

## 2019 Buildings XIV International Conference

### Session 26: Thermal and Hygrothermal Performance of Roofs

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#### Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in CZ 5A



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## Learning Objectives

**Objective 1** Explain the moisture risks inherent in unvented/compact roofs with fibrous (air-permeable) insulation.

**Objective 2** Explain the role that a vapor diffusion vent can have in ameliorating roof moisture risks.

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## Acknowledgements

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- Owens Corning
- Nu-Wool
- Dörken Systems Inc.

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## Background

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## 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
- HVAC in vented attic



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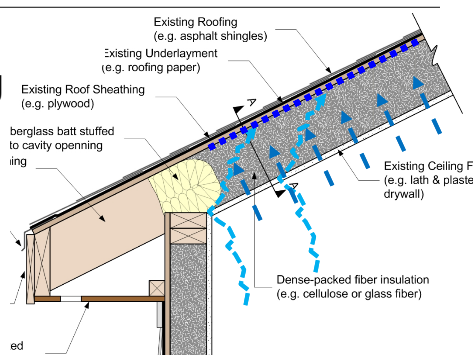
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## Why Unvented + Fibrous Risky?

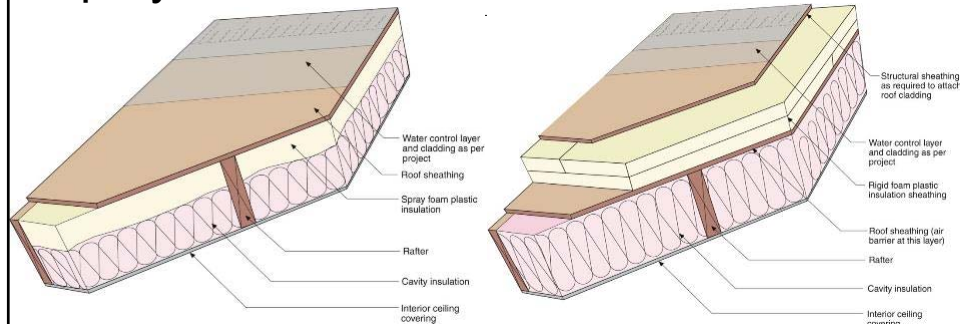
- Different than walls?
- Moisture risks at sheathing
  - Interior-sourced air leakage
  - Vapor contributing too?
  - Zero-perm exterior (“wrong side perfect vapor barrier”)
  - Night sky radiation cooling
  - Stack effect in winter
- “Ridge rot” (thermal and moisture buoyancy)



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## Spray Foam/Exterior Insulation Roofs



- 2006 IRC: § R806.4/5 Unvented attic assemblies
- Minimum R-value of “air impermeable insulation”
  - Actually ratio of R-values (BSI-100 Hybrid Assemblies)
- Effective but costly solutions
- All fibrous insulation could lower costs-but risks?

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## Experimental Setup

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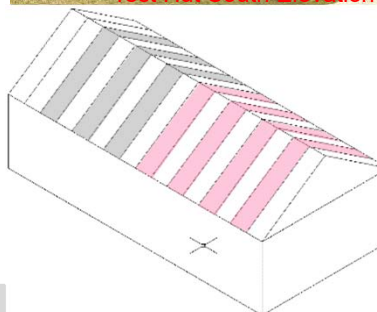
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## Test Hut Experimental Approach

- Climate Zone 5A test hut
- Eight north-south roof bays; guard bays
- ±R-50 (14-¾" framing, 2012 IECC)
- Test variables (changed year-to-year):
  - Vapor retarder: variable perm vs. fixed perm, various permeance curves
  - Diffusion vent at ridge: full size, none, "small," or "tight"
  - Fiberglass vs. cellulose
  - "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 South Elevation



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## Diffusion Vent



Ridge cap over 6" diffusion vent



"Small" and "tight" DV options



"Small" and "tight" DV options

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## Test Hut Construction



- Instrumentation completion

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## Test Hut Construction



- Interior air/vapor control installed

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# Experimental Findings (Qualitative)

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## Year 1 Findings (“Normal” Conditions)

- Roofs with diffusion vent & variable-perm vapor retarder safest
- Non-diffusion vent roofs worst; high moisture levels at ridge
- Viitanen mold index values below risk thresholds (3.0 MI); meets ASHRAE Standard 160
- Visible settling of insulation (when cutting new ridge openings from above)
- Summertime inward drive at fixed-perm VR roofs
- Eliminated non-diffusion vent roofs (“small”, “tight”) for following research

