Moisture Monitoring in Exterior Walls

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Overview of Presentation

- Project Summary
- Reasons for research
- Questions to be answered
- Modeling
- Field Testing
- Analysis
Project Summary

- Evaluate potential for moisture problems in 3 new wall assemblies
- Modeling – this year
  - WUFI
  - THERM
- Field Monitoring – beginning 2012
  - Brick rehab
  - High-R walls: R-40 & 60
  - Code walls: hybrid insulation w/ spray foam & fiberglass
Reasons for Research

- Changes in construction due to:
  - Drastic increase in retrofit activities
  - Programs like PH & NZEH challenges
  - Increased use of hybrid insulation strategies
  - New insulation products
  - Code changes
Reasons for Research

- Changes include:
  - Increased use of foam insulation
  - Increasing thickness & R-value of walls
  - Increased use of hybrid insulation strategies
  - Changes in vapor retarder/barrier strategies
Research Focus

- **Assemblies**
  - Brick walls with interior insulation;
  - Super insulated walls at least 12” thick: R-40 and R-60;
  - Code built walls using spray foam insulation and fiberglass batts.
Research Focus

- Climate zones 4A, 5A, 6A and 7
  - experience both cooling and heating seasons
  - considerable humidity during the summer
Questions to be Answered

- How does WUFI modeling compare to actual monitored moisture levels?
- What combinations of building and insulation products produce a durable, efficient wall assembly?
- Do any of the monitored wall systems show moisture accumulating? If so, where?
Questions to be Answered

- If high moisture conditions exist, are levels and durations long enough to risk mold and/or decay?
- If high levels of moisture occur, can the cause be determined?
- Can differences in modeling and monitoring be explained?
- Are the R-values specified in Table 601.3.1 of the 2009 IRC sufficient to prevent condensation?
### Table 1. 2009 IRC Code Wall Assemblies to be Evaluated in WUFI

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Medium Density (MD) SPF Insulation (R-value)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Cavity R-value (2009 IRC)&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2.5 – 7.4</td>
<td>R13</td>
</tr>
<tr>
<td>Marine 4&lt;sup&gt;3&lt;/sup&gt;</td>
<td>3.75 – 8.6</td>
<td>R20</td>
</tr>
<tr>
<td>5</td>
<td>7.5 – 12.4</td>
<td>R20</td>
</tr>
<tr>
<td>6</td>
<td>11.25 – 14.5</td>
<td>R20</td>
</tr>
<tr>
<td>7</td>
<td>15 – 18.25</td>
<td>R21</td>
</tr>
</tbody>
</table>

<sup>1</sup>Lower R-value in each range is based on the minimum R-value of 2lb foam required by the 2009 IRC, Table R601.3.1 Class III Vapor Retarders.

<sup>2</sup>Climate Zone 4 (A & B) assume 2x4 wall cavity, all others are 2x6.

<sup>3</sup>Marine 4 is moisture regime C.
Table 1. Brick Wall and High-R Walls to be Evaluated in WUFI

<table>
<thead>
<tr>
<th>Wall Type</th>
<th>Vapor Retarder</th>
<th>Cavity Insulation</th>
<th>Cavity Insulation Thickness (inches)</th>
<th>Spray Foam Thickness (inches)</th>
<th>Sheathing Type</th>
<th>Sheathing Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick Wall</td>
<td>None, 0.1, 1.0</td>
<td>Fiberglass</td>
<td>2-5</td>
<td>0.5 - 2</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose</td>
<td>2-5</td>
<td>0.5 - 2</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>R-40+1</td>
<td>None, 0.1, 1.0</td>
<td>Fiberglass</td>
<td>5-8</td>
<td>2-4</td>
<td>OSB</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose</td>
<td>5-8</td>
<td>2-4</td>
<td>OSB</td>
<td>0.5</td>
</tr>
<tr>
<td>R-60+2</td>
<td>None, 0.1, 1.0</td>
<td>Fiberglass</td>
<td>8-12</td>
<td>4-6</td>
<td>OSB</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose</td>
<td>8-12</td>
<td>4-6</td>
<td>XPS</td>
<td>4-6</td>
</tr>
</tbody>
</table>

1Evaluated in Climate Zones 4 & 5
2Evaluated in Climate Zones 6-8
3Spray foam will be evaluated in 1” increments
4XPS will be evaluated in 1” increments
Modeling - THERM

