Overview

- Background
- Cladding Support System: Direct Attachment Through Insulation
- Discrete Load Components
- Full Scale Assembly Testing
- Full Scale Environmental Exposure Testing
- Industry Impacts
- Recommendations

Building America Innovations

This research is paving the way for key innovations:
- Construction technology to promote the use of exterior insulation
- Wide adoption for a range of cladding systems
- Code development and integration

BSC Builder Resources

- Prescriptive Cladding Attachment Requirements
  - 2012 IRC – Table R703.4 Weather Resistant Siding Attachment and Minimum Thickness
  - Link to IRC FAQ: Cladding Attachment over Insulating Sheathing
  - RR-1204: External Insulation of Masonry Walls and Wood Framed Walls
  - Overview of BSC research conducted in 2011 regarding the use of furring strips installed over exterior insulation as the cladding attachment point
  - Report includes detail drawings for retrofitting wood framed and masonry buildings with exterior insulation
- Link to DOE resources: www.buildingamerica.gov
Background

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?

Problem Context

- Current Building Code does provide prescriptive means to attach cladding over exterior insulation
  - Table R704.3 – Note v: Minimum nail length must accommodate sheathing and penetrate framing a minimum 1 ½ inches.
- Current pneumatic nailers have maximum fastener lengths of 3” to 3.5” which limits insulation thicknesses to 1.5” max
  - 3.5” fastener, ¼” to ½” siding, 1 ½” embedment (3.5-0.5-1.5 = 1.5” max insulation)
- Therefore, for insulation 1.5” or less – direct attachment of cladding though insulation back to the structure is often practical

Problem Context

- For insulation greater than 1.5” – a secondary cladding support system is often needed.
- Current Building Codes do not provide any prescriptive means to use a secondary support structure for cladding attachment
- Without prescriptive code provisions, cladding support systems need to be designed (historically done with poor thermal performance and high cost) or pre-engineered solutions need to be used (generally higher cost)
Cladding Support System: Direct Attachment Through Insulation

Technical Approach

- Need to develop a means to attach cladding over thick layers of exterior insulation that can meet the following requirements:
  - Provides good thermal performance
  - Low cost
  - Easy to construct/install (low cost)
“Myths”

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

…..Unfortunately that is the wrong question

Typical Loads

- Typical cladding weights (psf)

<table>
<thead>
<tr>
<th>Material</th>
<th>low</th>
<th>high</th>
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</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>
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<tr>
<td>stucco</td>
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<td>12.0</td>
</tr>
<tr>
<td>adhered stone veneers</td>
<td>17.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Typical Loads 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>
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<tr>
<td>vinyl</td>
<td>1.8</td>
<td>2.7</td>
<td>4.0</td>
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<tr>
<td>wood</td>
<td>2.7</td>
<td>4.0</td>
<td>6.0</td>
</tr>
<tr>
<td>fiber cement</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

- 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

Discrete Load Components

Direct Attachment Through Insulation

- Theorized Load Components
  - Dependent on material properties
    - Strength of fasteners
    - Compressive strength of insulation
    - Coefficient of friction between layers
  - Dependent on boundary conditions
    - Pre-compression of insulation due to tightening of fasteners
Material Properties

Boundary Conditions

- Pre-compression 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
  - Forces relax over time
  - Affected by environmental conditions

Direct Attachment Through Insulation

*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
Forces relax over time
Affected by environmental conditions*
Discrete Load Component Testing

- Small Scale Discrete System Tests
  - Intent to evaluate individual force resistance components
    - Screw bending/wood bearing
    - Strut and tie model
    - Friction between layers

Discrete Load Component Tests

- System loaded with air gap between furring and wall
Discrete Load Component Testing

- System loaded with 4” of rigid mineral fiber insulation between furring and wall

Results

- Friction loads can be a large component of the total load depending on pre-compression forces and normal forces imposed by the strut and tie model
- Strut and tie provides additional capacity but requires rotation of the fastener to engage the compression of the insulation
- Screw bending and bearing capacity is low compared to other mechanisms

Full Scale Assembly Testing
Full Scale Testing

- Short Term and Long Term Deflection Testing
- Multiple insulation types
  - EPS
  - XPS
  - Foil faced polyisocyanurate
  - Rigid mineral fiber

Full Scale Testing

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

Full Scale Testing

- Multiple thicknesses
  - 1/64”
  - 1/32”
  - 1/16”
  - 1/8”
- Adhered stone veneers
- Stucco
- Fiber cement
- Wood
- Vinyl
Full Scale Testing

- **8" insulation thickness**
- **1/64" to 1/16" adhered stone veneers**
- **1/200"**
- **~1/64" to 1/16" stucco**
- **1/16" 1/8" fiber cement**
- **1/32" 1/64" 1/128" wood**

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

![Graph showing deflection over time for heavy weight claddings with different insulation thicknesses and loads.](image)

- **EPS 20psf**
- **XPS 20psf**
- **PIC 20psf**
- **Roxul 20psf**
- **Temperature (F)**
- **RH (%)**

![Graph showing temperature and relative humidity over time.](image)
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
- Need to examine the performance of these systems in exposed environments

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

Diurnal Movement of the Furring Strip with Respect to the Stud Framing (recorded over a three day period)

Temperature and Relative Humidity (°F, %)

Relative Deflection (in)

Deflection-T-Corrected (in)

Lightweight cladding (8lbs/fastener) movement over time

Temperature (°F) / Relative Humidity (%)

MF and PIC assemblies loaded at this time

Material Types:
- XPS 1
- EPS 1
- MF 1
- PIC 1

XPS 1

EPS 1

MF 1

PIC 1
Testing Results

- Movement due to environmental exposure can be significant (measured 1/32" in a single day)
- Lightweight claddings appear to be relatively stable
- Creep is a significant factor in heavier claddings
Industry Impacts

- 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”? 1/8”?
  - Brittle claddings ~1/64”? 1/32”? more?

Industry Impacts

- Movements due to environmental exposure may exceed proposed limits.
  - More research is needed to understand how much typically cladding systems move under environmental exposure
- Expansion and contraction of materials may impact system forces such as friction and the strut and tie
  - functions may need to be removed for design of the system capacity (ie. designed capacity based on fastener bending only or other structural connection)

Recommendations
Recommendations

- System performs well for lightweight claddings (5psf or less)
- Medium weight (5psf to 10 psf) and heavy weight claddings (10 psf to 25psf or greater) may need more design
  - Increase number of fasteners
  - Add a shear block or other structural attachment
- Code proposal should be developed that is based on acceptable deflection not ultimate capacity

Questions?

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