Wall Cladding System Durability Lessons Learned from the Premature Deterioration of Wood-Framed Construction Clad with Exterior Insulation and Finish Systems (EIFS) in the U.S.

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ABSTRACT

Despite well-intended laboratory testing of individual materials and components, unanticipated and severe durability failures of building wall systems can occur when the system design does not adequately integrate the various materials and components within the wall. Wall systems often fail when the design does not anticipate the deterioration and failure of individual components (such as sealant) and minimize the adverse consequences of such localized failures.

Exterior Insulation and Finish System (EIFS), a.k.a. "synthetic stucco," is an exterior-wall-cladding system that had been used on mass masonry wall construction in Europe since the 1940s and in the United States since approximately 1970. From the mid-1980s to the early 1990s, use of EIFS cladding became common on wood-framed residential construction in the U.S. Despite prior laboratory testing of the cladding system, unanticipated and spectacularly rapid deterioration problems occurred with the wood-framed walls beneath the cladding, particularly in regions with significant rainfall and humidity, such as the southeastern U.S. The EIFS cladding itself was typically intact and undamaged; however, the EIFS cladding trapped leakage from windows, sealant joints, and other wall components, resulting in the rapid deterioration of the underlying structural wood framing and/or the wood- or gypsum-based sheathing.

Extensive durability testing of individual materials and components alone is not adequate to ensure the durability of a wall system. To be durable over the long term, wall system designs should consider in detail the integration of numerous wall components (e.g., windows, cladding, sealants, etc.), anticipate the degradation and failure of individual components (such as sealant), and design the system to accommodate such localized component failures and minimize their adverse consequences.

KEYWORDS

Building, cladding, system, durability, EIFS

1 INTRODUCTION

While laboratory testing of individual building materials and components is often worthwhile and necessary, it is essential to maintain a broader view of the potential interrelationship of various building materials and components and their interrelated roles in the wall system in order to assess and provide for the durability of the overall wall.

The case study of the durability failure of wood-framed walls clad with barrier EIFS in the United States serves as a lesson and caveat for those concerned with the durability of building materials, components, and systems. From this case study, broader lessons can be learned to help designers, code officials, testing professionals, and manufacturers avoid similar wall system durability failures in the future.

2 CASE STUDY: DURABILITY FAILURE OF WOOD-FRAMED WALLS CLAD WITH BARRIER EIFS IN THE U.S.

2.1 Background information

Exterior Insulation and Finish System (EIFS), a.k.a. "synthetic stucco," is an exterior-wall-cladding system that had been used on mass masonry walls in northern Europe since the 1940s and in the U.S. since approximately 1970 [Williams &Williams 1994]. In its most common and conventional form, "barrier EIFS," the cladding system is a surface-sealed barrier wall designed to exclude all precipitation at the outermost cladding surface. Barrier-EIFS wall systems in the U.S. generally consist of the following components, from exterior to interior: lamina (consisting of an acrylic finish coat installed over a glass-fiber-mesh-reinforced polymer-modified cementitious basecoat) and expanded polystyrene insulation board adhesively attached to the wall substrate (masonry). Masonry's inherent resistance to degradation from incidental moisture provides the durability of the structural masonry wall, despite any defects in the surface-sealed barrier cladding that admit moisture to the masonry. Although some problems occured with barrier EIFS installed on masonry walls in the U.S. (notably debonding failure of sealants adhered to the finish coat and impact damage to the EIFS cladding near grade), these problems did not tend to result in failure of the overall wall-cladding system, in serious damage to other wall components, or in serious damage to the concealed masonry wall. Thus, as a wall system, masonry walls clad with barrier EIFS typically can accommodate localized damage or holes in the EIFS cladding and/or degradation or failure of other wall components (e.g., sealants) without serious adverse consequences such as overall wall-system failure or structural damage.

