Assessment of Durability for Cold Climate Interior Insulation

Dr John Straube, P.Eng.,
University of Waterloo, Waterloo, Canada
Chris Schumacher, B.Tech. M.A.Sc.
Building Science Corporation

Scope

- Cold climate
- Load-bearing masonry
  - Durability of the masonry
- Interior Retrofit

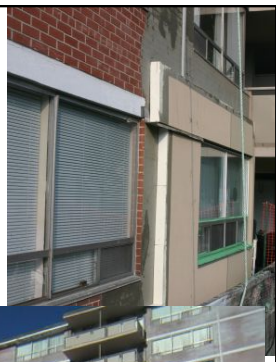
Why Retrofit Load bearing masonry

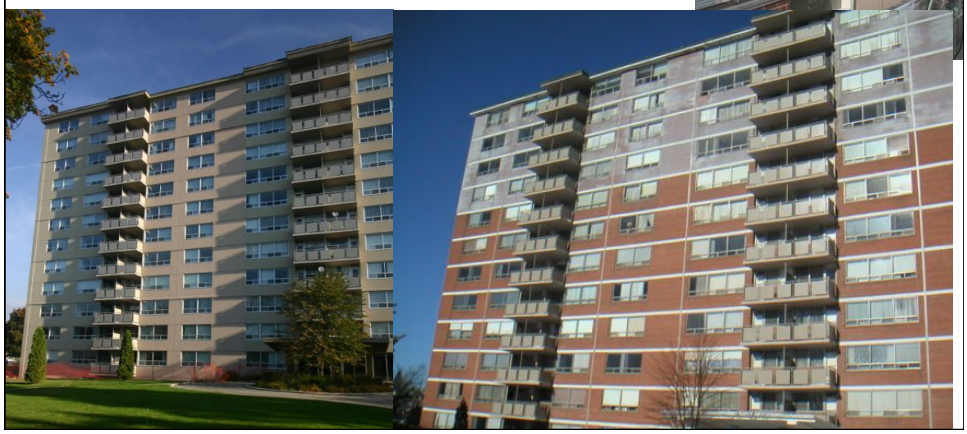
- Strong
- Beautiful, historic
- Flexible
- Existing

But energy/comfort problems

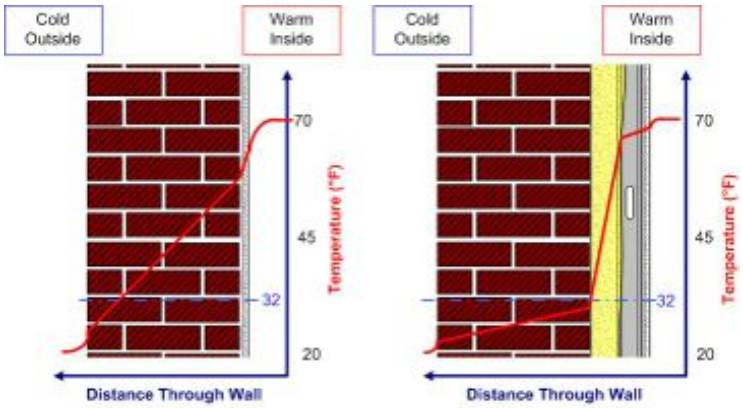
Exterior Retrofit

- Preferred Building Science solution
- Great for ugly buildings





Cold Climate Risks



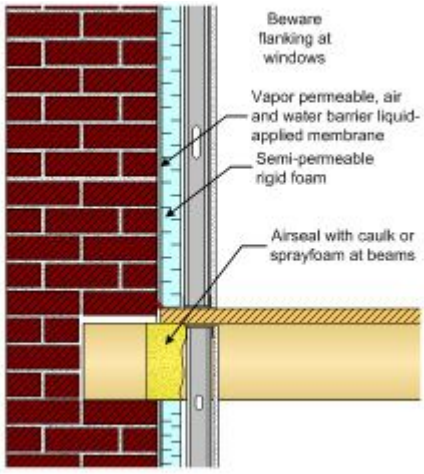
1. Freeze-thaw damage: colder +reduced drying
2. Air leakage condensation on interior face of masonry
3. Rot / corrosion of embedded elements (Kohta Ueno)

What to do?

