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Embedded Wood Joists in Insulated Masonry Walls-Simulations & Reality

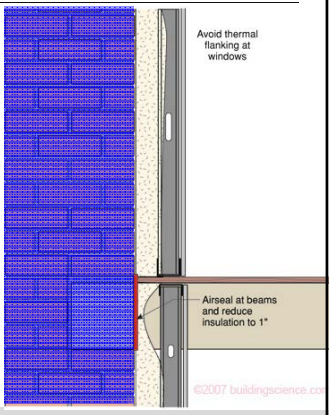
Building Science Hygrothermal Analysis Expert Session
November 19, 2014

Building Science Corporation

Background

Embedded Wood Members

- After interior insulation, wall and joist end will be colder
- Less energy flow, higher RHs, wetter conditions
- Wood can mold/rot
- How big is the risk?



2005 Monitoring Research (Canada)

- In SK, joists stayed dry (10-15% MC)
- In ON, sometimes up to 20% MC
  - Capillarity from foundation?
  - Rainwater absorption through face of masonry?

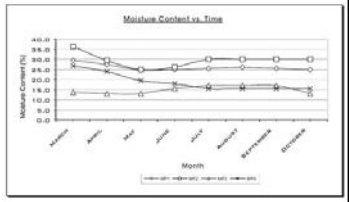


Figure 1

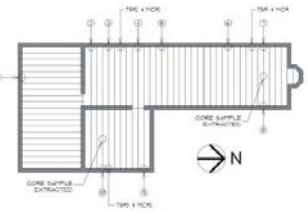


Figure 2

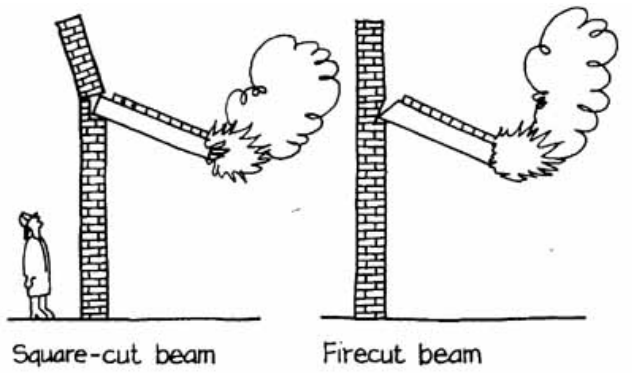
Literature Review (Con't)

- Scheffler (2009)
  - DELPHIN 2D hygrothermal simulations, steady state
  - Interior-sourced air and vapor flow risks
  - Transient simulations; beam end MCs increase w. insul.
  - Historic & modern methods to address beam end MCs
- Morelli (2010)
  - Gap in insulation above and below beam area (12" above and below → 30" left exposed)
  - 60% heat flow reduction from full insulation
  - 45% reduction with "gapped" insulation
  - "Gapped" insulation has less wetting than full insulation
  - Huge effect of rainfall deposition rates

Thermal Modeling

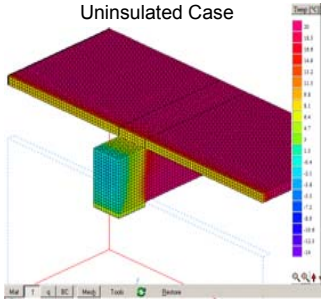
Terminology-"Beams" and "Joists"

Firecut Beams

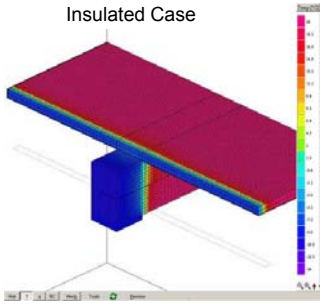


3D Heat Flow Simulations (Beam)

Uninsulated Case



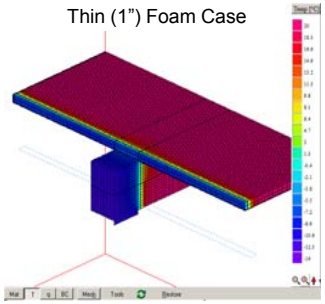
Insulated Case



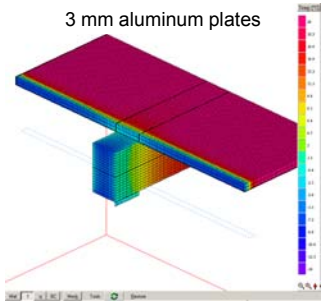
- Interior 68 F (20 C)
- Exterior 7 F (-14 C) (Boston 99.6% design T)
- Steady state (no thermal mass). Air space and no air space

