Building with Exterior Rigid Foam

Tuesday, December 13, 2011  1:00PM

Presented by: Mike Turns, Associate Director, PHRC

www.engr.psu.edu/phrc

Three types of rigid foam

- **Expanded polystyrene (EPS)**
  - Insulfoam
  - R-Tech
  - Benchmark Foam

- **Extruded polystyrene (XPS)**
  - STYROFOAM
  - FOAMULAR
  - GreenGuard
  - CodeBord/Celfort 200

- **Polyisocyanurate (ISO)**
  - Thermax
  - Tuff-R
  - RMax
Expanded Polystyrene (EPS)

- **Common uses**
  - Insulated concrete forms
  - SIPs
  - Sheathing

- **Typical thermal resistance:** R-4 per inch

- **Vapor permeability:** 5 perms (Class III vapor retarder)

- **Durability**
  - Avoid prolonged exposure to UV
  - Requires careful cutting and handling (edges can break off)

Note: Vapor permeability varies with material thickness. Values listed are based on 1 inch.

---

Extruded Polystyrene

- **Common uses**
  - Sheathing
  - Under-slab insulation

- **Typical thermal resistance:** R-5 per inch

- **Vapor permeability:** 1.1 perms (Class III vapor retarder)

- **Durability:**
  - Avoid prolonged exposure to UV
  - Matrix is stronger than EPS beads

Note: Vapor permeability varies with material thickness. Values listed are based on 1 inch.
Polyisocyanurate (ISO)

- **Common uses**
  - Sheathing

- **Typical thermal resistance:** R-6.5 per inch

- **Vapor permeability:**
  - <1.0 perms with fiberglass facing (Class II vapor retarder)
  - 0.03 perms with foil facing (Class 1 vapor retarder)

- **Durability:**
  - Facing can be more resistant to UV
  - Matrix is stronger than EPS beads

Note: Vapor permeability varies with material thickness. Values listed are based on 1 inch.

Summary of Insulation Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Fire – Must be covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS</td>
<td>Yes</td>
</tr>
<tr>
<td>XPS</td>
<td>Yes</td>
</tr>
<tr>
<td>ISO</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Unless tested and issued a specific approval
Foam and energy efficiency
Thermal Bridging

Simple R-value
Through Studspace

Clear Wall R-value

Window Opening

Corner

~25% of a typical wall is wood

This is the wood framing that makes up more than 25% of wall area, which is then uninsulated.
### Whole Wall R-Value

#### 2x6 wall @ 16” o.c.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cavity R-value</th>
<th>Frame R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside air film</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Lap siding</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>7/16” OSB</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Batt insulation</td>
<td>21</td>
<td>--</td>
</tr>
<tr>
<td>2x6 stud</td>
<td>--</td>
<td>5.44</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Inside air film</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total R-values</strong></td>
<td><strong>23.81</strong></td>
<td><strong>8.16</strong></td>
</tr>
<tr>
<td><strong>Total U-factor</strong></td>
<td><strong>0.0420</strong></td>
<td><strong>0.1225</strong></td>
</tr>
</tbody>
</table>

\[ U_{overall} = (0.0420 \times 0.75) + (0.1225 \times 0.25) = 0.0621 \]

\[ R_{overall} = \frac{1}{0.0621} = 16.1 \]

#### 2x4 wall @ 16” o.c. + foam

<table>
<thead>
<tr>
<th>Component</th>
<th>Cavity R-value</th>
<th>Frame R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside air film</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Lap siding</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>7/16” OSB</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Batt insulation</td>
<td>13</td>
<td>--</td>
</tr>
<tr>
<td>Rigid foam</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2x6 stud</td>
<td>--</td>
<td>5.44</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Inside air film</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total R-values</strong></td>
<td><strong>20.81</strong></td>
<td><strong>13.23</strong></td>
</tr>
<tr>
<td><strong>Total U-factor</strong></td>
<td><strong>0.0481</strong></td>
<td><strong>0.0756</strong></td>
</tr>
</tbody>
</table>

\[ U_{overall} = (0.0481 \times 0.75) + (0.0756 \times 0.25) = 0.0550 \]

\[ R_{overall} = \frac{1}{0.0550} = 18.2 \]
Mitigating moisture risks

Temp gradient insulated wall

Note that with insulation the temperature in the stud bay falls below freezing.

