Peter Baker

Exterior Insulation: Strategies and Cladding Attachment

November 16, 2017

Building Science Corporation

AIA New Hampshire

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 Options

Insulation Retrofit

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

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

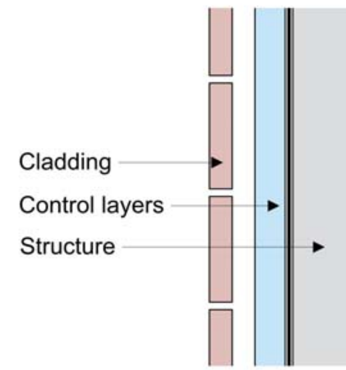
"Application of insulation over the entire exterior of a wall provides an ideal solution to the problems presented by thermal bridges."

"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?



Building Science Corporation Exterior Insulation and Cladding Attachment

1980s ON – a "weird" builder

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1990s ON – a "good" builder

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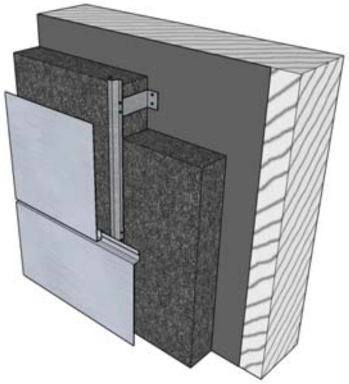
2000s ON – a "typical" builder

Exterior Insulation Approaches

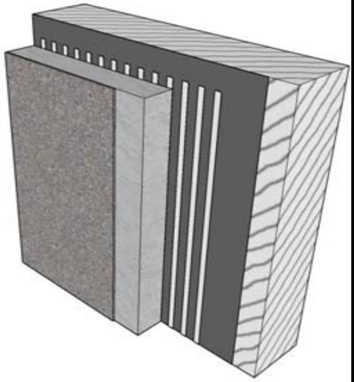
Exterior Insulation Approaches

- Insulation and cladding (discrete components)



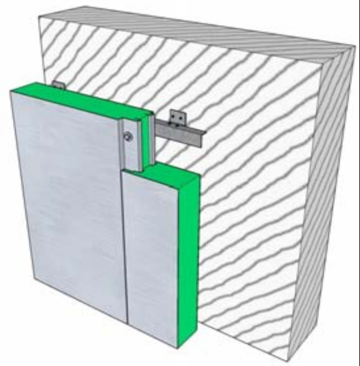
Exterior Insulation Approaches

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



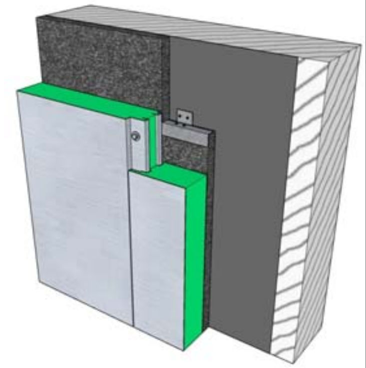
Exterior Insulation Approaches

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



Exterior Insulation Approaches

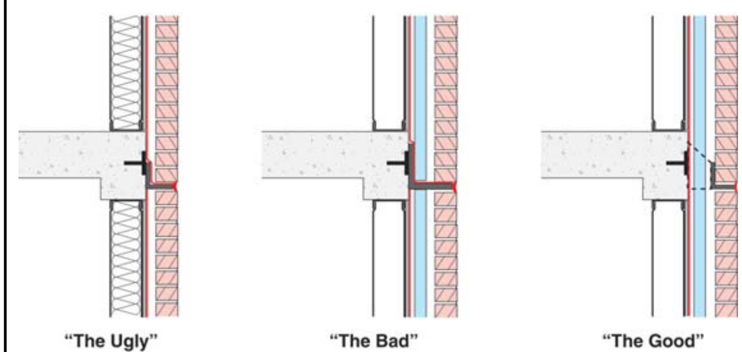
- Insulation and cladding (discrete components)
- Exterior Insulation and Finish System (EIFS)
- Insulated Metal Panels (IMP)
  - Used as a complete enclosure
  - Used as an insulated cladding



