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Laboratory Evaluation of Residential Window Installation Methods in Stucco Wall Assemblies

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Outline

- Project Description and Implications
- Laboratory Evaluation Protocols
- Window Installation Method Test Results
- Summary and Conclusions

Project Description

- Objectives
  - Perform laboratory evaluation of conventional and innovative residential building materials, assemblies, and construction practices
  - Provide experimental evidence of moisture loading characteristics and potential performance improvements
- Laboratory Evaluation Tasks
  - Test Plan
  - Construct test apparatus
  - Perform tests
  - Analyze and document results

Laboratory Evaluation Focus

- Window Installation Methods
  - Flanged Vinyl Windows (not recessed) in Stucco Walls
  - ASTM E 2112 and manufacturers' instructions
- Stucco Wall Assemblies
  - Water-Resistive Barrier (WRB) options
  - 3-coat, 1-coat with foam insulation, EIFS

Window Installation Method Test Protocol

- Water Spray Tests
  - Spray entire window/wall assembly
  - 15 minute spray typical, extended duration to meet goals
  - Local spray and water pour tests on targeted assemblies
  - No air pressure or temperature differential
- Wall Layer Test Sequence
  - WRB prior to stucco application
  - Window/wall assembly with stucco and caulk applied
  - With 1/8” hole drilled in vinyl window frame
  - With 1/8” hole, window weep holes plugged
  - With foam sealant applied to interior reveals

Spray Rig Setup

Stucco Window/Wall Assembly Construction Sequence

a) ? ” Scratch Coat b) ? ” Brown Coat c) ? ” Finish Coat

Three-Coat Stucco Wall Assembly

a) ? ” Base Coat b) ? ” Finish Coat

One-Coat Insulated Stucco Wall Assembly

a) Insulation Over WRB b) Mesh and Roughed Insulation c) ? ” Synthetic Stucco Coat

Exterior Insulation Finish System (EIFS) Wall Assembly

Window Installation Methods Tested

- ASTM E 2112-01 “Standard Practice for Installation of Exterior Windows, Doors, and Skylights”
  - Method A, B, A1, B1
  - Caulk Head, Jamb, and Sill Flanges
  - No Sill Pan Flashing
- ASTM E 2112-01R
  - Method A, B, A1, B1
  - No Caulk at Sill Flange
  - Sill Pan Flashing

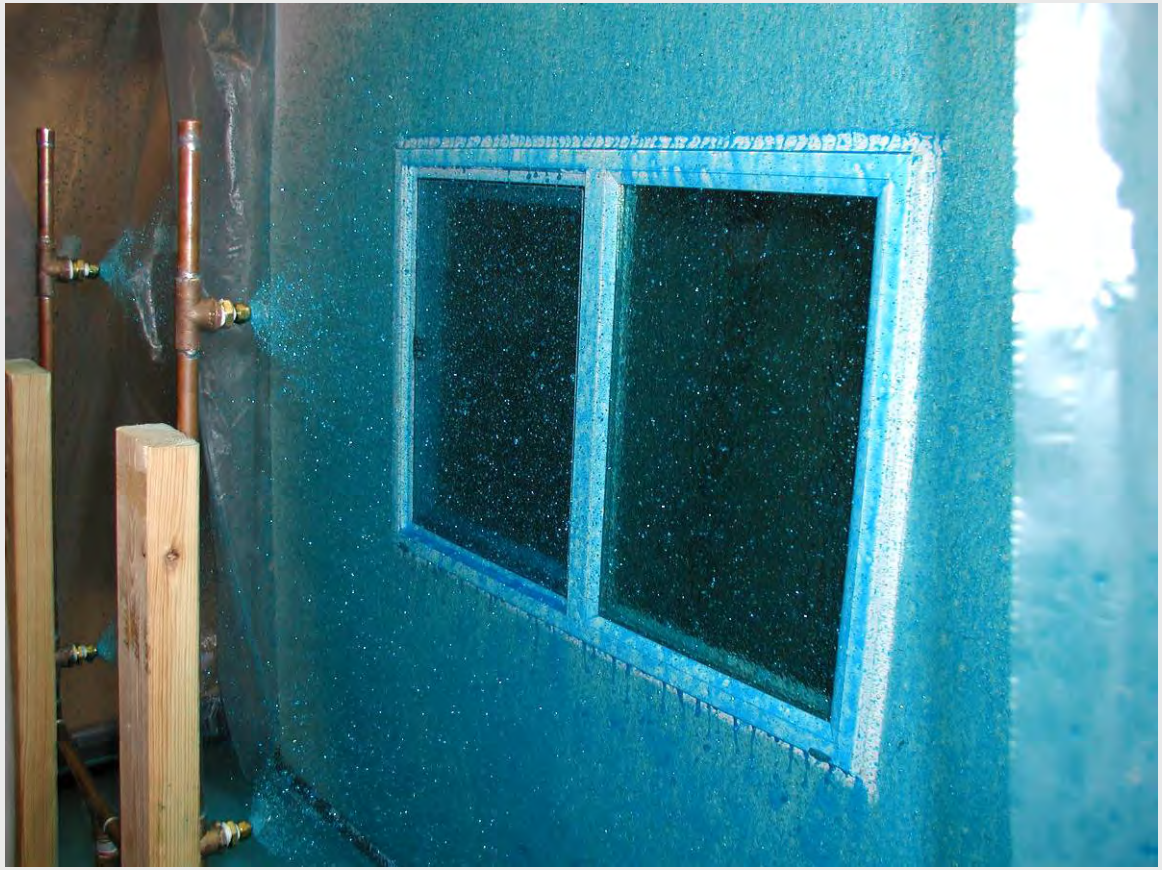
Window Installation Methods Tested (Continued)

