



# **Building Envelope Technology Symposium**

**The Westin Galleria  
Houston, Texas**

**2016  
October 17-18**

# **Performance of Weather Resistant Barriers in Stucco Assembly**

**Karim P. Allana, PE, RRC, RWC**

**Allana Buick & Bers, Inc.**



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# Karim P. Allana, PE, RRC, RWC

- **Education:** B.S., Civil Engineering, Santa Clara University
- **Registration:** P.E., Civil Engineering, California, Washington, Nevada, and Hawaii
- **Certification:** Registered Roof Consultant (RRC), Roof Consultants Institute, and Registered Waterproofing Consultant (RWC)
- **Overview:**
  - CEO and Senior Principal at Allana Buick & Bers.
  - Former Turner Construction Employee (Project Engineering and Superintendent)
  - Over 37 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
  - Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
  - Expert in all aspects of building envelope technology.
  - Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
  - Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.



# ABBAE Firm Overview

- Allana Buick & Bers (ABBAE) is an Architectural Engineering firm specializing in Building Envelope Systems
- ABBAE is one of the 5 largest building envelope consultants in the country
- ABBAE has over 33 years of experience & over 12,500 projects
- ABBAE is also a leading Forensic Defect firm with hundreds of forensic projects (litigation)
- Locations – 16 offices across California, Nevada, North Carolina, Oklahoma, Oregon, Texas, Virginia, Washington, Colorado and Hawaii



## Staff & In-House Expertise

- Licensed Professional Engineers – Civil, Structural, and Mechanical
- Registered Architects
- Building Enclosure Commissioning Process Providers (BECxPs)
- Registered Building Envelope Consultant (RBEC)
- Registered Roofing Consultants (RRCs)
- Registered Waterproofing Consultants (RWCs)
- Registered Exterior Wall Consultant (REWCs)
- Registered Roof Observers (RROs)
- Certified Exterior Insulation and Finish System (EIFS) inspectors
- Curtain Wall Specialists
- ICC Certified Building Inspectors
- Quality Assurance Monitors
- Water Testing Experts
- Leak Investigation and Diagnosis Experts
- Infrared Imaging and Nuclear Moisture Scanning Experts



# ABBAE Building Expertise

- Building Envelope Systems
  - Roofing Systems
    - High-Slope/Low-Slope Roofs
    - Green/Garden Roofs
    - Drainage Systems
    - Pedestrian Plazas
  - Exterior Wall Systems
    - Wall Cladding /Siding/GFRC/pre-cast
    - EIFS/cement plaster/stucco
    - Sheet Metal Flashings
  - Windows and Glazing Systems
    - Punched Windows
    - Curtain Wall/Window Wall Systems
    - Sliding Glass Doors
    - Skylights
- Building Envelope Systems (cont'd)
  - Roofing & Waterproofing Systems
    - Deck/Balcony/Lanai Waterproofing
    - Podium Waterproofing
    - Pool/Spa Deck Waterproofing
    - Above-Grade/Below-Grade Waterproofing
    - All types of low and steep sloped roofing
  - Commissioning BECx
    - OPR/BOD/Commissioning Plan
  - Mechanical/HVAC Systems
    - HVAC design
    - Plumbing systems
    - Commissioning and testing





# ABBAE Core Services

- Consulting and third-party peer review services
- Engineer of record for building envelope systems
- Contract administration services
- Inspection services (usually direct with owner)
- Air and water performance testing
- Mock-up design, observation, and testing
- Building assessments and forensic investigations
- Litigation support and expert witness services
- Educational seminars with AIA credits



# Presentation Outline

- How does cement plaster work?
- Water management in cement plaster
- Sources of water behind plaster
  - Control joint
  - Window and other openings
  - Plaster itself
  - Private Decks and roof diverting water behind plaster
- Performance of plaster mix design
  - Rilem tube tests
- Performance of Grade D Building paper
  - Pines color damage maps
  - OSB damage tests
  - Drying effects in moisture diffusion to interior
  - Options for upgrading paper

