Structural and Hygrothermal Field Monitoring of Thick Continuously Insulated Wall Assemblies Utilized in a Multi-Story Residential Building

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Agenda

- Continuous Insulation
- Vancouver BC Case Study
- Retrofit Structural Design
- Measurements
- Conclusions
Continuous Insulation Hypothesis

- A ci rain screen wall system with:
  - 7/8” Z-girts located 16” oc
  - Attached outboard of insulation with 4 ½” #10 self tapping corrosion resistant screws every 6” oc
- Provides a structurally robust wall
- Dimensionally stable
- Complies with ASHRAE 90.1

Vancouver BC Case Study – Before

Original Wall System
- Cement stucco with wire lath
- Semi-rigid fiberglass insulation (~ one inch thick)
- 3½ inch steel studs with fiberglass batt insulation infill
- Polyethylene air/vapor barrier
- ½ inch interior drywall
Vancouver BC Case Study – After

New (Rehabilitated Wall System)

- ⅜ inch acrylic stucco on paper backed lath
- ⅜ inch Z-girts at 16 in oc fastened with self-tapping screw fasteners at 6 in oc
- 3 in Type 4 rigid insulation (R15) with taped joints
- SA Membrane
- ½ inch fiberglass faced exterior gypsum sheathing
- Existing 3½ inch steel studs
- Existing ½ inch interior drywall

Structural Design

- Wind and gravity loads are transferred from the exterior through the vertical Z girts to the insulation and back up wall
- Rigid girt spreads gravity and wind load onto rigid insulation
- Gravity load puts a tension load on the fastener since rotation is constrained by insulation (fastener cannot rotate unless foam compresses) and a shear load
- Wind and gravity put a compression load on the rigid insulation or tension load on fastener
Scott to summarize into 1 or 2 slides
u369852, 29/02/2012
Background Work

- **Why are we comfortable doing this?**
- **What has Dow done in the past?**
  - Dow/Knight Kishwaukee College (see case study) plus others in design and construction.
  - “Strategies to Successfully Meet the New Energy Codes Using Foam Plastic Continuous Insulation” Jeff Hansbro, Dow Chemical
  - “Requirements for attaching Thermax ci Exterior Insulation and 3 Coat Stucco Cladding to Steel Stud Walls” TER Report – Dow Building Solutions & Jay Crandall, ARES Consulting
- **What has JRS done in the past?**
  - Burien Towne Square in Washington State, Several wood framed buildings, similar roof systems (metal over continuous XPS or polyiso), testing with Knight Wall

Validated Finite Element Modeling

**1.55” PIR ci exterior insulation** - Fastener Spacing : 16” on edge, 16” on field

Failure criteria for CAE: max. displacement = 1” at any point on the insulation (air leakage results in pressure drop in test)

- Max pressure: Test – 67 MPa
- CAE – 76 MPa

Displacement, in
Research Questions

- What is the dimensional performance of a retrofit wall system designed with only cladding attachment screw penetrations through the insulation?
- What is the hygrothermal performance of the system?

Measurement – Instruments

**Displacement**
- BI Technologies Model BI-404 linear displacement sensors
- Accuracy 0.085 mm +/- 5%

**Hygrothermal**
- Relative Humidity Sensor Humirel HTM2500
- CANTHERM MF52 Thermistor
Measurement–Location and Installation

N Elevation

Y Direction Measurements

Vertical Displacement (2nd floor, North)
**Y Direction Measurements**

Vertical Displacement (2nd floor, South)

- Range 0.9 mm
- Range 0.5 mm
- Delta 0.5 mm

**X Direction Measurements**

2nd floor, South

- Range 0.9 mm
- Range 0.4 mm
North Facade vs. South Facade

Vertical Displacement Measurements of N and S Panels

Thermal Expansion, Correlation to CTE

<table>
<thead>
<tr>
<th>Material</th>
<th>Coefficient of Thermal Expansion (mm/K)</th>
<th>Coefficient of Thermal Expansion (in/°F)</th>
<th>ΔT=35°C ∆L over 1.2m (48&quot;)</th>
<th>ΔT=22°C ∆L over 1.2m (48&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortar (Stucco)</td>
<td>(7.3-13.5) x 10^-6</td>
<td>(4.1-7.5) x 10^-6</td>
<td>0.3mm-0.55mm</td>
<td>0.19mm-0.36mm</td>
</tr>
<tr>
<td>Steel</td>
<td>13.0 x 10^-6</td>
<td>7.2 x 10^-5</td>
<td>0.54mm</td>
<td>0.34mm</td>
</tr>
<tr>
<td>XPS, Polyiso, EPS</td>
<td>62.7 x 10^-5</td>
<td>35 x 10^-5</td>
<td>2.63mm</td>
<td>1.65mm</td>
</tr>
</tbody>
</table>
Displacement vs Temperature

Correlation coefficient = 0.18

Displacement vs Temperature

Correlation coefficient = 0.19
Displacement vs Temperature

Correlation coefficient = 0.14

Hygrothermal Performance

North Wall
Hygrothermal Performance

Conclusions

- The ci rain screen system is a structurally robust wall and complies with ASHRAE 90.1.
- X,Y,Z displacement ranges are negligible and not dependent on measurement location.
- Temperature-displacement correlation is poor.
- Hygrothermal performance confirmed to be good, with low condensation risk.
- No stucco performance problems have been reported to date.
Future Work

- More thorough understanding of temperature observations
- Research expected movement of foamed plastic insulation due to differential temperature conditions and under restraint.
- Establish structural design parameters for designing rigid foam to support cladding and to withstand compression and bending loads that will vary depending on the design approach taken.

Thank You