

Moisture Matters: Durable Design for Mass Timber Buildings

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4EA building science

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Approved Continuing Education

Course Description

This session will focus on enclosure design and examine strategies to protect mass timber assemblies from moisture intrusion and accumulation, focusing on the unique hygrothermal behavior of products like cross-laminated timber (CLT) and glued-laminated timber (glulam). Attendees will explore building enclosure approaches for high-performance walls and roofs, including the appropriate use and detailing of water-resistive barriers, air barriers, and vapor retarders. The presentation will also describe the designer's role in construction-phase moisture protection. Through technical guidance and project case studies, participants will learn how to develop a comprehensive moisture management strategy that reduces the potential for decay, supports healthy indoor environments, and promotes the long-term performance, durability, and appearance of mass timber buildings.

Learning Objectives

1. Explain the hygrothermal properties and moisture behavior of mass timber products, including cross-laminated timber (CLT) and glued-laminated timber (glulam), and how these characteristics influence enclosure design and long-term durability.
2. Evaluate the appropriate use and placement of water-resistive barriers, air barriers, and vapor retarders in mass timber wall and roof assemblies to reduce the risk of moisture intrusion, condensation, and material deterioration.
3. Identify construction-phase moisture risks associated with mass timber and assess protection strategies based on climate, construction schedule, exposure duration, project risk, and budget.
4. Apply moisture-management principles to develop enclosure and construction strategies that support occupant health, limit conditions that can contribute to decay and biological growth, and improve the long-term performance of mass timber buildings.

About 4EA Building Science

(Pronounced "Fourier")

We have offices in

- Seattle, WA
- Oakland, CA
- Vancouver, BC









A Bit About Me...

Principal with 4EA

Lives in Shoreline, WA

Grew up in Nanaimo, BC Canada

- Mechanical Engineer by Education
- Civil/Structural Engineer by Licensure
- Certified Passive House Consultant
- Building Energy Modeling Professional

21 years in Building Science

Father of 2 goofy kiddos.

Outline

- Introduction
- Section 1 – Building Science Crash Course
- Section 2 – Building Science & Wood
- Section 3 – Design Considerations
- Section 4 – Construction Considerations
- Questions and Discussion



Why Building Science?

Why Now?

Why Now?

Less Craft, Less Tradition
Newly Developed Materials
Optimized Mechanical Systems
More Insulation
Airtight Buildings
Building Like Never Before

With Less Margin of Error
More Risk
More Value Requirements
Faster Delivery Schedules
Less Wasteful
Higher Performance Expectations

What do Building Scientists do?

What do any Engineers & Applied Scientists do?

illuminate this space

make this easier to build

keep this dry

make that cost less

enclose this space

make that taller

make it last a long time

cool it

make it sink

make this cleaner

PHENOMENAL GOALS

use less energy

separate this from that

spin it really fast

heat it

make it safe

make this go there

lower the volume

launch that as far as it can go

An Engineering Method



Phenomenal Goals



Distill into Quantifiable Variables



Establish Metrics



Analyze the Metrics and Variables



Find Ways to Improve Results



Find Ways to Control Results

illuminate this space

make this easier to build

keep this dry

make that cost less

make that taller

make it sink

make it last a long time

enclose this space

use less energy

make this cleaner

VARIABLES

heat

air

moisture

separate this from that

cool it

spin it really fast

heat it

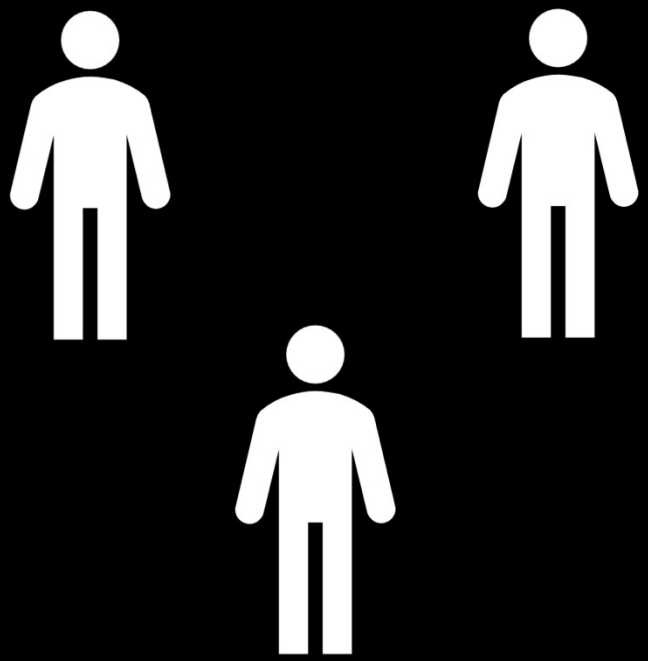
make this go there

make it safe

launch that as far as it can go

lower the volume

Building Science Concepts



CONTROL LAYERS

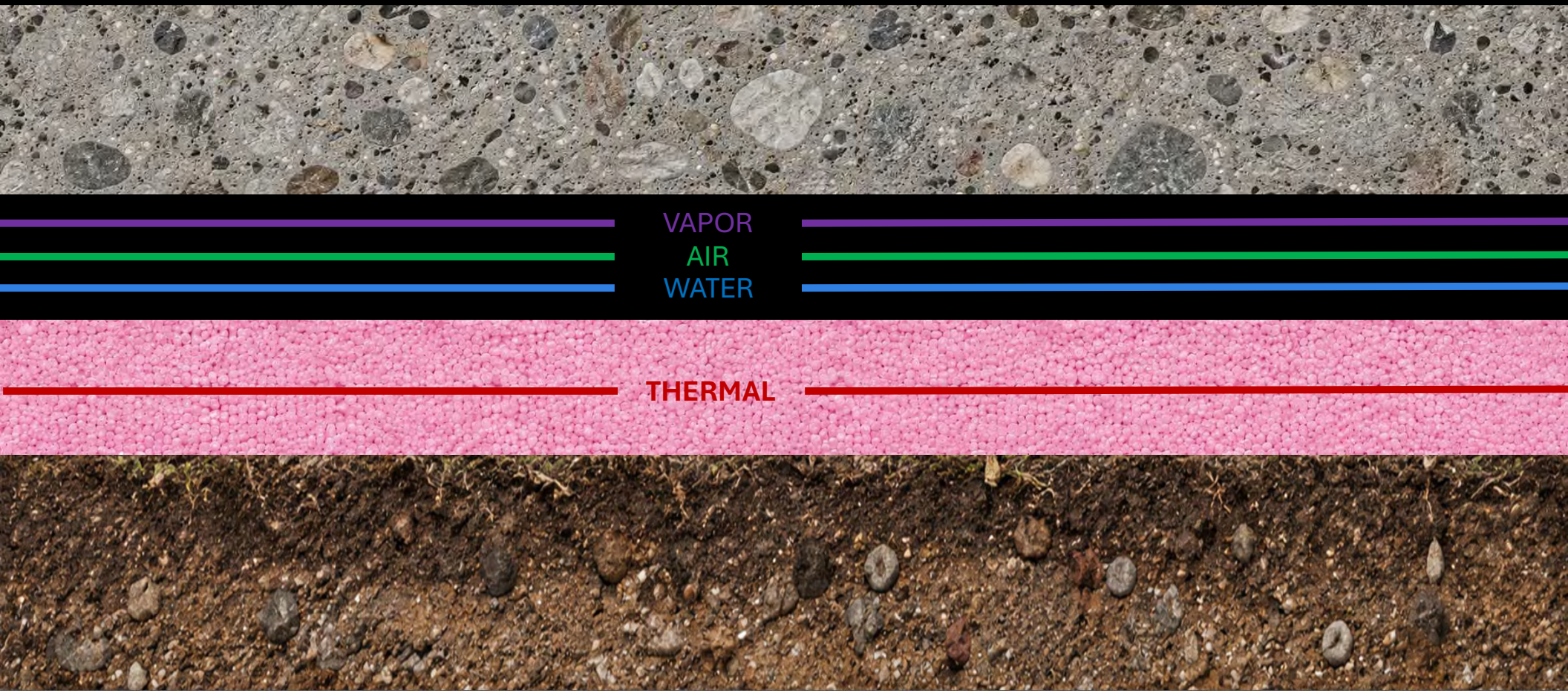
OUTSIDE

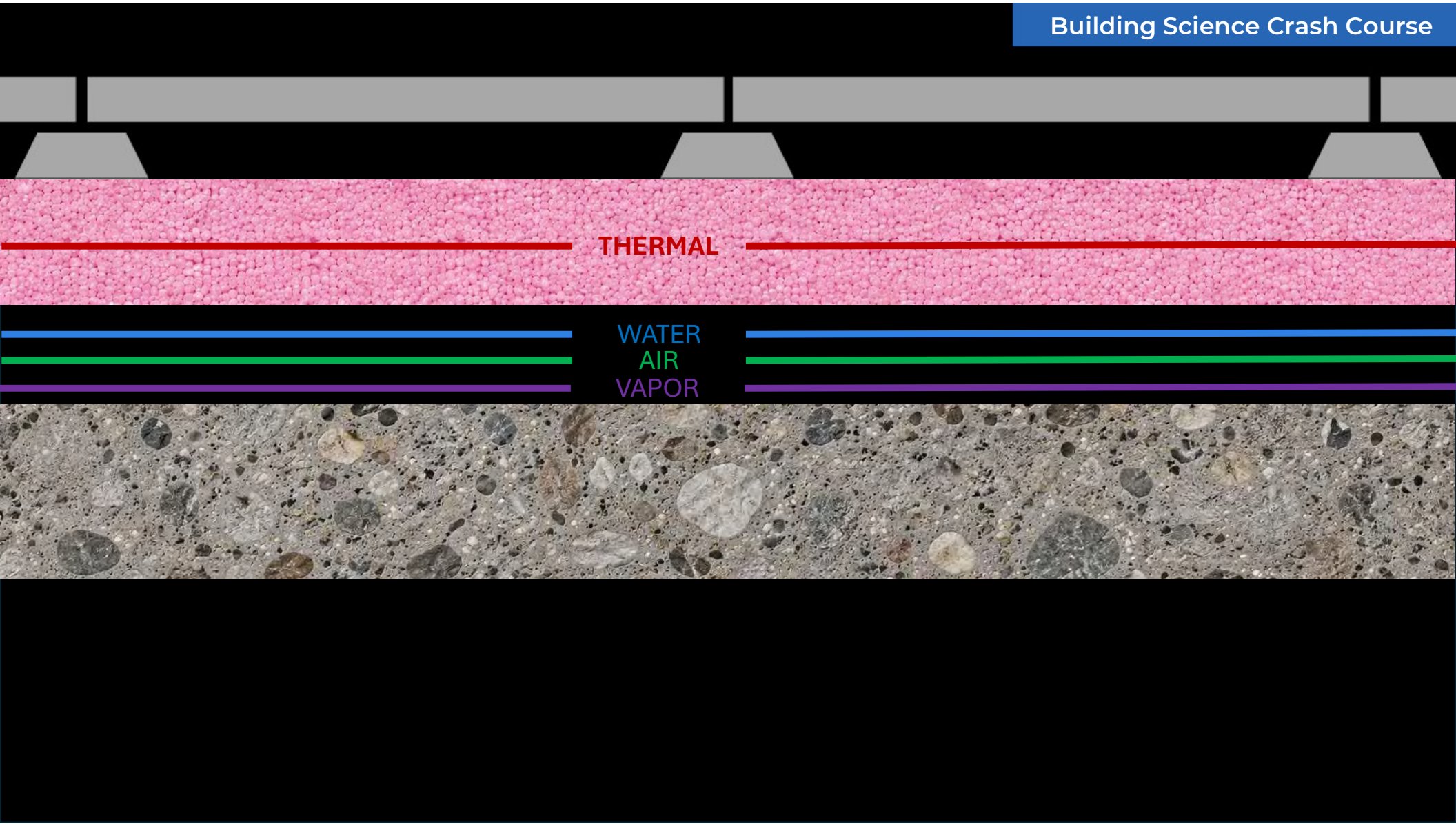
Heat

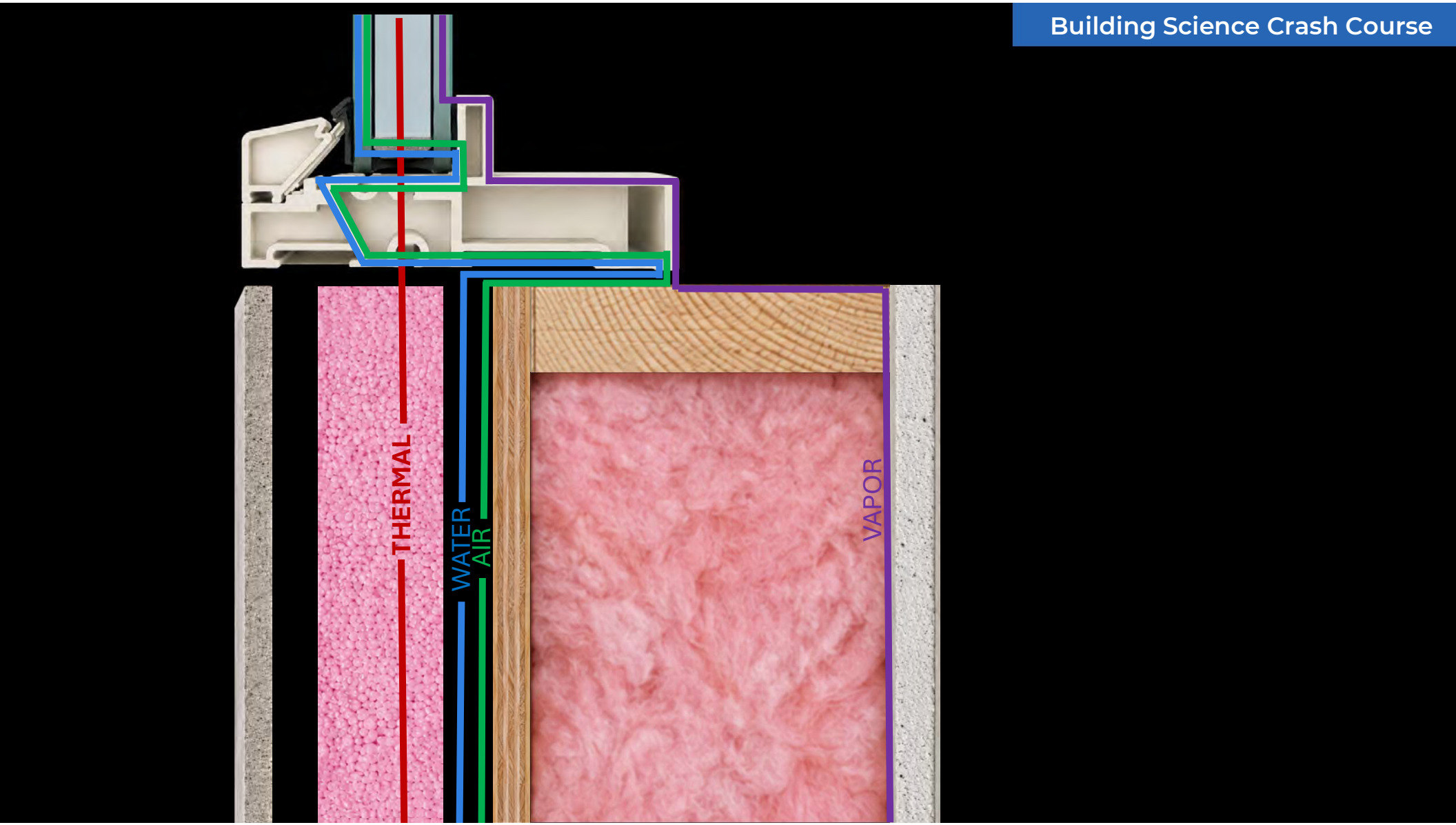
Air

Liquid Water

Vapor

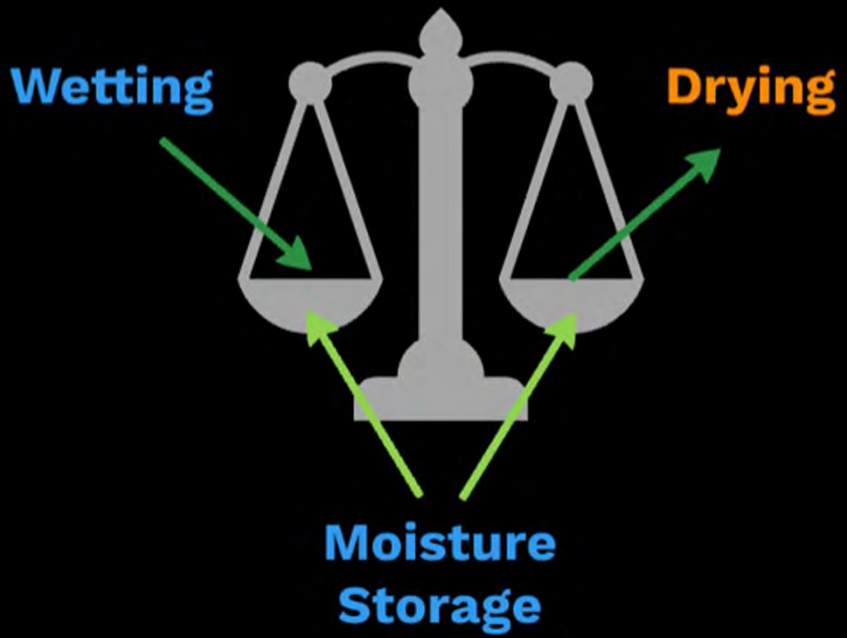

VAPOR
AIR
WATER
THERMAL


THERMAL
WATER
AIR
VAPOR


THERMAL
WATER
AIR
VAPOR

Building Science Concepts

Moisture Balance



“The Four D’s”

Deflections

Drainage

Drying

Durability

Outline

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Wood Behavior with Heat and Moisture

Hygrothermal Characteristics

Wood is Unique





Wood is anisotropic.

