27TH WESTFORD SYMPOSIUM ON BUILDING SCIENCE
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Mass Timber Wet?

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Outline

- Mass Timber Buildings and Moisture – Why this topic?
- A Decade of Lessons
- Demonstrative testing
  - Review some important moisture mechanics
  - **Wetting and Drying of two materials**
- Hygrothermal Simulation of Strategies and Expected Performance

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A Brief Background

For more detailed background see Graham Finch's 2018 Summer Camp presentation, "Mass Timber and Tall Wood Buildings"

https://buildingscience.com/sites/default/files/mass_timber_tall_wood_buildings_graham_finch.pdf

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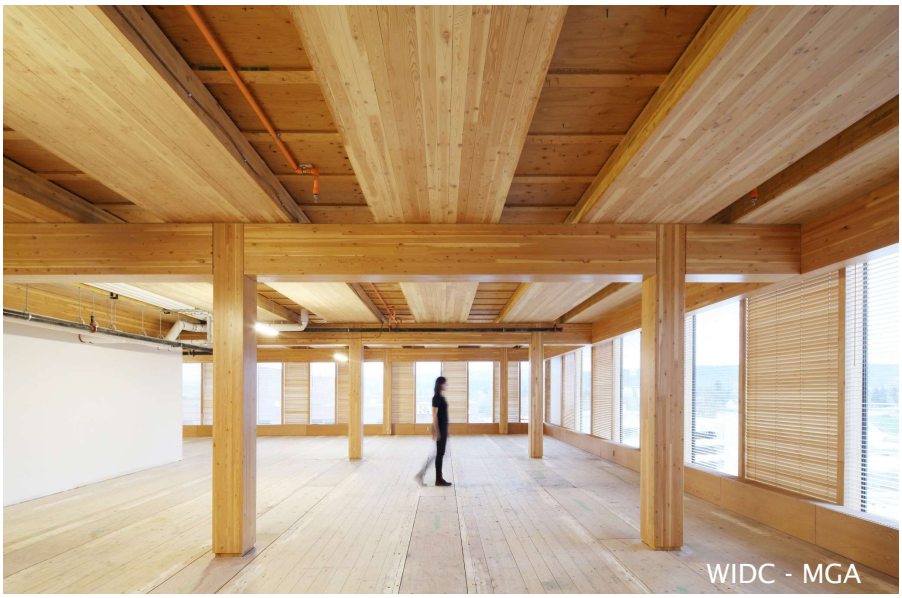
Why Mass Timber?



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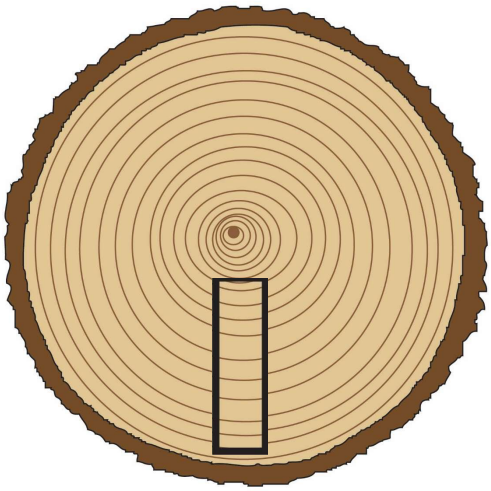
What is Mass Timber?

Dimensional Lumber and smaller wood elements



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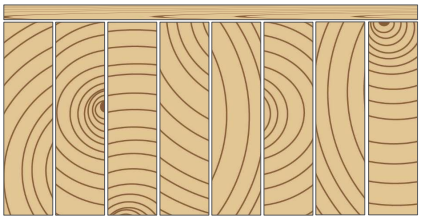
What is Mass Timber?

Dimensional Lumber and smaller wood elements

Assembled into larger, engineered wood structural elements

Using nails, dowels



Nail-Laminated Timber (NLT)

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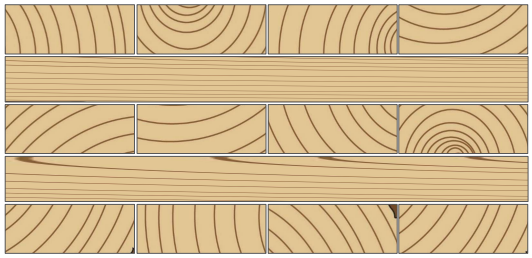
What is Mass Timber?

Dimensional Lumber and smaller wood elements

Assembled into larger, engineered wood structural elements

Using nails, dowels, adhesive, etc.



Cross-Laminated Timber (CLT)

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Cross Laminated Timber (CLT)

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Various forms of Mass Timber

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Similar to Post and Beam?

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But not like Post and Beam

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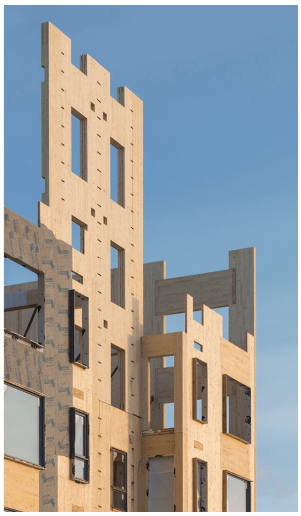
Similar to Precast and Tilt-up Concrete?



Origine – Nordic Structures

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But not like Concrete

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Over 10 yrs we've learned
a lot from 50+ Projects
Wet, dry and with 5-10 years of service

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Many Successful Projects
(not just a lot of wet wood buildings)

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Start Dry

Moisture Risk Management Strategies for Mass Timber Buildings
https://www.rdh.com/resource/moisture-risk-management-strategies-for-mass-timber-buildings-version-3/

Stay Dry

Mass Timber Building Enclosure Best Practice Design Guide
Mass Timber Building Enclosure Best Practice Design Guide Version 2 - Resources - RDH Building Science

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Wood, Mass Timber and Water

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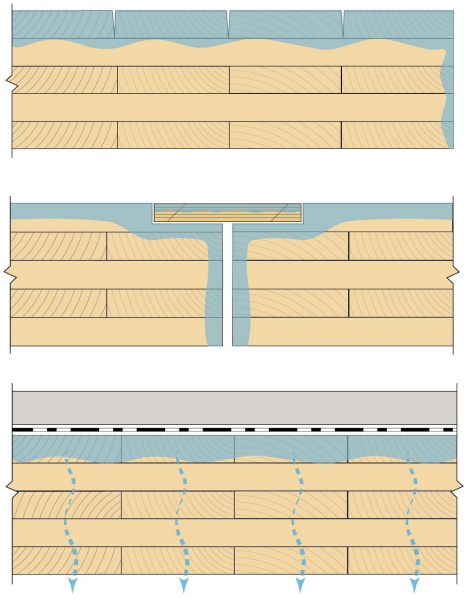
Mass Timber wetting during construction

Elements

Connections

Assemblies



- Gravity-driven
  bigger cracks & gaps
  (fastest)
- Capillarity
  smaller cracks & gaps
  (relatively fast)
- Capillarity
  material pores
  (slow to very slow)
- Adsorption
  fed by water vapor
  diffusion (very slow)

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Gravity-driven Wetting

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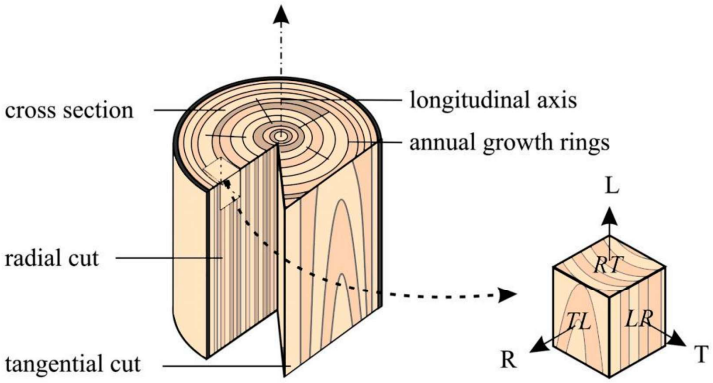
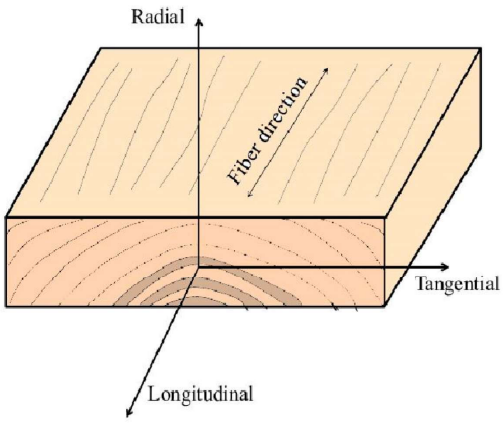
Capillary Suction (Wicking) and Vapor Diffusion are governed by wood structure





