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

Gary Parsons – The Dow Chemical Company
Jeff Hansbro -The Dow Chemical Company
Craig Buck -The Dow Chemical Company
Scott Croasdale -JRS Engineering
Joel Schwartz -JRS Engineering

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



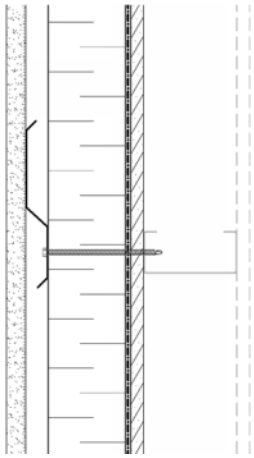
Original Wall System

- 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

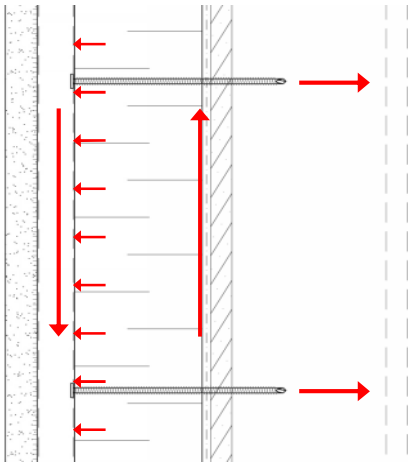
New (Rehabilitated Wall System)

- ⅞ inch acrylic stucco on paper backed lath
- ⅞ 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



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Slide 6

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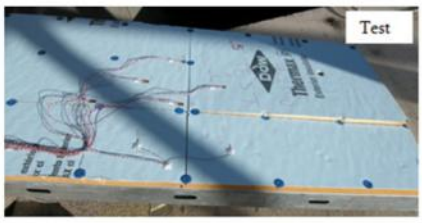
Scott to summarize into 1 or 2 slides
u369852, 29/02/2012

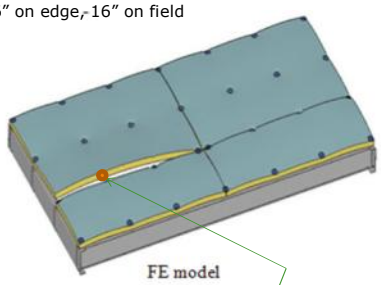
Background Work

- **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*

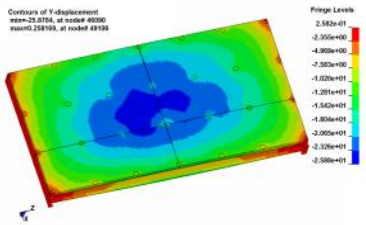
Validated Finite Element Modeling

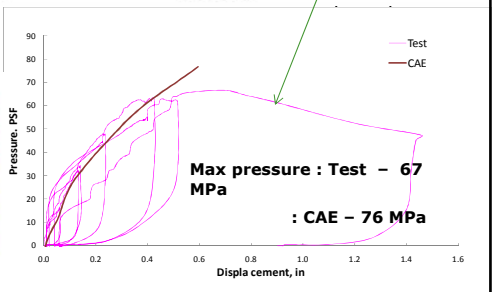
1.55" PIR ci exterior insulation - Fastener Spacing : 16" on edge, 16" on field





Failure criteria for CAE – max. displacement ≈ 1" at any point on the insulation (air leakage results in pressure drop in test)