Water can redistribute quickly, but mainly in one direction.

Liquid transport through the sidewall is significantly lower than the end grain.

Somewhat like a bundle of straws.

Wood is Unique

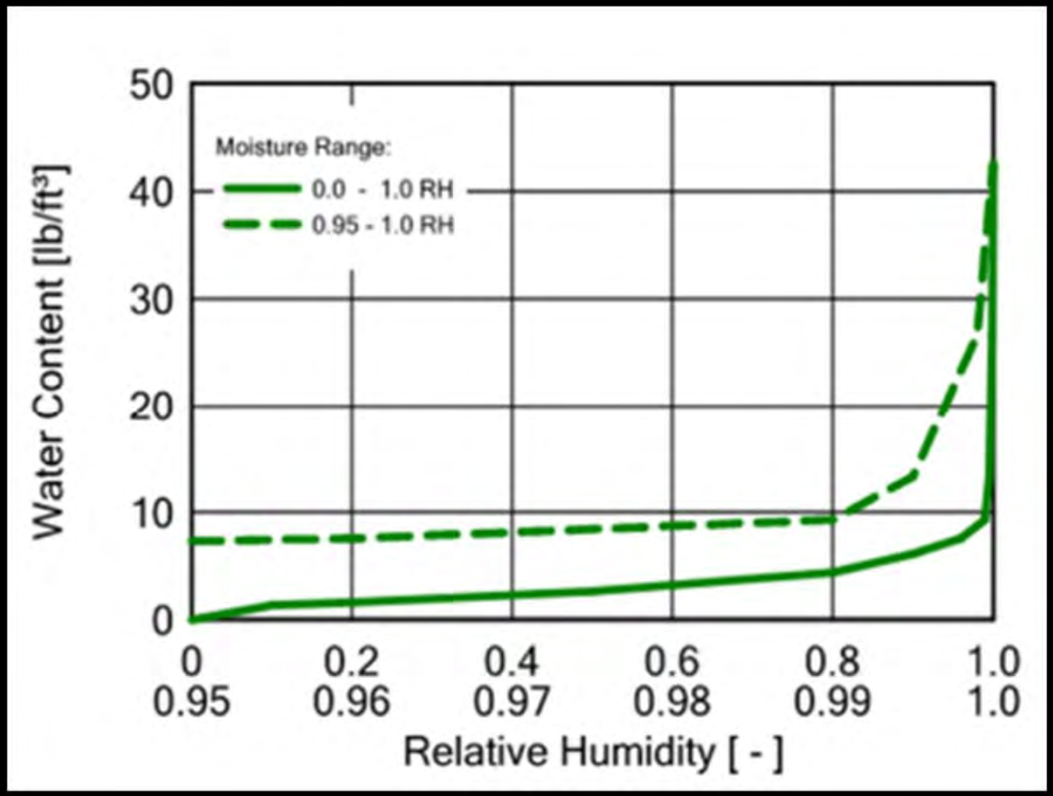
Wood is hygroscopic.

Constantly interacting with surrounding environment.

Moisture content changes when the surrounding temperature and relative humidity changes.

Under steady state conditions – moisture content reaches equilibrium based on a surrounding relative humidity.

Wood is Unique



Hygroscopic & Over Hygroscopic Ranges

Even over 99%, water in wood is mostly bound in the cell walls – when shrinking and drying occur.

Above 99.9% RH capillary water increases moisture content rapidly as pores fill with free water.

Temperature & RH Matter

Table 1—Dependence of equilibrium moisture content (EMC) of wood on relative humidity (RH) and temperature

	EMC (%)																		
Temperature (°F (°C))	5% RH	10% RH	15% RH	20% RH	25% RH	30% RH	35% RH	40% RH	45% RH	50% RH	55% RH	60% RH	65% RH	70% RH	75% RH	80% RH	85% RH	90% RH	95% RH
30 (–1.1)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
50 (10.0)	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
70 (21.1)	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
90 (32.2)	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
110 (43.3)	1.1	2.2	3.2	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4
130 (54.4)	1.0	2.0	2.9	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5
150 (65.6)	0.9	1.8	2.6	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4

Simpson, William Turner. *Equilibrium moisture content of wood in outdoor locations in the United States and worldwide*. Vol. 268. US Department of Agriculture, Forest Service, Forest Products Laboratory, 1998.

Outdoor Location Matters

State	City	EMC (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AZ	PHOENIX	8.9	8.3	7.4	6.0	4.9	4.4	6.2	6.8	6.5	6.9	7.8	9.0
CA	LOS ANGELES	9.4	10.2	10.5	10.4	11.0	11.7	11.6	11.2	10.8	10.6	9.8	9.9
CO	DENVER	10.1	10.0	8.8	9.1	9.2	8.3	8.0	8.4	8.4	9.1	9.6	10.5
FL	MIAMI	13.5	13.1	12.7	12.2	12.5	13.7	13.4	13.8	14.4	13.8	13.6	13.5
GA	ATLANTA	13.3	12.5	12.2	11.8	12.3	12.7	13.4	13.5	13.5	12.9	12.8	13.2
IL	CHICAGO	14.3	14.1	13.4	12.4	12.3	12.3	12.7	13.3	13.3	13.2	13.9	15.1
MA	BOSTON	12.1	11.7	11.8	11.5	12.0	12.0	11.8	12.4	12.8	12.6	12.5	12.2
MN	MINNEAPOLIS-ST.PAUL	14.0	13.8	13.3	11.8	11.7	12.3	12.4	13.1	13.4	13.1	14.2	14.9
NY	NEW YORK	12.2	11.9	11.4	11.0	11.5	11.9	11.8	12.4	12.7	12.3	12.5	12.3
TX	HOUSTON	14.3	14.3	13.9	13.9	14.1	14.1	14.0	13.9	14.2	13.8	14.3	14.6
WA	SEATTLE	16.3	14.9	14.4	13.6	12.9	12.8	12.0	12.4	13.4	15.7	16.6	16.9

Bergman, Richard. "Drying and control of moisture content and dimensional changes." *Chapter 13 in FPL-GTR-282* (2021): 13-1.

Volume Changes



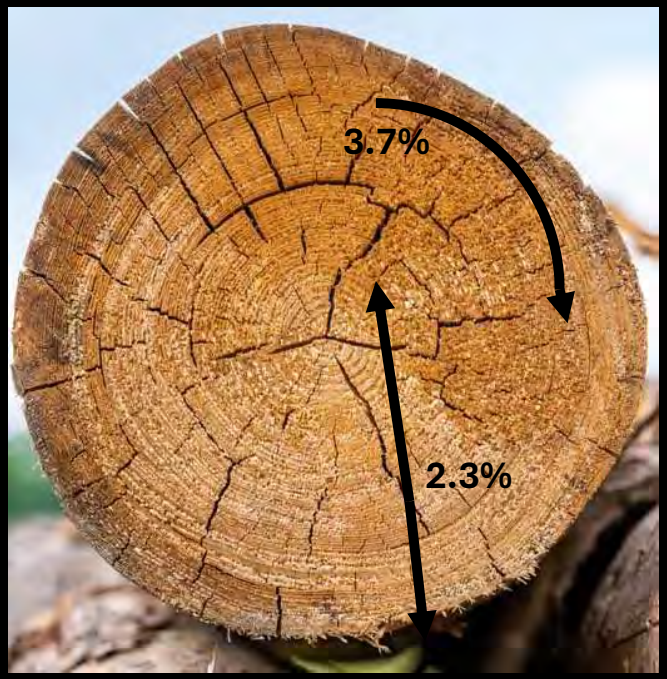
Wood cells contain free water above the Fiber Saturation Point (FSP).

Swelling and shrinking typically starts and stops at the FSP -typically around 30%MC.

Wood shrinks and swells below the FSP once the cells are empty of free water.

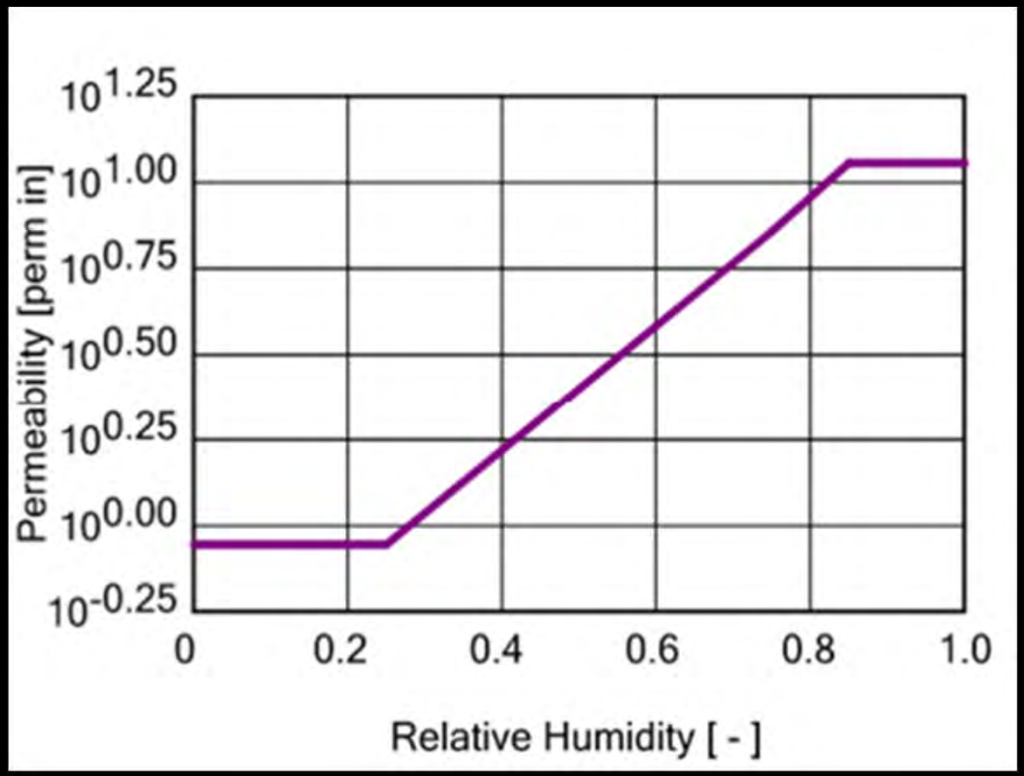
Approximate Dimension Changes

(D-Fir 20%MC to 6%MC)





Vapor Permeability Changes



Thermal Conductivity by Species

Woods (12% moisture content)[1]	**Conductivity[b] *k*, Btu·in/h·ft²·°F**
Hardwoods	
Oak	1.12 to 1.25
Birch	1.16 to 1.22
Maple	1.09 to 1.19
Ash	1.06 to 1.14
Softwoods	—
Southern pine	1.00 to 1.12
Southern yellow pine	1.06 to 1.16
Eastern white pine	0.85 to 0.94
Douglas fir/larch	0.95 to 1.01
Southern cypress	0.90 to 0.92
Hem/fir, spruce/pine/fir	0.74 to 0.90
Spruce	0.74 to 0.85
Western red cedar	0.83 to 0.86
West coast woods, cedars	0.68 to 0.90
Eastern white cedar	0.82 to 0.89
California redwood	0.74 to 0.82
Pine (oven-dried)	0.64
Spruce (oven-dried)	0.69

Douglas fir is more conductive than S-P-F, by 5% up to 36%.c

Typical values of R-1.25 per inch apply more to S-P-F not D-Fir.

For example, a 5-ply panel (6-7/8 thick) is roughly R-8.4 with S-P-F and R-6.9 with D-Fir.

Outline

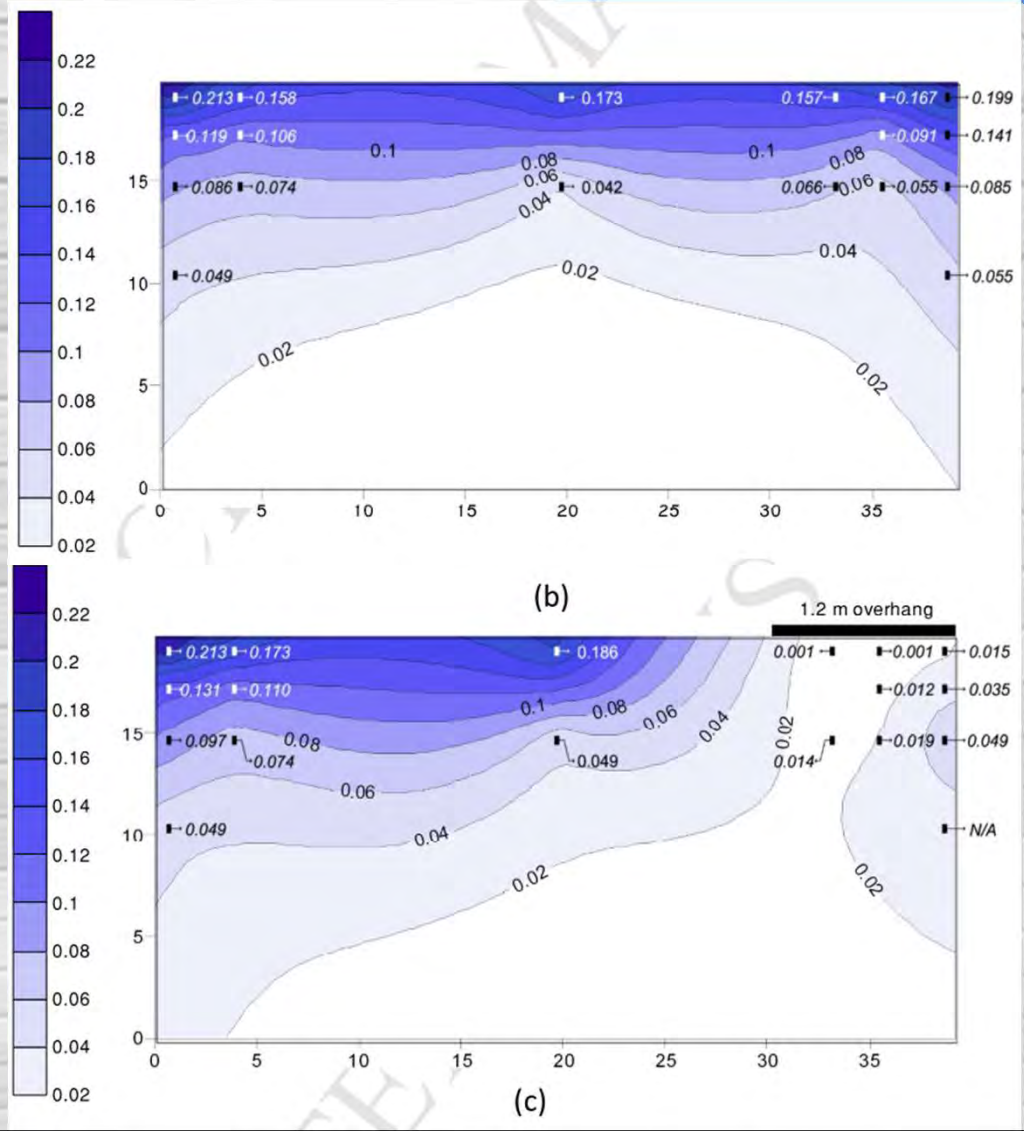
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Overhang Protection

Recent research at Concordia University is quantifying the impacts of overhang protection.