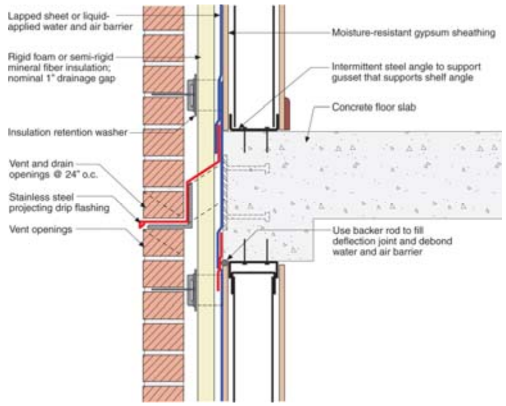
Brick Veneer

- 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



Brick Veneer



Building Science Corporation Exterior Insulation and Cladding Attachment

Brick Veneer

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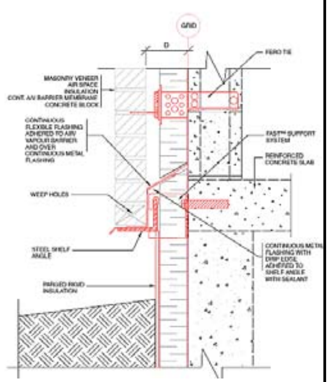

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Brick Veneer

- Alternate details and support options exist
- Support systems for brick can be modified for other building elements
  - Decks
  - Balconies
  - Canopies
  - Etc.

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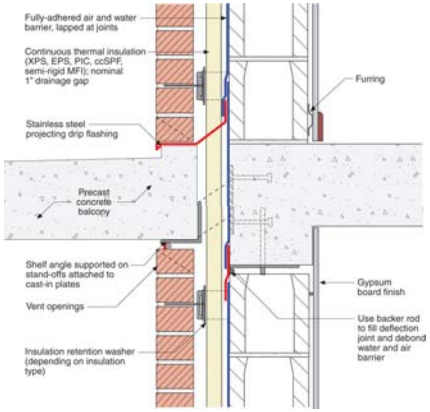
Brick Veneer



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Brick Veneer

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Other Claddings

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

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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

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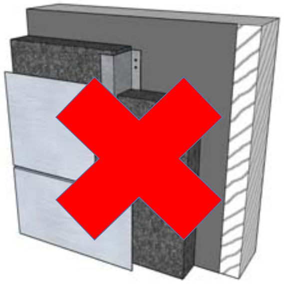
Other Claddings

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



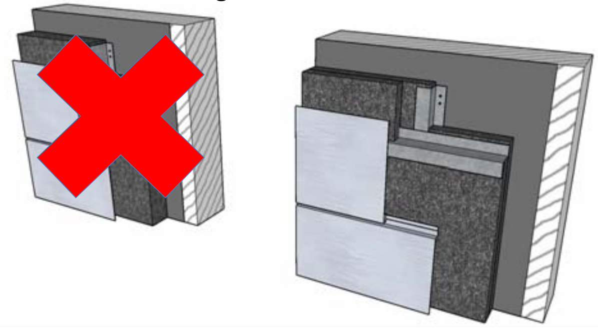
Other Claddings

Other Claddings

- 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”

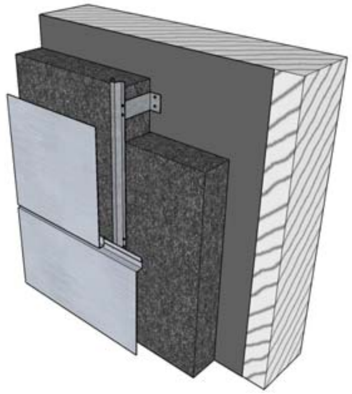
Other Claddings

- Single “z-furring”
- Double “z-furring”



Other Claddings

- Single "z-furring"
- Double "z-furring"
- Clip and "z-furring" or hat channel
  - Metal clip
  - Fiberglass clip