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## Ridge Retrofits, Insulation Settling



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## Ridge Retrofits, Insulation Settling



**Cellulose settling along entire roof length only occurred on north side**

**Roofs left as-is for Winter 2:  
realistic settling of insulation?  
Also, damage to instruments  
when retrofitting insulation**

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## Summertime Inward Drive

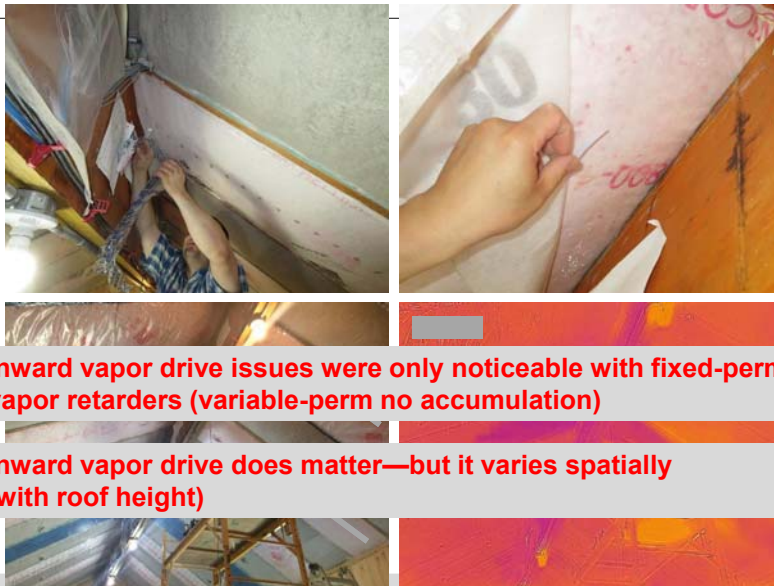


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## Summertime Inward Drive



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## Year 2 Findings (50% RH Constant)

- Interior at 50% RH creates much more challenging conditions: many pushing edge of risk
- Many MCs over 20% to 30%, sustained high RH
- Mold Index #s remain below 3.0
- Mold growth occurred on framing & sheathing
- “Tight” diffusion vent did not work acceptably
- Code-compliant ccSPF roof acceptable
- Repacked insulation after disassembly; filling all voids
- Replaced all ridge sensors (data failures)

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## Summer 2 Ridge Disassembly Work

- Fiberglass: staining, rundown, some mold spotting



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## Summer 2 Ridge Disassembly Work

- Cellulose: worst mold, settling (greater at north)



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## Year 3 Setup & Findings (Air Injection)

- Early winter 50% RH, no air leak
- February onward-add air leak
- Air injection system
  - Interior-to-interior leak
  - Very small air leak, 0.5 CFM per bay
  - Comparable to very airtight construction
- Before air injection: much drier than Year 2
  - Repacking insulation suppresses convection?
- Air injection: severe spike in sheathing MC
  - Localized to injection site
  - Disassembly in summer: no visible damage

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## Air Injection System



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## Disassembly



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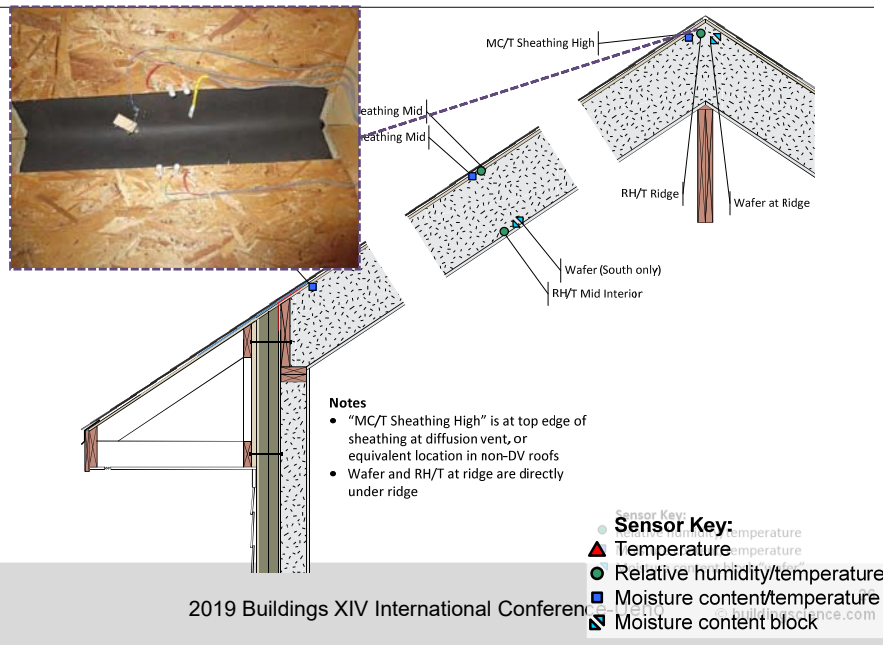
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# Experimental Findings (Measured Data)

