Contributing Factors

Inadequate seal — In light of the overriding need for moisture tightness, all through-wall openings must be properly sealed. Improperly sealed through-wall penetrations such as windows (Figures 45 through 48), fixtures (Figures 49 through 55), and doors facilitate moisture intrusion beyond the EIFS barrier. The correct design and installation of sealant joints at penetrations is essential to a successful EIFS barrier wall. Figure 56 shows a door jamb which was properly and successfully sealed.

Inadequate maintenance/repair: Correct repair and timely maintenance ensure the long life of EIFS buildings. Maintenance and repair methods provided by EIFS manufacturers should be followed. Although damaged lamina can be patched by methods other than those recommended, the results can be disappointing. Short-sighted or haphazard methods may result in more costly repairs at a later time. Under certain lighting conditions (light source parallel to building face), most patches will be somewhat visible due to changes in surface texture. However, patches on light colored finish coat material are less noticeable if guidelines are followed. In comparison, it is more difficult to achieve undetectable patches on dark colored facades.

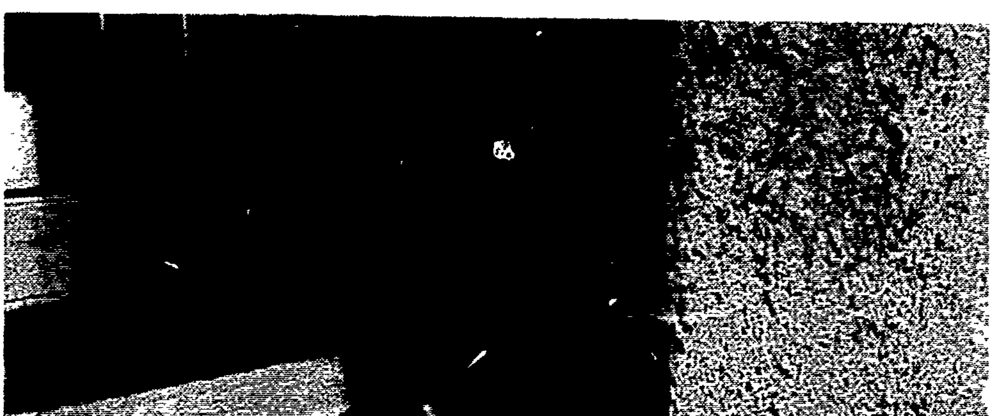

Figure 45. Inadequate closure — EIFS/metal sill.

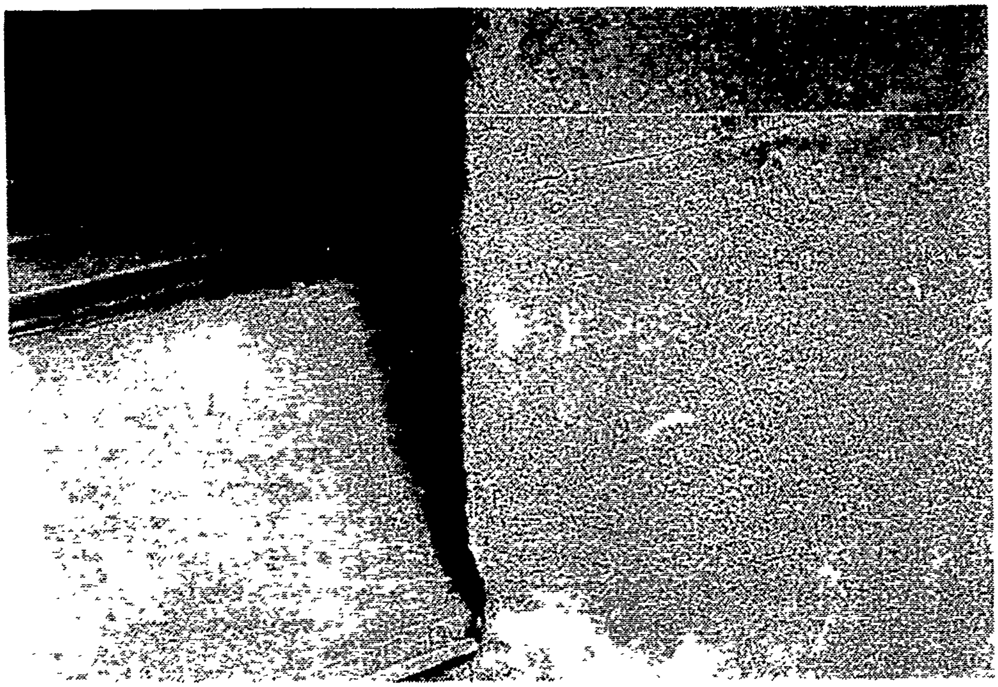

Figure 46. Inadequate closure at metal sill.

Figure 47. Inadequate closure at metal sill.

Figure 48. Inadequate closure at window sill.

Figure 49. Inadequate closure at pipe.

Figure 50. Inadequate closure at pipe.

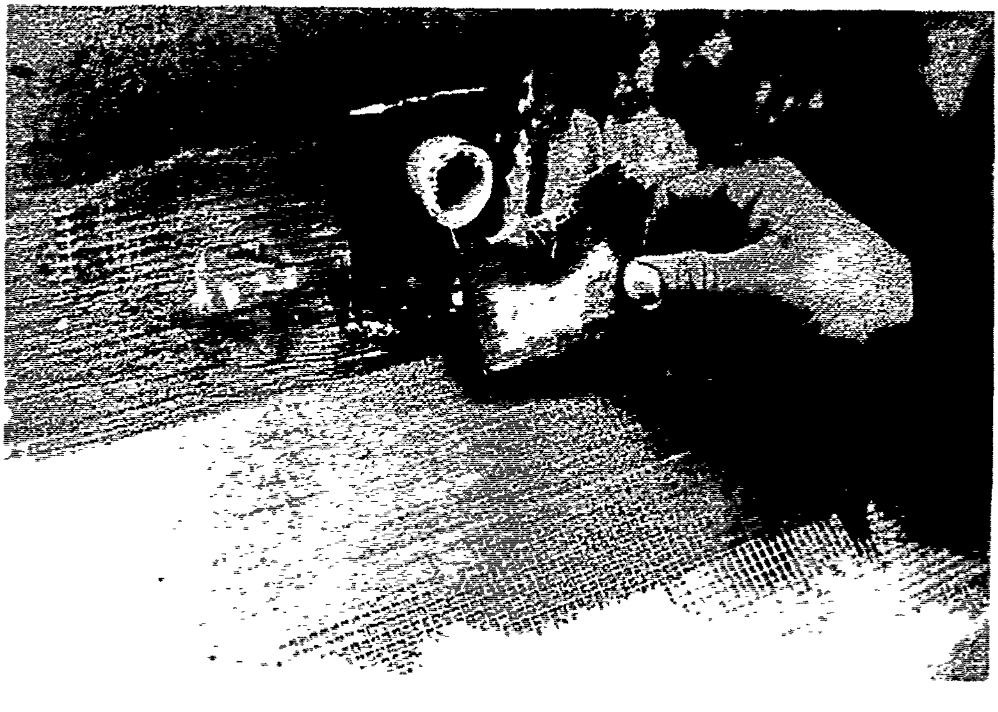

Figure 51. Inadequate closure at pipe.

Figure 52. Inadequate closure at pipe.

