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Forensic Engineering Investigation of Leakage at Flanged Windows In Stucco

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Introduction

Water intrusion and accumulation in the exterior envelope of wood frame structures with stucco siding and flanged windows has been recognized as a major cause of damage characterized by deterioration of sheathing and framing. Invasive inspections of hundreds of wood framed structures constructed in this manner have clearly shown that the overwhelming cause of deterioration has resulted from chronic water entry into the envelope at window and door locations. Substantial deterioration has been observed in sheathing and framing as early as the third season following construction with extensive deterioration observed in many structures by the fifth or sixth year following construction manifesting primarily at window and door penetration areas in the envelope. Repair costs commonly exceeding 20%-40% or more of the total values of such structures has lead to extensive litigation.

This study was undertaken to quantitatively ascertain the causes of the water entry at flanged windows in stucco siding installations and compare with water entry at wood windows in stucco siding utilizing ASTM E1105-00 “Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference”. Effects of sealing/caulking of the perimeter of the window at the stucco/window intersection were also studied and quantified using the test apparatus. This paper provides a description of the common construction conditions and presents the quantitative results of the study of causes of leakage at flanged windows in stucco and the effect on leakage of sealing/caulking of perimeter joint.

Background and History

A brief history and primer in the main elements of construction with use of stucco siding and of window design utilized in wood frame construction in the United States and Canada will provide the reader with perspective of the principle elements of construction as relates to the problems of moisture intrusion and accumulation in the building envelope.

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Portland Cement Plaster (Stucco) siding was popular and widely used in the United States in all levels of the residential market on wood frame construction in the twentieth century through the 1920's and 1930's. In relevant regard to this study, such structures were built with windows manufactured from wood with natural wood trim on the exterior and at window and door openings and other penetrations in the envelope. The structures have performed well with minimal maintenance for over a century with no significant adverse water accumulation or related deterioration of the building envelope. Little construction occurred in this market category in the early 1940's during World War II.

Demand for affordable housing following World War II was accommodated by new more efficient methods of construction and new materials. Techniques of platform construction combined with labor saving materials such as plywood and drywall entered and rapidly dominated the market displacing traditional labor intensive methods of balloon framing and use of conventional sawed lumber for sheathing of floors and walls. Labor and materials intensive plaster coated walls both on the interior and exterior receded in popularity due to cost and by the 1960's dwindled from positions of dominance to relative insignificance in many regions. During the post war period from 1945 to the early 1980's windows and doors generally continued to be manufactured of wood and attached from the exterior with nails driven through the jambs and brick mold. Wood frame structures built during this period generally performed well with little or no experience of moisture problems in the building envelope.

Beginning in the mid 1980's a wave of new construction emerged fueled by expanding economies which continues as of this writing. The present period is marked by larger homes often having two or three times the square footage of earlier mid market homes and is influenced by trends toward "low maintenance" and "no maintenance" exterior finishes. The architectural styles and size produce large exterior surfaces interrupted with numerous windows and doors exposed to weather as compared with earlier styles. Platform framing of walls remains essentially unchanged, however building codes changed with the advent of "energy codes" which focused on reduction of energy loss from heating and cooling. The result is generally higher insulation levels which in the northern regions of the United States and in Canada effectively resulted in construction of framed walls with 2x6 dimension lumber wall studs resulting in an insulated wall cavity of 5.5 inches thickness which compares with the previous wall thickness of 3.5 inches. The insulation level has increased by nearly 50%. New lower cost sheathing materials came into widespread use which include oriented strand board (OSB) and fiberboard sheathing. Vapor barriers are applied consisting of polyethylene sheeting. This period of construction has seen a resurgence in the use of stucco which is widely perceived to be durable, low maintenance and aesthetically pleasing. Stucco (exterior plaster) generally is made with portland

cement and sand and commonly reinforced with fiberglass which allows for a thinner base. A single base coat is commonly applied as compared with the old technique of two base coats. Finish coats may be either portland cement plaster or acrylic. The process of application of stucco siding remains essentially the same today as at the beginning of the last century utilizing metal lath reinforcing attached over building paper. Expansion joints are infrequently used in residential applications, but commonly appear in commercial applications.