We should be concerned with condensation and in some cases freezing.
Temp gradient insulated wall

Inside Condition
70 °F

Outside Condition
10 °F

Thicker Framed Walls

R-40 wall

Source: IBACOS, Best Building Practices Research Alliance, Building America Project
Minimizing Condensation Risk
R-values required for Class III vapor retarder (latex or enamel paint):

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Minimum R-Value of Foam Sheathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine 4</td>
<td>R-2.5 for 2x4 walls; R-3.75 for 2x6 walls</td>
</tr>
<tr>
<td>5</td>
<td>R-5 for 2x4 walls; R-7.5 for 2x6 walls</td>
</tr>
<tr>
<td>6</td>
<td>R-7.5 for 2x4 walls; R-11.25 for 2x6 walls</td>
</tr>
</tbody>
</table>

Drying to the Inside

- Foam sheathing reduces ability of wall to dry to outside
- Moisture must be allowed to dry to the inside
- No poly vapor retarders
- No vinyl wallpaper
Foam and water-resistant barriers

Water-Resistant Barrier Strategy 1

WSP + WRB + foam
- Most durable
  - WRB is supported by WSP
  - WRB is protected by foam
- Recommended for areas with:
  - High exposure
  - High rainfall
- Best for “innie” windows
Water-Resistive Barrier Strategy 2

**WSP + foam + WRB**
- Best for “outie” windows
- More exposure to the elements
- Longer fasteners required for housewrap

Water-Resistive Barrier Strategy 3

**WRB under foam**
- No structural sheathing
- Housewrap stretched across studs
- WRB is protected by foam
- Take care installing WRB
- Best for “innie” windows
Water-Resistive Barrier Strategy 4

**WRB over foam**
- No structural sheathing
- More exposure to the elements
- Best for “outie” windows

Water-Resistive Barrier Strategy 5

**Foam as WRB**
- Check ES Report
- Tape all seams
- Carefully detail flashing at openings
Inset Window Exterior Jamb Details

Courtesy of the Cold Climate Housing Research Center

Inset Windows

Azek Stucco Steel

Courtesy of the Cold Climate Housing Research Center
Innie Window Sill Detail

Innie Window Head Detail

Source: www.greenbuildingadvisor.com
Innie Window Sill Detail

- Head trim sloped 5°, sill sloped 15°
- Triple-pane vinyl window
- Peel-and-stick membrane on sloped blocking
- Nailing flange, not set in sealant. Lap flange with peel-and-stick.
- Barrier membrane

Source: Journal of Light Construction

Innie Window Head Detail

- Window installed flush with sheathing
- Peel-and-stick membrane
- Head trim (not caulked to head extension)
- 3/4" PVC trim jamb extension,
- Nailing flange, set in sealant at head and jamb. Lap flange with peel-and-stick.
- Backer rod and expanding foam

Source: Journal of Light Construction
Outie Windows

Outies – Window Bucks

Courtesy of the Cold Climate Housing Research Center
Outie Window Sill Detail

Outie Window Head Detail

Source: www.greenbuildingadvisor.com
Outie Window Sill Detail

Outie Window Head Detail

Source: Journal of Light Construction
Wall bracing and wind resistance

Let-in-bracing

<table>
<thead>
<tr>
<th>METHOD</th>
<th>MATERIAL</th>
<th>MINIMUM THICKNESS</th>
<th>FIGURE</th>
<th>CONNECTION CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIB</td>
<td>Let-in-bracing</td>
<td>1 x 4 wood or approved metal strips at 45° to 60° angles for maximum 14&quot; stud spacing</td>
<td>Wood: 2-8d nails per stud including top and bottom plate metal: per manufacturer</td>
<td></td>
</tr>
<tr>
<td>DWB</td>
<td>Diagonal wood boards</td>
<td>1/4&quot; (1&quot; nominal) for maximum 24&quot; stud spacing</td>
<td>2-8d (2&quot; x 0.1&quot;) nails or 2 staples, 1/2&quot; per stud</td>
<td></td>
</tr>
<tr>
<td>WSP</td>
<td>Wood structural panel (see Section R604)</td>
<td>3/8&quot;</td>
<td>For exterior sheathing, see Table R602.2(2) For interior sheathing see Table R602.3(1)</td>
<td></td>
</tr>
</tbody>
</table>
3.1.3.3 WB and WBC Wall Bracing: The WB and WBC wall braces are fabricated from 1 1/4 inch-wide (31.7 mm) No. 16 gage galvanized steel with a series of precut nail holes used to fasten the metal braces to the wood wall studs spaced either 16 or 24 inches (406 or 610 mm) on center. The WB and WBC wall braces resist tension loads only. Consequently, these wall braces must be installed in pairs to resist in-plane racking shear loads applied to the top of the wall. The WBC wall bracing is similar to the WB wall bracing except that it packaged in a coil, and the coil has V-shaped notches indicating where to cut the steel strap for use as wood wall bracing. See Table 5 for the WB and WBC models recognized in this report, brace lengths, wall heights and brace angles measured from the horizontal (8 feet (2438 mm) at 45 degrees and 60 degrees, and 10 feet (3048 mm) at 45 degrees), and the fastener schedule. See Figure 5a for a drawing of the WB brace, Figure 5b for the WBC brace, and Figure 5c for wall braces installed X-pairs or in opposing V-pairs.