- Manage risks
- Eliminate rain leaks
- Eliminate air leakage condensation
- Minimize diffusion condensation
  - BUT allow drying

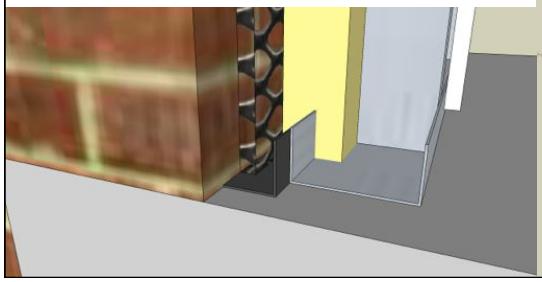
Insulation choices

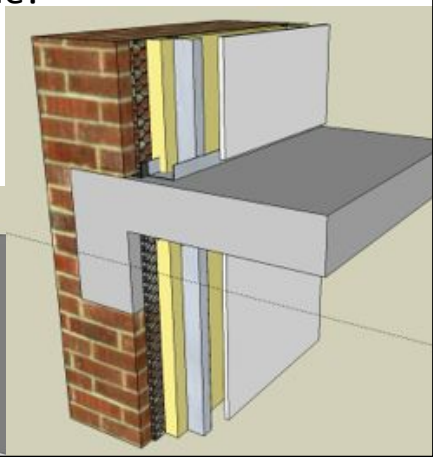
- Open-cell or closed-cell spray
- board products
- Do we need interior membranes



Rain Control

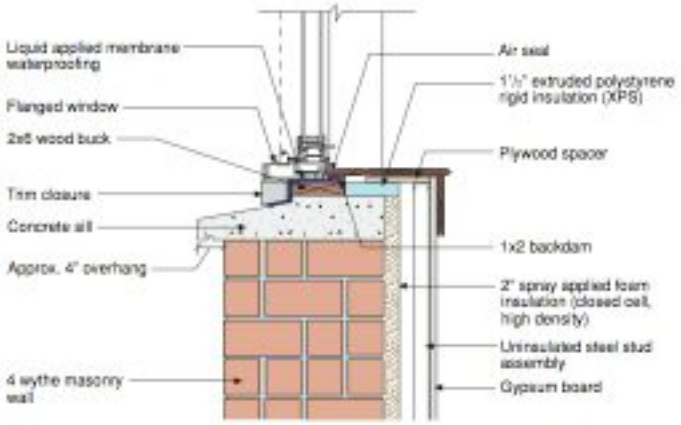
- Don't change a successful mass rain control to a problematic drained one!
- Flashing, weeps, etc. are a huge challenge





Windows

- Rain control and thermal continuity



Retrofit Assessment Stages

In order of importance:

- 1. Site Visit Assessment
- 2. Simple Materials Tests & Assembly Modeling
- 3. Detailed Material Tests & Assembly Modeling
- 4. Site Moisture Load Assessment
- 5. Prototype Monitoring
- 6. Maintenance and Repair

1. Site Visit

- Most important!
  - Walk around exterior and interior of the building
- Rain leaks?
  - Large/small, often/rare
- Freeze-thaw damage
  - parapet, chimney, at-grade, below windows
  - Check all water concentration points

2. Simple Tests & Modeling

- Simple Tests
  - Water uptake A-value (transport)
  - Saturation moisture content (storage)
- WUFI modeling
  - Many choices
  - Requires knowledge, experience, comparison to measured data, and real experience
  - Need much better guidance on how to model and analyze results