3D Heat Flow Simulations (Beam)

Thin (1") Foam Case



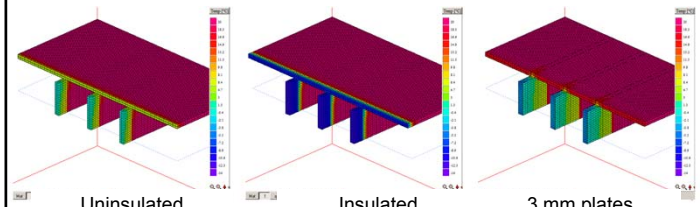
3 mm aluminum plates



- Thinned foam ~16" around beam in all directions
- 3 mm aluminum plates, sides of beam, 2x beam pocket interior depth
- Air leakage and condensation risks? 44-46 F (6-8 C) → 70 F, 35-40% RH

3D Heat Flow Simulations (Joist)

Isometric of assemblies



Uninsulated Insulated 3 mm plates

Conclusions: Thermal simulations (3D)

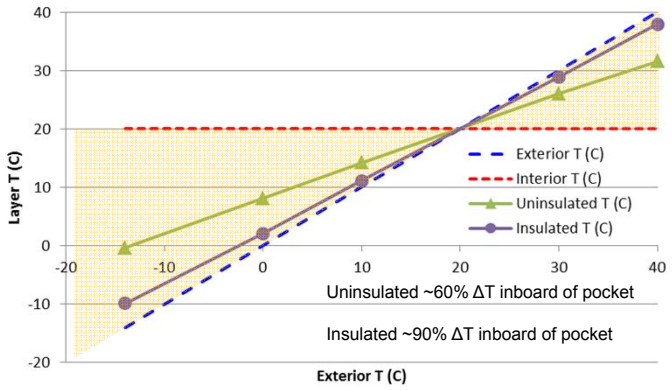
- Addition of insulation makes ends of embedded wood members colder in winter
- Metal plates add heat at beams, BUT risks of condensation and air leakage
- Thinned insulation shows little effect on beam end temperatures
- Elimination of rim joist insulation results in higher beam end temperatures, but with an energy performance penalty

Hygrothermal Modeling

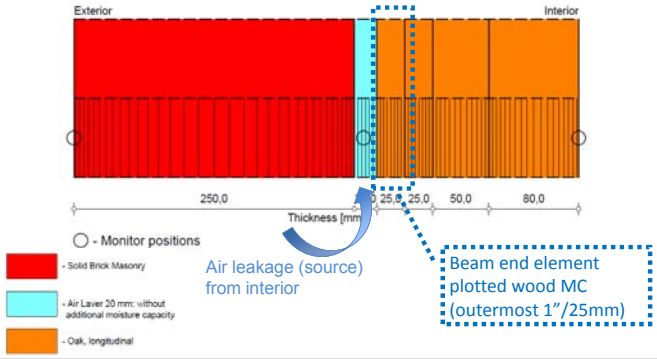
Hygrothermal (1D) Simulations

- Why bother with 1D model at all?
- One dimensional section same in uninsulated and insulated cases
- Modify wood material thermal conductivity, to result in correct beam end temperatures
- Needed to develop a “temperature index” at end of beam pocket from HEAT3 simulations

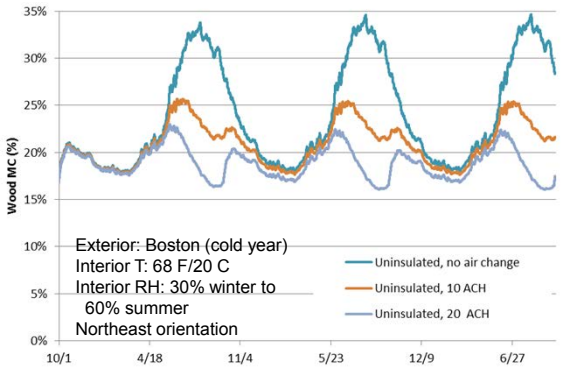
Beam End Temperature Index



Hygrothermal (1D) Simulations



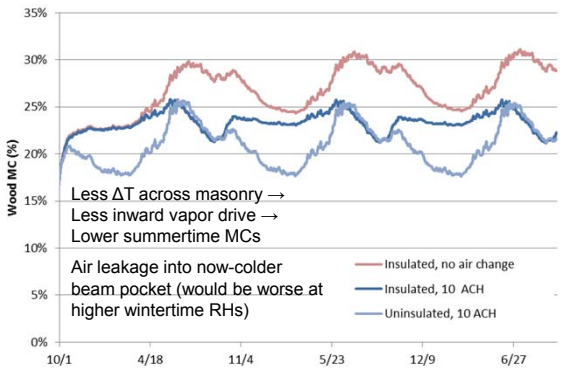
Uninsulated Beam Results



Air change plays role in drying of beams in existing buildings?

