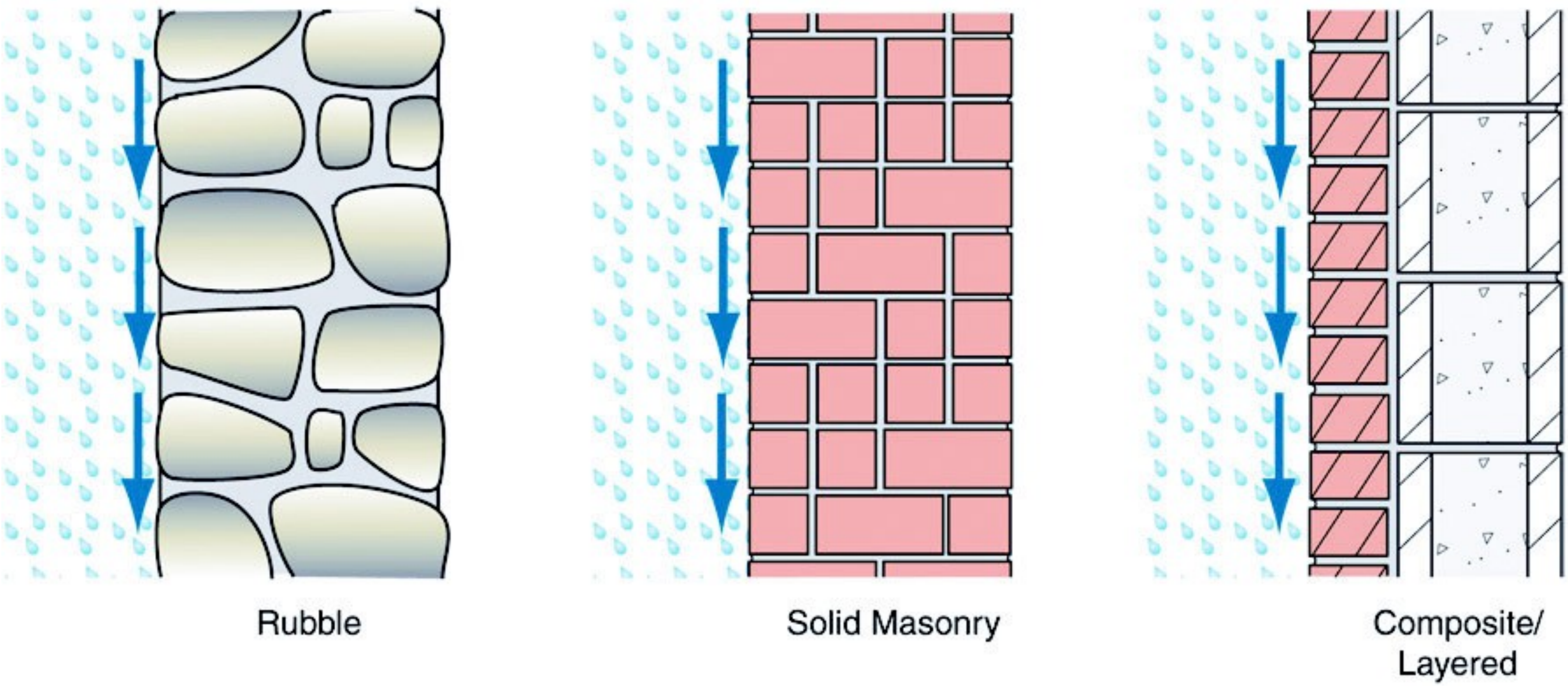
Insulating Load-Bearing Masonry Buildings

Overview

Mass Walls (Rain Control)



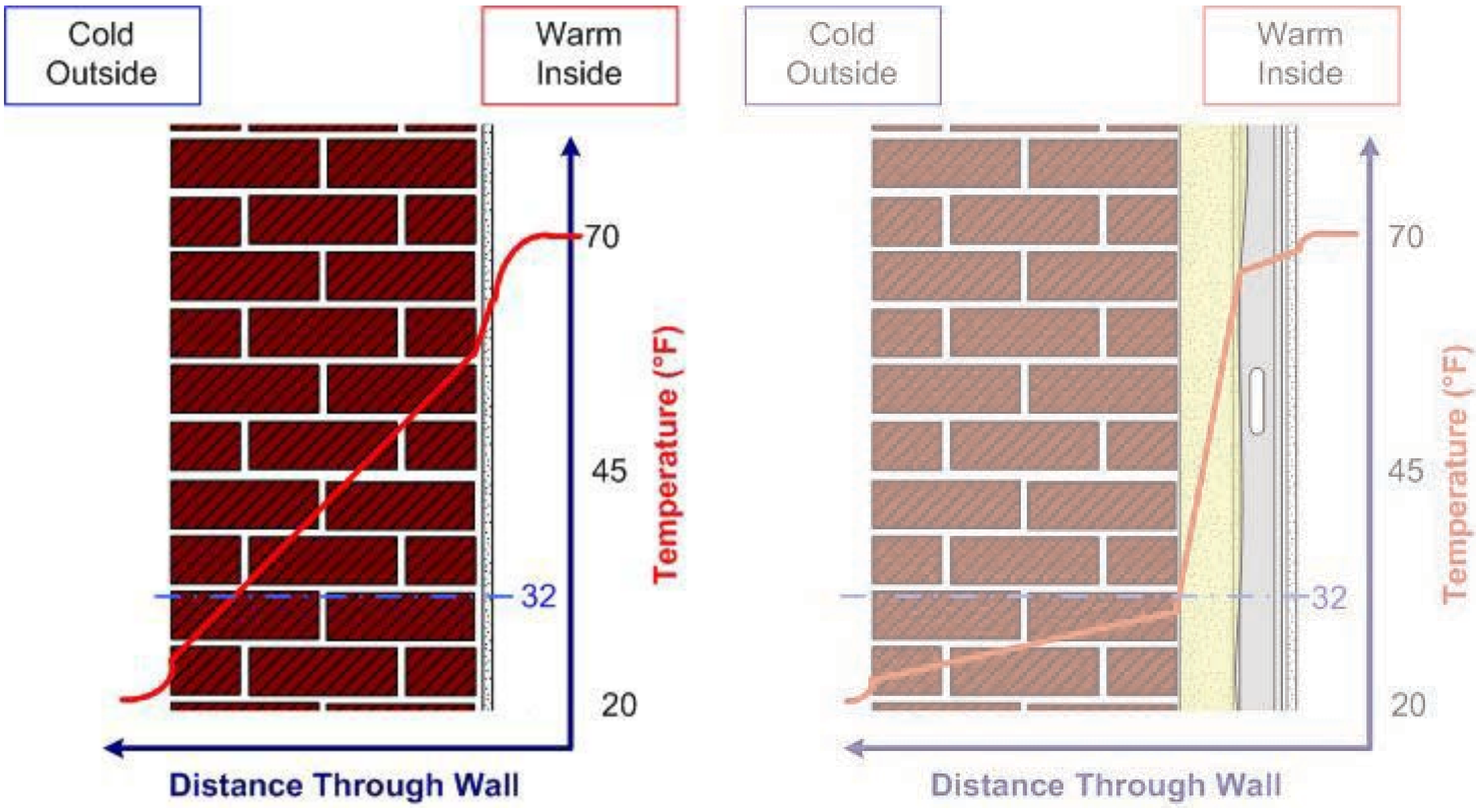
- Moisture is absorbed/safely stored during rain
- Moisture re-evaporates/dries while warmer
- No “drainage plane”

Inside or Outside Insulation?

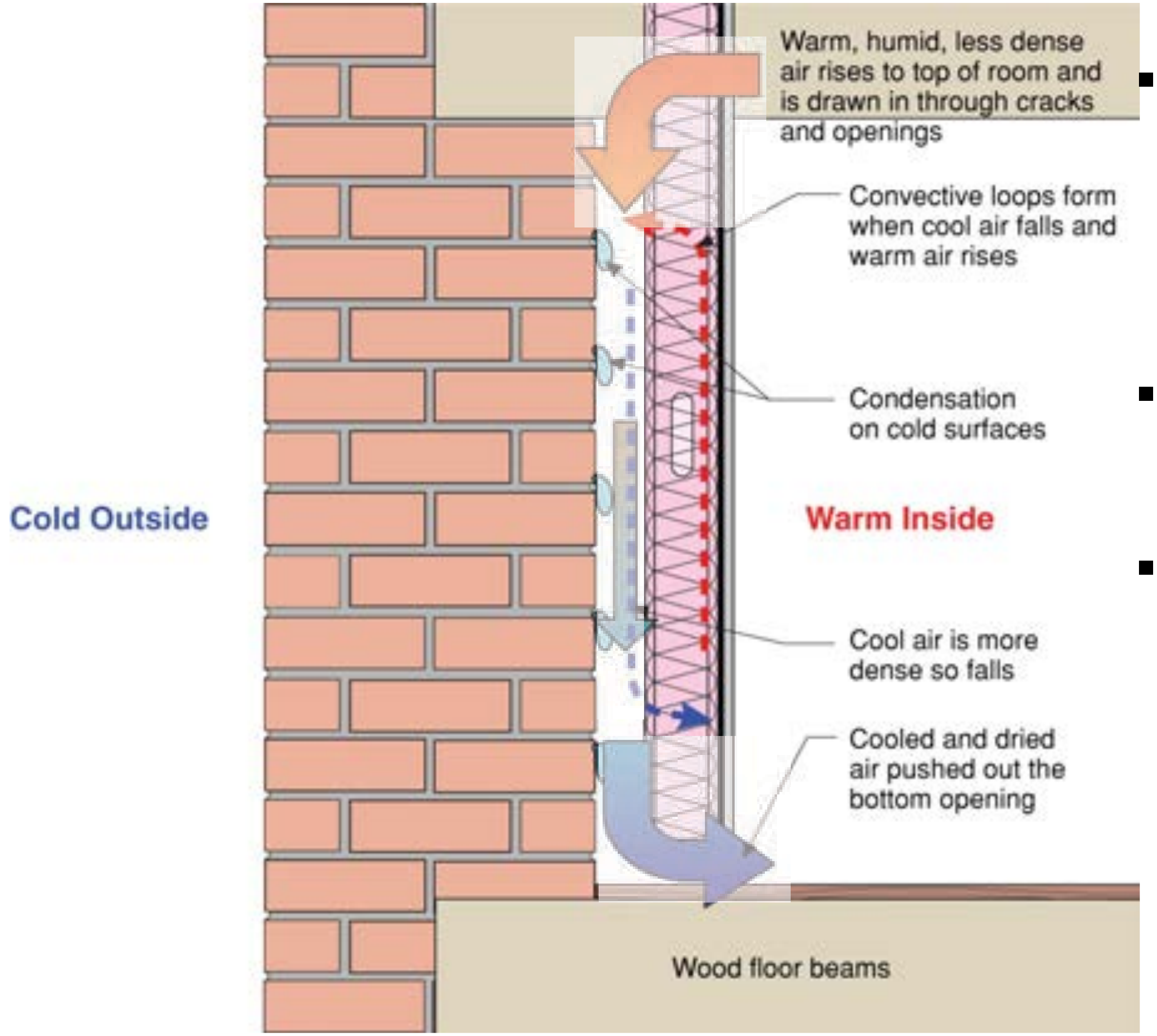
- Insulating on exterior always preferable (masonry durability, condensation risks)
- Interior insulation → historic preservation reasons
- Interior → potential durability risks
- Energy efficiency, preserve exterior, museum-level durability: choose 2 of 3