- Selected Manufacturer Instructions
  - Horizontal sill flashing option
  - Building paper for flashing option
  - 2-Ply lapped building paper option
  - Reverse flashing with 2-Ply lapped building paper option
- Open Frame and OSB Sheathing Options
  - Method A (jamb flashing after window) or Method B (jamb flashing before window), for open frame
  - Method A1 (WRB installed first) or Method B1 for OSB sheathing
  - Single layer WRB except as noted

Spray Test with Stucco and Caulk Applied (Full Barrier)

Spray Test on Stucco with Freshly Caulked Window Frames

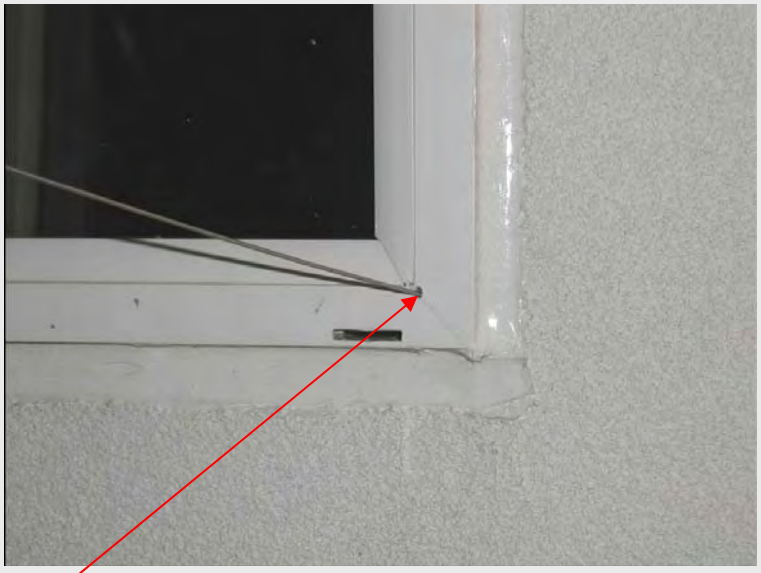
Spray Test with Dyed Water



Dyed Water Spray Test for Assemblies with OSB Sheathing
To Identify Hidden Leaks After Destructive Disassembly

Cracked Window Frame in New Home Simulated in Lab

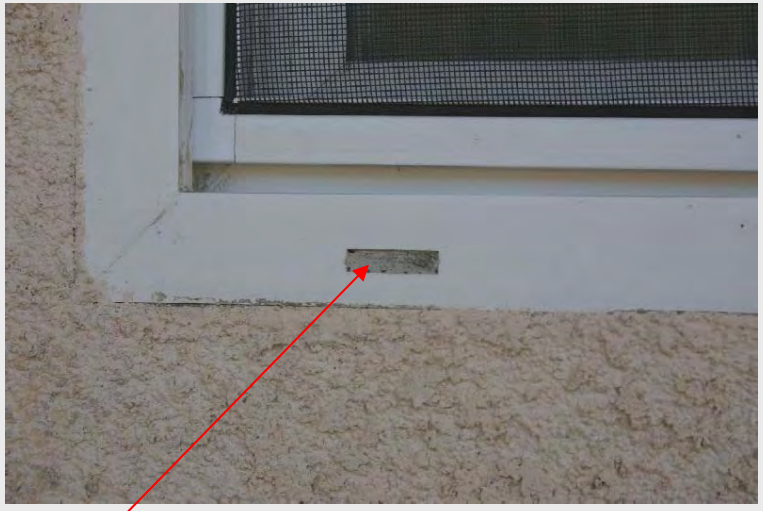
Cracked Window Frame in New Home



⅛” Drilled Holes at Flange Welds to Simulate Cracked Flange

Typical Site of Window Frame Leak in Field and Laboratory Simulation Using ⅛” Drilled Holes

Plugged Weep Hole in New Home Simulated in Lab



Weep Hole Plugged with Stucco in New Home

Plugged Weep Holes in Lab to Provide Head Pressure

Typical Site of Plugged Weep Hole in Field and Laboratory Simulation Using Foam Inserts

Dyed Water Experiment, Weep Holes Open

Water on Interior Track Through Brush Gasket is “Normal” and Drains to Outdoors Through Weep Holes

Dyed Water Experiment, Weep Holes Plugged

Abnormal Water Level in Track Shows Head Pressure for Greater Flow Through 1/8” Holes with Weep Holes Plugged

Window Installation Method Test Results Summary

Assembly	Wood Sill Covered	Observed Leakage				
		No Stucco	With Stucco, Caulked Except as Noted	Caulked, With Drilled 1/8" Holes	Drilled Holes, Plugged Weep Holes	Plugged Weep Holes, Foam Sealant
1	No	No	No	No	Yes	No
2	No	No	No	No	Yes	No
3	Yes	Yes*	No	No	Yes	Yes
4	Yes	No	No; Not Caulked	No	No	No
5	Yes	No	No	Yes	Yes	Yes
6	Yes	No	No	Yes	Yes	Yes
7	Yes	No	No	No	Yes	Yes
8	Yes	Yes*	No	No	Yes	Yes*
9	No	No	No	Yes	Yes	Yes
10	Yes	No	No	No	Yes	No
11	Yes	No	Yes; Not Caulked	Yes	Yes	No
12	No	Yes	No	Yes	Yes	Yes
13	No	Yes	Yes; Not Caulked	No	Not Tested	Yes
14	Yes	No	No	No	Yes	No
15	Yes	Yes	No	No	Yes	No