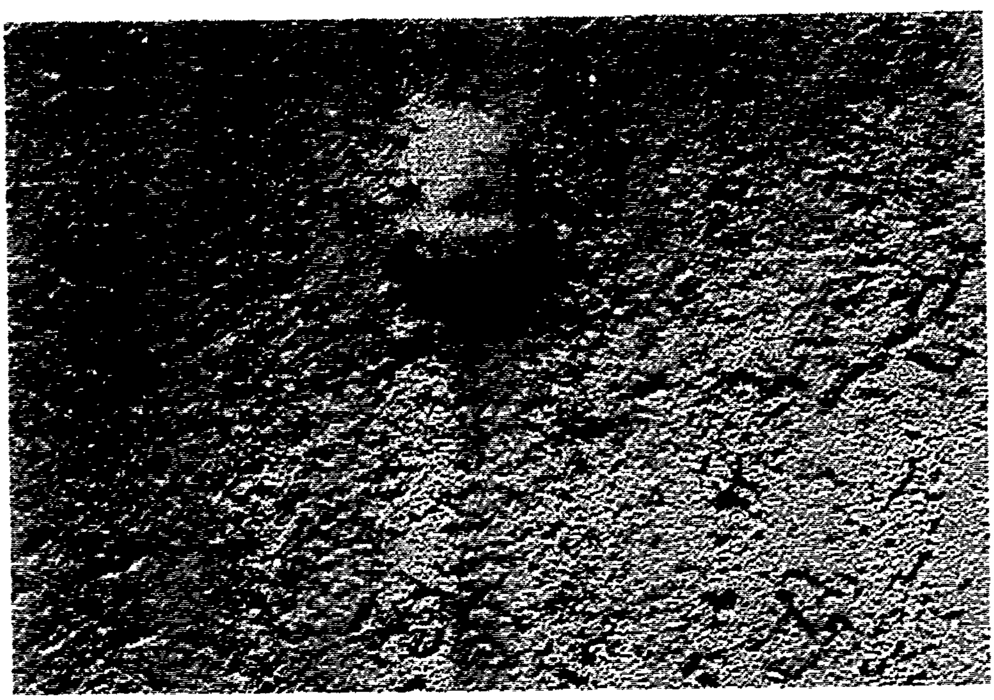

Figure 53. Improper covering of pipe.

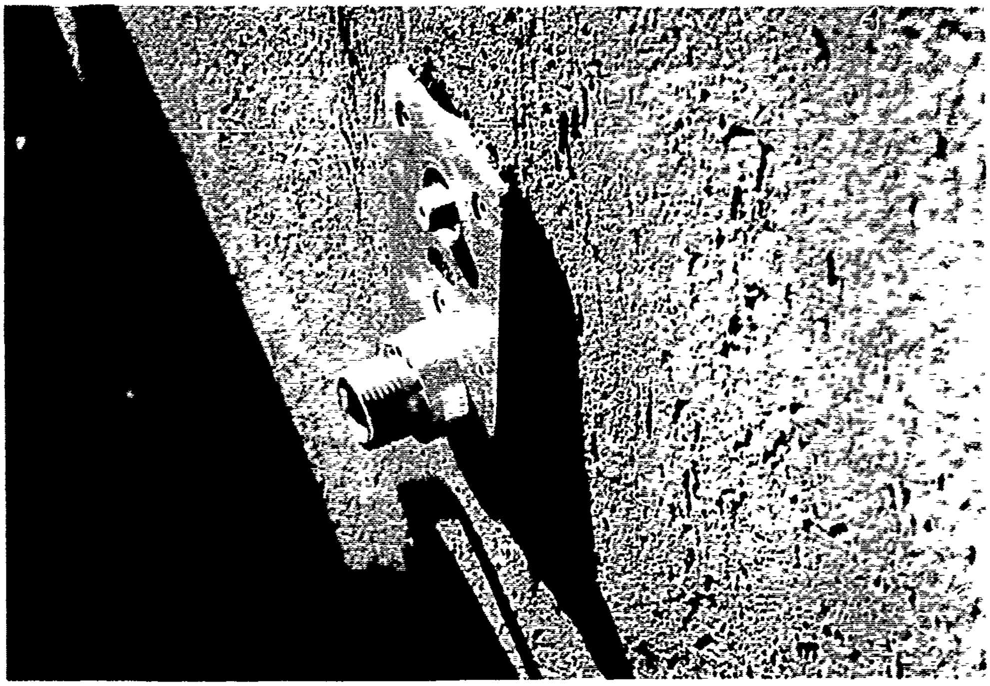

Figure 54. Inadequate closure at hose bib.

Figure 55. Inadequate closure at through-wall cable.

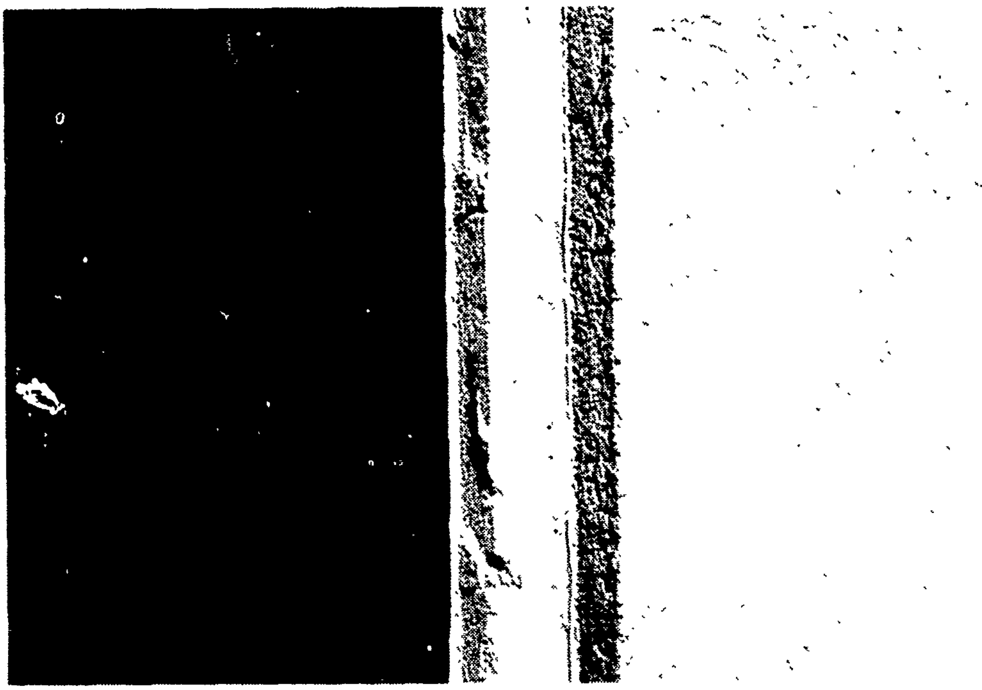

Figure 56. Good termination at door jamb.

EIFS TERMINATIONS

Contributing Factors

Poor detailing at roof line: Careful attention to the design, installation, and maintenance of roof line details is important. Parapets should be sealed at joints, and adequate provisions for water drainage should be made. Figure 57 illustrates insufficient slope at a parapet detail which allows moisture to collect on the EIFS. Finish coat softening and moisture penetration usually result. Gutters and downspouts carry water from the roof to the ground. These elements should be properly detailed and maintained. Figure 58 shows a gutter which was not properly sealed. Incorrect placement, faulty installation, or insufficient maintenance of these details can result in roof water falling directly on the cladding. This can cause finish coat softening, staining, and overall EIFS deterioration (Figure 59).

Poor detailing at ground: Standard measures for drainage of water at ground level are required. An unsealed cladding in contact with ground moisture can carry water up the wall and into the system (Figure 60). Granular drainage beds of stone or aggregate around the perimeter of buildings allow water to seep into the ground rather than collect at the building's base. Ideally, EIFS claddings should terminate above ground to avoid contact with moist conditions. An expansion joint above grade on buildings with masonry or cement foundations prevents moisture migration.

Improper backwrapping: Backwrapping is typically required at all exposed edges of EIFS. Boards at the roof and ground require backwrapping. Figure 61 shows backwrapping which was improperly installed. This can subject insulation boards to moisture and chemicals. In addition, the continuity of system reinforcement is interrupted, making unwrapped areas more vulnerable to impact damage.