2.2 Laboratory testing of EIFS cladding and separate laboratory testing of windows

Prior to its acceptance by various building codes in the U.S., EIFS underwent a series of tests for weathertightness and durability. For example, the code-required independent testing under the 1993 International Conference of Building Officials Accceptance Criteria for EIFS [ICBO 1993] includes the following durability tests: accelerated-weathering tests (ASTM G23-81), freeze/thaw tests, salt-spray-resistance tests (ASTM B117), structural performance testing (ASTM E330-84, Procedure B), water penetration tests (ASTM E331), and water resistance tests (ASTM D2347). Additional testing was required for other considerations, such as structural performance, fire resistance, and impact resistance. Code-compliance testing of EIFS under ICBO 1993 required the EIFS test specimen to include control joints *if* control joints were used in the design; however, the testing did not require the inclusion of other wall components (e.g., windows, doors, conduit penetrations, deck or balcony framing members, etc.) within the EIFS test panels. Because other major wall components such as windows and doors are typically subject to separate individual laboratory tests, some may contend that their inclusion in the test panel for a wall-cladding system would be superfluous and an undue complication and burden on the wall-cladding test. Nevertheless, the omission of these other wall components from the EIFS test panels resulted in laboratory tests that failed to reveal the gross incompatibility between the design concept and plane of watertightness of surface-sealed barrier wall EIFS, and the non-surface-sealed design concept and plane of watertightness of common residential windows and doors.

Further compounding this incompatibility between surface-sealed barrier EIFS and common windows and doors was the definition of leakage under the water-penetration-test requirement for windows and doors. ICBO 1993 code-compliance-testing requirements of EIFS refer to ASTM E331, *Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference* [ICBO 1993 and ASTM E331-93 1993]. ASTM E331-93 defines water pentration as "penetration of water beyond the vertical plane intersecting the innermost projection of the test specimen, not including interior trim or hardware, under the specified conditions of air pressure difference acrosss the specimen." Under this definition, water passing through the window-frame corner outboard of the nailing flange is not considered water penetration ("leakage"). While water in this zone is controlled and accomodated in claddings that include a secondary weather barrier at the sheathing level (e.g., most traditional residential claddings in the U.S.), water in this zone would prove to be a major contributor to the rapid durability failures in wood-framed buildings clad with barrier EIFS.

2.3 Durability failure of wood-framed walls clad with EIFS

From the late 1980s to the early 1990s, use of barrier-EIFS cladding became common on wood-framed residential construction in the U.S. In the mid-1990s, despite laboratory testing of the EIFS cladding, unanticipated and spectacularly rapid deterioration problems occurred on many wood-framed walls beneath the barrier-EIFS cladding, particularly in regions with significant rainfall and humidity, such as the southeastern U.S. In many cases, significant localized deterioration (rot) of the wood sheathing and, less often, the wood framing occurred within the first five years after the house was constructed. In such cases, the EIFS cladding was typically intact and undamaged; however, the undamaged, intact cladding concealed significant wood deterioration.

Figure 1. Rapid durability failure of wood-framed wall clad with barrier EIFS in the southeastern U.S. EIFS cladding is removed at lower right to reveal deterioration of wood-based oriented strand board (OSB) sheathing. The house is fewer than five years old at the time of the photo. Note the localized deterioration of the wood-based sheathing (black areas) beneath locations of leakage at window-frame corners and window-perimeter sealant joints.

Several factors contributed to the rapid deterioration (i.e., durability failure) of wood-framed walls clad with barrier EIFS. In all wall claddings, as exposed materials and components weather and degrade, numerous entry points occur where water may bypass the outer cladding surface (Figure 2). From our field investigations and water testing, it appears that barrier EIFS is typically more effective than most traditional residential claddings at excluding precipitation at the outermost surface of the cladding, particularly in the "field" of the wall (away from other wall components). However, it is inevitable that some water will bypass the cladding, particularly at its juncture with other wall components such as doors, windows, roofs, vent and conduit penetrations, etc.

