

Kohta Ueno

Edge of Risk Assemblies - Double Stud Walls & Fibrous Insulated Cathedral Ceilings



1

Course Description

Double stud walls and unvented dense pack cellulose roofs are sometimes touted as simpler-to-build and lower cost alternatives to assemblies involving exterior rigid insulation (on walls) or spray foam insulation (on roofs). However, there is substantial building science research and monitoring that demonstrate that these assemblies are at least at the "edge of risk," if not too risky to include in the building codes. Participants will be able to understand the risks associated with these assemblies, gauge and ameliorate the risks if they choose to use them, and provide alternate assemblies that avoid these risks

AIA
Continuing
Education
Provider

2

Learning Objectives

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

1. Explain the moisture risks associated with unvented roofs using only fibrous insulation (e.g., dense pack unvented roofs).
2. Define the roles that vapor diffusion and air leakage have moisture levels in roofs.
3. Explain the difference in performance between code-level insulated walls and double stud walls insulated with fibrous insulation.
4. Explain the benefits of exterior insulation or air-impermeable rigid insulation in reducing condensation in wall assemblies.

AIA
Continuing
Education
Provider

3

Double Stud Wall Background

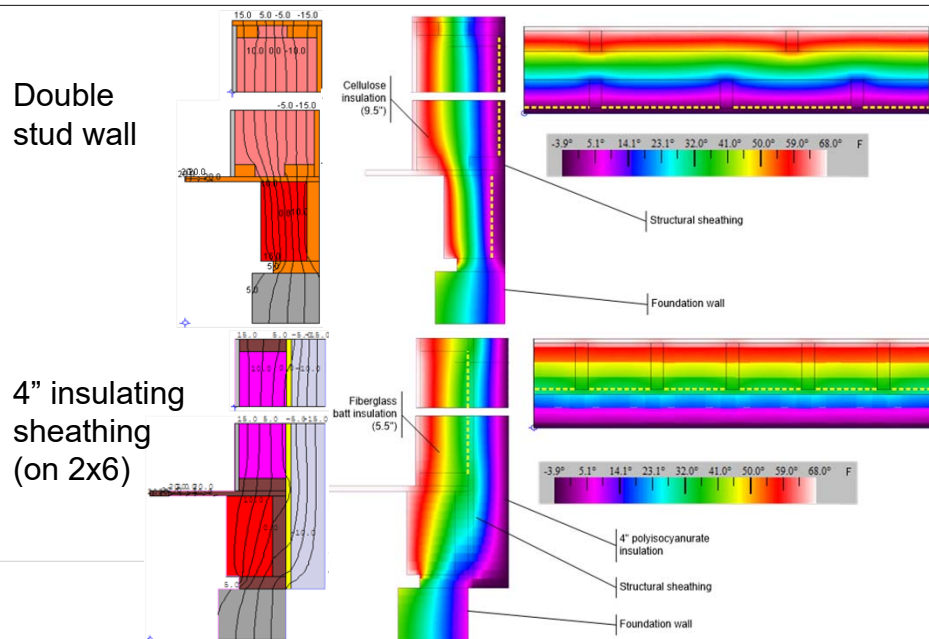
4

Double Stud Walls Overview

- Double stud wall advantages:
 - High R values
 - Simplifies exterior detailing (few changes to standard practice)
 - Lower cost vs. other high-R walls?
- Moisture risks due to interstitial condensation?
 - Most common failure, after rain control issues
 - Air barrier imperfections—increase risk
 - Air permeable low-density insulations—increase risk (convective looping)
 - Air impermeable insulations—decrease risk

5

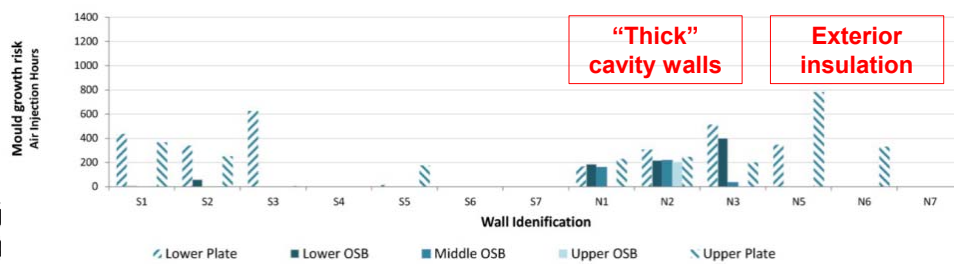
Wall Condensation Potentials



6

Exterior Continuous Wall Insulation

- Decades of papers: exterior insulation → drier sheathing (warm dry side)
- Fox (2014): high-R walls, air injection & drying
- Vapor-impermeable exterior rigid insulation
 - Cuts off outward drying (impermeable)
 - Reduces interior-sourced condensation risks
 - Worst case: thin vapor-impermeable foam



