Overview

Mass Walls (Rain Control)

- Rubble
- Solid Masonry
- Composite/ Layered

- Moisture is absorbed/safely stored during rain
- Moisture re-evaporates/dries while warmer
- No “drainage plane”

Inside or Outside Insulation?

- Insulating on exterior always preferable (masonry durability, condensation risks)
- Interior insulation → historic preservation reasons
- Interior → potential durability risks
- Energy efficiency, preserve exterior, museum-level durability: choose 2 of 3
**Cold Climate Risks**

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

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**Cold Climate Risks: Condensation**

- Requires perfect workmanship at air barrier—around penetrations, etc.
- Made worse by air gap behind insulation
- **NOT RECOMMENDED**
The Moisture Balance

- Large storage capacity (mass wall)
- Drying decreases with insulation
- Design should reduce/control wetting to compensate

Do We Need to Insulate Mass Walls?

Case 2 (add 1.5" ccSPF, R-8.7) ≈ 60% reduction in heat flow through walls vs. uninsulated case
Case 3 (add 3" ccSPF, R-17.3) ≈ 75% reduction in heat flow through walls vs. uninsulated case

Mass vs. no mass → Adds ~R-1

Window Heat Loss in Context

- Large windows (4’ x 8’), high glass %
- Can’t change frame profile (historic)
- Aluminum, double, low E: U=0.5
  (center of glass U-0.30)
- R-2 holes in R-20 walls

Improved thermal breaks available
Improved edge spacers available
Improved center-of glass (triple, films, etc.)
All add cost; not typical construction
Alternate frame materials?
Wintertime Heat Loads by Component

- Ventilation
- Infiltration
- Door Conductance
- Window Conductance
- Wall Conductance
- Roof Conductance

Retrofit Approaches

- Spray foam against masonry
- Open cell (0.5 PCF)? Closed cell (2.0 PCF)? Intermediate (1.0 PCF)?
- Air seal at joist pockets
- Montreal experience

Hybrid Wall Insulation Assembly
Rain Control

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

Non-Foam Options?

- Dense pack cellulose against brick
- High-density mineral fiber/glass fiber & variable permeability vapor retarder
- Requires meticulous workmanship/air barrier—air barrier outboard of framing & services

Problem Items

Tapered Window Openings

Minimum ~R-5 for thermal comfort (radiant surface temperatures)
Leverage spray foam for air barrier continuity to window opening
**Thermal Bridging at Slab Floors**

- **R-20 for 10 foot wall**
- **R-3 for 1 foot floor slab**
- **R-13 overall R value**

**Typical Insulation Levels**
- **R-14 for 8 foot wall**
- **R-3 for 8 inch floor slab**
- **R-10.9 overall opaque R value**
- **22% loss from nominal value**

**High Insulation Levels**
- **R-38 for 8 foot wall (6” ccSPF)**
- **R-3 for 8 inch floor slab**
- **R-19.9 overall opaque R value**
- **47% loss from nominal value**
**Interior Brick Exposed to Exterior**

Reference: Canadian Building Digests 138: On Using Old Bricks in New Buildings

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**Air Barrier Issues**

Can’t rely on masonry alone to be an air barrier

13" brick wall, 100 sf = 3.1 sq. in. leakage EqLA

Same with 3 coat plaster = 0.054 sq. in. EqLA

Source: CBD-23. Air Leakage in Buildings

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**Assessment Steps**

Freeze-Thaw Risk Assessment Process

In order of importance:
- 1. Site Visit Assessment
- 3. Site Load Assessment
- 4. Prototype Monitoring
- 5. Retrofit and Repair (execution)
- 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

Site Assessment: Where is it Wet?

Water Concentrations

Windows (Water Concentration)
Drip Edges

- Minimum projection of drip edge

Windows (Potential Rain Entry Point)

Roof-Wall Interface

Existing Damage

- Where is it? Still active or not?
**Existing Damage**

- Map damage—can correlate to exterior drainage issues?
- If you can identify the source, you can fix it

**2. Materials Tests & Modeling**

- Brick sample testing (basic tests)
  - Thermal conductivity
  - Dry density
  - Water uptake A-value (transport)
  - Saturation moisture content (storage)
- Quantitative freeze-thaw resistance
  - Fagerlund’s Critical Degree of Saturation ($S_{cr}$)
  - More details in following section
- WUFI modeling
  - Requires knowledge, experience, comparison to measured data, and real experience

