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Exterior Cladding Attachment Research

Building America Expert Meeting
Overview

- Cladding Attachment Options
- Cladding Attachment Direct Through Exterior Insulation
- TO2 Building America Research (2011)
- TO3 Building America Research (2012)
Cladding Attachment Options
Exterior Rigid Insulation

- The “Perfect” Wall

- Increase overall thermal performance
- Minimize thermal bridges
- Minimize potential for air leakage condensation
- Improve air tightness?
- Improve rainwater management?
Cladding Attachment

- For insulation 1.5” or less – direct attachment of cladding though insulation back to the structure is often practical
- For insulation greater than 1.5” – a secondary cladding support system is often needed.
  - Cladding support systems historically done poorly
  - Systems are getting better
Cladding Attachment

- Single “z-furring”
  - Poor thermal performance (steel stud wall on the exterior – why bother?)
Other Claddings
Cladding Attachment

- Single “z-furring”
- Double “z-furring”
  - Can be made to function reasonably well provided that two layers of insulation are used.
  - Often designed with first layer bridging insulation and second layer creating a gap behind the cladding = single “z-furring”
Cladding Attachment

- Single “z-furring”
- Double “z-furring”
Cladding Attachment

- Single “z-furring”
- Double “z-furring”
- Clip and “z-furring” or hat channel
  - Metal clip
  - Fiberglass clip
Cladding Attachment

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Cladding Attachment

- Single “z-furring”
- Double “z-furring”
- Clip and “z-furring” or hat channel
  - Metal clip
  - Fiberglass clip
- Attach furring directly back to structure through insulation
Cladding Attachment

- Single top plate
- 2x6 stud wall @ 24” o.c.
- Taped and painted 5/8” gypsum wall board as interior finish
- Sheathing
- Corrugated spunbonded polyolefin (SBPO) air and water barrier
- Tape joints in sheathing
- 1” to 6” of insulating sheathing (XPS, EPS, rockwool, PIC)
- 1x3 furring strips
- Fiber cement lap siding

Fibrous cavity insulation
Latex paint (Class III) vapor control
Cladding Attachment

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Direct Cladding Attachment Through Insulation
Direct Attachment Through Insulation

- Lots of practical experience with this approach for lightweight cladding systems over thick layers of insulation (several decades).
- Approach has demonstrated very good long term performance
- High resistance from industry
Direct Attachment Through Insulation

- “Does the insulation provide any additional capacity for the system?”
- BSC staff test
Direct Attachment Through Insulation

- System loaded with air gap between furring and wall
Direct Attachment Through Insulation

- System loaded with 4” of rigid mineral fiber insulation between furring and wall
Direct Attachment Through Insulation

- The answer is yes!

**Vertical Deflection of Furring Strips with Imposed Gravity Load**

- **No insulation**
- **4" mineral fiber**
Direct Attachment Through Insulation

- “Does the insulation crush under load?”
- The answer is yes!
- Loading a system until failure (500lbs to 1000lbs or more per screw fastener) will crush most rigid insulations

…..Unfortunately it is the wrong question
Direct Attachment Through Insulation

- “Does the insulation crush under a load similar to what will be imposed on it in a cladding support application?”
- The answer is no!...

Context is important
### Direct Attachment Through Insulation

**Typical cladding weights (psf)**

<table>
<thead>
<tr>
<th>Material</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>wood</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>fiber cement</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>stucco</td>
<td>10.0</td>
<td>12.0</td>
</tr>
<tr>
<td>adhered stone veneers</td>
<td>17.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>
## Direct Attachment Through Insulation

- **Typical weights per fastener (lbs)**

<table>
<thead>
<tr>
<th>fastener spacing (in)</th>
<th>16&quot; x 16&quot;</th>
<th>16&quot; x 24&quot;</th>
<th>24&quot; x 24&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>area/fastener (ft²)</td>
<td>1.78</td>
<td>2.67</td>
<td>4</td>
</tr>
<tr>
<td>vinyl</td>
<td>1.8</td>
<td>2.7</td>
<td>4.0</td>
</tr>
<tr>
<td>wood</td>
<td>2.7</td>
<td>4.0</td>
<td>6.0</td>
</tr>
<tr>
<td>fibercement</td>
<td>8.9</td>
<td>13.3</td>
<td>20.0</td>
</tr>
<tr>
<td>stucco</td>
<td>21.3</td>
<td>32.0</td>
<td>48.0</td>
</tr>
<tr>
<td>adhered stone veneers</td>
<td>44.4</td>
<td>66.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Direct Attachment Through Insulation

- Acceptable deflection not ultimate capacity governs
- What is acceptable deflection?
  - Movement a cladding system can accommodate without physical damage or exceeding aesthetic tolerances
- Proposed limits
  - Lap sidings and panel cladding ~ 1/16”
  - Brittle claddings ~1/64” (after initial deflection)
TO2 Building America Research (2011)
Gravity Load Response Testing (2011)

