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March 1, 2021

Care & Feeding of Brick:

Interior Insulation Retrofits of Mass Masonry Buildings

Building Science Corporation

BUILDINGENERGY BOSTON
FEBRUARY 28–MARCH 1 • WESTIN BOSTON SEAPORT DISTRICT • NESEA.ORG/BE22
Conference + Trade Show of the Northeast Sustainable Energy Association (NESEA)

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Course Description

Solid mass masonry buildings are a significant fraction of the existing building stock, and many contribute to the historic fabric of neighborhoods. However, with wall R-values of R-3 to R-5, they do not meet modern standards for energy efficiency and comfort. Insulating these buildings successfully—without causing long-term damage—is a vital part of the 'toolkit' for meeting energy and climate goals. This session will cover potential pitfalls and risks of interior insulation, including interstitial condensation, freeze-thaw damage, decay of embedded wood members, and surface water concentrations. We will then cover assemblies and details that work to control these risks.

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Learning Objectives

At the end of this course, participants will be able to answer:

1. Explain freeze-thaw and condensation risks associated with interior insulation of mass masonry buildings
2. Discuss potential decay risks in embedded wood members
3. Appraise various interior retrofit insulation assemblies for potential moisture risks
4. Interpret the use of material property testing and hygrothermal simulations to judge freeze-thaw risks

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Housekeeping

- Slides will be available on website (https://www.buildingscience.com/past-events)
- Resources: list of links at end of presentation
- Questions—during plus reserved Q&A time at end

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Masonry Wall Insulation Background

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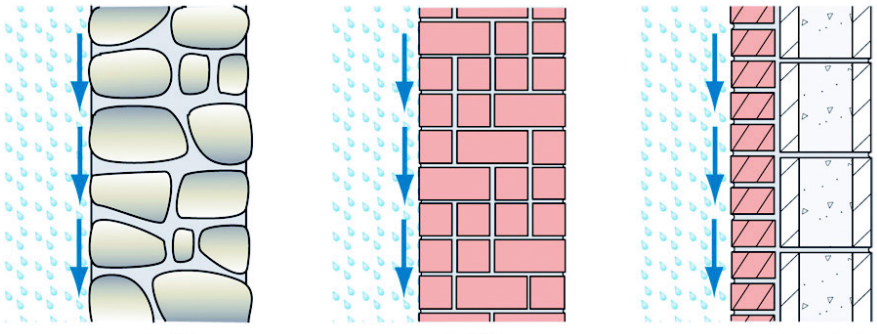
Mass Walls (Rain Control)

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



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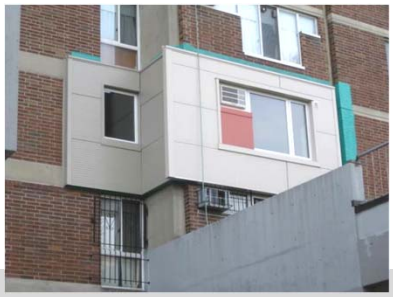
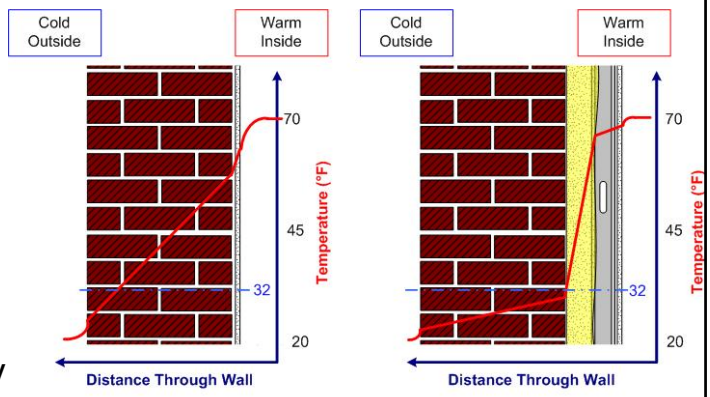
Inside or Outside Insulation?

- Insulating on exterior always preferable (masonry durability, condensation risks, thermal performance)
- Interior insulation → historic preservation reasons
- Interior → potential durability risks



Cold Climate Risks

- Freeze-thaw (colder + reduced drying)
- Air leakage condensation on interior face of masonry
- Rot/corrosion of embedded elements
- Covering interior → less early warning of damage problems in the wall



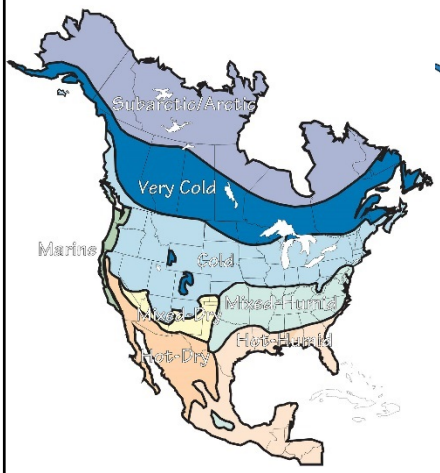
Cold Climate Risks: Freeze-Thaw

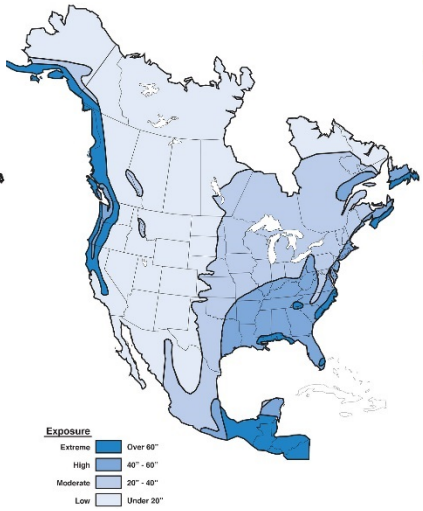
- Below & above freezing cycling (actually ~23 F)
- Soaking wet brick
- Surface “flaking off”

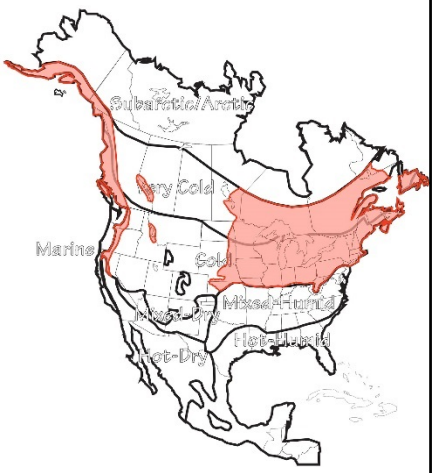
- Brick more/less resistant to freeze-thaw
- S_{crit} or critical degree of saturation measurement




