New England’s Favorite Roof Retrofit: Moisture Data from Three MA Case Studies

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Course Description

Dense packing cellulose in roof slopes has been a common insulation retrofit strategy in New England for a long time, however technically it has not been allowed by code without the inclusion of venting or foam insulation at the roof sheathing for condensation control. Previous BuildingEnergy presentations have suggested that further research should be done to evaluate whether vented attic space above unvented dense-packed slopes could manage moisture more effectively than insulating all the way up to the ridge. Byggmeister and Building Science Corp have collected 2 years of monitoring data on 3 case studies of this type and will be presenting this data and discussing future implications.

Learning Objectives

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

1. Identify insulation strategies permitted by the current building code for unvented roof slopes and the reasons for the limitations
2. Evaluate which roof situations could be good candidates for using only dense packed fibrous insulation in unvented sloped assemblies
3. Analyze monitored moisture performance data from an unvented sloped roof assembly
4. Evaluate whether these strategies could be implemented in your own practices
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

Unvented Roofs Background
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)

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)
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

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
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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)
Test Hut Experimental Approach

- Climate Zone 5A test hut
- Eight north-south roof bays; guard bays
- ±R-50 (14-⅜” 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
Test Hut Construction

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

Summer 2 Disassembly Work: Found Some Mold
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

Recommendations and Further Work

- If implementing unvented fibrous insulation roofs
  - Keep interior RH low for life of building
  - Airtightness of interior air/vapor control layer
  - Variable-perm vapor retarder (allows downward drying)
  - Large 300 perm diffusion vent recommended
  - Fibrous insulation without voids or empty cavities
  - Light colored roofs & shading increase risks
What About the Story and a Half?

Story and a Half (Cape Cod Short Slope)

- Possible application to retrofitting “short slope” of kneewall attic geometry
- Eliminates “chute,” possible to retrofit longer runs

"Cold storage," insulation at kneewall, across ceiling of first floor. Wise-washing air barrier recommended at exposed kneewall insulation.

"Warm storage," insulation at roofline. Air barrier required beneath interior to insulation. Recommended approach for air barrier continuity.

Blocking and air barrier required at floor framing cavities in “cold storage” approach.

"Short slope" portion of roof
Story and a Half (Cape Cod Short Slope)

- Higher R-value in limited cavity
- Test hut: no problems low in roofs
- Not proven by BSC research, but this is “lower half of roof” geometry (low risk portion)
- Rafter bay has “full-size diffusion vent”
- Common practice in weatherization NE/Midwest
What makes a project a good candidate?

Roof sheathing
- OSB: Less resilient
- Plywood: OK
- Board: More resilient
Let’s meet our line up

The Micro Attic
Belmont, MA
Completed Autumn 2020
Clients want to convert to heat pumps and addressing the leaky 3rd floor first was important.
Interesting conditions to test this approach

The Dormer Challenge
Brookline, MA

The Diffusion Vent
Lexington, MA

Case Study #1

The Micro Attic

• Completed Autumn 2020
• Clients want to convert to heat pumps and addressing the leaky 3rd floor first was important.
• Interesting conditions to test this approach
Pre-work Exterior Conditions

• No roof venting
• Front roof faces north, asphalt shingles, shading on the east side
• Chimney at center to be removed
• Rear roof faces south, large low slope shed dormer

Post-work Exterior Conditions

• Chimney removed
• Ridge vent installed
• New 3rd floor bath fan vented at gable end
Pre-work Interior Conditions

- Small portion of finished low slope on south side shed dormer
- Flat ceiling across much of the middle
- Recessed lights and duct work introduce many air leakage points

Pre-work Interior Conditions

- North side roof has steeper pitch with plywood sheathing above AC system
- All spaces have 1" batt insulation, air space, and board roof sheathing with no venting
**Insulation plan**

- **ADD RIDGE VENT**
- **EXISTING ASPHALT SHINGLE ROOF**
- **ADD 16’’ CELLULOSE**
- **REMOVE EXISTING 1’’ FIBERGLASS BATT**
- **FILL RAFTERS WITH CELLULOSE**
- **DRILL HOLE FOR DENSE PACK IF NECESSARY**
- **REMOVE SECTION OF PLASTER CEILING FOR ACCESS**
- **DEMO ACCESS TO (2) REAR CORNER EAVES**
- **REMOVES PLYWOOD AND FLOOR SHEATHING AS NECESSARY FOR AIR SEALING**
- **AIR SEAL THIS AREA WITH POLYISOCYANURATE BETWEEN RAFTERS AND VOIDS**
- **EXISTING PV ARRAY**
- **EXISTING EPDM ROOF**
- **EXISTING 2x6 RAFTERS @ 20’’ O.C., TYP.**
- **DRILL HOLES FOR DENSE PACK IF NECESSARY**
- **MAIN ROOF RAFTERS BEYOND DORMER SIDEWALL, FILL WITH CELLULOSE**

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**The messy part**

- Images showing the process of insulation and the mess involved.