* Leakage Occurred in Wall Assembly Away from Window/Wall Interface

No Leaks with Full Stucco/Caulk Seal

No Leaks Under All Tests In Only One Case

No Leaks with Most WRB's Without Stucco

Perforated WRB Leaks With/Without Stucco

Leaks Most Often with Most Severe Test

Foam Sealant Contained Leak in Some Cases

Reverse Shiplap Construction Before Stucco Application

2-Ply Building Paper Ineffective with Reverse Shiplap

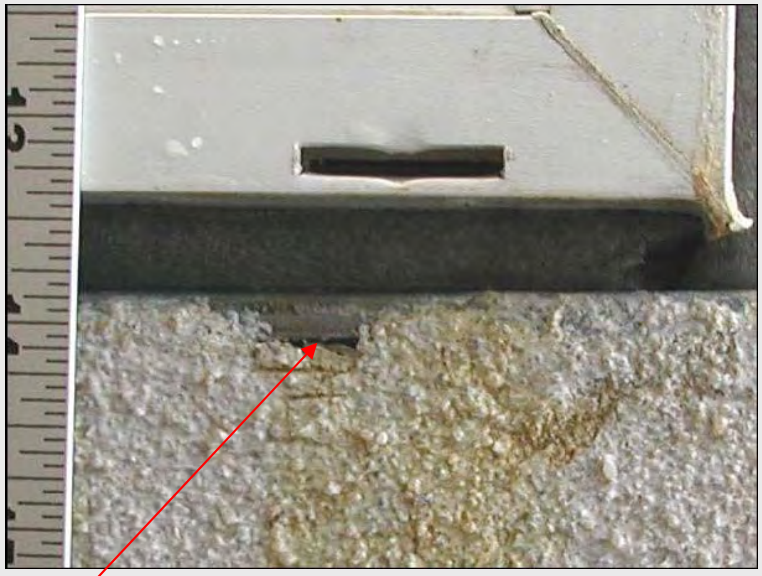
Reverse Shiplap Drains Water to Interior of Wall

Significant Leakage Behind 2-Ply Reverse Shiplap WRB Before Stucco Application with Gravity-Dominated Drainage

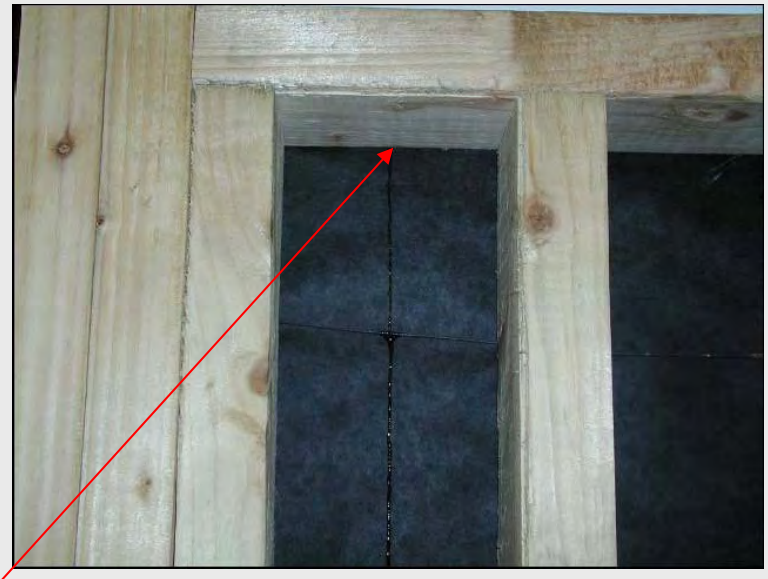
Leaks at Reverse Shiplap Before Stucco Application

Numerous Rivulets On Interior Side of 2-Ply Paper with Leaks Due to Gravity Drainage

Leak at Stucco Flaw



Stucco Flaw Beneath Window Frame



Resulting Leak Through Small Hole in WRB

Bulk Water Flow Through Stucco Flaw, Coupled with Small Hole in WRB, Resulted in Leak at Sill

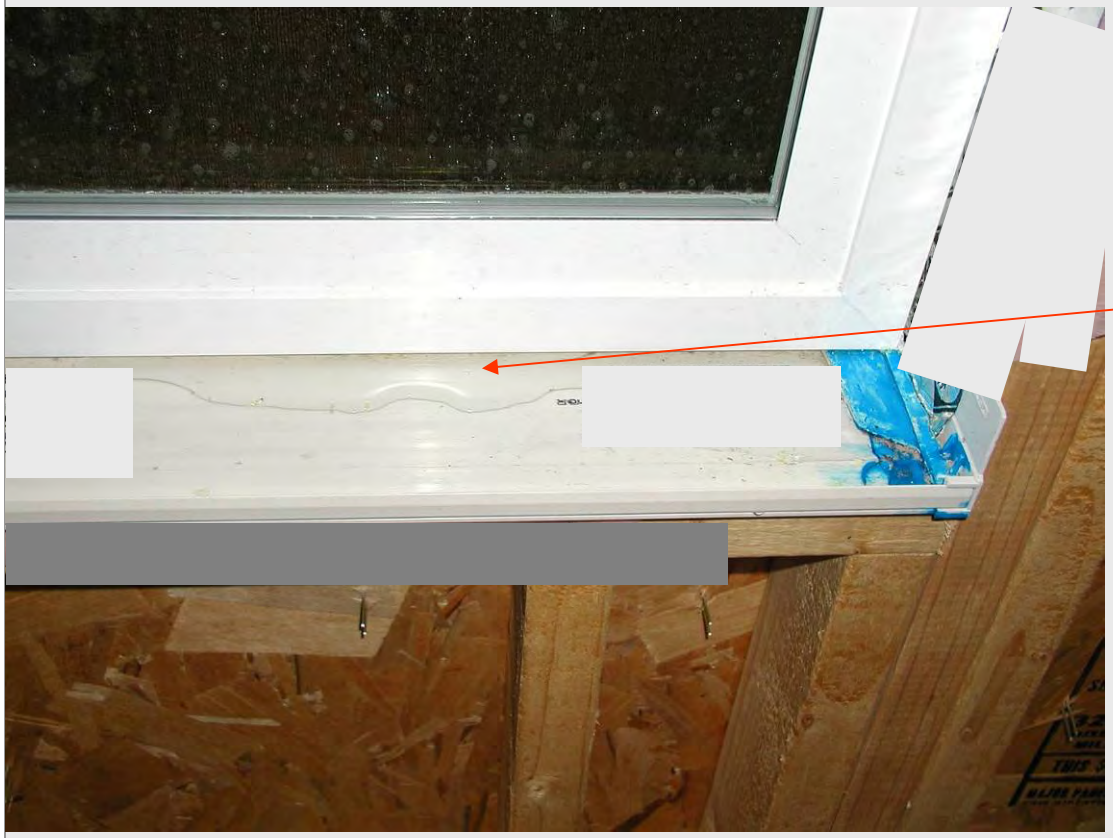
No Leak with Stucco Cladding and Caulk for Full Face Seal