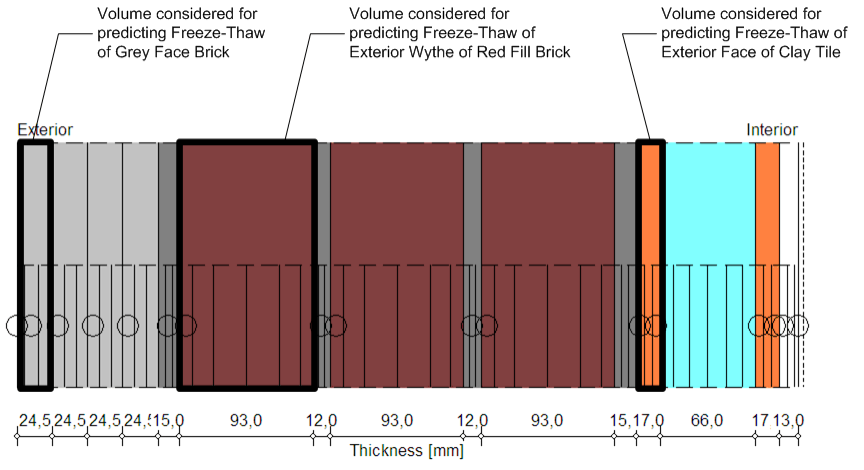
Fundamental Basis

- Fagerlund (Lund University, 1970s)
- *No such thing* as a freeze-thaw resistant material!
- There is a *critical degree of saturation* , S_{crit}
  - Below S_{crit} no freeze-thaw damage will occur regardless of number of freeze-thaw cycles
  - Above S_{crit} damage is measurable after only a few cycles
- What is S_{crit}? Guess or Measure.

Hygrothermal modeling

- Model wall before and after retrofit in WUFI
- Compare moisture levels in all layers
- Count freeze-thaw cycles
  - Below freezing, above critical degree of saturation

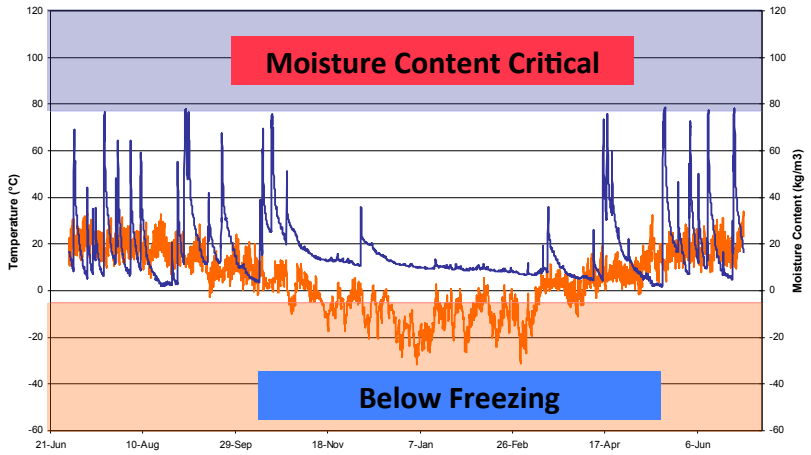
Hygrothermal Simulations



Building Science Corporation

Assessment

- Freeze Thaw Event



Building Science Corporation

3. Detailed Tests & Modeling

- Measure Quantitative Freeze Resistance
  - E.g. Fagerlund's Critical Degree of Saturation
- BSC / U Waterloo has developed methods over time
  - See ASHRAE paper (Mensinga et al)
  - Uses Frost-dilatometry
    - Brick expands when freeze-thaw damage occurs

Collecting Representative Material Samples

Multiple bricks of each "type" and wythe

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Preparing Test Specimens (Brick Slices)

Multiple small slices from each of several different bricks

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Preparing Test Specimens (Brick Slices)

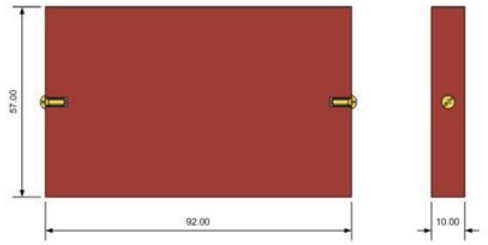


Figure 4-2 Typical brick sample with measuring pin targets.

Various methods of measuring size of test sample

Saturation Moisture Content

Careful measurement of oven dry density and Vacuum saturation necessary.
24 hr boils is not saturated!

