Exterior Insulation: Strategies and Cladding Attachment

Overview

- Building Insulation Retrofit Strategies
- Exterior Insulation Approaches
  - Insulation and Separate Cladding
  - Exterior Insulation and Finish System (EIFS)
  - Insulated Metal Panels
- Cladding Attachment Research

Insulation Retrofit

- Existing buildings are often un-insulated/poorly insulated
- Insulation options are:
  - Cavity fill
  - Interior insulation
  - Exterior insulation
Exterior Insulation and Cladding Attachment

**Cavity Fill Insulation**
- Cavity fill insulation is most common retrofit – but has limitations
  - 4” cavity for older wood frame
  - ¾” cavity for mass masonry

**Interior Insulation**
- Interior insulation retrofit concerns
  - Continuity of insulation (partition walls, floors, etc.)
  - Loss of floor space
  - Occupant disruption
- Desirable if exterior appearance is needed/wanted to be maintained
- Often the best approach for historic buildings
- Not ideal from a building physics perspective

**Exterior Insulation**
- Exterior insulation retrofit
  - Ideal from a building physics perspective
  - Can be completed with less disruption to occupants
  - May come at a higher cost than other approaches

**Exterior Insulation**
- New approach!
- New approach?
- Not a new approach...
- Pesky Canadians...
- Benefits discussed in Canadian Building Digests produced by the National Research Council of Canada in the 1960’s
Exterior Insulation

- CBD 44 (W.P. Brown, A.G. Wilson) – Published in 1963

“Application of insulation over the entire exterior of a wall provides an ideal solution to the problems presented by thermal bridges.”

“It should be stressed that many of the thermal bridges occurring in present-day construction can be avoided, or their effects minimized, if they are recognized in the early stages of design.”

Exterior Insulation

- The “Perfect” Wall

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

Exterior Insulation and Cladding Attachment

1980s ON – a “weird” builder

1990s ON – a “good” builder
2000s ON – a “typical” builder

Exterior Insulation Approaches

- Insulation and cladding (discrete components)
- Exterior Insulation and Finish System (EIFS)
Exterior Insulation Approaches

- Insulation and cladding (discrete components)
- Exterior Insulation and Finish System (EIFS)
- Insulated Metal Panels (IMP)
  - Used as a complete enclosure

Exterior Insulation Approaches

- Insulation and cladding (discrete components)
- Exterior Insulation and Finish System (EIFS)
- Insulated Metal Panels (IMP)
  - Used as a complete enclosure
  - Used as an insulated cladding

Brick Veneer

- Brick veneer has some of the longest history with exterior insulation
  - Long history = more common
  - More common = less questions
- Not always well done

Brick Veneer

"The Ugly"  
"The Bad"  
"The Good"
Alternate details and support options exist
Support systems for brick can be modified for other building elements
- Decks
- Balconies
- Canopies
- Etc.
**Other Claddings**

- For insulation less than 1.5” – direct attachment of cladding through insulation back to the structure is practical
- For insulation greater than 2” – a secondary cladding support structure is often needed.

**Other Claddings**

- Lighter weight claddings (metal/wood/fiber cement)
  - Less common = less experience
  - Less experience = more questions
- Cladding support systems historically done poorly
- Systems are getting better
Other Claddings

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

• 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”
Other Claddings

- 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
**EIFS**

- Exterior Insulation and Finish System (EIFS)
  - Lightweight
  - Cost effective
  - Water managed
- Minimal Thermal Bridging
- R-4 per inch
- System has a tainted history

**Insulated Metal Panels**

- Insulated Metal Panels (IMP)
  - Lightweight
  - Moderate cost
  - Water managed
- Minimal Thermal Bridging
- R-7.5+ per inch
- Can be an excellent enclosure system
- Requires some consideration for retrofit applications
Insulated Metal Panels

- Can be used as both a complete enclosure system
- Can also be used as an insulated cladding system

Insulated Metal Panels

- Attachment often to metal hat channel or z-furring
  - In retrofit applications out of plane walls can require special adjustable systems or shims

Insulated Metal Panels

- IMP as a complete enclosure system
  - Provides all enclosure functions into a single system
  - System design as intended by panel manufactures
Insulated Metal Panels

- IMP as a complete enclosure system
  - May require special detailing for compartmentalization at floors or partition walls, particularly in retrofit applications

Insulated Metal Panels

- IMP as an insulated cladding system
  - Provides thermal insulation and cladding
  - Rain water management and air tightness are provided by other elements
  - Modification to manufacturers intended design

Insulated Metal Panels (Retrofits)

- IMP as an insulated cladding system
  - Need to fill space between the panel and back up wall to prevent air by-pass of the insulation
  - Can simplify certain details such as interfaces at balconies, lower roofs, and compartmentalization
  - More in line with common construction detailing

Cladding Support System:
Direct Attachment Through Insulation
Exterior Insulation and Cladding Attachment

**Background**

- Industry trend to using exterior rigid insulation
  - Increased thermal value
  - Condensation resistance
  - Increased air tightness (possibly)
  - Increased rainwater management (possibly)
- 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)