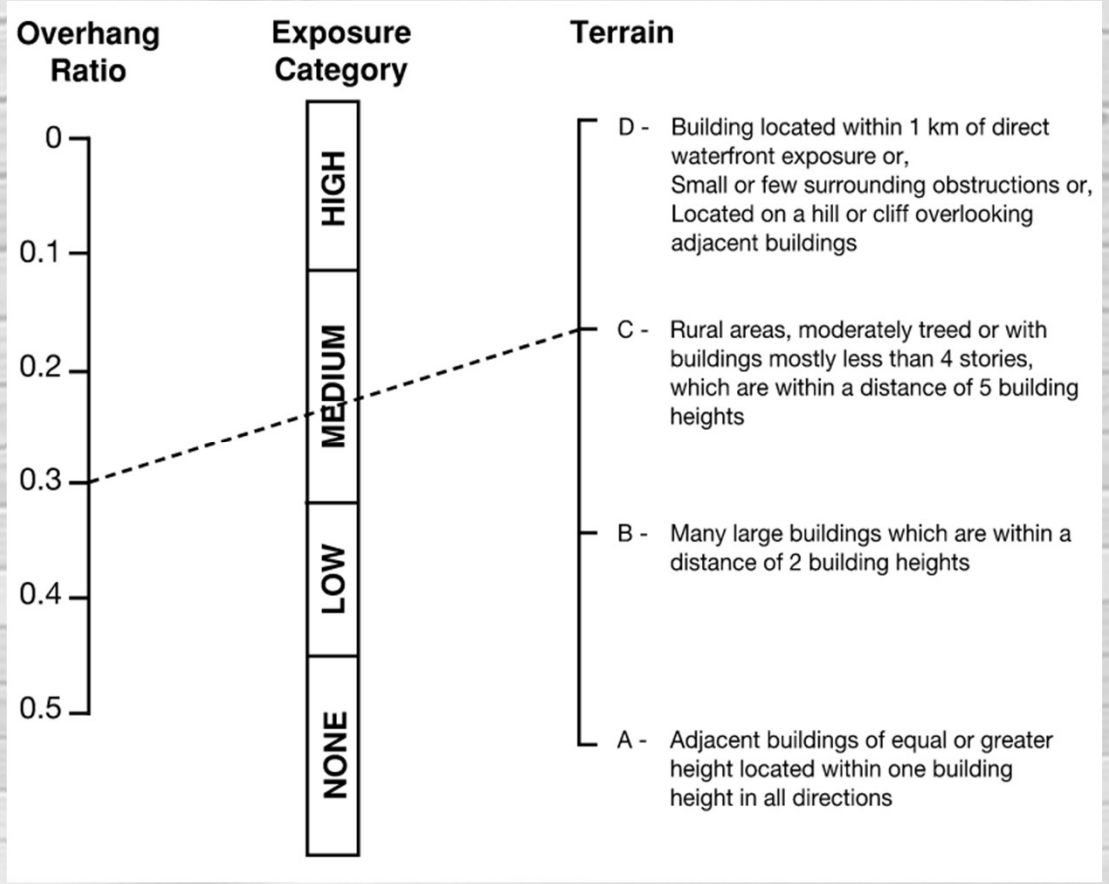
A 4’-0” overhang substantially reduces the rain exposure of the wall 8’ to 10’ below.



Ge H, Chiu V, Stathopoulos T, Effect of overhang on wind-driven rain wetting of facades on a mid-rise building: Field measurements, Building and Environment (2017), doi: 10.1016/ j.buildenv.2017.03.034

Overhang Protection

The overhang ratio can help determine whether timber will be adequately protected from or exposed to rain water.



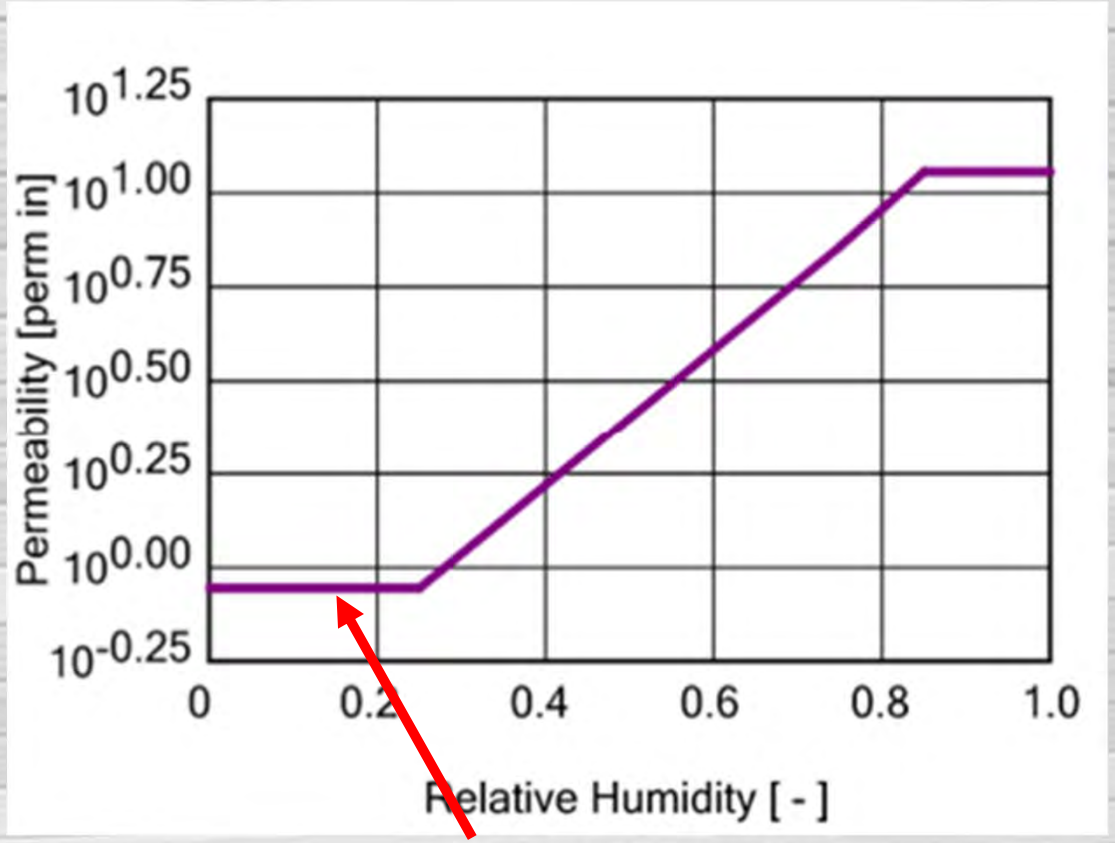
Canada Mortgage and Housing Corporation. 1999. *Wood-Frame Envelopes in the Coastal Climate of British Columbia*. Ottawa: CMHC. publications.gc.ca.

Vapor Control Guidance

Wood behaves like a Class III vapor retarder (<10 US Perms) under most operating conditions.

Behaves like a Class II vapor retarder (<1 US Perm) under dry conditions.

Best practice is to avoid additional vapor control layers, with the exception of roofs.



Wall Assembly Design Guidance

Preferred Option – All Exterior Insulation

- Mass Timber Wall Structure
- Vapor Permeable Air/Water Control Layer
- Vapor Permeable Insulation
- ½"+ Ventilated Rainscreen Cavity

  + Thermal Clips if required.
- Exterior Cladding



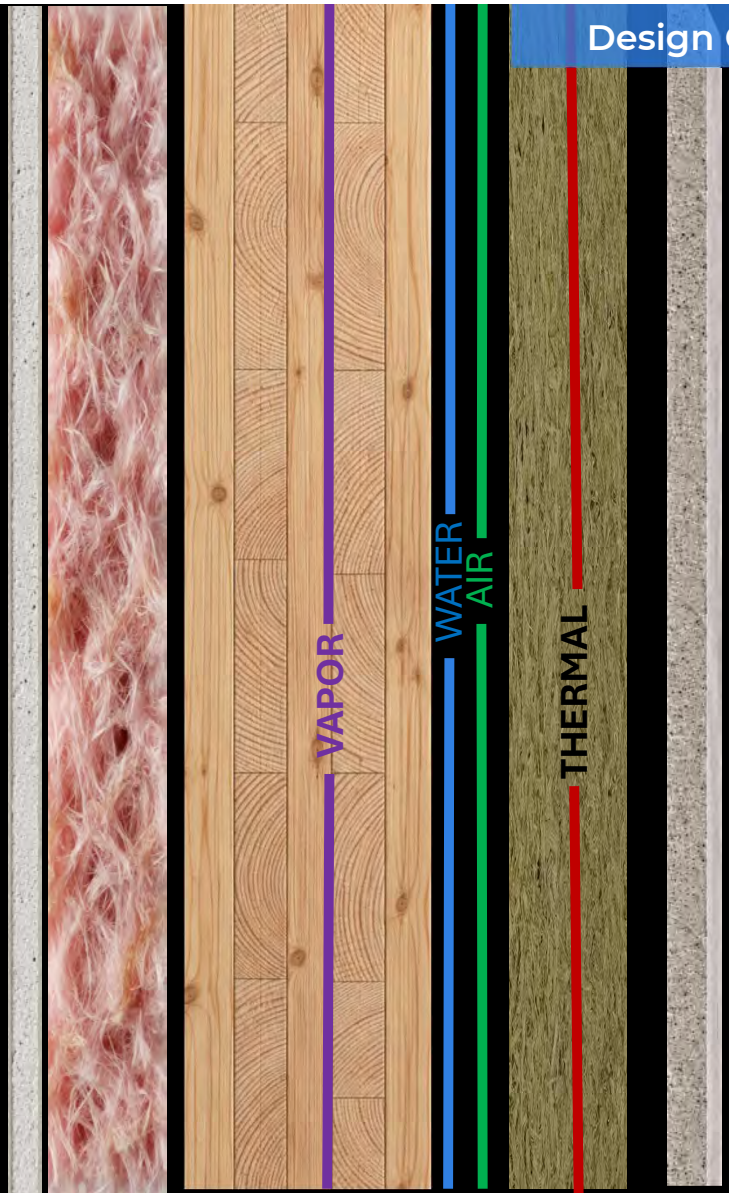
Wall Assembly Design Guidance

Split Insulation Assembly Design

- Interior GWB
- Fiberglass Batt and Framing
- Mass Timber Wall Structure
- Vapor Permeable Air/Water Control Layer
- Vapor Permeable Insulation
- ½"+ Ventilated Rainscreen Cavity

  (+ Thermal Clips if required).
- Exterior Cladding

INSULATION RATIO IS CRITICAL



Split Insulation Ratio Guidance

The table is derived from moisture safe insulation ratios in the IECC.

We use this as a starting point for insulation ratios.

Not an absolute limit. We typically evaluate assemblies outside of these ratios through hygrothermal analysis.

Climate Zone	Rounded Insulation Ratio Exterior :Interior
1	20 : 80
2,3	15 : 85
2B, 3B Tile Roof	0
4A, 4B	40 : 60
4C	30 : 70
5	55 : 45
6	65 : 35
7	80 : 20
8	95 : 5

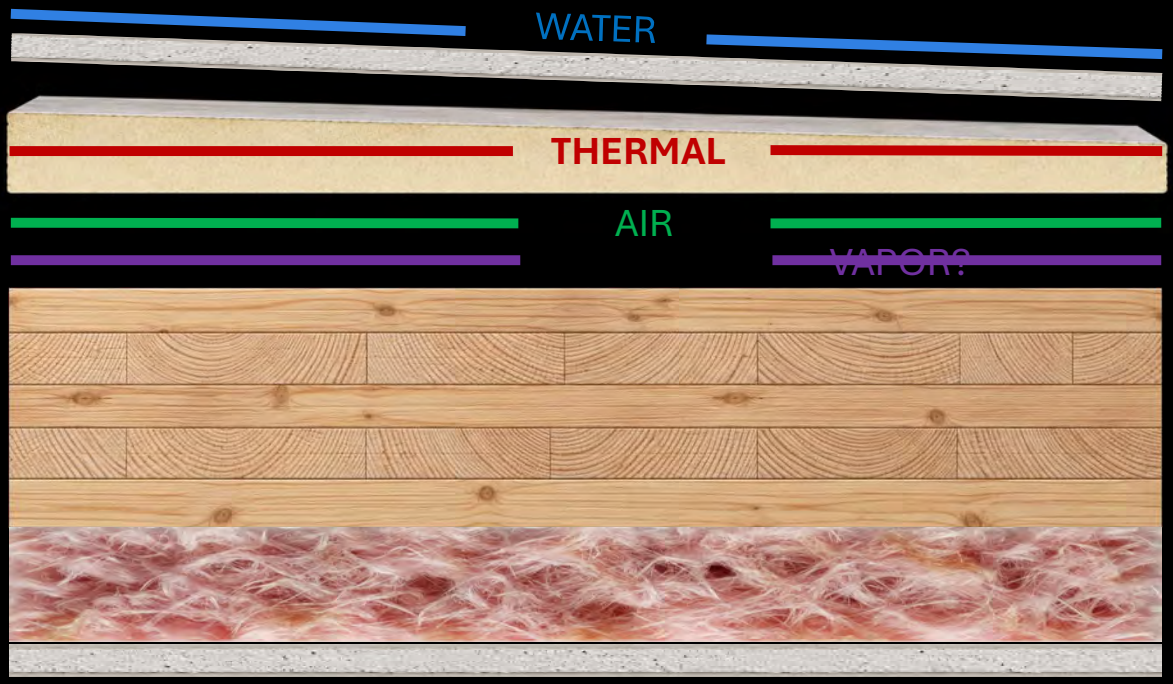
Conventional Roof Assembly Design Guidance



Conventional Roof

- Roof Membrane
- Coverboard
- Tapered Insulation
- Temporary Roof and Air Barrier – Vapor Control Optional
- Mass Timber Wall Structure
- Ceiling (If Required)