- WUFI can only analyze continuous components
- Want to analyze condensation potential due to thermal bridging at framing members - THERM

Image from THERM
Field Testing

- **Short Term**
  - moisture content of components using a hand held moisture meter
  - Adjust values in WUFI if necessary

- **Long Term**
  - RH & Temp at critical interfaces
  - Moisture content – OSB, brick, studs
  - Climatic conditions

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Failure Criteria

- Moisture Content (MC)
- Condensation
- Mold growth
- Critical water content
- Rot/decay
- Freeze-thaw cycles

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MC & Condensation Potential

- Moisture Content (MC) of OSB < 20%
- Condensation Potential – graph interior air dew point temp vs. surface temp
  - Several interfaces will be analyzed – OSB/foam, foam/cavity insulation, interior surface of brick
  - THERM – framing/OSB, framing/insulation
## Moisture Content

<table>
<thead>
<tr>
<th>Representative City</th>
<th>Wall ID</th>
<th>Climate Zone</th>
<th>FG insulation thickness (in)</th>
<th>MD SPF Ins. Thick (In)</th>
<th>Vapor Barrier Perm rating</th>
<th>Avg. MC in OSB %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nashville, TN</td>
<td>4A-1</td>
<td>4A</td>
<td>2.6</td>
<td>0.4</td>
<td>None</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>4A-2</td>
<td>4A</td>
<td>2.2</td>
<td>0.6</td>
<td>None</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>4A-3</td>
<td>4A</td>
<td>1.8</td>
<td>0.9</td>
<td>None</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>4A-4</td>
<td>4A</td>
<td>1.4</td>
<td>1.1</td>
<td>None</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>4A-5</td>
<td>4A</td>
<td>2.6</td>
<td>0.4</td>
<td>1.0</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>4A-6</td>
<td>4A</td>
<td>2.2</td>
<td>0.6</td>
<td>1.0</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>4A-7</td>
<td>4A</td>
<td>1.8</td>
<td>0.9</td>
<td>1.0</td>
<td>10.7</td>
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<tr>
<td></td>
<td>4A-8</td>
<td>4A</td>
<td>1.4</td>
<td>1.1</td>
<td>1.0</td>
<td>10.6</td>
</tr>
</tbody>
</table>
Condensation Potential

Condensation Potential of Wall with 2.6" FG+ 0.4" SPF + No VPB in Climate Zone 4A

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Mold Growth

Following conditions must be met:

- Temperature is between 32° and 122°F,
- Relative humidity is above 70%,
- Food is present for the mold,
- There is sufficient time for germination and growth to occur,
- Other factors such as pH value, salt content of the substrate, light, oxygen content, surface condition and biotic influences must be favorable for growth
**Table 1. Critical Humidity (RH %) Levels for Mold Growth and Decay on Different Materials.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Mold Growth</th>
<th>Decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine sapwood</td>
<td>&gt;80-95</td>
<td>&gt;90</td>
</tr>
<tr>
<td>Particle Board</td>
<td>&gt;80-95</td>
<td>&gt;90</td>
</tr>
<tr>
<td>Gypsum Board</td>
<td>&gt;80-95</td>
<td>&gt;95</td>
</tr>
<tr>
<td>Fiber board</td>
<td>&gt;80-95</td>
<td>&gt;95</td>
</tr>
<tr>
<td>Wall papers</td>
<td>&gt;75-95</td>
<td>&gt;90</td>
</tr>
<tr>
<td>Different coatings</td>
<td>&gt;75-95</td>
<td>-</td>
</tr>
</tbody>
</table>

(Table reproduced from ASTM MNL 40)
Mold Growth

- ASHRAE Standard 160 performance criteria:
  - 30-day running average: surface RH<80% & temp 41°F to 104°F
  - 7-day running average: surface RH<98% & temp 41°F to 104°F
  - 24-h running average: surface RH< 100% & temp 41°F to 104°F

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Mold Growth

Isopleth showing mold growth possibility on the interior surface of a wall assembly along with the limiting isopleths
Critical Water Content
Rot/Decay

- Typical conditions for decay/rot in building materials:
  - RH - 90-95% coincident with
  - Temperature range of 41°F to 104°F.
Freeze-Thaw Damage

- Two factors influence frost damage
  - MC on freezing – critical level for brick 90%
  - Number of freeze thaw cycles – higher number of cycles, more potential for freeze-thaw damage
Questions?
Thank You.