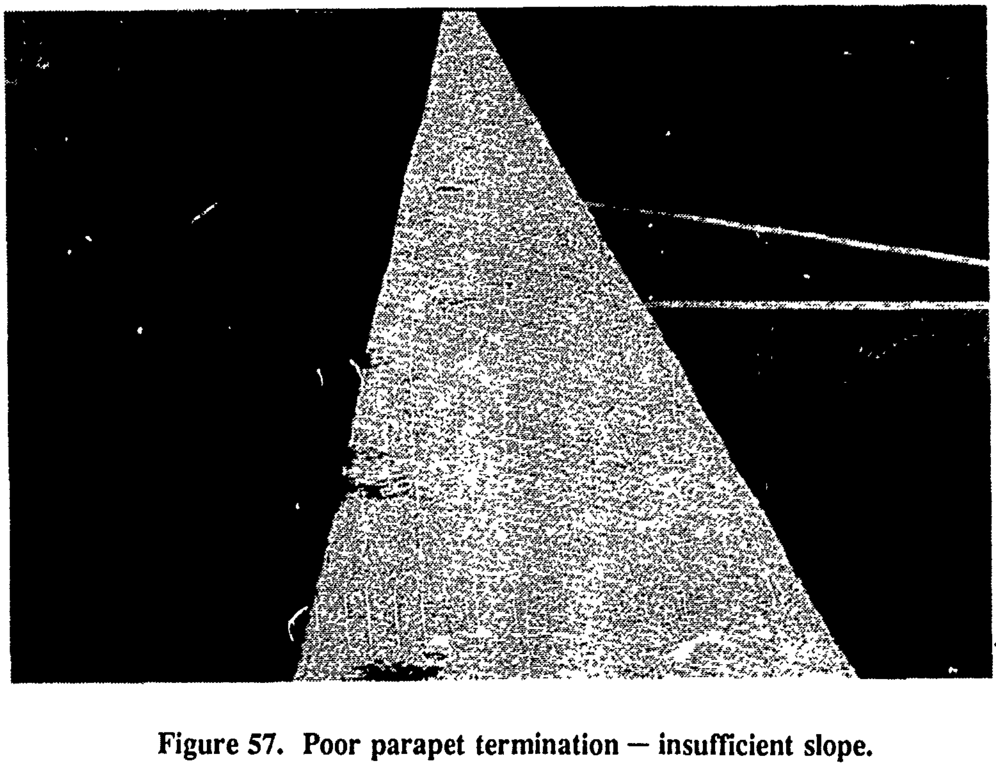

Figure 57. Poor parapet termination — insufficient slope.

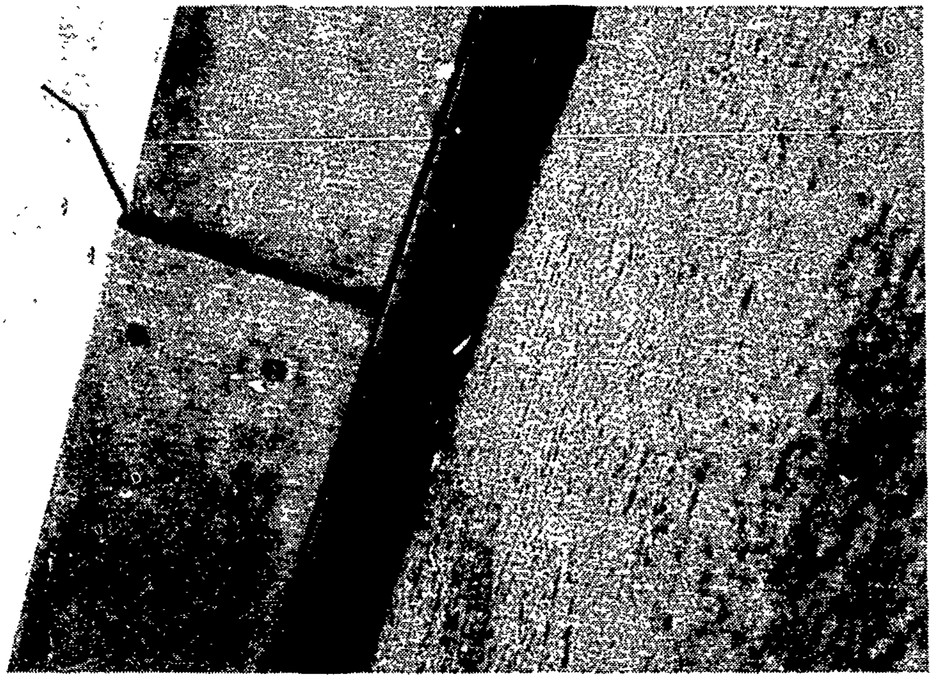

Figure 58. Poor EIFS termination behind gutter.

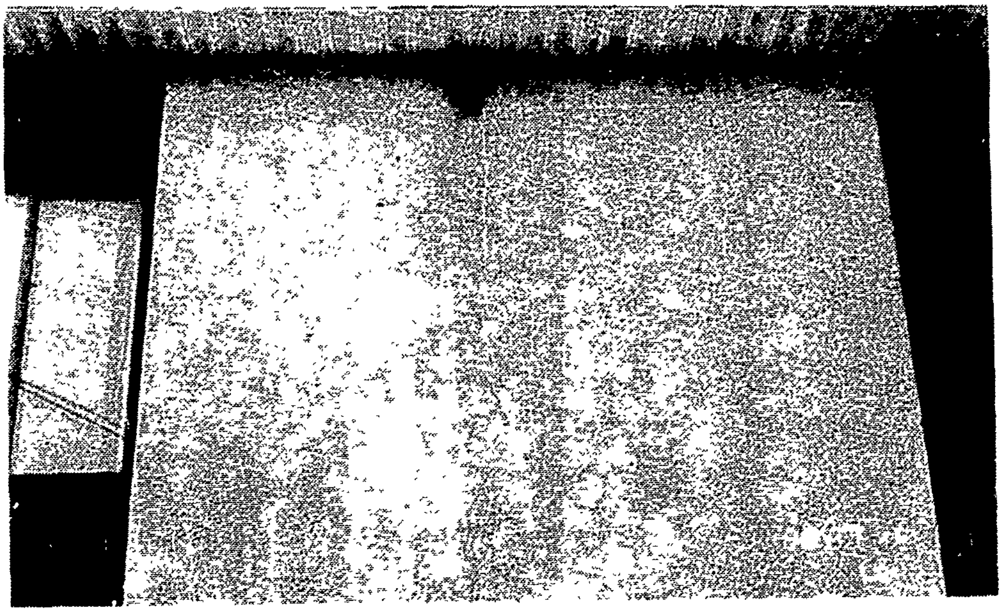

Figure 59. Poor EIFS termination at downspout.

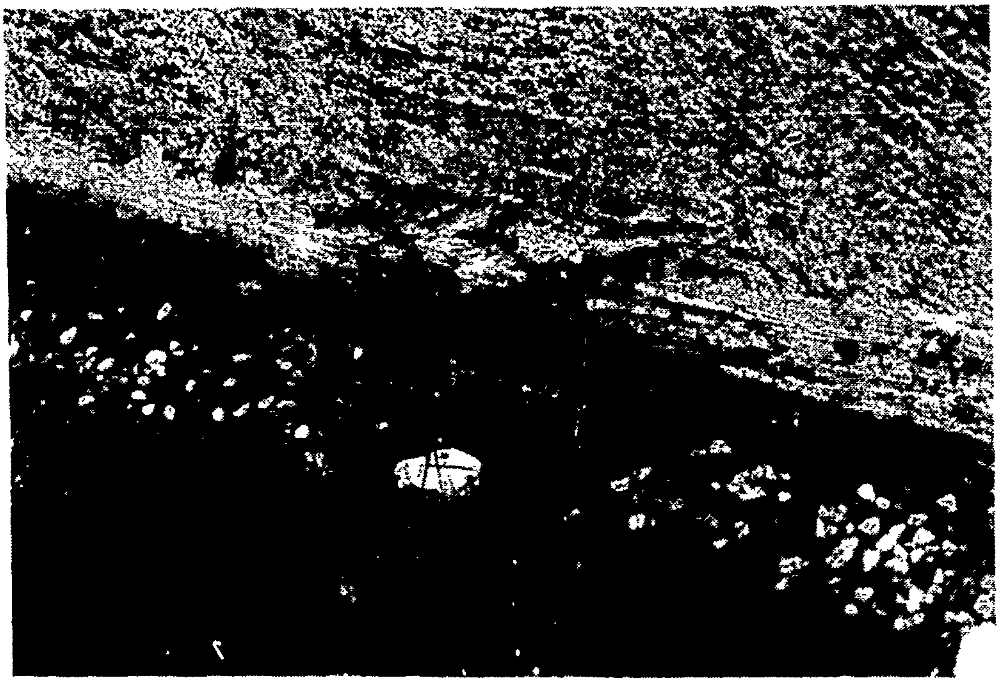

Figure 60. Poor EIFS termination at grade.