7

Double Stud Test Wall Work

8

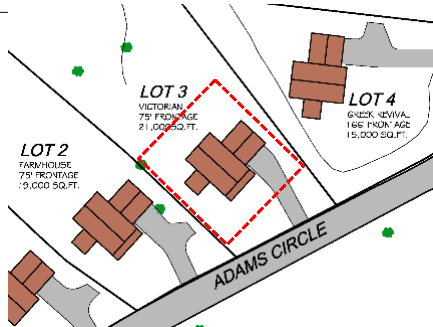
Wall Construction

- Vinyl siding
- ZIP wall sheathing (OSB)
- 12" ocSPF, double stud
 - Builder was considering cellulose alternate
- Class III vapor control (latex paint) on GWB



9

Site and Orientation



10
lingscience.com

10

Test Wall Instrumentation

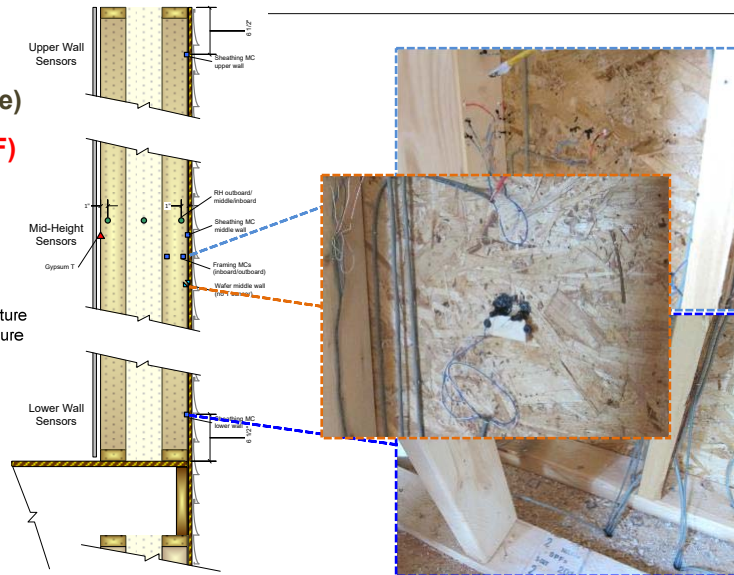
N1/S1 (12-in. ocSPF)

N2/S2 (12 in. cellulose)

N3/S3 (5-1/2 -in. ocSPF)

Sensor Key:

- ▲ Temperature
- Relative humidity/temperature
- Moisture content/temperature
- Moisture content block



11

Operating (Boundary) Conditions

- First Winter (Partial)
 - Unoccupied conditions (no occupant moisture generation)
 - **Very low interior RH**
 - Wimpy winter (5220 HDD vs. 6220 HDD “normal”)
- Second Winter
 - Occupied family of four (2 adults, 2 children)
 - Ventilation system not running, ~1 ACH 50 → **High RHs**
- Third Winter
 - Winter of the “polar vortex”
 - Occupied conditions (same family)
 - Ventilation system running → **RHs ~15-30%**

12

Results: Double Stud Wall Monitoring

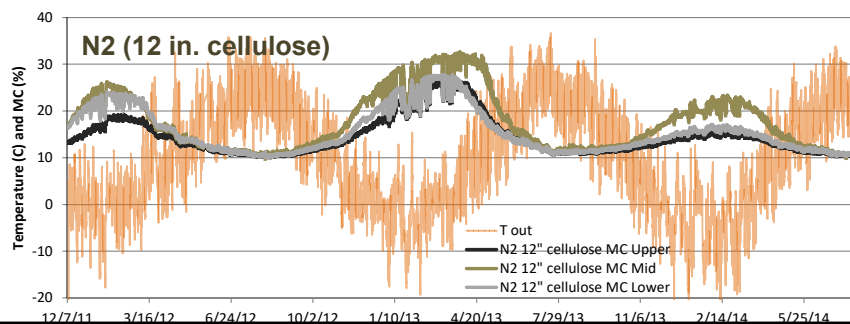
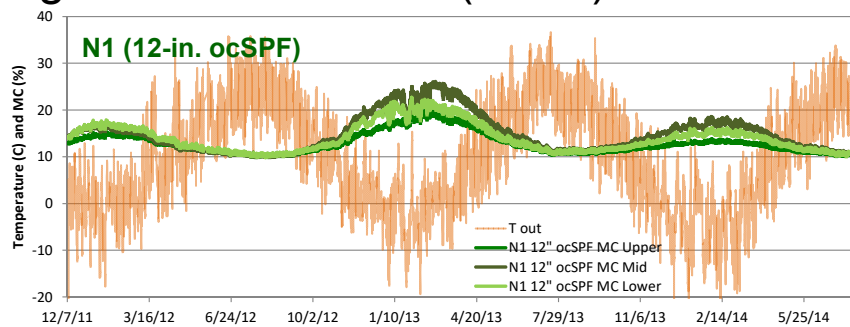