10 ACH = 0.0013 m/s air velocity (1/3 in & 1/3 out)

Insulated Beam Results



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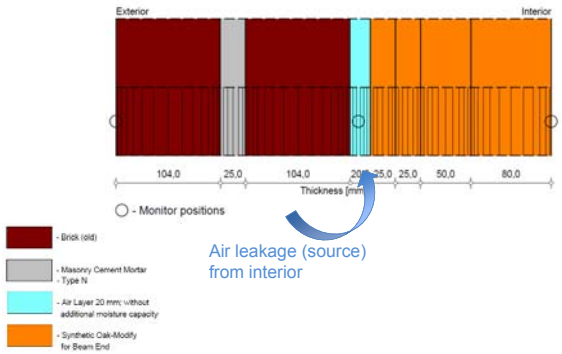
Alternate Masonry Assemblies



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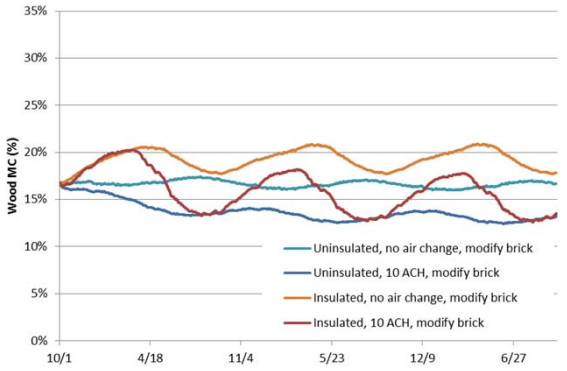
Alternate Masonry Assemblies Results



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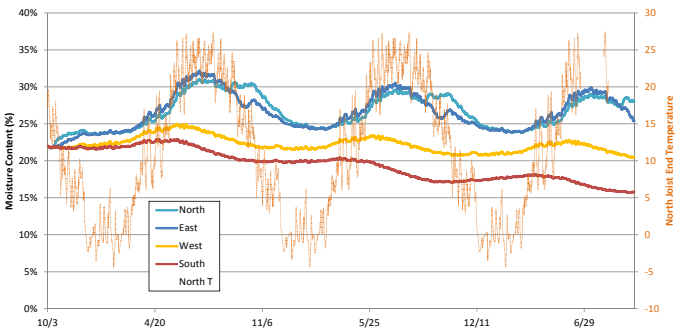
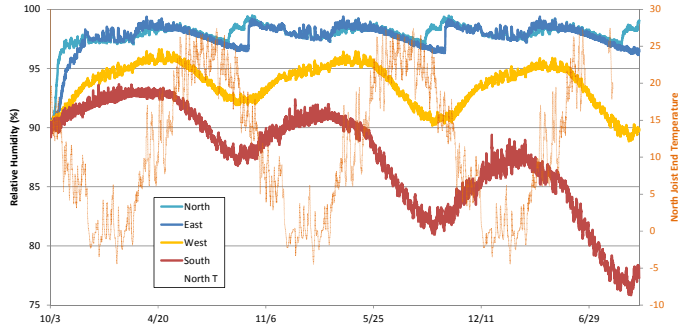
Orientation Effects: Moisture Content

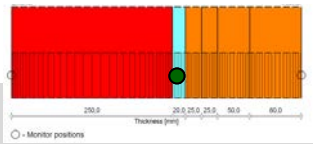


- Insulated, no air change

Orientation Effects: Relative Humidity



- Insulated, no air change
- Long term run-south drier



Conclusions: Hygrothermal simulations

- Air leakage has a strong effect on beam end moisture contents
- Airflow lowers moisture content in some cases, but can raise MC in wintertime (insulated case vs. uninsulated with airflow)
- Alternate material assemblies can have strong effect on results
- Substantial uncertainty in actual behavior—simulations here were a “workaround”
- Use of 2-dimensional hygrothermal simulations?
- Field monitoring of actual behavior (wood MCs)!