Stucco cladding and caulked frame provide full seal

Effective even with reverse shiplap 2-ply building paper

Stucco Cladding with Caulk Stops Bulk Water Flow. Capillary Suction Transports Moisture to Interior Side of Stucco

Drilled 1/8” Hole Experiment, Weep Holes Plugged



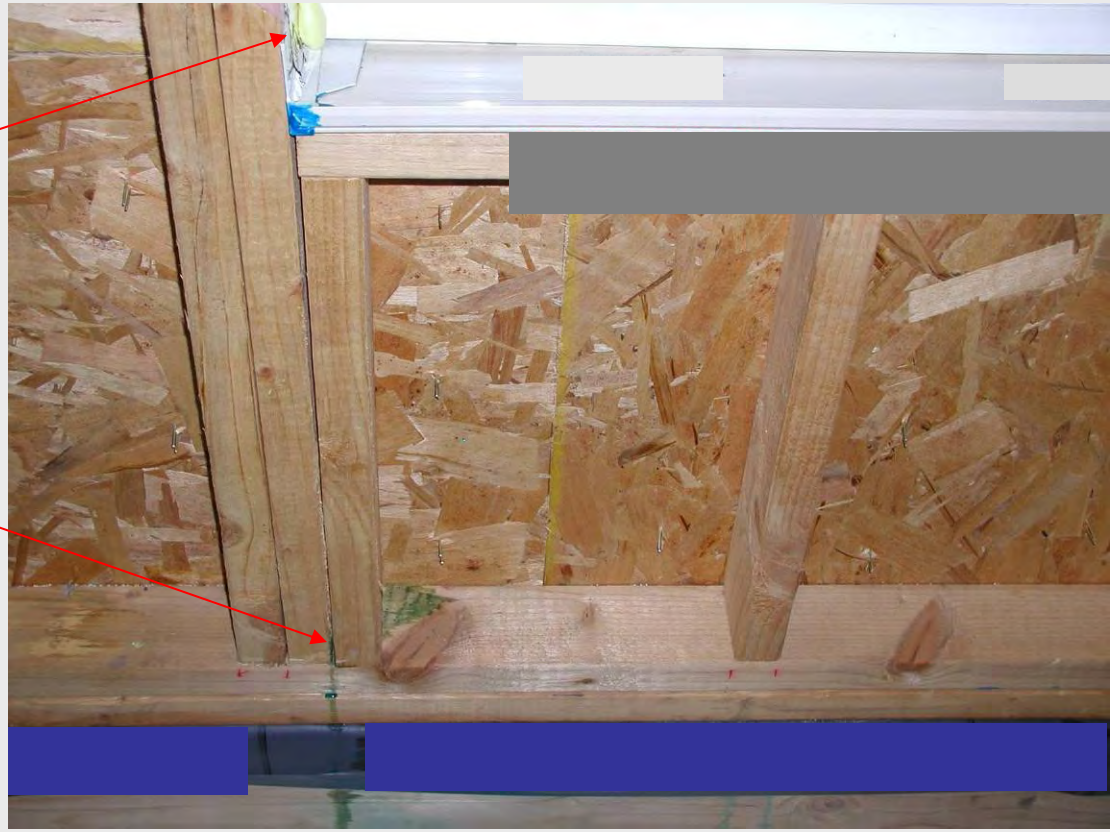
Water In Sill Pan From Leak Under Head Pressure Through 1/8” Hole Drilled In Window Frame, with Weep Holes Plugged

Sill Pan Effectively Collected Water Leaking Through Window Frame

Leakage with Sill Pan and OSB Sheathing

Leak Point of Origin at Junction of Sill Pan, Stucco, and WRB

Dyed Water Shows Visible Leakage Between Studs on Interior Side of OSB



Leak to Interior Side of OSB Sheathing Due to Capillary-Dominated Drainage and Head Pressure from Water in Sill Pan