Northeast BS Conference - Edge of Risk Assemblies

13
© buildingscience.com

13

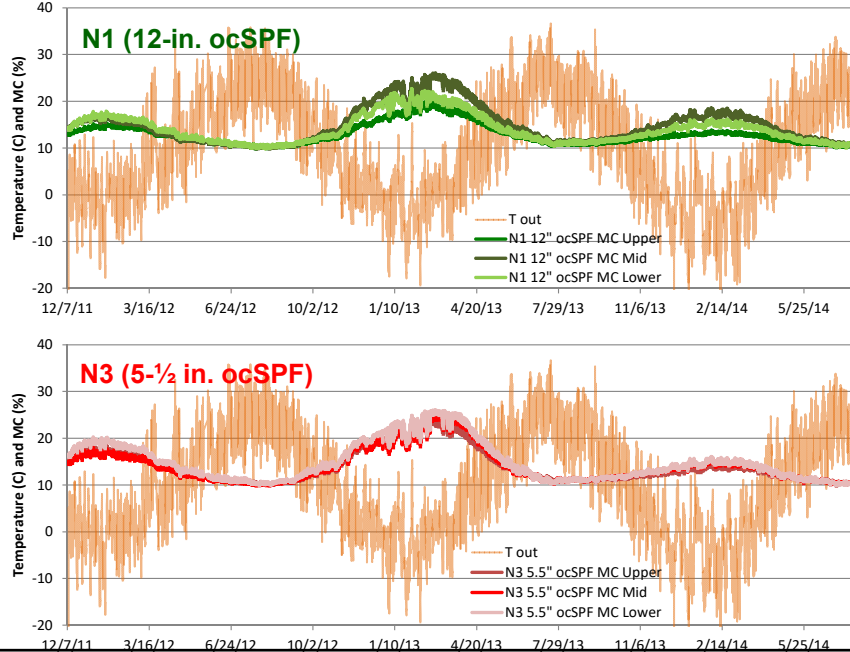
Sheathing Moisture Content (North)



14
lingscience.com

14

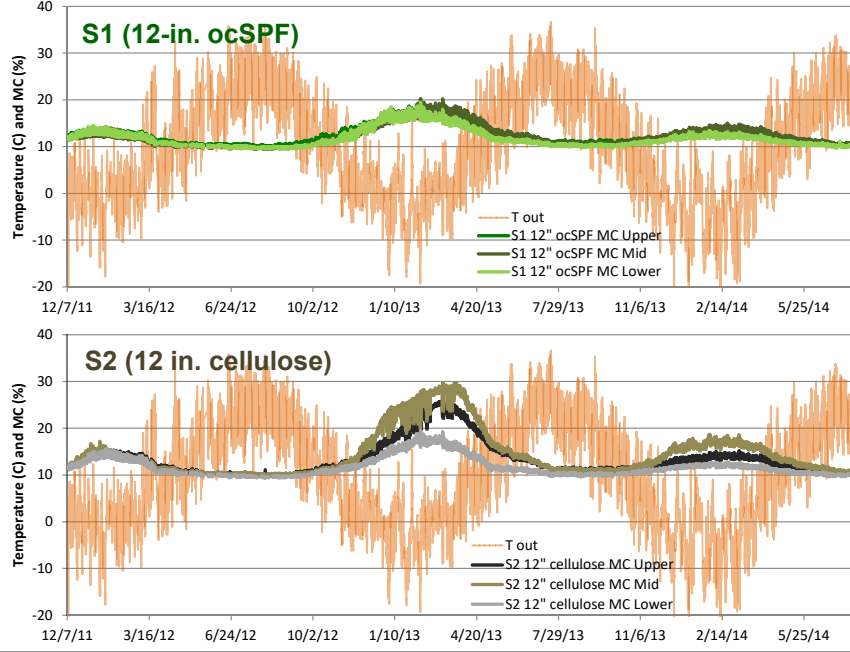
Sheathing Moisture Content (North)