Demand for low maintenance exterior finishes also resulted in introduction of flanged windows and doors which appeared in quantity in the 1980's and which now dominate all levels of the market. Flanged windows generally are made of wood and clad on the exterior with vinyl or aluminum sheet metal. Some windows are made entirely of synthetics such as vinyl with no wood products. The protective cladding requires no painting and no maintenance, however the protective cladding cannot be penetrated with fasteners for attachment to the wall structure. The problem of attachment was solved by introduction of the perimeter flange concept. Flanges typically consist of vinyl strips or metal which attach to the window frame by way of insertion into a slot in the outside of the frame or fold or hinge or bend outward from the window frame. Some are integrally molded with the vinyl or vinyl cladding. The flanges marketed by some companies as integral perimeter flashing and windows were commonly understood to be self flashed and the International Residential Code 2000 (IRC 2000) flashing section, paragraph 703.8 provides exception to additional flashing at penetration areas in the envelope for continuously flanged windows.

The flange method of attachment remains the predominant method of attachment of this class of windows to the building envelope. The common brick mold feature which is used to attach wood windows was eliminated with window jambs extended outward to replace the brick mold as the interface surface for the surrounding siding.

Flanges project from the window jamb, sill and head outward in plane with the exterior sheathing and are typically 1.25 inches to 1.5 inches wide. Most manufacturers specify attachment of flanges with roofing nails to the exterior surface of the sheathing. Installation instructions vary widely by manufacturer with some calling for use of sealants (caulk) at various points during and following attachment to the sheathing. Others provide no requirements for use of sealants. Some manufacturers provide self adhering corner gaskets to be field applied at the open corners of the flanges. Special field applied head flashings are included by certain manufacturers while others provide no additional flashing and no instructions for such. Although the flange concept is essentially similar between manufacturers of doors and windows, no common practice exists among manufacturers of similar flange types of windows and doors with respect

to application of sealants (caulk) or of additional flashing. Most manufacturers do not specify sealants (caulk) at the perimeter joints between the window and the stucco following installation of the stucco siding with the result that the majority of installations in stucco siding have no sealant or caulk at this important joint. Performance of the building envelope with respect to moisture intrusion, accumulation, and consequent deterioration of the envelope meaning rotting of the sheathing and framing is epidemic in structures constructed during the current period. This compares starkly with structures constructed in prior periods described above which continue to perform well in this respect.

Experimental Methods

Two wall sections were constructed using the methods of construction in common use in this type of construction during the 1980's through the present. In the first wall section, a wood window with aluminum cladding and vinyl flange was installed as per the window manufacturer's installation instructions. In the second wall section a wood window with wood brick mold was installed, also per the manufacturer's instructions.

The assemblies were tested in conformance with the American Society of Testing and Materials ASTM 1105-00 "Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Air Pressure Difference." The method utilized in this study was the Cyclic Air Pressure Difference method B.

The test protocol consists of four cycles each consisting of 5 minutes with differential air pressure applied to the interior chamber followed by one minute with air pressure off. Water spray is continuously applied during the 24 minute test sequence. Water is sprayed onto the exterior of the assembly at the rate of 5 gallons per square foot per hour correlating to 8 inches of water per hour. Differential air pressure (vacuum) was applied at negative 0.55 inches of water designed to simulate cyclic wind pressures. Water collected via the three troughs was measured at the end of each of the four cycles in a test sequence. Overage runoff was captured by a poly chamber and diverted away from the test sections. The joint between the window and the stucco and the stucco surface of the wall receive water spray.

The first series of tests was run on the assemblies with no caulk at the perimeter joint between the window cladding and the stucco siding. A second series of tests was run on each test assembly in which the joints between the stucco siding and the windows were sealed with common single part polyurethane caulk. The tests were otherwise conducted as in the first phase. The purpose of this series of tests was to evaluate the effect of sealant/caulk at the perimeter joints between the window and the stucco siding.

Details of Test Assemblies

Overall wall dimensions measure 4 feet wide by 8 feet in height. Walls were constructed using 2x6 dimension lumber wall studs set at 16 inch centers. Window openings were framed to the rough opening dimension specified by the manufacturer of the window. Commonly this dimension is 3/4 inch - 1 inch larger in width and height than the frame of the window. Walls were sheathed in 7/16 inch OSB which was attached to the studs using pneumatically driven staples. Building wrap (weather resistive barrier) consisting of one layer of 15 pound asphalt impregnated felt building paper was applied to the exterior of the sheathing around the rough opening of the window extending 9 inches outward from the rough opening. The paper was installed in a shingle like manner meaning that the bottom section was applied first and subsequent sections applied overlapped in the way roof shingles are applied.