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## Instrumentation Design: Fibrous Insulation



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## Instrumentation Design: Fibrous Insulation

**Typical Unvented Bay**

- Asphalt shingles
- Self-adhered membrane
- OSB 5/8" ZIP roof panel
- Cavity insulation (dense pack cellulose or blown fiberglass)

**Notes**

- "MC/T Sheathing High" is at top edge of sheathing at diffusion vent, or equivalent location in non-DV roofs
- Wafer and RH/T at ridge are directly under ridge

**Sensor Key:**

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

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## Instrumentation Design: Fibrous Insulation

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## Instrumentation Design: Fibrous Insulation

**Typical Unvented Bay**

- Asphalt shingles
- Self-adhered membrane
- OSB 5/8" ZIP roof panel
- Cavity insulation (dense pack cellulose or blown fiberglass)
- Interior vapor control layer (fixed or variable perm membrane)

**Notes**

- "MC/T Sheathing High" is at top sheathing at diffusion vent, or equivalent location in non-DV r
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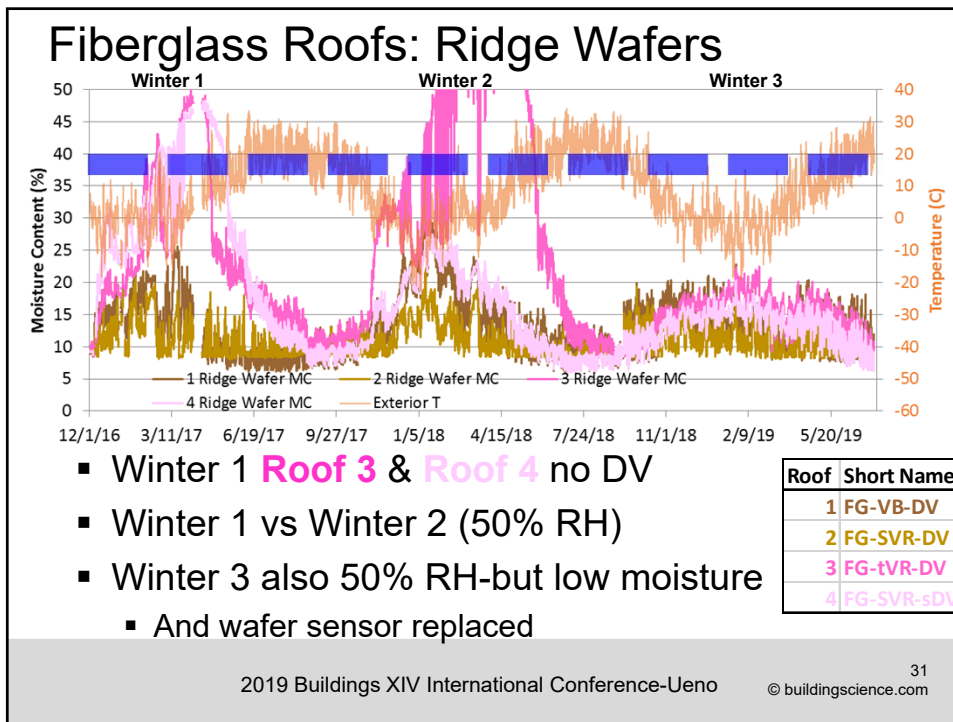
## Fiberglass Roofs: Ridge RH 24 hr Average

- 24 hr. averaging for readability
- Winter 1 dry, Winter 2 wetter
- Winter 3 much drier than Winter 2