15
ildingscience.com

15

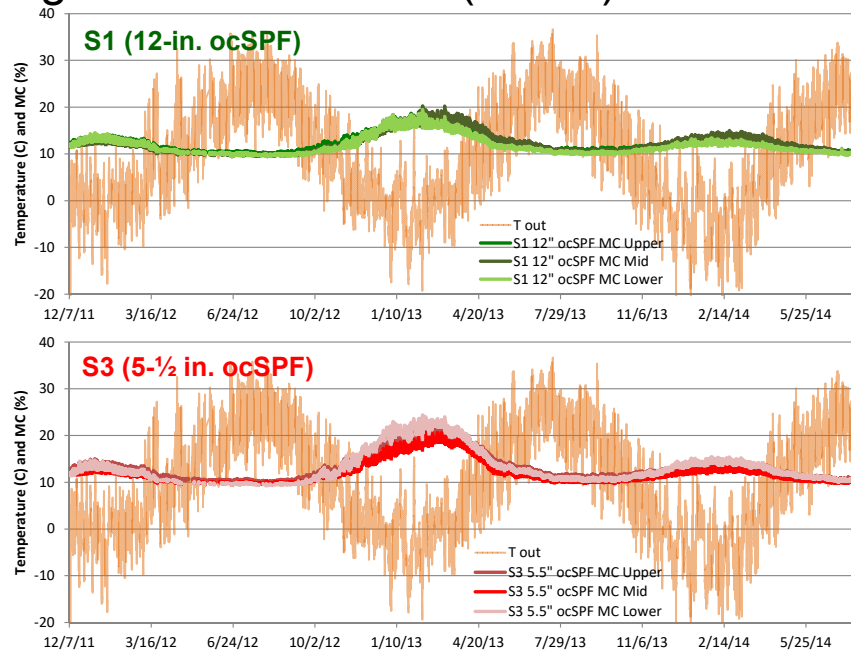
Sheathing Moisture Content (South)



16
ildingscience.com

16

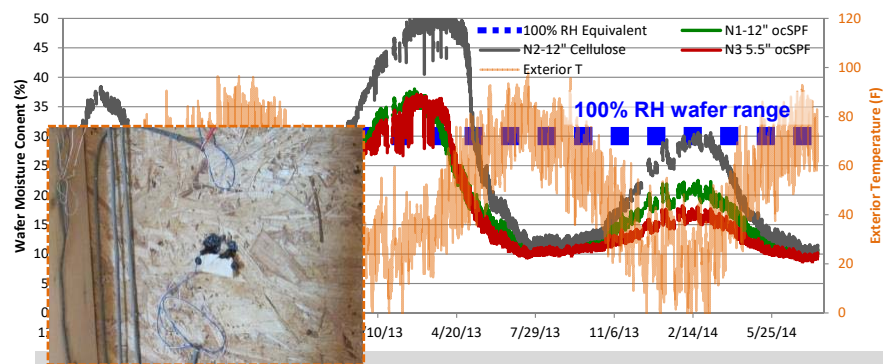
Sheathing Moisture Content (South)



17

Sheathing "Wafer" Moisture Contents

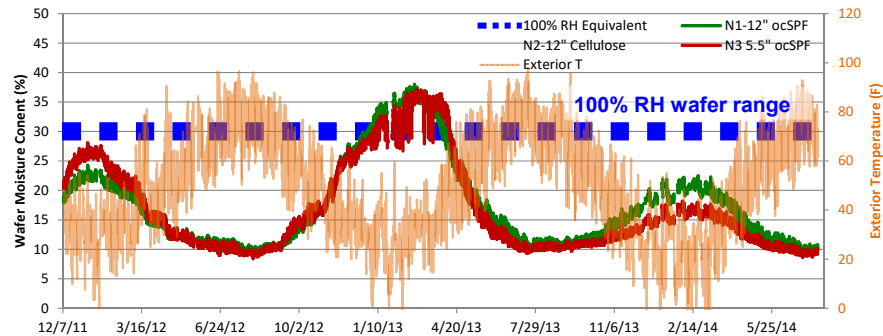
- 30% MC wafer \approx 100% RH
- 40-45% MC wafer \rightarrow liquid water immersion
- Data consistent with condensation at sheathing
- Same indication of condensation on south side



18

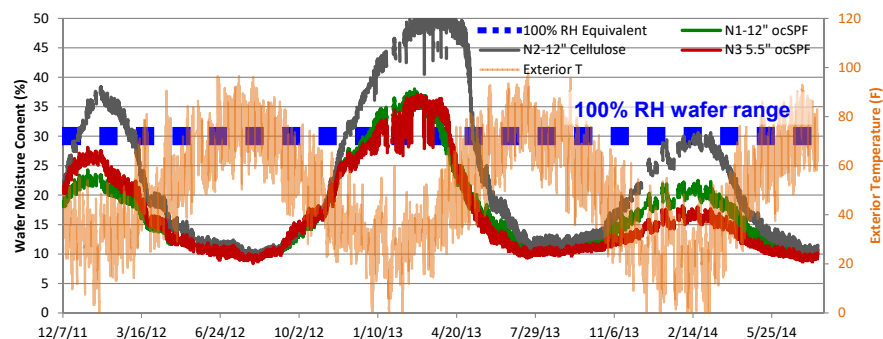
Sheathing “Wafer” Moisture Contents

- 30% MC wafer \approx 100% RH
- 40-45% MC wafer \rightarrow liquid water immersion
- Data consistent with condensation at sheathing
- Same indication of condensation on south side