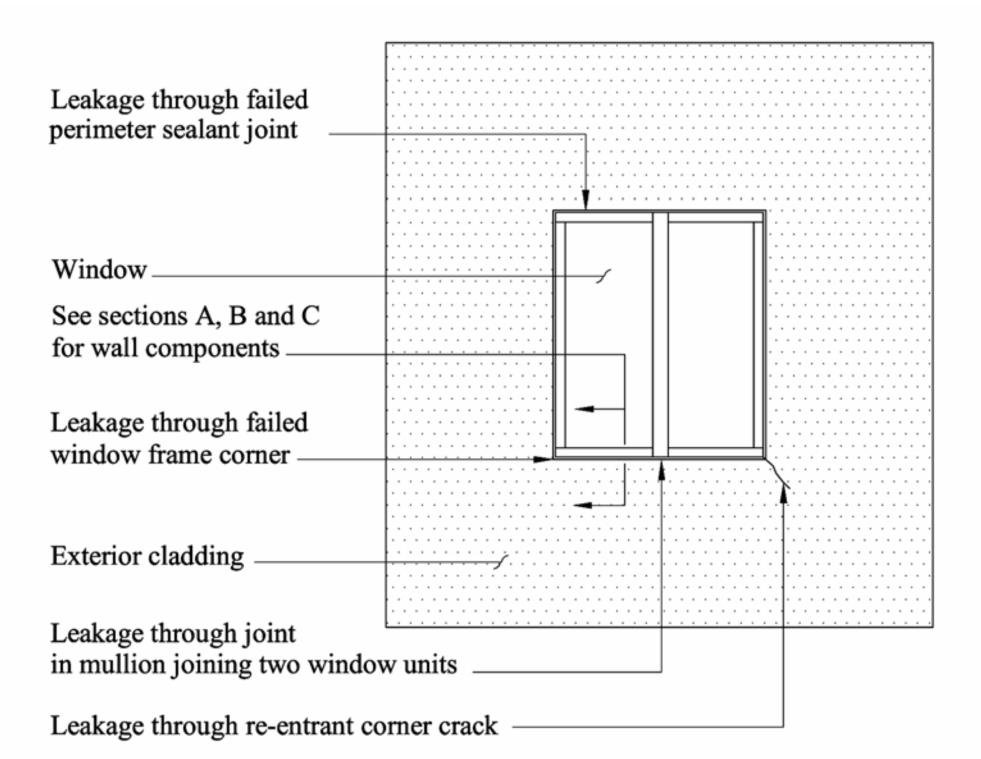

Figure 2. Several common entry points for water behind exterior cladding.

While all wall systems will admit some precipitation past the outermost cladding surface, the fundamental difference between traditional residential claddings and barrier-EIFS-clad walls is in their respective abilities to control precipitation that inevitably bypasses the cladding and in the resulting consequences of this incidental moisture ingress. Common, traditional residential claddings such as brick, stucco, wood clapboard, and wood shingles typically include a secondary waterproofing layer ("building paper") installed over the sheathing, while barrier EIFS does not (Figure 3). As a result, in claddings that include a secondary waterproofing layer, incidental moisture ingress (through joints or defects in the cladding, failed sealant joints, etc.) is controlled by the secondary waterproofing and flashings, so the wood-framed wall structure is protected from moisture, and the serious adverse consequences of incidental moisture ingress are minimized.

