High Performance Wood Framed Wall Systems for Passive House Design

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CertainTeed Corporation

Session Learning Objectives:
• Understand low-energy building design goals
• Understand how to assess moisture risk in low-energy wall designs
• Review the four moisture flow mechanisms
• Identify the critical components in constructing low-energy walls
• Understand the concept of hygrothermal analysis
Low-Energy Building Design Goals

- Control Heat and Air flow
  - Control heat transfer & air leakage:
    - Increase thermal insulation levels & reduce thermal bridging
    - Integrate continuous air barrier systems & space compartmentalization
    - Specify high performance fenestration systems

- Space improvements
  - Improve indoor environmental quality (IEQ):
    - Specify high performance HVAC systems that include insulated & air tight ductwork
    - Require controlled & pre-conditioned fresh air ventilation
    - Integrate materials that improve indoor air quality (low emitting, VOC capturing, moisture & mold resistance, etc...)

- Energy reduction
  - Reduce solar loads, energy dependence and electricity use:
    - Integrate passive solar design techniques and technologies
    - Improve visual comfort through by increasing natural light
    - Specify renewable energy resources
    - Require energy efficient equipment, appliances and lighting
Traditional Residential Wall Assembly

- Cladding type
- Water resistive barrier
- Air barrier
- Exterior sheathing
- Frame type
- Cavity insulation
- Interior vapor retarder
- Interior gypsum board
- Interior finish

Moisture Balance Risk Analysis for Low-Energy Wall Designs

<table>
<thead>
<tr>
<th>Less Risk</th>
<th>More Risk</th>
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<tbody>
<tr>
<td>Dry</td>
<td>Climate</td>
</tr>
<tr>
<td>Less</td>
<td>Insulation</td>
</tr>
<tr>
<td>Less</td>
<td>Air Tightness</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Vapor Control</td>
</tr>
<tr>
<td>Drain &amp; Vent</td>
<td>Cladding Design</td>
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<tr>
<td>Non-Absorptive</td>
<td>Cladding</td>
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<tr>
<td>Non-Absorptive</td>
<td>Substrate</td>
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</table>

Original concept presented by Mark Williams with Williams Building Diagnostics, Ltd
Continental US Climate Zone Descriptions with 2012 IECC Climate Zone Designations

- Marine 4C
- Pacific NW
- Cold & Dry 5B, 6B
- Cold & Humid 5A, 6A
- Mixed & Humid 3A, 4A
- Hot & Humid 1A, 2A, 3A
- Extreme Cold & Humid 7A
- Extreme Cold & Dry 7B

Original concept was developed through funding by the US Dept. of Energy’s Building America Program

Gravity Flow Protection

- Gravity moves rainwater down the exterior surfaces of buildings and water enters through sloped openings
- Use shingles and flashings to protect buildings
- Overlap joints in shingle fashion
- Avoid reversed laps
- Use drainage holes along horizontal and sloped surfaces
- Protect vertical joints with sealants, gaskets, covers, etc.
Block & Manage Rainwater

- Cladding’s primary purpose is to block rainwater
- Use water resistant barriers (WRBs) as drainage planes behind exterior claddings
- Provide a drainage space between claddings & WRBs
- Ventilated air spaces increase drying potential of wall assembly
- Weep holes required to allow water to drain away from system

Break Capillary Flow of Moisture

- Capillary suction, caused by water surface tension, draws water into porous material and tiny cracks
- Create capillary breaks to protect building materials from absorbing moisture
Wall System Type Defines Moisture Control Strategy

Moisture Storage Properties of Common Exterior Building Materials

Sorption Isotherms of Wall Materials

Source: Oak Ridge National Laboratory (Wilkes)
Moisture is Largest Indoor Air Contaminant!