Monitoring Project

Embedded Joist Monitoring

- HfH Lawrence renovation
  - c. 1906 & 1930
- Ongoing interior retrofit
- Joist moisture content:
  - 3 measurements/joist
  - 10 joists
- Variables
  - Orientation/exposure
  - Wall type
  - Insulated/non-insulated
  - Air sealed

Interior Insulation Details

- 3x 2” (6” total) layers extruded polystyrene, adhered to masonry walls
- Joist pockets insulated with XPS blocks, air sealed with spray foam kits

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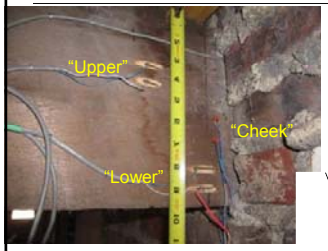
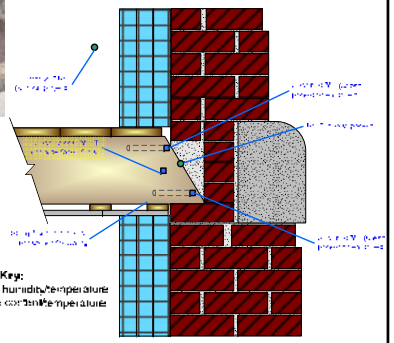
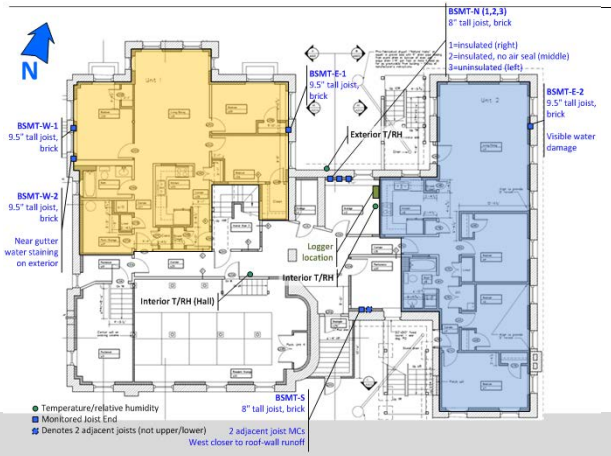
Joist Monitoring Package





Joist Monitoring Locations (Basement)



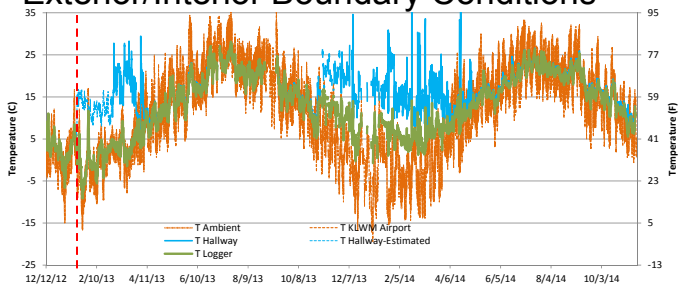
Insulation Option Comparison (North)

- Same orientation, 3 different insulation techniques
- Fiberglass = insulated but no air leakage control

Joist Monitoring Locations (First)

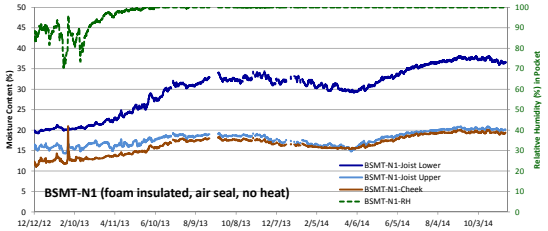
Monitoring Results

Exterior/Interior Boundary Conditions



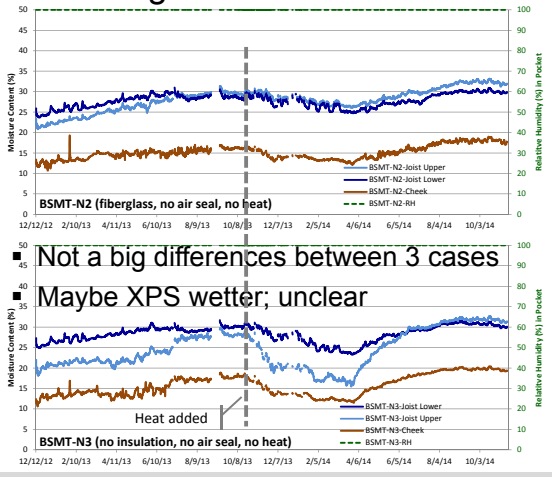
- Some parts heated ("Hallway"), others unheated ("Logger") → construction heating during winters
- Not very representative; still under construction
- Interior dewpoints ~identical to exterior dewpoints
- Some joists still uninsulated/unsealed