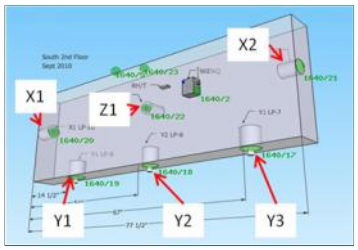
Research Questions

- **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%



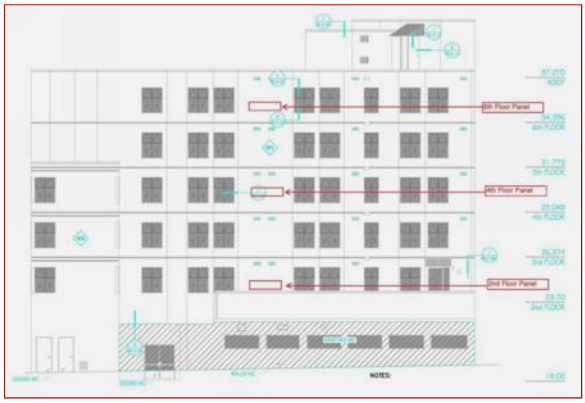
Hygrothermal

Relative Humidity Sensor Humirel HTM2500

CANTHERM MF52 Thermistor

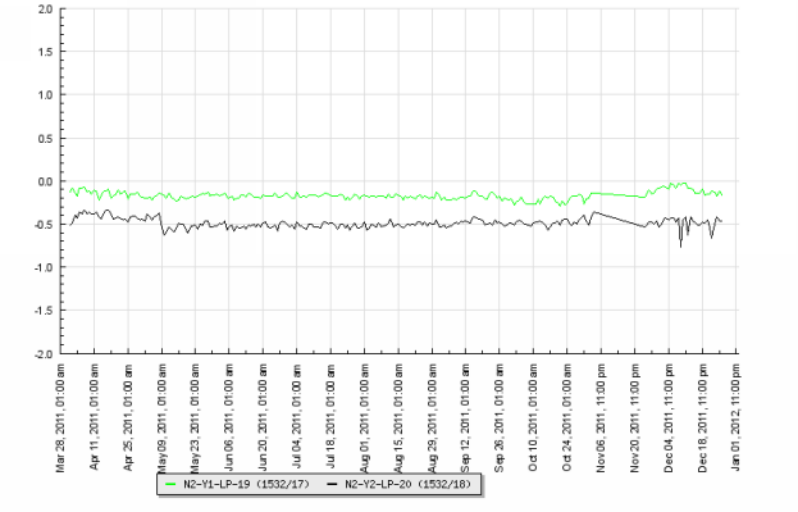
SMT Structure Monitoring Technology

Measurement–Location and Installation



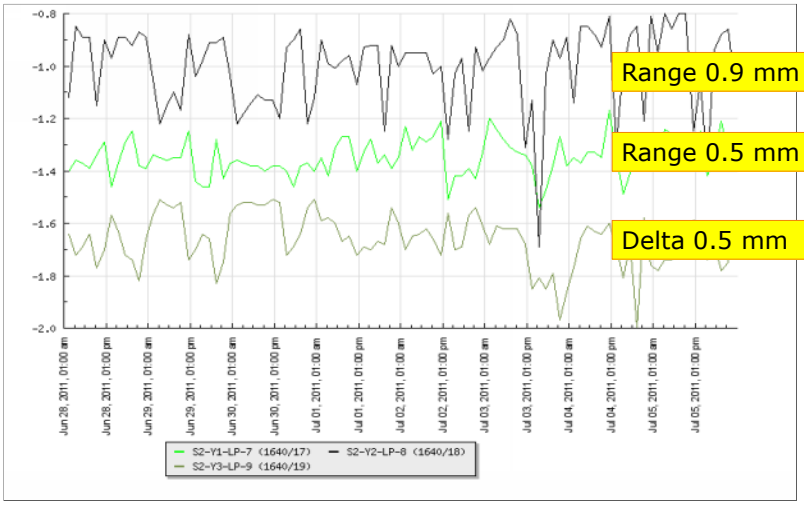
N Elevation

Y Direction Measurements



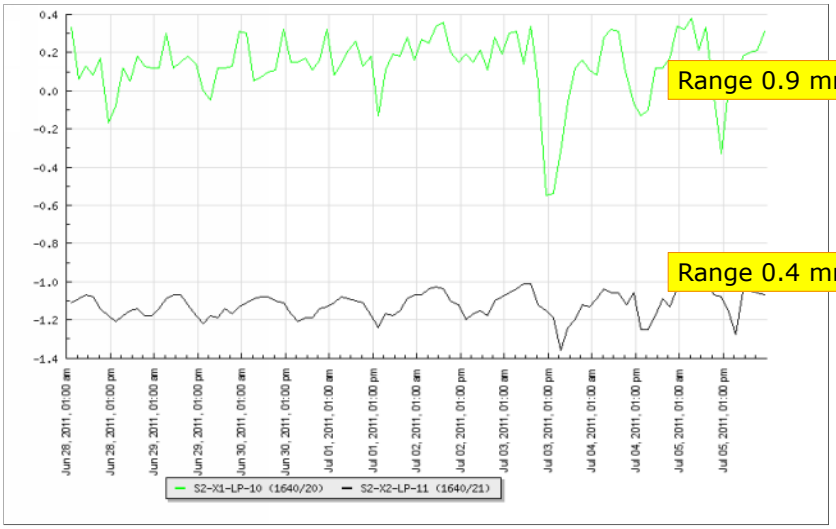
Vertical Displacement (2nd floor, North)