Figure 61. Good EIFS termination — incorrect backwrap.

SEALANT JOINTS

Contributing Factors

Improper joint design — Proper joint dimensions are critical to successful joint design. Joint depth on EIFS should not exceed joint width, with a maximum of 1/2 inch stipulated. Poorly designed sealant joints are a common cause of EIFS failure. Narrow as well as excessively wide joints may fail to accommodate building movement. Cracking will occur at improperly designed joints.

Improper installation — Sealant joint installation requires informed and skilled workmanship. Field applicators must verify that sealant substrates are clean, dry, and sound. Only specified materials should be used. Back-up rods, for example, should have a closed-cell construction; opened-cell rods retain moisture which damages the system. Improperly mixed sealant or poorly tooled joints (Figure 62) facilitate moisture intrusion. Moisture tightness is the prime goal of sealant installation, and any condition or practice counter to this goal should be avoided.

Cohesive EIFS lamina failure — Cohesive EIFS lamina failure at sealant joints in Class PB systems is common. A major cause is the tendency of certain Class PB finish coats to soften with extended exposure to moisture. Softening in combination with the standard practice of sealing to the finish coat leads to this type of failure (Figures 63). Sealing to the base coat or sealing to accessories are alternative approaches to sealant installation which avoid failure due to finish coat softening.

Cohesive sealant failure — Cohesive sealant failures, those within the sealant material itself, are usually caused by incorrect application procedures (Figure 64). EIFS and sealant manufacturers recommend joint preparation procedures, specify joint materials such as bond-breaker tape and back-up rods, and provide directions for sealant mixing and installation. Noncompliance with these recommendations is a common reason for cohesive failure. Improper tooling is another. Techniques standard for all sealant joint installation as well as those particular to EIFS should be followed.

Adhesive sealant failure — Adhesive sealant failure occurs between the sealant material and sealant joint substrate. Improper sealant preparation, omission of primer or back-up rods, the presence of exposed mesh (Figure 65), and improper backwrapping are factors which contribute to adhesive failure.

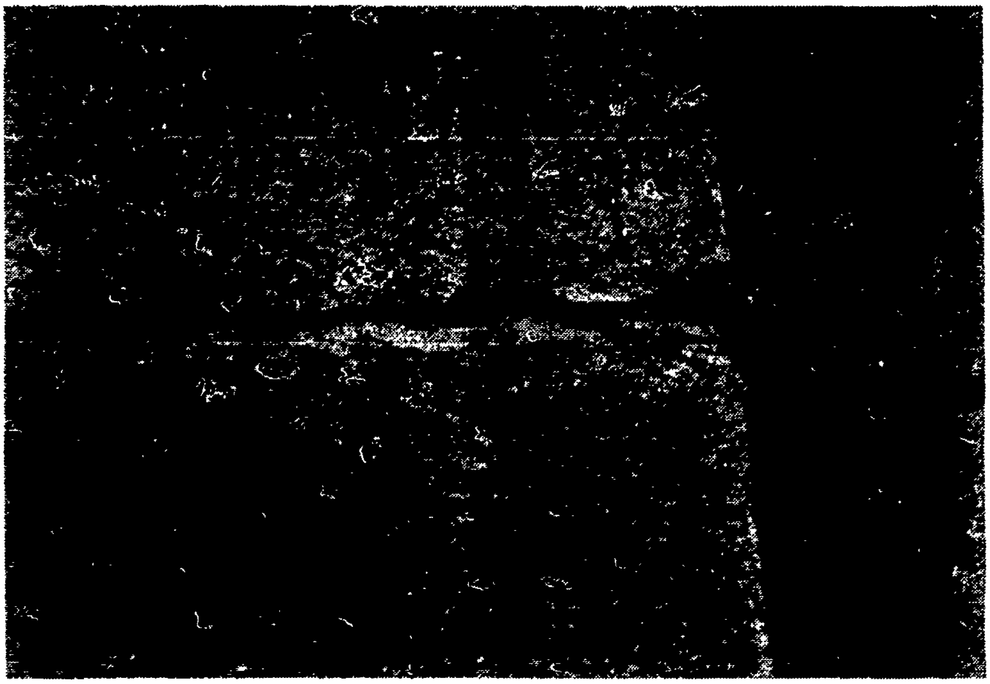

Figure 62. Improper tooling.

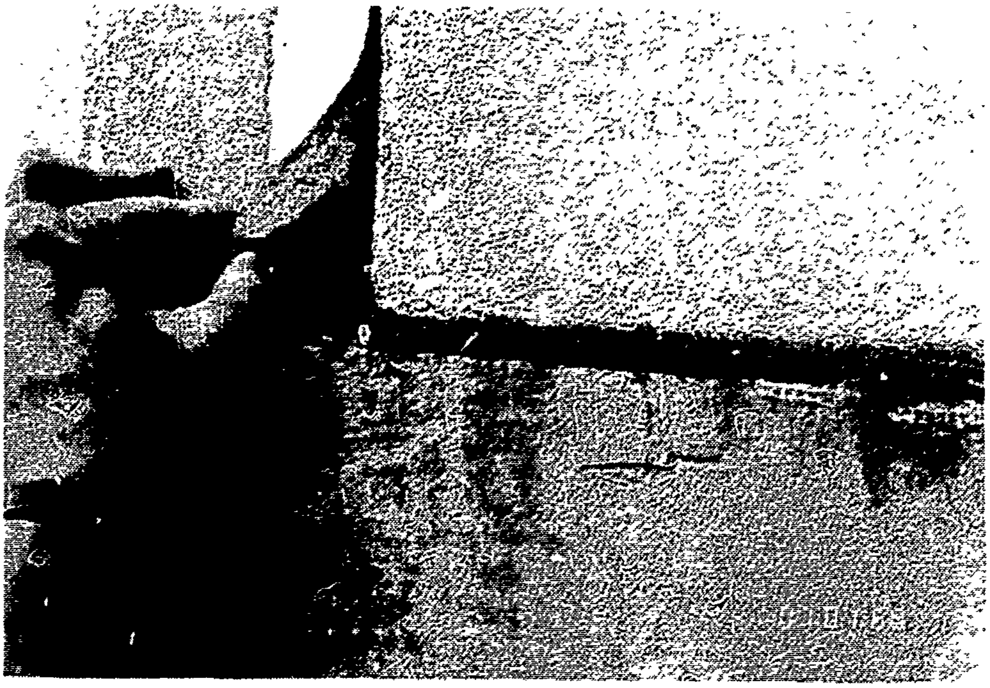

Figure 63. EIFS/sealant — cohesive EIFS lamina failure.