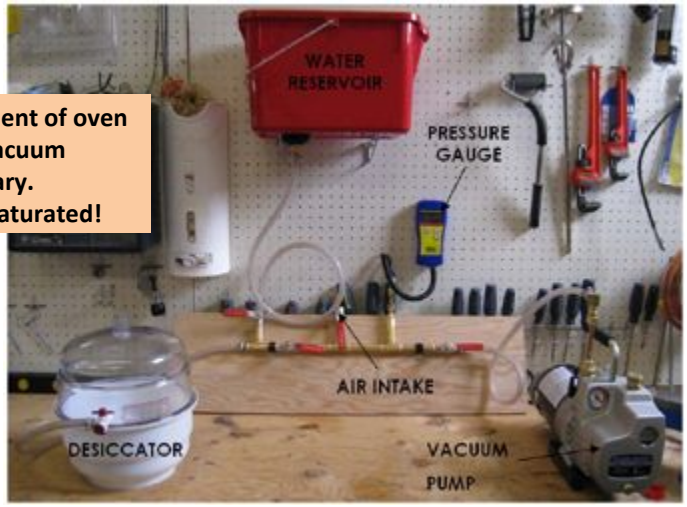


Image: P. Mensinga, UofW BEG

Measuring Dimension (before & after F/T test)

Measure sample to better than 10 microstrain (<1/10,000 inch)

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Establishing Degree of Saturation (S)

S = 0 to 0.6

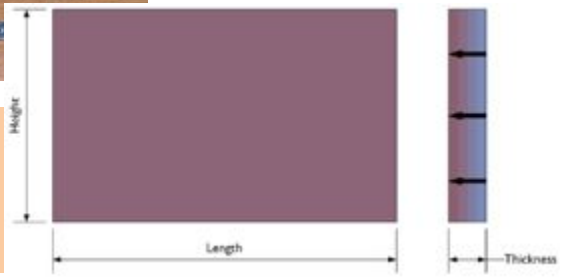
S = 0.6 to 1.0

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Establishing Degree of Saturation (S)

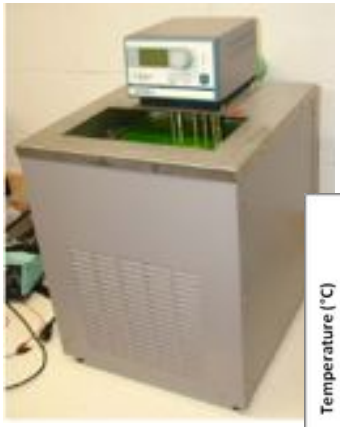
Saturated sample slices are vapor sealed and allowed to rest until moisture is evenly distributed



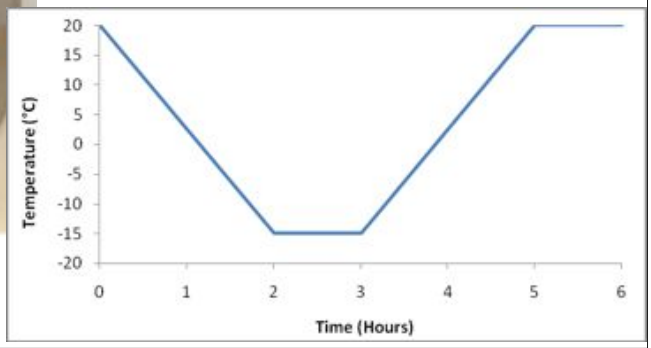
Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Running Freeze-Thaw Cycles



Sealed sample immersed in stirred bath: very fast& precise temperature response



Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Assessing Critical Degree of Saturation

- Assess strain at various degrees of saturation
- Critical degree of saturation at x-intercept

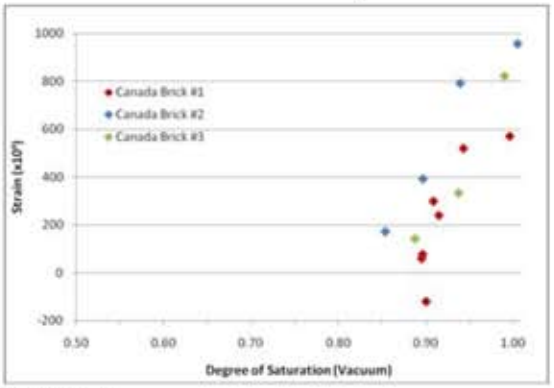


Image: P. Mensinga, UofW BEG

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

Assessing Critical Degree of Saturation

- Assess strain at various degrees of saturation
- Critical degree of saturation at x-intercept