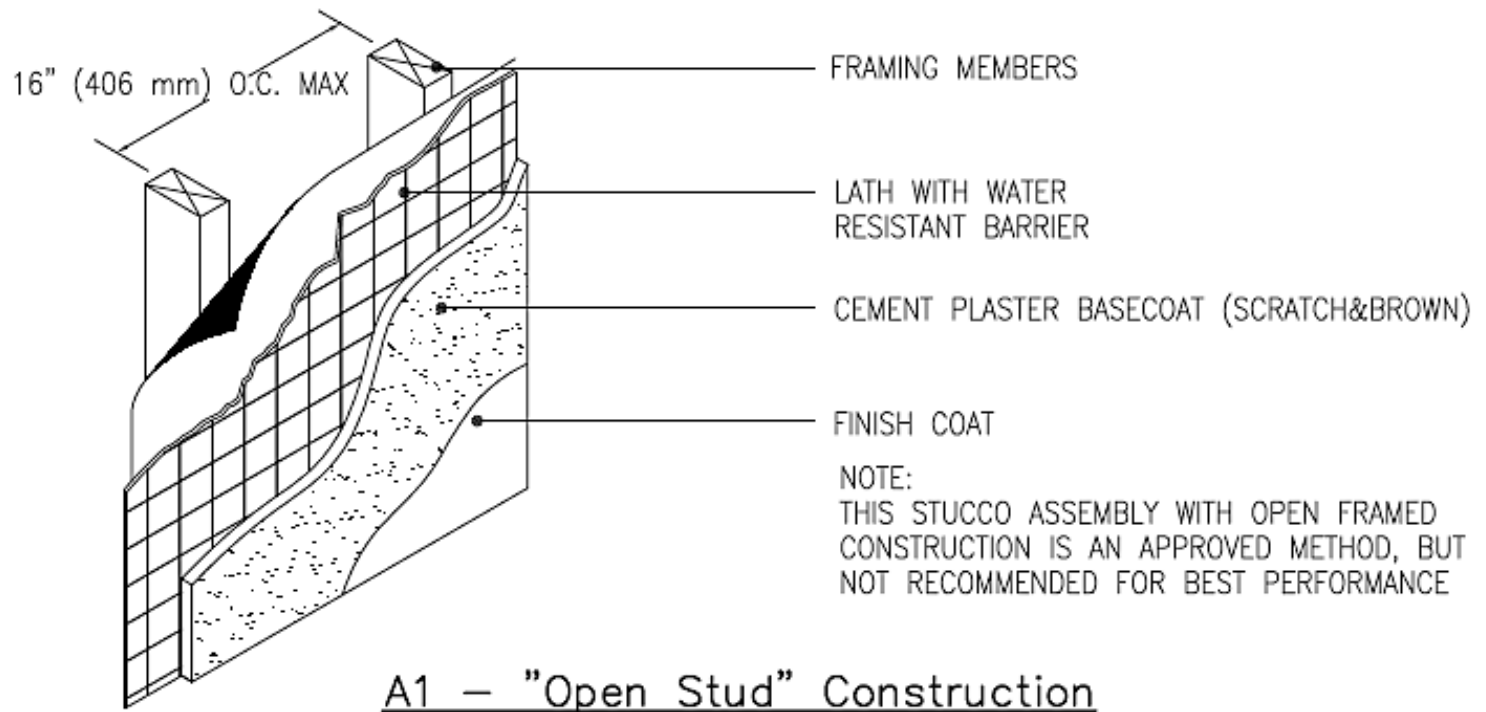


# How Does Cement Plaster Work?

## Stucco Assemblies

### Stucco Wall Assemblies

NOTE: THESE ASSEMBLIES INDICATE ONLY THE BASIC COMPONENTS



# Exterior Wall Systems

## 3 Options For Walls To Manage Water

- Barrier / Face Sealed
- Drainable
- Rain Screen





# Barrier vs. Moisture Management

## BARRIER / SHEDDING / FACE SEALED

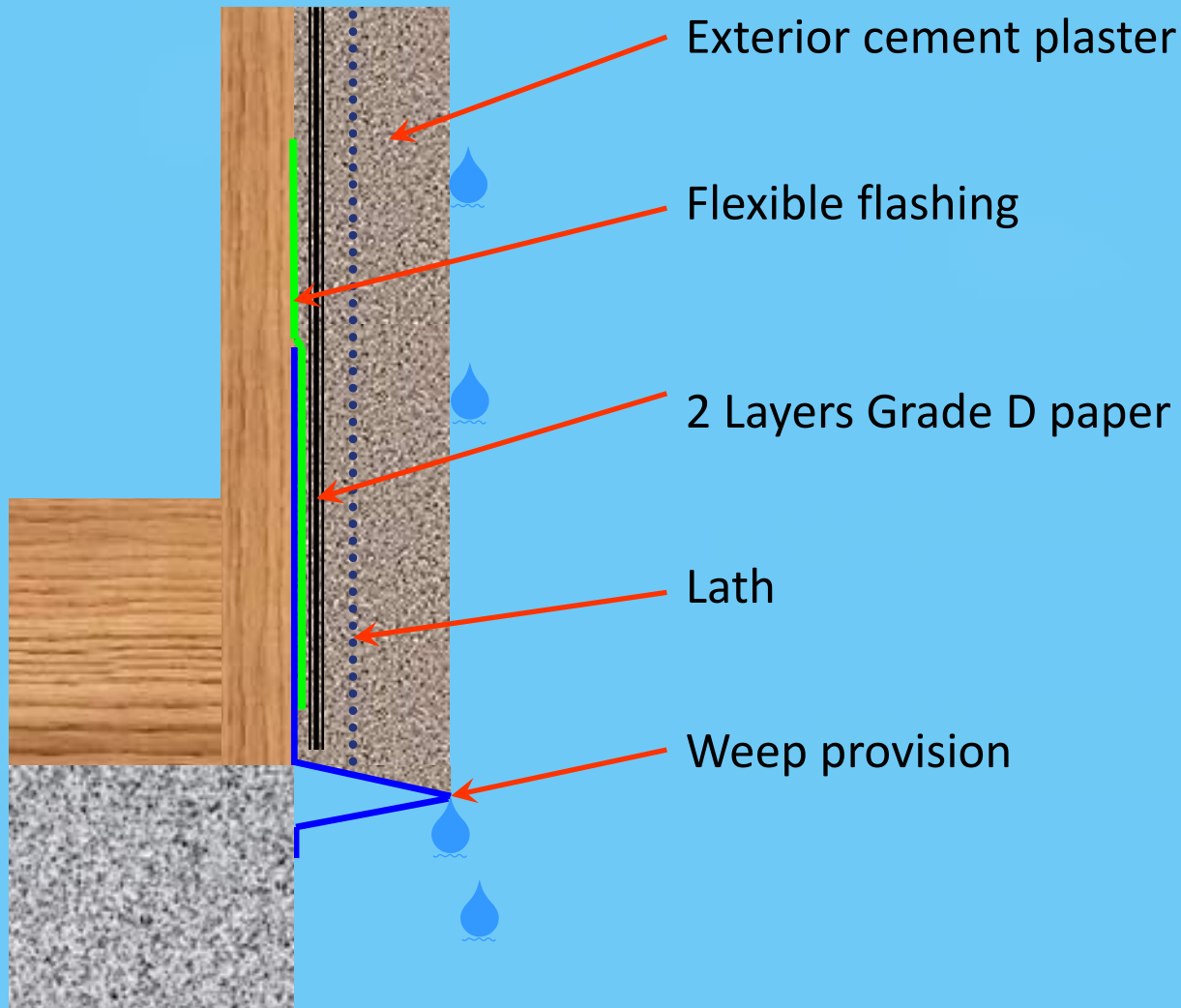
- Exterior surface is the primary means of excluding water from entering the barrier wall system
- Interior waterproofing elements are secondary to the surface barrier
- Expects the water shedding surface barrier to be perfect
- Represents the vast majority of pre-cast concrete, GFRC, curtain wall systems

## MOISTURE MANAGEMENT/ RAIN SCREEN

- Exterior surface is the initial means of excluding water from entering the wall system
- Interior waterproofing elements work in tandem with the exterior skin
- Water admitted into the system is captured and managed through weather resistive barrier
- Rain Screen Provides “Air Flow and Better Drainage”



# Cement Plaster, Moisture Drained System



# Moisture Management Wall – Rain Screen

## Rain Screen Drainage System

- Concealed barrier systems with air space for ventilation and drainage
- Most of the water is handled by shedding of water from face of cladding, however... relies on weather resistant barrier to handle very small amount incidental water.
- Much greater capacity to handle moisture on the WRB
- Wets and dries quickly, not sensitive to moisture unless drying is prohibited by incorrect placement of vapor barrier
- Quick drying of WRB means very little moisture is absorbed through the wall and diffused to the interior space
- Exterior sheathing and wall cavity stays much dryer and lowers the chance from mold growth and damage



# Wall Wetting Mechanism

Ventilated Rainscreen for Improved  
Moisture Management

## Wall Wetting Mechanisms are Complex

### 1. Rain

- Absorption (wicking)
- Penetration
- Splash and drips

### 2. Water Vapor

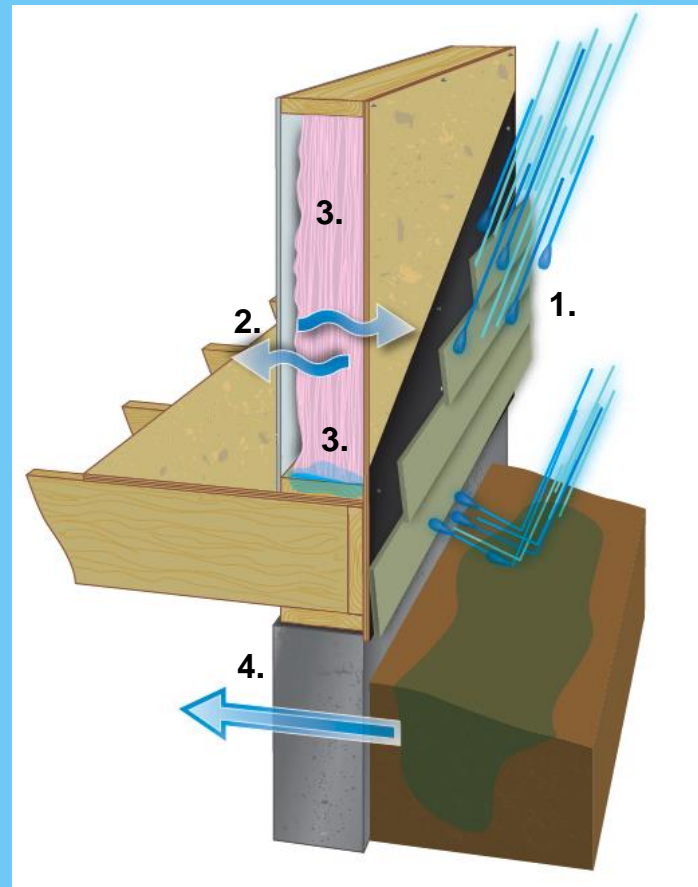
- Diffusion
- Convection (air leaks)