Y Direction Measurements



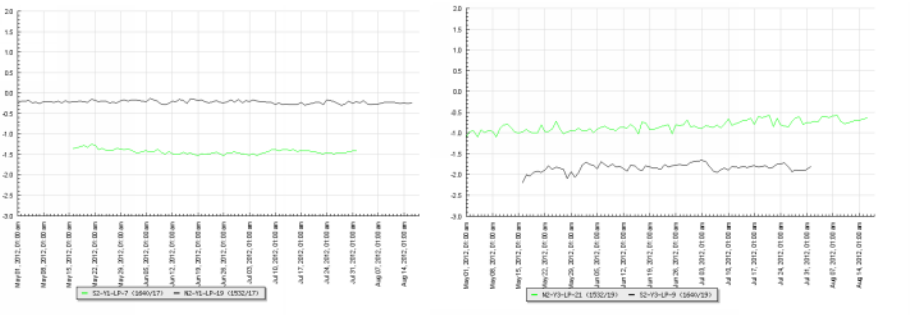
Vertical Displacement (2nd floor, South)

X Direction Measurements



2nd floor, South

North Facade vs. South Facade

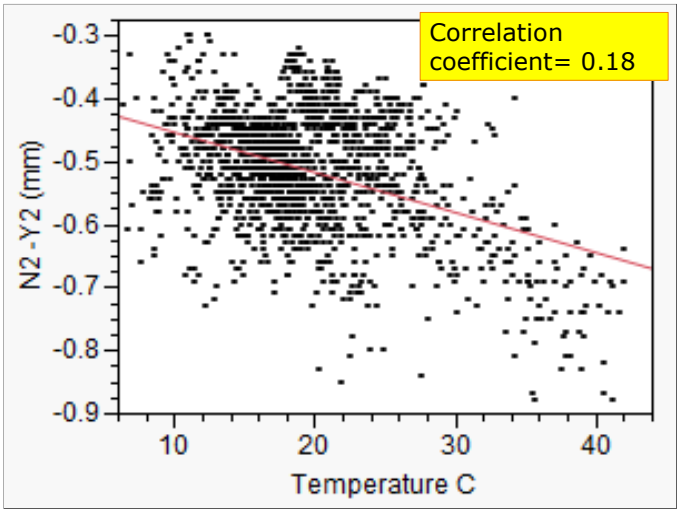


Vertical Displacement Measurements of N and S Panels

Thermal Expansion, Correlation to CTE

Material	Coefficient of Thermal Expansion (m/m K)	Coefficient of Thermal Expansion (in/in F)	ΔT=35°C ΔL over 1.2m (48")	ΔT=22°C ΔL over 1.2m (48")
Mortar (Stucco)	(7.3-13.5) x 10^{-6}	(4.1-7.5) x 10^{-6}	0.3mm-0.57mm	0.19mm-0.36mm
Steel	13.0 x 10^{-6}	7.2 x 10^{-6}	0.54mm	0.34mm
XPS, Polyiso, EPS	62.7 x 10^{-6}	35 x 10^{-6}	2.63mm	1.65mm

Displacement vs Temperature



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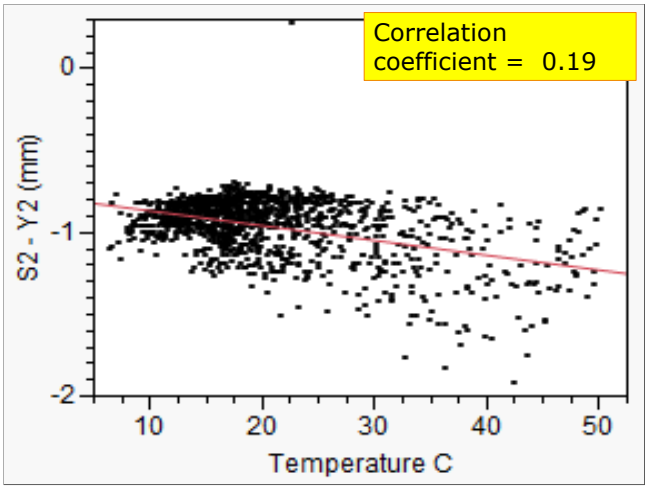