Conventional Roof Assembly Design Guidance

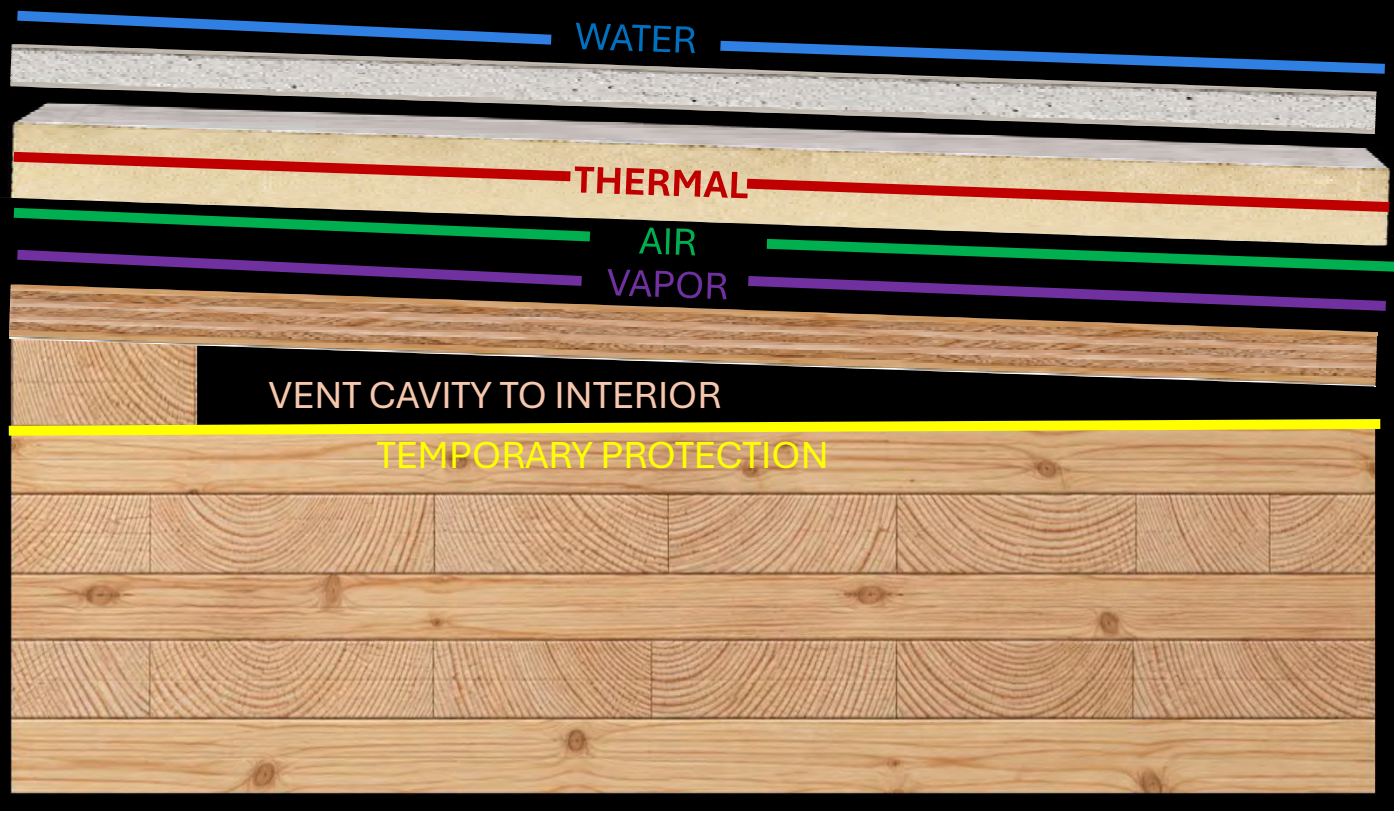


Split Insulation

- Roof Membrane
- Coverboard
- Tapered Insulation
- Temporary Roof and Air Barrier – Vapor Control Optional
- Mass Timber Wall Structure
- Vapor Permeable Insulation
- Ceiling

INSULATION RATIO IS CRITICAL

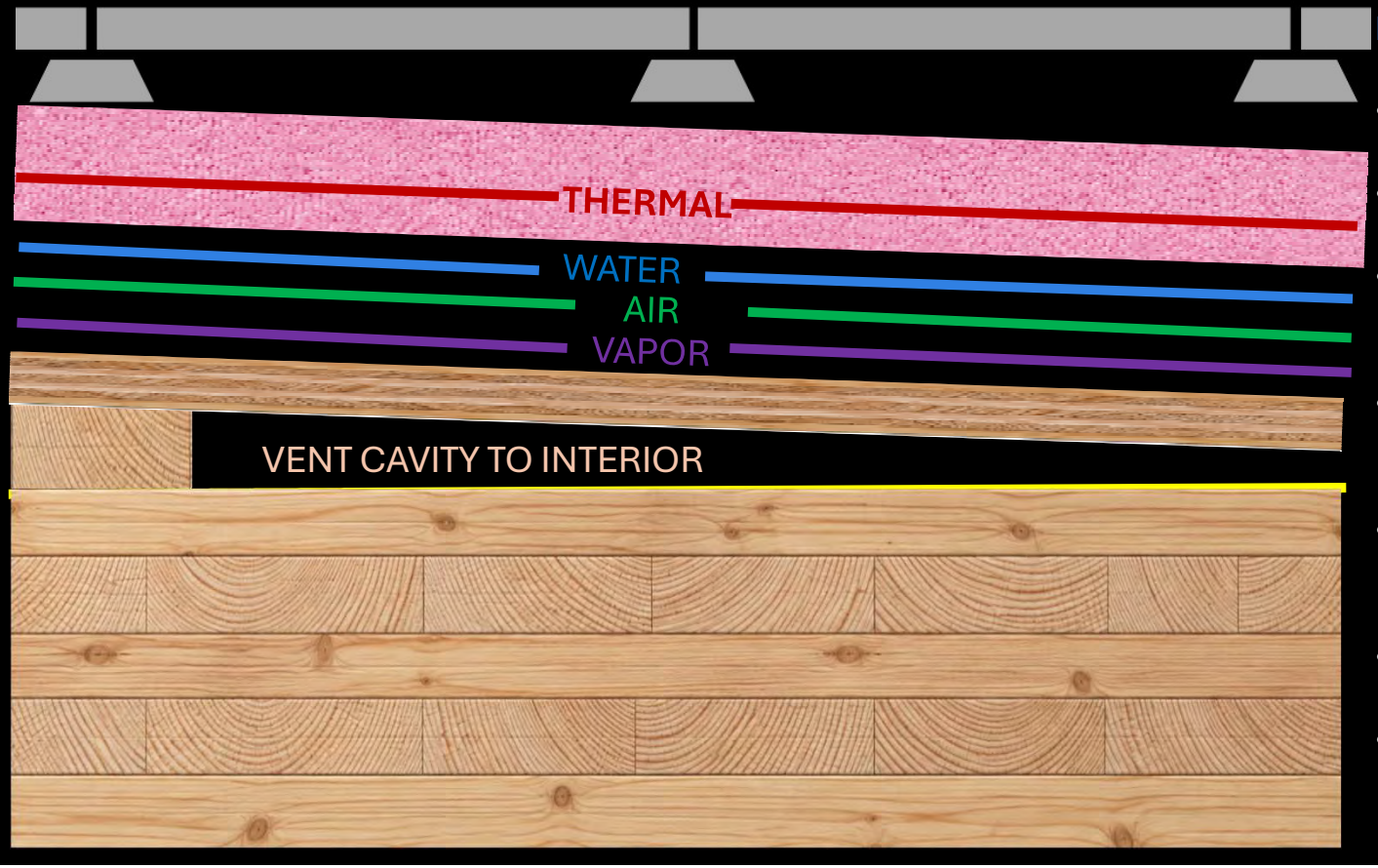
Conventional Roof Assembly Design Guidance



Conventional Roof

- Roof Membrane
- Coverboard
- Flat Stock Insulation
- Temporary Roof and Air Vapor Barrier
- Overframed Slope
- Vent Airspace to Interior
- Permeable Temporary Protection
- Mass Timber Wall Structure

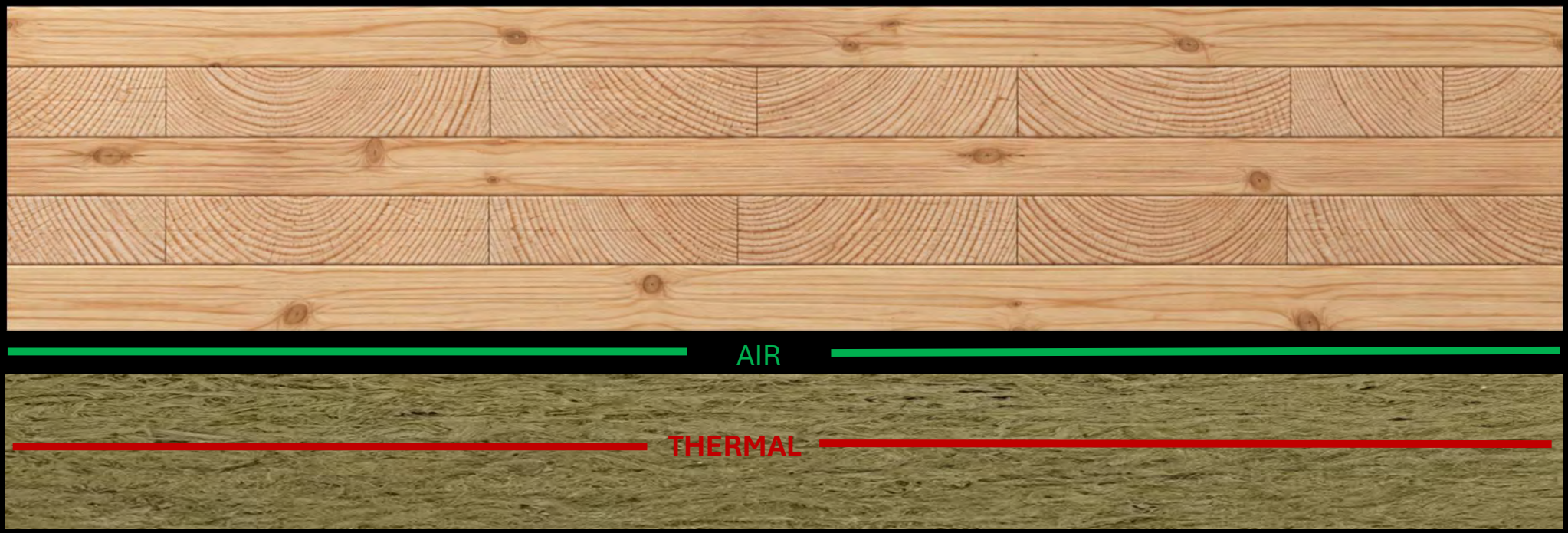
Protected Roof Assembly Design Guidance



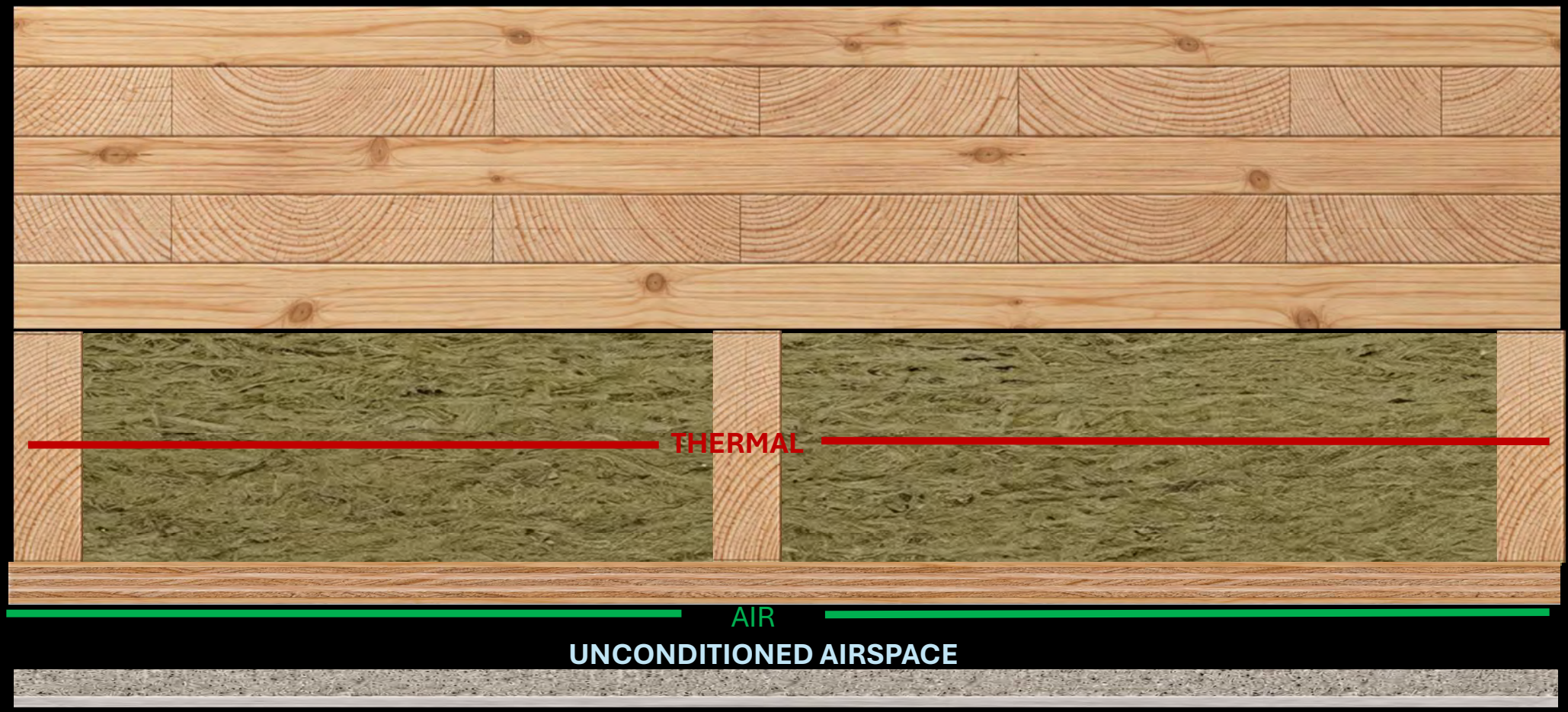
Protected Roof (PRMA/IRMA)

- Overburden
- Flat Stock Insulation
- Roofing/Waterproofing Membrane
- Overframed Slope or Tapered Insulation
- Vent Overframed Airspaces to Interior
- Permeable Temporary Protection
- Mass Timber Wall Structure