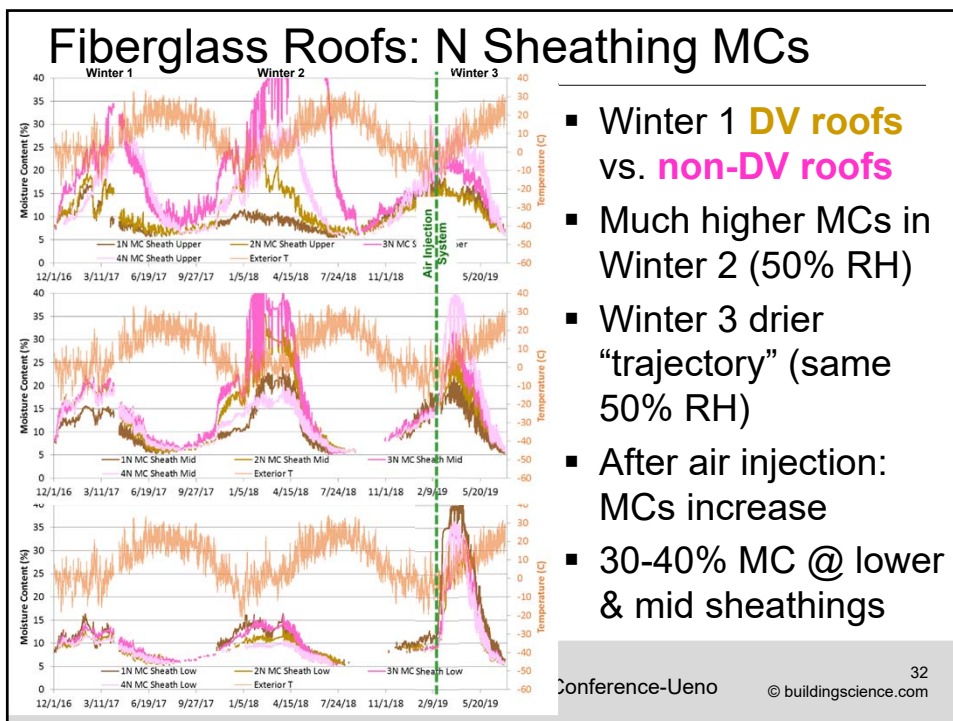
Roof	Short Name
1	FG-VB-DV
2	FG-SVR-DV
3	FG-tVR-DV
4	FG-SVR-sDV

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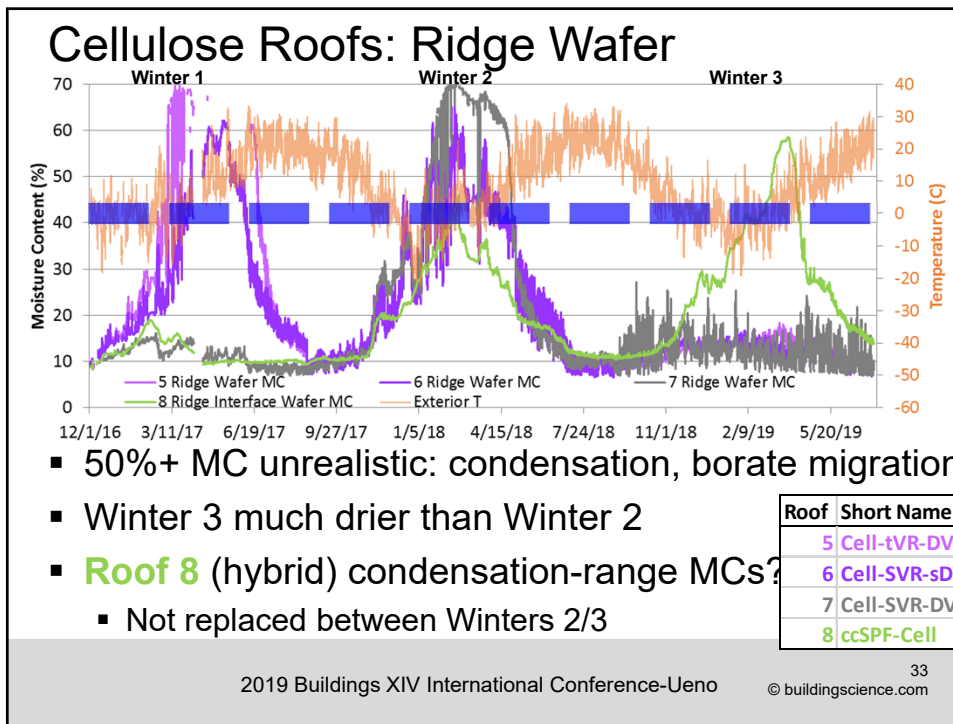