Geographic Risks

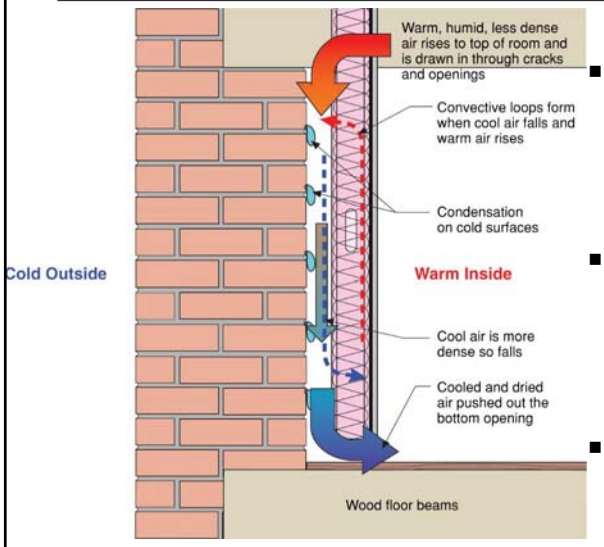






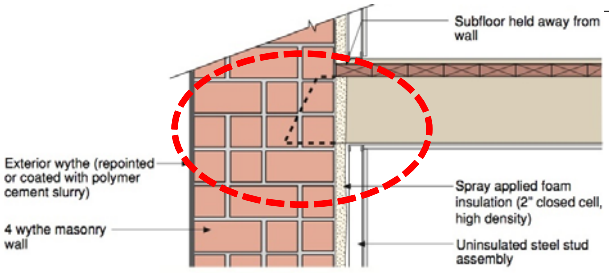
- Cold + rain = risks

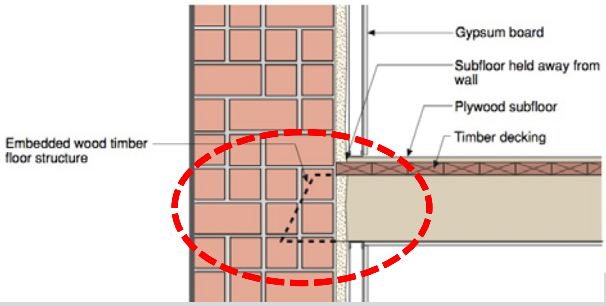
Cold Climate Risks: Condensation

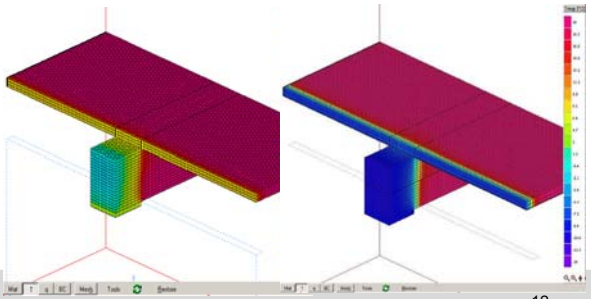


- Requires perfect workmanship at air barrier—around penetrations, etc.
- Made worse by air gap behind insulation (“chimney”)
- **NOT RECOMMENDED**

Embedded Wood Member Risks

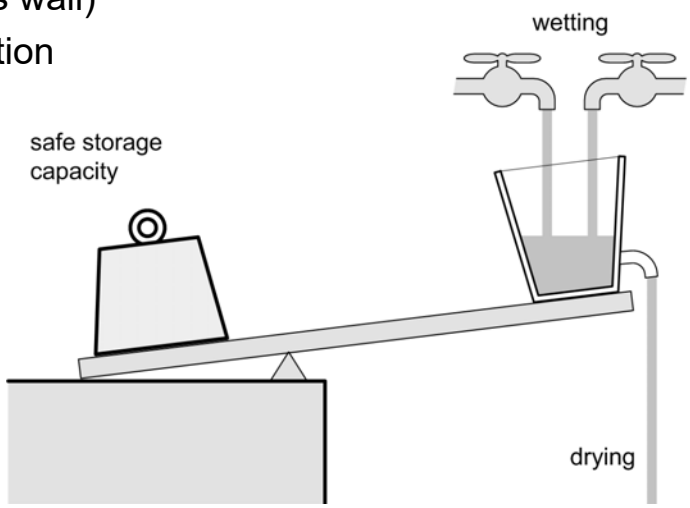






The Moisture Balance

- Large storage capacity (mass wall)
- Drying decreases with insulation
  - Less heat flow in winter
  - Inhibited inward drying?
- Reduce/control wetting to compensate



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Risk Assessment Process

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Freeze-Thaw Risk Assessment Process

In order of importance:

- 1. Site Visit Assessment
- 2. Materials Tests & Modeling
- 3. Site Load Assessment
- 4. Prototype Monitoring
- 5. Retrofit and Repair (execution)
- 6. Maintenance and Repair

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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

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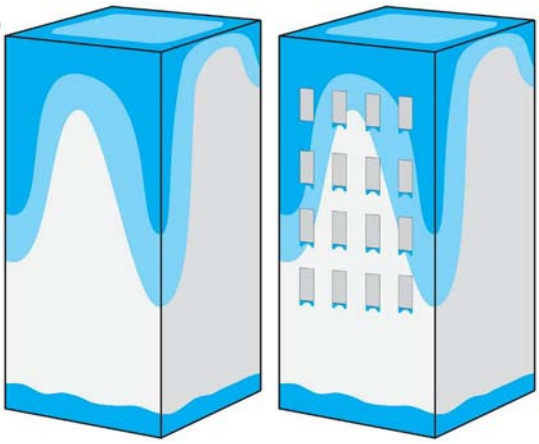
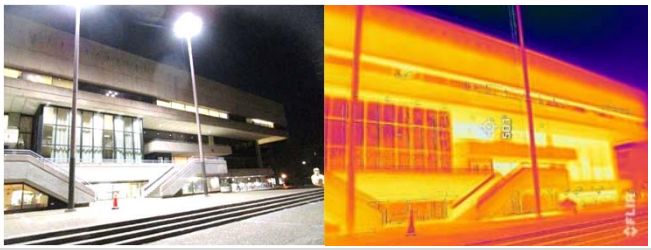
Wetting Patterns: What Does the Building Tell Us?

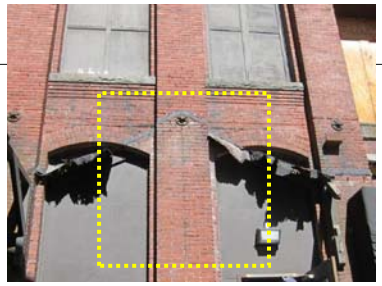
- Where to look at the building (damage)
- "Where the building touches the ground and the sky"
- Add windows
- Parapets—cold & wet
- Unheated conditions

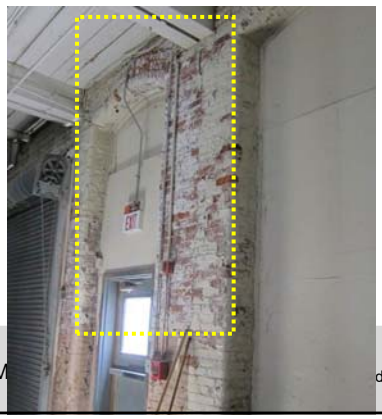




Water Concentrations

- Damage, interior and exterior





Existing Damage




- Where is it? Still active or not?
- Moisture meters to look for active/ ongoing leakage