Cold Climate Risks

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



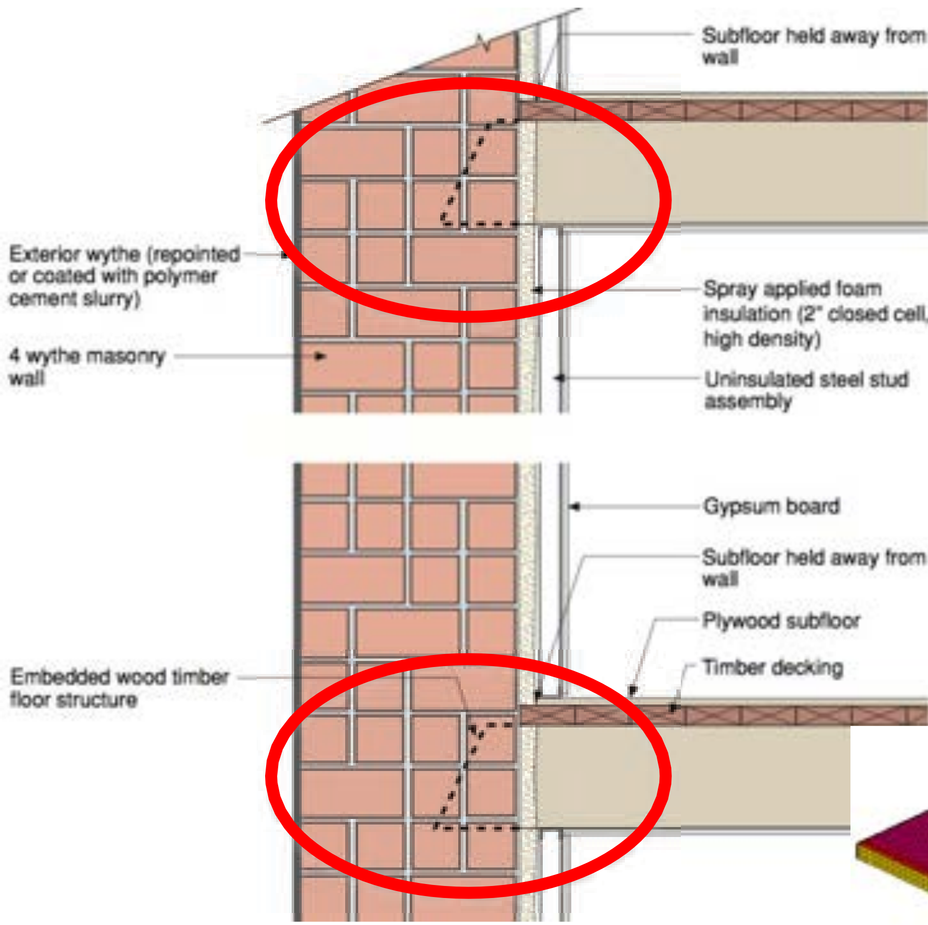
Cold Climate Risks: Condensation

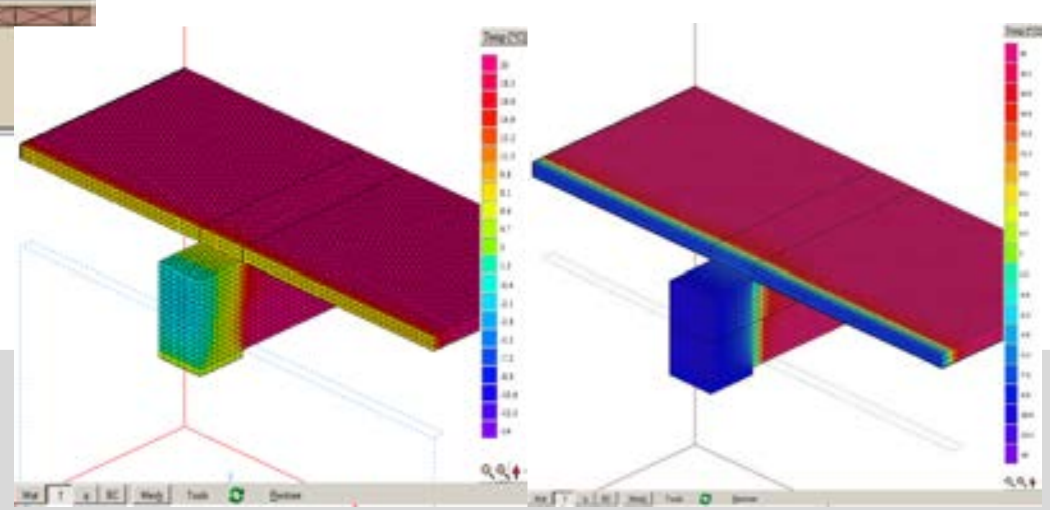


- Requires perfect workmanship at air barrier—around penetrations, etc.
- Made worse by air gap behind insulation
- **NOT RECOMMENDED**

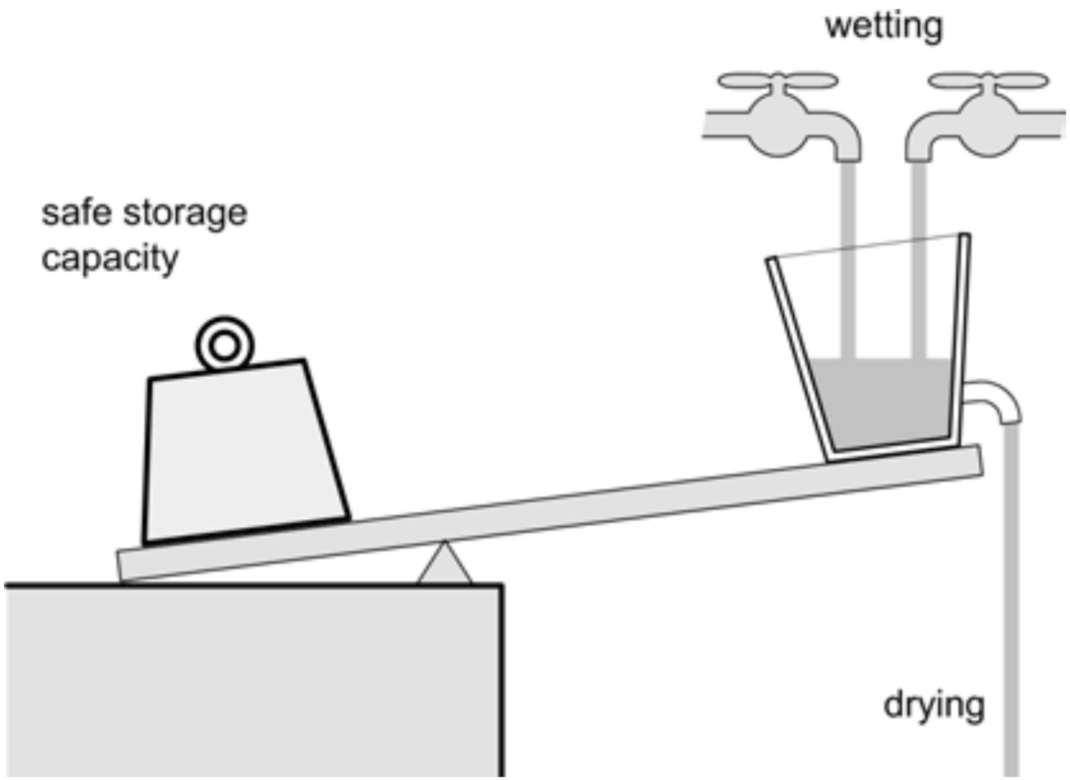
Condensation Risks

Embedded Wood Member Risks



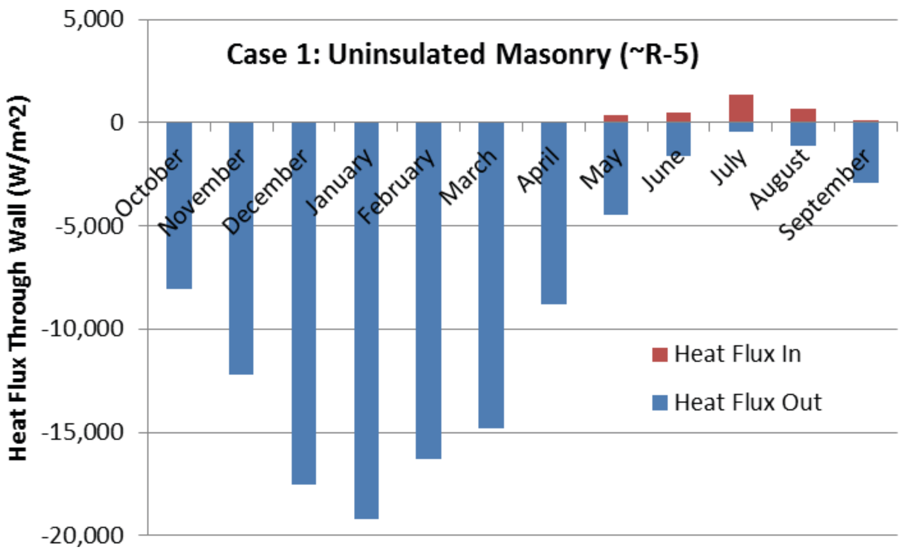


The Moisture Balance

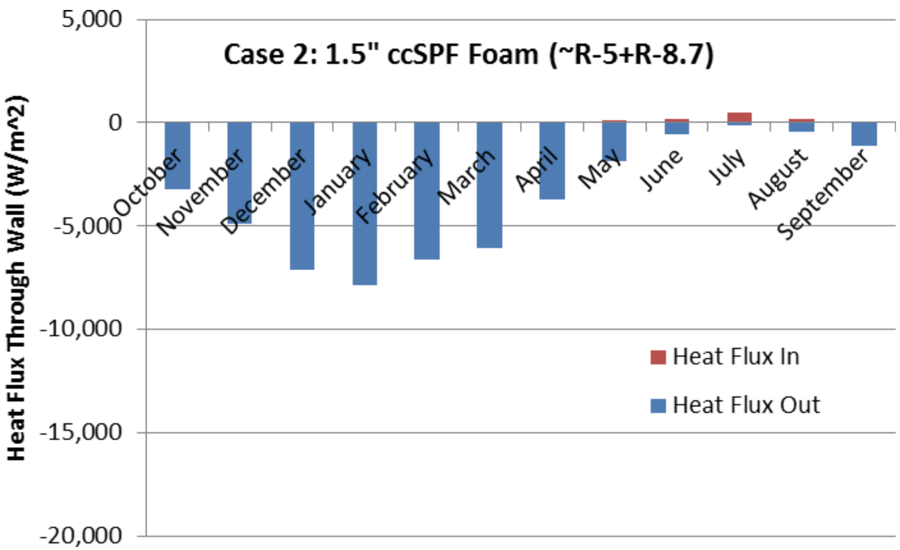


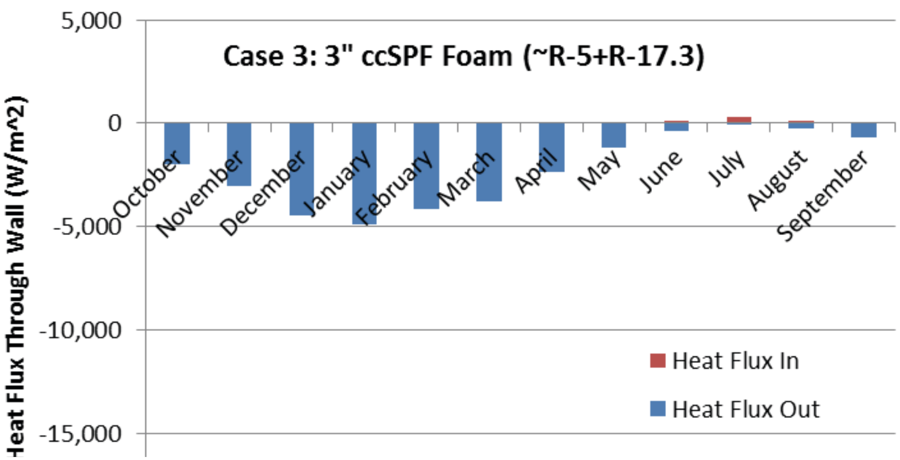
- Large storage capacity (mass wall)
- Drying decreases with insulation
- Design should reduce/control wetting to compensate

Do We Need to Insulate Mass Walls?