### 3. Built-in Moisture

- Vapor
- Liquid/frozen

### 4. Ground Moisture

- Capillary
- Diffusion
- Liquid penetration





# Sources of Water On WRB

- Control joints
- Window and other openings
- Private decks and roof diverting water behind plaster
- Porosity and absorption through plaster and other siding



# Sources of Water Behind Cladding





# Water Soaked Through Paper



Area under the flexible flashing was not damaged



# Moisture behind Siding and Stucco

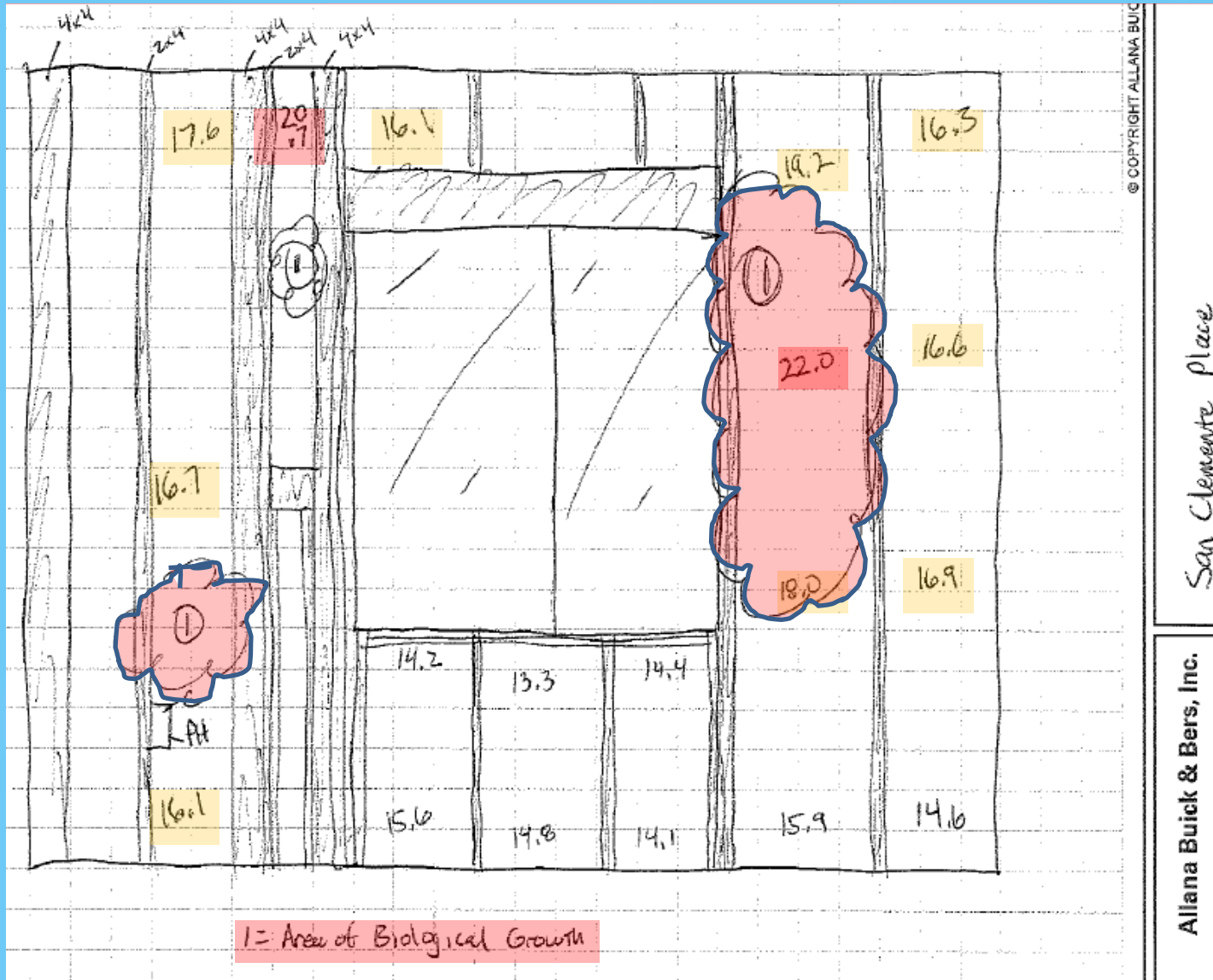


Faster (Shiner)  
corroded from  
inside





# Elevated Moisture Levels Exterior Sheathing



## Sources of Water, Corners of Control Joint



ABB2053-134828





## Control Joints Nailed Tight To Paper





## Sources of Water, Corner Mold at Control Joint



ABB2053-136014



## Water Actively Dripping Under Control Joint





# WRB is Completely Saturated



ABB2053-136401





# Damage from Window Flashing Issues



ID: Window-2104 LR, Unit: 2104, Window, Severe Damage, Peel and stick installed to face of fin and not adhered

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# Improperly Installed Window Flexible Flashings



ABB2053-20740

ID: Window-2104 LR, Unit: 2104, Window, Severe Damage, Peel and stick installed to face of fin and not adhered

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## Under Window Damage to OSB



ABB2053-20788

ID: Window-3108, Unit: 3108, Window

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# Stucco Demo at Handrail Penetration

Test area: Handrail  
penetration  
At Unit 431 E



Wet and damaged  
building paper





# High Moisture Content in OSB 24.8%

Test area: Handrail  
penetration  
At Unit 431 E



## Horizontal Areas Of Plaster



ABB2053-03260

ID: Walkway-1406, Unit: 1406, Scupper at Walkway  
2010-01-12 Chris Johnson

ABB2053-03260

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# Highly Absorbent Siding or Cladding

## Issues and Problems with highly absorptive claddings and incidental water

### Inward Vapor Drive

- Stucco & Adhered Veneers = very high moisture storage
- Wet cladding + undrained water + solar heating = rising vapor pressure  
**Drives vapor inward!**
- Wet blanket effect against building paper