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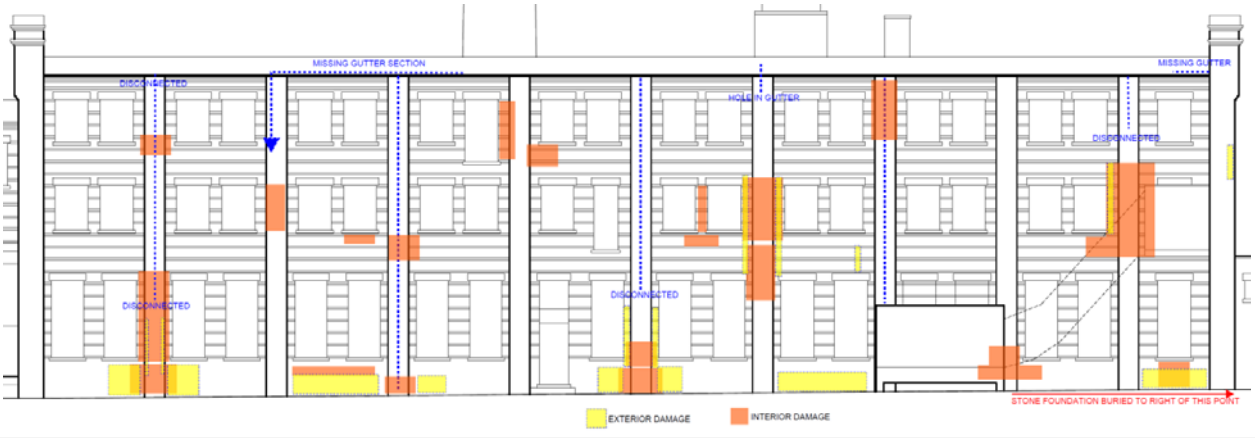
Existing Damage

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



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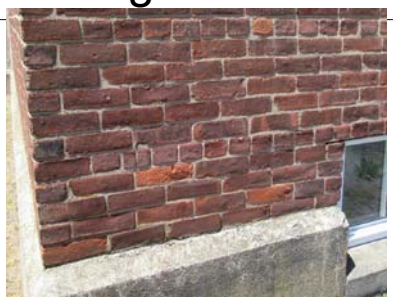
"Darwinian" Brick Damage

- Most of the brick looks great
- Selected brick have spalling surfaces
- No pattern matching exposure
- Poorly-fired brick?
- "Culling of the herd"

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Freeze-Thaw Risk Assessment Process

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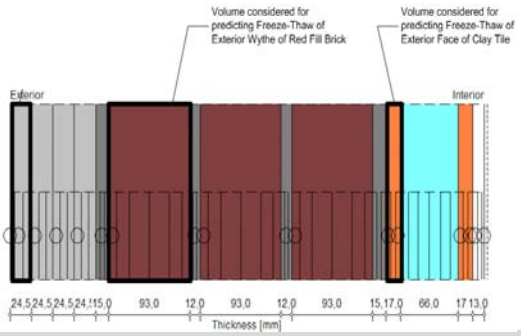

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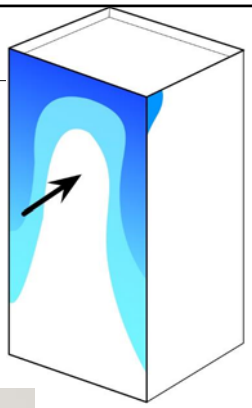
Freeze-Thaw Risk Assessment Process



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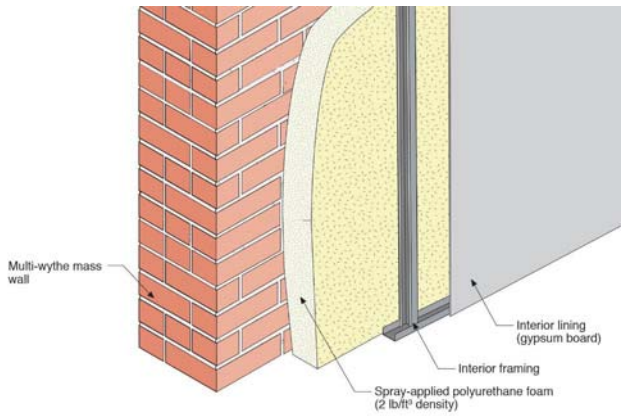
Masonry Wall Assemblies

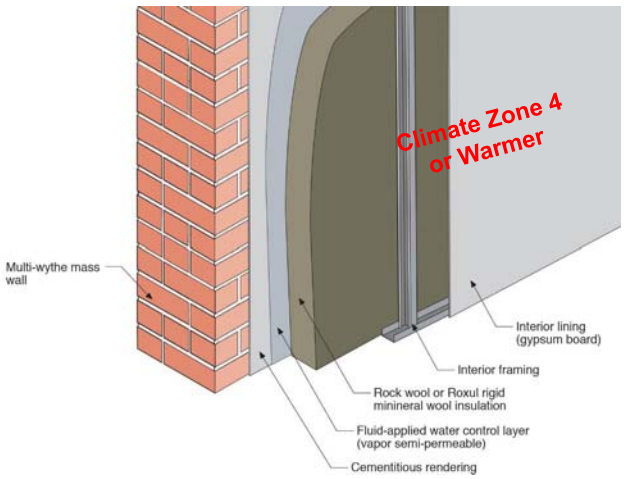
Masonry Interior Insulation Retrofit Assemblies