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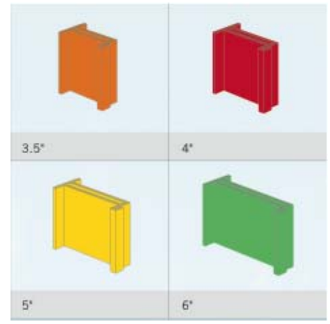
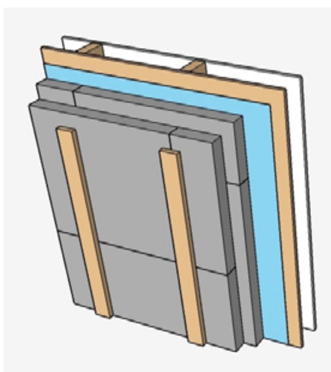


Other Claddings

- 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



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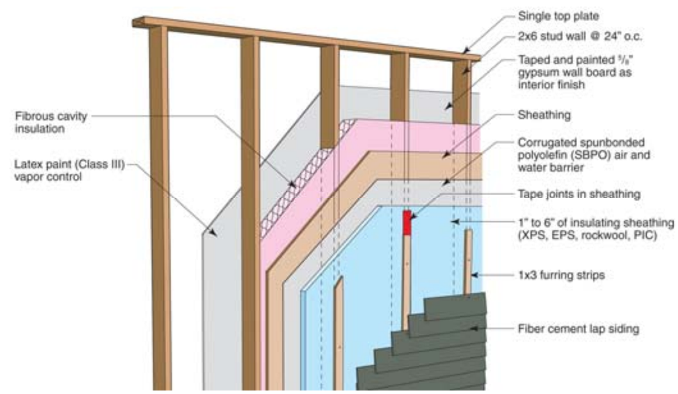
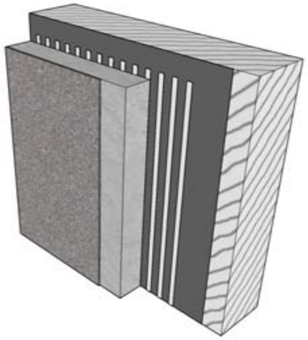


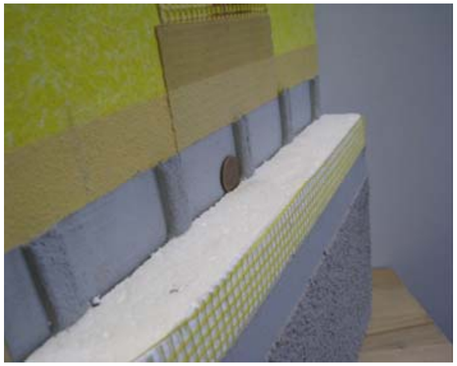
EIFS

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



EIFS

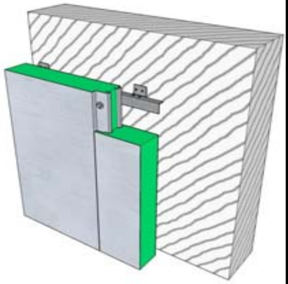
- Commonly installed using adhesive
- The adhesive can also form the drainage gap in water managed systems