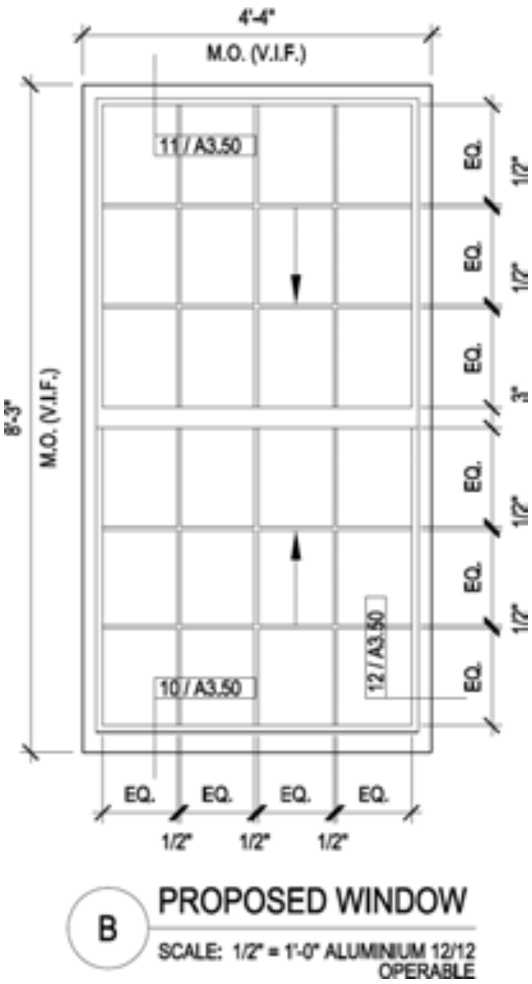
Climate: Burlington, VT





Mass vs. no mass → Adds ~R-1

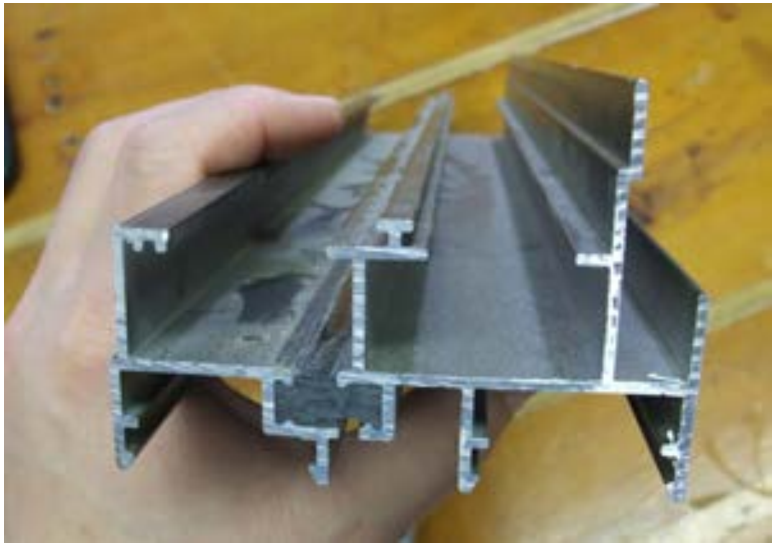
Window Heat Loss in Context

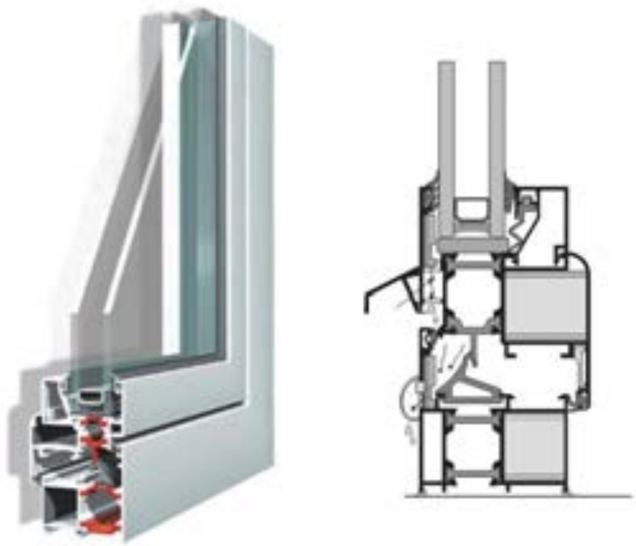


- Large windows (4’ x 8’), high glass %
- Can’t change frame profile (historic)
- Aluminum, double, low E: U≈0.5 (center of glass U-0.30)
- R-2 holes in R-20 walls

Window Heat Loss in Context

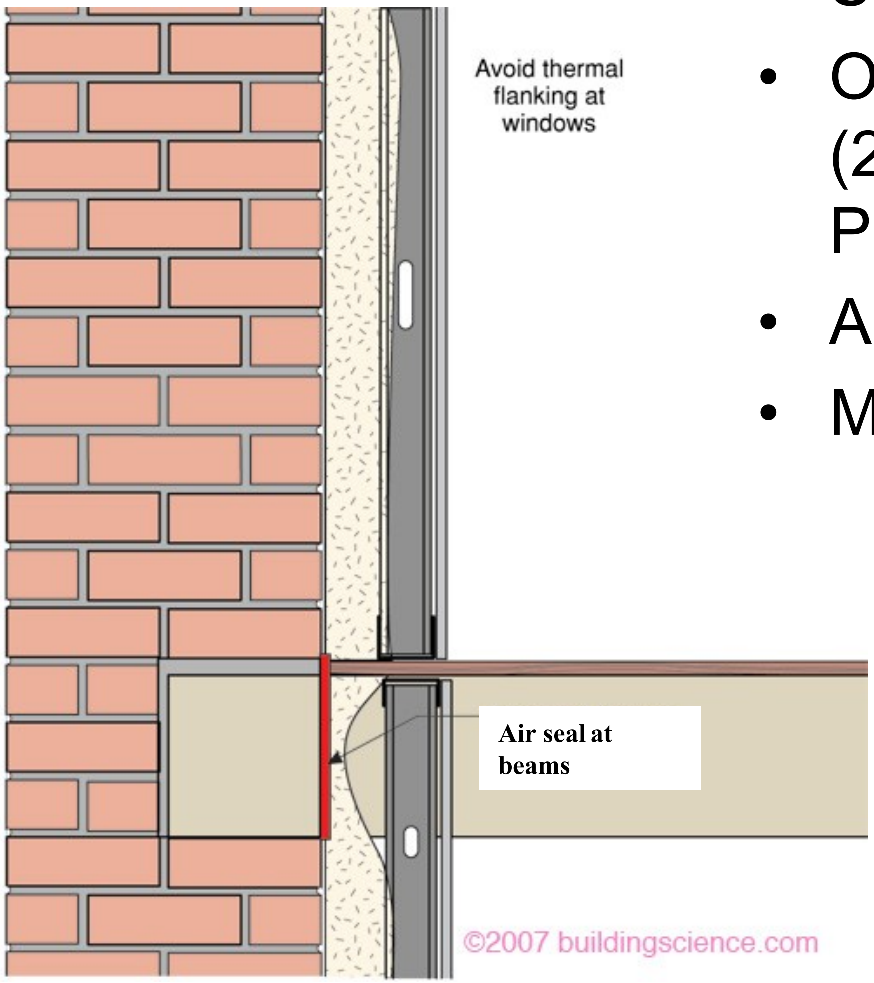
- Improved thermal breaks available
- Improved edge spacers available
- Improved center-of glass (triple, films, etc.)
- All add cost; not typical construction
- Alternate frame materials?





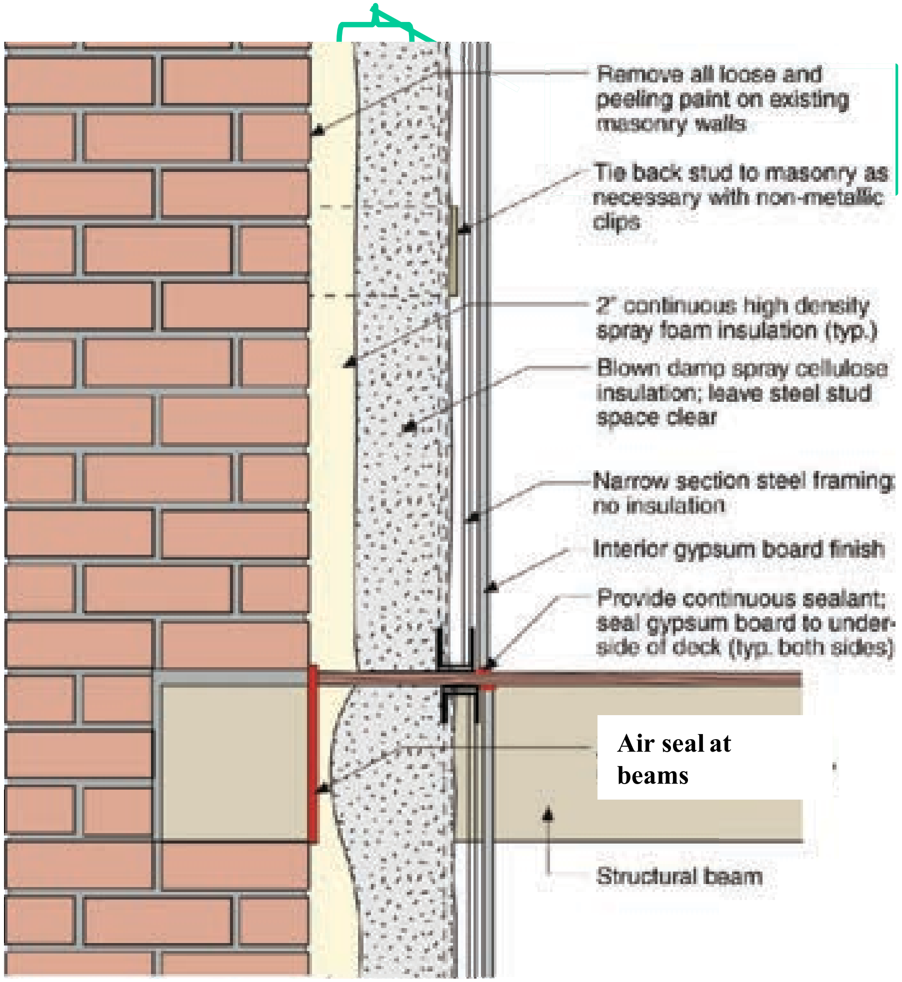
Retrofit Approaches

Recommended Approaches



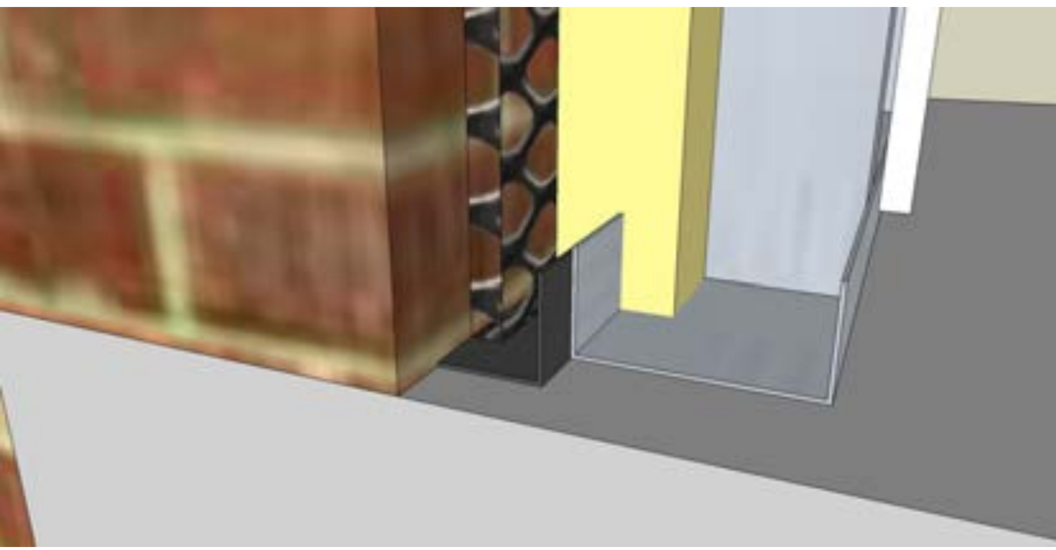
- Spray foam against masonry
- Open cell (0.5 PCF)? Closed cell (2.0 PCF)? Intermediate (1.0 PCF)?
- Air seal at joist pockets
- Montreal experience

