Building Solutions
A business unit of Dow Advanced Materials Division

Structural Field Monitoring and Modeling of Thick Continuously Insulated Wall Assemblies

Gary Parsons
July 28th, 2012
Agenda

- Brief Overview of Finite Element Modeling
- Vancouver BC Case Study
Development of Screw Connection FE Model
1-D Beam Models of Two Fasteners with PIR foam

#6 x 1-5/8" (US-1) screw

- Load, lbf
- Crosshead displacement, in

- Pull out
- Shear (bending)
Wind Pressure Testing – PIR ci 1.55”

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
FE Model of 3-coat Stucco clad PIR ci Wall

- Interior Gypsum
- Steel Framing
- ‘ci’ Layer
- Building Paper Bond Break
- Woven Wire Lath
- 3-Coat system per ASTM C926
Gravity Load Case for 3-coat Stucco clad PIR ci Wall

Maximum vertical displacement (CAE)
Washer contact model - 2.25 mm
Direct connection model - 0.5 mm

Maximum vertical displacement
Test value (creep test) – 0.04 mm

Maximum stress in foam
0.05 MPa
(1/3 of foam yield stress)
Creep Testing under Gravity Load

- Creep displacement of the stucco with respect to foam is of the order of 0.04 mm after a period of about two months.
Vancouver Case Study
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)**

- ⅞ inch acrylic stucco on paper backed lath
- ⅛ 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 peel and stick flashing at 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 through exterior 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.
Displacement Measurement

BI Technologies
Model BI-404 linear displacement sensors.
Accuracy 0.085 mm +/- 5%
Measurement—Location and Installation

N Elevation
Y Direction Measurements

Vertical Displacement (2nd floor, South), mm
Y Direction Measurements

Y Displacement (2nd floor, South), mm

Range 0.9
Range 0.5
Range 0.5
X Direction Measurements

2nd floor, South, mm
North Facade vs. South Facade

Vertical Displacement Measurements of N and S Panels, mm

Range 0.4
Range 0.5
Range 0.9
## Thermal Expansion & Correlation to CTE

<table>
<thead>
<tr>
<th>Material</th>
<th>Coefficient of Thermal Expansion (m/m K)</th>
<th>Coefficient of Thermal Expansion (in/in F)</th>
<th>( \Delta T=35^\circ C ) ( \Delta L ) over 1.2m (48”)</th>
<th>( \Delta T=22^\circ C ) ( \Delta L ) over 1.2m (48”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortar (Stucco)</td>
<td>(7.3-13.5) ( \times 10^{-6} )</td>
<td>(4.1-7.5) ( \times 10^{-6} )</td>
<td>0.3mm-0.57mm</td>
<td>0.19mm-0.36mm</td>
</tr>
<tr>
<td>Steel</td>
<td>13.0 ( \times 10^{-6} )</td>
<td>7.2 ( \times 10^{-6} )</td>
<td>0.54mm</td>
<td>0.34mm</td>
</tr>
<tr>
<td>XPS, Polyiso, EPS</td>
<td>62.7 ( \times 10^{-6} )</td>
<td>35 ( \times 10^{-6} )</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
Conclusions

- Vancouver Project
  - X,Y,Z displacement ranges are negligible and not dependent on measurement location.
  - Temperature-displacement correlation is poor.
  - No stucco performance problems have been reported to date.

- Modeling and Validation
  - FEA modeling correlates reasonably well to connection scale tests
  - FEA modeling over predicts movement of test assemblies
Questions?