Closed-cell spray foam

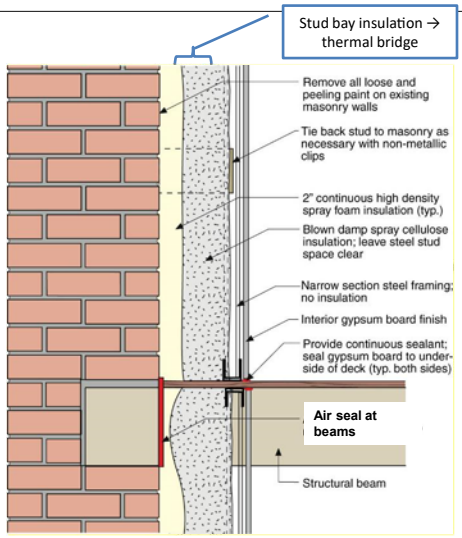


2”-3” ccSPF? ~R-13 to R18
vs. R-12.9 2x6 stud frame wall

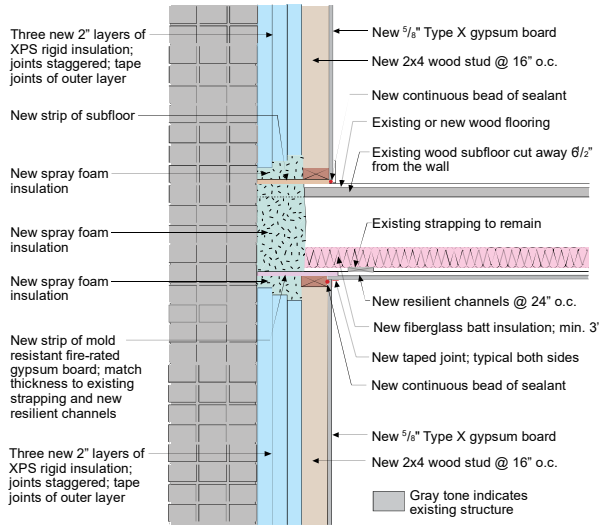
Semi-rigid mineral fiber board



Hybrid Wall Insulation Assembly



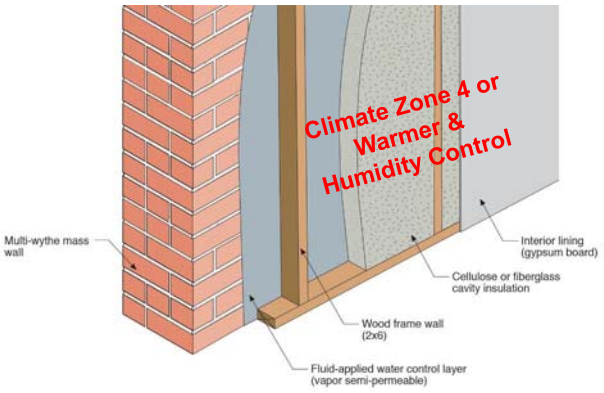
Rigid Board Interior Retrofit



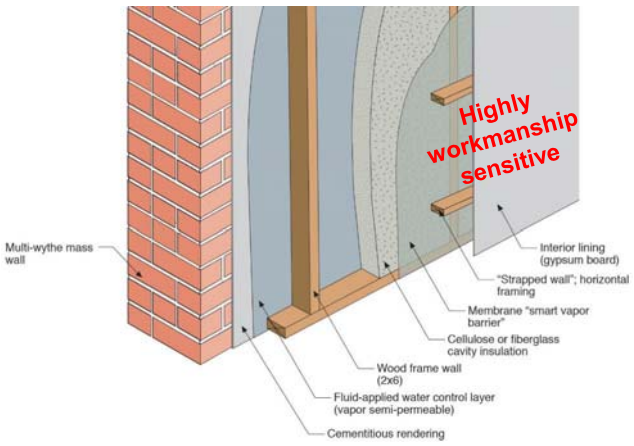
- Adhered, pin board to wall
- Much more labor (piece-work)
- Workmanship-sensitive
- Poor match for "bumpy" substrates

Masonry Interior Insulation Retrofit Assemblies

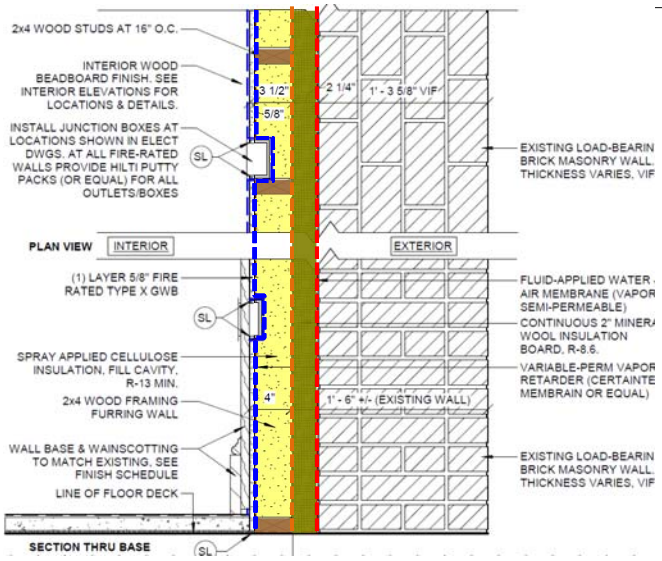
Cellulose/Batt & GWB



Cellulose/Batt, Smart VR, Service Cavity



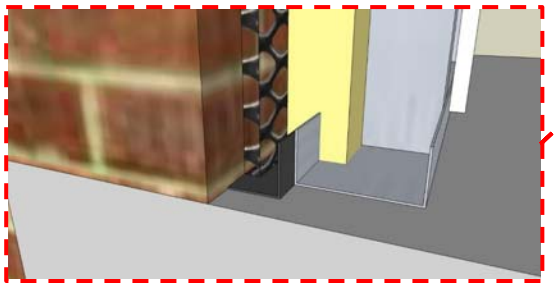
Mineral Fiber Retrofit Assembly

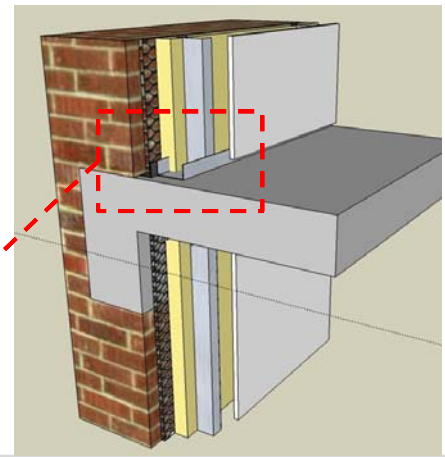


- Historic requirements limited build-in to 4 inches
- Requirement for high R-value (Passive House)
- Airtightness/air barrier requirements

Rain Control-Interior Drainage?

- Don't change a successful mass rain control to a problematic drained one!
- Flashing, weeps, etc.
- Neither robust nor simple assembly





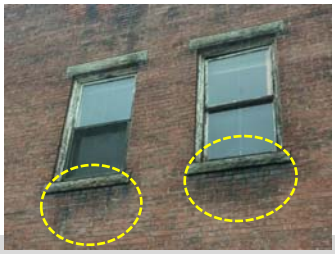
Injection/Poured Foam Behind Existing Plaster




- Small ~1” holes
- Limited insulation thickness (~1”)
- Need “slow rise” formula
- Airtightness improvement
- Interrupted by existing furring/framing
- Quality control (infrared camera for complete fill)
- Talk to Henri Fennell!

Windows

Wetting Patterns: Windows



Testing Window Runoff Patterns

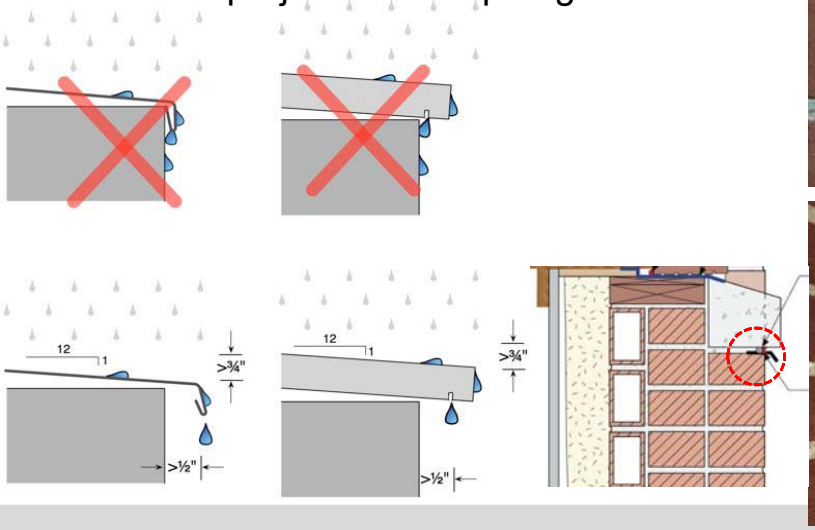
- Water squirt bottle testing
- Add infrared in some cases
- Often matches existing staining and damage patterns