Sheathing “Wafer” Moisture Contents

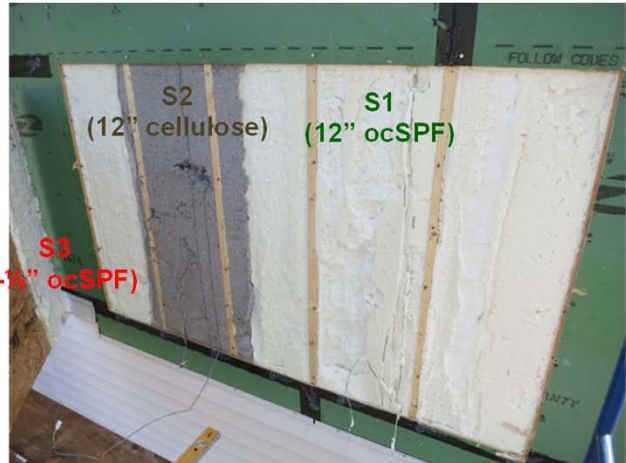
- 30% MC wafer \approx 100% RH
- 40-45% MC wafer \rightarrow liquid water immersion
- Data consistent with condensation at sheathing
- Same indication of condensation on south side



Double Stud Wall Disassembly

21

South Side Disassembly



22

South Side Disassembly



Northeast BS Conference - Edge of Risk Assemblies

23
© buildingscience.com

23

North Side Disassembly



Northeast BS Conference - Edge of Risk Assemblies

24
© buildingscience.com

24

North Side Disassembly



North Side Disassembly



Double Stud Wall Conclusions

27

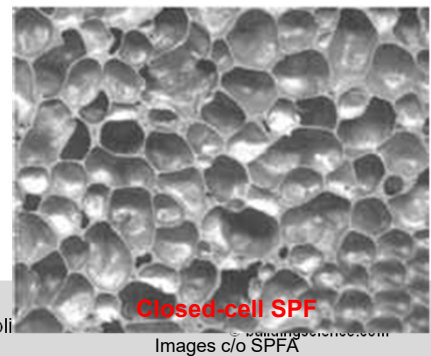
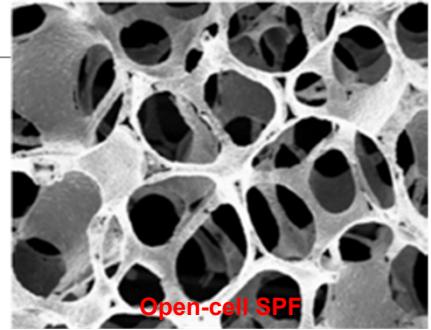
Why Aren't The Walls Oatmeal?

- 20% MC or lower—decay fungi inhibited
- Best growth 25-30% MC range
- All walls had MCs over 20% in winter 2; cellulose 30%+
- Condensation indicated—liquid water is kicker for decay activity

28

Protective Mechanisms

- OSB Sheathing—high MDI adhesive
- Cellulose fiber insulation
 - Borate preservative/fire retardant—also leaches into adjacent materials
 - Moisture storage in cellulose
 - Airflow retarding qualities
- Open cell polyurethane spray foam
 - Oxygen restriction?
 - “Flash heating”? Hot enough long enough?
 - Surface treatment (film formation)?
 - Capillary redistribution (through ocSPF pores)?

