Background

- Ducts in unconditioned attic = huge energy losses
- Solution: bring ducts into conditioned space
  - Builders reluctant to move ducts out of attic
- Unvented/conditioned attic—keeps ductwork in conditioned space, duct leak issues eliminated
- Also, retrofit insulation—cond. space within roof

Why this Project?

- Dense pack insulation of unvented roofs common in cold-climate retrofits
  - Moisture risks (see BSI-043 “Don't Be Dense—Cellulose and Dense-Pack Insulation”, Derome’s work)
  - Violates I-codes (see IRC § R806.4)
  - “Ridge rot”—localized problems (SIPS same problem)
Why this Project?

- Current code-compliant compact roof assemblies are higher cost (spray or board foams typical)
- Material costs:
  - Cellulose: 2-3¢ (per sf•R-value)
  - Polyisocyanurate: 7-10¢ (per sf•R-value)

Why this Project?

- Unvented roofs without spray/board foams could reduce costs and increase market penetration... IF moisture damage risks are addressed
- Retrofit opportunities (existing uninsulated living space at roof line, without removing finishes)

Experimental Setup

- Seven roof bays (east-west pairs) in test garage attic in Chicago, IL (5A) area
- 72 F/50% RH interior conditions through winter: stressing assemblies to failure
### Experimental Design

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Venting</th>
<th>Insulation</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vented</td>
<td>Vent space (2&quot;)</td>
<td>Fiberglass</td>
<td>Gypsum Bd</td>
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<tr>
<td>2</td>
<td>Top Vent Cathedral-Cellulose</td>
<td>Cedar Breather (~½&quot;)</td>
<td>Cellulose</td>
<td>Gypsum Bd</td>
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<tr>
<td>3</td>
<td>Top Vent Cathedralized-Cellulose</td>
<td>Cedar Breather (~½&quot;)</td>
<td>Cellulose</td>
<td>Open</td>
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<tr>
<td>4</td>
<td>Top Vent Cathedralized-FG</td>
<td>Cedar Breather (~½&quot;)</td>
<td>Fiberglass</td>
<td>Open</td>
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<tr>
<td>5</td>
<td>Top Vent Cathedralized-FG</td>
<td>Cedar Breather (~½&quot;)</td>
<td>Fiberglass</td>
<td>Gypsum Bd</td>
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<tr>
<td>6</td>
<td>Diffusion Vent Cellulose</td>
<td>Diffusion Vent</td>
<td>Cellulose</td>
<td>Gypsum Bd</td>
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<tr>
<td>7</td>
<td>Unvented Cellulose</td>
<td>None</td>
<td>Cellulose</td>
<td>Gypsum Bd</td>
</tr>
</tbody>
</table>

### Top Vent Details

- Unvented cellulose roof (example plan)
- Instrumentation at ridge: worst moisture failures localized there

### Instrumentation, Insulation, Finishes…

### Typical Sensor Package

- Temperature
- Relative humidity/temperature
- Moisture content/temperature
- Moisture content block “wafer”
Typical Sensor Package

- Top vent and vented roofs add T/RH sensors at outside air intake & exhausts

Results

- Winter of the “polar vortex” (7110 HDD vs. 6460)
- Losses of temperature control due to logger failures
Boundary Conditions (Temperatures)

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- Various losses of RH control, mostly 50%
- Into spring, interior RH rises above 50%
  (sheathing desorbing moisture, outdoor DP)

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Sheathing Moisture Contents (1-Vented)

- Upper, Middle, & Lower
- East-West Pairings
  (West = warmer)
- Exterior T shown for reference
Monitoring Result Takeaways

- Vented roof = great performance—even @50% RH!
- Unvented cellulose assembly driven to failure
- Cellulose + diffusion vent helps, but not enough
- Top venting not enough to save roofs in:
  - Zone 5A climate
  - With a small (~1/2” vent space)
  - With OSB sheathing
- In top vent roofs, fiberglass roof much worse than cellulose
  - Unless there’s an air leak letting the moisture out
- Moisture accumulation driven by RH & outdoor T
Disassembly

Removal of Doghouse

Sheathing Ridge Condition

Sheathing Ridge Condition
Sheathing Ridge Condition

Top Vent Cellulose Ridge Conditions

Top Vent Fiberglass Ridge Conditions
Diffusion Vent & Unvented

Sheathing Further from Ridge-West

Sheathing Further from Ridge-East

More Sheathing-Underside
Disassembly Takeaways

- Results consistent with monitoring data
- Sheathing stained but not punky/structural damage
- Damage concentrated/severe at ridge
- Fiberglass sheathing & framing: extensive damage & staining, possible mold growth
- Cellulose sheathing: some delamination, adhesions, and rusty fasteners—not as bad
- Cellulose did not settle over one winter
- Fiberglass batts leave lots of air leakage paths—possible cross-contamination with Roof 3?
- Liquid water rundown issues in fiberglass roofs

Experimental Conclusions

- No roof except for “control” vented roof showed “safe” performance in Zone 5A @ 50% RH
- Cellulose roofs generally showed lower MCs than fiberglass roofs, less damage to structure
- “Top vent” configuration not effective
  - OSB too restrictive for diffusion drying, even with outward thermal gradient? (part of the time)
  - Ventilation space too small?
- Diffusion vent allowed greater drying than conventional unvented, but still higher MCs than generally considered safe
Further Work—Other Diffusion Vents?

- Cosella Dörken Delta Foxx: **215-550 perms (?)**

Houston Diffusion Vent Preliminary Info

- Houston Zone 2A (Hot Humid)
  - Not Chicago-level challenging, but have seen failures!
  - Data from April 2014-present (spring/summer)
  - Unvented roofs vs. diffusion vent roofs, no interior humidification
  - Monitoring results so far:
    - Unvented roof wetter coming out of winter, drier in summer
    - Diffusion vent roof drier in winter, wetter in summer
    - Neither roof anywhere near failure levels
    - This winter’s data will provide the interesting results

Questions?

Kohta Ueno
kohta [at] buildingscience [dot] com

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