Nature-Provided Window Runoff Testing

- Tricky part—catching building after the “right” amount of rainfall
- Outdoor temperature and sun too (T rising/falling)

Drip Edges

- Minimum projection of drip edge

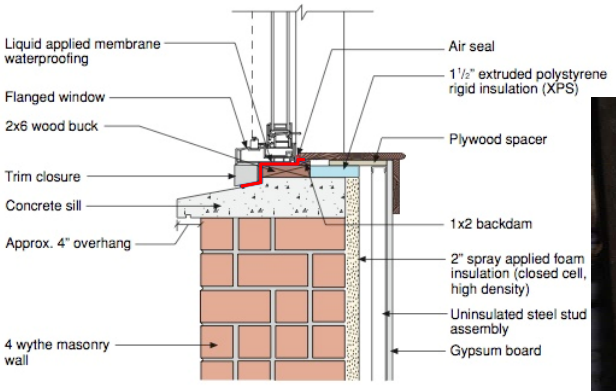


Rowlock Window Sills




- Rowlock = many mortar joints, facing sky, taking window runoff
- Much worse water management than stone/cast stone sills
- Overclad with metal
- Add drip edge

Windows (Potential Rain Entry Point)





- Adhered membrane or fluid applied rough opening “wrap”

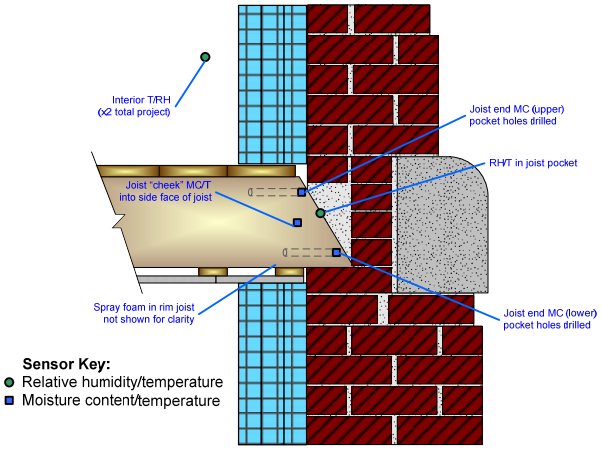
Embedded Wood Joists

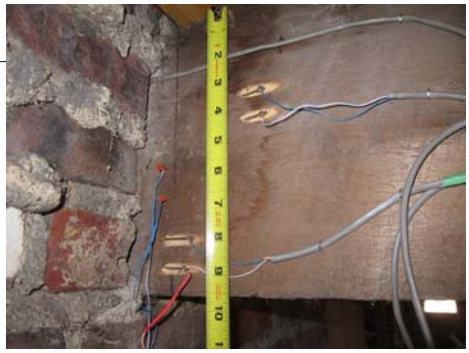
Embedded Joists




- Steel or iron bearing plates, saddle connectors
- Connecting wood to below-grade masonry → composting your framing

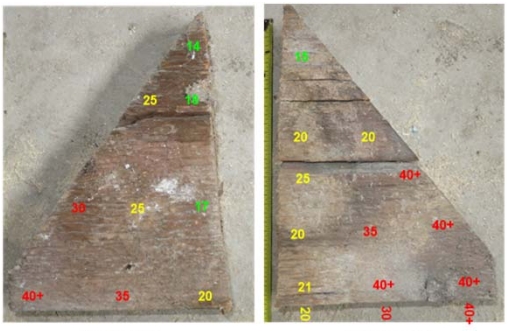
Embedded Joist End Monitoring



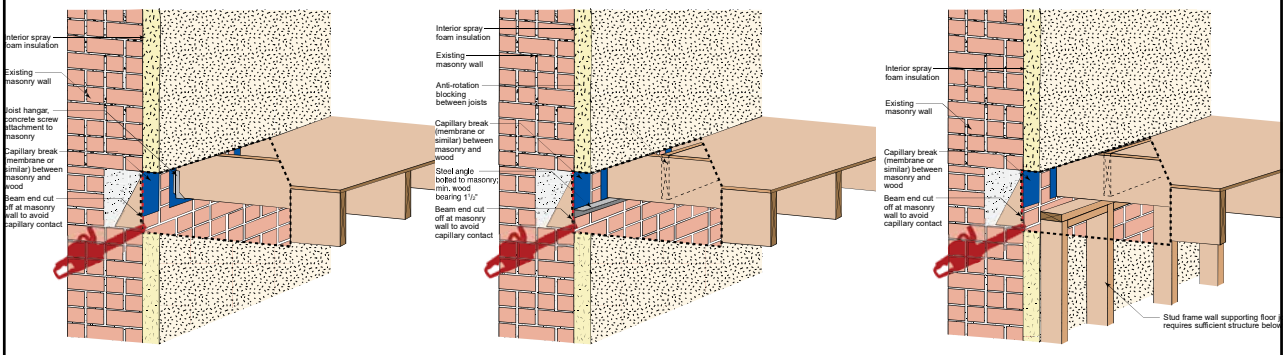


Embedded Joist End Monitoring Results

- Insulation makes wood wetter
- Heating dries wood
- Wood wettest in summer (!)
- Orientation-sensitive (N/S/E/W)
- Brick wall vs. hollow block wall
- Embedded wood is already wet (40%+ MC) & moldy in uninsulated walls
- Durability of old-growth timber
- ***Damage reported only with macroscopic cracks at masonry***



Joist End “Nuclear Options” for Retrofits



- Joist hangers into masonry
- Steel ledger
- Structural frame wall inboard of masonry

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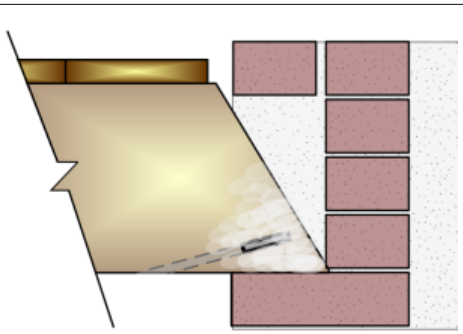
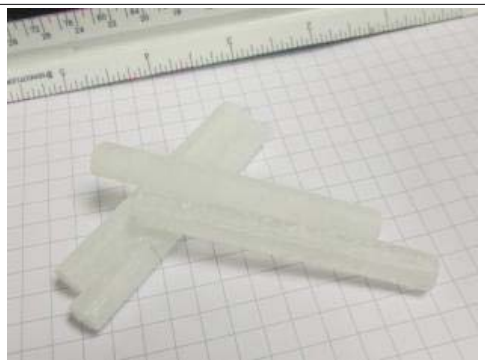
Borate Preservative Rods at Embedded Wood





- Currently commonly used in outdoor wood/timber structures (bridges)
- Water soluble; dissolves into wood when wetted
- Drilling holes → is wood joist already punky?