# Field Performance Testing South Carolina



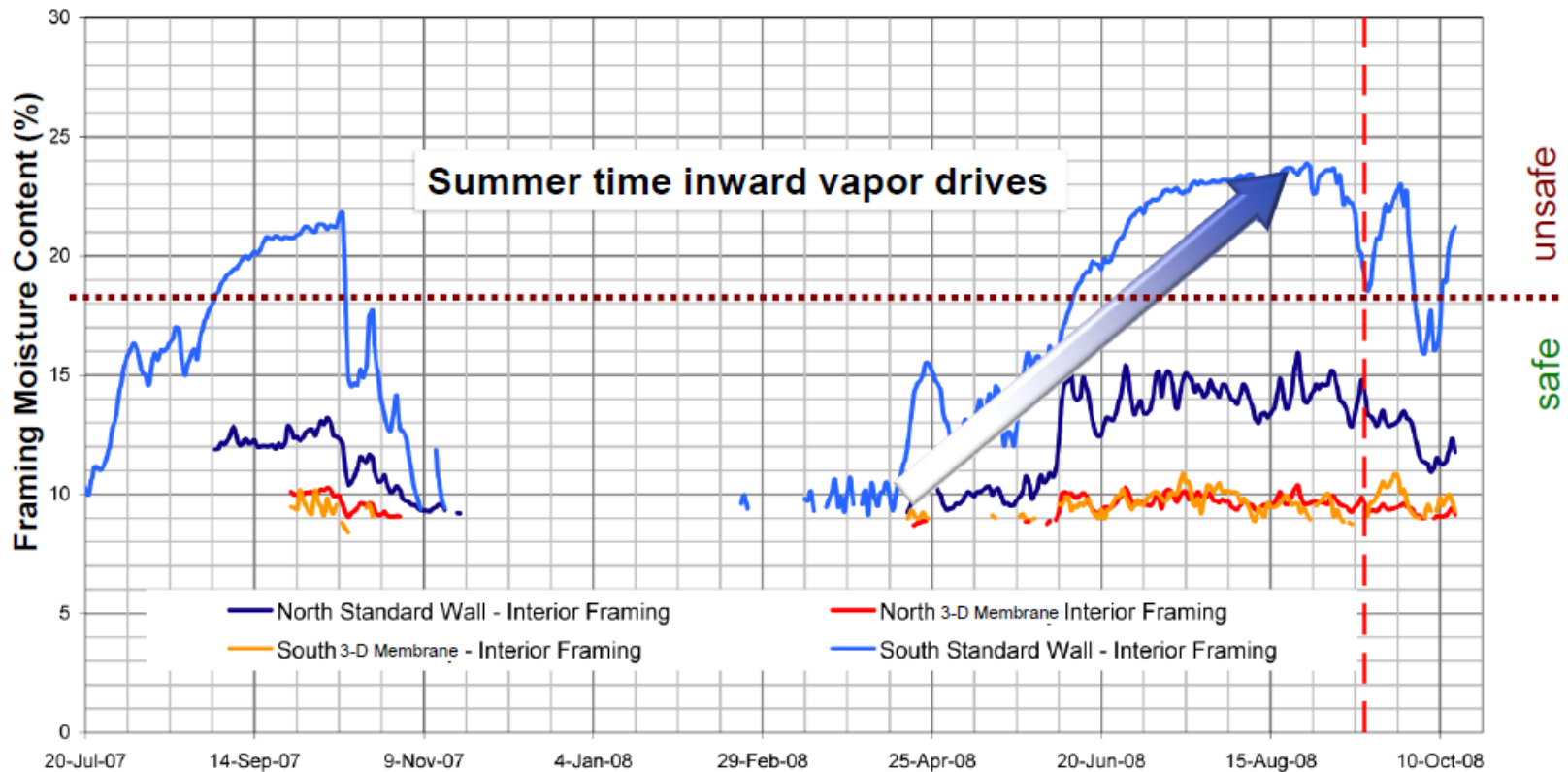
Field performance testing at testhut in Waterloo, ON  
Dr. John Straube, Building Science Corporation





# Absorption of Water Can Lead To Damage

## Framing Moisture Content



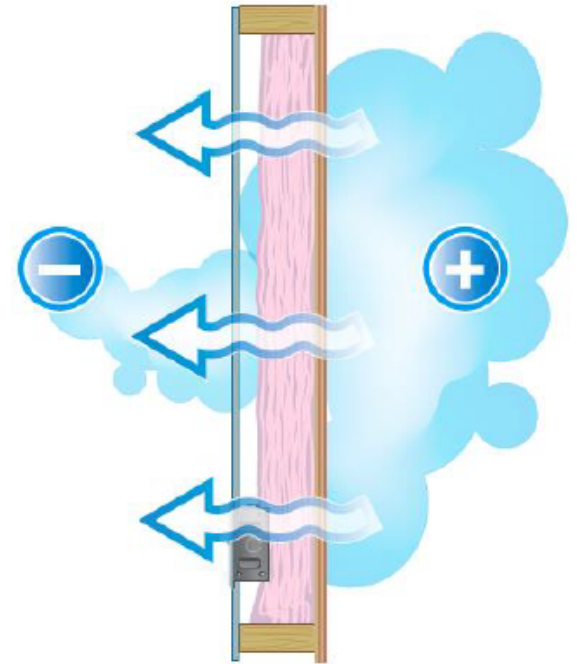
# Vapor Diffusion - Permeation

## Why Does Vapor Diffusion Occur?

Vapor diffusion is driven by  
**Vapor Pressure Differentials**

If moisture content in air is different inside and outside of a wall, vapor diffusion will occur until the vapor pressure differential is eliminated (equal vapor pressure on either side of the wall)

