Overview

Mass Walls (Rain Control)

- 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

Cold Climate Risks: Condensation

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

Condensation Risks

Embedded Wood Member Risks
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

Window Heat Loss in Context

- 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

<table>
<thead>
<tr>
<th>Component</th>
<th>Design Load (kBtu/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninsulated Masonry</td>
<td>2,500</td>
</tr>
<tr>
<td>Proposed (Insulated+HRV)</td>
<td>2,000</td>
</tr>
<tr>
<td>Add YH 0.5 Window</td>
<td>1,500</td>
</tr>
</tbody>
</table>

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

- Remove all lath and cement/mortar siding
- Remove top stud or masonry wall sheathing
- Insulate with 2" xps foam insulation
- Face nailing strips in place
- Replace exterior and interior siding
- Provide continuous interior and exterior air seal in wall cavities
- Air seal at beams
- Structural beam
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

Mineral Fiber Interior Retrofit?

- Climate Zone 4-OK
- Climate Zone 5—wintertime RH under 30%?
- Preferred approach: air/vapor control outboard of stud wall

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
Thermal Bridging at Slab Floors

- **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

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

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
Drip Edges

- Minimum projection of drip edge

Windows (Potential Rain Entry Point)

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 ($S_{crit}$)
  - 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 F and >32 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

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?
Kohta Ueno
kohta@buildingscience.com
This presentation will be available at:
http://www.buildingscienceconsulting.com/presentations/recent.aspx
Insulating Load-bearing Masonry Buildings

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: Internal Insulation of Masonry Walls: Final Measure Guideline

- BA-1307: Interior Insulation of Mass Masonry Walls: Joist Monitoring, Material Test Optimization, Salt Effects

- Interior Insulation Retrofit of Mass Masonry Wall Assemblies Workshop

- CP-1301: Field Monitoring and Simulation of a Historic Mass Masonry Building Retrofitted with Interior Insulation

- Thermal Performance of the Exterior Envelopes of Whole Buildings XII: Field Monitoring and Simulation of a Historic Mass Masonry Building Retrofitted with Interior Insulation

- Canadian Building Digest 2. Efflorescence

- Canadian Building Digest 138. On Using Old Bricks in New Buildings

- Green Building Advisor: Insulation Retrofits on Old Masonry Buildings: Building Science Podcast

- Green Building Advisor: Insulating Old Brick Buildings

Insulating Load-bearing Masonry Buildings

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