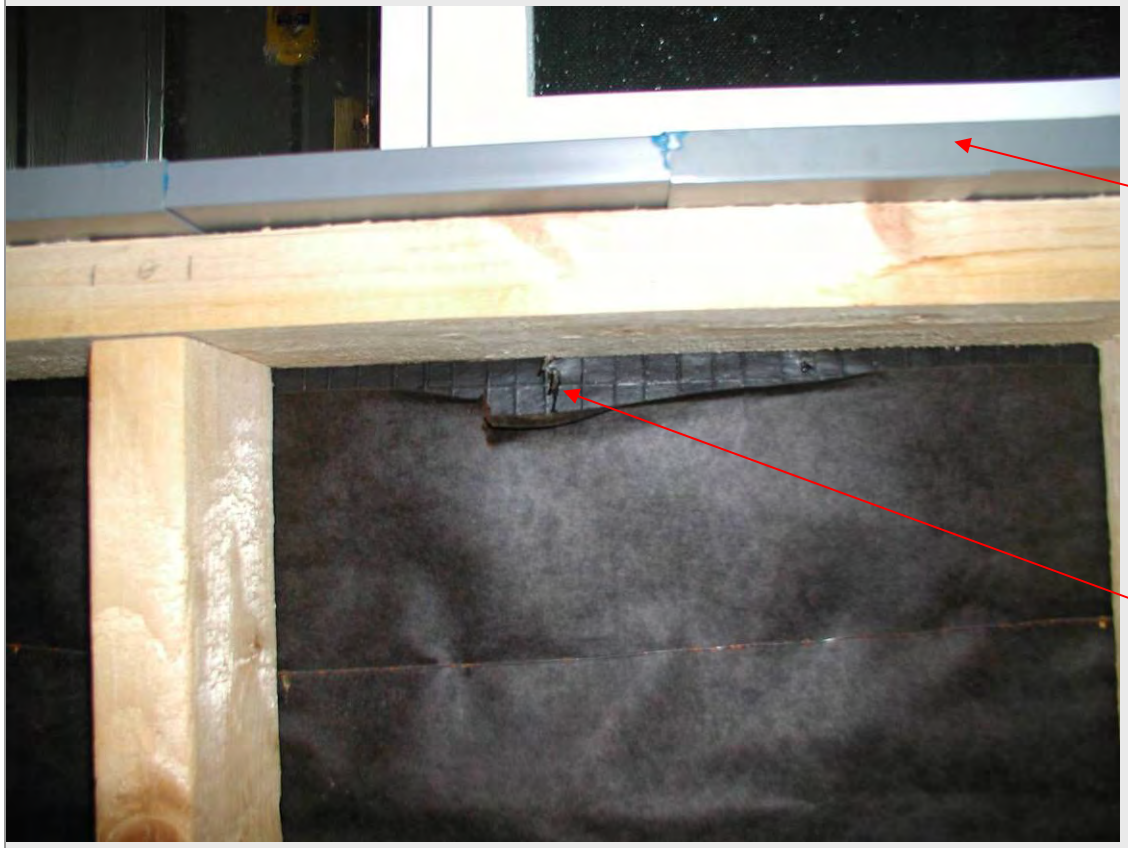
Leak with Foam Sealant Due to Misapplication/Incompatibility

Foam Sealant Did Not Contain Leak in This Case

Foam Sealant Contained Leak in This Case

All Stakeholders Involved in Design and Installation Need to Ensure Compatibility of Materials for Intended Use

Leakage with Sill Pan and Open Frame Construction

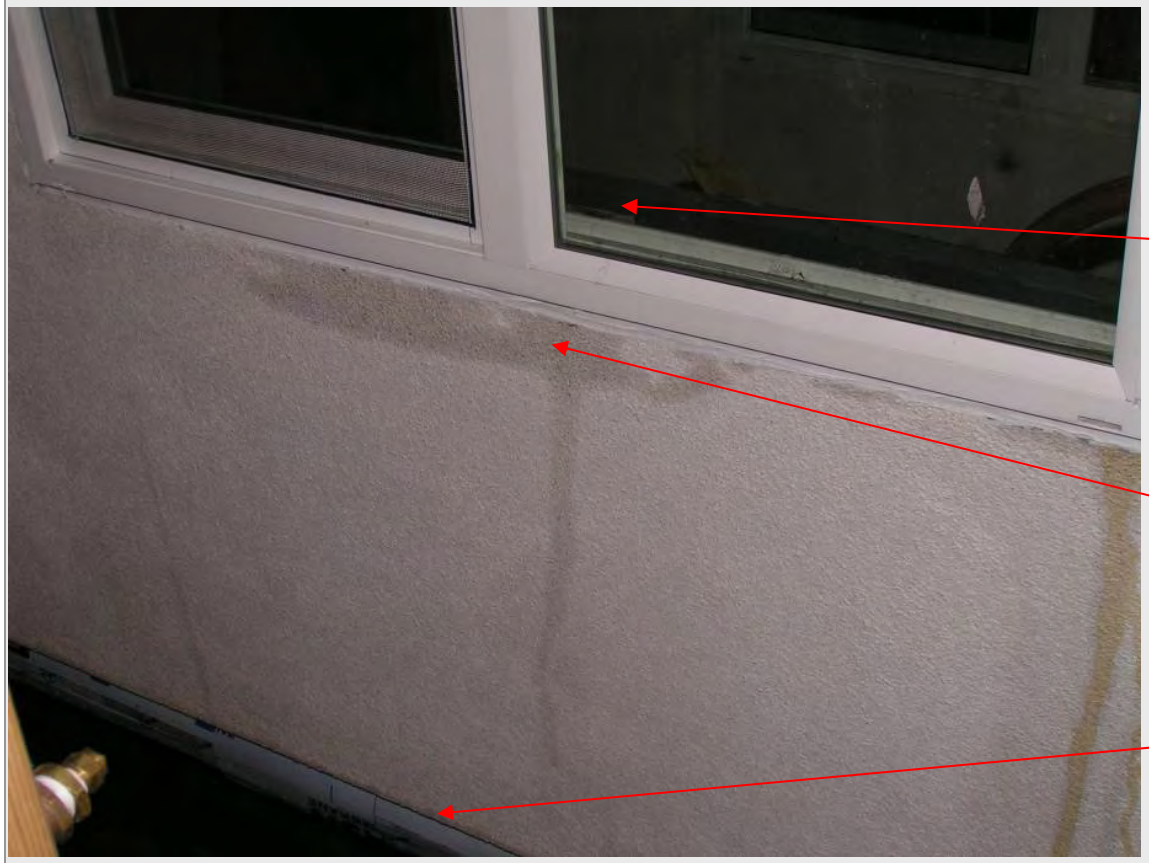


Sill Pan with Water Collected from Window Frame Leak with Plugged Weep Holes

Leak at Staple Pinhole in Sill Flashing (Staple Missed Sill)