**Resistance** to vapor diffusion depends on water vapor permeance of materials  
**(perm rating)**

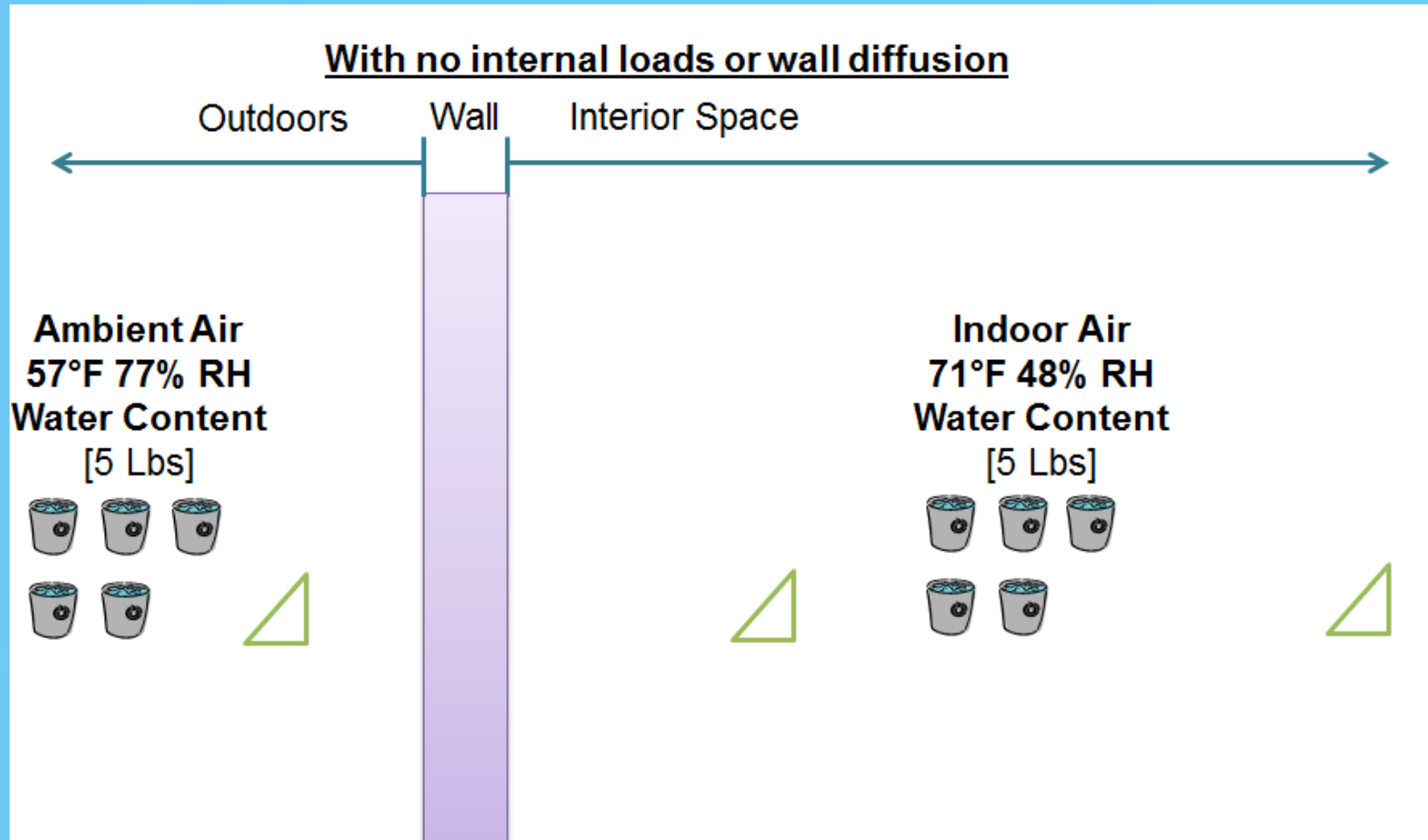


# Study of Rising Interior Humidity

- Moisture absorbed through exterior cladding raises humidity inside living spaces
- Verify exterior moisture intrusion is raising humidity as opposed to internal moisture sources (occupant activity).
- The preliminary study based its findings on data collected during routine site inspections. This data was not initially intended for the use of this study.
- Following routine gathering of information, a small number of test units were chosen
- Study was conducted in San Jose, CA during winter in-between periods of rain



# Moisture Diffusion Study Results

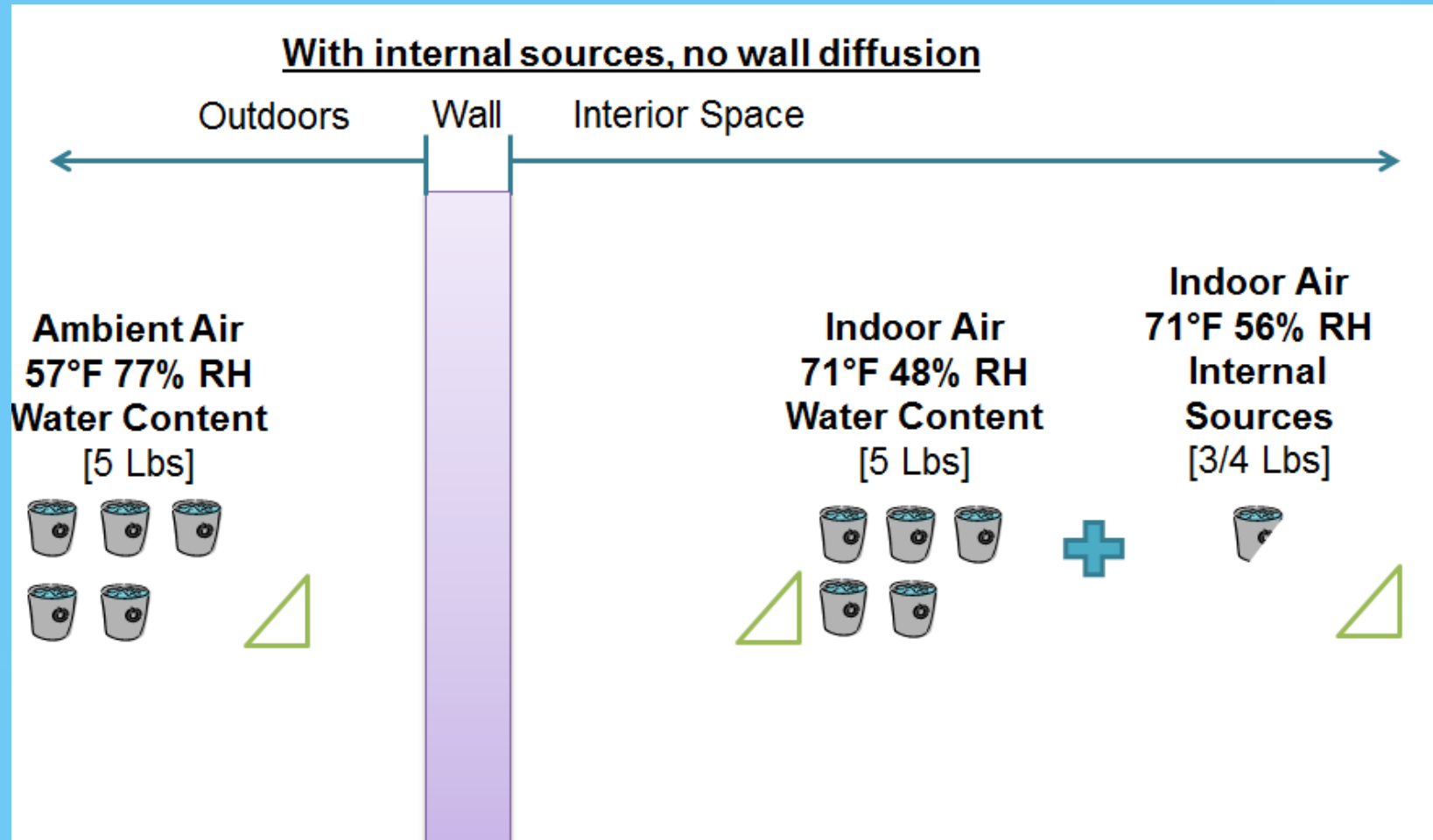


# Moisture Diffusion Through Cement Plaster

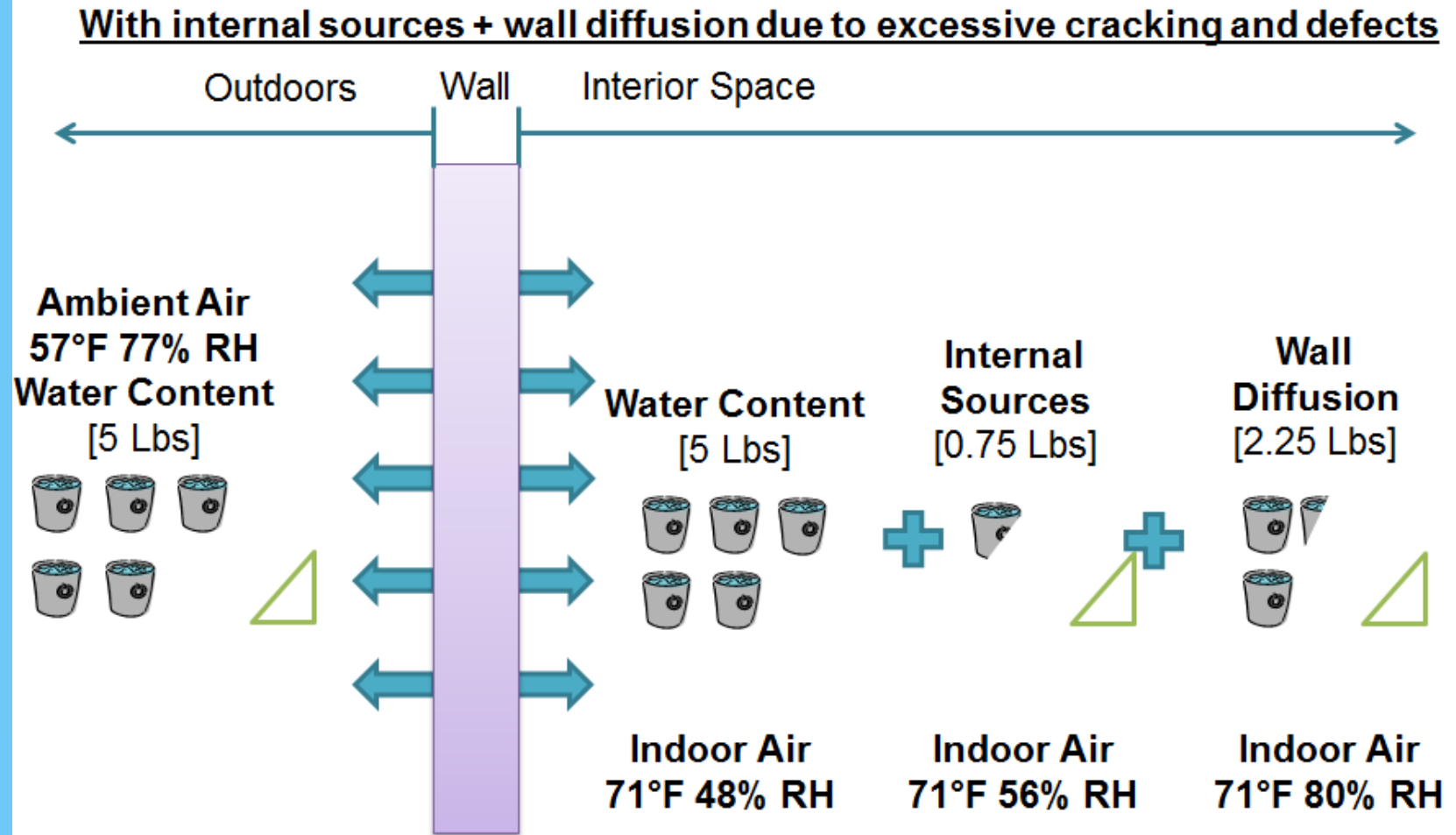
- **Actual conditions measured in a 2 bedroom residential unit:**
  - 937 sq. ft.
- **Natural ambient air moisture content:**
  - 57°F dry bulb, 77% relative humidity
- **Interior space room conditions:**
  - 71°F dry bulb, 80% relative humidity
- **Internal moisture sources include:**
  - (2) 15 min. showers a day
  - (1) 10 min. boiling pots a day
  - (1) 20 min. hand dish washing
  - 12 hours of person seated at rest
  - 2 hours of person at moderate work
  - 1 hours of person at light exercise