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Parallel Ledger Condition

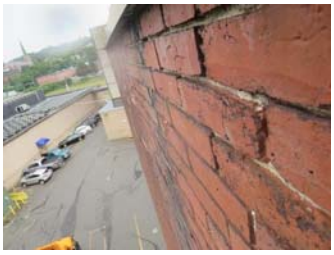
- Leaving parallel ledger uninsulated?
- Wood on “warm and dry” side, open drying to interior
- Sacrifice of thermal performance for moisture/durability performance

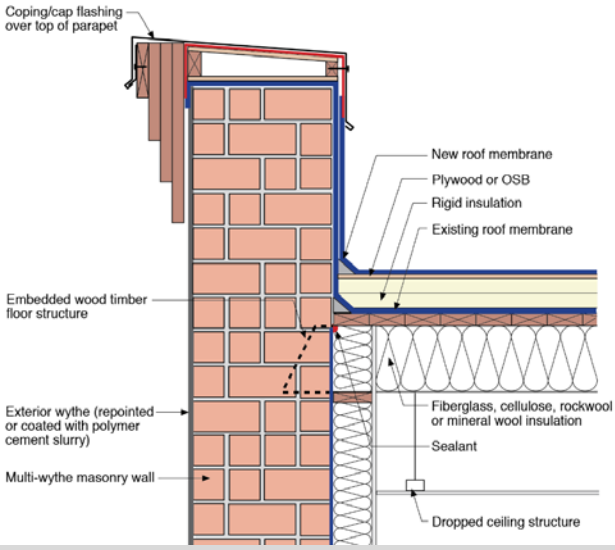
New Ledger Condition

- Sandwich rigid foam between brick and wood ledger
- Wood is on “warm and dry” side, wicking from masonry
- Structural thermal break if conservative designers (Armatherm, etc.)

Other Tricky Enclosure Items

Roof Copings

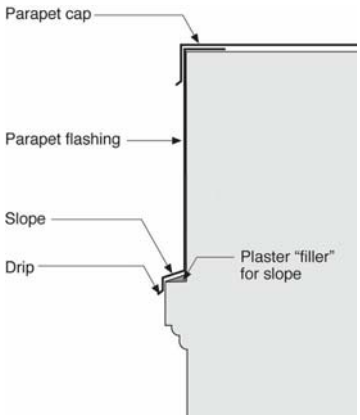




Band or Cornice Details

- Sky-facing mortar joints will leak over time
- Injects water deep into wall

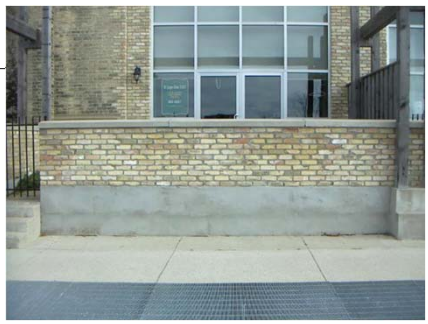
Band or Cornice Overclad Option



- Metal overclad with drip edge
- Water control layer (membrane or fluid) on topside of sky-facing surface?
- Historical pushback?

Interior Brick Exposed to Exterior

- Or reusing salvaged brick



See Canadian Building Digest 138: On Using Old Bricks in New Buildings
Detroit brick salvaging operations

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Grade Contact (Wicking Brick)

- Brick is a “dense sponge”
- Capillary wicking through brick
- Plants growing into brick = plants think your building is dirt

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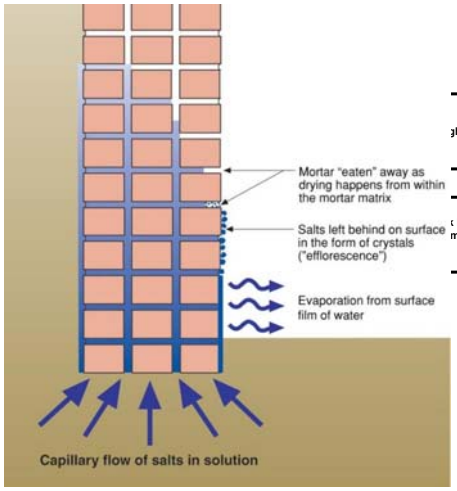
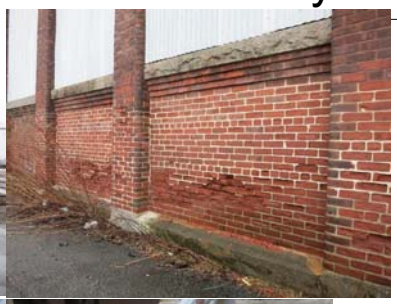
Grade Contact Conditions

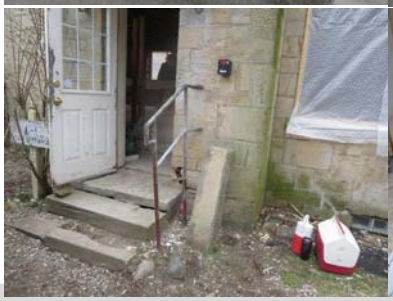
Firehouse

Syndicate



Salt Effects on Stone & Masonry



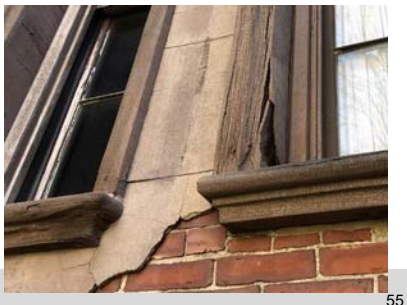


- De-icing salts typical problem
- Localized around walking areas, steps, parking lots
- Massive F-T increase

Intrinsically Vulnerable Materials (Brownstone)



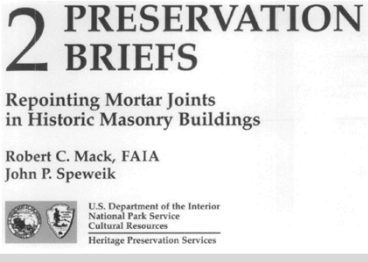




- NYC architects working in Maine
- Sandstone easy to cut & carve
- Weathers easily too!