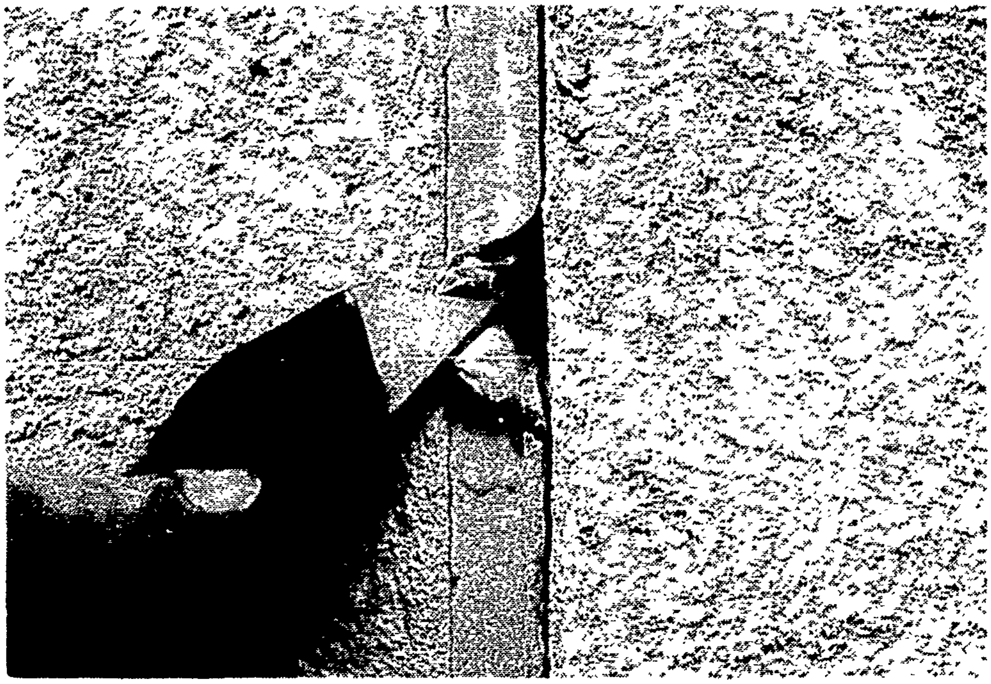

Figure 64. Cohesive and adhesive sealant failure.

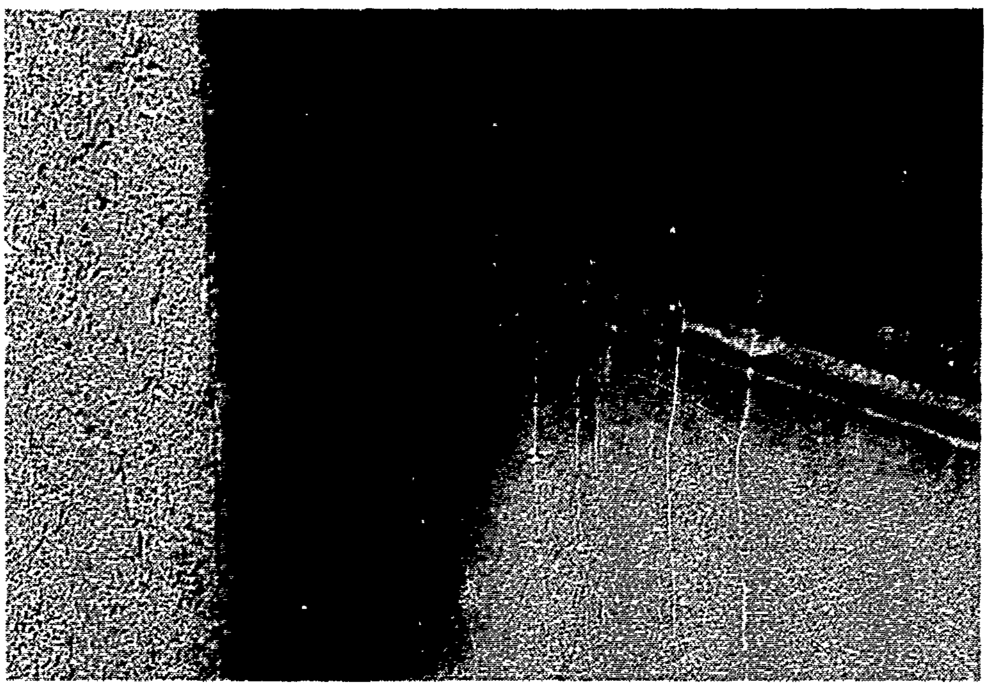

Figure 65. EIFS/sealant - adhesive failure.

SYSTEM DETACHMENT

INSULATION/SUBSTRATE

Contributing Factors

Adhesive attachment — System detachment is often related to improper installation procedures or the deterioration of insulation/substrate materials (Figures 66 and 67). In the case of adhesive use, permanent system attachment is unlikely if improperly prepared or nonapproved substrates are used; for example, questionably painted substrates or those contaminated with foreign substances result in bond failure (Figure 68). One of two methods of adhesive application are typically used: ribbon-and-dab or notched trowel. Some manufacturers and users approve only the latter method because the ribbon-and-dab approach is perceived to carry the risk of inconsistent application, which results in inadequate protective coverage if moisture penetrates the system.

Mechanical attachment — In the case of mechanical attachment, fasteners improperly placed or spaced can result in system detachment (Figure 69). Fasteners should generally not be placed on board perimeters. Spacing should be in accordance with manufacturer directions. In Class PB systems, fasteners are sometimes countersunk and covered with plugs of insulation board. Figure 70 shows a protruding, exposed fastener. The spot application of base coat to cover fasteners is not an accepted practice (Figure 71).

Unsound substrate — An initially sound substrate can deteriorate when exposed to moisture. Paper-faced gypsum sheathing serves as a good example. In the presence of moisture, the paper facing of gypsum board debonds and causes system detachment (Figures 72). Substrates in marginal or poor condition can lead to system detachment if adhesive alone is used. In such cases, a mechanically attached metal lath with a bond breaker placed over the substrate is an attachment alternative.

Figure 66. Insufficient adhesive attachment.

Figure 67. Insufficient adhesive attachment.

Figure 68. Catastrophic system detachment.

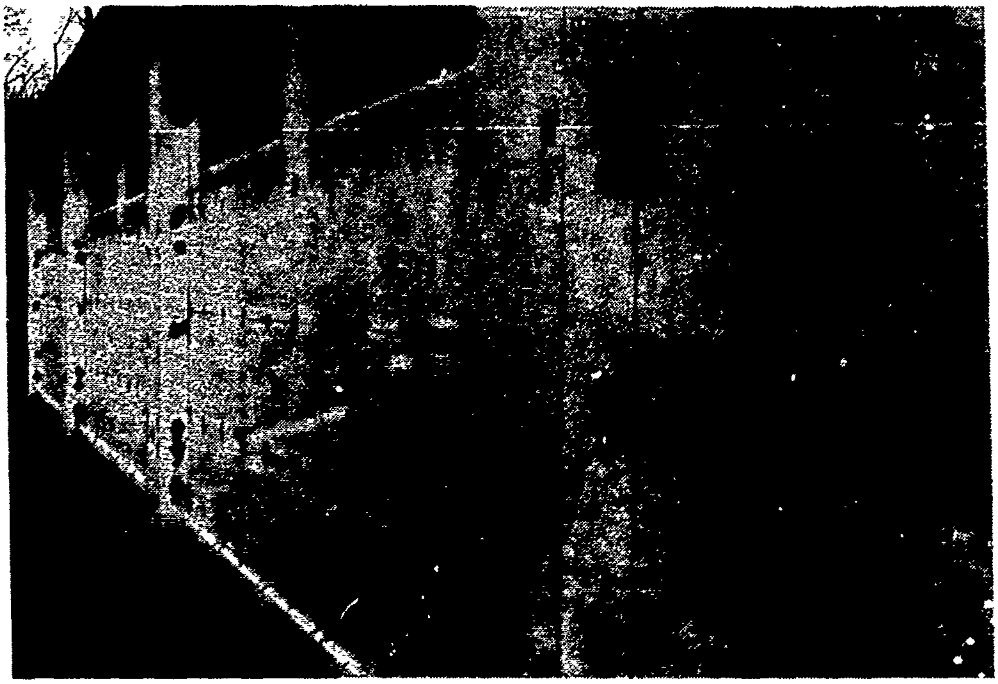

Figure 69. Improper mechanical fastener spacing.