**Hygrothermal Simulations**

- Simulate existing ( uninsulated) wall
- Simulate retrofitted (insulated) wall
- Vary rain loading—sensitivity analysis

**Assessment**

- Freeze Thaw Event
  - Brick must have higher moisture than Critical Degree of Saturation
  - Brick must freeze/thaw ($<23^\circ F$ and $>32^\circ F$)
3. Site Load Assessment

- Assess driving rain load
  - Monitor rain deposition on building
  - Monitor run down
- Driving rain is the largest load
- Large uncertainty

4. 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, e.g., ultrasonic transit time

5. Retrofit and Repair (execution)

- Repair masonry—repointing, improve rain control features and detailing as indicated by site survey
6. Maintenance & Repair

- As for all building enclosures
- Require a program of inspection/repair
- Mortar will often be damaged first
- Downspouts? Roof flashing? Backsplash?
- Formal manual for owner would be helpful
- Damage less visible from inside compared to pre-retrofit building (assuming bare masonry inside)

Freeze-Thaw Testing

Freeze-Thaw Damage

- The physics of Freeze-Thaw damage in porous materials is still NOT completely understood
- Several theories proposed
  - Some decades old
  - Some recent
  - “Closed container”—milk bottle in freezer
  - Ice lensing theory—ice “pulls” water from voids
  - Hydraulic pressure theory—freezing pipes

Old Approach: Use Graded Bricks

- ASTM C62 & C67
  - Grade Bricks SW, MW, NW
  - Weather Index = days of cycling around freezing x annual rainfall
  - If weather index > 50, must use SW brick
Old Test Methods

- **Method A: c/b ratio**
  - \( c = \) Moisture Content after 24 hr cold soak
  - \( b = \) Moisture Content after 5 hr boil
  - SW brick if Saturation Coefficient \( (c/b) < 0.78 \) or \( 0.80 \)

- **Method B: 50 Cycle Freeze-Thaw**
  - Freezing (20 hrs); brick in 12 mm of standing water in cold room
  - Thawing (4 hrs); brick submerged in thawing tank
  - Repeat 24 hr cycle 50 times & measure loss of dry mass; must be less than 3% for ASTM

Problems with the Old Methods

- Freeze-Thaw resistance is a misnomer
- Both A & B are digital test methods
- Lead to false positives & negatives
  - Butterworth & Baldwin, 1960s
- A is based on incomplete physics of freeze thaw
  - Closed Container (expansion of water as it freezes)
- Hydraulic Pressure
- Ice Lensing
- Disequilibrium Theory
- B doesn’t identify critical degree of saturation

Measurement of \( S_{crit} \)

- Critical Degree of Saturation (\( S_{crit} \))
  - European research on stone and masonry
  - Below this moisture content: no damage w. F/T
  - Above this moisture content: damage occurs quickly

- Cut brick samples; measurements
- Vacuum saturate to range of moisture contents
- Subject to freeze-thaw cycles
- Measure dilation (growth) of samples (very small!)
- “Hook” in graph signifies \( S_{crit} \)

Preparing Test Specimens (Brick Slices)
Saturation Moisture Content

Image: P. Mensinga, UofW BEG

Measuring Dimensions (Dilation)

- Small dilation ~200 to 3000 microstrain
- One microstrain = one part per million (10⁻⁶)
- 1000 microstrain = 0.1%

Running Freeze-Thaw Cycles

- Minimum 8 cycles
- Sometimes more to “draw out” damage

Dilation (Growth) of Samples
Current Research

Masonry Temperature/Moisture

- “Prototype monitoring” (Step 4)

Embedded Joist End Monitoring

Questions?

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This presentation will be available at:
http://www.buildingscienceconsulting.com/presentations/recent.aspx
Document Resources

- Building Science Digest 114: Interior Insulation Retrofits of Load-Bearing Masonry Walls In Cold Climates
- Building Science Insight 047: Thick as a Brick
- CP-1013: Assessing the Freeze-Thaw Resistance of Clay Brick for Interior Insulation Retrofit Projects
- BA-1105: Interior Insulation of Masonry Walls: Final Measure Guideline
- BA-1307: Interior Insulation of Mass Masonry Walls: J oist Monitoring, Material Test Optimization, Salt Effects
- Interior Insulation Retrofit of Mass Masonry Wall Assemblies Workshop