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Monitoring plan

Monitor locations

3/30/2023
Ambient Temp & Humidity

- Attic just below ridge board
- 3rd floor just above closet
- No exterior probe

North Roof Monitors Only

- % MC, Temp, RH
- % Moisture Content
- Temp, RH 3rd floor
- Temp, RH Attic
North Roofs – Inside dense pack

Low Slope South Roof Only

% MC, Temp, RH
% Moisture Content
Temp, RH 3rd floor
Temp, RH Attic
Moisture spikes near shower

- New recessed light in shower (air sealed)
- New bath fan just outside (also air sealed)
- Timer switch for bath fan
Generally I feel the risk for growth on the roof sheathing is low, if it were to happen it would likely take a very long time.

No greater risk than roof leaks?
Case Study #2

The Dormer Challenge

• Completed Spring 2021
• Various dormers make roof geometry and venting challenging
• Converting top floor to heat pumps, insulating will be important
• Homeowners want to maintain as much existing plaster as possible

Pre-work Exterior Conditions

• Roofing, solar panels, and ridge venting installed just before
• Pre-existing soffit & gable vents
• Insulation in some areas, not others
• Dormers & bump outs added on, built over old roof system
**Post-work Exterior Conditions**
- Chimney removed
- Ridge vent patched
- ERV installed & vented at rear gable end

**Pre-work Interior Conditions**
- Small scuttle to access attic
- Variable insulation quality in finished slopes, none in walls
- No recessed lights or ducts
Pre-work Interior Conditions

- Board roof sheathing again
- No baffle venting installed in finished slopes
- Gable & ridge vents move a lot of air

Pre-work Eave Conditions

- Fiberglass stuffed to dam slopes
- Open to walls, no air sealing
Insulation & Monitoring Plan

- % MC, Temp, RH
- % Moisture Content
- Temp, RH 3rd floor
- Temp, RH Attic

The Dormer Challenge
- Not enough room to install back dam or netting membrane on rafters
- Seal each end and dense pack triangle
The Dormer Challenge

• If we can't solve this now, then what?
• Pop a monitor in and see how it goes
North Roof Monitor Locations

- % MC, Temp, RH
- % Moisture Content
- Temp, RH Attic

Air sealer’s concern
North Roof Dormer Setback %MC & Temp

Soffit sealing completed

Temperature (F)  Sheathing Moisture Content

Water getting in ridge vent

67 68
The Dormer Challenge
observations and conclusions...

• A bigger attic with more ventilation helps a lot
• Air sealing to outside and vapor control to the inside are crucial, especially in vulnerable areas
• Roof leaks are still bad

Generally I feel the risk for growth on the roof sheathing here is virtually none, we’ll keep an eye on the area behind the bathroom but no concerns elsewhere.

Case Study #3

The Diffusion Vent

• Completed Summer 2021
• Homeowners have had major issues with ice damming
• Various dormers make roof geometry and venting challenging
• Top floor has a large amount of finished slopes
Pre-work Exterior Conditions

- Front faces North & slightly east
- Soffit vents in most areas are minimal small circular vents only
- Small ridge vent across both roof areas
- Gable vents on either side of main roof only

Pre-work Exterior Conditions

- Rear faces south & slightly west
- Low slope roof had larger soffit venting installed, didn't help
- Substantial shading from surrounding trees, however few pines so solar exposure in winter increases
**Pre-work Exterior Conditions**

- Ice dams throughout
- Winter management difficult for aging homeowners
- Electric cable & panels installed at high roof after increased soffit venting didn’t help

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**Pre-work Interior Conditions**

- Front roof dormers finished with built-ins
- Rear low slope dormer similar to the micro attic
- Bathroom with shower under low slope rear
Pre-work Interior

- Lower side roof has smaller inaccessible attic cap, dormer at rear, & accessible eaves at front and back

Pre-work Interior

- Main roof has accessible eaves & access to main attic space via space above the stairway ceiling
Pre-work Interior

- Main attic has gable vents and make shift power venting system by homeowner

Insulation prep

- Cut openings to dormer roofs
- Installed membrane at tops of finished slopes for high density packing
Insulation prep

- Create insulated air tight access to attic
- Install Intello membrane on rafters

Insulation prep

- Opened up various areas of roof to install cellulose from exterior
- Install monitors in lower roof cap
Monitor & Insulate

- %MC monitor in roof sheathing near ridge
- Temp & RH installed in attic below ridge

Insulate & Air Seal

- Insulated around the wood stove flue with mineral wool and then air sealed the opening with tape
New Roof & Ridge Vent?

- High perm roofing membrane installed at lower roof ridge & accidentally at main ridge too

Monitor locations

- % MC, Temp, RH
- % Moisture Content
- Temp, RH 3rd floor
- Temp, RH Attic
Ridge & gable vents

- Insulated around the wood stove flue with mineral wool and then air sealed the opening with tape
The Vapor Diffusion Vent
observations and conclusions...

- Results consistent with the 2 previous case studies
- Less monitors might mean less interesting data
- Wondering what is truly less risk, insulating to the ridge or this approach?

No concerns at all here, very happy with the performance.

Questions?
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Presentation will be available at:
https://buildingscience.com/past-events
Document Resources


- BA-2001: Monitoring of Unvented Roofs with Fibrous Insulation, Diffusion Vents, and Interior Vapor Control in a Cold Climate

- 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