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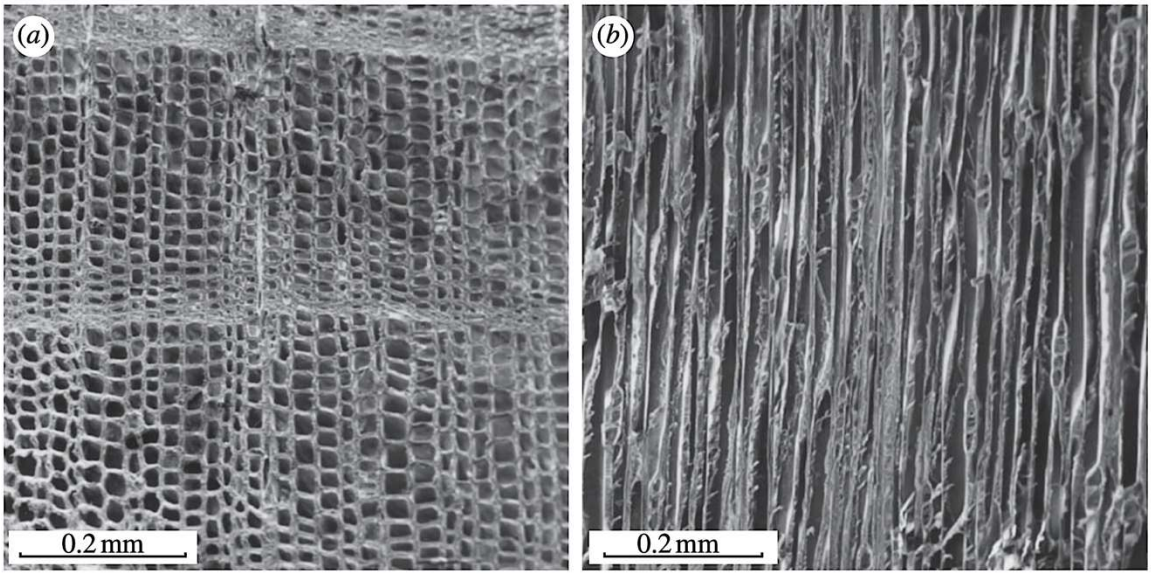
Cross-grain vs along-grain



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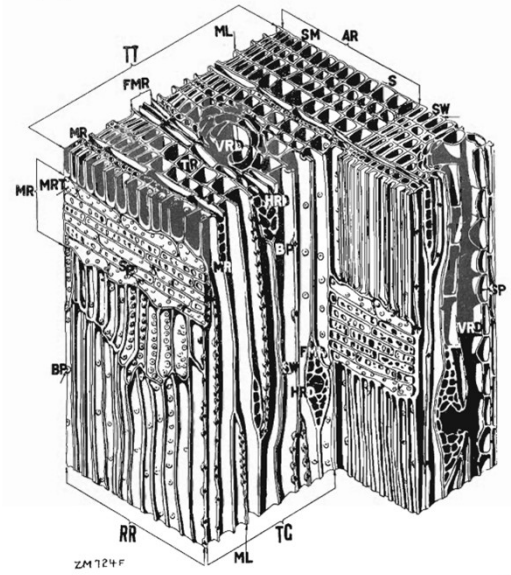
Wood – Capillary Suction (Wicking) of Liquid Water

- Equivalent to a bundle of tubes
  See John Straube's 2022 Summer Camp presentation, "Capillarity"
  https://buildingscience.com/sites/default/files/gaps_in_knowledge_-_yogi_berra_building_science_-_in_theory_there_is_no_difference_between_theory_and_practice_-_in_practice_there_is.pdf
- Flow much *faster along grain* while *slower against the grain*
- Suction feeds tree leaves; capillary pressures will pull water hundreds of feet



FPL Technical Note 209, 1940s

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Wood – Water Vapor Diffusion

- The water vapor permeance of wood varies with the moisture content or relative humidity in the material
- Permeability under wet conditions can be many times greater than under dry conditions
- The rate of vapor diffusion drops significantly as the wood dries

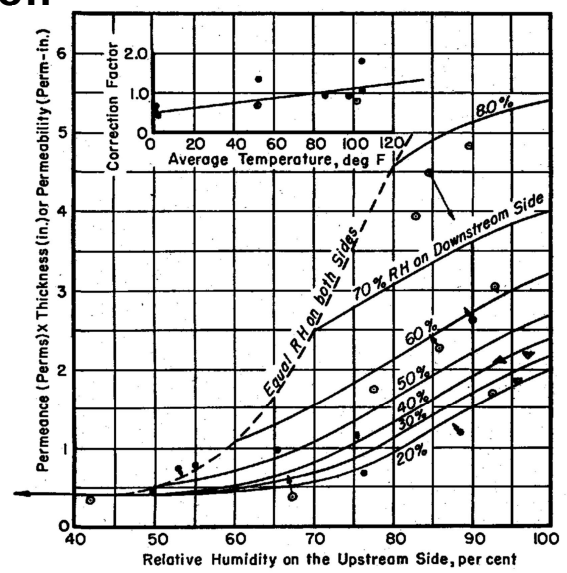

FIG. 3.—Permeability of Sugar Pine Wood 80 F Average Temperature.

F. A. Joy, 1951

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Wood Moisture Absorption Visualized

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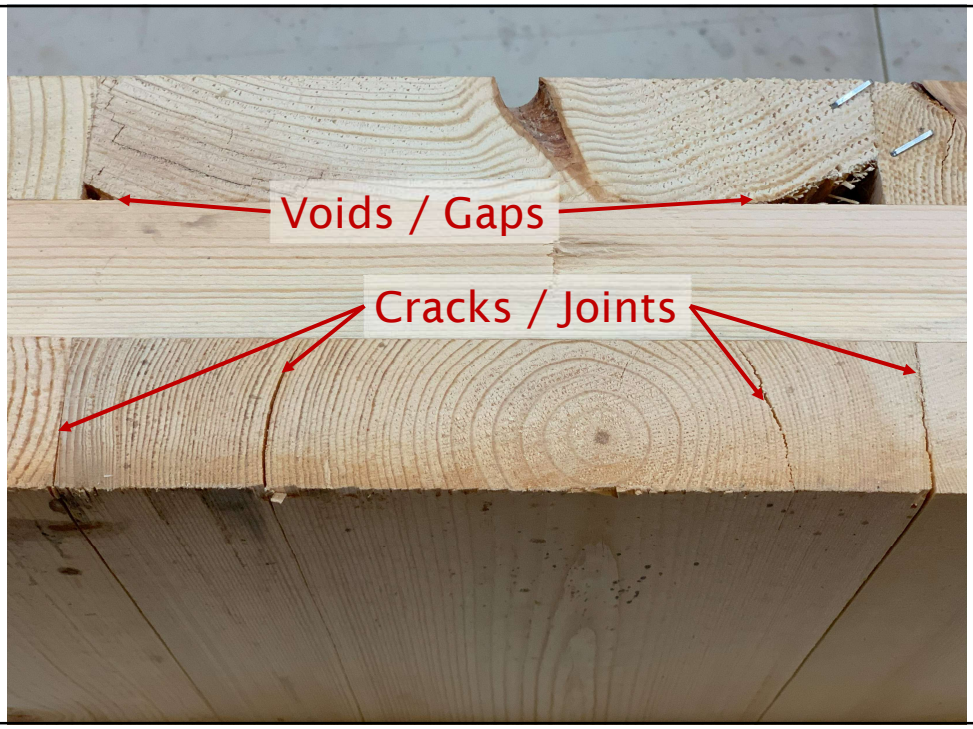

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Demonstration Tests
- Wetting -