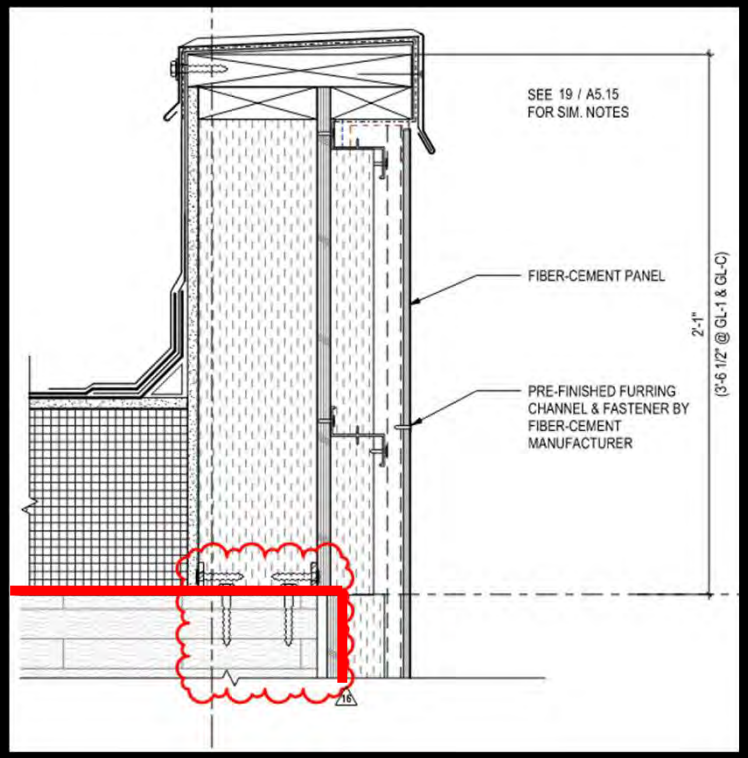
“Cold” Soffit Design Guidance



“Warm” Soffit Design Guidance



Critical Details

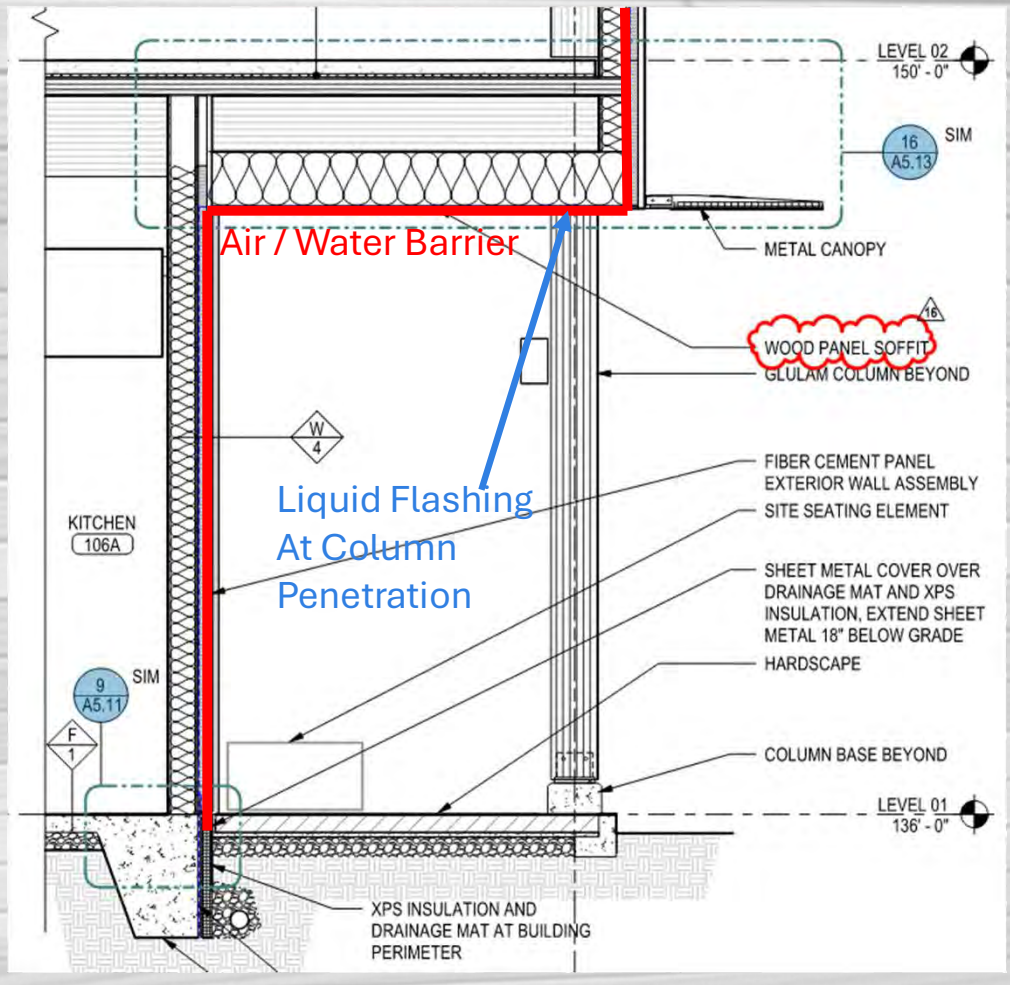




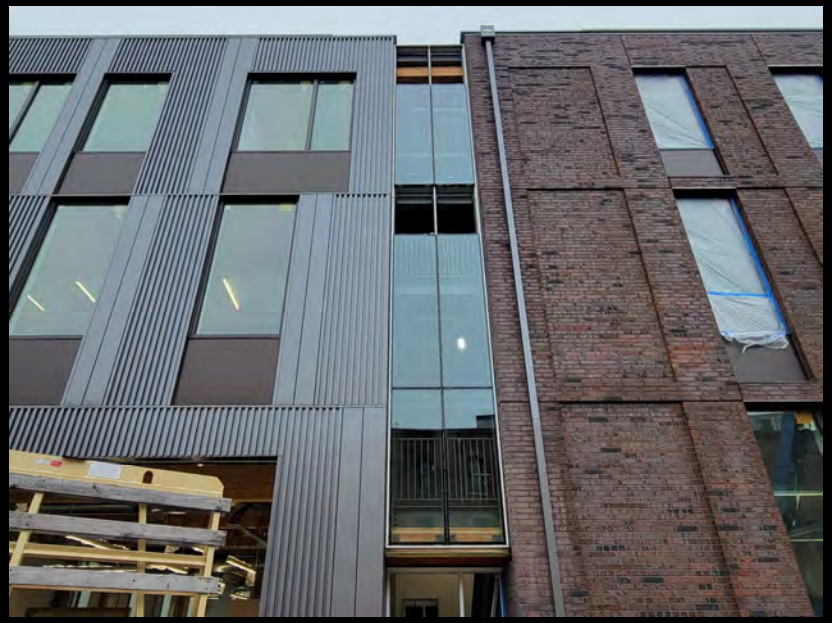


Critical Details

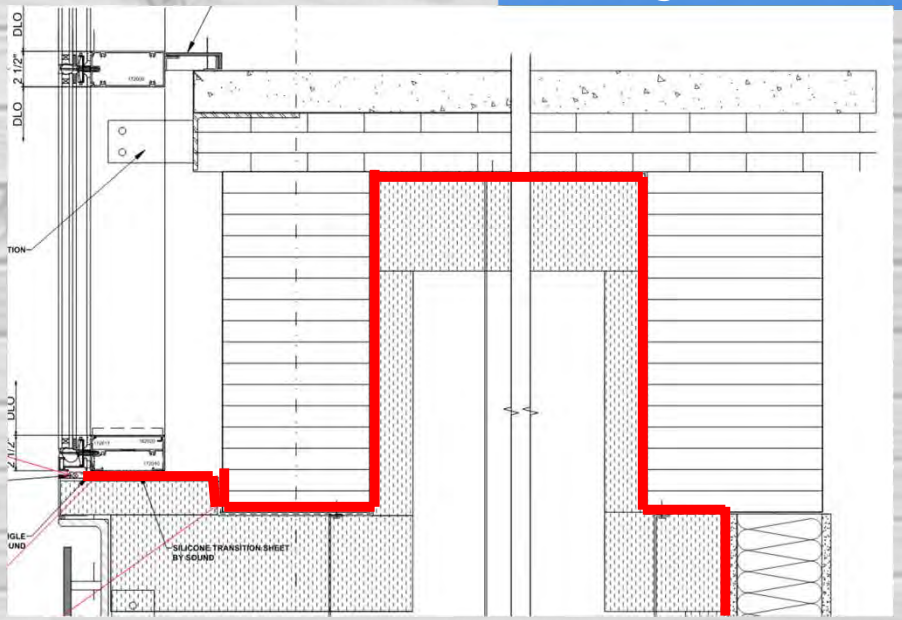




Critical Details

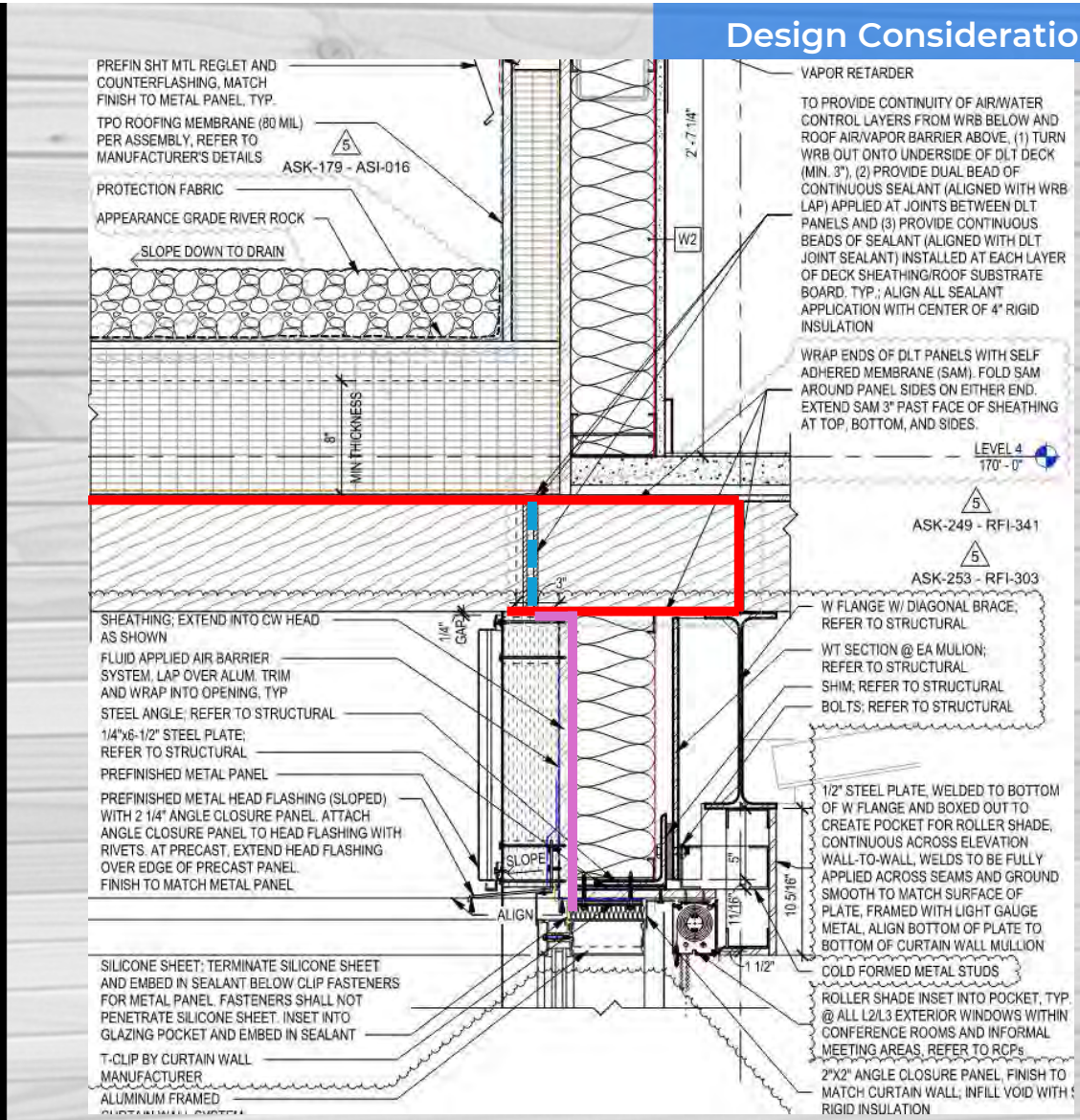


Design Considerations

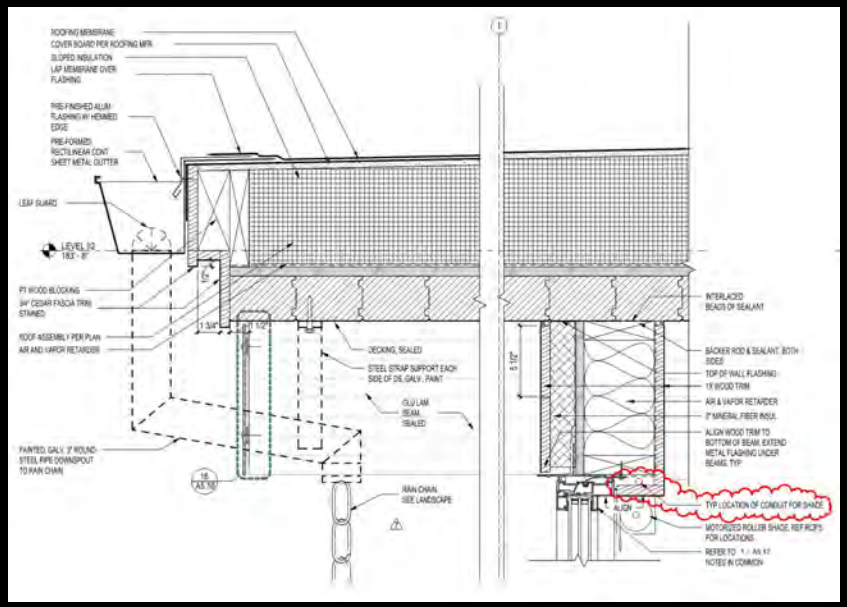




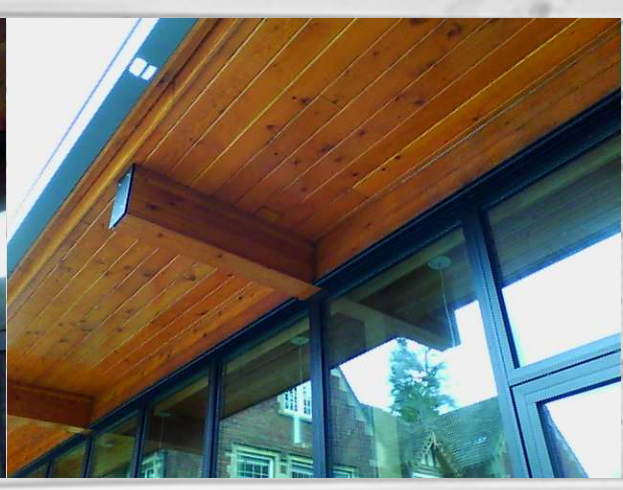
Critical Details



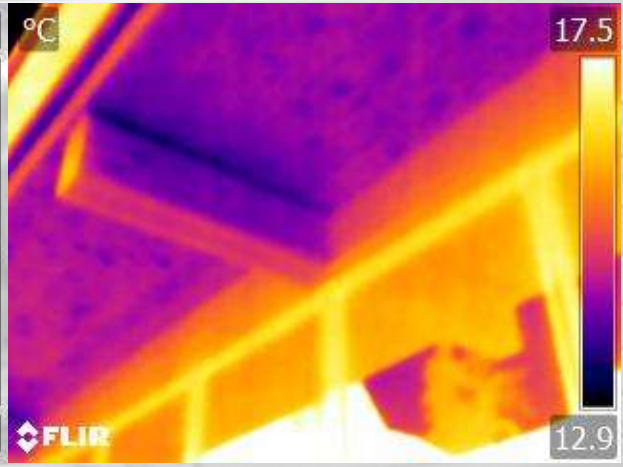
Critical Details









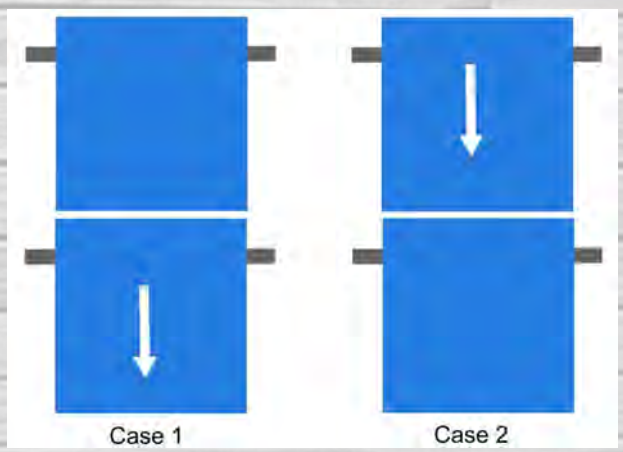


Before Sealing

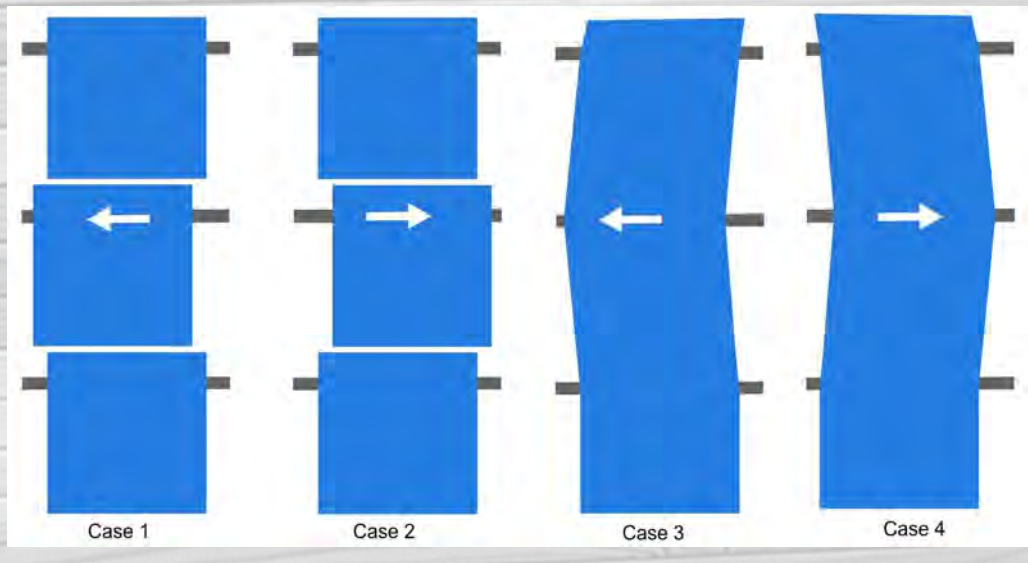
After Sealing

Critical Details





Greater Floor Line Deflection



Greater Elastic Interstory Drift (~1.1%)

Outline

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Construction Moisture Planning









Mass Timber Moisture Risks

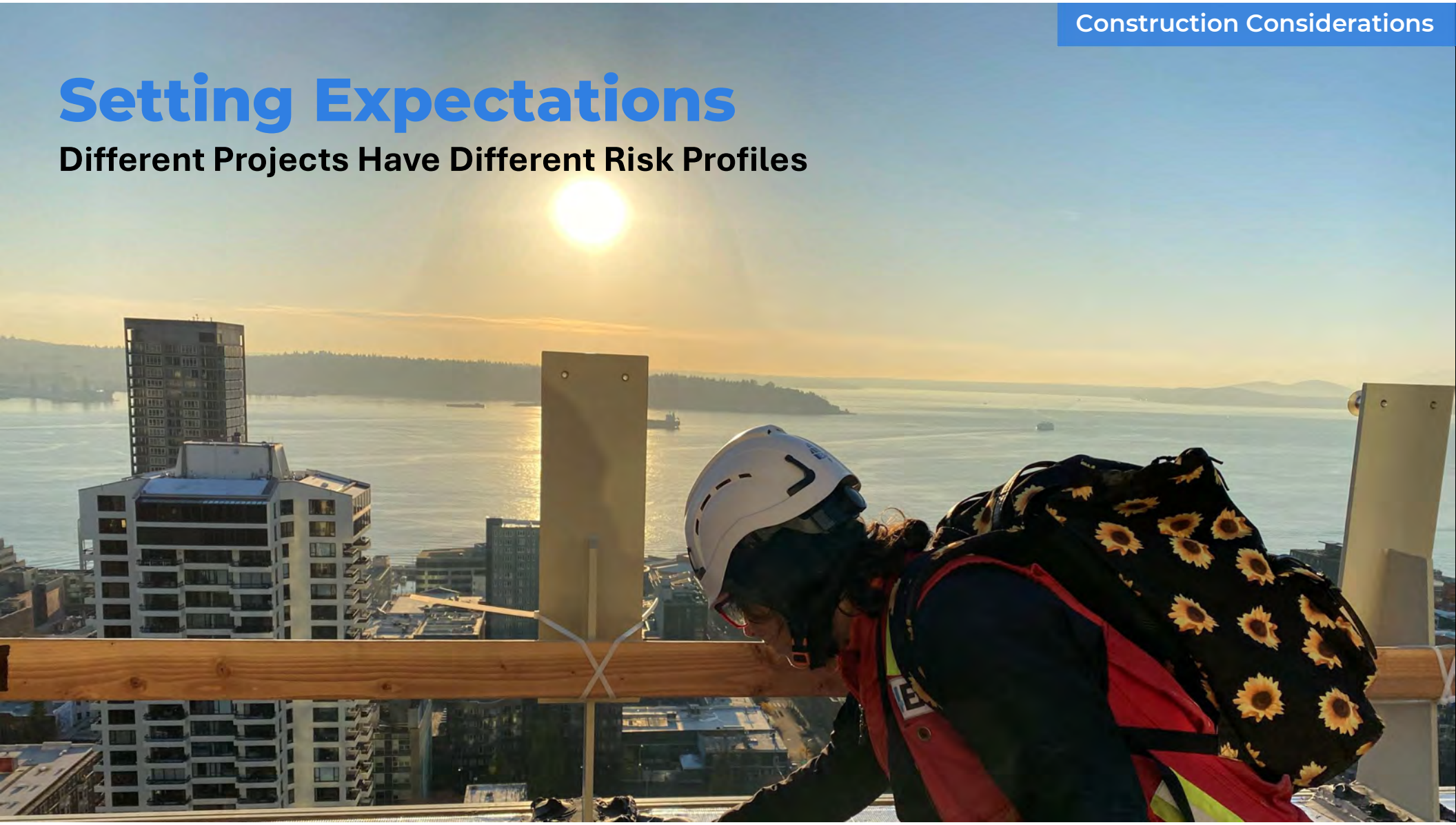
- Project Delays
- Staining
- Swelling, Shrinking, Checking
- Fungal Growth
- Wood Decay





Setting Expectations

Different Projects Have Different Risk Profiles



Risk Is A Spectrum

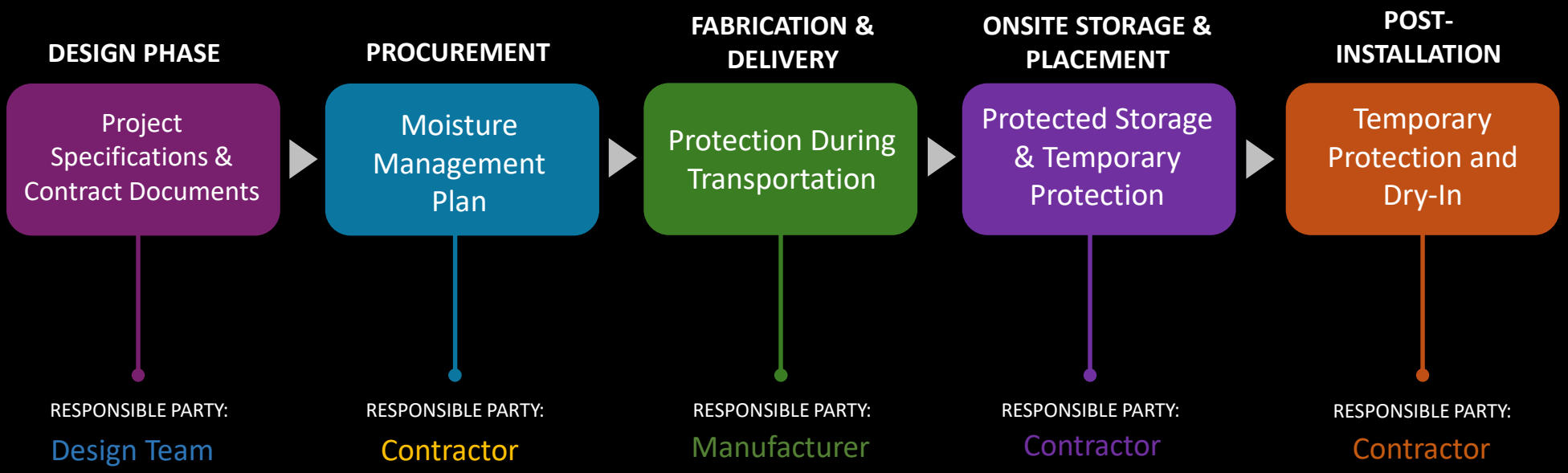
Lower Risk Case Examples

- Dry season install
- Fast-tracked enclosure sequence with protection at sides and top.
- Unexposed panels