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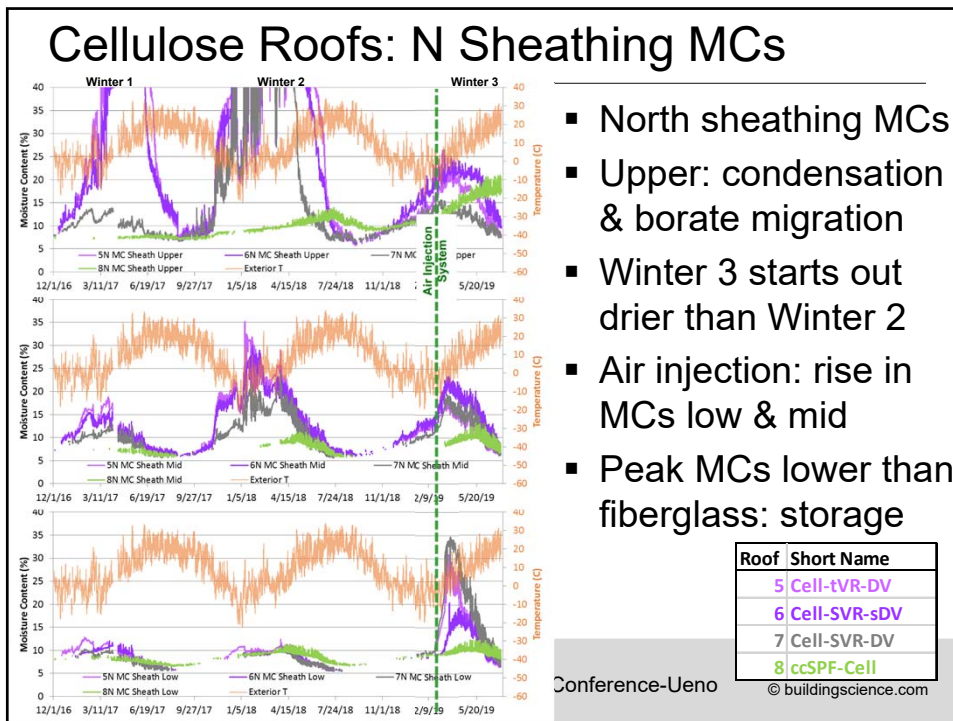


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# Conclusions and Recommendations

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## Recommendations and Further Work

- Unvented fibrous insulation roofs **can** work, **BUT**
  - Ensure complete packing of insulation
  - Still vulnerable to small (0.5 CFM) air leaks
- Mold found after Winter 2, despite mold index < 3.0
  - Vulnerability to moisture damage at ridge
- Difficult to recommend for widespread use and acceptance in building 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

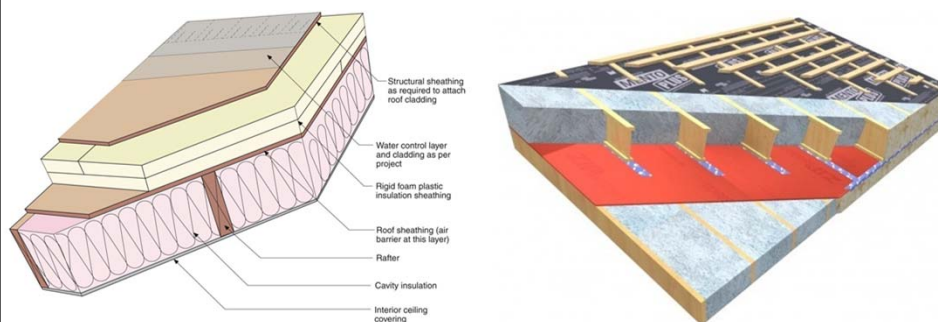
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## Recommendations and Further Work

- Foam-free unvented roof options
  - Fibrous + continuous exterior insulation outside air barrier, per § R806.5
  - Ventilated cavity outboard of vapor-permeable air/water control membrane



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## 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
- Future work?
  - Moisture risks demonstrated; not sure if additional research useful
  - “Story and a Half Geometry” (Cape Cod short slope)

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## Bibliography

Ueno, K., and J. Lstiburek. 2019. Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in CZ 5A. Presented at the 2019 Buildings XIV Conference, Clearwater Beach, Florida, December 9 - 12.

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## QUESTIONS?

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