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>STRAP LENGTH (feet - inches)</th>
<th>WALL HEIGHT (feet)</th>
<th>REQUIRED INSTALLATION ANGLE OF THE WB AND WBC BRACES FROM THE HORIZONTAL</th>
<th>FASTENERS (Quantity Type)</th>
<th>Top and Bottom Plates</th>
<th>Each Stud</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB106</td>
<td>9 - 5/16&quot;</td>
<td>8</td>
<td>60°</td>
<td></td>
<td>2 - 18d</td>
<td>1 - 8d</td>
</tr>
<tr>
<td>WB126</td>
<td>11 1/2 - 21/2&quot;</td>
<td>8</td>
<td>45°</td>
<td></td>
<td>2 - 18d</td>
<td>1 - 8d</td>
</tr>
<tr>
<td>WB10IC</td>
<td>9 - 5/16&quot;</td>
<td>8</td>
<td>60°</td>
<td></td>
<td>2 - 18d</td>
<td>1 - 8d</td>
</tr>
<tr>
<td>WB14IC</td>
<td>11 1/2 - 21/2&quot;</td>
<td>8</td>
<td>45°</td>
<td></td>
<td>2 - 18d</td>
<td>1 - 8d</td>
</tr>
<tr>
<td>WB14DC</td>
<td>14 - 3&quot;</td>
<td>10</td>
<td>45°</td>
<td></td>
<td>2 - 18d</td>
<td>1 - 8d</td>
</tr>
</tbody>
</table>

For Bi: 1 inch = 25.4 mm, 1 lbs = 4.45 N.

1The WB and WBC wall bracing straps can be used as alternates only to the code prescribed braced wall panel construction identified as a nominal 1x6 diagonal wood brace let into studs. The WB and WBC wall bracing straps are not recognized to replace or be used as alternates to other braced wall construction methods described in the code.

2The WB and WBC resist tension loads only. Consequently, the WB and WBC straps must be installed in pairs, as shown in Figure 5c. The allowable in-plane racking shear load of a wall braced with the WB strap installed in "X" pairs or in opposing "V" fashion is 160 lbs, and must not be combined with other shear resisting elements or components. This allowable racking shear load must not be increased for short term loading. Summing shear capacities of the WB or WBC wall braces with dissimilar materials applied to either side of the same wall is not allowed.

3The wall studs may be spaced 16 inches on center or 24 inches on center.

4The WB and WBC wall bracing straps must be installed at the installation angle specified in the table.

---

Figure 5a—WB Wall Brace Strap

---

BREAK OFF WB AT PREDETERMINED LENGTH

Figure 5b—WBC Wall Brace Strap
Horizontal wall distance required for let-in braces

Intermittent Wood Structural Panels

<table>
<thead>
<tr>
<th>METHOD</th>
<th>MATERIAL</th>
<th>MINIMUM THICKNESS</th>
<th>FIGURE</th>
<th>CONNECTION CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIB</td>
<td>Let-in-bracing</td>
<td>1 × 4 wood or approved metal strips at 45° to 60° angles for maximum 16&quot; stud spacing</td>
<td><img src="image" alt="Diagram" /></td>
<td>Wood: 2-8d nails per stud including top and bottom plate metal per manufacturer</td>
</tr>
<tr>
<td>DWB</td>
<td>Diagonal wood boards</td>
<td>1/4&quot; (1&quot; nominal) for maximum 24&quot; stud spacing</td>
<td><img src="image" alt="Diagram" /></td>
<td>2-8d (2&quot;) or (0.115&quot;) nails or 2 staples, 1/4&quot; per stud</td>
</tr>
<tr>
<td>WSP</td>
<td>Wood structural panel (see Section R604)</td>
<td>3/8&quot;</td>
<td><img src="image" alt="Diagram" /></td>
<td>For exterior sheathing see Table R602.30.3 For interior sheathing see Table R602.3.1</td>
</tr>
</tbody>
</table>
Intermittent Wood Structural Panels

- IECC Table 402.1.1 – Footnote h
  - R-13 + 5 means R-13 cavity insulation plus R-5 insulated sheathing
  - If structural sheathing covers 25% or less of the exterior, insulating sheathing is not required where structural sheathing is used
  - If structural sheathing covers more than 25% of the exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2