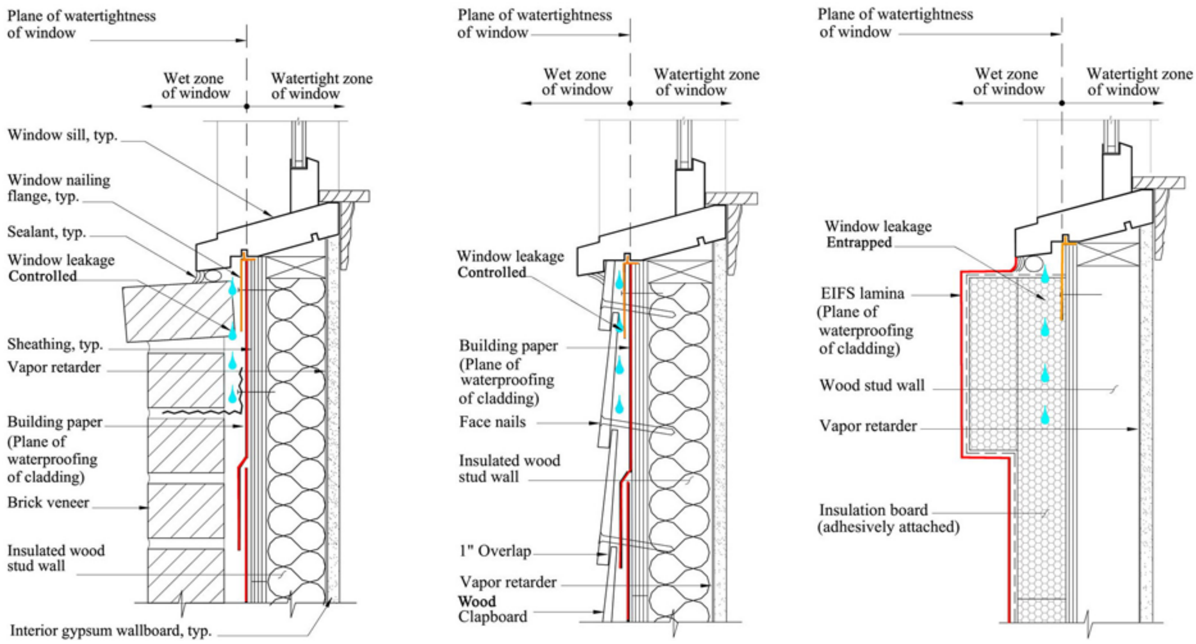

Figure 3. Verical sections through walls. Typical wood-framed wall shown with brick cladding (left), wood cladding (center), and barrier-EIFS cladding (right). Note the location of the plane of watertightness of windows assumed by certain test standards (shown in orange) with respect to the plane of waterproofing for cladding (shown in red). In brick- and wood-clad walls, the location of cladding waterproofing accomodates and controls typical window and sealant joint leakage (shown in blue) in the "wet zone," protecting the wood structure from water and decay. In EIFS cladding, the outer location of wall waterproofing with respect to windows and sealant results in a wall system that cannot accommodate typical window and sealant joint leakage in the "wet zone." When window or sealant-joint leakage inevitably occurs, moisture is trapped behind the EIFS cladding, promoting rapid deterioration of the wood-framed wall and sheathing.

In traditional residential claddings, the secondary waterproofing layer is shingled behind the nailing flange; thus, window leakage occuring between the nailing flange and the outermost portion of the sill (an area termed the "wet zone" by some wood window manufacturers) is accomodated by the secondary waterproofing. However, Figure 3 makes clear the incompatibility between the location of the wateproofing on a barrier EIFS cladding and the location of the watertight zone of common residential windows. With the 25–50 mm thickness of EIFS common at windows, the outermost surface of the EIFS (the cladding's sole waterproofing) is significantly outboard of the nailing flange of the window (the outermost plane at which the window is required to be watertight by certain test standards). Thus, water passing through the window frame corner outboard of the nailing flange (in the "wet zone" of the window) is behind the waterproofing plane of the EIFS, where it becomes entrapped within the wall system. The low vapor permeability of the EIFS cladding prevents this trapped moisture from readily drying, and the conditions are ripe for the rapid decay of the unprotected wood sheathing and framing [Bronski & Ruggiero 2000].

2.4 Broader lessons learned toward the design of durable wall systems

Laboratory testing of individual wall components, materials, and systems, such as windows, sealant, and EIFS, would not necessarily predict (and did not predict) the durability failures that occurred in EIFS-clad wood-framed walls in the U.S. However, this durability failure, and the inherent design incompatibility between barrier EIFS and common residential windows described in Figure 3 above, could have been predicted by critical visual review of the wall-system-design details by a professional experienced in wall-system design and forensics.

Masonry walls clad with EIFS, and wood-framed walls clad with brick or wood siding that include secondary waterproofing, have proved significantly more durable than wood-framed walls clad with EIFS primarily because the former can tolerate or accommodate the weathering, degradation, and localized failure of individual wall components and materials such as sealant and windows while minimizing the serious adverse consequences to the overall wall system, whereas wood-framed walls clad with barrier EIFS cannot.

3 CONCLUSIONS

Laboratory testing of the durability of individual wall materials and components is often useful and necessary, but testing of individual components and materials alone is not sufficient to assess the durability of a wall system. For assessing overall wall-system durability, critical review and assessment of design details by technically knowledgeable design and forensic professionals experienced with wall systems is also necessary.

To be durable over the long term, wall-system designs should consider in detail the integration of numerous wall components (e.g., windows, cladding, sealant, etc.), anticipate and accomodate the inevitable degradation and performance failure of individual components (such as sealant), and design the system to accommodate such localized component failures and minimize their adverse consequences.

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