Building for Sustainability
AIHA Conference & Exposition
Philadelphia, PA
June 5, 2007
PO 114 – Engineering & Control Technology

Roger G. Morse AIA
Morse Zehnter Associates
Rensselaer Technology Park
165 Jordan Road
Troy, New York 12180
rgmorse@mzaconsulting.com
Sustainable Design

• Recyclable Materials
• Highly Insulated
• Lightweight
• Tight – low air leakage
• Relies on modern materials
  – Membranes
  – High Performance Sealants (Caulk)
Typical Sustainable Construction

- Masonry
- Drainage Space
- Membrane Air Barrier
- Flashing
- Weep Hole
- Steel Studs
- Insulation
- Gypsum Sheathing
- Vapor Retarder
- Drywall
Wall Construction

1800s
- 1st PLASTER
- 1/2" BRICK BACKUP
- 8" MASS STONE

1930s
- 1st PLASTER
- 8" BRICK BACKUP
- 8" STONE

Present
- 1 13/16" STONE VENEER
- 1 1/2" AIR SPACE
- 1/2" GYPSUM SHEATHING
- 3 1/2" METAL STUDS & FIBERGLASS INSULATION
- 1/2" GYPSUM BOARD
Modern Walls More Mold Susceptible

- Lighter construction – less mass to store water
- Materials with less water storage capacity
- Highly Insulated – Increase vapor drive across wall
- More organic materials
- Improper use of vapor retarders
## Water Storage Per Square Foot of Wall

<table>
<thead>
<tr>
<th>Era</th>
<th>Type and Material</th>
<th>Water Storage #/sq. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800s</td>
<td>Stone and Brick Bearing Wall</td>
<td>3.5</td>
</tr>
<tr>
<td>1930s</td>
<td>Brick and Block Curtain Wall</td>
<td>2.1</td>
</tr>
<tr>
<td>Present</td>
<td>Brick and Insulated Metal Studs</td>
<td>0.5</td>
</tr>
</tbody>
</table>
# Water Vapor Condensation

<table>
<thead>
<tr>
<th></th>
<th>Stored Water</th>
<th>Max Relative. Humidity</th>
<th>Location of Damp Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone and Brick Bearing Wall</td>
<td>1.63 lbs/ft³</td>
<td>65%</td>
<td>None</td>
</tr>
<tr>
<td>Brick and Block Curtain Wall</td>
<td>1.63 lbs/ft³</td>
<td>67%</td>
<td>None</td>
</tr>
<tr>
<td>Brick and Insulated Metal Studs</td>
<td>0.39 lbs/ft³</td>
<td>&gt;95%</td>
<td>At face of sheathing</td>
</tr>
</tbody>
</table>

Results of Year Long Simulation by WUFI Pro 3.3  
Albany, New York
Modern and Recycled Materials
More Mold Susceptible

• Organic
• Biodegradable
• More Absorbent
SEM of Softwood
White Pine

Cross

Radial
Plywood
OSB
Particleboard (MDF)
Particleboard at 40X
Particleboard Affected by Water
Paper Structure
Taping Compound Less Porous
Mold – Requirements for Growth

[Diagram showing temperature scale and mold growth on a surface with labels for nutrient and moisture content]
Mold Nutrient Sources

- Wood
- Plywood
- Oriented Strand Board
- Particle Board
- Paper products, Paper on gypsum panels used for drywall, facing for insulation, wall coverings, etc.
- Resins and adhesives. Glue such as wallpaper paste
- Oily surfaces
Organic Materials
Moisture and Mold Growth

- EQUILIBRIUM RELATIVE HUMIDITY (ERH)
- WATER ACTIVITY (Aw)
- SUBSTRATE
- MOISTURE CONTENT (MC)

Drawing 04
Mold Germination and Growth Rates

Figure 01
WUFI Presentation "2003 - Sep. -25
Clemson - Mould" Used with Permission.
Moisture Balance
Water Enters Building Components

- Liquid Water
- Air Infiltration
- Water Vapor Diffusion
Moisture Uptake Exceeds Drying
Drying

• Liquid Water Removed by Flashing
• Water Vapor Transport Out of Assemblies
• Evaporation
Water Storage Capacity Depends on Density of Material

DENSE MATERIALS CAN STORE A LIMITED AMOUNT OF WATER BEFORE BECOMING WET.