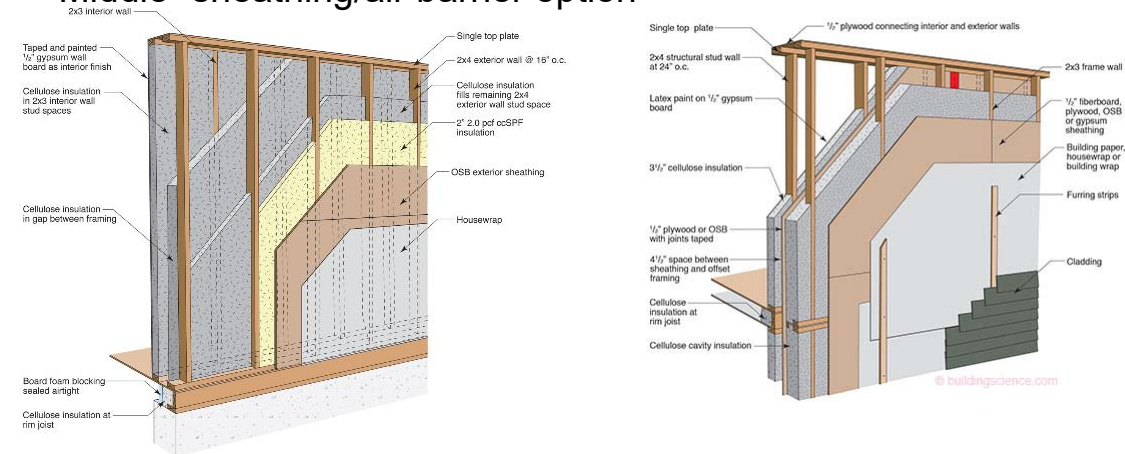


Double Stud Recommendations

- Double stud always riskier than correctly-done exterior insulation
- Class II vapor retarder (variable perm best) safest (vs. Class III)
- ocSPF might be OK on its own
- Air leakage testing/quality control
- Plywood vs. OSB (vs. other sheathings)
- Double stud sensitivity to high wintertime interior RHs
 - More and more likely to occur!
- “The Yeti of Building Science” (Dan Kolbert, Ben Bogie)
 - Double stud not a bad assembly with good quality control/airtightness
 - BUT poor quality control, air leakage, air permeable insulation
 - 1960’s car vs. 2020’s car (airbags or no airbags)

Double Stud Recommendations

- Flash and batt construction option
- “Middle” sheathing/air barrier option



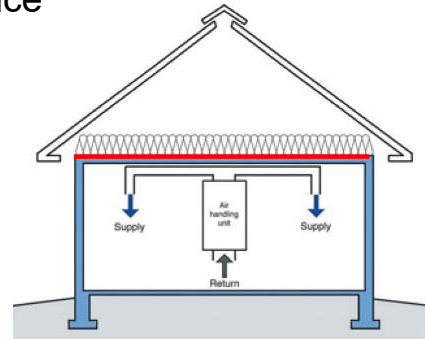
31

Unvented Roofs Background

32

Ventilated Attics—Best Choice

- Roof sheathing dries to ventilated attic-moisture safe
- Interior moisture (air leaks) ventilated away in winter
- Air sealing at ceiling critical for best performance
 - (e.g., spray foam air barrier, detail with sealant)



Then Why Unvented Roofs?

- Living space built into roof
- Vented cathedral assemblies—often poor performance
- Complicated rooflines, hip geometries—how to vent?
- Unworkable air barrier at ceiling line
- Blown-in rain (coastal)
- Hurricane tear-off
- HVAC in unconditioned attic—energy losses
 - Bring attic and ductwork into conditioned space



Fibrous Insulation Unvented Roofs

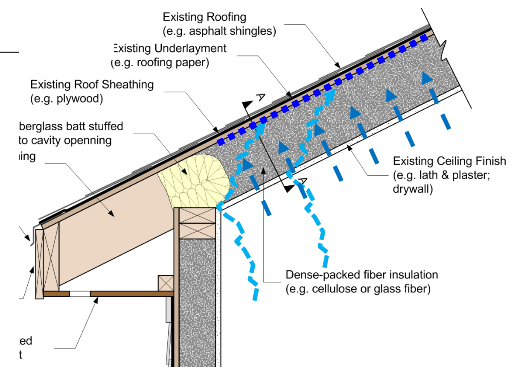
- Dense pack of unvented roofs common in cold-climate retrofits
 - Moisture risks (see BSI-043 “Don't Be Dense—Cellulose and Dense-Pack Insulation”)—2 in 10 failure?
 - Violates I-codes (see IRC § R806.4/R806.5)
 - “Ridge rot”—localized problems (SIPS same problem)



35

Why Unvented + Fibrous Risky?

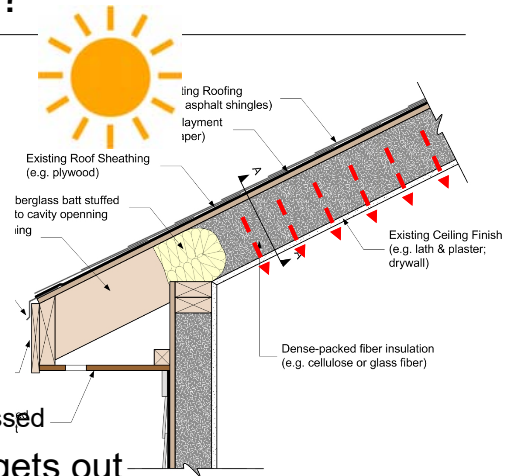
- Different than walls?
- Moisture risks at sheathing
 - Interior-sourced air leakage
 - Vapor contributing too?
 - Zero-perm exterior (“wrong side perfect vapor barrier”)
 - Night sky radiation cooling
 - Stack effect in winter
 - “Ridge rot” (thermal and moisture buoyancy)



36

Why Unvented + Loose Fill Risky?