# Moisture Diffusion Study Results

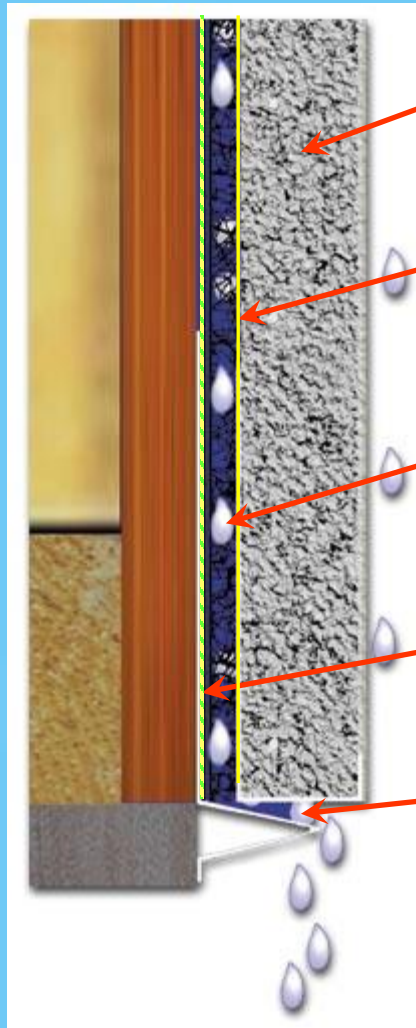


# Moisture Diffusion Study Results





# Moisture Management System With Drain Mat



Exterior cement plaster

Outboard moisture barrier

Drainage cavity

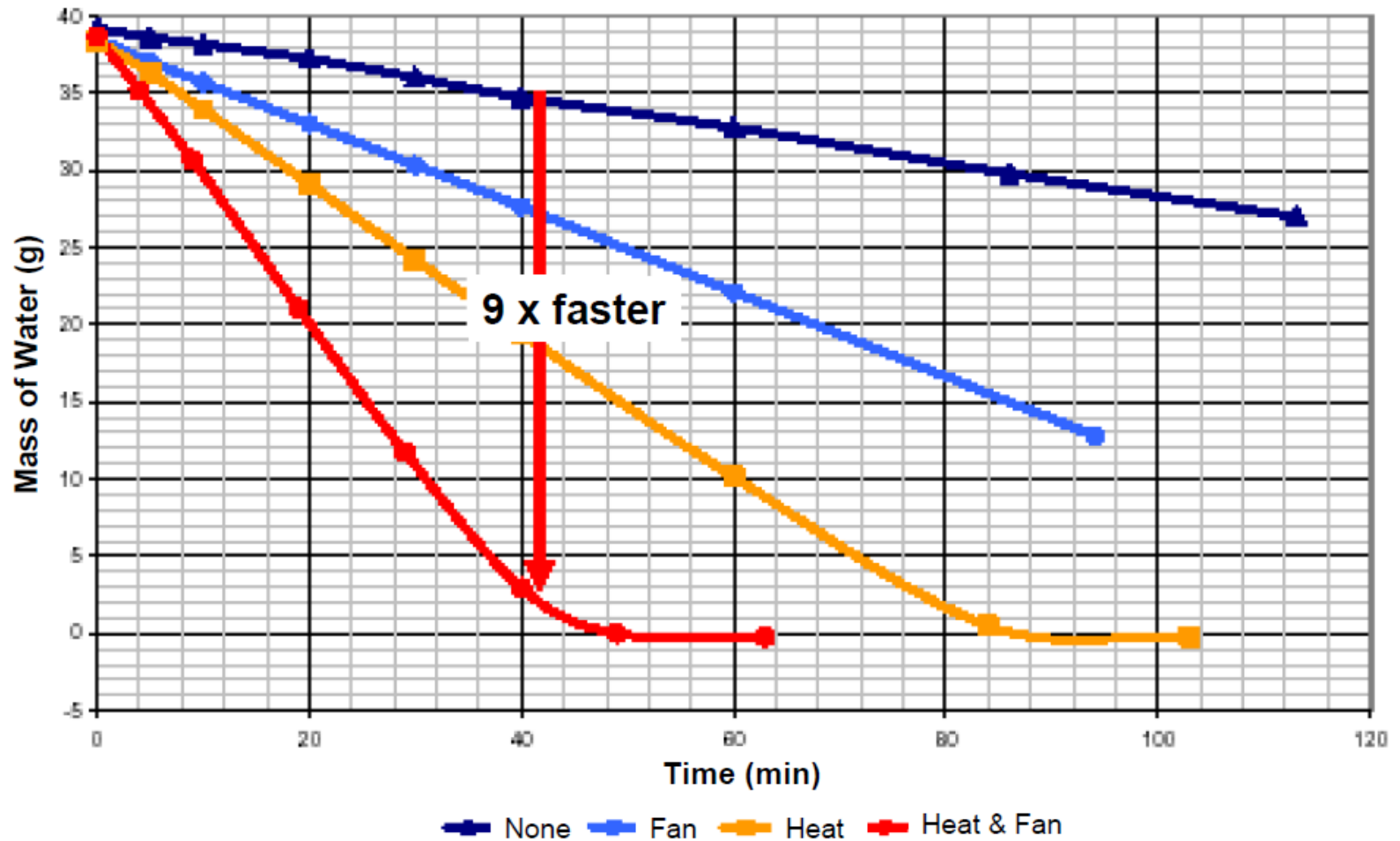
Inboard moisture barrier

Weep provision



# Paper Towel Wetting Analysis (Dr. Straube)

Comparison of different Drying Techniques on Paper Towel Wetting



© Dr. J. Straube; Westford Symposium '06



# Performance of Plaster Mix

Absorption through cladding can add significant moisture

Rilem tubes - used to test water absorption rate

## Results:

- **Pines B-2**
  - 11/18 locations significantly lost water = 61%
- **Pines B-1 STO Finish**
  - No locations lost water
- **Pines B-1 BMI Stucco**
  - No locations lost water



