ARE THE WALLS CLOSING IN?

MOISTURE PERFORMANCE OF HIGH-R WALLS

June 2016

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Outline

- Wall Construction Market: Materials and Trends
- Builders’ Perspective: Results of Builder Survey
- Design Principles and Case Studies:
  - Vapor retarder selection
  - Vapor diffusion vs. air leakage
  - Is poly bad?
  - Do walls with foam sheathing dry?
  - Is interior RH important? What are observed RH levels?
  - Is construction moisture important?
  - Is spot ventilation needed?
  - Is moisture important?
  - Are the dew point calculations useful?
- Is there a perfect wall?
# Wall Market Trends

- Wall Framing (% new home starts)

<table>
<thead>
<tr>
<th>Framing</th>
<th>2001</th>
<th>2006</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x4 @ 16&quot; o.c.</td>
<td>74%</td>
<td>73%</td>
<td>60%</td>
<td>53%</td>
</tr>
<tr>
<td>2x4 @ 24&quot; o.c.</td>
<td>2%</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>2x6 @ 16&quot; o.c.</td>
<td>22%</td>
<td>22%</td>
<td>32%</td>
<td>37%</td>
</tr>
<tr>
<td>2x6 @ 24&quot; o.c.</td>
<td>2%</td>
<td>2%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Wall Market Trends

### Wall Sheathing (% new home starts)

<table>
<thead>
<tr>
<th>Wall Sheathing (primary)</th>
<th>2001</th>
<th>2006</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (concrete, SIPs or others)</td>
<td>10%</td>
<td>12%</td>
<td>12%</td>
<td>8%</td>
</tr>
<tr>
<td>WSP (plywood, OSB, ZIP)</td>
<td>65%</td>
<td>68%</td>
<td>79%</td>
<td>84%</td>
</tr>
<tr>
<td>1/2 inch fiberboard</td>
<td>3%</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>1/8 inch (Thermoply, EnergyBrace)</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>SIS</td>
<td>n/a</td>
<td>n/a</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Foam (XPS, EPS, ISO)</td>
<td>17%</td>
<td>12%</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>3%</td>
<td>4%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Wall Market Trends

### Oversheathing (% new home starts)

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2012</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homes with foam sheathing over wood structural panel</td>
<td>7%</td>
<td>9%</td>
<td>10%</td>
<td>11%</td>
</tr>
</tbody>
</table>

### House wrap (% new home starts)

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2012</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homes with House wrap</td>
<td>54%</td>
<td>74%</td>
<td>74%</td>
<td>76%</td>
</tr>
</tbody>
</table>
Wall Market Trends

- Cavity Insulation (% new home starts)

<table>
<thead>
<tr>
<th>Insulation Type</th>
<th>2006</th>
<th>2011</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass batt</td>
<td>76%</td>
<td>68%</td>
<td>68%</td>
<td>66%</td>
</tr>
<tr>
<td>Fiberglass blown</td>
<td>7%</td>
<td>8%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Spray foam</td>
<td>3%</td>
<td>11%</td>
<td>10%</td>
<td>12%</td>
</tr>
<tr>
<td>Cellulose</td>
<td>11%</td>
<td>8%</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>Other or none</td>
<td>3%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Builder Survey of Key Challenges and Opportunities

- Web-based survey
- 308 builders
  - Decision-making authority or influence
- Range of categories
  - Occupant Comfort
  - Fire Resistant Construction
  - Indoor Air Quality
  - Energy Efficiency Issues
  - Durability
  - Disaster Resistance
  - Costs and Labor Availability
Builder Survey of Key Challenges and Opportunities

Number of Reporting Types of Homes

- Multifamily: 41
- Townhouses: 56
- SFD-Luxury: 171
- SFD Move-up: 188
- SFD Starter: 123

ENERGYSTAR for Homes: 51%
No energy/green programs: 38%
LEED: 16%
WaterSense: 11%
NGBS Certified: 10%
Other Program: 8%
Passive house: 6%
Indoor airPlus: 6%
Net Zero Energy Ready: 5%