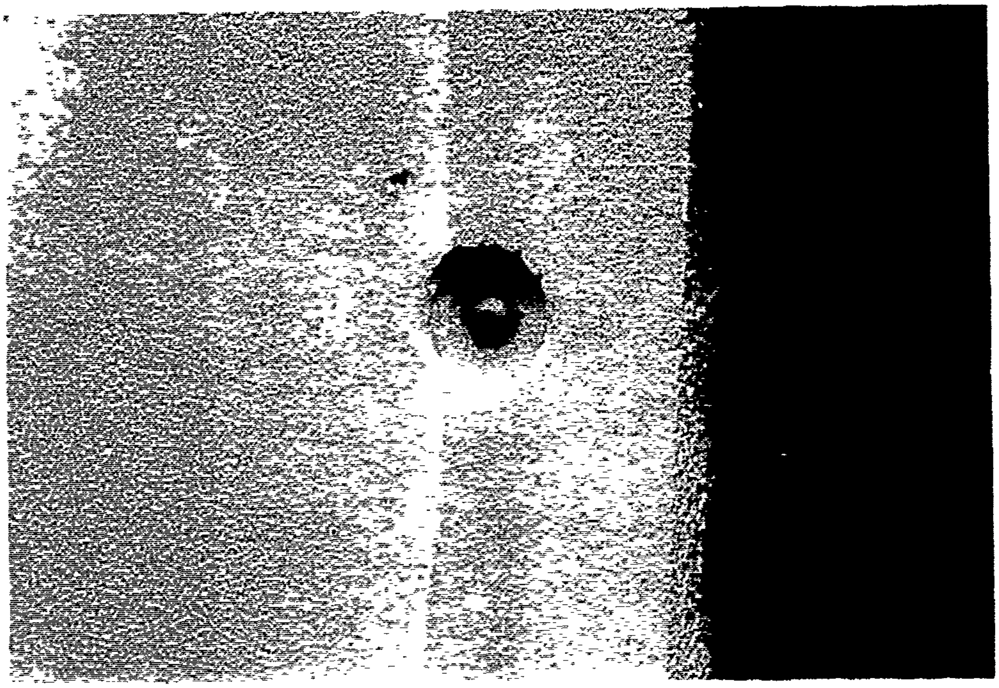

Figure 70. Improper mechanical fastener application.

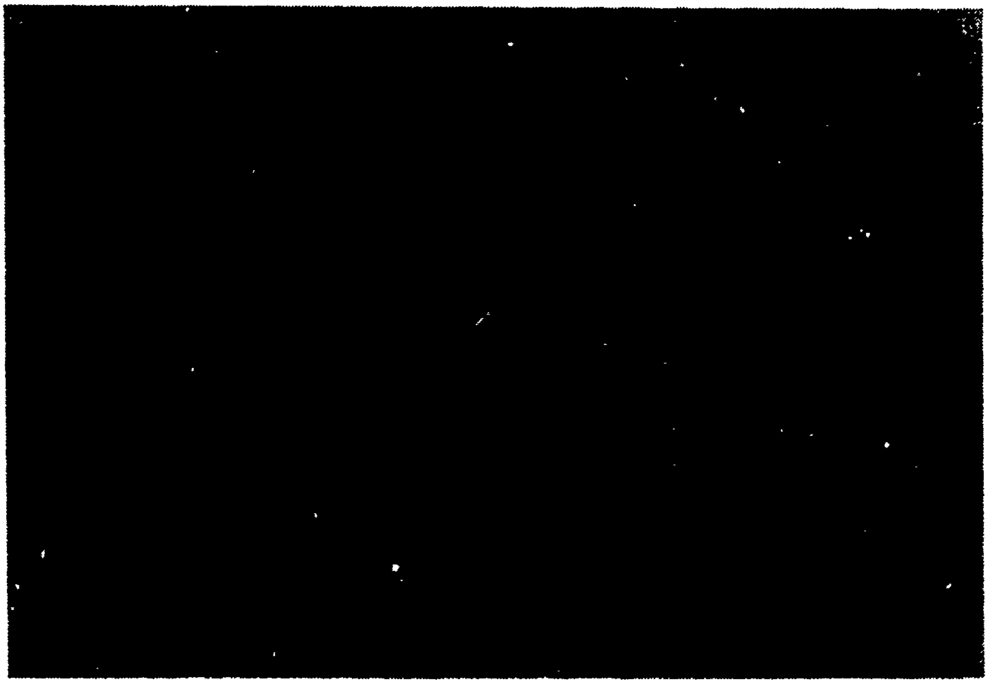

Figure 71. Improper mechanical fastener coating.

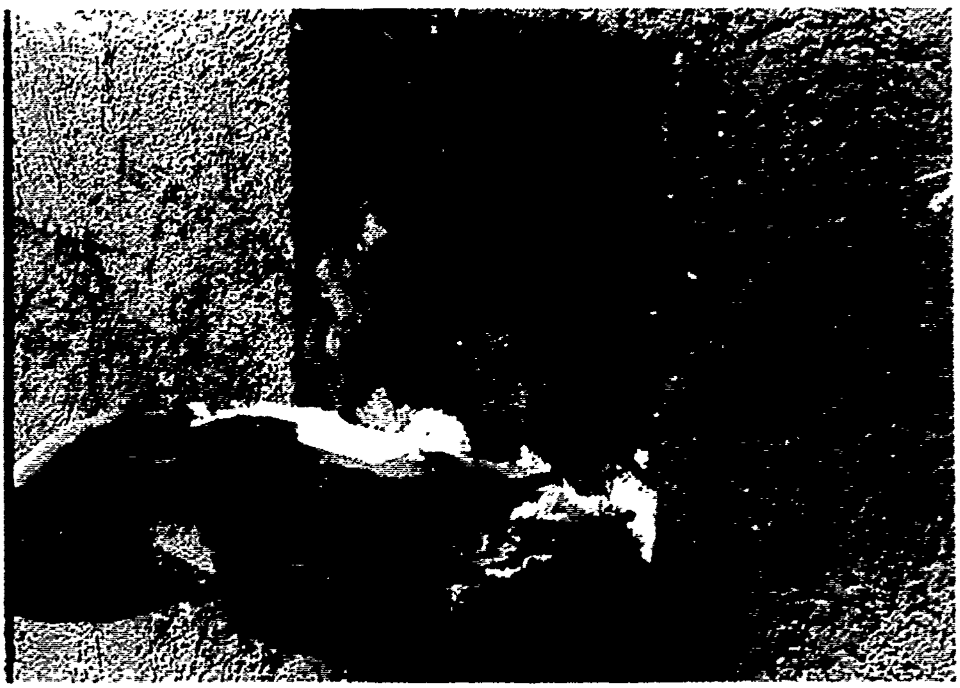

Figure 72. Water intrusion - deteriorated exterior gypsum.

SURFACE DEGRADATION

FINISH COAT

Contributing Factors

Fading — Finish coat fading due to sun or moisture exposure can occur over time. Moisture-induced fading is often seen in conjunction with finish coat cracking. Micro-cracks allow water to settle in the finish coat, causing the color to fade. Dark colors are more likely to fade than light colors (Figure 73).

Staining — Staining of the finish coat can occur at the location of gutters, sills, or other elements if these details are not properly installed or maintained (Figures 74 through 76).

Mildew — The continuous exposure of EIFS finish coats to moisture can facilitate the growth of mildew microorganisms on EIFS facades (Figures 77 through 79). Sources of moisture such as shrubs and planting should not be placed close to the building.

Iron spots — Impurities contained in the finish coat can oxidize and appear as rust colored spots on the cladding surface (Figure 80). Until the impurity is removed, iron spots tend to redevelop even when covered with remedial coatings.