## Pines B2 - Water Dropped Almost Immediately

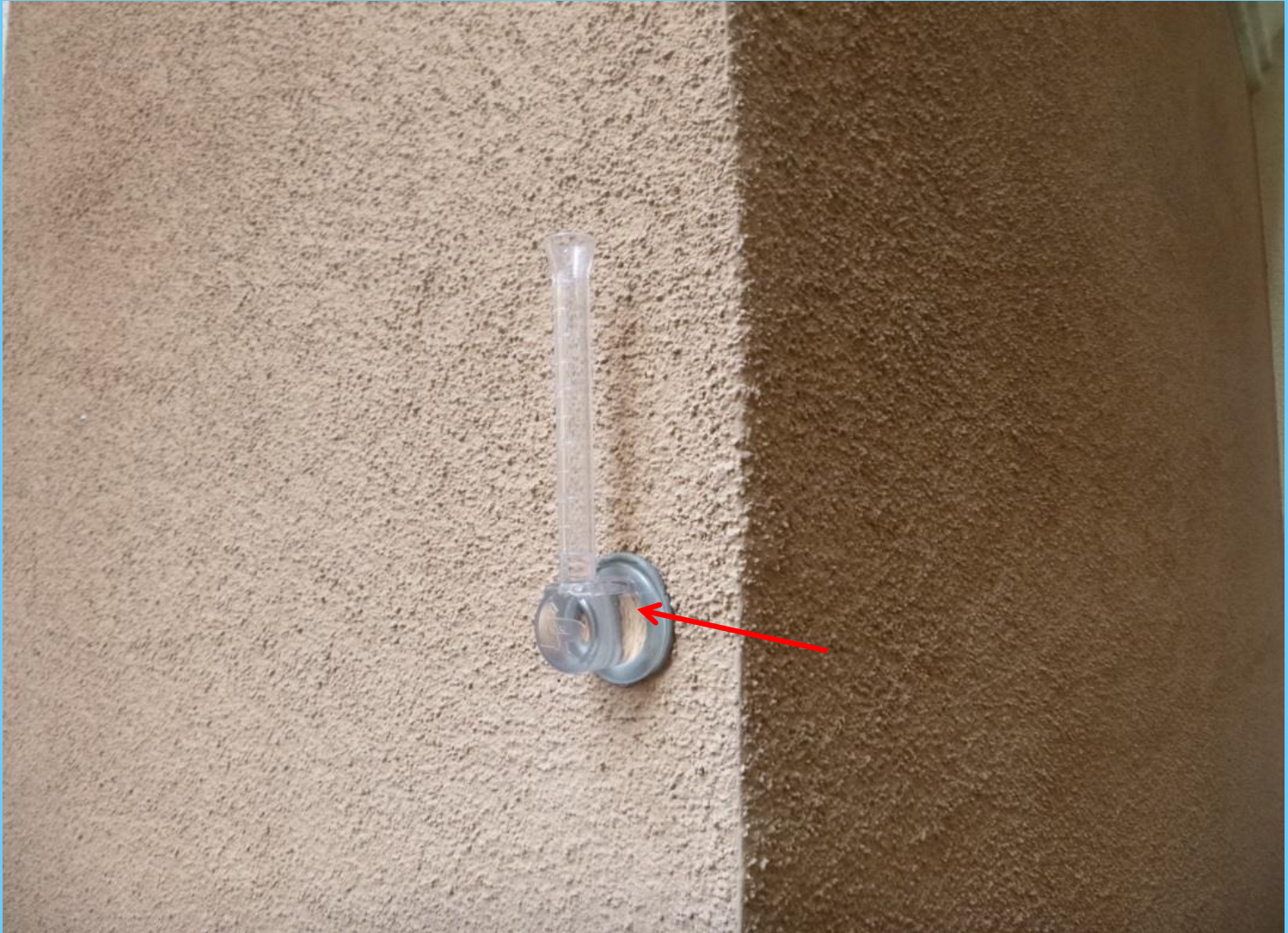


Building 4-Location 8-A. Water dropped to a level almost immediately before we could take a photo of full tube.





## End of Test – In 15 Minutes



Building 4-Location 8-A. Water dropped to bottom of the tube near the end of the test.





## End of Test – In 15 Minutes



Building 3 Location 6-A, full Rilem tube



## Rilem Tube Level Dropped in 15 min



Building 3 Location 6-A, water level at end of test.





## STO Finish - End of Test –Tube Full



Building Pines B-1 Bldg. 1 Unit 1111 Rilem test over new Sto Finish-Tube is full at end of test.

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## Pre-Mix Stucco - End of Test –Tube Full



Building Pines B-1 Bldg. 2 Unit 2110 Rilem test over new BMI stucco-tube is full at end of test.





# Damage – San Jose Apartment– South Elevation



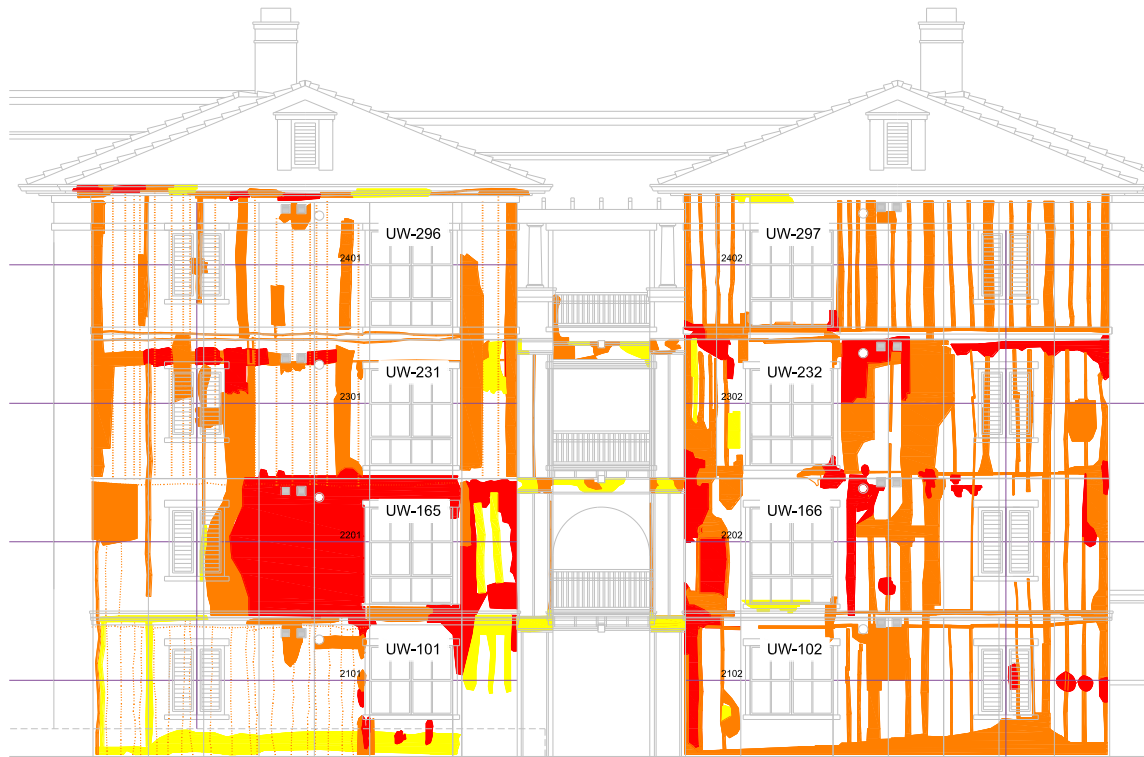
# Damage - San Jose Apartment South Elevation