Shares of SFD Homes Reported by Participants

- Local Builder, 84%
- Regional or National Builder, 16%
- Custom, 27%
- Semi-Custom, 25%
- Production, 48%
## Top Challenges in Energy Efficiency

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Bar Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture performance of energy efficient walls</td>
<td>Longest</td>
</tr>
<tr>
<td>Moisture performance of energy efficient attics</td>
<td></td>
</tr>
<tr>
<td>System/whole-house integration when transition' to more energy effic homes</td>
<td></td>
</tr>
<tr>
<td>Long-term effectiveness of insulation materials &amp; systems</td>
<td></td>
</tr>
<tr>
<td>Window installation solutions in walls w/more insulation</td>
<td></td>
</tr>
<tr>
<td>Details for integration of exterior insulation w/other materials</td>
<td></td>
</tr>
</tbody>
</table>

*Total of 14 issues/challenges presented to respondents*
Top Challenges in Durability

- Understanding impact of new code reqs on the long-term performance
- Proven durability of new products & materials
- Durability of exposed exterior wood trim & other finish wood products
- Durability of conditioned (unvented) crawlspace
- Determining correct vapor retarders for walls
- Product integration that ensures long-term performance of entire system

*Total of 19 issues/challenges presented to respondents
Moving and Interconnected Parts

- Higher insulation levels
- Location of insulation (CI vs cavity)
- Insulation ratio (CI/cavity)
- Permeance of insulation and other materials
- New materials with built-in characteristics
- Claddings
- Vapor retarders
- House interior relative humidity

Practical combination of variables in terms of walls used in residential construction is more manageable
Case Studies on Moisture Performance of Energy Efficient Walls

Research:
- Field Study of 22 homes
- Test Huts
- Analytical Studies (WUFI)

Results ([www.homeinnovation.com](http://www.homeinnovation.com)):
- Research Reports
- Wall Construction Guides
- Tech Notes
- [Draft Standard Practice for DETERMINING MOISTURE PERFORMANCE OF WALL ASSEMBLIES FROM THE IN-SITU DATA (intended for a consensus standard)]
Moisture Monitoring of Energy Efficient Houses

- Cataloguing and monitoring EE walls used by builders in various climates
Monitoring System

378 sensors total
Test Huts – CZ 4
Case Studies of Design Principles

- Vapor retarder selection
- Vapor diffusion vs. air leakage
- Is poly bad?
- Do walls with ext. foam sheathing dry out?
- Is interior RH important for walls?
- Is construction moisture important?
- Is spot ventilation needed?
- Do we care about moisture in walls?
- Are the dew point calculations useful?
Three Interior Vapor Control Strategies in Heating Climates

1) Ext. continuous insulation (T controlled)
   ✓ Class III
   ✓ No vapor retarder

2) No exterior insulation (Vapor controlled)
   ✓ Vapor retarder based on Climate Zone

3) Hybrid (T and Vapor controlled)
   ✓ Class II vapor retarder
   ✓ Smart vapor retarder
1. Exterior Continuous Insulation

1) T controlled
2) Minimum outboard R-value (code)
3) Ratio of outboard to cavity (design)
4) Primary drying to the inside
5) Drying to the outside based on material permeability
6) Class III or no VR
2. No Exterior Insulation

1) Vapor controlled
2) Vapor retarder based on CZ
   ✓ Class I, II, III, vapor-open
3) Drying can be in either direction
4) Air sealing is more important
3. Hybrid

1) T and Vapor controlled
2) Int. vapor retarder
   ✓ smart
3) Primary drying to the inside
4) Drying to the outside depends on layer permeability
5) Allows for limiting exterior insulation thickness -- constructability
Example: Adjacent Homes

Vapor-controlled

RH: 49-57%

Hybrid: 1”XPS+Kraft facing VR

RH: 46-51%

Climate Zone 3A - Alabama (2) - Home 5 - Wall Cavity Moisture Content

Climate Zone 3A - Alabama (1) - Home 4 - Wall Cavity Moisture Content

Note: Wall Type G - OSB, 2x4, R18 ccSPF

gypsum/paint unless noted. Roof with ccSPF

Note: Wall Type C - 1” XPS, OSB, 2x4 w/ R13 FG Batts

gypsum/paint unless noted. Roof with ccSPF

CZ 3
Example: Ext. Continuous Insulation

CZ 6A: Walls with 1” XPS w/o interior vapor retarder – Insufficient CI R-value for the application