MORE POROUS MATERIALS CAN STORE MORE WATER BEFORE BECOMING WET ENOUGH TO SUPPORT MICROBIO GROWTH.
## Water Storage of Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Water Stored at 70% Relative Humidity (pounds/cubic foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (B45)</td>
<td>4.32</td>
</tr>
<tr>
<td>Concrete Block (Pumice aggregate)</td>
<td>0.96</td>
</tr>
<tr>
<td>Fiber Glass</td>
<td>0.00</td>
</tr>
<tr>
<td>Gypsum Board</td>
<td>0.38</td>
</tr>
<tr>
<td>Gypsum Plaster</td>
<td>0.09</td>
</tr>
<tr>
<td>Softwood</td>
<td>3.16</td>
</tr>
<tr>
<td>Solid Brick Masonry</td>
<td>0.61</td>
</tr>
<tr>
<td>Steel Studs</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Water Entry Into Walls

- Leaks
- Capillary Action
- Wetting (surface tension)
- Air Infiltration
- Water Vapor
Water Flow – Walls

• Water generally flows downhill
• Water can flow sideways or even up if it wets a surface
• Water can wick upward in cracks due to capillarity action
• Wind blown rain can flow upward
Wall Must
Keep Water Out

• Weather barrier (Rain Screen)
• Drainage Space
• Drainage Plane
• Flashing carries water from drainage plane out to surface of weather barrier
Wall Components
Moisture Management

• Weather Barrier or Screen – keeps out rain and weather
• Drainage Space
• Drainage Plane
• Air Barrier – stops the free transfer of air
• Vapor Barrier or Retarder – stops or retards water vapor transmission
Paint over 5/8-inch Gypsum Board
6-Inch Foil-Faced Batt Insulation Inside Metal Studs (foil facing toward the outside)
1/2-inch Gypsum Board Sheathing

**Weather Barrier**  
(4-Inch Face Brick)

**Air Barrier**  
1 Layer 30-lb Building Felt Paper

**Vapor Barrier**

2-Inch Cavity Air Space

Water Vapor

Flashing

Weep Hole

**BRICK CAVITY WALL - WITH VAPOR RETARDER**
Weather Barrier

• Stops rain and other precipitation
• Stops leaks into building (flashing)
• Stops capillary action into building
• Allows air to pass
• Allows water vapor to pass
General Principles

• Caulk will always fail
• Consider the ends of a weatherproofing detail, not just the middle
• Look at the transition points
• Look at the corners
• Weatherproofing elements are not infinitely long – consider the joints
BAD EIFS DETAIL

- Batt Insulation Saturated
- Gypsum Board Saturated
- Water Saturated
- Gypsum Sheathing Wetted
- EIFS System
- No Slope
Sill Flashing
Vapor Barrier/Retarder

- Impeded the passage of water vapor through the wall
- Should always be located on warm humid side of wall
- Can create more problems than they solve
Vapor Diffusion

High Rate of Diffusion

Outside
90°Fdb
90% RH
(1.27 in. Hg)

Inside
70°Fdb
50% RH
(0.37 in. Hg)

Low Rate of Diffusion

Outside
72°Fdb
70% RH
(0.60 in. Hg)

Inside
70°Fdb
50% RH
(0.37 in. Hg)
Permeance of Building Materials

- BUR Hot Mopped
- Brick Masonry 4"
- Concrete 12"
- Concrete Block 8"
- Plaster 3/4"
- Gypsum Board 3/8"
- Gypsum Sheathing 1/2"
- Plywood (exterior glue) 1/2"
- Plywood (interior glue) 1/2"