**Direct Attachment Through Insulation**

**Wood structure**
- 2” to 4” of exterior rigid insulation
- 1x3 wood furring strips

**Masonry Structure**
- 2x4 framing attached to surface of masonry
- 2” to 4” of exterior rigid insulation
- 1x3 wood furring strips

**Background**

- 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 greater than 1.5” direct attachment of cladding though the insulation back to the structure is often not practical
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
  - Compression resistance of insulation
  - Long term creep

“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

“Myths”

- “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

Typical Loads

- 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>
### Typical Loads

- 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>4.0</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>

### Design Criteria

- Acceptable deflection not ultimate capacity governs
- What is acceptable deflection?
  - Movement a cladding system can accommodate without physical damage or exceeding aesthetic tolerances
- Proposed limit of $1/16"$ vertical deflection

### BSC Cladding Attachment Research

- Began in 2011
- Looking to expand on previous research
- Broken into two sections:
  - Mechanics of the cladding attachment system
  - Long term environmental exposure

### Full System Laboratory Tests

- Looked at initial response full system capacity as well as long term sustained loading
- Used full scale samples to limit variations in fastener installation
Full System Laboratory Tests

- **Results**
  - Insulation type not a significant influence on system capacity
  - System capacity is a function of the number of fasteners used
  - High measured capacities and stable performance under controlled environmental conditions

---

Full System Laboratory Tests

- **System Mechanics**
  - Shear and rotational resistance provided by fastener to wood connections
  - Rotational resistance provided by tension in fastener and compression of the insulation
  - Vertical movement resistance provided by friction between layers
Exterior Insulation and Cladding Attachment

- **Screw Bending**
  - Cantilever
  - Double Bending
  - Screw Shaft Bearing

  - Double bending resistance was significantly higher (~4 times) than simple cantilever.
  - Double bending is more in line with the expected performance of the assemblies but still only accounted for a fraction of the total measured system capacity.
  - Screw shaft bearing on the insulation was hard to quantify, but appeared to be significant in short term (initial response) tests.

Exterior Insulation and Cladding Attachment

- **Screw Bending**

Exterior Insulation and Cladding Attachment

- **System Friction**
  - Compression Forces
  - Coefficients of Friction
System Friction

- Compression Forces were measured at around 150lbf/fastener to drive a #10 wood screw flush with face of furring
- Coefficients of frictions were typically around 0.25
- Compression forces were also measured to drop off over time (around 20% to 30%) after initial loading and be highly sensitive to environmental conditions

Compression Strut

- Function of fastener tension and insulation compression
- Measured insulation compression properties
- Difficult to measure directly
  - Fastener bending present
  - Hard to create a "frictionless" system
- May have a more significant contribution in the form of additional friction than compression resistance

Exterior Exposure Testing

- Looked at long term movement of systems under sustained loads in an exposed environment

Exterior Exposure Testing

- Vertical deflection movement of a wood furring strip loaded to 8lbs/fastener over time in an exposed environment
Exterior Exposure Testing

Vertical deflection movement of a wood furring strip (loaded to 15lbs/fastener) over time in an exposed environment

Date

Temperature (F) / Relative Humidity (%)

XPS  EPS  MF  PIC  Temperature  RH

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

Deflection – T Corrected (in)

Deflection – T Ambient Air Temperature (°F)

Deflection – RH Relative Humidity (%)

Conclusions (System Mechanics)

- Initial load response measurements are on the order of 40 to 50lbffastener at 1/16” deflection and 4” of insulation
- Insulation type does not appear to be overly significant
- Capacity is a function of the number of fasteners used.
- Capacity would be expected to increase for less insulation due to higher fastener component at a smaller cantilever
- Friction component is significant, but highly variable due to initial clamping magnitudes and thermal expansion and contraction of materials
- Compression strut component is present, however the magnitude of the impact is difficult to quantify.

Exterior Exposure Testing

Vertical deflection movement of a wood furring strip (loaded to 30lbs/fastener) over time in an exposed environment

Date

Temperature (F) / Relative Humidity (%)

XPS  EPS  MF  PIC  Temperature  RH

Relative Deflection (in)

Time and Date (hours/day)

Deflection – T Ambient Air Temperature (°F)

Deflection – RH Relative Humidity (%)

Relative Deflection (in)

Exterior Exposure Testing

Exterior Insulation and Cladding Attachment
Conclusions (Long Term Exposure)

- System creep was apparent at high per fastener sustained loading (30lbs/fastener)
- At low per fastener loads (8lbs/fastener) the system demonstrated stable performance
- At moderate per fastener load (15lbs/fastener) the system demonstrated relatively stable performance, though there is some possible slight indication of system creep

Recommendations

- Based on the results of the testing it is currently recommended to use a maximum load per fastener of no more than 10lbs for up to 4” of insulation

| Vertical fastener spacing (in) per cladding weight |
|-------------------|------------------|------------------|
| Cladding weight (psf) | 16” oc Furring | 24” oc Furring |
| 5                  | 18               | 12               |
| 10                 | 9                | 6                |
| 15                 | 6                | 4                |
| 20                 | 4                | 3                |
| 25                 | 3                | 2                |