Note: All walls have 1”XPS, OSB, 2x6, blown fiberglass, gypsum/foil

Average: 2011-2012 winter indoor RH, 32%
2012-2013 winter indoor RH, 32%
2013-2014 winter indoor RH, 29%
2014-2015 winter indoor RH, 32%
Test Huts – Direct Comparison

CZ 4

North Wall- Vinyl Siding

OSB Moisture Content (%)

OSB, framing, unfaced batts
OSB, framing, faced batts
1" XPS, OSB, framing, faced batts

RH: 50-60%
2016 Building America

Air leakage vs. Vapor Diffusion

Moisture Content - Infiltration Walls

CZ 4

2x6 Walls with Kraft Paper VR

RH: 35-45%
Air leakage vs. Vapor Diffusion

CZ 4

Moisture Content - Infiltration Walls

RH: 35-45%
Air leakage vs. Vapor Diffusion

Both are important!

- 33F DP
- 4'x8' sheet of drywall (50 perm)
- + Kraft Paper (1 perm)
- Condensing Surface
- 70F 40%RH
- Outdoors: Cold & Dry

30 days
Polyethylene as an interior vapor retarder?

- Poly is an effective vapor (and air) barrier
- Use with caution

**CZ 5**

2x6 walls w/o CI

- Average Indoor RH: 12/15, 12/3, 12/15 = 26%
- 12/15/13-3/15/14 = N/A
- 12/15/14-3/15/15 = 29%
Do walls with ext. foam dry out?

2x4+R5 Walls w/o int. VR

CZ 4
Do walls with ext. foam dry out?

CZ 6A: Walls with 1” XPS w/o interior vapor retarder – Insufficient CI R-value for the application
Are indoor RH levels important for walls?

- Yes, in combination with other variables

**RH: 46-48%**

**CZ 4**
Are indoor RH levels important for walls?

- Yes, in combination with other variables
Are indoor RH levels important for walls?

- Yes, in combination with other variables

RH: 35-38%

CZ 4
What are the observed indoor RH levels?
Is Construction Moisture Important?

- Construction moisture can be highest moisture load in walls
Is point source ventilation important?

- MC is often highest in the bathroom
Is water damage from vapor drive real?

19% drop in bending strength after one winter season
Are conventional dew point calculations accurate?

- Conservative
- Tend to overestimate the risk, particularly in terms of duration
- Steady-state assumption
- Walls’ response dynamic following daily temperature and RH cycles
- Wood has moisture storage capacity (buffer)
- WUFI provides good trends; absolute values are more challenging
Why there are so many different wall systems?

- Any system has its pros and cons
- Broad range of metrics

| ✔️ R-value | ✔️ Fire resistance |
| ✔️ Air barrier | ✔️ Sound control |
| ✔️ Drainage of exterior water | ✔️ Other Green attributes |
| ✔️ Vapor control | ✔️ LCA |
| ✔️ Structural | ✔️ Cost |
| ✔️ Constructability | ✔️ Value |

- There is more than one “sweet spot” based on the specific value proposition
Resources

- BASC – https://basc.pnnl.gov/
- Wall Construction Guides: www.homeinnovation.com/wallguides
- Tech Notes www.homeinnovation.com/technotes
- Reports: http://www.homeinnovation.com/reports

Search: moisture, walls
Code and Design Recommendations

- Interior vapor retarder in CZ 4A (Class II, smart)
- Coordinate energy code provisions for R20+5 walls and int. vapor retarder provisions
- Rated paints as a vapor retarder (standard latex paint not a Class III vapor retarder)
- Avoid a double vapor barrier configuration
- Add classification for variable vapor retarder
- Not to use Class I int. vapor retarder in CZ 1-2
Ongoing Study

- Monitoring of additional energy efficient homes
- Broader range of materials and wall configurations
- Still can add a couple of homes in the Hybrid category in CZ 5 or 6
  (vkochkin@homeinnovation.com)
THANK YOU

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