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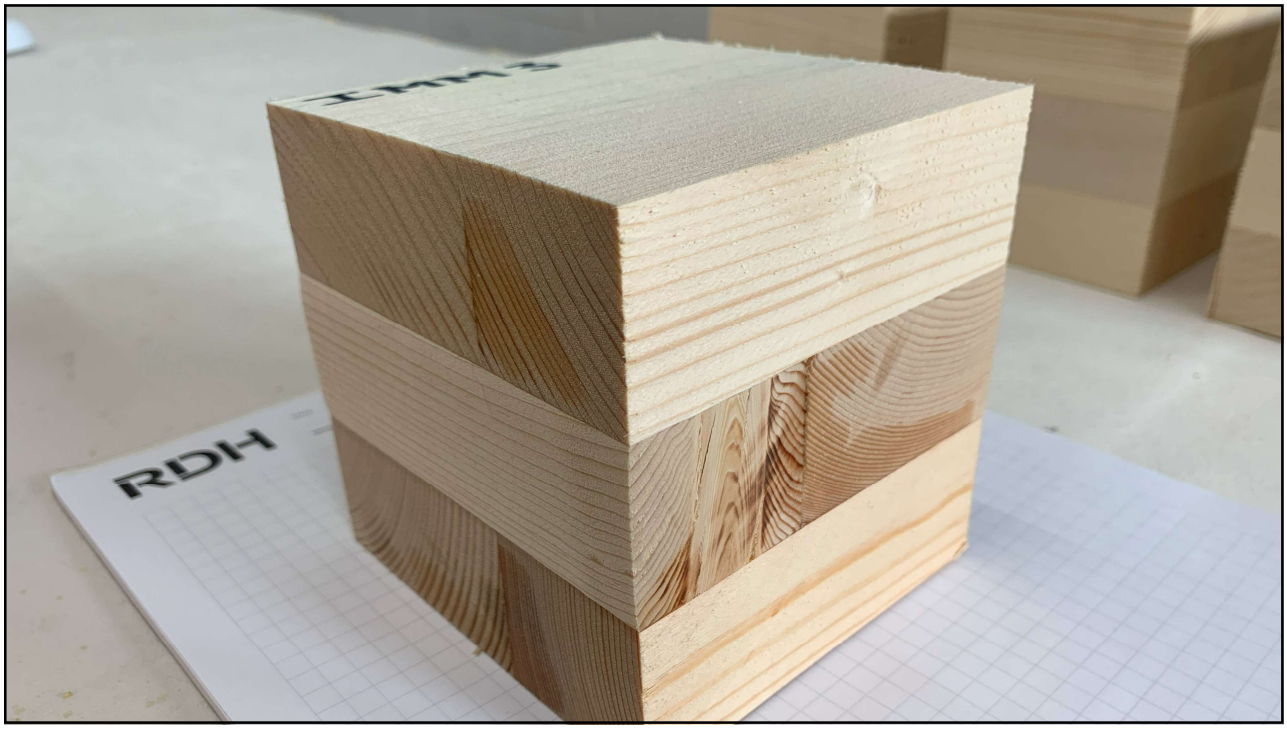

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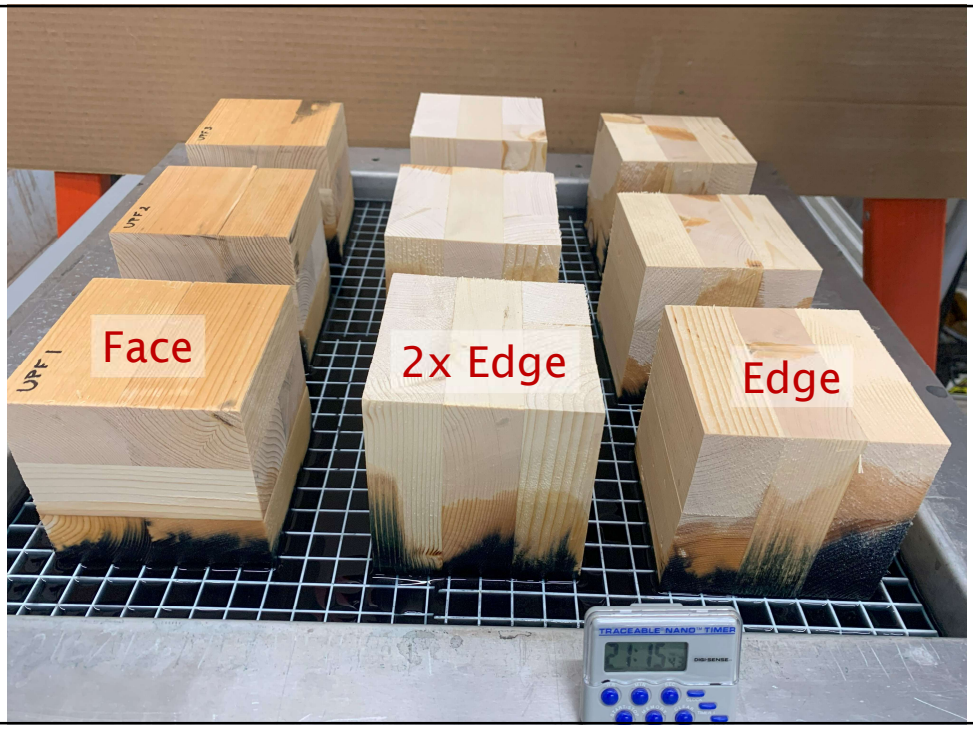

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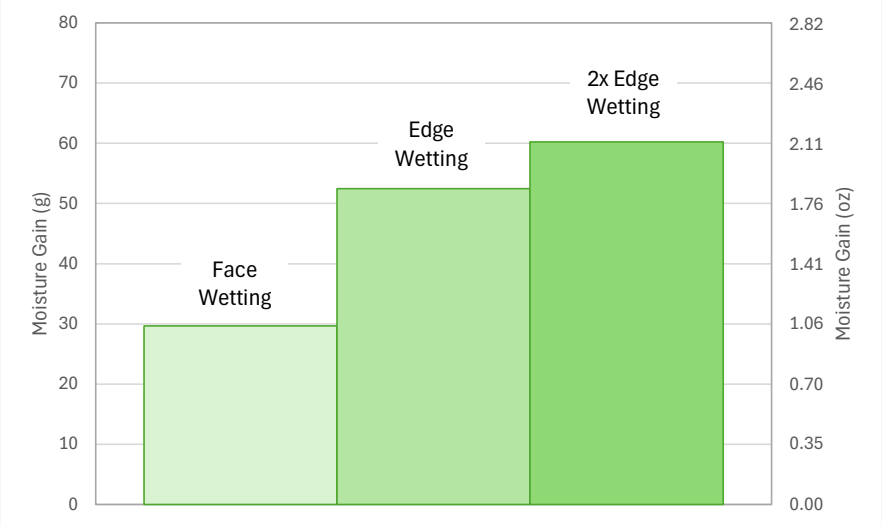
Capillary Wetting of CLT ("Wicking")



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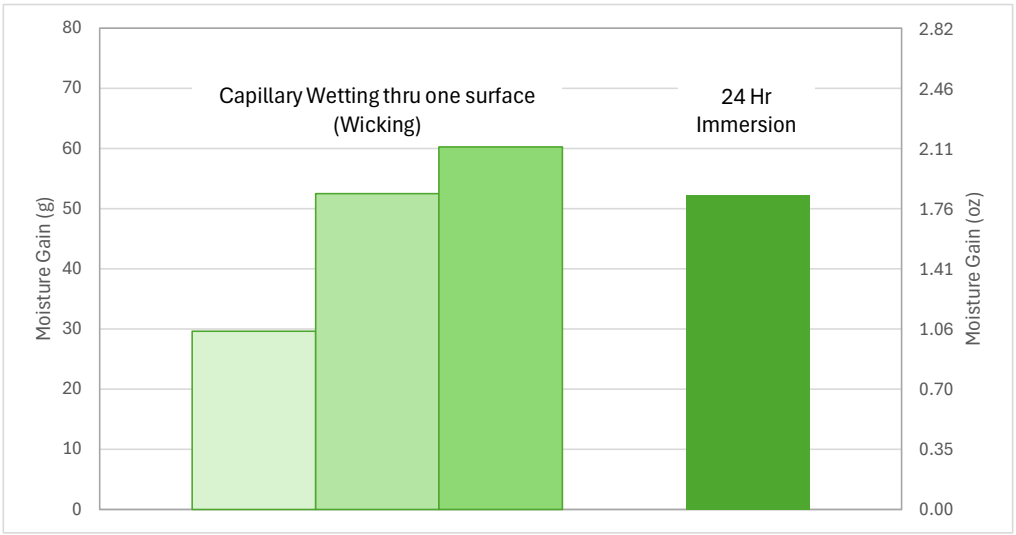
Wicking thru one surface vs “Short-term” Immersion