- Hybrid CLT or Mass Ply Structures without sheathing overly or vertical elements.
- Surface-applied connections
- Low rise or low exposure

Higher Risk Case Examples

- Wet season install.
- Complicated install sequence with extended exposures.
- Horizontal and vertical elements to be left as an exposed finish.
- Panels requiring overlay sheathing. (e.g. DLT, NLT, ADLT)
- Recessed connections
- High rise or high exposure

Typical Chain of Custody



Mass Timber Moisture Management Plan

What is It?

- Project specific document required by specifications.
- Sets expectations for level of protection desired.
- Defines project-specific roles and responsibilities.
- Gets stakeholders on the same page.

Prepared by Contractor and Reviewed by Owner and Design Team



Mass Timber Moisture Management Plan

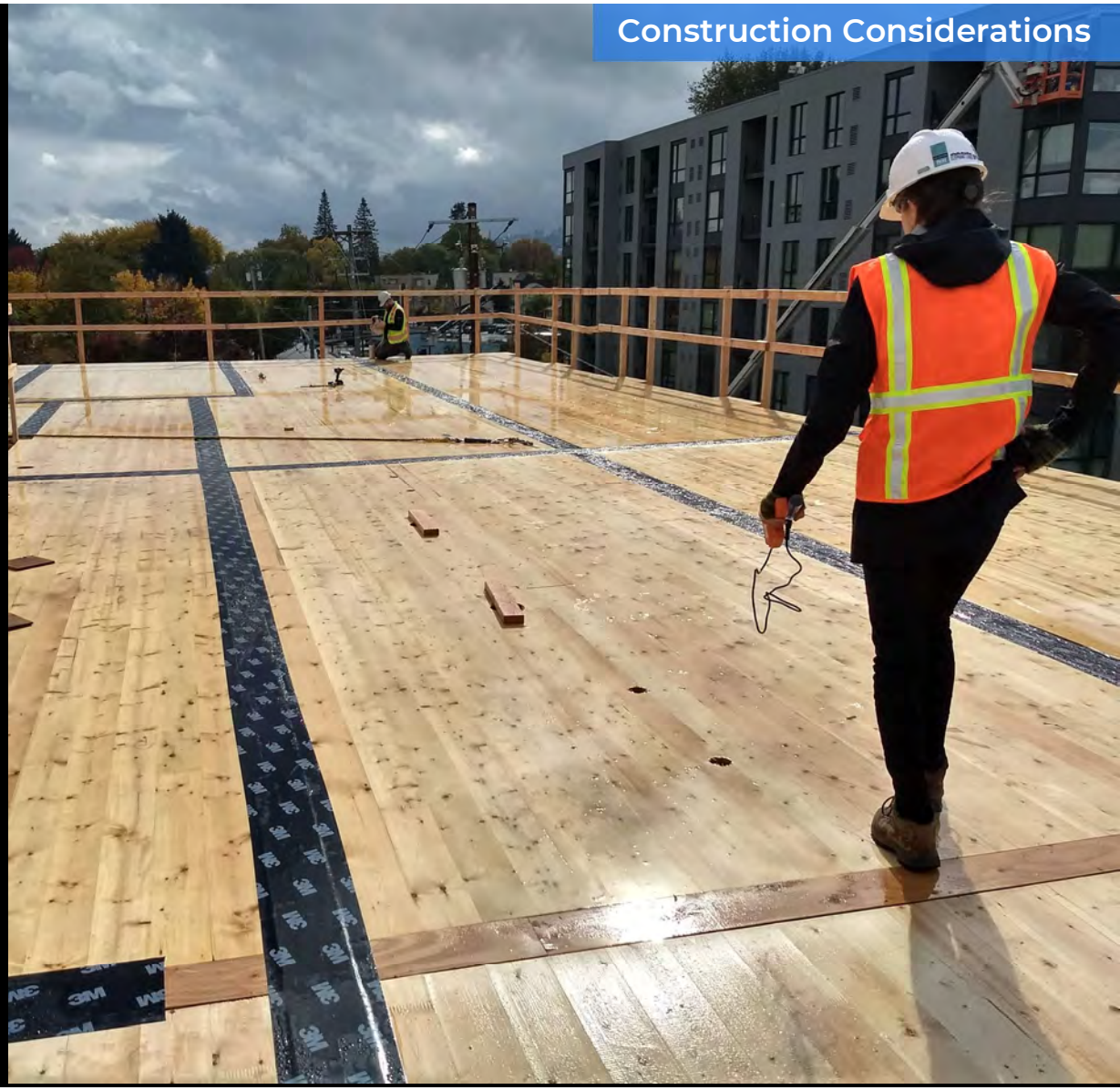
What's in it?

- Shipping protection
- Acceptance criteria for shipped panels
- Onsite storage & construction plan
- Temporary protection measures
- Bulk water management and removal
- Dry-In Process & Moisture Content Targets
- Moisture monitoring & ongoing inspection plan
- Protection measures for non-weather stains (spills, corrosion, dirt, plumbing)
- Mitigation, cleaning & restoration processes



Low Moisture Protection Level

Examples: Edge sealers or joint protection only.