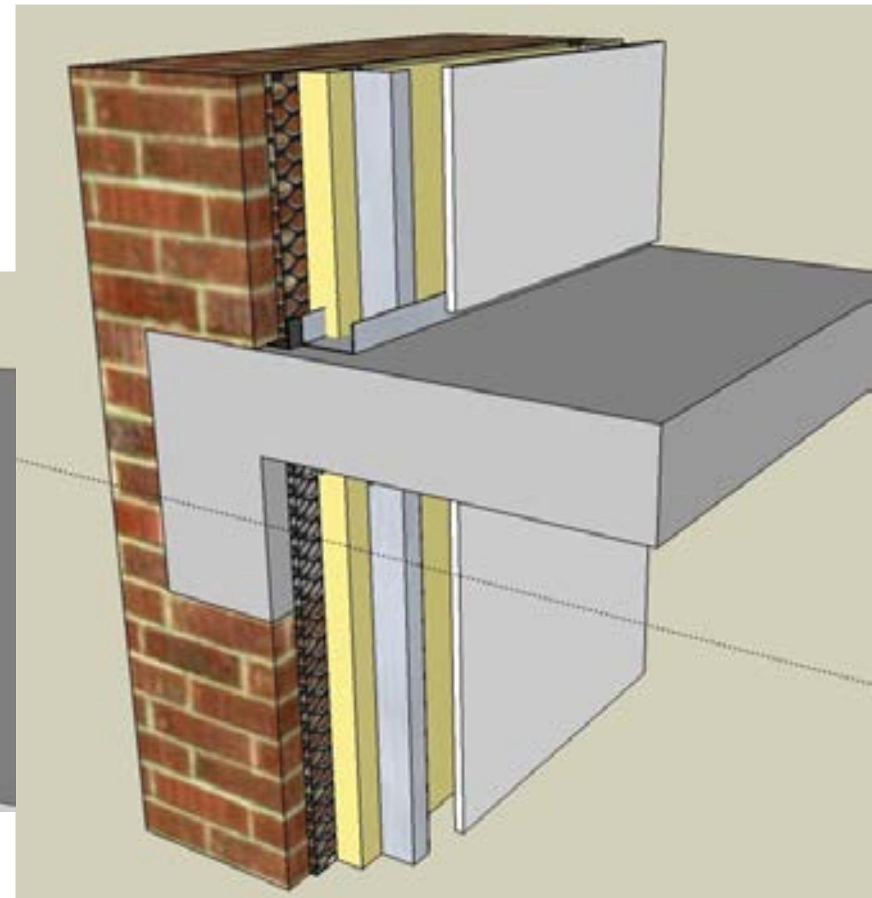
Hybrid Wall Insulation Assembly



Rain Control

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



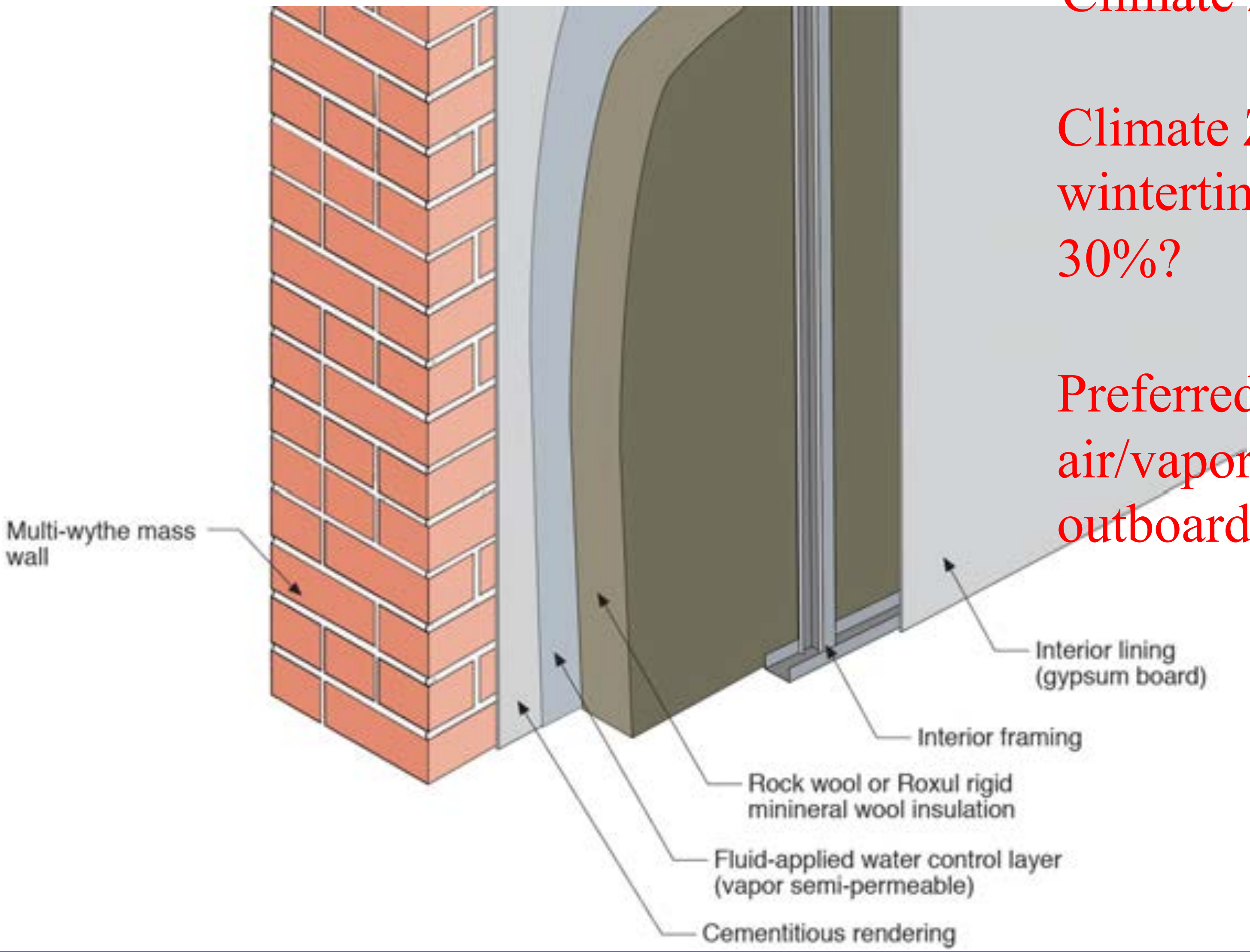


Non-Foam Options?

- 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

Photo: Chris Benedict

Mineral Fiber Interior Retrofit?



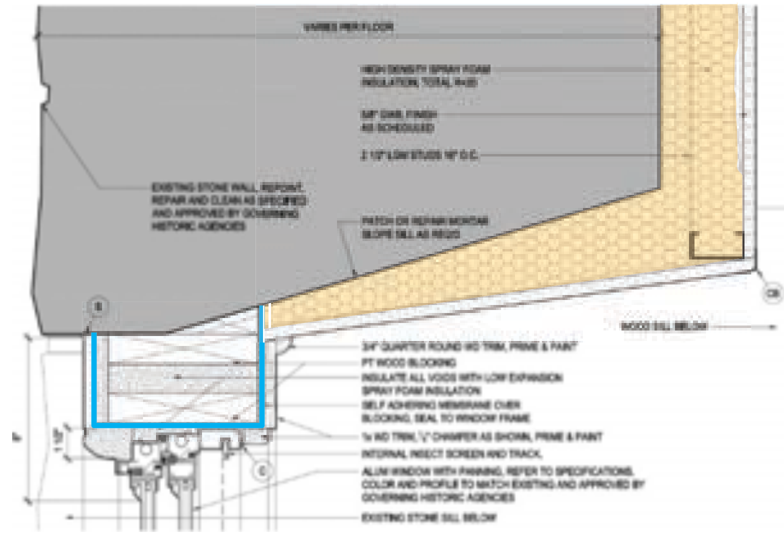
Climate Zone 4-OK

Climate Zone 5- wintertime RH under 30%?

Preferred approach: air/vapor control outboard of stud wall

Problem Items

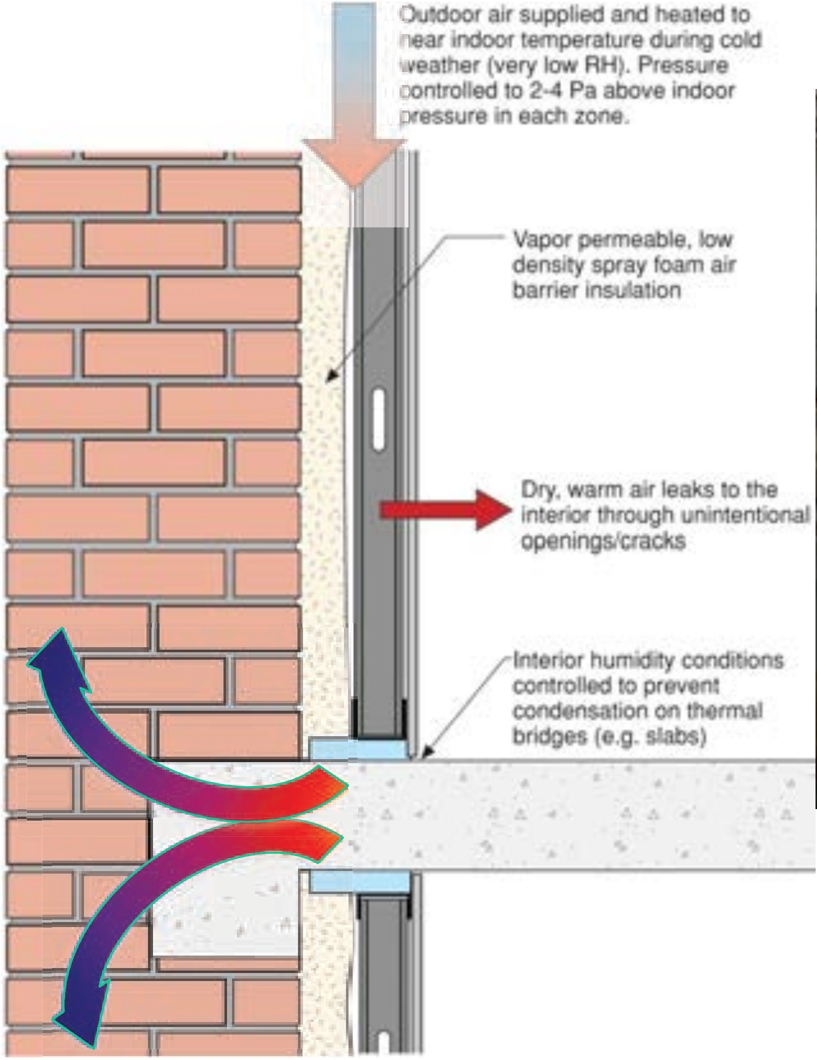
Tapered Window Openings



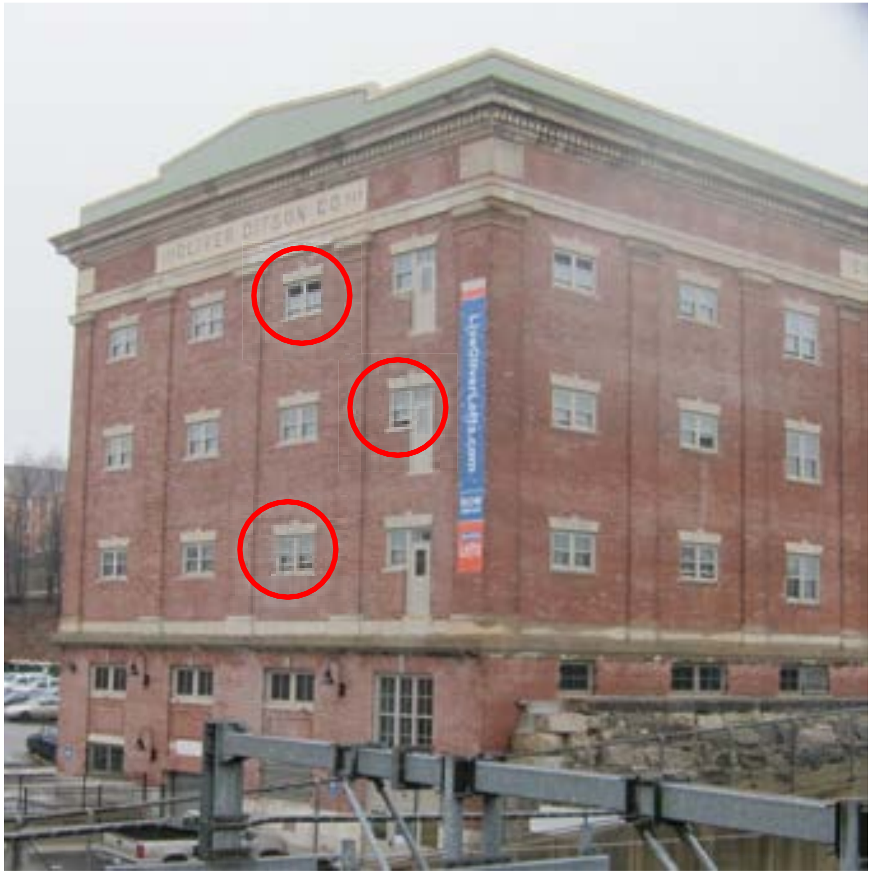
Minimum ~R-5 for thermal comfort (radiant surface temperatures)