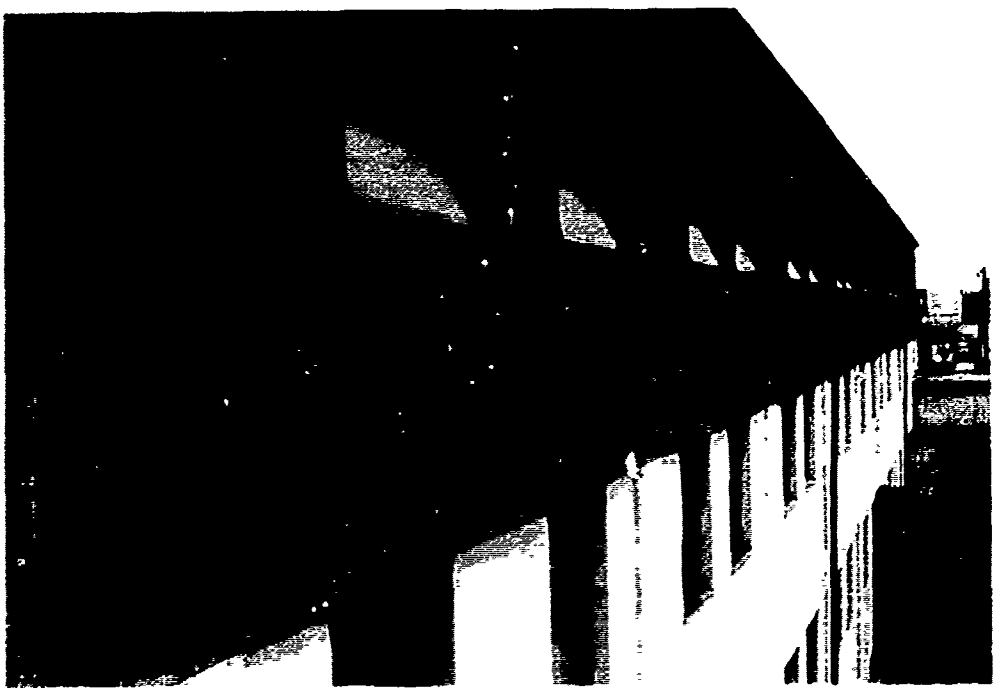

Figure 73. Faded finish coat.

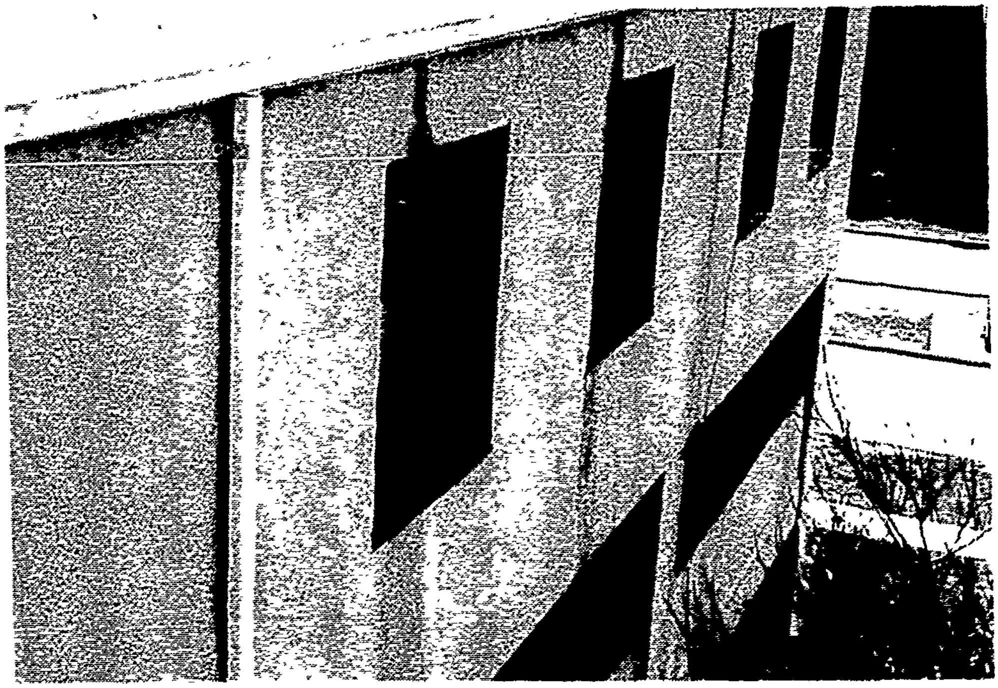

Figure 74. Stains due to leaks in gutter.

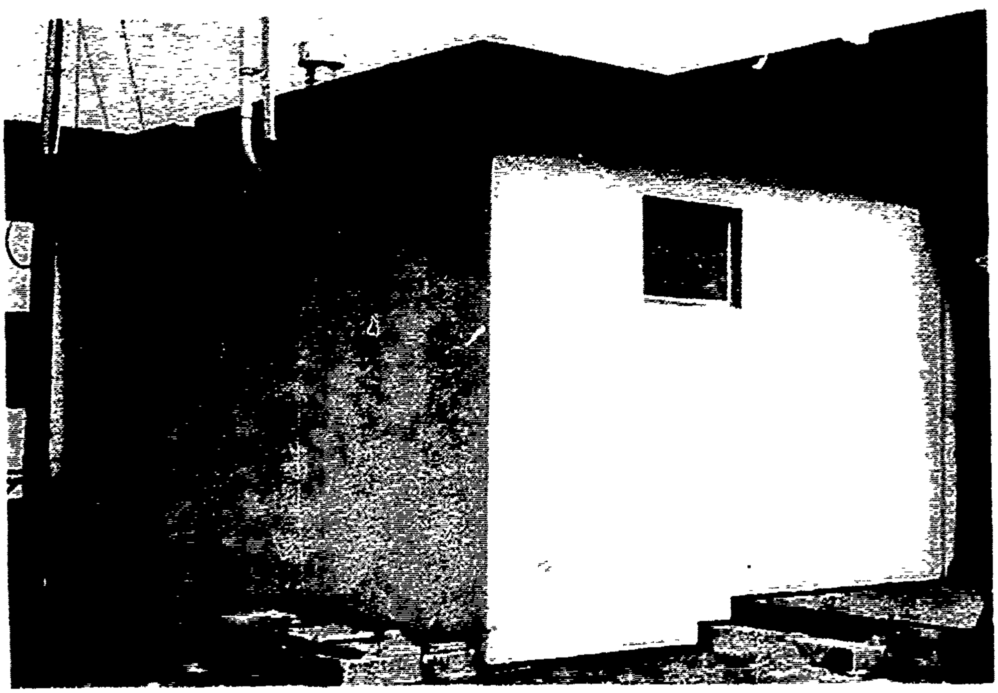

Figure 75. Stains due to laundry room exhaust.

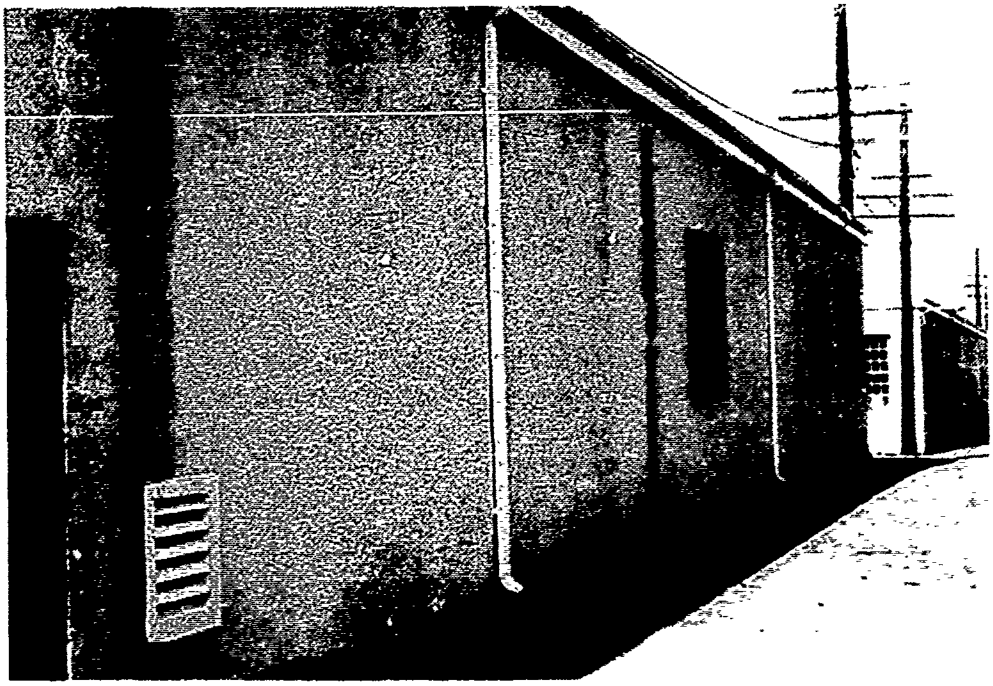

Figure 76. Stains due to leaks in gutter.