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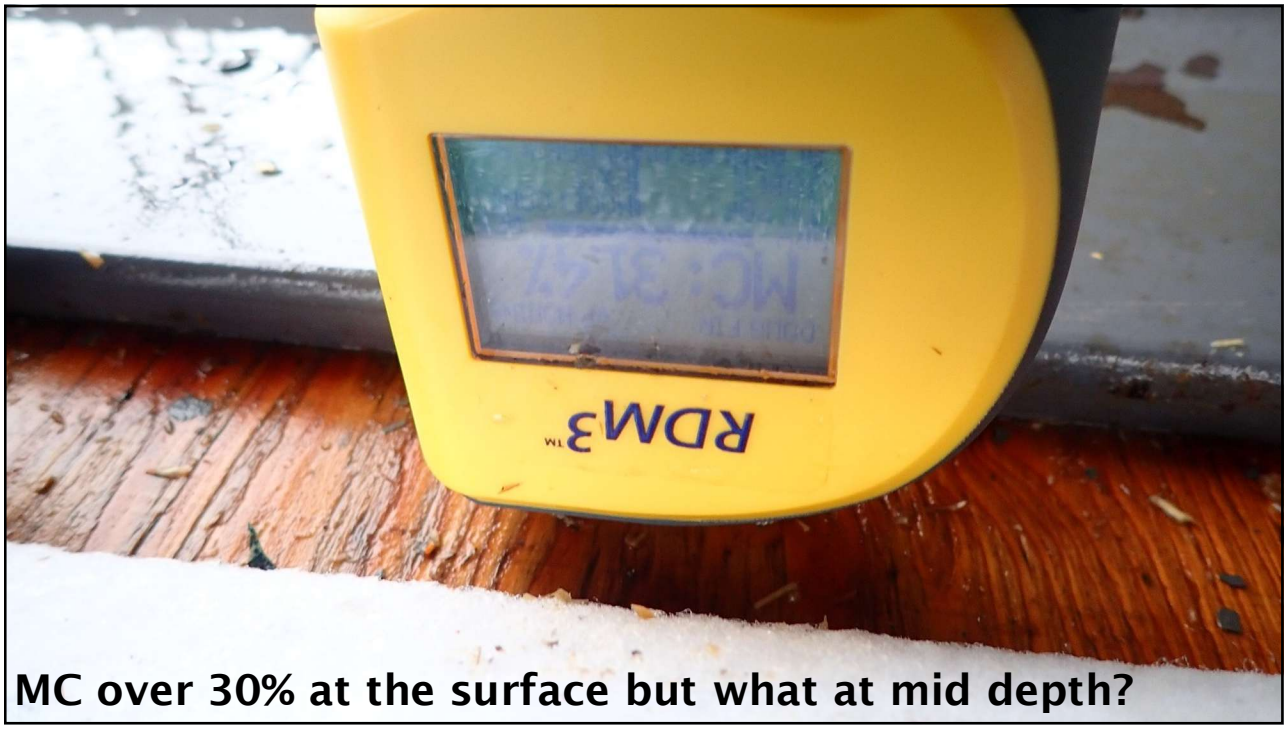

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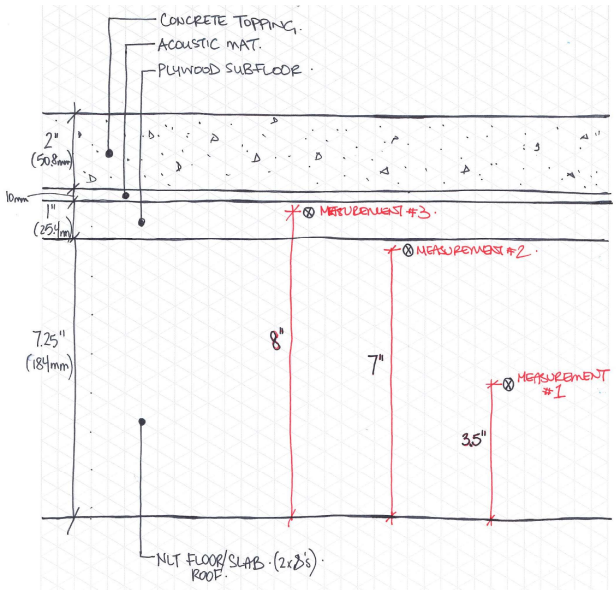
Moisture Monitoring Measurement Points



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Moisture Monitoring Measurement History

	Date	25-Apr	2-May	27-May	31-May	4-Jun	25-Jun
	Temp	11	7	17	17	10	24
A	PLY	HI	HI	HI	HI	HI	HI
	T/O	36.1	51.9	HI	HI	HI	HI
	C/O	31.5	35.6	37.9	40.2	40.8	35.2
	U/S NLT	35.4	24.6	21.3	21.3	23.7	23.0
B	PLY	16.2	18.3	20.4	-	21.1	23.2
	T/O	19.6	21.0	23.2	-	25.6	20.0
	C/O	19.6	19.9	19.9	-	21.4	16.8
	U/S NLT	14.7	16.8	13.0	-	12.5	9.2
C	PLY	32.4	36.0	36.4	-	37.5	42.5
	T/O	18.2	19.5	20.7	-	22.1	19.4
	C/O	16.8	16.6	16.3	-	17.3	14.0
	U/S NLT	12.2	13.8	12.5	-	11.7	9.2
D	PLY	21.0	29.5	33.8	32.9	33.1	39.0
	T/O	17.9	18.7	20.4	20.4	21.4	18.0
	C/O	17.5	16.7	16.8	16.9	17.5	14.4
	U/S NLT	13.5	15.2	13.4	13.2	12.3	10.5
E	PLY	31.7	31.2	29.5	-	31.6	33.2
	T/O	18.0	20.1	20.6	-	21.1	17.7
	C/O	16.5	16.7	16.2	-	17.5	14.1
	U/S NLT	11.3	14.1	14.8	-	13.2	10.7

Plywood and top half of NLT in excess of 40% MC!

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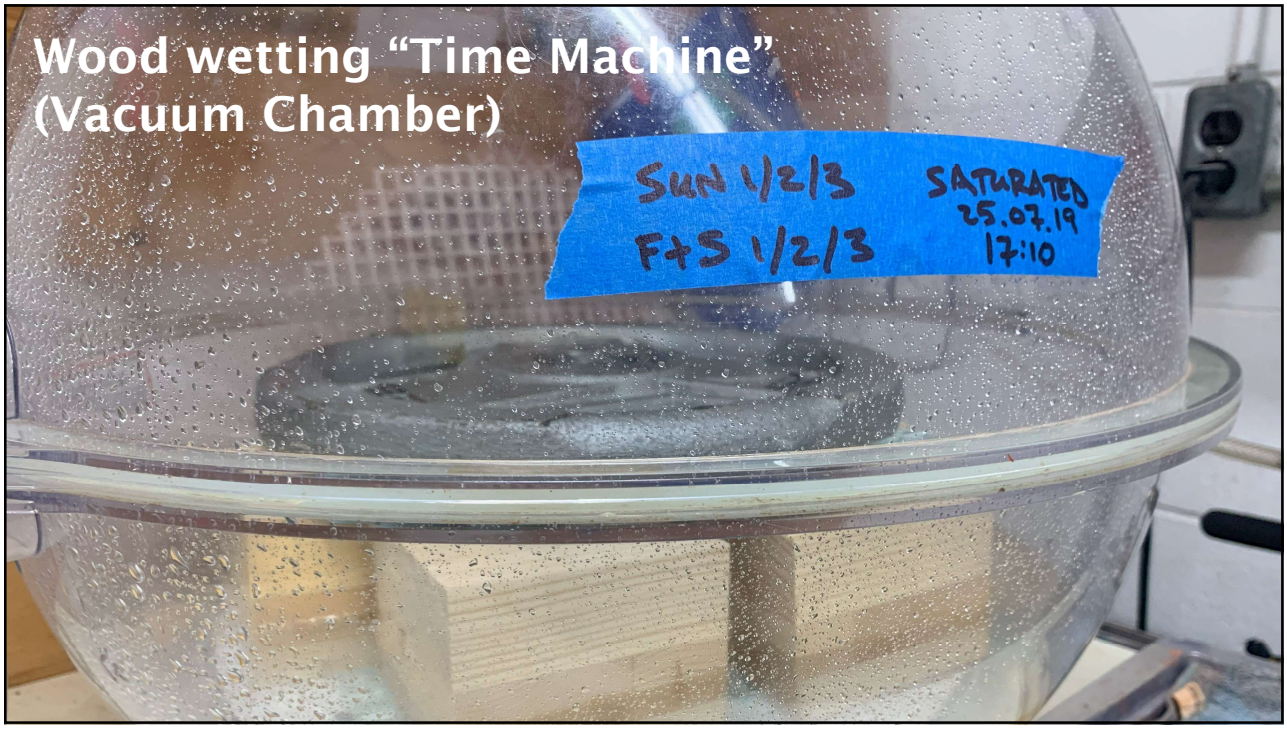