North-Facing Basement Joists



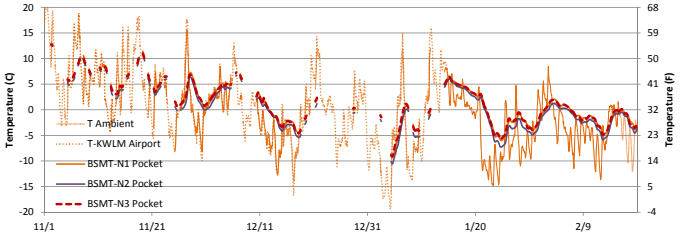
- "Lower" vs. "Upper" & "Cheek" MCs
- RH tracking to moisture contents
- All pretty high MCs, especially "lower"
- "Mothballed" condition of building
- Rise in RH every summer, not winter

North-Facing Basement Joists



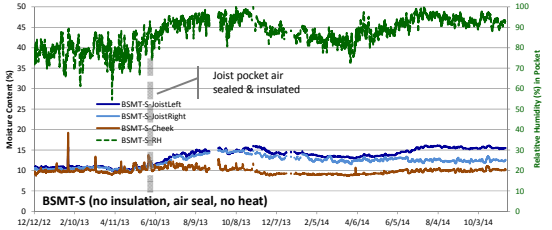
- Not a big differences between 3 cases
- Maybe XPS wetter; unclear

Results: Joist Pocket Temperatures



- Minimal interior heating in winter 2013-2014
- Small temperature differences
  - N2 coldest (fiberglass)
  - N3 (uninsulated) and N1 (XPS) almost identical

South-Facing Basement Joists



- Left/right pairing (2 "lowers" not upper/lower)
- Much drier MCs than north-facing (warmer)
- Lower RHs in joist pocket
- Sealed/insulated in spring 2013

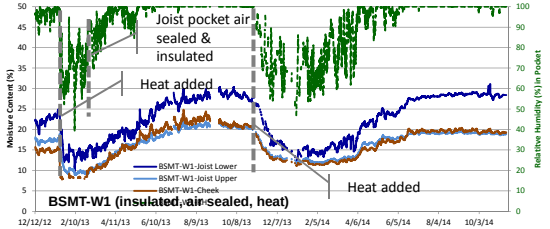
First Floor Joists

- All semi-/unheated, uninsulated, unsealed
- All in hollow clay tile/brick walls

- FIRST-N: 20-30% MCs, 100% RH pocket
- FIRST-E: 9-15% MCs 60-95% RH pocket (seasonal?)
- FIRST-S: 9-12% MCs—very safe

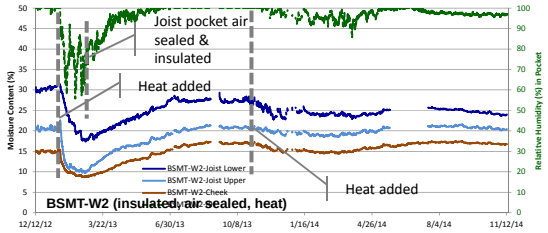
- Huge effect of orientation/exposure
- Basement East vs. First East

Heated Basement Joists



- Adding heat drops MCs/RH
- Even with insulation (and air sealing)
- Highest MCs/RHs in summer—inward T gradient? Seasonal rainfall?

Heated Basement Joists



- W2 similar responses as W1
- BSMT W1 vs. W2—wetted by gutter?
- No noticeable difference

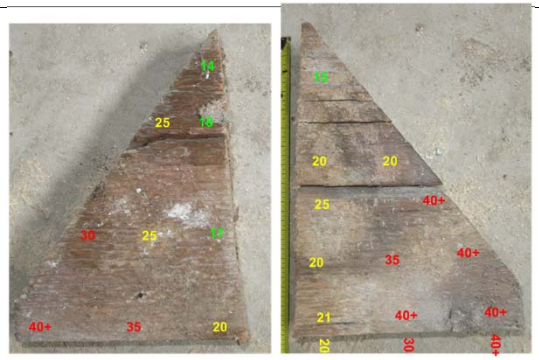
Monitoring Conclusions

- All high MCs—20% recommended. But do they operate this way already?
- Mothballed conditions—started at high MCs?
- Higher MCs/RHs in summer—inward drive?
- "Normal" in-service response not clear yet
- Orientation very large effect
  - South-facing joists in the safe range
  - North-facing joists among the wettest
- Continued monitoring (late 2014 construction completion target, 10 units)