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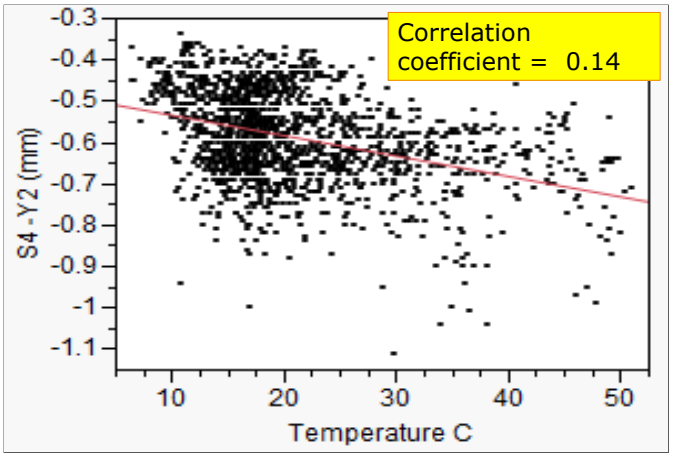
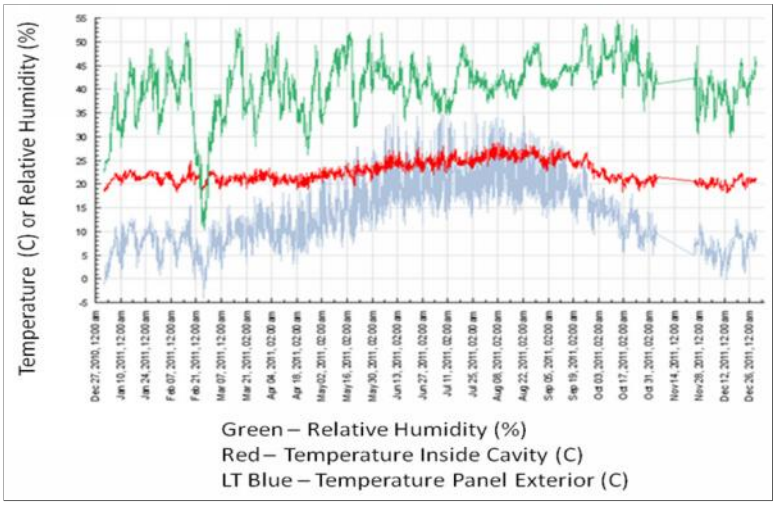
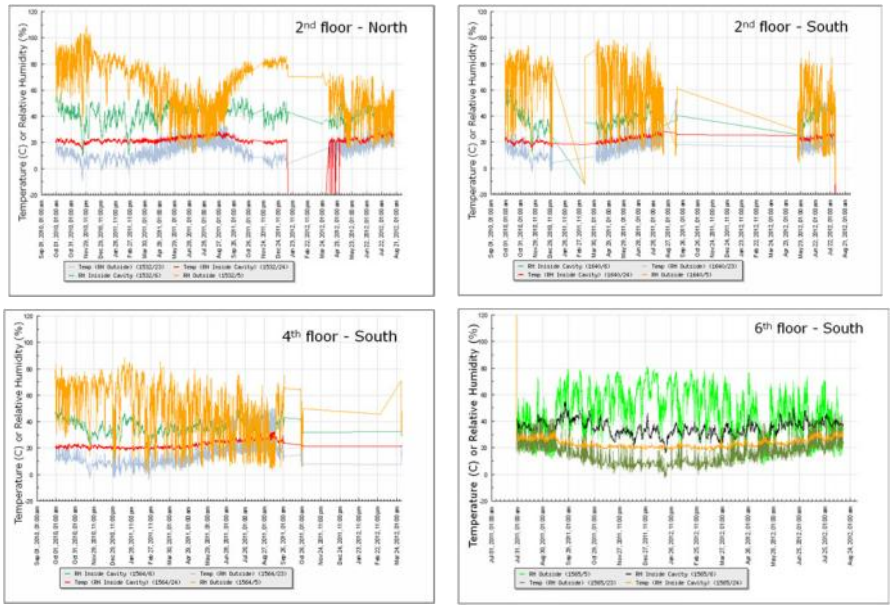


Hygrothermal Performance



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