Context
Stucco Evolved As A Barrier System
Mass Wall Evolution
Frame Wall Evolution
Building Science Corporation

Single top plate

2x6 @ 24" o.c.

Taped and painted 1/2" gypsum wall board as interior finish

Blown cellulose insulation in stud space

Insulating sheathing

Furring strips

Cement siding
Recent History
Exterior Insulation Finish Systems
EIFS
Exterior Insulation Finish Systems
EIFS
Barrier System
Face-Sealed Not Water Managed
Life Is Hard Enough As It Is
It’s Harder When You Are Stupid
Don’t Do Stupid Things
Side Trip To Vancouver....
Side Trip To Vancouver….
Vancouver Condo Crisis….
Should Have Put Everyone on Notice
What Happened In Vancouver?
OSB Instead of Plywood
Non Traditional Building Wraps
Interior Vapor Barriers
Increased Thermal Resistance
Portland Cement Instead of Lime
Materials
Inward Drive
Energy
Typical predicted sorption isotherm according to Kelvin equation and modified BET theory
From Straube & Burnett, 2005
Sorption isotherm for several building materials [Kumaran 2002]
From Straube & Burnett, 2005
PERMEABILITY

RELATIVE HUMIDITY

A - Single-layer of absorbed molecules
B - Multiple layers of absorbed molecules
C - Interconnected layers (internal capillary condensation)
D - Free water in pores, capillary suction
E - Supersaturated regime

Relationship between Dry Cup and Wet Cup
Adapted from Joy & Wilson, 1963
Water Vapor Permeance vs. Relative Humidity

- Dry cup limits
- Wet cup limits

$\mu_1$ = Dry cup permeance
$\mu_2$ = Wet cup permeance
Water Vapor Permeance of Sheathing Materials

Water Vapor Permeance, US perms

Mean Relative Humidity, %

Dry Cup

Wet Cup

Plywood

OSB
Rain Screen
Beer Screen?
<table>
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<tr>
<th>Pascals</th>
<th>mph</th>
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<tr>
<td>50 Pa</td>
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<td>65 mph</td>
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<tr>
<td>1,000 Pa</td>
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Wind Speed (mph) vs. Stagnation Pressure (Pa)
Side Trip To Woodbury, MN....
EIFS No Longer Has Issues
Stucco

Expanded polystyrene insulation (EPS)

Concrete masonry unit wall

Metal channel

Gypsum board interior lining

Latex paint
Stucco

Expanded polystyrene insulation (EPS)

Air gap

Water control layer

Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)

Uninsulated steel stud cavity

Gypsum board

Latex paint or vapor semi-permeable textured wall finish
Stucco

Expanded polystyrene insulation (EPS)

Air gap

Water control layer

Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)

Insulated wood stud cavity

Gypsum board

Latex paint or vapor semi-permeable textured wall finish
Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
High density spray polyurethane foam (SPF)
Gypsum board
Latex paint or vapor semi-permeable textured wall finish
Back To Stucco....
Lime vs Portland Cement
Polymer Modification
Traditional Lime Stucco          Greater than 20 perms
Lime/Portland Cement Stucco     5 to 10 perms
Portland Cement Stucco           1 to 5 perms
Polymer Modification             Less than 1
Increasing Permeance

- Scratch Coat
- Brown Coat
- Finish Coat
Horizontal “scoring” provides mechanical bond and “shelf” for water during “wet” curing
Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

Figure 1b. Brick, sintered clay, porosity 40 per cent.
Calculating capillary rise

\[ h = \frac{2 \sigma \cos \theta}{g \rho r} \]

\[ P_{\text{cap}} \]

\[ P_0 \]

\[ \Delta z \]

\[ 2 \sigma \cos \theta \]

\[ r \]

\[ g \rho \Delta z \]

ambient pressure

pressure
Capillary rise versus diameter
Ancient Modification Additives
Cow Dung
Egg Whites
Pig Blood
Non Traditional Building Wraps
Dimensionally unstable hygroscopic wrb's "good"
Side Trip To My Backyard....
Timber frame

Three-coat hard-coat stucco rendering

Two layers of building paper (concealed barrier)

Cavity insulation

Interior gypsum liner

Exterior

Engineered wood sheathing (OSB)

Flashing

Interior
“Lumpy Stucco”....
Should Have Been The Big US Warning....
Back To America…Pennsylvania…
And Then Pretty Much Anywhere It Rains…
Building Science Corporation
Back To Lumpy Stucco....
Easy Solution....
Diagram showing a drainage mat and a WRB (Water Resistance Barrier).
Map of DOE's Proposed Climate Zones

March 24, 2003
Recommendations....
Provide a 3/8 inch air space behind all stucco in regions where it rains more than 20 inches per year
Provide a 3/8 inch air space behind all stucco over three stories
Don’t install interior vapor barriers
Air space can be reduced to 1/16 inch where inward vapor drive is limited
Recommendations....
Barrier works in Florida over block
Barrier does not work in Florida over OSB
Don’t install interior vapor barriers in Florida
Don’t drain a drained system into a barrier system
Exterior Conditions
- Temperature: 80°F
- Relative humidity: 75%
- Vapor pressure: 2.49 kPa

Conditions within Cavity:
- Temperature: 100°F
- Relative humidity: 100%
- Vapor pressure: 6.45 kPa

Interior Conditions
- Temperature: 75°F
- Relative humidity: 60%
- Vapor pressure: 1.82 kPa

Vapor is driven both inward and outward by a high vapor pressure differential between the brick and the interior and the brick and the exterior.
Brick veneer back-ventilated to flush inward-driven moisture out of assembly

Clear 1" air space open at both bottom and top

Seat in foundation acting as flashing
Drainage plane

Impermeable rigid insulation

Drainage space (1/4" or greater)

Seat in foundation acting as flashing
Interior lining - gypsum board with latex paint

Cavity insulation

Gypsum sheathing, plywood, OSB

Water resistance barrier (WRB) - 10 to 20 perms

Vented air space - 1 inch

Brick veneer
Interior lining - gypsum board with latex paint

Cavity insulation

Gypsum sheathing, plywood, OSB

Water resistance barrier (WRB) - 10 to 20 perms

Drainage mat with filter fabric

Vented air space

Stone
Interior lining - gypsum board with latex paint

Cavity insulation

Gypsum sheathing, plywood, OSB

Water resistance barrier (WLB) - 10 to 20 perms

Drainage mat with filter fabric (or building paper over drainage mat)

Vented air space

Stucco with paint - paint layer greater than 10 perms
Water Vapor Permeance of WRB’s

- Felt
- ASK
- High Perm Plastic WRB
- Low Perm Plastic WRB

Permeance "Sweet Spot"

Mean Relative Humidity, %

Dry Cup

Wet Cup