- BSC Research TO2 (DOE Building America Program)
- Short Term and Long Term Deflection Testing
- Multiple insulation types
  - EPS
  - XPS
  - Foil faced polyisocyanurate
  - Rigid mineral fiber
Gravity Load Response Testing (2011)

- Short term testing
- Test panels
  - 4’x8’
  - 1x3 furring spaced 24” oc
  - 16” vertical spacing of fasteners
- Multiple thicknesses
  - 4” and 8” tests
Short-term Gravity Load Response
Short-term Gravity Load Response

- 1/64"
- 1/32"
- 1/16" 1/8"
- 4" insulation thickness

- Adhered stone veneers
- ~1/64"
- Stucco
- ~1/200"
- Fiber cement
- Wood
- Vinyl

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Short-term Gravity Load Response

8” insulation thickness

~1/64” to 1/16”

1/200”

1/32” 1/16” 1/8”

1/64”

adhered stone veneers

stucco

fiber cement

wood

vinyl

8” Roxul
8” EPS
8” Thermax
8” XPS

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Long-term Gravity Load Response

- Long term testing
- Test panels
  - 2’x8’
  - 1x3 furring
  - 16” vertical spacing of fasteners
- Load
  - 13 psf if 24” oc
  - 20 psf if 16” oc
  - 30 lb/fastener
Long-term Gravity Load Response

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Long-term Gravity Load Response

Long term deflection by date (not all started simultaneously)

- 1/64”
- 1/32”
- 1/16”
Testing Results

- Lightweight claddings (vinyl, wood, fiber cement) have very little movement both under initial loading and long term loading (~1/200”)
- For lightweight claddings deflection does not even approach proposed deflection limit (1/16”)
- Testing results in line with long history of performance of buildings constructed with this assembly
Testing Results

- Heavier brittle claddings (stucco, adhered stone veneers) initial deflection is not as important as long term deflection.
- For stucco claddings (10psf), long term deflection after initial deflection is within proposed deflection limit in stable environmental conditions.
- For adhered stone veneer (17psf to 25psf), capacity could be increased with increased fastener spacing.
Additional Questions

- Creep is still not well understood or quantified
- Affected by multiple factors
  - Expansion and contraction of wood
  - Expansion and contraction of insulation
  - Relaxation of wood fibers
  - Plastic deformation of insulation
- Many of these are affected by temperature and relative humidity
- More research is needed to examine the performance of these systems in exposed environments
Additional Questions

- The exact mechanisms of the load deflection resistance are not well quantified.
- Discrete load components are theorized but have not been measured.
- Important to understand factors that affect the development of system capacity to examine means to design the attachment systems.
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TO3 Building America Research (2012)
Gravity Load Response Testing (2012)

- BSC Research TO3 (DOE Building America Program)
- Discrete Load Component Testing
- Long Term Deflection Testing in Exposed Environment
- Multiple insulation types
  - EPS
  - XPS
  - Foil faced polyisocyanurate
  - Rigid mineral fiber
Gravity Load Response Testing (2012)

- Discrete Load Components

1. Shear and rotational resistance provided by fastener to wood connections
2. Rotational resistance provided by tension in fastener and compression of the insulation
3. Vertical movement resistance provided by friction between layers
Discrete Load Component Testing

- Series of tests to measure material properties
  - Coefficients of friction
  - Compression modulus of insulation
- Small scale test to try to isolate the discrete functions
  - Screw bending/wood bearing
  - Strut and tie model
  - Friction between layers
    - Due to pre-compression (clamping) forces
    - Due to rotational forces
Discrete Load Component Testing

- Pre-compression (clamping) forces
  - Forces imposed on the system by tightening of the screw fasteners that hold the wood furring in place
  - Tested using common #10 Wood Screws
Discrete Load Component Testing

- Pre-compression (clamping) forces
  - Failure mechanism – head pull through of fastener through the furring
  - Preliminary results indicate pretty consistent force magnitudes
    - ~150 lbs per fastener with screw head flush with furring surface
    - ~180 lbs per fastener with screw over driven
  - Additional testing to be completed to examine relaxation in load over time
Discrete Load Component Testing

- Small Scale Discrete System Tests
  - Custom built test apparatus
  - Intent to evaluate individual force resistance components
    - Screw bending/wood bearing
    - Strut and tie model
    - Friction between layers
Discrete Load Component Testing

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Discrete Load Component Testing
Climate Exposure

- Full Scale Wall Assemblies
- Loaded to three representative cladding weights
  - Fiber cement
  - Stucco
  - Cultured stone
- Deflection measured over the course of the year
Climate Exposure

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Climate Exposure

Long Term Deflection of strapping installed over 4" of XPS (2 layers x 2") when subjected to 8, 15, and 30 psf Loads
note for relevance 1/32" = .03"

Elapsed Time (days)

Deflection (thou)

1/64
1/32
1/16
1/8

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Climate Exposure

Long Term Deflection of strapping installed over 4" of EPS (2 layers x 2") when Subjected to 8,15, and 30 psf Loads

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Deflection (thou)

1/64
1/32
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Testing Results

- Testing is still underway
- Results have not been fully analyzed
Thank you for your time!
Any Questions?