Medium Moisture Protection Level

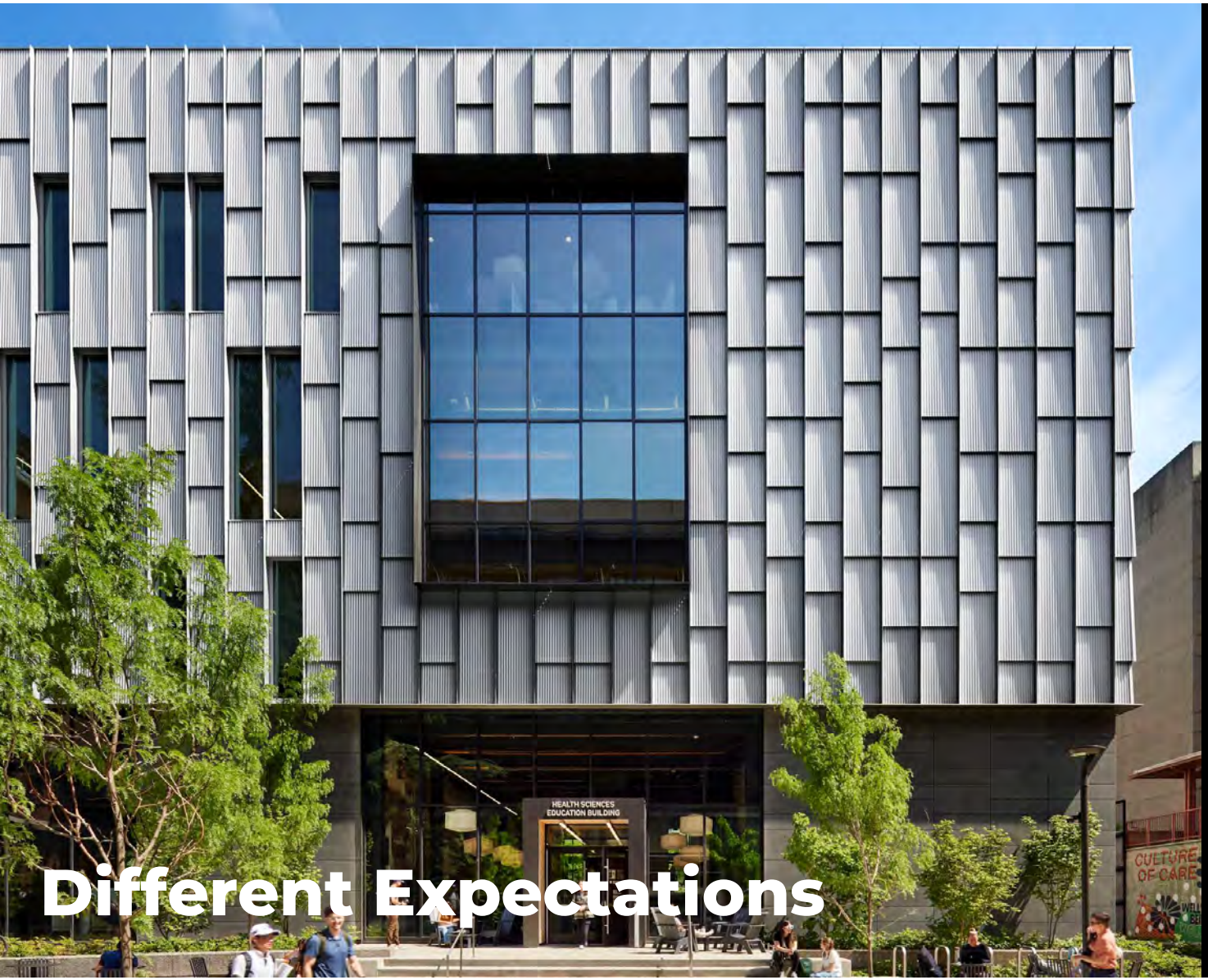
Examples: Joint protection plus vapor-permeable self-adhered sheets. Preferably pre-applied.



High Moisture Protection Level

Examples: Full tenting or pre-applied roofing grade membranes.





Different Expectations

UW Health Science Education Building

Owner: University of Washington

Design-Builder: Lease Crutcher Lewis

Architect: The Miller Hull Partnership

Structural Engineer: KPFF

Mass Timber Supplier: Structurlam

Enclosure Consultant: 4EA Building Science

Unique Project Expectations

- Integrated Design-Build Project Delivery
- Demonstrate mass timber as a competitive structural material
- CLT-Concrete Composite Deck
- Demonstrate speed of construction
- Lean project delivery – just-in-time placement
- Very fast panelized enclosure sequence
- Limited exposed finish areas – refinishing planned, cosmetic stains mostly deemed acceptable.



Low Moisture Protection Level

- Team prioritized speed
- No onsite storage
- 6” gaps around panels
-
- Sloped roof
- Pre-Cut Openings
- Sealed edges
- Immediate water removal
- MC% Measurement
- Quick overhead cover




Early April – CLT Starts


Mid April – Level 4 Complete


Mid May – Temp Roof Down


Mid June – Mostly Enclosed

Low Moisture Protection Level

The Canyons
Portland, Oregon











The Canyons – Portland, Oregon

- 6-Story, 70 Unit Apartment Building
- 5 CLT floor decks over 1 story concrete podium
- Platform Framed
- Exterior walls sheathed immediately
- Wood frame construction through rainy October – December 2019
- Dry-in process commenced January 2020 through April 2020

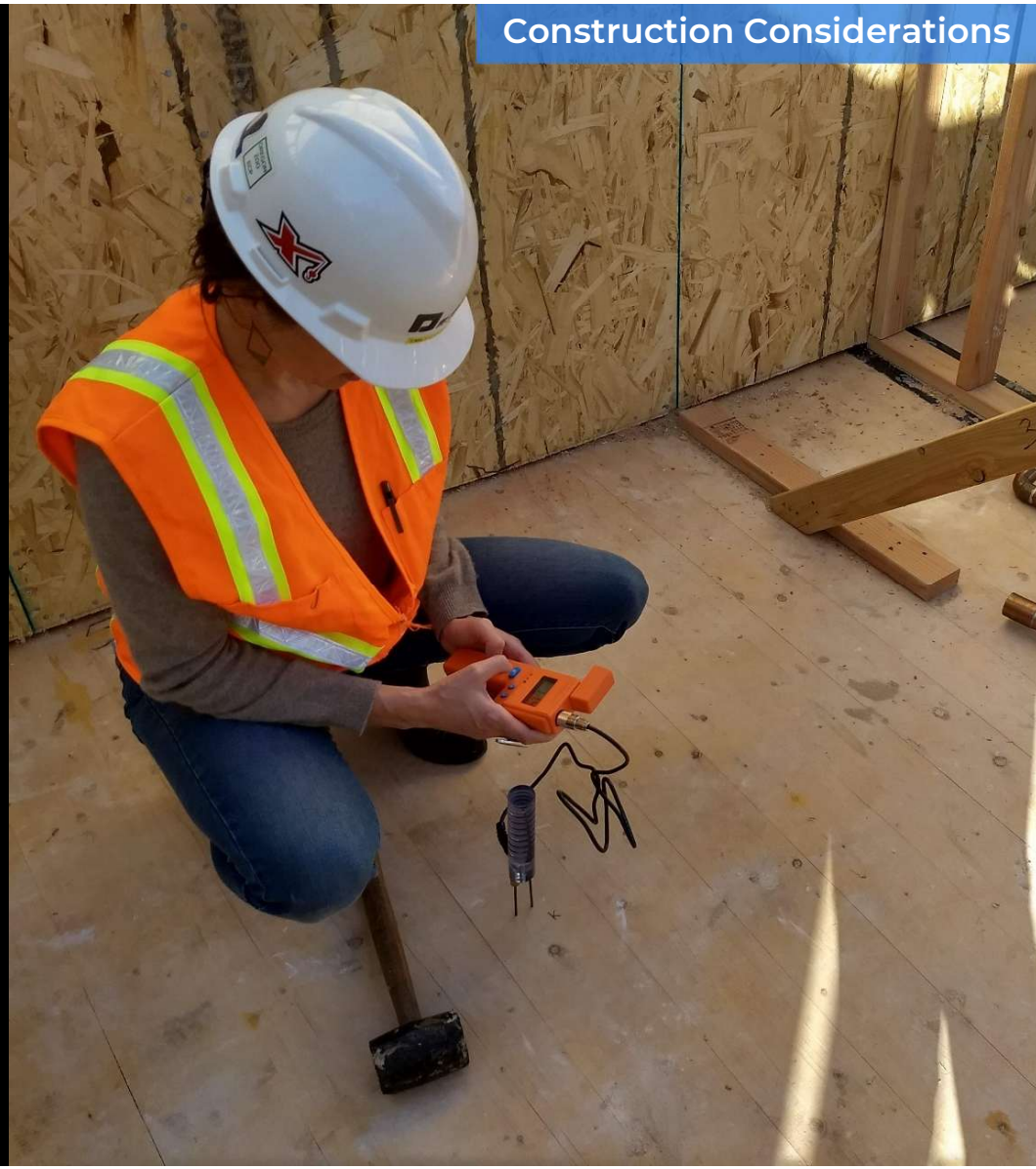


5-Point Moisture Mitigation Plan

- **Sealers** - Shop-applied sealers at ends, edges and cuts.
- **Stain Prevention** – Fully wrapped during transport. Only galvanized or painted steel connectors. No steel cutting on deck surface. No non-water food or drinks on floors. Regular cleanup.
- **Joint Control** – Same day installation of 9” wide tape at joints.
- **Dry-Out** – Dry out phase with heat and fans until < 14% MC +/- 1%
- **Protection** – Masking surfaces adjacent paint/caulking. Glove requirements.

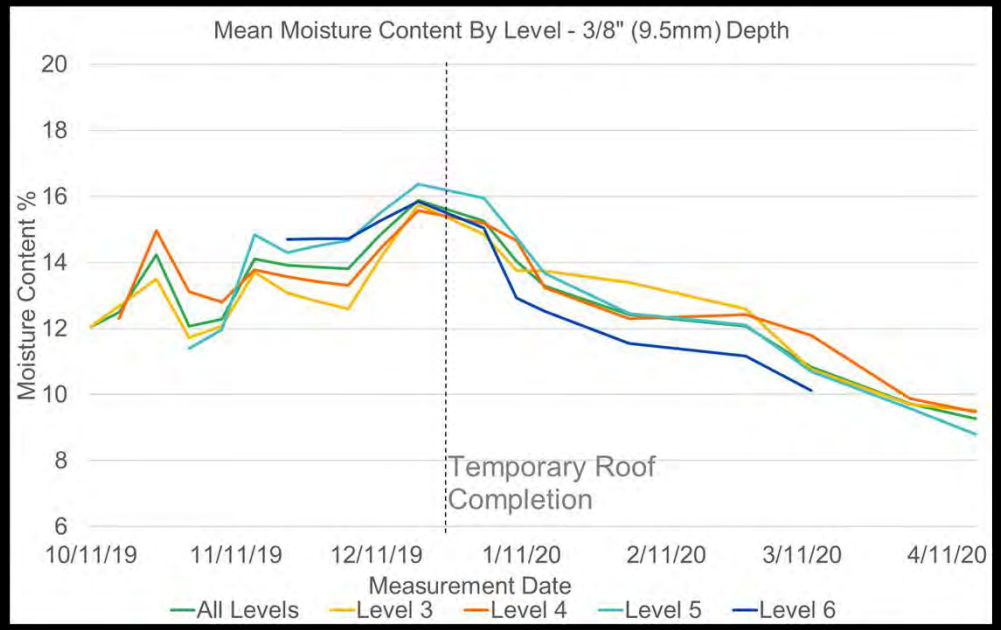
Moisture Monitoring Plan

- Monitored October 2019 to April 2020
- Intermediate floors monitored – roof received immediate vapor barrier.
- Weekly measurements with Delmhorst BD-2100.
- 14 locations per floor, 56 locations total.
- Measurements at two depths – 3/8” and 2”. Both depths used insulated prongs.
- Weekly measurements taken >2” and <12” away from prior location.
- Total of 1540 individual moisture readings. Some weeks (holidays, etc) were skipped.



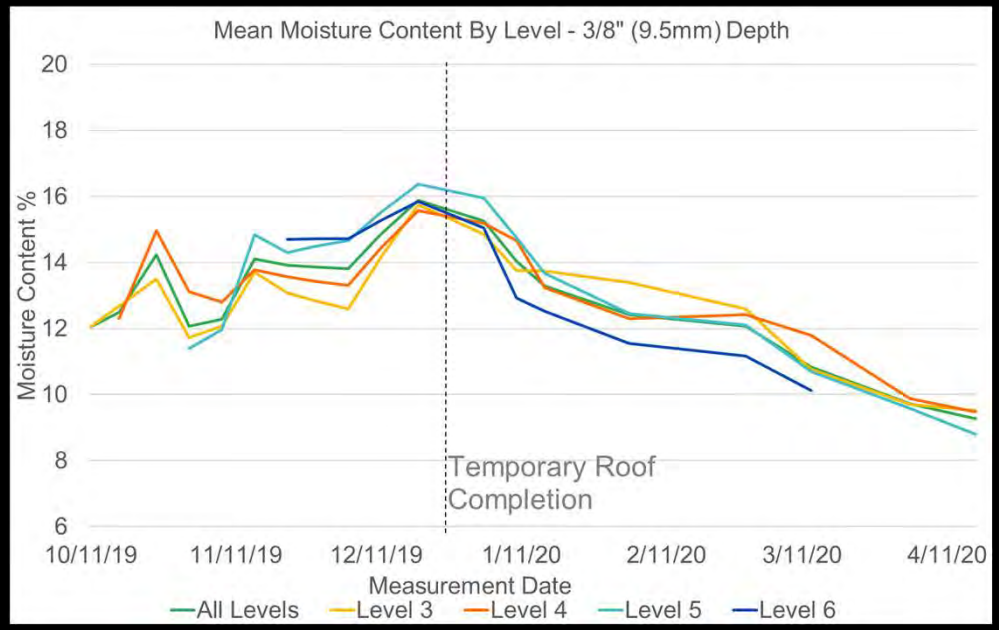
Key Findings @ 3/8” Depth

- Panels were generally dry after transportation, with exception of 6th floor. Range of initial MC% was low. 33 of 34 initial readings at 15% or lower. One reading at 21%. Average 12%.
- 6th Floor had higher initial moisture content. 4 of 14 readings above 15%. Average 14.7%.
- On average, mean moisture content did not rise above 16%.
- 6 of 56 locations recorded at least one measurement above 20% MC.
- No locations measured above 20% for more than 2 consecutive weeks.



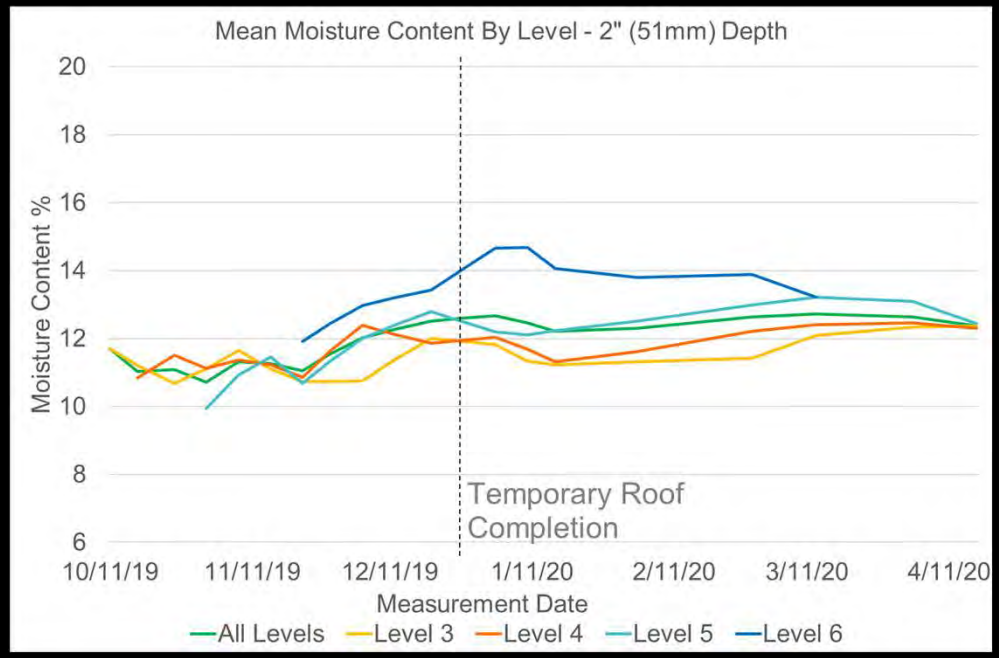
Key Findings @ 3/8” Depth

- Maximum measured moisture content was 28% - though MC readings are highly inaccurate in this range.
- All locations at all four floors consistently measured <14% at end of dry-in period. Typically 9%-12% range.
- Introduction of heat at dry-in has significant influence at all levels.



