Enclosure Monitoring: Background

Background

- Not an originator—only a practitioner
- U Waterloo BEG/John Straube and RDH
- Not much of a how-to presentation: research level instrumentation... but inspiration/ideas?
- Thank you, Building America/DOE!

Monitoring Projects (Back to 2003)

- Kraft vs. polyethylene vs. MemBrain (w. Cellulose/FG)
- Basement wall insulation
- Polyethylene vs. latex paint and brick veneer inward drive
- Drainage gaps and wetting/drying
- Masonry walls with interior insulation
- Masonry wall embedded joist ends after insulation
- Double stud walls w. cellulose & ccSPF
- Unvented roofs with fibrous insulation, diffusion vents
  - Chicago, Houston, Orlando, Boston
Enclosure Experimental Design

- What do you want to learn?
- Comparing side-by-side variations
- Orientation/exposure (North vs. South)
- What are the key interfaces to measure?
  - Wintertime condensation = sheathing-to-insulation, first condensing plane
  - Summertime condensation or inward vapor drive = cavity insulation-to-interior gypsum
- How long do you have access to the site?
  - Multiple years best—performance over time
  - Vary conditions over time—e.g., interior RH

Enclosure Monitoring: Instrumentation
Typical Monitoring Instruments/Sensors

- Temperature
- Relative humidity
- Wood moisture content
- “Wafer” sensor
- Redundant placement—instrumentation failures
- Differential pressures—hard problem

Moisture Content Measurement

- Delmhorst BD10
- Pin-based MC meter
- Wood products (typical)
- Electrical resistance

Wood Moisture Contents

- Below 20% MC=safe
- 25-30% MC mold range
  - But seasonally survivable!
- 28%+ MC decay fungi
- Really wet wood is obvious (feels wet)
- Liquid water condensation
- Don’t forget about temperature when wet (mold doesn’t grow in the freezer)

Wood Wafer Sensors

- MC pins embedded in small wood pieces
- Long term RH at interfaces, mold growth
- Can indicate liquid water condensation (mold ↑↑)
Enclosure Monitoring: Implementation and Examples

Instrumentation Design: Double Stud Walls

Wall 1 = 12” o.c. SPF
Wall 2 = 12” Cellulose
Wall 3 = 5-½” o.c. SPF

Test Wall Instrumentation

Sensor Key:
- Temperature
- Relative humidity
- Temperature
- Moisture content
Instrumentation Design: Unvented Roof

Notes:
- "MC/T Sheathing High" is at top edge of shingling or diffusion vent, or equivalent location in non-DV roofs.
- Wafer and RH/T at edge are directly under ridge.

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Exterior Conditions: Field Monitoring

- Basics: Temperature/RH
- Advanced: Add rain, wind direction/speed
- Budget: Hourly airport weather data

Logger Setups: Simple, Complicated

Experimental ‘Guard Bays’

- Keep test assemblies from cross-communicating
- Air leakage, vapor flow?
Adding Air Leakage Injection System

Adding “Wetting Events”
- How well does this assembly recover from occasional water leaks? Drying out
- Most useful in side-by-side comparisons

Moisture Failure Criteria
- No mold growth with wood below 20% (FPL)
  - Optimum growth 25%–30% MC range
- Decay fungi @ MC > 28%
- Doll (2002)—liquid water (e.g., condensation), mold growth takes off
- Calculations to show “is this assembly moisture-safe or not?”

Enclosure Monitoring: Interpreting Data
Moisture Failure Criteria

- Old ASHRAE 160 criteria too conservative
  - Multiple field tests-160 shows failure, visual OK
  - Walls with known track records of success fail ASHRAE 160 criteria

Viitanen’s mold index

<table>
<thead>
<tr>
<th>Index</th>
<th>Description of growth rate</th>
<th>Microscopic observation</th>
<th>Observation with the naked eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No growth</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Initial stages of local growth</td>
<td>Small amounts of mold on surface</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>---</td>
<td>Several local colonies</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>New spores produced</td>
<td>&lt;50% coverage</td>
<td>&lt;10% coverage</td>
</tr>
<tr>
<td>4</td>
<td>Moderate growth</td>
<td>&gt;50% coverage</td>
<td>10%-50% coverage</td>
</tr>
<tr>
<td>5</td>
<td>Plenty of growth</td>
<td>---</td>
<td>&gt;50% coverage</td>
</tr>
<tr>
<td>6</td>
<td>Heavy and tight growth</td>
<td>---</td>
<td>about 100% coverage</td>
</tr>
</tbody>
</table>

Based on work by Hannu Viitanen and colleagues since the 1980s

Moisture Failure Takeaways

- Mold index model is a big improvement
  - Does not fail assemblies that work
  - Test cases using measurements show that model agrees with observations (mold & no-mold cases)
  - Material sensitivity, mold decline accounted for
- But is mold index passing risky assemblies?

Opening the Walls
Best Case: Monitor then Disassemble

UWaterloo (CZ 6A) Walls

- Interior run at 68 F/50% RH year round
- Very challenging interior condition
- Walls 2x4 + XPS, 2x6 paint/poly

North Side Sill Plate MCs

- 20-30% MC usual “concerning” range
- XPS wall sill plate soaking wet

UWaterloo (CZ 6A) Year 1 Disassembly

- Slight spotting on XPS surface
- Wetting event correlated with XPS T>32 F
- Frost accumulation followed by thaw & rundown
Questions?

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This presentation will be available at http://buildingscience.com/past-events

Indoor Air Quality Monitoring

Consumer-Level IAQ Monitors
- Temperature, humidity, VOCs, CO₂, PM2.5

Temperature
- Tracking HVAC cycling/operation

Daily Average
- 65.8° F

Chart showing temperature and humidity data over a period of time.
**CO₂ Carbon Dioxide-Ventilation Metric**

- Somerville Triple Decker, third floor unit

**Stack Effect in Multifamily Buildings**

- Make-up air comes from units below

**CO₂ Carbon Dioxide-Ventilation Metric**

- Effect of adding an ERV to ~1000 sf unit, BR CO₂
- High CO₂ levels and cognition

**VOCs/Volatile Organic Compounds**

- Harmful…
**VOCs/Volatile Organic Compounds**

- ... Vs. not too harmful?

**PM2.5 Particulates**

- Health effects of breathing PM2.5 (LBNL)
- Cooking causes big spikes—even w. range hood
- PM2.5 spike while out of town… Thanksgiving
- But also, humidifiers!