EIFS

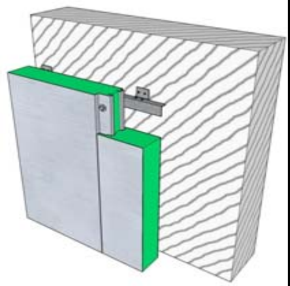
Insulated Metal Panels

- 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



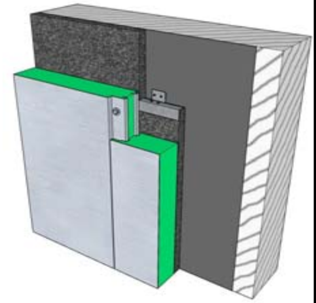
Insulated Metal Panels

- Can be used as both a complete enclosure system



Insulated Metal Panels

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

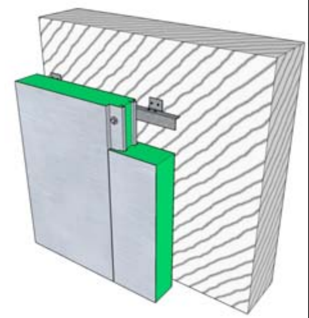


Insulated Metal Panels

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

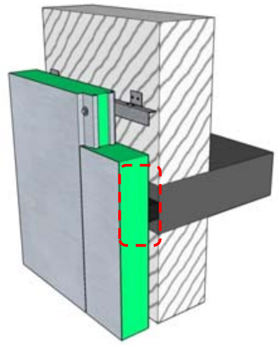
Insulated Metal Panels

- 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



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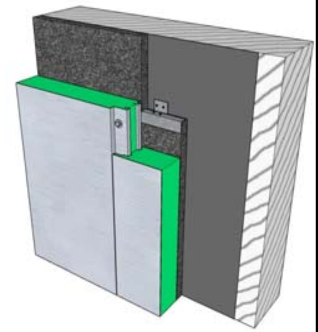
Insulated Metal Panels

- 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



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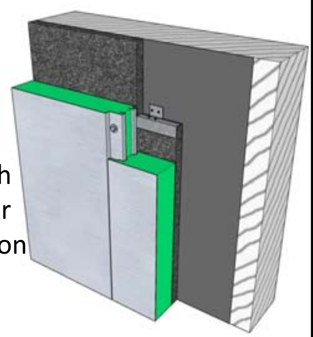
Insulated Metal Panels (Retrofits)

- 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



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Cladding Support System: Direct Attachment Through Insulation

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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)

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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

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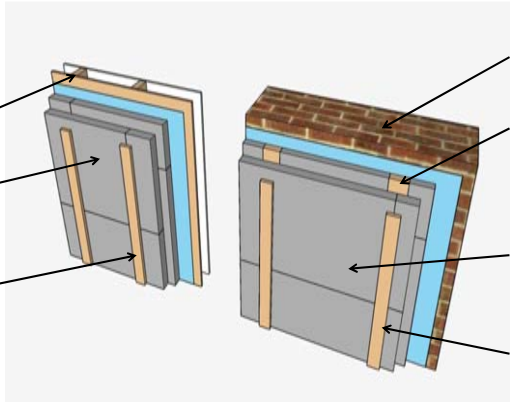
Direct Attachment Through Insulation

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

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Direct Attachment Through Insulation

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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)

	low	high
Vinyl	0.6	1.0
wood	1.0	1.5
fiber cement	3.0	5.0
stucco	10.0	12.0
adhered stone veneers	17.0	25.0

Typical Loads

- Typical weights per fastener (lbs)

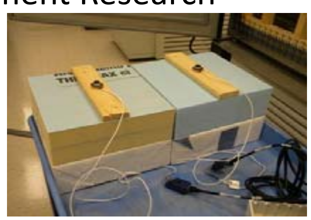
fastener spacing (in)	16" x 16"	16" x 24"	24" x 24"
area/fastener (ft2)	**1.78**	**2.67**	**4**
vinyl	1.8	2.7	4.0
wood	2.7	4.0	6.0
fibercement	8.9	13.3	20.0
stucco	21.3	32.0	48.0
adhered stone veneers	44.4	66.7	100.0

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

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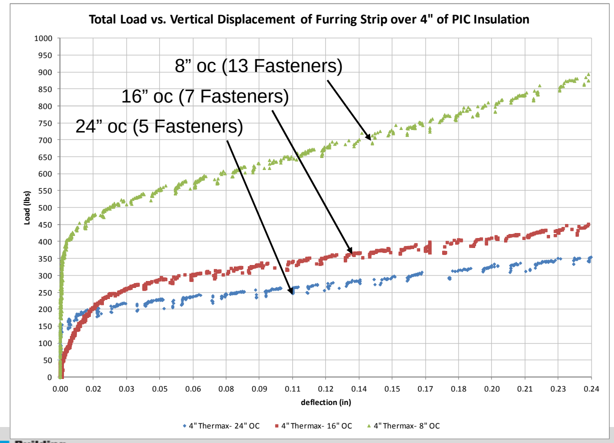
Full System Laboratory Tests