Figure 77. Mildew at grade.

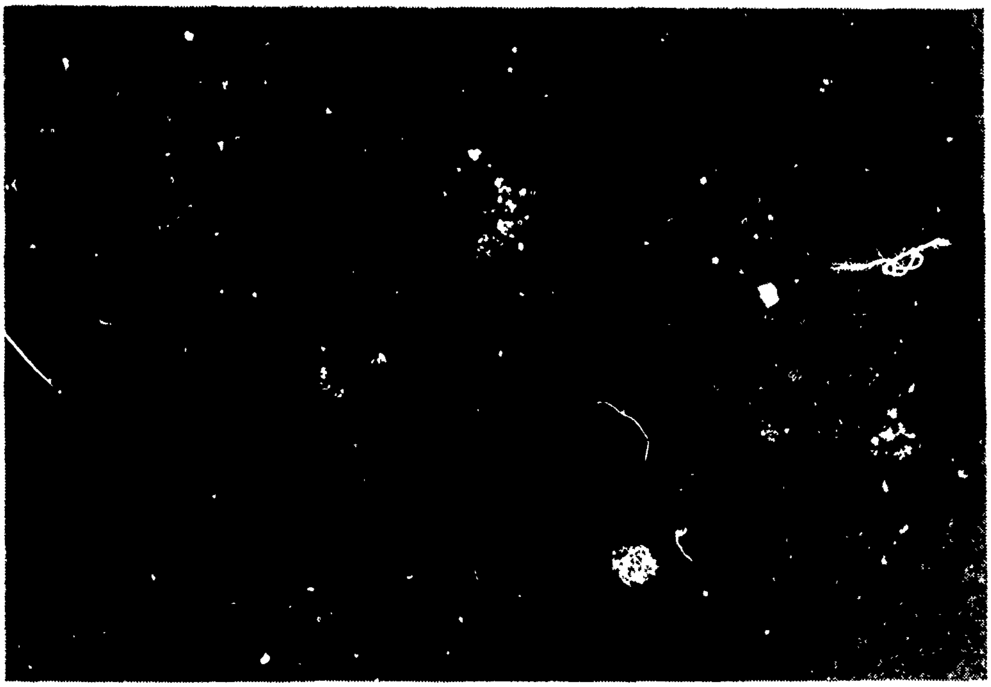

Figure 78. Mildew at mid-wall section.

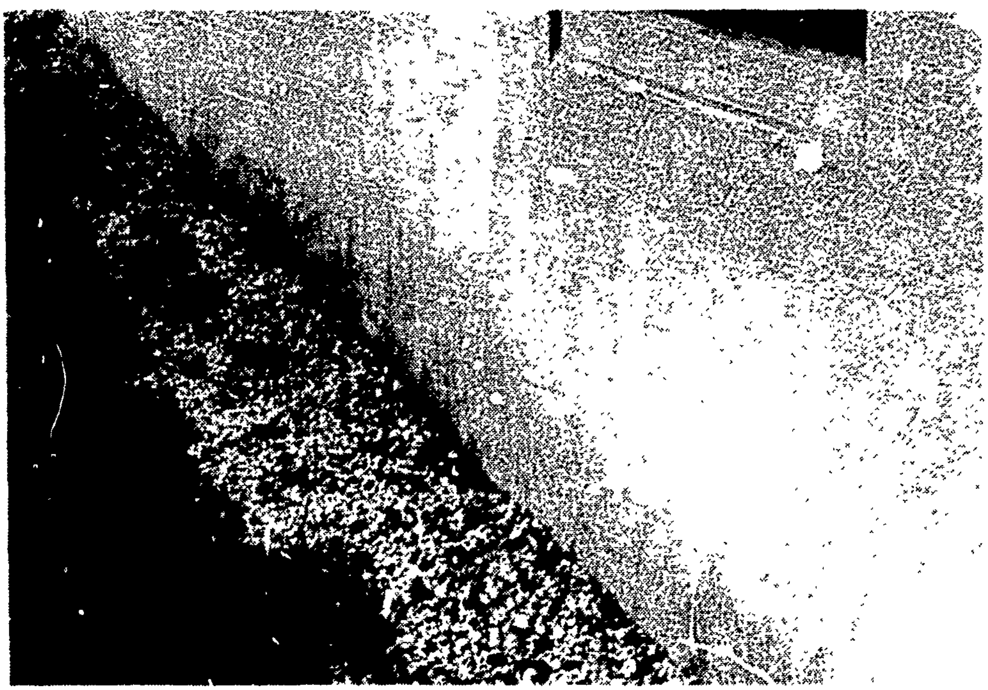

Figure 79. Mildew at grade.

Figure 80. Stains due to finish coat impurities.

7 SUMMARY AND RECOMMENDATIONS

EIFS is a relatively new type of exterior wall cladding. These nonloadbearing systems are composed of several materials. A single, integrated cladding is achieved by the systematic application of the following individual components:

1. An insulation board
2. An adhesive and/or mechanical attachment of the insulation board to the substrate
3. An integrally reinforced base coat on the face of the insulation board
4. A textured protective finish.

The possibilities presented by a combination of rigid insulation and synthetic coatings as in Class PB and Class PM systems are many. However, an understanding of cladding limitations as well as possibilities is necessary for successful use. EIFS limitations relate to the unique material composition, properties, and behavior of these claddings. When these are taken into consideration, EIFS can provide a thermally-efficient, moisture-protective cladding for building exteriors.

Based on the survey of nearly 50 EIFS-clad facilities on seven Army and Air Force installations, the U.S. Army Corps of Engineers has generally specified these systems appropriately. In most cases, the type of system specified—Class PB or Class PM—is suitable to building use and occupancy. (It is noted that the EIFS buildings surveyed were relatively new installations in good to excellent condition at the time.)

The survey did, however, find circumscribed signs of failure including varying degrees of cracking, impact damage, and inadequate closure. While it is difficult to single out any one cause, application deficiencies as opposed to improper specification and maintenance appear to account for most of these problems. Tighter monitoring of application procedures during installation would undoubtedly diminish application inadequacies.

Even though a couple of major problem areas were noted in the field survey, overall the Army's and Air Force's use of the systems is still considered successful. This success is due to the fact that the predominant application has been retrofit use on existing low-rise masonry structures--a use consistent with the original intent of these systems. In many respects, this type of application carries a diminished risk of failure. Not only has the original construction had ample time to settle, but also most military buildings surveyed had masonry or concrete substrates which are highly durable. Since the buildings surveyed were for low-rise structures, EIFS exposure to positive and negative wind loads is also minimized.

Recommendations

As the Army continues to upgrade and replace aging facilities, EIFS use will no doubt increase. Greater emphasis is likely to be placed on EIFS for new construction projects. The Corps must attend to the special conditions that new construction brings. For example, the climate and intended occupancy of the project assume heightened importance because—unlike with retrofit use—these factors have not been tested by time.

Successful EIFS installation on a wide range of project types is possible, given knowledgeable EIFS specification, design, and installation, along with careful attention to the particulars of a given project.

To assist in this regard, it is recommended that information on the design, application, and repair/ maintenance of EIFS be formally developed for use by Corps' personnel.*

* *Development of an EIFS Application and Inspection Manual and an EIFS Maintenance and Repair manual are under development at USACERL. These manuals should be available by early FY 93. Development of an EIFS Design Manual is planned pending final funding approval. This proposed Design Manual will include such topics as EIFS selection criteria relative to potential energy savings and life-cycle costs and HVAC system considerations when using EIFS in retrofit applications.*

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