Cleaning and Repointing

- Cleaning—“as gently as possible”
- Match cleaning agent to substrate type (brick vs. various stone types)
- Damaging cleaning—e.g., sandblasting; strips hard surface
- Repointing (as needed)
- Soft vs. hard mortars
- National Park Service Preservation Briefs 1 & 2



Clear Coatings (Silanes & Siloxanes)

- Can make masonry surfaces water repellent
- Some practitioners report great success
- “Glossy” surface
- Ongoing maintenance
- Overwhelm with water → “haze” or “fogging” (water trying to dry outward)

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Energy and Thermal Performance

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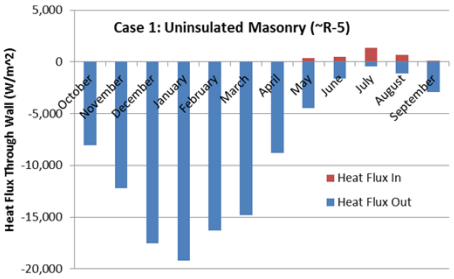
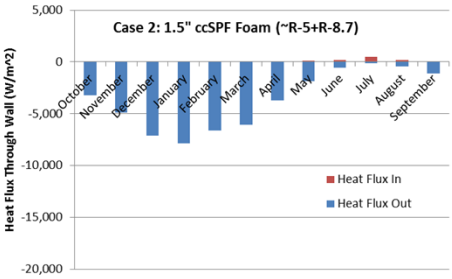
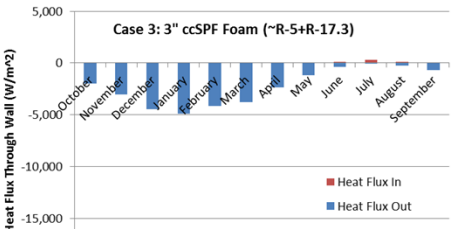
Do We Need to Insulate Mass Walls?







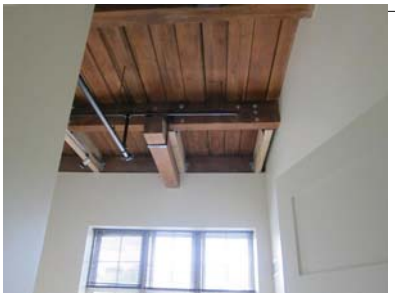
Climate: Burlington, VT

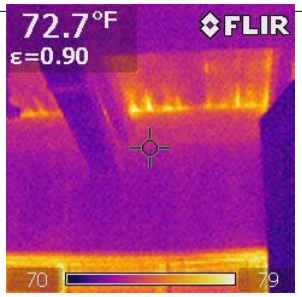
Case 2 (add 1.5” ccSPF, R-8.7) ≈ 60% reduction in heat flow through walls vs. uninsulated case

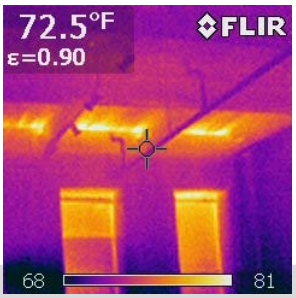
Case 3 (add 3” ccSPF, R-17.3) ≈ 75% reduction in heat flow through walls vs. uninsulated case

Mass vs. no mass → Adds ~R-1

Air Barrier Issues

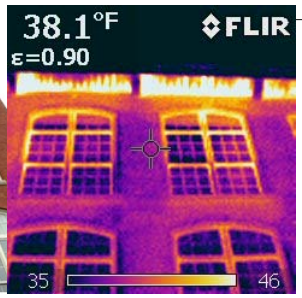


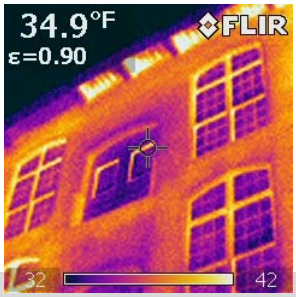




- Can’t rely on masonry alone to be an air barrier
- 13” brick wall, 100 sf = 3.1 sq. in. leakage EqLA
- Same with 3 coat plaster = 0.054 sq. in. EqLA
- Source: CBD-23. Air Leakage in Buildings

Air Barrier Issues





- Spray foam doesn't do anything if it is not there!
- Incorporating tongue & groove boards into air barrier → difficult
- Drilled holes at joints + seal?

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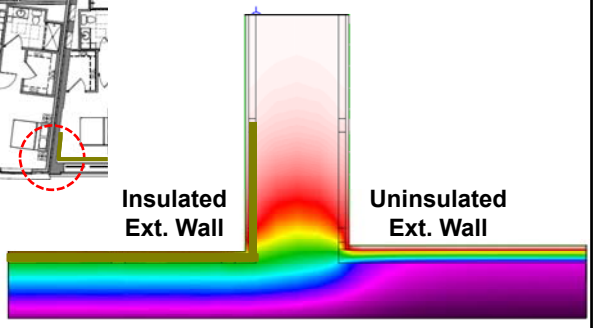
Masonry Thermal Bridges



Add tee wall "wrap" for flanking loss

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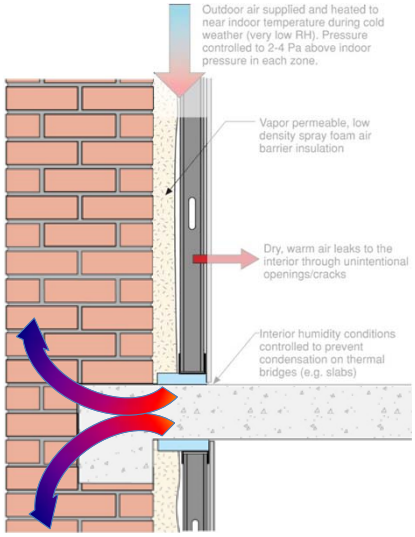
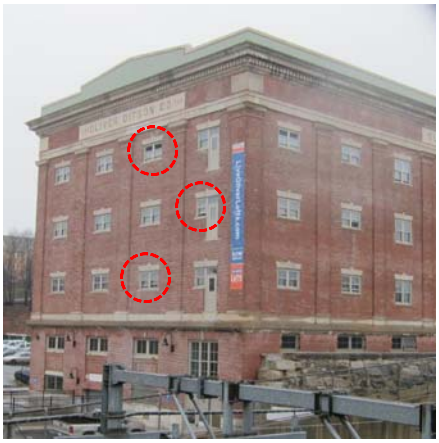
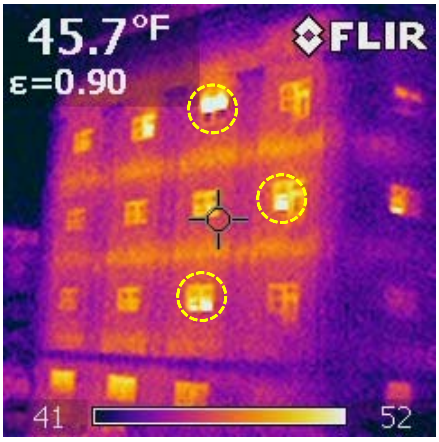
Thermal Bridging at Slab Floors



- Thermal bridge built into structure
- Can't remediate w/o "heroic measures"