Water Under Any Head Pressure Can Leak Through Small Holes; Capillary-Dominated Drainage Created the Head Pressure

Capillary-Dominated Drainage With Water Poured into Sill Pan



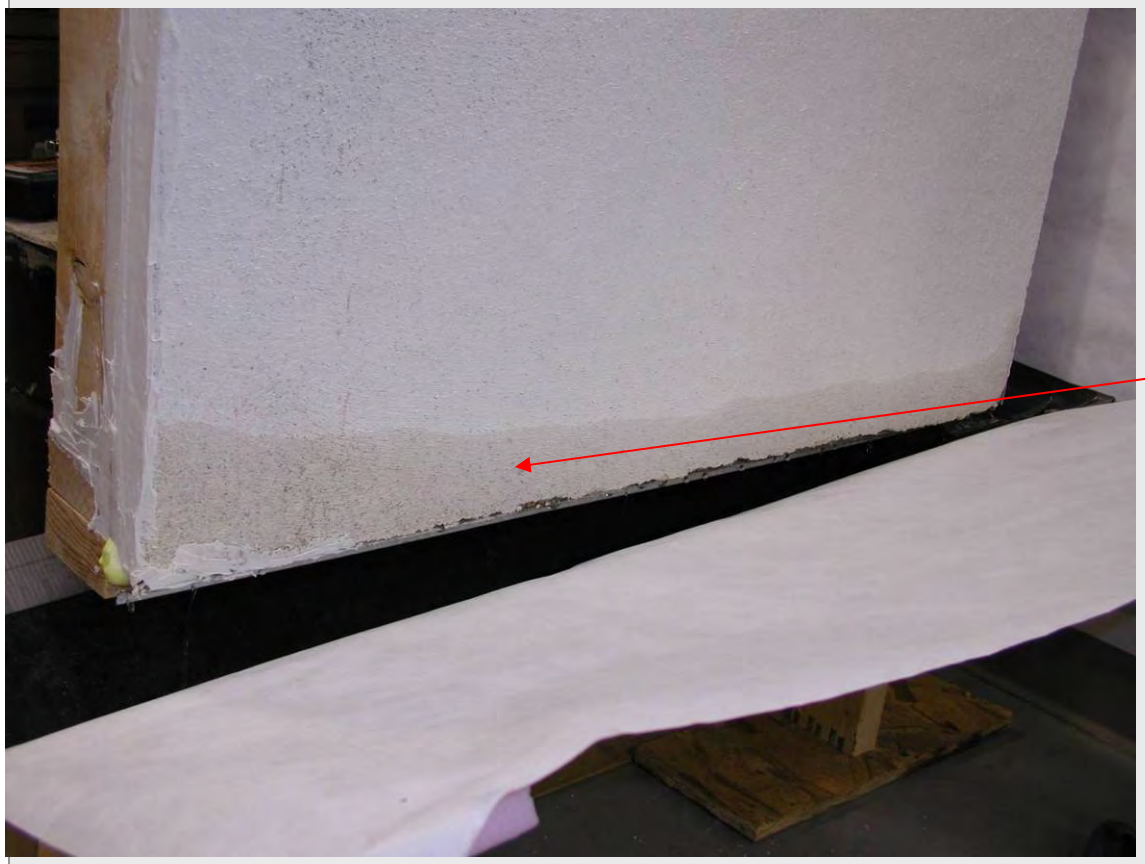
Water Poured into Sill Pan Behind Window

Capillary Suction Flow from Back to Front of Stucco

Limited Gravity Drainage at Weep Screed

Water Drained Slowly from Sill Pan, with Capillary Moisture Transport to Front of Stucco Dominating Gravity Drainage