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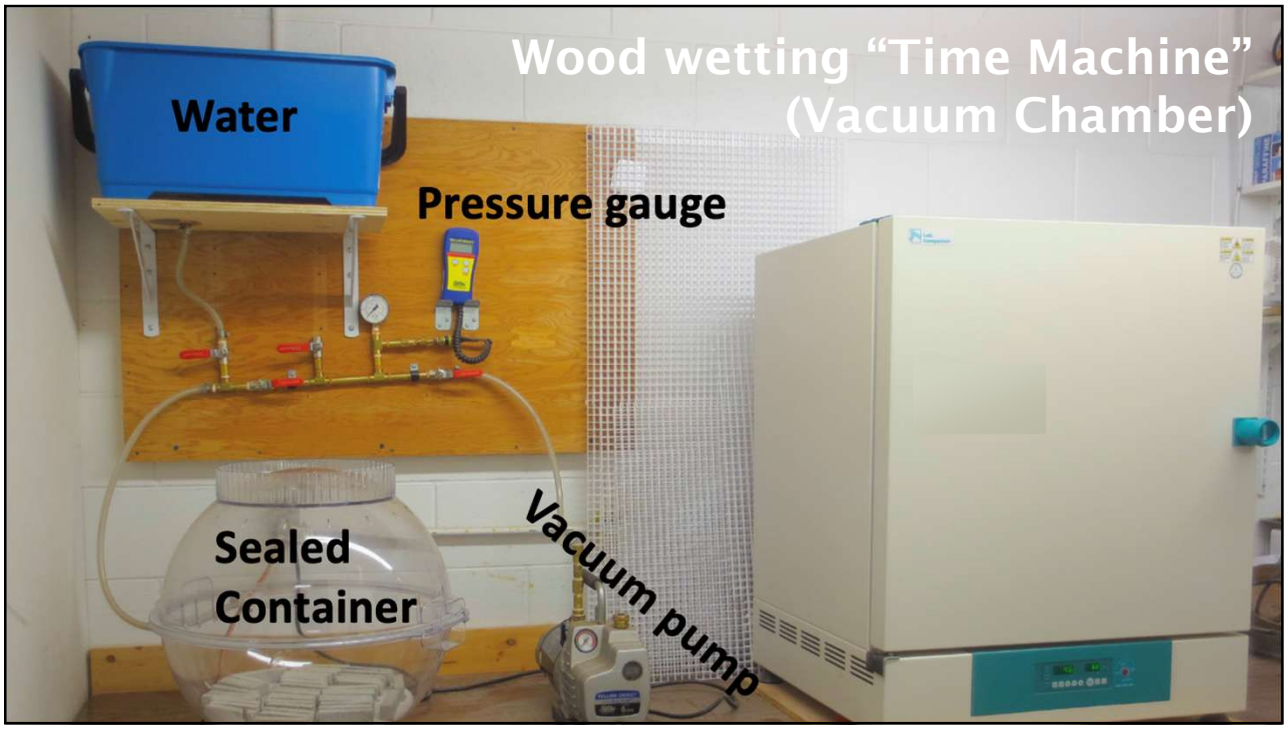

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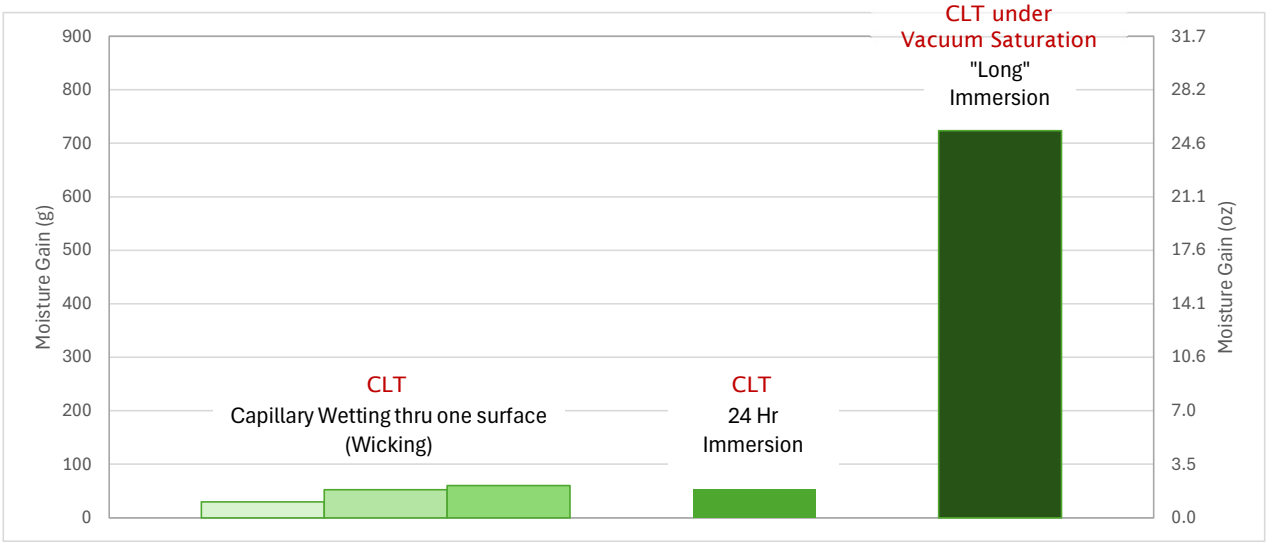
Impact of "Long-term" Immersion?



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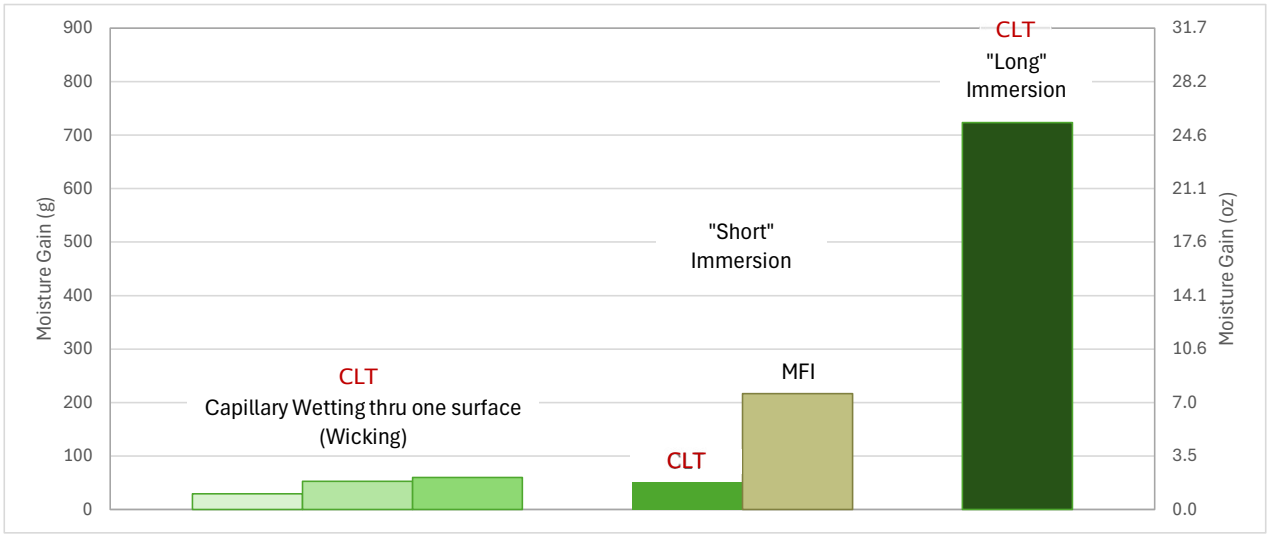
CLT vs Mineral Fiber Insulation (MFI – stonewool)