Thermal Bridging at Slab Floors

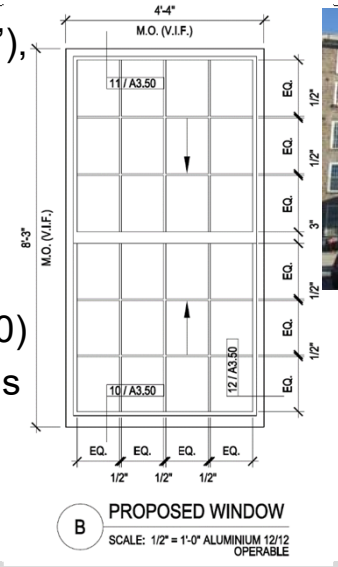




R-20 for 10 foot wall
R-3 for 1 foot floor slab
R-13 overall R value

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



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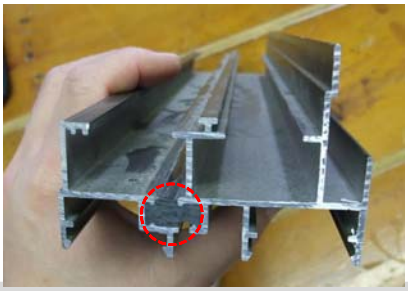
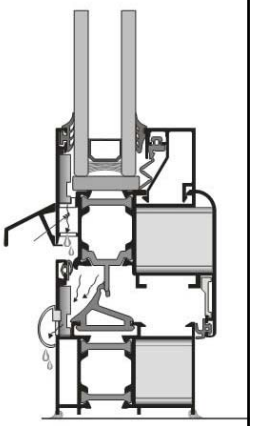
Window Heat Loss in Context

- Improved thermal breaks, edge spacers
- Improved center-of glass (triple, films, etc.)
- All add cost; not typical construction
- Alternate frame materials?
- Historic restrictions common





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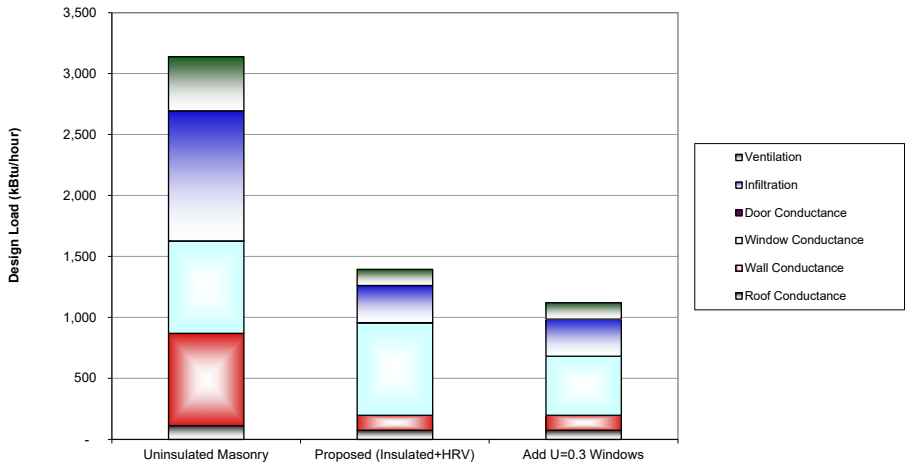
Wintertime Heat Loads by Component

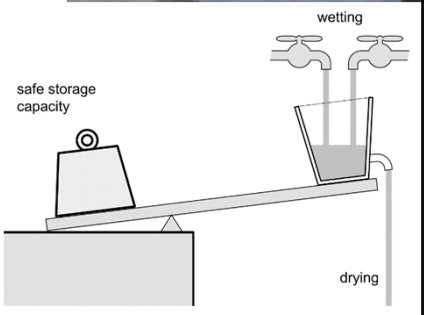


- Basic UA analysis (U-factor × area)

Conclusions

Conclusions

- Yes, you can insulate mass masonry on the inside
- Outside is better (durability, energy performance), but is a non-starter in cases
- Balance out decreased drying with decreased wetting (exterior water control)
- So… many… details…
- Then, many options for interior insulation
- In some cases: don't make an old building something it shouldn't be (built-in thermal bridges, marginal masonry)



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Questions?

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This presentation will be available at http://buildingscience.com/past-events

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Document Resources

- Building Science Digest 114: Interior Insulation Retrofits of Load-Bearing Masonry Walls In Cold Climates
  http://www.buildingscience.com/documents/digests/bsd-114-interior-insulation-retrofits-of-load-bearing-masonry-walls-in-cold-climates
- Building Science Insight 047: Thick as a Brick
  http://www.buildingscience.com/documents/insights/bsi-047-thick-as-brick/
- Building Science Insight 080: Tailor Made
  http://buildingscience.com/documents/insights/bsi080-tailor-made
- Building Science Insight 095: How Buildings Age
  http://buildingscience.com/documents/building-science-insights/bsi-095-how-buildings-age
- Building Science Insight 105: Avoiding Mass Failures
  https://www.buildingscience.com/documents/building-science-insights/bsi-105-avoiding-mass-failures
- Building Science Insight 011: Capillarity—Small Sacrifices
  https://www.buildingscience.com/documents/insights/bsi-011-capillarity-small-sacrifices

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Document Resources

- Building America Report 1105: Internal Insulation of Masonry Walls: Final Measure Guideline
  http://www.buildingscience.com/documents/reports/rr-1105-internal-insulation-masonry-walls-final-measure-guideline/
- Building America Report 1307: Interior Insulation of Mass Masonry Walls: Joist Monitoring, Material Test Optimization, Salt Effects
  https://buildingscience.com/documents/bareports/ba-1307-interior-insulation-mass-masonry-walls/view
- Building America Report 1508: Analysis of Joist Masonry Moisture Content Monitoring
  https://buildingscience.com/documents/building-america-reports/ba-1508-analysis-joist-masonry-moisture-content-monitoring
- Building America Expert Meeting Report: Recommended Approaches to the Retrofit of Masonry Wall Assemblies
  https://www.buildingscience.com/sites/default/files/bsc_to2_1_3_final_expert_meeting_report.pdf
- Green Building Advisor: Insulation Retrofits on Old Masonry Buildings: Building Science Podcast
  http://www.greenbuildingadvisor.com/blogs/dept/building-science/insulation-retrofits-old-masonry-buildings-building-science-podcast
- Canadian Building Digest 138. On Using Old Bricks in New Buildings
  http://web.mit.edu/parmstr/Public/NRCan/CanBldgDigests/cbd138_e.html
- National Park Service Preservation Brief 1: Cleaning and Water-Repellent Treatments for Historic Masonry Buildings
  https://www.nps.gov/tps/how-to-preserve/briefs/1-cleaning-water-repellent.htm
- National Park Service Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings
- https://www.nps.gov/tps/how-to-preserve/briefs/2-repoint-mortar-joints.htm

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Document Resources (Exterior Retrofits)

- Building Science Insight 079: Deep-Dish Retrofits
  https://buildingscience.com/documents/insights/bsi079-deep-dish-retrofits
- Building Science Insight 048: Exterior Spray Foam
  https://buildingscience.com/documents/insights/bsi-048-exterior-spray-foam
- Building Science Insight 013: Face Lift for Old Buildings
  https://buildingscience.com/documents/insights/bsi-013-face-lift-for-old-buildings
- BA-1106: Leveraging Limited Scope for Maximum Benefit in Occupied Renovation of Uninsulated Cold Climate Multifamily Housing
  https://www.buildingscience.com/documents/bareports/ba-1106-winn-development-retrofit-community-final-report/view
- 2017-11-16 03 Castle Square - Mid Rise
  https://www.buildingscience.com/sites/default/files/2017-11-16_03_castle_square_-_mid_rise.pdf