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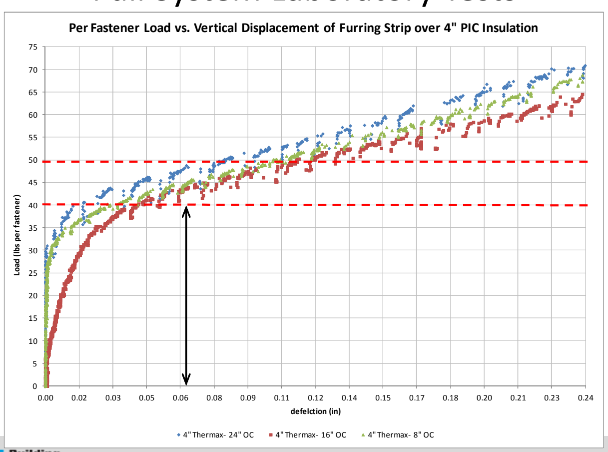

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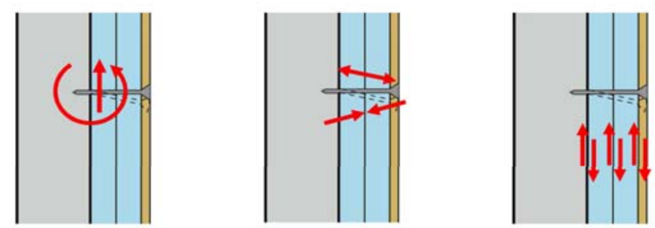
BSC Cladding Attachment Research

- 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

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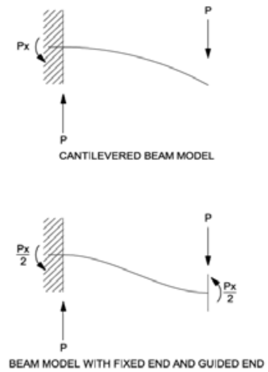
Screw Bending

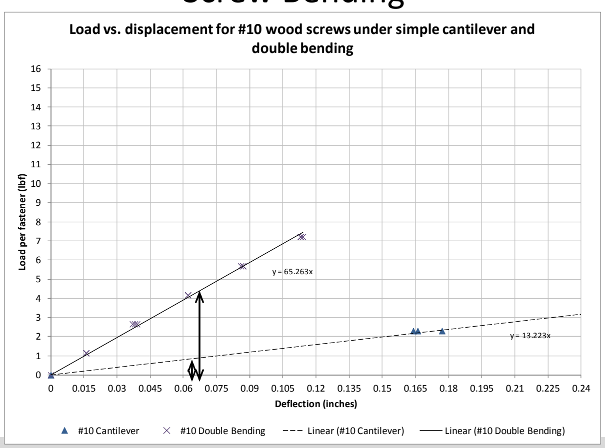
- Cantilever
- Double Bending
- Screw Shaft Bearing



Screw Bending

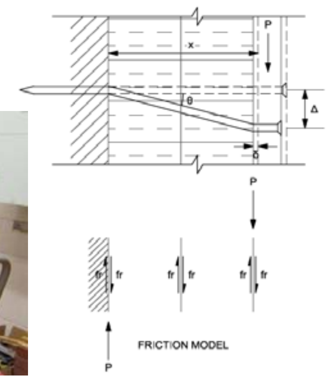
- Double bending resistance was significantly higher (~4 times) than simple cantilever.
- Double bending is more in line with the expected performance of the assemblies but still only accounted for a fraction of the total measured system capacity
- Screw shaft bearing on the insulation was hard to quantify,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

Screw Bending



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

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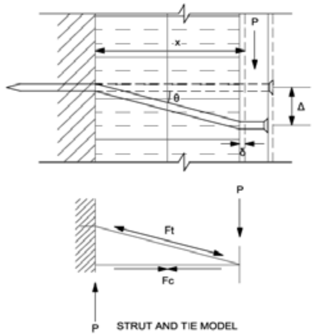
Compression Strut