Vapor Diffusion

4 x 8 Sheet of Gypsum Board
1/3 Quart

Air Transport

1 in² Hole
30 Quarts

100X More Moisture by Air Transport than by Diffusion

2012 IECC Air Sealing Requirements

- All joints, seams and penetrations
- Site-built windows, doors and skylights
- Openings between windows and doors
- Utility penetrations
- Dropped ceilings or chases
- Knee walls
- Walls and ceilings separating a garage from conditioned spaces
- Behind tubs and showers on exterior walls
- Common walls between dwelling units
- Attic access openings
- Rim joist junction
- Other sources of infiltration
- Specific requirements for fireplaces, fenestrations & recessed lighting
Water Vapor will move from areas of high vapor pressure to areas of low vapor pressure through building materials

ASTM E 96 Water Vapor Diffusion Testing

- Test method for determining the water vapor permeance of building materials
- Building codes evaluate materials using the standard dry cup method, aka Method A or the Desiccant Method
- Some exterior building materials are evaluated using the standard wet cup method, aka Method B or the Water Method
Water Vapor Permeance of Common Exterior Wall Materials

Source: Oak Ridge National Laboratory (Wilkes)

Water Vapor Permeance of Common Interior Wall Materials
## Vapor Retarder Categories

Traditionally vapor retarders are defined by building codes as having a standard dry cup water vapor permeance of 1 perm or less.

<table>
<thead>
<tr>
<th>Vapor Barrier (Class I)</th>
<th>Vapor Retarder (Class II)</th>
<th>Semi-permeable (Class III)</th>
<th>Permeable</th>
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<tbody>
<tr>
<td>Perm</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
<td>10</td>
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<td></td>
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- **6 mil Polyethylene (0.05 - 0.06)**
- **Latex Primed and Painted Gypsum Bd. – 1 & 2 Coats (3 - 35)**
- **Asphalt Coated Kraft Paper (0.3 - 3)**
- **Latex Primed Gypsum Board - 1 Coat (22 - 66)**
- **2 mil polyamide film (0.8 - 36)**
- **Plain Gypsum Board (45 - 85)**

## Vapor Retarder Requirements

- Vapor retarder should be placed at the interior.
- Avoid low permeance vapor retarders, such as polyethylene film or aluminum foil in:
  - Climates with high summer moisture loads
  - Walls with moisture storage claddings
  - Walls with low permeability exterior sheathings
- IECC requires Class I or II vapor retarder in Climate Zones 4C, 5, 6, 7 and 8
- SVR works in all North American climate zones.
Survey of Certified 30+ PHIUS Projects
Wall Assembly Details

Certified PHIUS Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Project n.</th>
<th>Status</th>
<th>Lead CPNC</th>
<th>Location</th>
<th>Constr. type</th>
<th>Bulky, function Floor area</th>
<th>Project type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1006</td>
<td>1222 State Street</td>
<td>Pre-cert</td>
<td>Christopher Gonzales</td>
<td>Billings, MT</td>
<td>Single Family</td>
<td>1,400 sq ft</td>
<td>New Construction</td>
</tr>
<tr>
<td>1005</td>
<td>1202 Lemon</td>
<td>Certified</td>
<td>Katy Hollis</td>
<td>Merriam, KS</td>
<td>Single Family</td>
<td>2,300 sq ft</td>
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<td>1025</td>
<td>Eason Residence</td>
<td>Certified</td>
<td>Paul H. Parish</td>
<td>Sherwood, WA</td>
<td>Single Family</td>
<td>3,166 sq ft</td>
<td>New Construction</td>
</tr>
<tr>
<td>1004</td>
<td>Chancellor’s Bend</td>
<td>Certified</td>
<td>John Eng</td>
<td>Warren, OH</td>
<td>Single Family</td>
<td>3,159 sq ft</td>
<td>New Construction</td>
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<tr>
<td>1016</td>
<td>Breckenridge House</td>
<td>Certified</td>
<td>David Brain</td>
<td>Salt Lake City, UT</td>
<td>Single Family</td>
<td>2,770 sq ft</td>
<td>New Construction</td>
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<tr>
<td>1009</td>
<td>Center for Design Research (CDR)</td>
<td>Pre-cert</td>
<td>Ryan Abandish</td>
<td>Lawrence, KS</td>
<td>Government</td>
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<td>New Construction</td>
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<tr>
<td>1015</td>
<td>Center for Energy Efficient Design (CEED)</td>
<td>Certified</td>
<td>Adam Cohen</td>
<td>Rocky Mount, UT</td>
<td>School</td>
<td>3,822 sq ft</td>
<td>New Construction</td>
</tr>
</tbody>
</table>

Low-Energy Wall Design Strategies

- Framing
- Interior & exterior sheathing
- Insulation
- Bulk water, air and water vapor flow resistance
- Cladding type & attachment methods
**Wood Framing Design Strategies**