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Demonstration Tests
- Drying -

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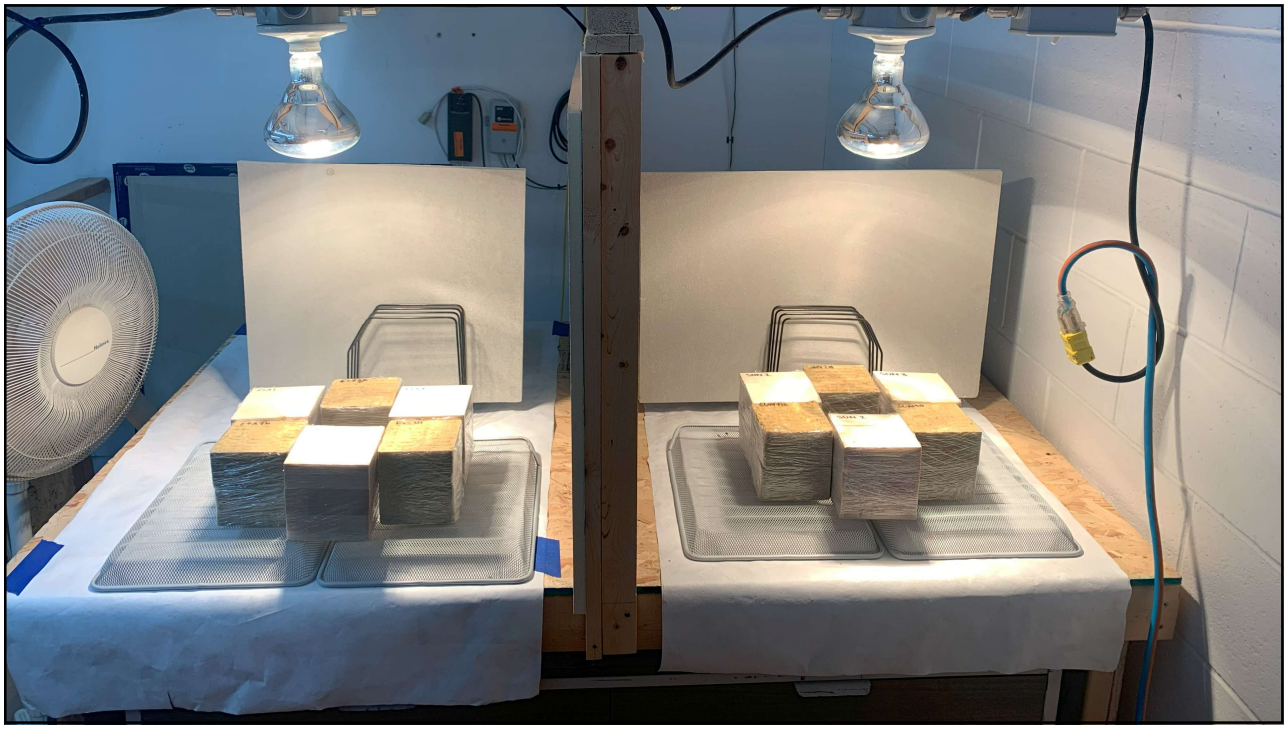

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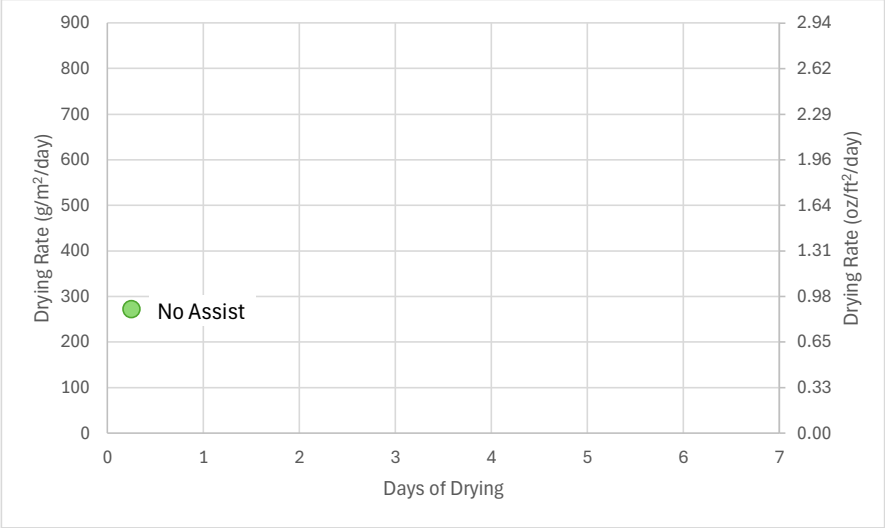
Drying Rate of MFI – Initial Rate



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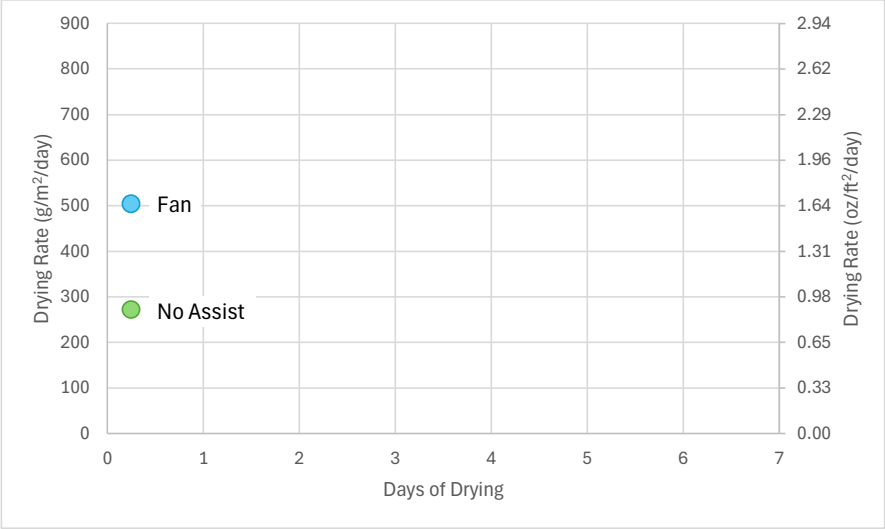
Drying Rate of MFI – Initial Rate



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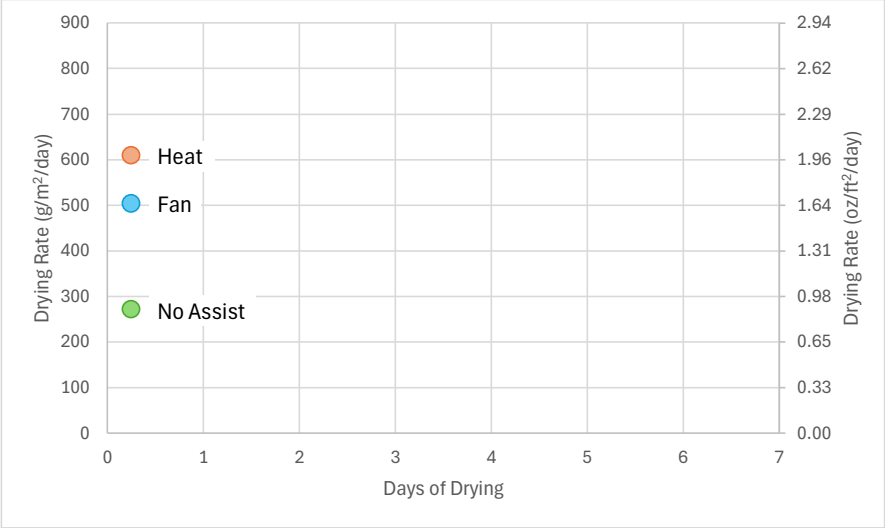
Drying Rate of MFI – Initial Rate