Windows were single units of similar size with no mullions. The metal clad vinyl flange window measured 28 inches in width by 48 inches in height. The wood window with brick mold measured 28 inches in width by 50 inches in height at the brick mold. Both windows were manufactured in 2002 and bore current installation instructions. Windows were installed in the rough openings as per the installation instructions attached to the windows. Following attachment of the windows to the wall sections over the first layer of building wrap, corner gaskets were applied over the open corners of the vinyl flanges of the flanged window. Corner gaskets are not required and were not used on the wood window installation. Following installation of the windows, a second layer of 15 pound asphalt impregnated felt building paper was applied in a weather board manner over the sheathing and carried over the top of outboard side of the vinyl flanges of the flanged window and to the sides, top and bottom of the brick mold of the wood window. Self furring galvanized metal diamond lath was applied over the building paper. A two coat stucco system was applied to a thickness of approximately 5/8 inch - 3/4 inch thickness leaving a gap of 0.015 inches between the cladding of the flanged window and a 0.015 inch gap between the brick mold and stucco at the wood window. The gap between the stucco and the window was provided to simulate actual field conditions resultant to shrinkage of the stucco with curing. Stucco was terminated approximately 4 inches below the bottoms of the windows and building paper exposed. Stucco was permitted to cure for 1 week prior to commencing tests. Windows were completely sealed to water.

Test sections were configured with three clear vinyl troughs attached to three surfaces of the test wall assemblies which drained into collection vessels. Troughs were continuously sealed to the following three surfaces of the assembly and captured waters which passed into the assembly through the joint between the window and the stucco siding. Troughs were configured as follows;

1) Interior surface of the sheathing in the wall cavity below the window sealed to the interior of the sheathing. This trough collected all water which passed through the joint between the stucco siding and the window and which passed the interior plane of the sheathing.

2) Exterior of the sheathing, below the windows, sealed to the sheathing. This trough collected all water which passed through the joint between the stucco siding and the window which drained on the exterior of the sheathing between the sheathing and the building paper.

3) Exterior surface of the building paper. This trough collected all water which passed through the joint between the window and the stucco which drained on the exterior of the paper.

Summary of Experimental Results

The data are presented in the following four graphs which show water entry at three zones of the test assemblies at the end of each of the four segments of the test sequence and a fourth curve showing total of all water entry. The test assembly with the flanged window experienced total water entry of 119.5 ounces with 79% passing into the wall cavity (figure 1). Application of sealant/caulk at the perimeter joint between the stucco siding and the clad surface which covered the 0.015 inch gap at the perimeter reduced water entry to 0.9 ounces resulting in reduction of water entry by more than 99% (Figure 2).

In the test section with the wood window without caulk total water entry was 16.3 ounces with 92% of water appearing on the exterior of the building paper and 0.3 ounces or less than 2% entering the wall cavity (figure 3). In certain commonly utilized acceptance standards such American Architectural Manufacturers Association (AAMA) 502-90, the allowable quantity of water entry is 0.5 ounces. Water draining exterior to the building paper is considered to be outside of the plane of the window. Thus the wood window test assembly without caulk meets acceptance criteria of this voluntary standard. Application of sealant/caulk to the perimeter joint between the stucco

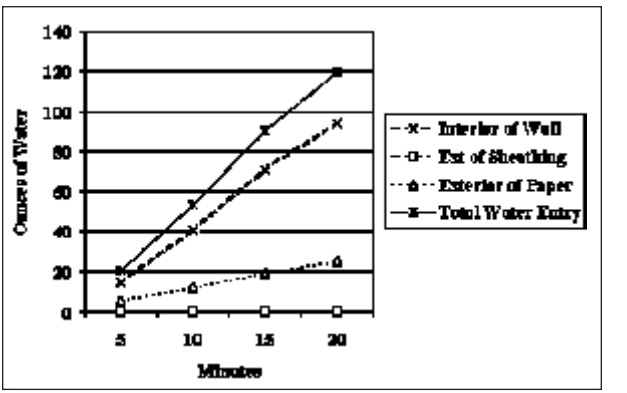

Figure 1
Water Entry by Zone – Flange Window without Caulk.