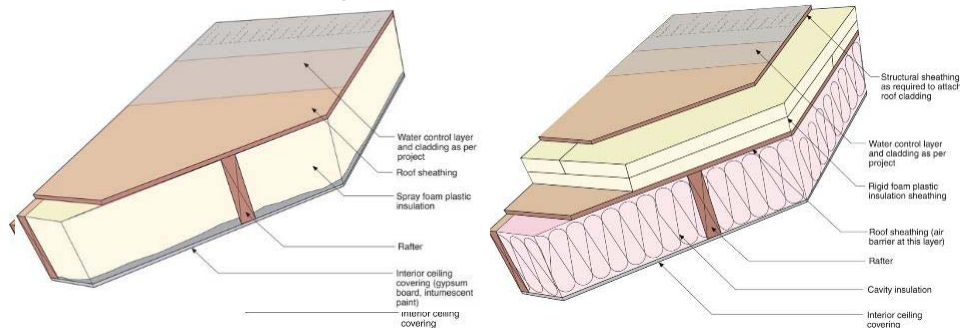
- Risk reduced by:
 - Airtightness of ceiling
 - Dense insulations that suppress airflow
 - Solar drive (north vs. south)
 - But white roofs, shading
 - Lower interior RH (winter)
 - Why many of them work?
 - Lower permeance interior
 - Need good airtightness—vapor retarder not bypassed
- Moisture accumulation: what gets in vs. gets out



37

Spray Foam/Exterior Insulation Roofs

- 2006 IRC: R806.4 Unvented attic assemblies
- Minimum R-value of “air impermeable insulation”
 - Actually ratio of R-values (BSI-100 Hybrid Assemblies)
- Nail base needed with rigid foam on roof deck



38

Why Fibrous Fill Unvented Roofs?

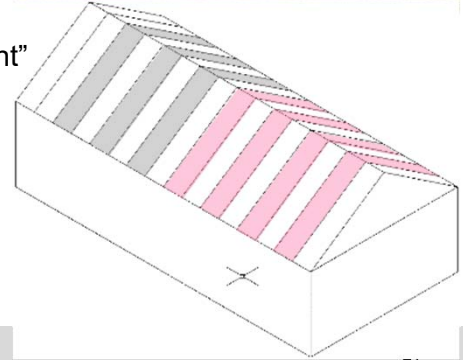
- Unvented roofs without spray/board foams could reduce costs and increase market penetration... IF moisture damage risks are addressed
- Retrofit opportunities (existing uninsulated living space at roof line, without demolishing finishes)



Unvented Test Hut Research

Test Hut Experimental Approach

- Climate Zone 5A test hut
- Eight north-south roof bays; guard bays
- $\pm R-50$ (14- $\frac{3}{4}$ " framing, 2012 IECC)
- Test variables (changed year-to-year):
 - Fiberglass vs. cellulose
 - Vapor retarder: variable vs. fixed perm
 - Diffusion vent at ridge: full size, none, "small," or "tight"
 - "Control" comparison § R806.4 spray foam + fibrous
- Varying interior boundary conditions
 - Winter 1: "Normal" interior conditions
 - Winter 2: Elevated RH (50% constant)
 - Winter 3: Air leakage into rafter bays



Ridge Diffusion Vents



- ~6 in. opening (fits under typical ridge cap)
- Dörken Delta-Foxx membrane
 - 214 perms dry cup, 550 perms wet cup

Test Hut Construction

- Test bays & guard bays alternate
- Cellulose & FG
- Various VBs
- Too much data to talk about here...



43

Summer 2 Disassembly Work: Found Some Mold



44

Unvented Roofs Recommendations

45

Recommendations and Further Work

- Unvented fibrous insulation roofs **can** work, **BUT**
 - Ensure complete packing of insulation/density
 - Still vulnerable to small (0.5 CFM) air leaks
- Mold found after Winter 2, despite “calculated safe” (mold index < 3.0)
 - Vulnerability to moisture damage at ridge
- Difficult to recommend for widespread use and acceptance in codes
 - High indoor RHs more likely w. tighter construction and high occupant density/multifamily
- Retrofit solution for failing assemblies?
 - Demolition + spray foam not possible?
 - No place in code to allow