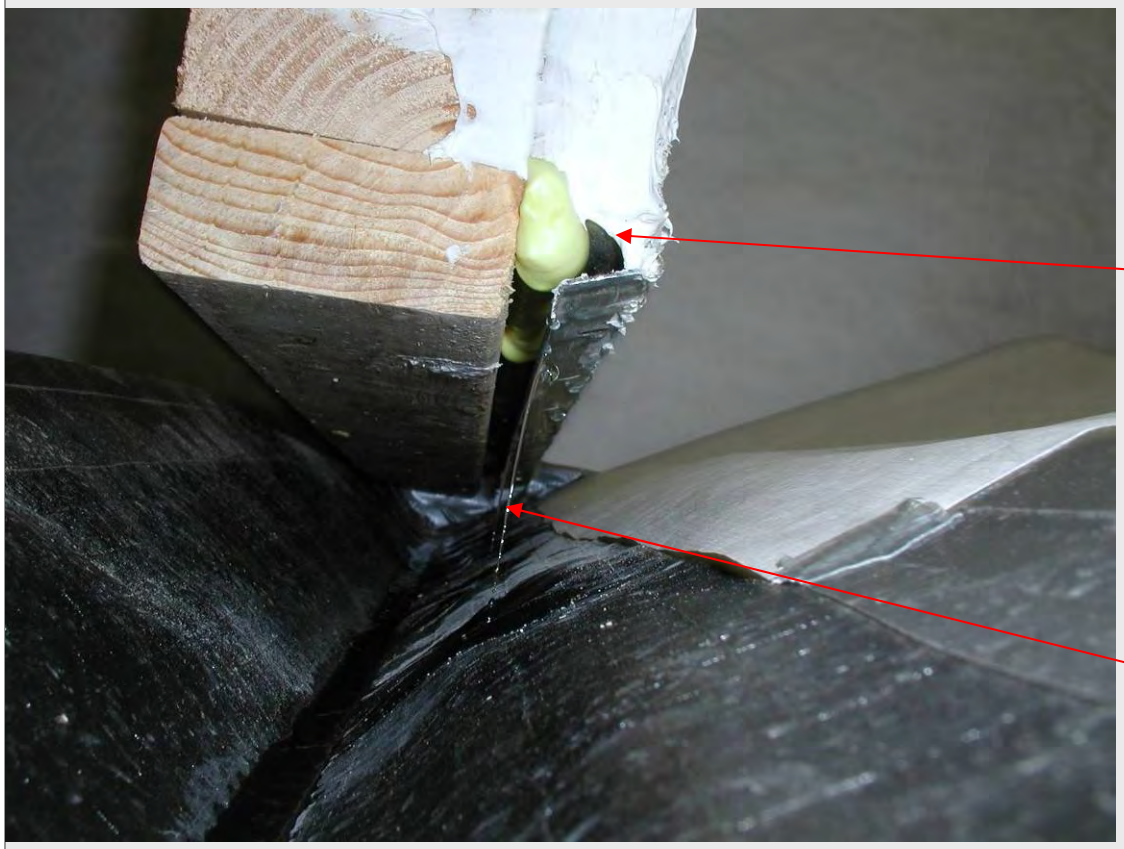
Drainage at Weep Screed for 3-Coat Stucco Wall



Water Soaked Through Stucco From WRB Side When Water Was Poured Between Stucco and WRB at Top

Capillary Drainage Dominated in 3-Coat Stucco Wall with Weep Screed; Flow Trickled at Weep Screed

Drainage Channel at Weep Screed for 3-Coat Stucco Wall

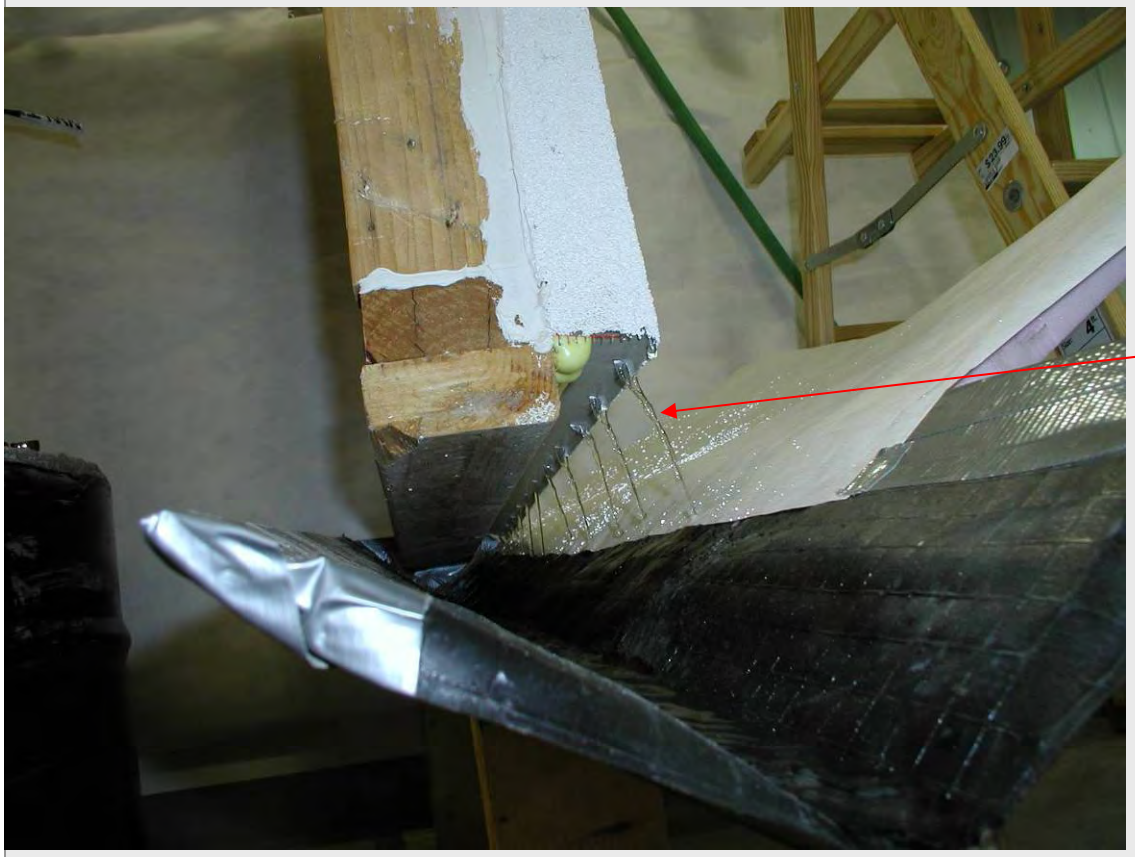


Stucco Adhering Directly to Weep Screed Severely Restricted Gravity Drainage Rate

Capillary-Dominated Drainage Trickled at Exterior Side of Weep Screed

Capillary-Dominated Drainage Capacity Was an Order of Magnitude Lower Than Effective Gravity Drainage