Vapor Retarders < 1 perm

Permeance $^2$ (perm: gr/h-ft$^2$-in. Hg)
First Plane of Condensation

• Location in wall assembly where infiltrating air or water vapor as a gas first contacts a surface chilled below the dew point.
• Moisture will condense inside a wall at the first plane of condensation
• Should be outside wall cavity or in area that drains or breathes to allow drying
Hygrothermal Modeling

- Rules of Thumb for placement of vapor retarders are unreliable
- Hygrothermal Modeling Software
- \textit{WUFI-ORNL/IBP Hygrothermal Model for Architects and Engineers}. Dr. Achilles N. Karagiozis, A. Oak Ridge National Laboratory, Kuenzel, H. Fraunhofer Institute fur Bauphysik, Holzkirchen, Germany
- \texttt{http://www.ornl.gov/sci/btc/apps/moisture/}
Air Barrier

• Resists air flow
• Resist 50% or more of air pressure
• Completely enclose air in building
• Continuity is key
Air Barrier Materials

- Gypsum board
- Exterior Sheathing - Plywood, OSB
- Exterior housewraps
- Membranes
- Bitumen or rubber on masonry
Air Infiltration vs. Vapor Diffusion

NEW YORK

EXTERIOR
42.2°F 75% RH

INTERIOR
68°F 50% RH

WATER VAPOR DIFFUSION

1" SQUARE HOLE

# OF GRAINS /HR

10,000 1,000 100 10 1 0.1

AIR INFILTRATION
Air Infiltration vs. Vapor Diffusion

- Air Infiltration
- Exterior 91°F 56% RH
- Water Vapor Diffusion
- 1" Square Hole
- Florida
- Interior 70°F 50% RH
- # of Grains / HR
Air Infiltration vs. Vapor Diffusion

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameter</th>
<th>Temperature Exterior (F)</th>
<th>Relative Humidity Exterior</th>
<th>Moisture Transport Rate (grains/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>Infiltration</td>
<td>42.2</td>
<td>75</td>
<td>1140</td>
</tr>
<tr>
<td></td>
<td>Diffusion</td>
<td>42.2</td>
<td>75</td>
<td>0.1602</td>
</tr>
<tr>
<td>Florida</td>
<td>Infiltration</td>
<td>91</td>
<td>56</td>
<td>3858</td>
</tr>
<tr>
<td></td>
<td>Diffusion</td>
<td>91</td>
<td>56</td>
<td>0.5028</td>
</tr>
</tbody>
</table>

Moisture Transport Rate calculated in accordance with ASHRAE 2001 Fundamentals Handbook
Wind Creates Pressure Differentials
Wind Speed Increases with Height
Stack Effect – Warm Climate

STACK EFFECT - HOT CLIMATE

Figure 11
Stack Effect – Cold Climate
Air Leakage Pathways

Diffusion
Positive Pressure
Membrane and Sheathing Acting as Air Barrier
Wind
Unsealed Hose Bib Penetration Through Air Barrier

Air Leakage Into Building
Orifice Leakage

Lower Pressure
Electrical Outlet

Drawing 12
Air Leakage Through Wall
Forgiving Wall System (North)
Exterior Siding
Vapor Retarder and Air Barrier
Exterior Sheathing
Insulation
Interior GWB
Interior Permeable Finish (paint)

Dry to Inside

Degree of Air Tightness
High
Low

Degree of Vapor Resistance
High
Low

Forgiving Wall System
(South)
Concrete Block

Weather Barrier &
Air Barrier
(Stucco)

Water Vapor

Concrete Block

Plaster

OLD SOUTHERN CONSTRUCTION
For More Information

- Whole Building Design Guide
- Building Envelope Design Guide
- http://www.wbdg.org/design/envelope.php
Building for Sustainability

Roger G. Morse AIA
Morse Zehnter Associates
Rensselaer Technology Park
165 Jordan Road
Troy, New York 12180
rgmorse@mzaconsulting.com