- 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



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Exterior Exposure Testing

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

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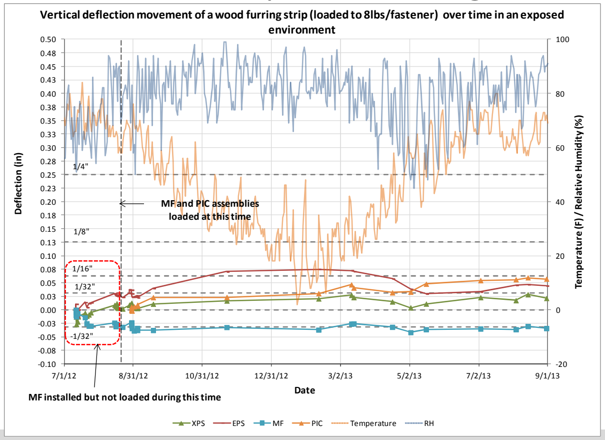
Exterior Exposure Testing



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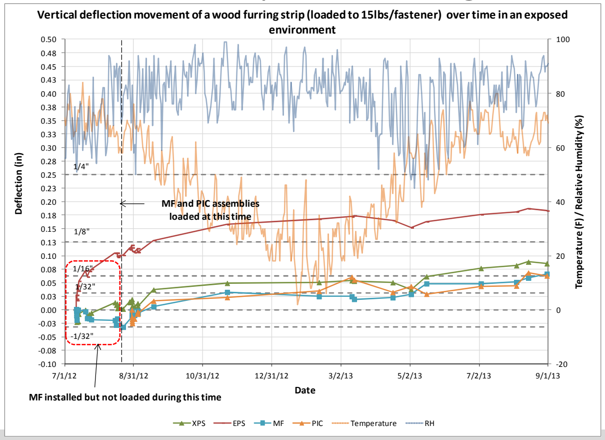

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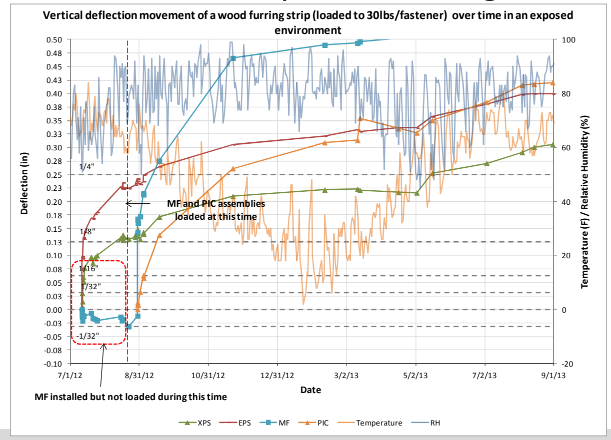

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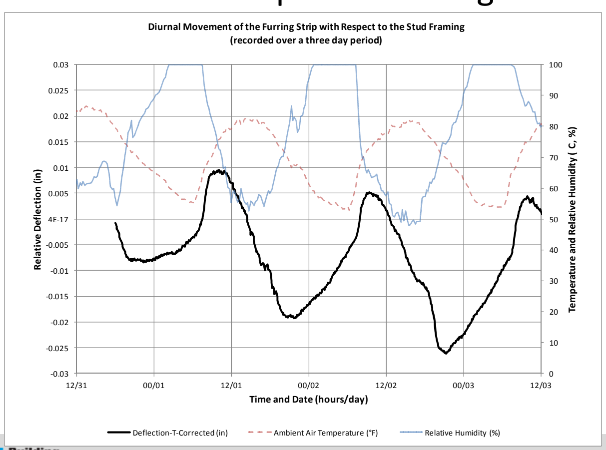
Exterior Exposure Testing



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Conclusions (System Mechanics)

- Initial load response measurements are on the order of 40 to 50lbf/fastener 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.

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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