EIFS Drainage Through Screed



EIFS with Drainage Mat Encourages Gravity Drainage Through Designed Weep Screed Holes

Gravity Drainage Dominates in EIFS Wall with Drainage Mat and Designed Weep Screed with Functional Holes

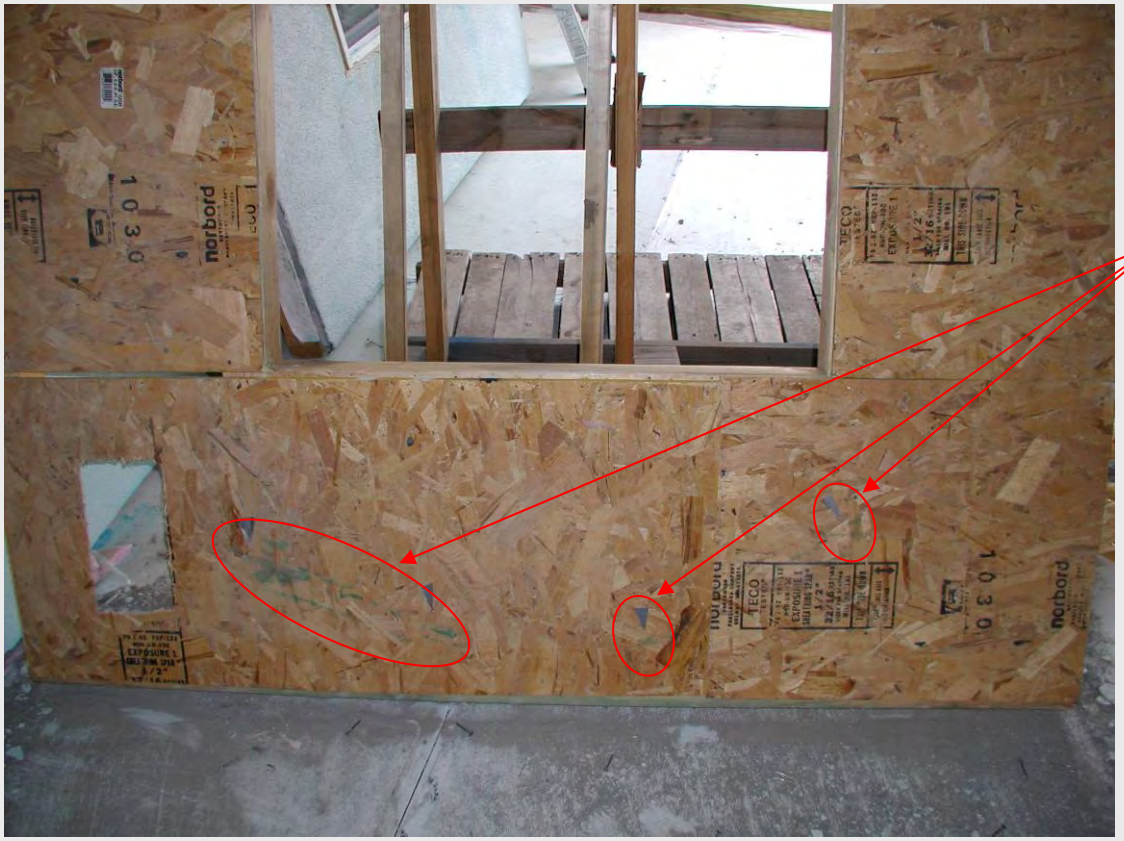
Leak Through Perforated Housewrap

Dyed Water Leak Through Perforated Housewrap After Stucco Application

No Leakage Occurred at Staple Penetration

Leak Through Perforated Housewrap Occurred Away From Staple Penetration, with Capillary-Dominated Moisture Transport

Leak Through Perforated Housewrap Onto OSB



Dyed Water Illustrates Leaks Through Perforated Housewrap After Stucco Application

Leaks Through Perforated Housewrap to Exterior Side of OSB Occurred After Stucco Application

Summary

- Stucco Moisture Transport Mechanisms Are Complex
  - Barrier, capillary suction, gravity drainage, vapor diffusion
  - Different mechanisms dominate depending on design, installation, and maintenance parameters
  - Porous material complicates drainage flows
    - Variable adhesion to WRB
    - Barrier with cracks
    - Interfaces with openings

Summary (Continued)

- Stucco Drainage Mechanisms Impacted WRB Drainage Capacity and Leak Risk
- Weep Screed/Stucco Interface Substantially Reduced Gravity Drainage Capacity
- Stucco with Drainage Channels and EIFS with Designed Drainage Had Much Higher Drainage Capacity
- Stucco with Freshly Caulked Window Frame Prevented Liquid Water Penetration At Window/Wall Interface, Even With Reverse Shiplap

Summary (Continued)

- WRB Drainage Capacity Impacted Sill Pan Performance
- Low Pressure Expanding Foam Sealant (an Air Barrier) Contained Leaks at Sill When Full Seal Was Achieved
- Foam Sealant Did Not Reliably Seal at Sill When Misapplied or Incompatible with Substrates
- Perforated Housewrap Leaked Through Perforations With and Without Stucco Cladding

Conclusions

- Air Space Between Stucco and WRB Is Required for Optimal Gravity Drainage
  - Double layer important, sacrificial layer for bond break
  - Sill pan drains to interior layer (the functional WRB)
- Additional Design Elements Needed When Windows Leak
  - Unpredictable amount and location
  - Panned sill drainage system essential
  - Full air barrier required at all reveals
- Consensus Standards Needed
  - Performance and prescriptive, material and installation
  - Realistic, supported by field data and validated models