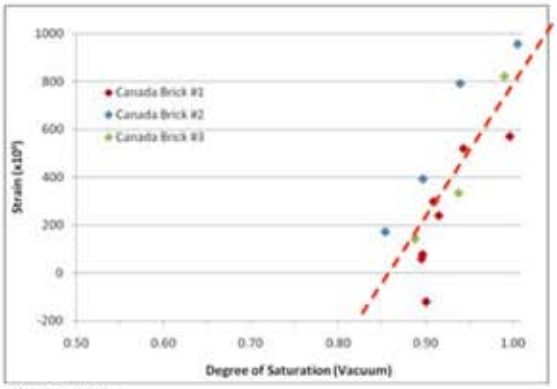


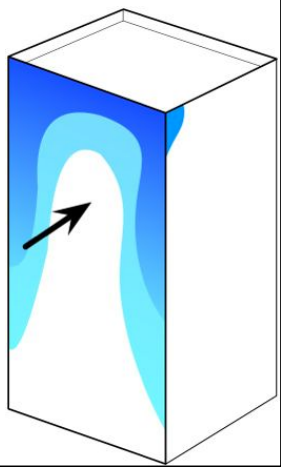
Image: P. Mensinga, UofW BEG

Assessment for Cold Climate Interior Insulation
2012.04.04

Building Science Corporation

4. Site Load Assessment

- Driving rain is the largest load
- Predictive methods available
  - But large uncertainty
- So, measure site driving rain load
  - Monitor rain deposition on building
  - Monitor run down
- Research needed
  - Esp. run down and drip edges



5. Prototype Monitor

- Install retrofit over a small area
- Measure temperature and moisture content
- Compare wetting, MC, temperatures to model results
- Potentially could compare bricks after 1-2 years,
  - eg. Ultrasonic transit time

Monitoring

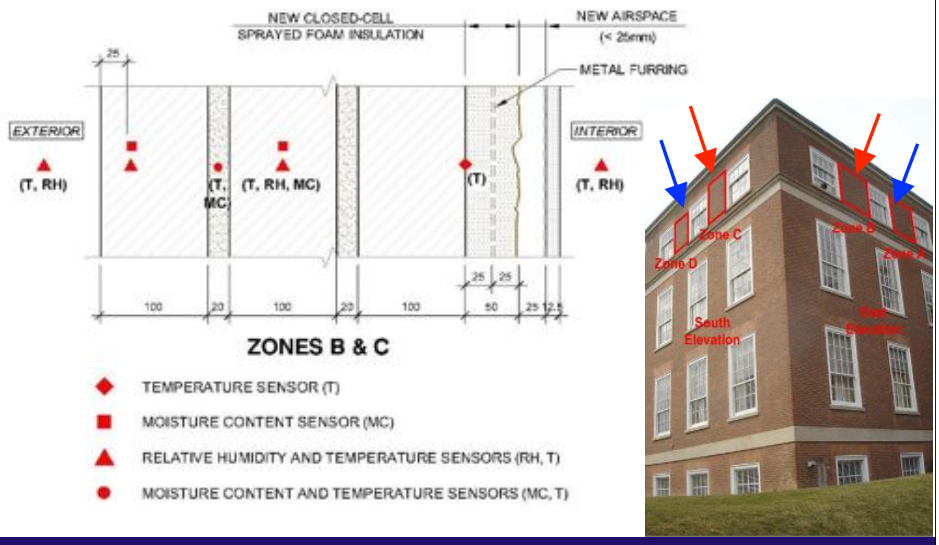


Photo: Halsall Engineering

6. Maintenance & Repair

- As for all building enclosures

Require a program of inspection/repair

- Mortar will often be damaged first
- Downspouts? Roof flashing? Backsplashing?
- Formal manual for owner would be helpful
- Inspection cycle (2 yr, 5 yr)

Conclusions

- Assessing masonry durability
  - Must assess as-built condition
  - Control rain penetration
  - Control air leakage
- Need better material freeze-thaw resistace measures
- Understanding rain loading is critical
- More measured examples demonstrating performance

Freeze-thaw vs pore size