- **Single stud**
  - 2 x 6 to 2 x 8 stud
  - 12” to 16” TJI joists
- **Double stud**
  - 2 x 4 plus 2 x 6
  - 2 x 4 plus 12” to 14” TJI joist
- **Standard stud framing** thermally improved with 2” to 6” insulation board

**Interior & Exterior Sheathing Design Strategies**

- **Exterior**
  - Fiberboard
  - OSB
- **Interior**
  - Gypsum
  - OSB
  - Structural Insulation Panels (SIPS)
**Insulation Design Strategies**

- High density fiberglass batts
- Blown in blanket systems using loose fiberglass
- Dense packed dry cellulose with exterior insulation
- Hybrid insulation systems that include 2” closed cell spray polyurethane foam at the exterior sheathing
- 2” to 6” thick exterior insulation board (PISO or XPS)

**Water and Air Flow Resistance Design Strategies**

- Water resistive barriers
  - House wraps
  - Multi-functional OSB sheathing boards
  - Multi-functional coatings
- Air barrier systems
  - Sealed sheathings
  - Interior films
  - Multifunctional coatings
- Detail is critical at:
  - Penetrations & seams
  - Large rough openings
  - Material transitions
  - Framing intersections
Cladding Design Strategies

<table>
<thead>
<tr>
<th>Material type</th>
<th>Attachment methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorptive</td>
<td>Drainage</td>
</tr>
<tr>
<td>Non-absorptive</td>
<td>Ventilation</td>
</tr>
</tbody>
</table>

Photograph courtesy of K. Klingenberg

Hygrothermal Analysis Examples
Hygrothermal Analysis of Building Envelopes

- Hygrothermal analysis predicts the impact of transient heat and moisture transfer on building envelopes over time.
- Used on planned construction projects and existing buildings with moisture problems.
- Specialized software helps the user visualize:
  - Surface condensation and mold growth potential.
  - Wetting and drying potential of the building envelope.
  - Moisture content of building components.
- Helps building designers evaluate potential pre-construction moisture risks.
- Post-construction, helps analyze and solve moisture problems.

Passive House Wall Construction

- 9 ¼" Thick R39
- 3 ½" thick R13
- Fiber Cement Siding
- 1" Air Space
- SBPO Building Wrap
- ½" OSB
- ½" Gypsum Bd
Cold Climate – Indianapolis, IN

Sheathing Moisture Content Comparison

Exterior Sheathing Moisture Content

Date (m/d/y)

Moisture Content (%)
Surface Relative Humidity Comparison

Surface Relative Humidity Comparison
Backside of Exterior Sheathing

Date (m/d/y)

Passive House Wall Design
Pittsburgh, PA

- Cladding
  - Fiber cement
  - Mounted on furring
- Double stud wall with 10" TJI and 2 x 4 studs
- OSB exterior sheathing
- Gypsum interior sheathing
  - 1" XPS or high-density fiberglass board, air tight stud separator (with and without water vapor control)
- WRB
  - Spun bonded polyolefin
  - Air tight install
Passive House Wall Design
% Moisture Content (MC) Comparison

No Interior Vapor Control
Max. MC after 36 months ~23%

With Interior Vapor Control
Max. MC after 36 months ~15%

Passive House Wall Design - Indianapolis, IN
Paint Only vs. SVR as Vapor Control Layer

- Cladding
  - Fiber cement
  - Mounted on furring
- Single 16” TJI stud
- Sheathing (air tight)
  - Fiberboard exterior
  - Gypsum interior
- WRB
  - Spun bonded polyolefin
  - Air tight install
Passive House Wall Design
% Moisture Content Comparison

No Interior Vapor Control
Max MC after 36 months ~17%

Smart Vapor Retarder
Max MC after 36 months ~12%

Good Low-Energy Wall Information

Summary & Discussion

- Know the climate & microclimate
- Orientation makes a difference
- Building envelope air tightness is critical
- Successful integration of water resistive and air barrier systems are critical
- Use cladding ventilation and drainage strategies to enhance drying to the outside
- Use dynamic vapor control layers with smart, hygroscopic material properties
- Use hygrothermal analysis to predict and/or check performance

Question & Answer Session

Thank you for your attention!