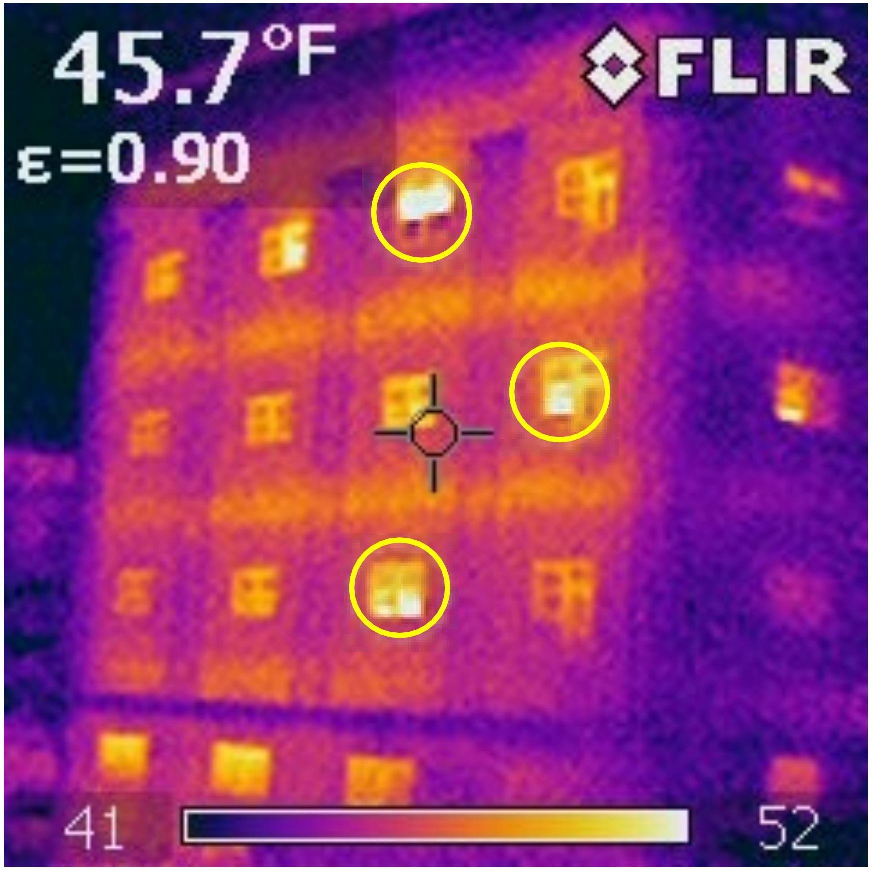
Leverage spray foam for air barrier continuity to window opening

Thermal Bridging at Slab Floors



Thermal Bridging at Slab Floors





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

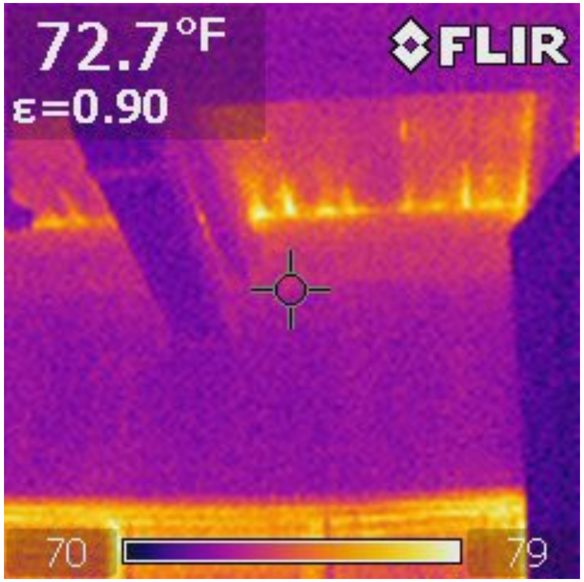
Thermal Bridging at Slab Floors

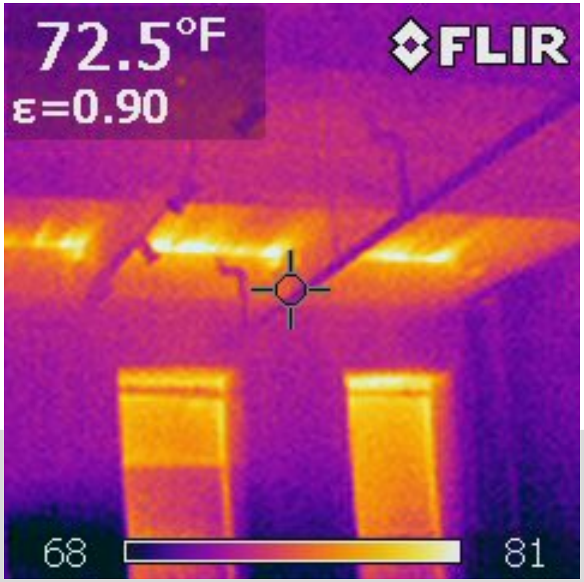
- Typical Insulation Levels
  - R-14 for 8 foot wall
  - R-3 for 8 inch floor slab
  - R-10.9 overall opaque R value
  - 22% loss from nominal value
- High Insulation Levels
  - R-38 for 8 foot wall (6” ccSPF)
  - R-3 for 8 inch floor slab
  - R-19.9 overall opaque R value
  - 47% loss from nominal value

Interior Brick Exposed to Exterior

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

Air Barrier Issues





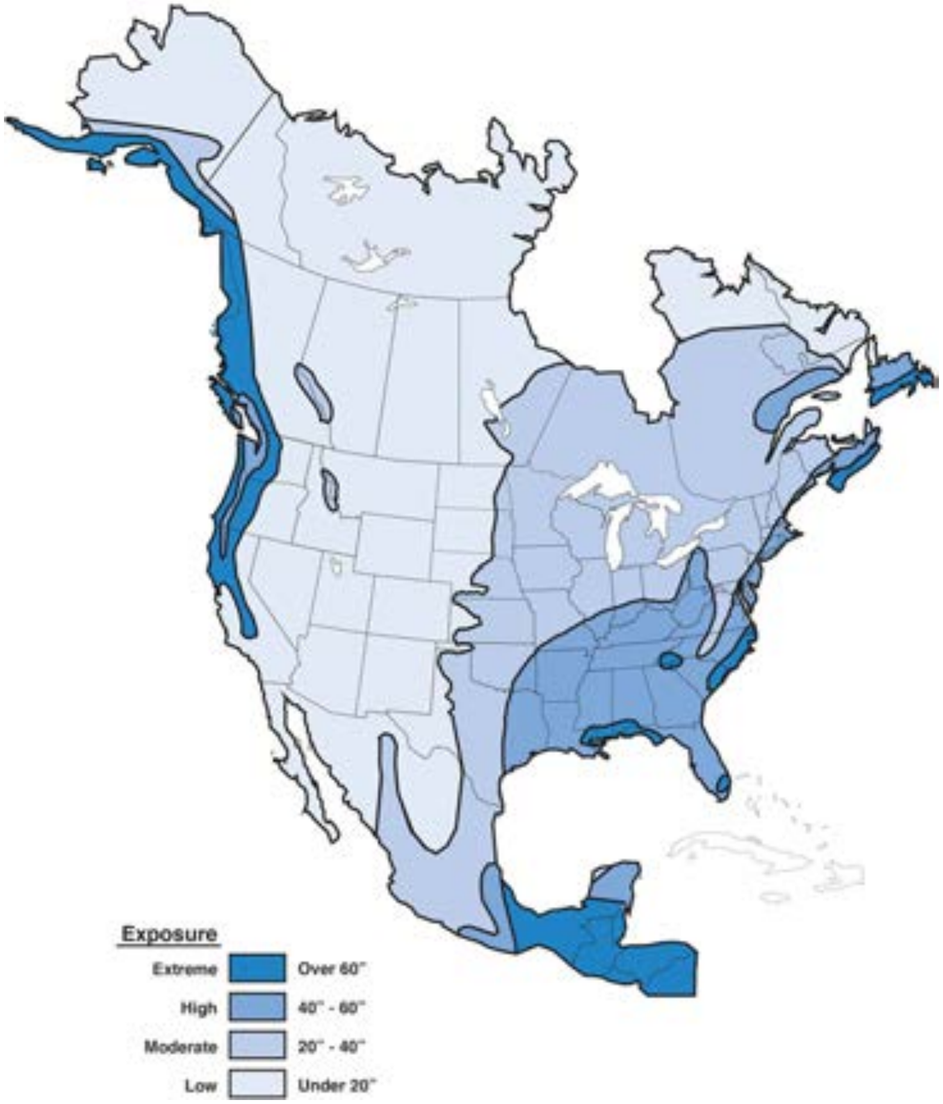
Can't rely on masonry alone to be an air barrier

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

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

Assessment Steps

Where is the Building?



Freeze-Thaw Risk Assessment Process

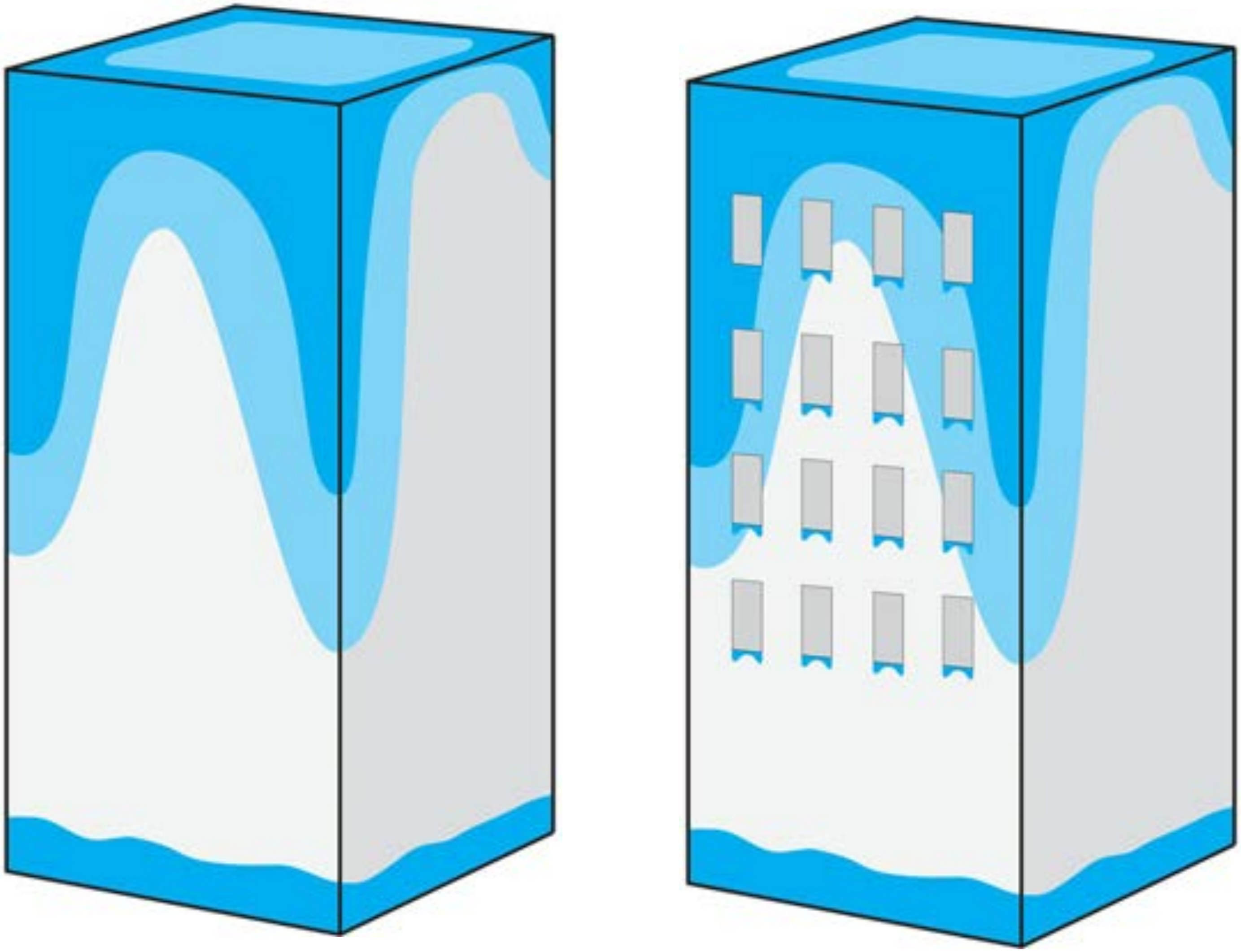
In order of importance:

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

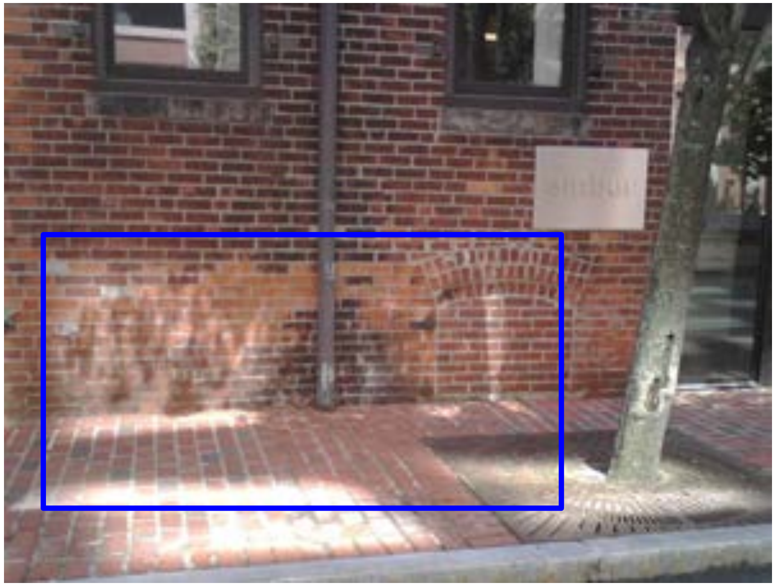
1. Site Visit

- 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

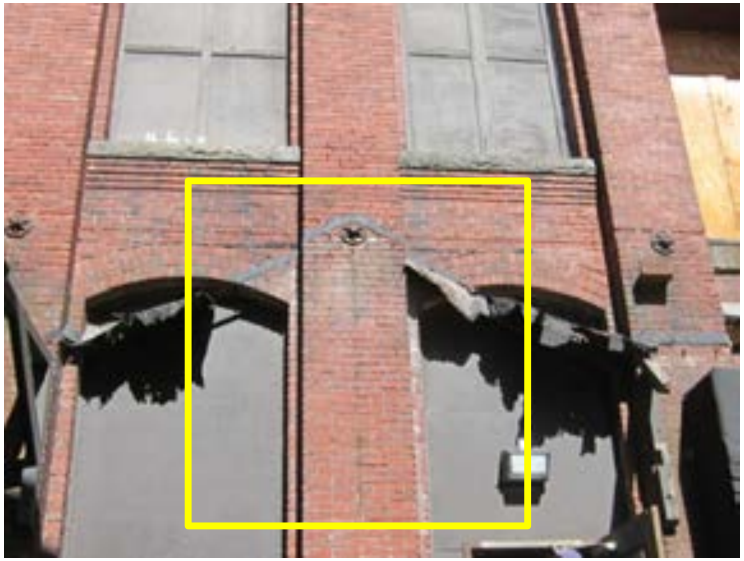
Site Assessment: Where is it Wet?



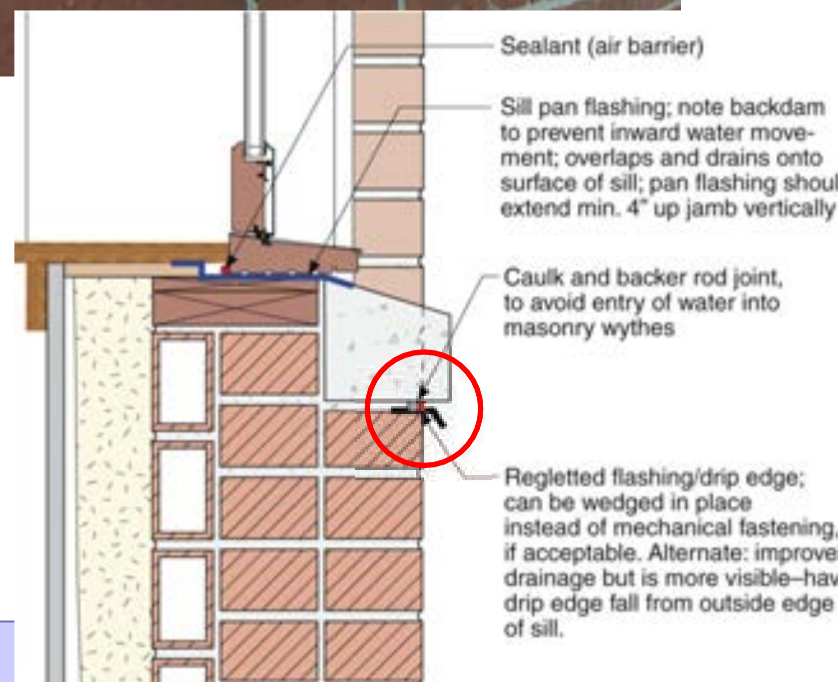
Site Assessment: Where is it Wet?



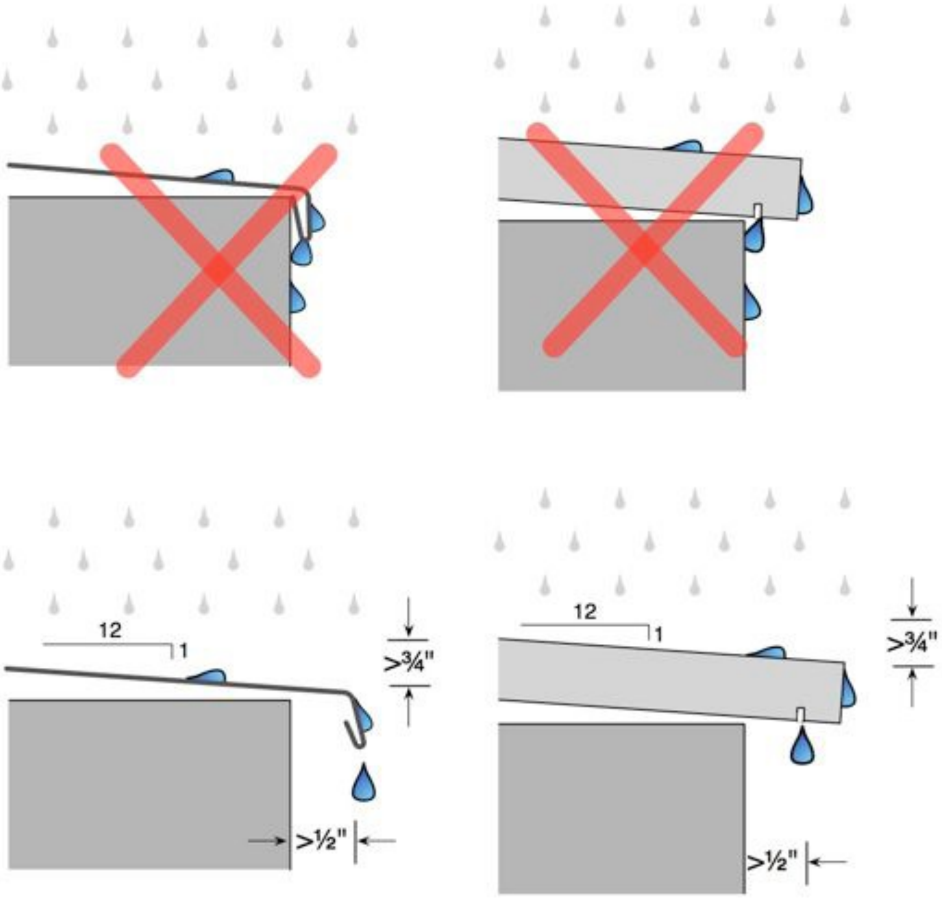
Water Concentrations



Windows (Water Concentration)

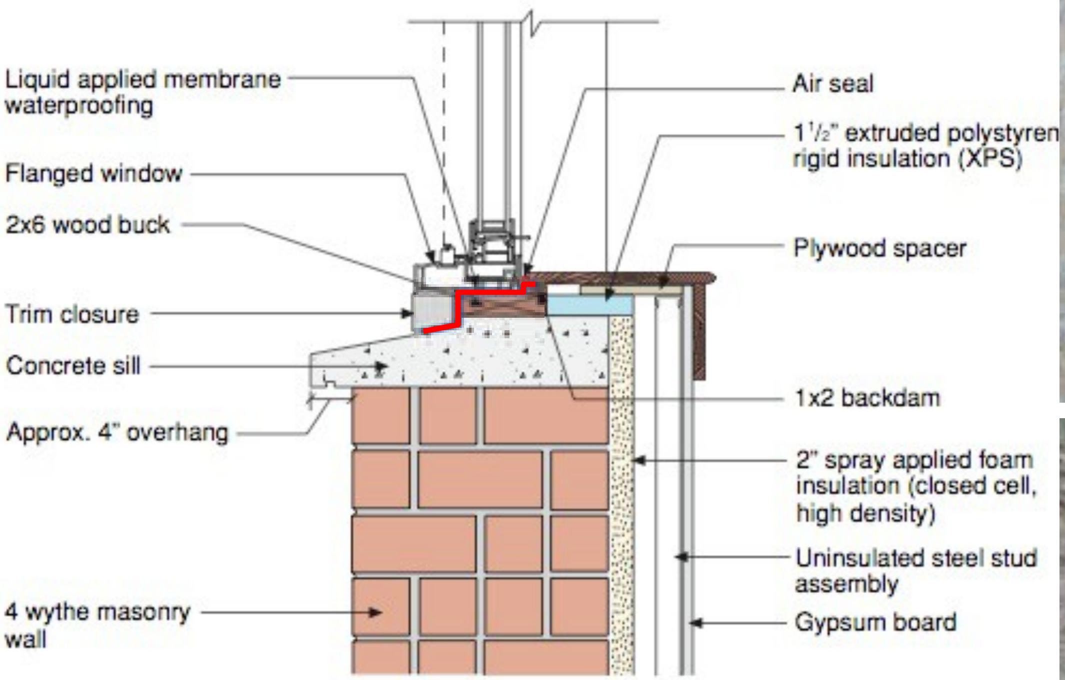


Drip Edges

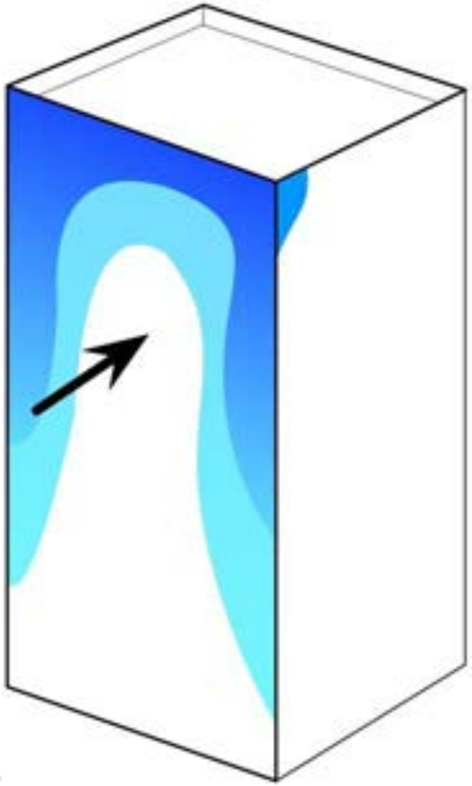


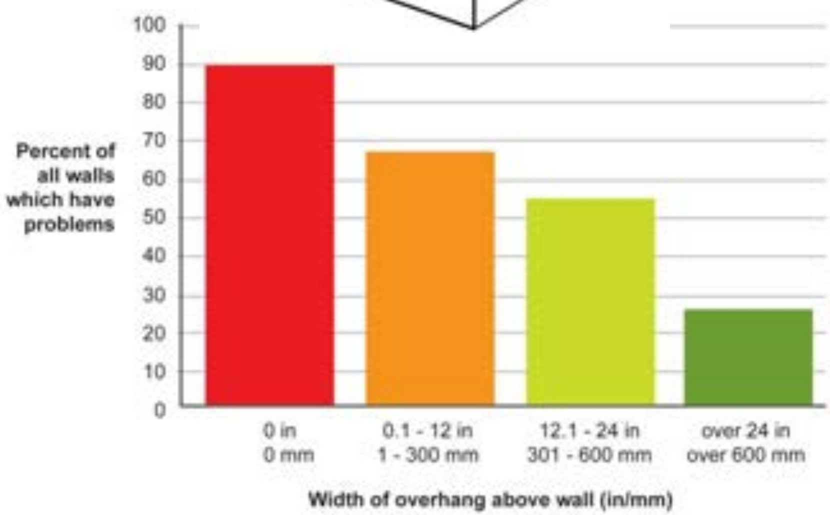
dri

Windows (Potential Rain Entry Point)



Roof-Wall Interface





Existing Damage

- Where is it? Still active or not?