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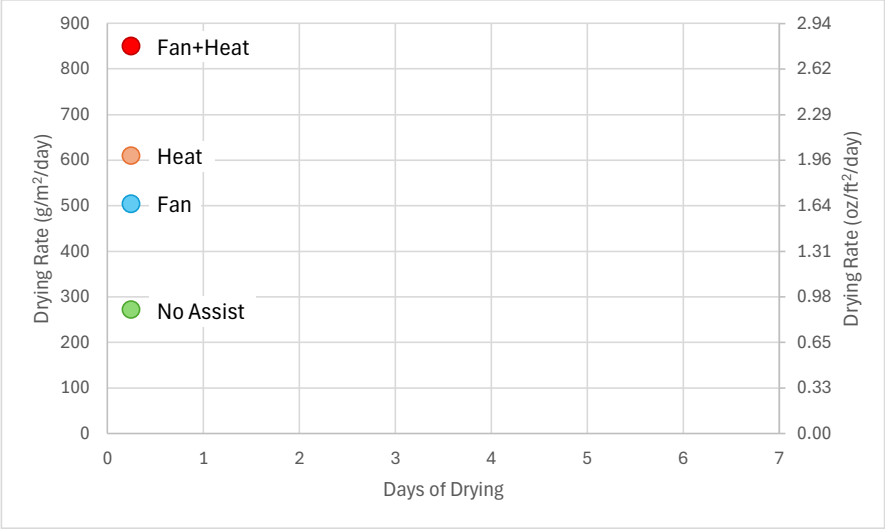
Drying Rate of MFI – Initial Rate



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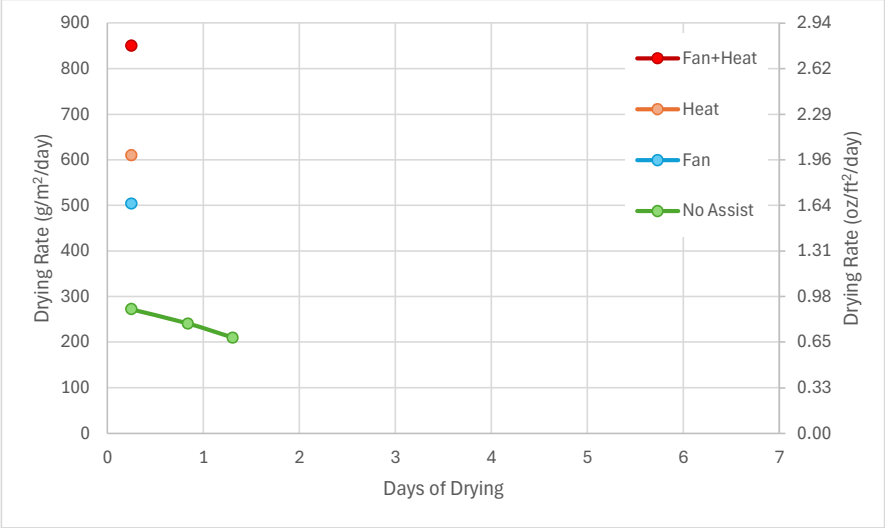
Drying Rate of MFI – First Day



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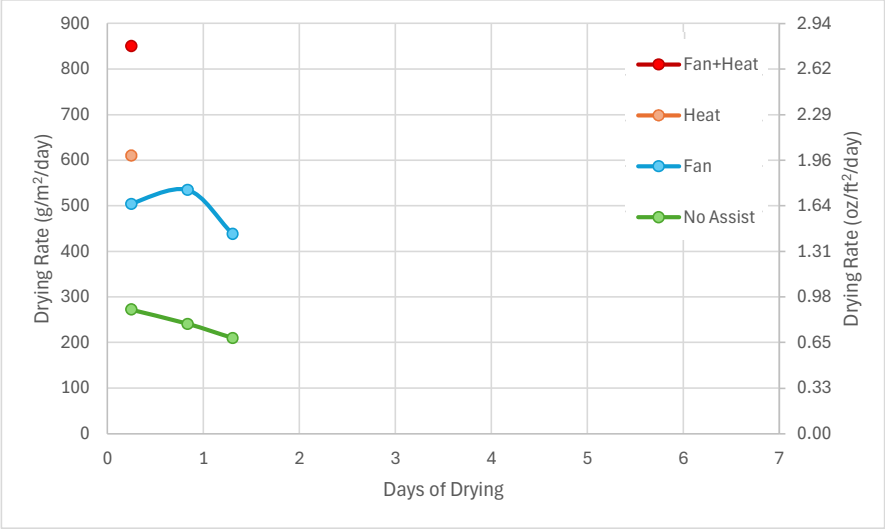
Drying Rate of MFI – First Day



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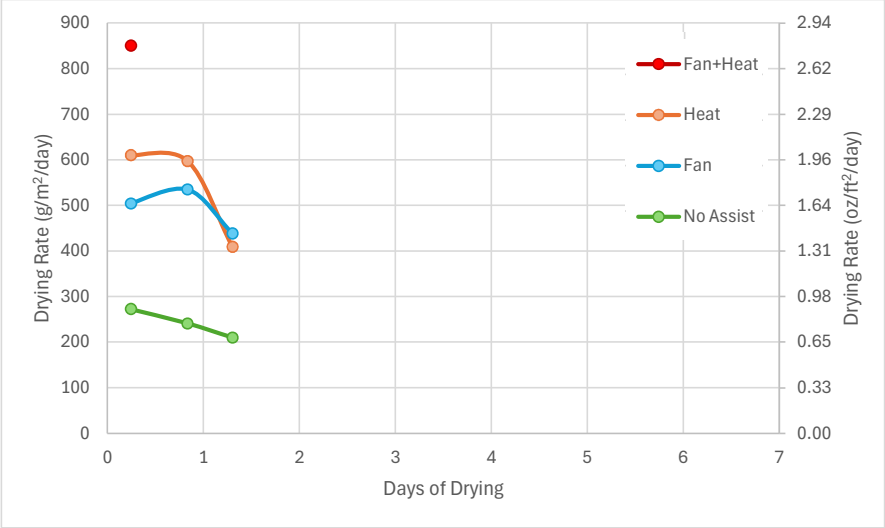
Drying Rate of MFI – First Day



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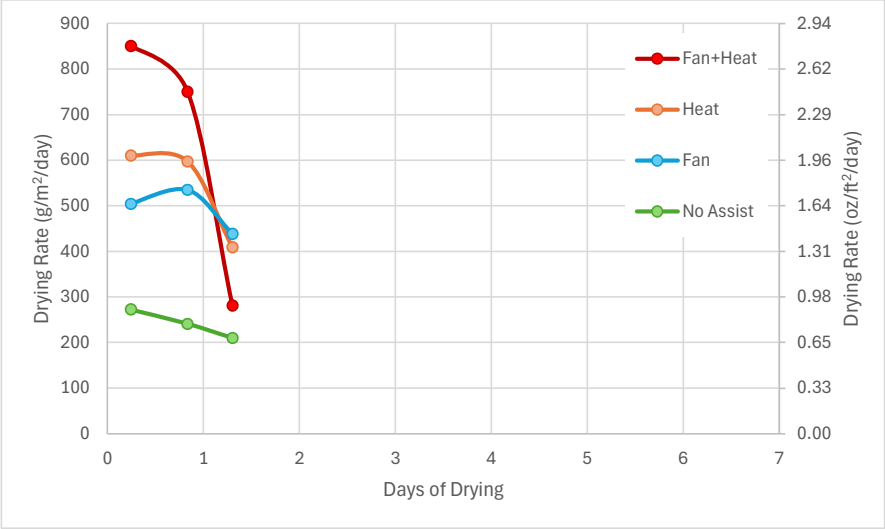
Drying Rate of MFI – First Day



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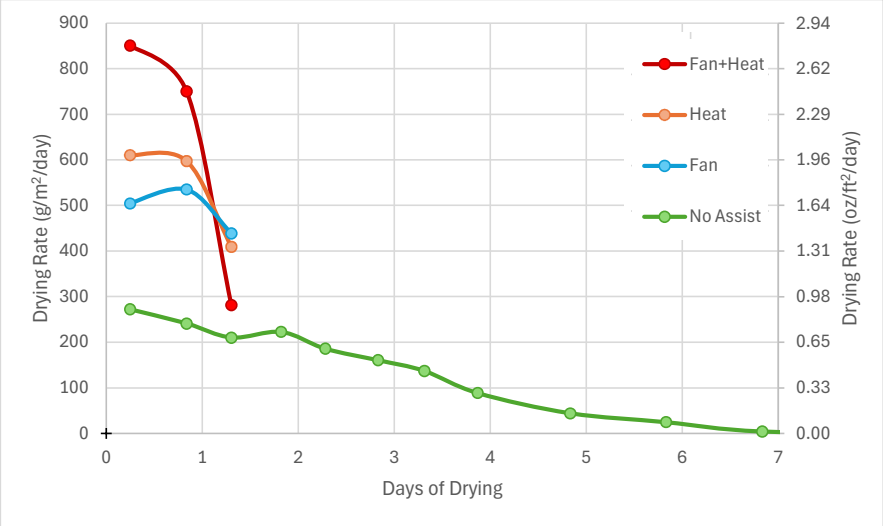
Drying Rate of MFI – Thru to "Dry"