# Damage - San Jose Apartment North Elevation



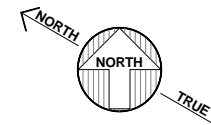
# Damage - San Jose Apartment North Elevation



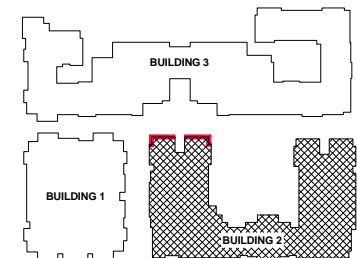
## KEY - TYPE OF DAMAGE

Yellow	Slight:	Water Stains
Orange	Moderate:	High Moisture Content
Red	Severe:	Decay / Rot

Blue line Cracks  
Purple line Control Joint



## SITE KEY PLAN





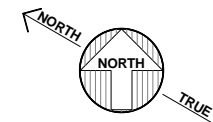
# Damage - San Jose Apartment West Elevation



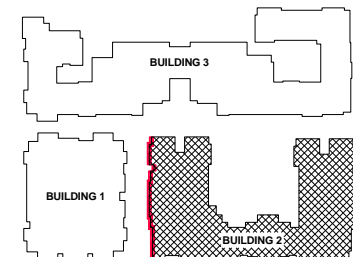
## KEY - TYPE OF DAMAGE

<span style="background-color: yellow; border: 1px solid black; display: inline-block; width: 20px; height: 10px;"></span>	Slight:	Water Stains
<span style="background-color: orange; border: 1px solid black; display: inline-block; width: 20px; height: 10px;"></span>	Moderate:	High Moisture Content
<span style="background-color: red; border: 1px solid black; display: inline-block; width: 20px; height: 10px;"></span>	Severe:	Decay / Rot

~ Cracks  
— Control Joint



## SITE KEY PLAN



# Damage - San Jose Apartment East Elevation



## Damage Ranges From Slight To Severe



ABB2053-23818



# Analysis of OSB Damage

Structural Loss of Strength in OSB and plywood wall sheathing can be measured empirically

## Damage States Defined

- No Damage
- Slight Damage
- Moderate Damage
- Severe Damage





## OSB Damaged State: No Damage



## OSB Damaged State: Slight Damage





## OSB Damaged State: Moderate Damage



## OSB Damaged State: Severe Damage





## OSB Damaged State: Severe Damage



ABB2053-23785



# Nail Pull Through Strength Test: ASTM D1037



# Nail Pull Tests Per ASTM D1037

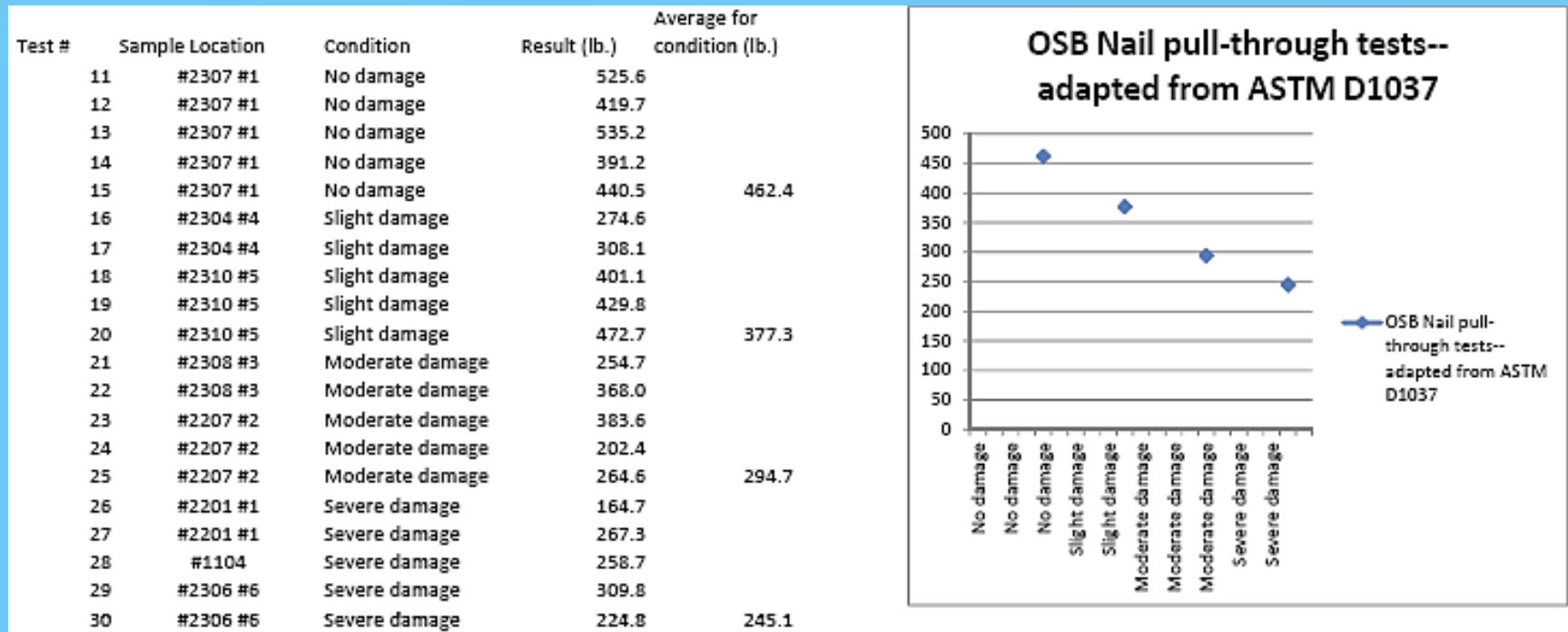
- ABBAE performed 5 pull tests of each damage state level of Pines OSB Per ASTM 1037
- A Pull Through Test is an indication of loss of strength and structural integrity





# OSB Nail Pull Tests – Loss of Strength

Pull through test results are:



2053: Pines Parcel B-1, Tests Performed by Dennis Wobber 10/9/2012

OSB Nail pull-through tests--adapted from ASTM D1037



# OSB Nail Pull Tests – Loss of Strength

Water Damaged Panels significantly lose structural strength:

Slight Damage	19% less nail pull out strength
Moderate Damage	36% less
Severe Damage	46-100% less

In shear tests, panels typically fail from edge nail pull out or panel tear-through.

The above results show the projected approximate loss of shear values for each damage level.



# Wall Drying Mechanisms

Ventilated Rainscreen for Improved  
Moisture Management

1. Surface Evaporation
2. Diffusion / Convection
3. Drainage
4. Air Exchange (Ventilation)