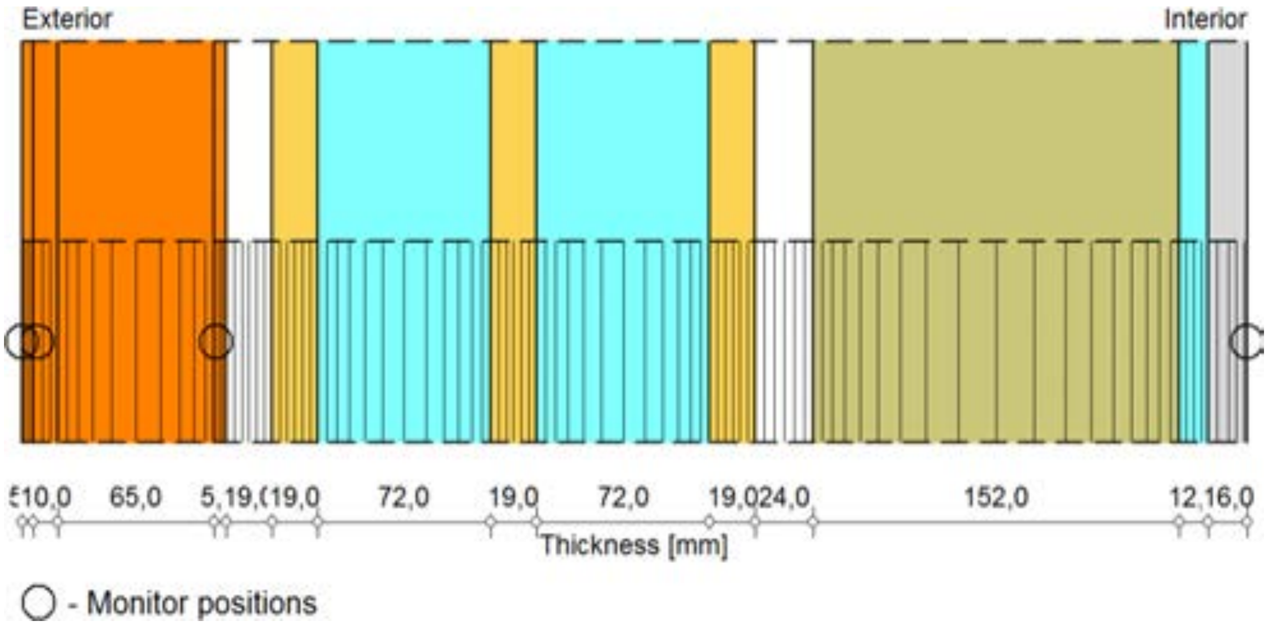
Existing Damage

- 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_{crit})
  - More details in following section
- WUFI modeling
  - Requires knowledge, experience, comparison to measured data, and real experience

Hygrothermal Simulations

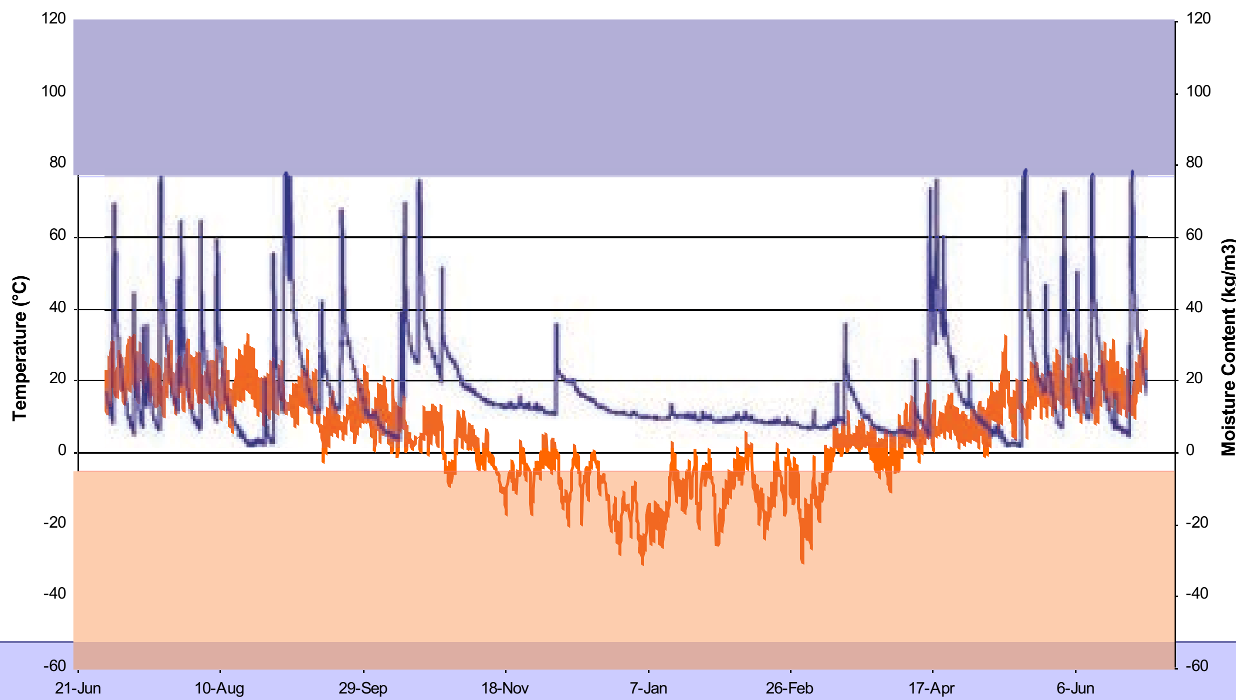


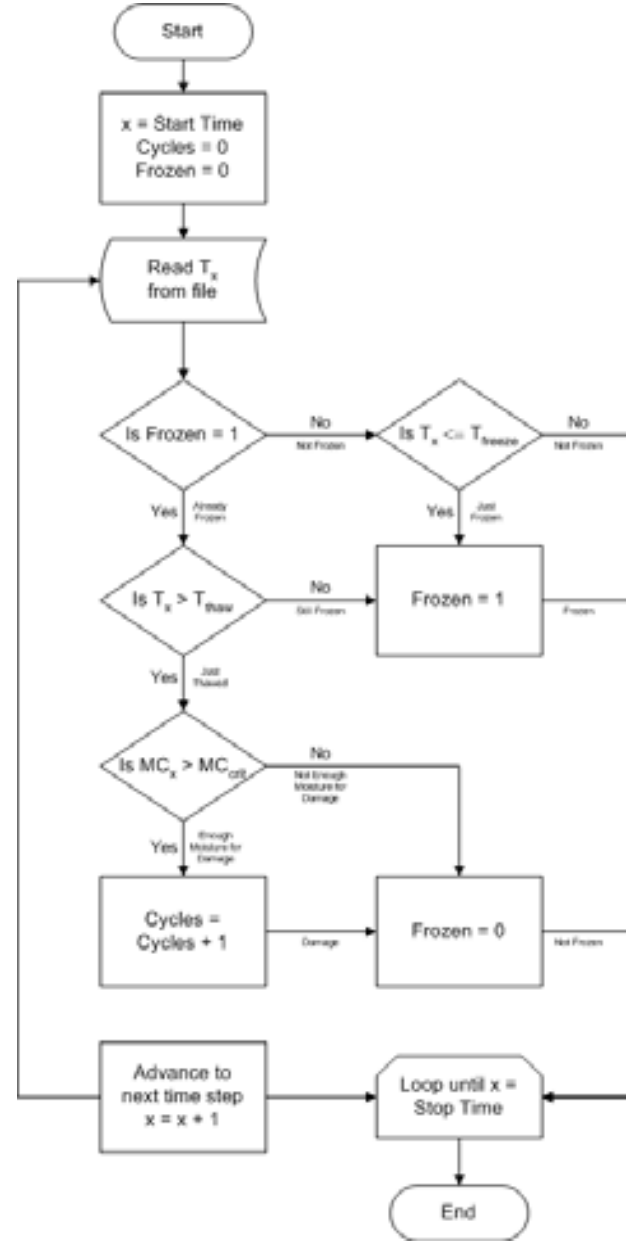
- Simulate existing (uninsulated) wall
- Simulate retrofitted (insulated) wall
- Vary rain loading—sensitivity analysis

- Brick
- Mortar
- Terra cotta
- Air Space
- Plaster
- ccSPF
- Air Space
- Gypsum Board

Assessment

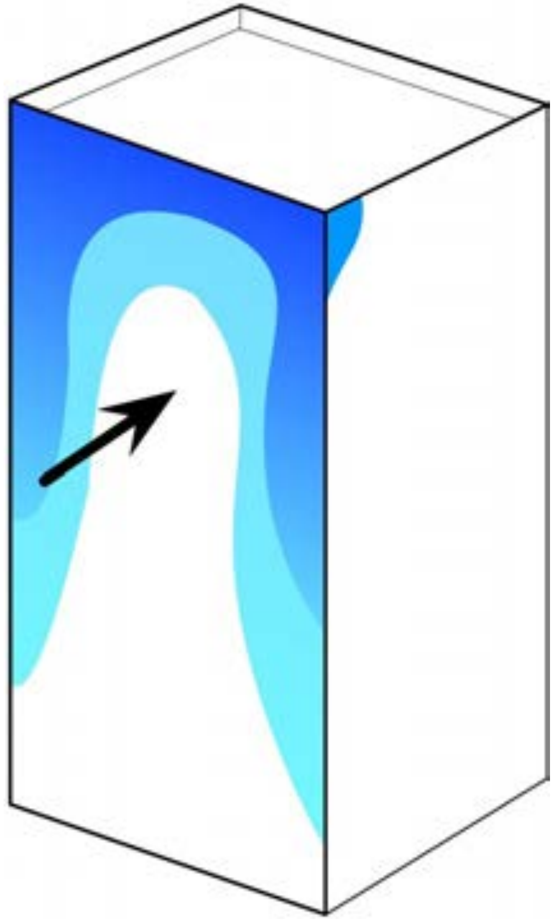
- Freeze Thaw Event
  - Brick must have higher moisture than Critical Degree of Saturation
  - Brick must freeze/thaw (<23 F and >32 F)





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)