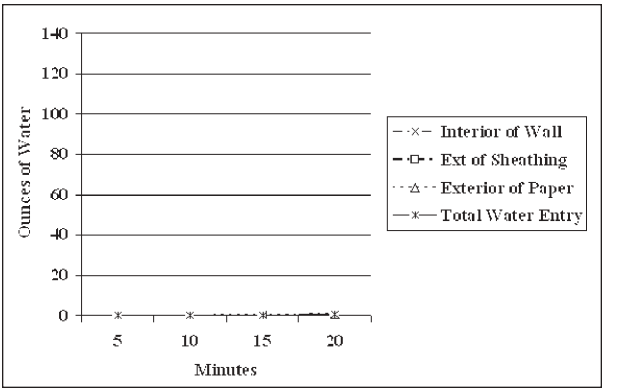

Figure 2
Water Entry by Zone – Flange Window with Caulk

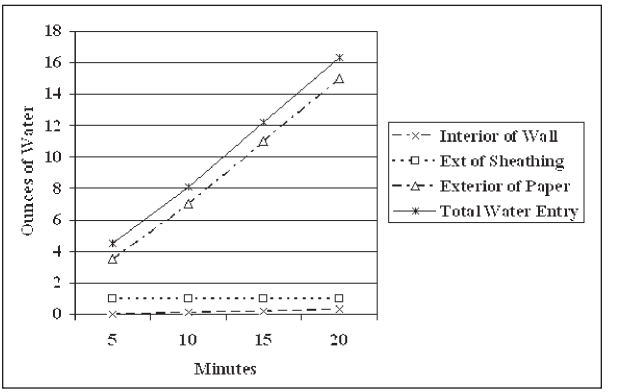

Figure 3
Water Entry – Wood Window Without Caulk

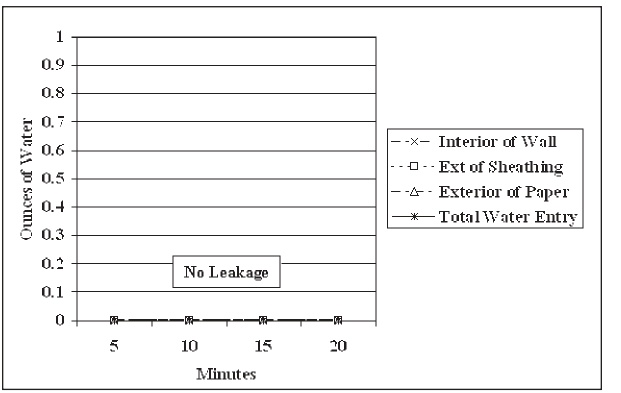

Figure 4
Wood Window with Caulk.

siding and the brick mold surface reduced total water entry to zero (figure 4).

Field Testing

Over one hundred field spray tests of installed windows which included 15 different manufacturers has been conducted by this office. Many more have been observed by this office, which have been conducted by others. Tests included both window isolation tests and perimeter isolations tests. Comparison of reported quantities of water entry from field data against data taken in the testing performed in the research work for this paper, reveals that the quantities reported in the field tests are far lower than those determined in the research specimens. This results from the practical aspects of field testing which permits only limited observation of points of entry. In field testing, the stucco siding remains installed and small areas of interior

finishes are removed for observations. Water passing over the sheathing or over the building paper cannot be observed in the field and thus is not reported. Small streams of water observed flowing in wall cavities and along wall studs in field tests are difficult to quantify and hence typically under reported.

In window isolation tests, water commonly enters at mullion areas, miter joints, sash seals, hardware locations and between glazing and frames. Actual water entry during field testing is under reported due to the fact that water is stored in joints and mullion areas which cannot be viewed in field testing conditions. This water appears following the tests as leaking out of mullions on the exterior but is not documented in the test results. Further, variations in isolation methods at corners, perimeters and mullions in the field along with placement of spray nozzles have large effects on water entry. Failure of field test isolation seals can result in water entry through a window joint which is reported as water entry from a perimeter test.

Conclusions

Flange type windows when installed in conventional wood frame construction with stucco siding leak excessively large quantities of water which primarily enters at the joints between the stucco siding and the window cladding. The majority of the water entry is into the building envelope and wall cavity. Chronic entry of water from this source and inability of the wall cavity to dry has resulted in rapid deterioration of the sheathing and framing in many structures. Application of sealant/caulk at the perimeter joint between the stucco siding and the window substantially reduces water entry.

By comparison, conventional wood windows with brick mold sustain a small fraction of the leakage from the perimeter joint and water which does pass through this joint drains over the exterior of the building paper and not into the wall cavity. Application of sealant/caulk at the perimeter joint between the stucco siding and the brick mold reduced water entry in the test window assembly to zero.

Data from the testing program support extensive observations in the field of wood frame structures with stucco siding and flange windows. Spray testing of windows in the field combined with invasive inspections has shown that windows with sealant/caulk experience substantially less leakage and correspondingly less deterioration compared with applications which are not sealed/caulked.

Brick mold or casement in the wood windows functionally flashes the open space between the rough opening and the window frame and places the joint between the stucco siding and the window jamb outside of the rough opening

and over the building paper and wall field. Water which passes this joint is channeled over the building paper and away from the rough opening. This century old detail was eliminated with the advent of flange type windows with the result that the joint between the stucco siding and the window frame was moved inside of the rough opening area. Water entering at the joint between the stucco siding and the frames of flanged windows channels downward along the flanges which are located inside of the rough opening into the building envelope.