46

Recommendations

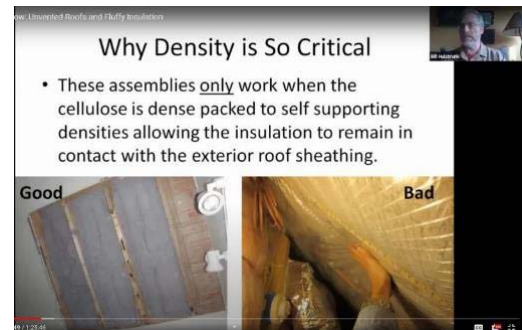
- Code-compliant (IRC § R806.5) still safest (spray foam or exterior rigid insulation)
 - Foam free: mineral fiber, wood fiberboard exterior rigid insulation
 - Corson/EcoCor/PH roof assembly



47

Fibrous Insulation Unvented Roofs Debates Rage On

- The BS* + Beer Show: Unvented Roofs and Fluffy Insulation (with Bill Hulstrunk/NatureTech), May 2020
- Moisture buffering from cellulose storage
- Critical role of density



- <https://www.youtube.com/watch?v=xZInpQYdsuM&t=1551s>

48

If Implementing Unvented Fibrous Insulation Roofs

- “Against medical advice” (AMA)
- Keep interior RH low for life of building
- Airtightness of interior air/vapor control layer
 - Air leakage testing/quality control
- Variable-perm vapor retarder (downward drying)
 - CertainTeed MemBrain, Intello
- Large 300 perm diffusion vent recommended
- Fibrous insulation without voids/empty cavities
- Light colored roofs & shading increase risks



Closing

- This concludes The American Institute of Architects Continuing Education Systems Course
- Edge of Risk Assemblies - Double Stud Walls & Fibrous Insulated Cathedral Ceilings
- Course #: (TBD - waiting on final approval from AIA)
- Provider: Huber Engineered Woods
- Provider #: K094
- Contact: Anna Moore
- Email: Anna.Moore@huber.com

Questions?

Kohta Ueno
kohta [at] buildingscience [dot] com

Presentation will be available at:
<https://buildingscience.com/past-events>



U.S. DEPARTMENT OF
ENERGY | Energy Efficiency & Renewable Energy



Northeast BS Conference - Edge of Risk Assemblies

51
© buildingscience.com

51

Document Resources (Double Stud Walls)

- BA-1501: Monitoring Double-Stud Wall Moisture Conditions in the Northeast
<https://buildingscience.com/documents/bareports/ba-1501-monitor-double-stud-moisture-conditions-northeast/view>
- BA-1316: Moisture Management for High R-Value Walls
<https://buildingscience.com/documents/bareports/ba-1316-moisture-management-for-high-r-value-walls/view>
- ETW: Wall - Double Stud Wall Construction
<https://buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-double-stud-wall-construction>
- ETW: Wall - Double Stud with Spray Foam Wall Construction
<https://buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-wall-double-stud-with-spray-foam-wall-construction>
- Lstiburek's Ideal Double-Stud Wall Design: Air and vapor control layers inside the wall are key
<https://www.greenbuildingadvisor.com/article/lstibureks-ideal-double-stud-wall-design>
- Double-Stud Wall vs. Exterior Insulation
<https://www.greenbuildingadvisor.com/article/double-stud-wall-vs-exterior-insulation>
- The Hygrothermal Performance of Exterior Insulated Wall Systems
<https://uwspace.uwaterloo.ca/handle/10012/8550>
- Hygrothermal Performance of Highly Insulated Wood Frame Walls With Air Leakage: Field Measurements And Simulations
<https://digital.library.ryerson.ca/islandora/object/RULA%3A2603>



Northeast BS Conference - Edge of Risk Assemblies

52
© buildingscience.com

52

Document Resources (Unvented Roofs)

- NESEA Building Energy Boston 2020: Unvented Roofs Without Spray Foam: The Rest of the Story
<https://buildingscience.com/other-event/nesea-building-energy-boston-2020-unvented-roofs-without-spray-foam-rest-story-0>
- BA-2001: Monitoring of Unvented Roofs with Fibrous Insulation, Diffusion Vents, and Interior Vapor Control in a Cold Climate
<https://buildingscience.com/documents/building-america-reports/ba-2001-monitoring-unvented-roofs-fibrous-insulation-diffusion>
- BA-1409: Field Testing Unvented Roofs with Asphalt Shingles in Cold and Hot-Humid Climates
<https://buildingscience.com/documents/building-america-reports/ba-1409-field-testing-unvented-roofs-asphalt-shingles-cold-and>
- BSI-043: Don't Be Dense—Cellulose and Dense-Pack Insulation
<https://buildingscience.com/documents/insights/bsi-043-dont-be-dense>