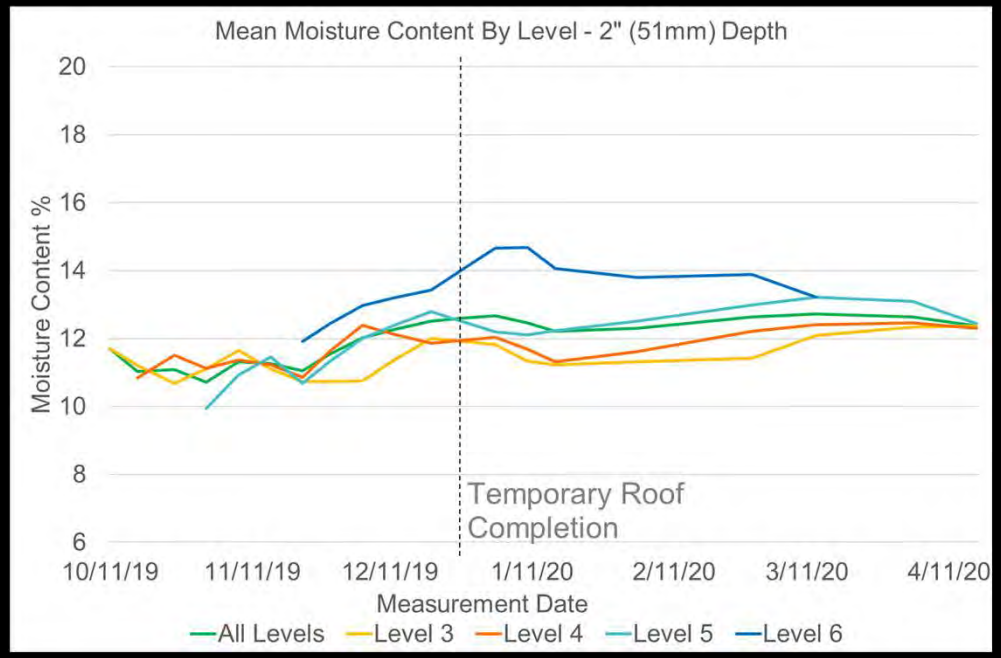
Key Findings @ 2” Depth

- Consistently lower MC% than 3/8” depth until end of January.
- Less overall variance in MC% than 3/8” depth.
- On average, mean moisture content did not rise above 13%.
- 17 of 56 locations recorded at least one measurement above 15% MC.
- 3 of 56 locations reached MC% of 20% or higher.
- No locations measured above 20% for more than 2 consecutive weeks.

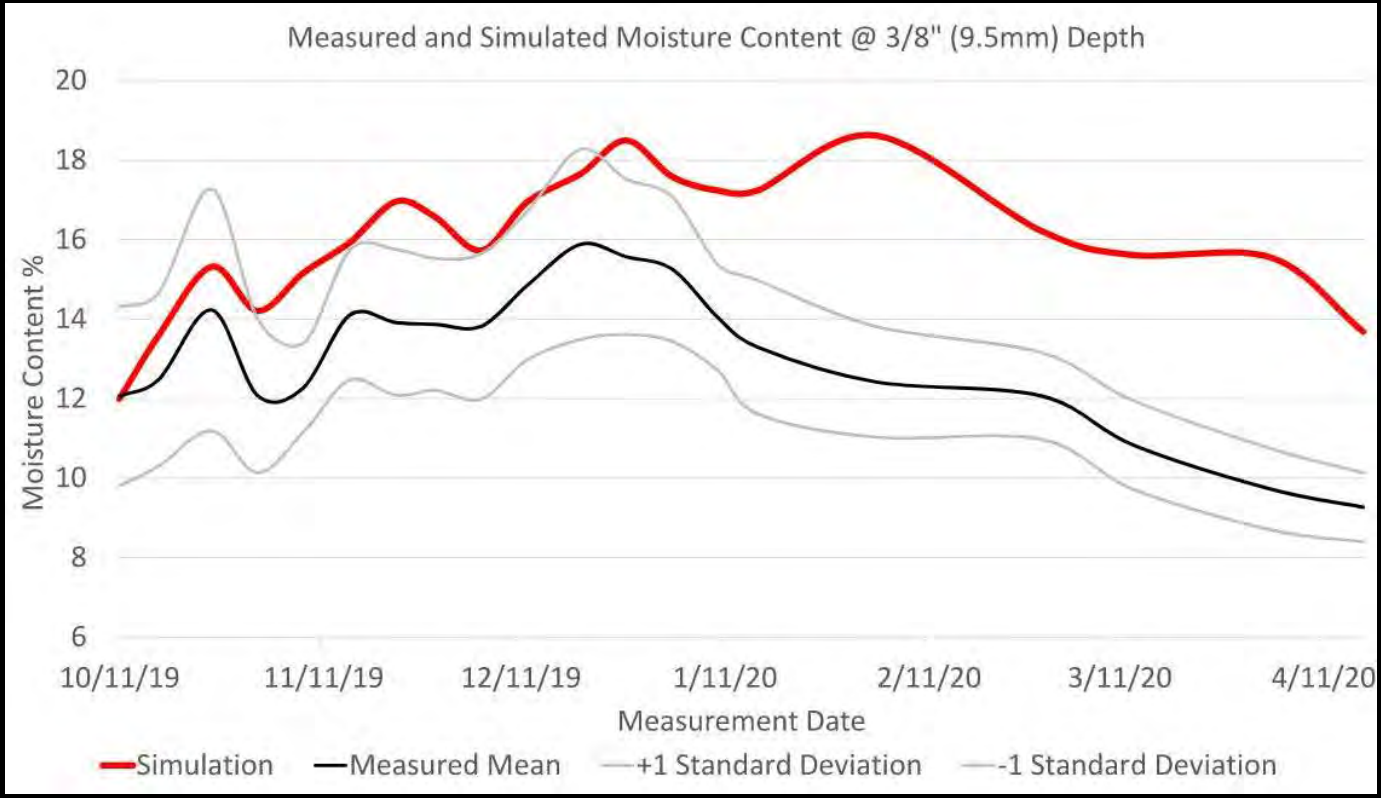


Key Findings @ 2” Depth

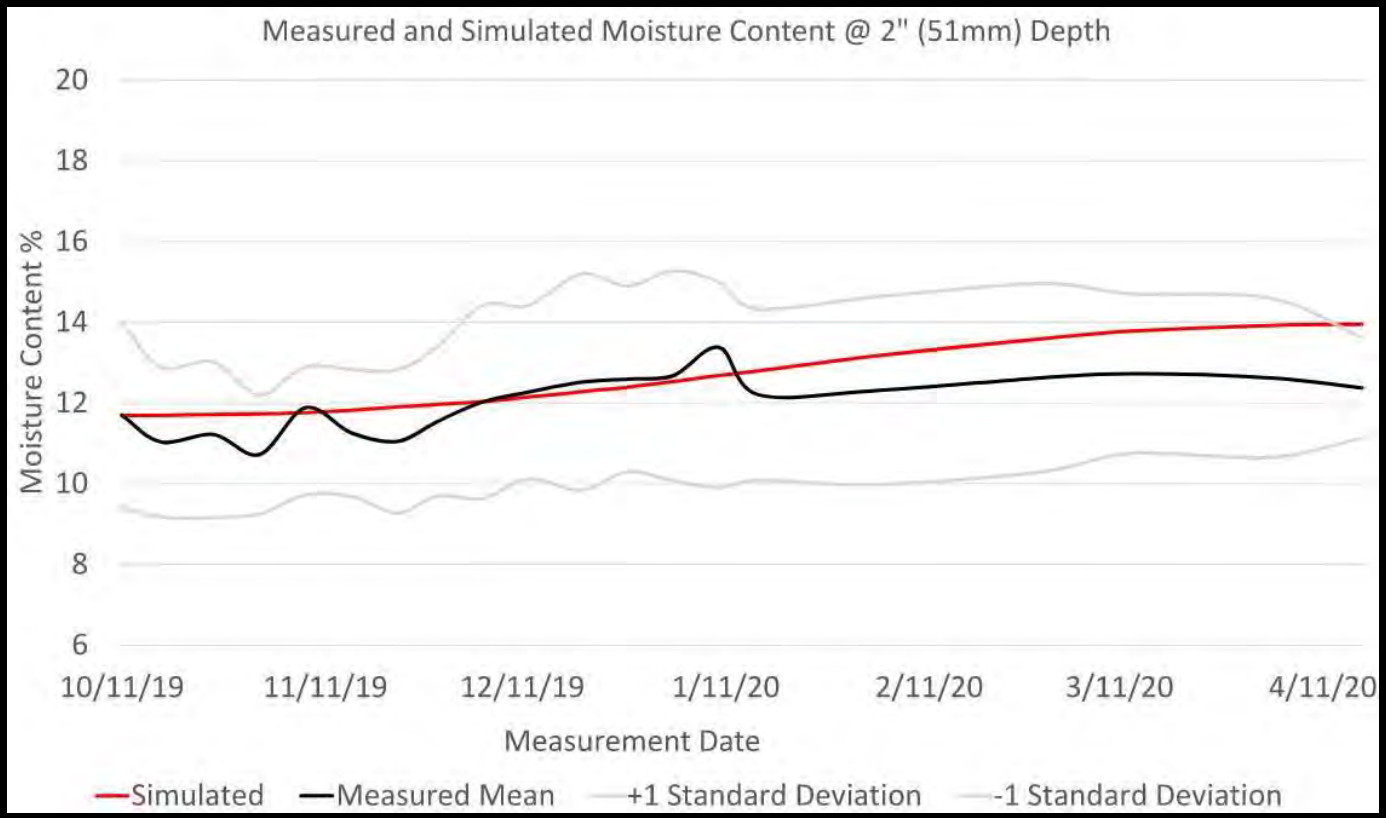
- Slightly elevated MC% at 2” depth compared to 3/8” depth after January.
- All locations at all four floors consistently measured <15% at end of dry-in period. Typically 10%-15% range.
- MC% had an initial drop at start of dry-in, then slight gradual rise and plateau.
- Approximate 2-week “phase shift” between 3/8” and 2” measurements



Simulation Results (3/8” Depth)



Simulation Results (2” Depth)



Construction Considerations

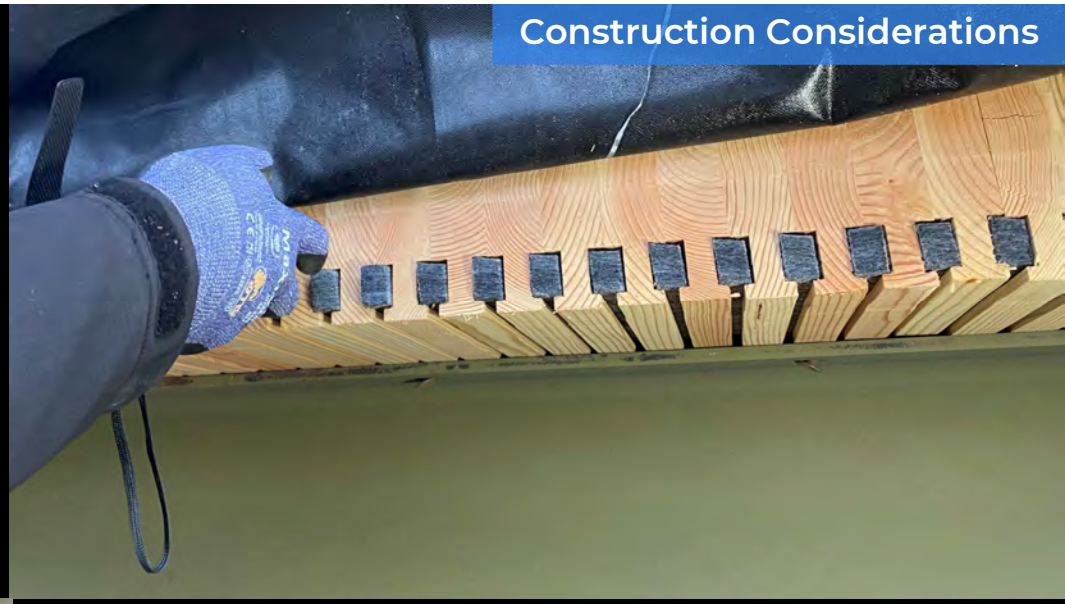
Medium Moisture Protection Level

Newhouse
Olympia, Washington



Construction Considerations

- ADLT Panels with Plywood Overlay
- Factory Applied Self-Adhered Membrane – Pre-applied vapor permeable sheets to protect ADLT.
- Plywood Sheathing Overlay – Could not get factory-applied for this project. Joints and fasteners were field sealed with STPE flashing.





- Factory Applied Self-Adhered Membrane – Pre-applied vapor permeable sheets to protect ADLT.
- CDX Plywood Overlay – Could not get factory-wrapped sheathing for this project. Joints and fasteners were field sealed with STPE flashing.

Construction Considerations

- Tenting with Tarps
- Water Diversion at Openings
- Active water removal

- Ongoing MC% Monitoring– Weekly stain inspections and moisture content measurement at both plywood and DLT.
  - Top of Sheathing
  - Bottom of Sheathing
  - Top 3/8” of DLT
  - DLT Panel Edges

- Tenting & Dry-Out – Plywood needed additional dry out with fans and dessicant. Dry out slowly until < 14% MC +/- 1% prior to flooring. Careful humidity management.





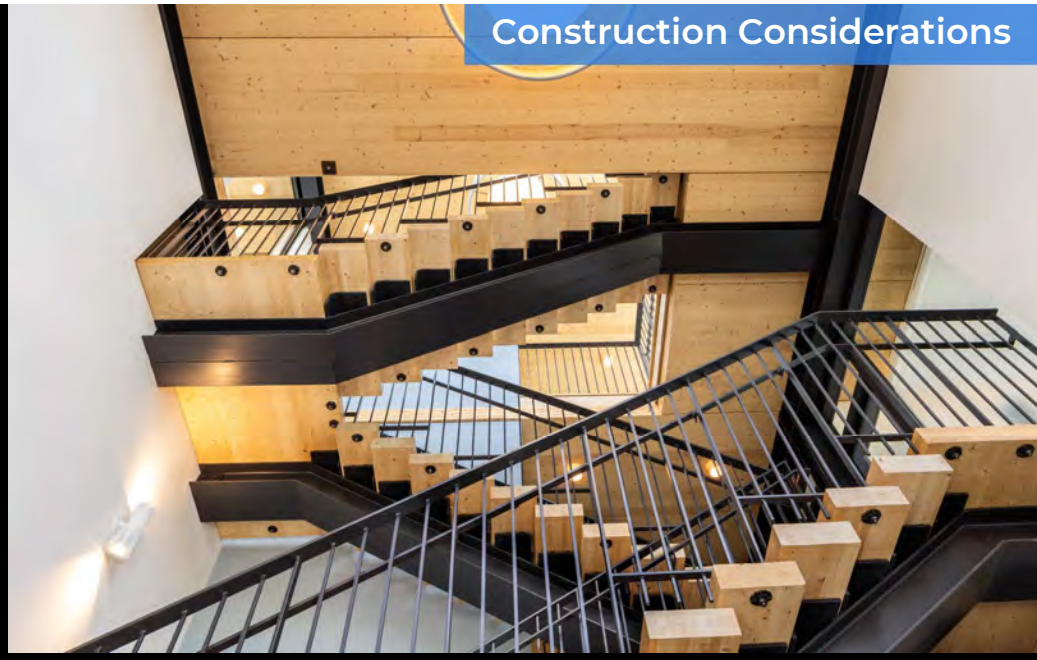
High Moisture Protection Level

East Seattle Partners
Seattle, Washington



Steel Structure with CLT Decks





Exposed Timber Interior Finish







Wet Weather Install

Outline

- Introduction
- Section 1 – Building Science Crash Course
- Section 2 – Building Science & Wood
- Section 3 – Design Considerations
- Section 4 – Construction Considerations
- Questions and Discussion



Thank You!



Contact Me:

bradc@team4ea.com

- *This concludes The American Institute of Architects Continuing Education Systems Course.*

4EA building science