Beam "Stub" Measurements

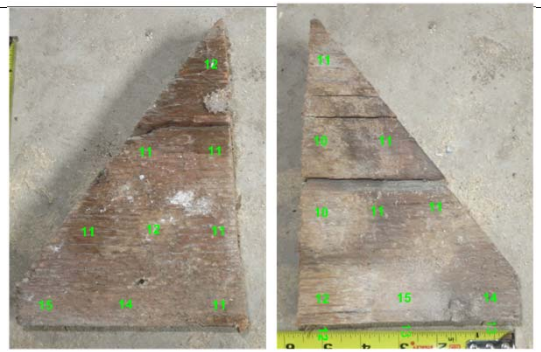
In-Situ Beam Moisture Contents

In-Situ Beam Moisture Contents



- Southeast corner (facing back of building)

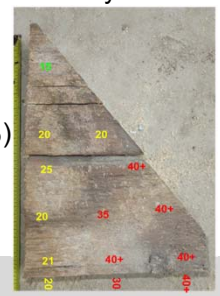
In-Situ Beam Moisture Contents



- Southwest corner (facing front of building)

In-Situ Beam MC Conclusions

- Beams not insulated or air sealed, bldg. unheated
- Orientation has a huge effect—sunny or shaded sides (plus driving rain, possibly)
- Joist Hi vs. Joist Lo—monitoring accurately capturing spatial difference
- Portion buried most deeply in masonry wall wettest
- "Dangerously" high MCs (35-40%) at bottom of SE joist—
  but not punky!
- Moldy and smelly, though…



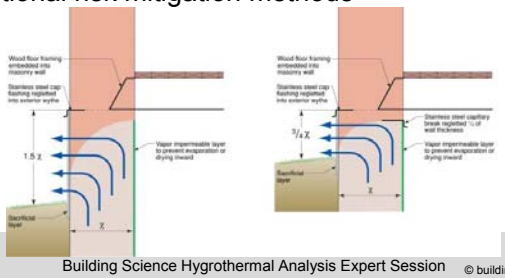
Conclusions & Takeaways

Takeaway: Models vs. Reality

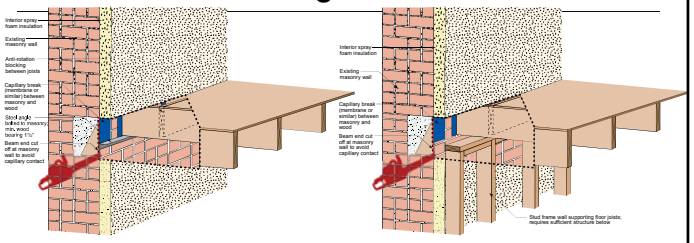
- Using a 1-dimensional model on a 3-dimensional hygrothermal problem—not recommended!
- Lots of inputs and variables, not obvious for modeling:
  - Wood properties
  - Masonry properties
  - Imperfections in masonry
  - Geometry of beam pocket
- Many factors "right direction," but absolute #s?
  - Measured MCs >>> than modeled
- Could spend a lot of time trying to tune a model… but in the end, is it a useful predictive tool?

Takeaway: Joist Recommendations

- Keep bulk water (rainwater) away from joist ends
  - Pointing, reglets, sheltering details
- Keep capillary water away (see BSI-011 "Small Sacrifices")—near grade conditions, reglet?
- Additional risk mitigation methods

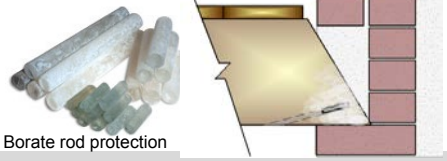


Additional Risk Mitigation Methods



Steel angle support

Interior bearing wall



Borate rod protection

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Risk Mitigation Methods

- No risk: cut off end, support from masonry (steel ledgers) or interior bearing wall or replace structure
- Borate “sticks” in joist ends?
- Leave uninsulated? → “Defensible”… but condensation risks? Heat loss
- Heat spreader plates? → Passive ones not effective? Not realistic for joist geometry.
- Encapsulate embedded end in sealant? → Imperfections have big risks

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Questions?

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