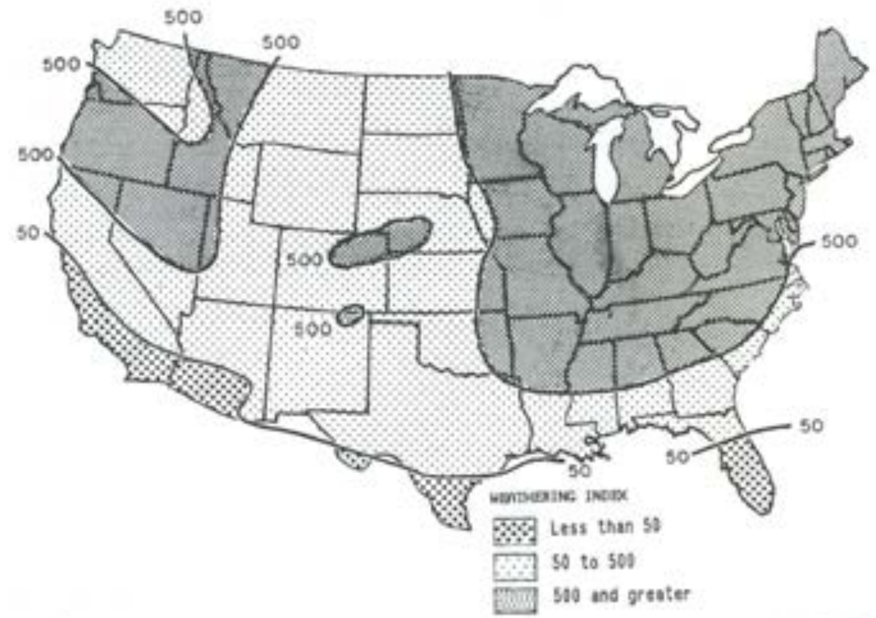
Freeze-Thaw Testing

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

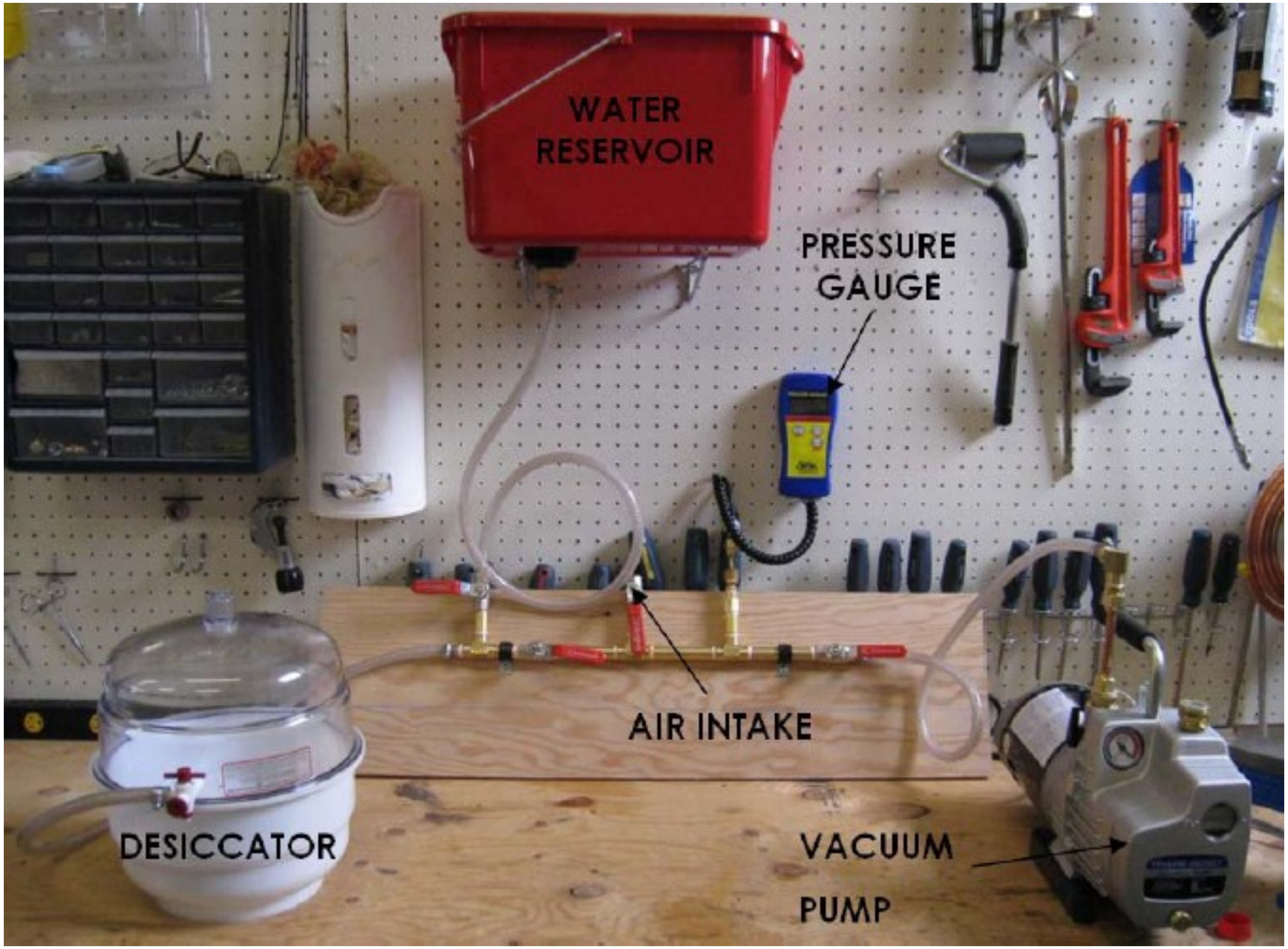
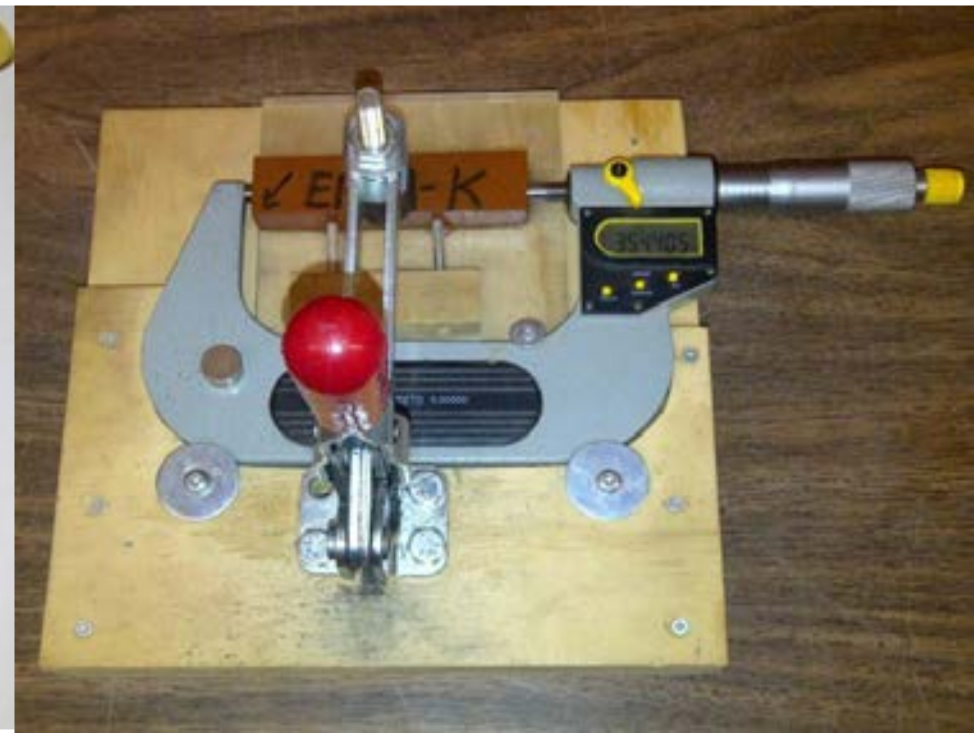


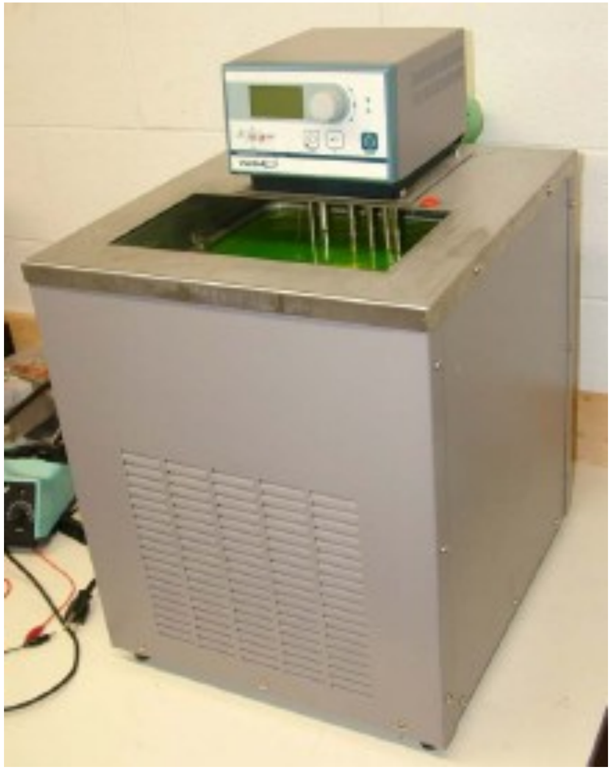
Image: P. Mensinga, UofW BEG

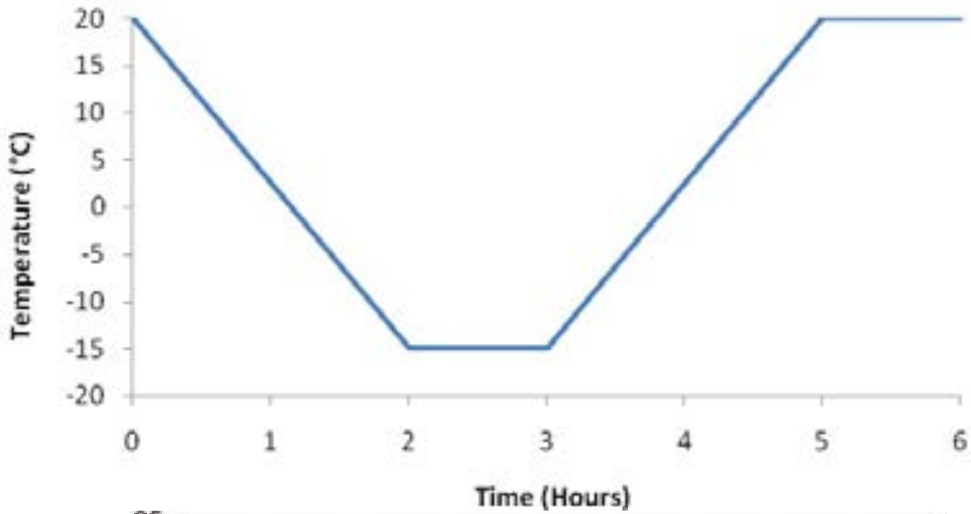
Measuring Dimensions (Dilation)

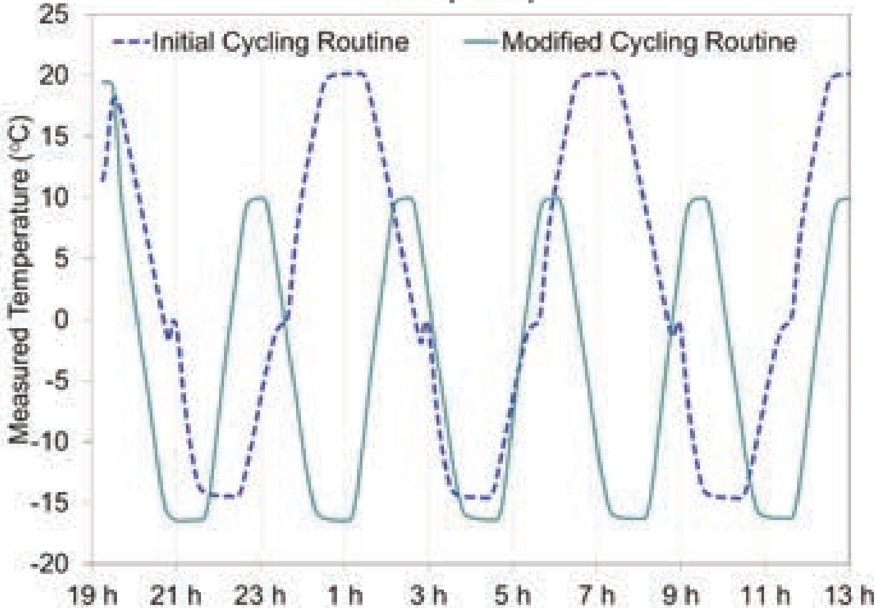
- Small dilation ~200 to 3000 microstrain
- One microstrain=one part per million (10^{-6})
- 1000 microstrain=0.1%



Running Freeze-Thaw Cycles







- Minimum 8 cycles
- Sometimes more to "draw out" damage

Dilation (Growth) of Samples