Structural Insulated Sheathing

**Dow SIS**
- R-3 @ 0.5”
- R-5 @ 1.0”

**Huber Zip R-Sheathing**
- Launched Sept. in PA
- R-3.6 @ 1”
- R-6.6 @ 1.5”

**Both:**
- Structural sheathing
- Water resistive barrier
- Use compatible tape
- Follow MII for nailing
Wind Resistance

- For Wind Resistance (when used in place of structural sheathing)
  - Foam thick enough to achieve R-5 is generally OK for 90 mph, exposure B
    - 1" XPS
    - ~3/4" Polyiso
    - 1.5" EPS

Attachment of Foam to Framing
Fastening
Follow Manufacturer’s Instructions

- Use 1” diameter plastic cap nails, 3/8” head roofing nails, or staples with a minimum ¾” crown
- All fasteners should be long enough to penetrate wood studs at least ¾”
- Secure the boards 12” o.c. around the perimeter and 16” o.c. in the field

Foam as a WRB

- Check product’s ES Report
  - Look for a water-resistant barrier section
  - Product X may be used as an alternate water-resistant barrier as prescribed in Section 1404.2 of the IBC and Section 703.2 of the IRC, when installed on exterior walls as prescribed in this section
  - Broad head/crown fasteners – not overdriven
- Windows
  - Nailing flange set in bedding of sealant
  - Sill, head, and jamb flashing
- Joints and seams sealed with compatible tape of specified width
- Penetrations sealed
Taping the Joints
Follow Manufacturer’s Instructions

- Tape joints with 2-7/8” Weathermate Construction tape

- Note: 2-7/8” tape must be used if installing foam as a Water Resistant Barrier

- Center the tape over the joint to cover nails

- Note: tape must be installed in temperatures from 15º to 120ºF

Window Flashing

Source: Huber Engineered Wood Products
Roof/Wall Flashing
Follow Manufacturer’s Instructions

- Turn up roofing paper at the wall behind the foam sheathing about 12”

- After foam sheathing is in place, install L-shaped step flashing at the wall

- Install 4” Straight flashing to cover the top edge of the step flashing

- Install Construction Tape to cover the top edge of the Straight Flashing

- Install shingles per manufacturer’s recommendations

Foam as a WRB

- Potential concerns:
  - Dimensional instability over time (shrinkage)
  - Reliance on adhesive tapes, sealants, self-adhering flashing, rather than shingling
  - Look for 3rd party testing and warranties

- Tape characteristics
  - UV resistance
  - Temperature range
  - Temperature at installation
  - Cohesion strength
  - Flexibility

Alternate flashing details found in EEBA Water Management Guide
Testing of Tape

Siding Attachment

- Vinyl, wood, hardcoat stucco, and manufactured stone veneer directly through foam sheathing up to 2 inches thick
- Fiber cement siding limited to 1.5-inch foil-faced polyiso
- Thicker foam requires furring strips
Furring Strips for Siding

Vinyl Siding Over Foam (No WSP)

- For the follow conditions:
  - Basic wind speed ≤ 90 mph
  - Exposure Category B
  - Gypsum board installed on interior

- Siding fasteners:
  - Penetration into wood framing ≥ 1.25-inch
  - Nail shank diameter ≥ 0.12-inch (1/8“)
  - Nail head diameter ≥ 0.313-inch (5/16“)
  - Spacing ≤ 16-inch o.c.

- Foam sheathing thickness
  - XPS and ISO: ≥ 0.5-inch
  - EPS: ≥ 1-inch
Vinyl Siding Over Foam

Vinyl soffit nailed to supports
Vinyl siding
Water-resistant barrier
Foam plastic sheathing:
• Minimum 1/2 in. extruded polystyrene or
• Minimum 1/4 in. polyisocyanurate or
• Minimum 1 in. expanded polystyrene

Vinyl siding installed over foam plastic sheathing, wind speed ≤90 mph, Exposure B

Exterior Corner Detail

Support block attached to wood corner trim prior to fastening wood corner trim
Vinyl or aluminum siding
Rigid insulation (taped or sealed at corners)
Airspace

Wood corner trim (back primed and field cuts sealed)

Source: Builder's Guide to Cold Climates, Joe Lstiburek
Summary

- Identify type of foam to be used/has been used
- Specify foam thick enough to avoid condensation
- Decide where to locate water-resistive barrier
- Consider wall bracing options at the design phase
- Innie or outie windows
  - Jamb extensions for innies
  - Window bucks for outies
- Proper flashing at openings
- Attach foam to framing per manufacturer’s instructions
- Tape seams for air barrier and WRB
- Fasten siding through foam to framing or use furring strips