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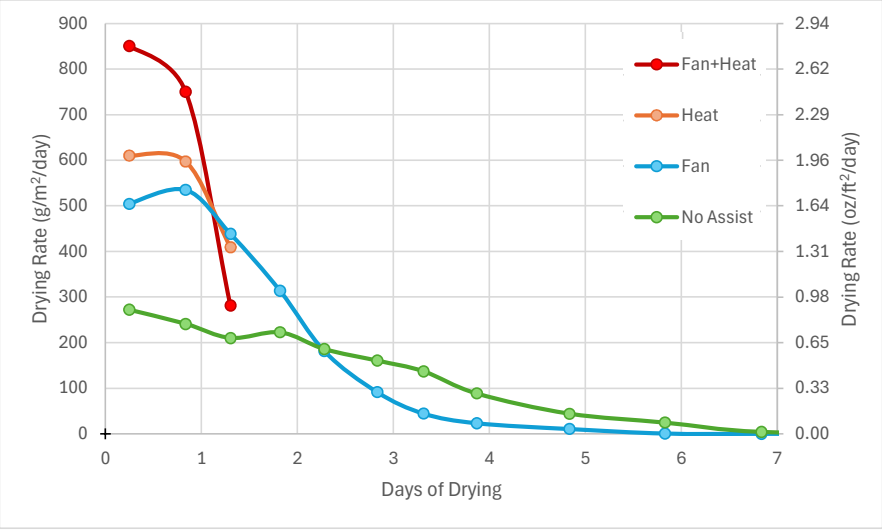
Drying Rate of MFI – Thru to "Dry"



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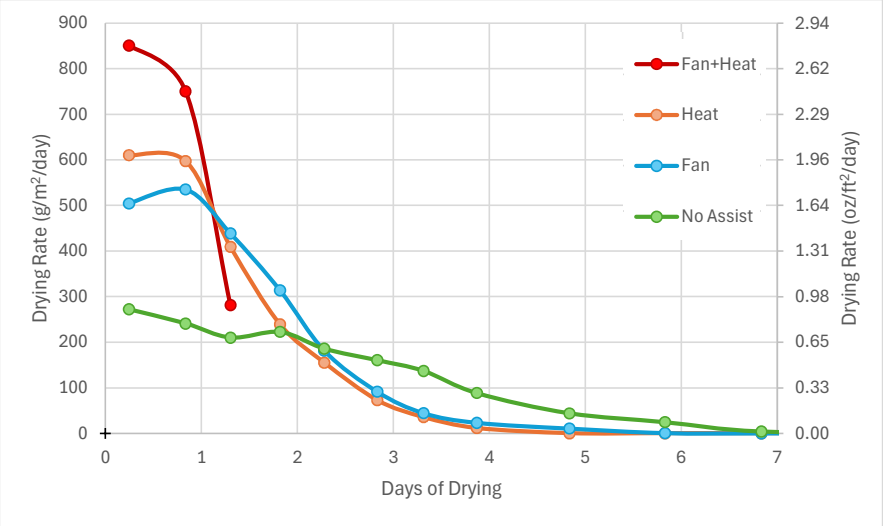
Drying Rate of MFI – Thru to "Dry"



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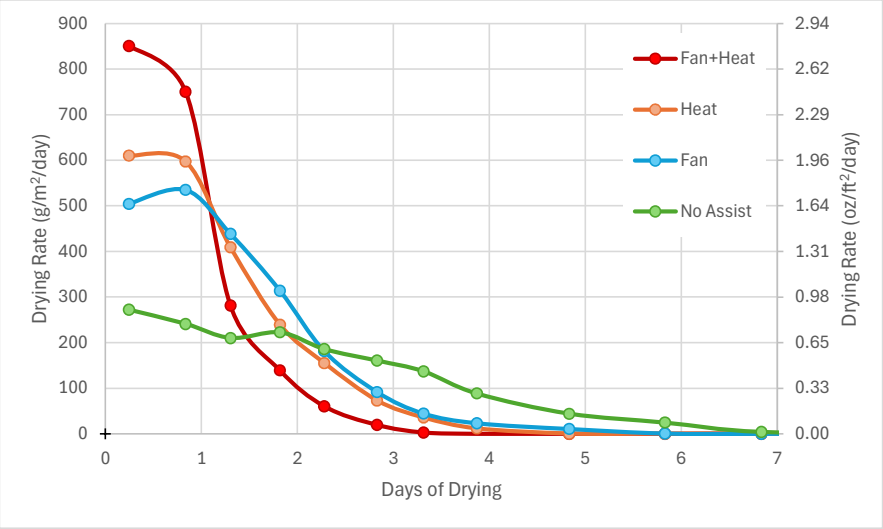
Drying Rate of MFI – Thru to "Dry"



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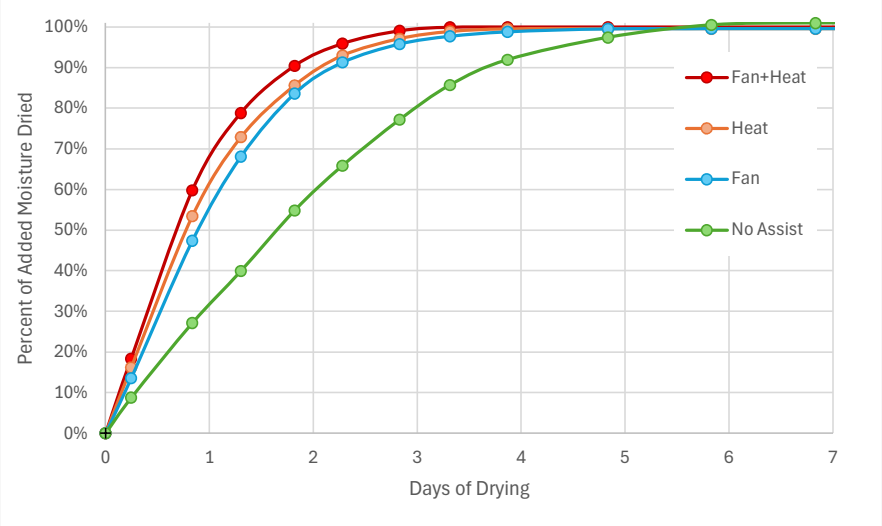
Drying of MFI



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Considering Mineral Fiber Insulation Test Results

As a material

→MFI has *no* meaningful *capillarity* (it doesn't wick)

→MFI is *highly vapor permeable*

This means that

→MFI *dries very quickly*

→"Assists" such as airflow and heating result in meaningful increase in the rate of drying

Many people expect this behavior of other construction materials

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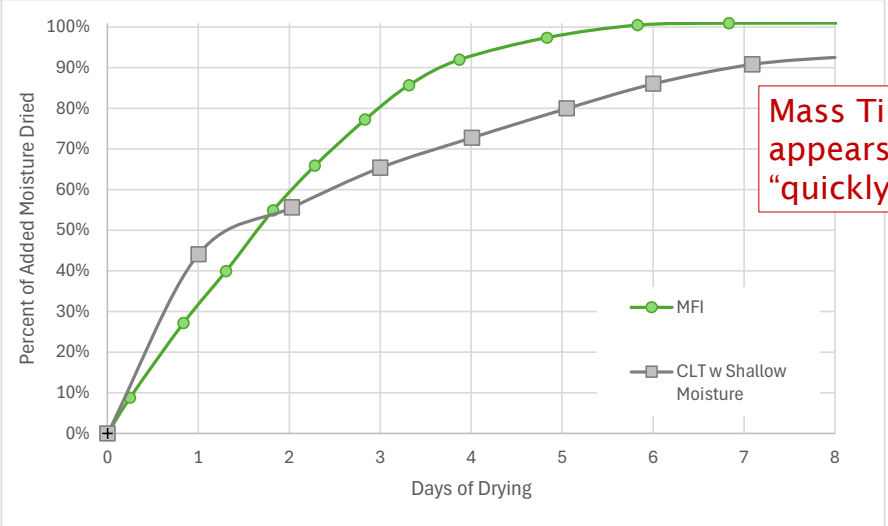
Drying of MFI vs CLT w “shallow” moisture (no Assist)



Mass Timber appears to dry “quickly”

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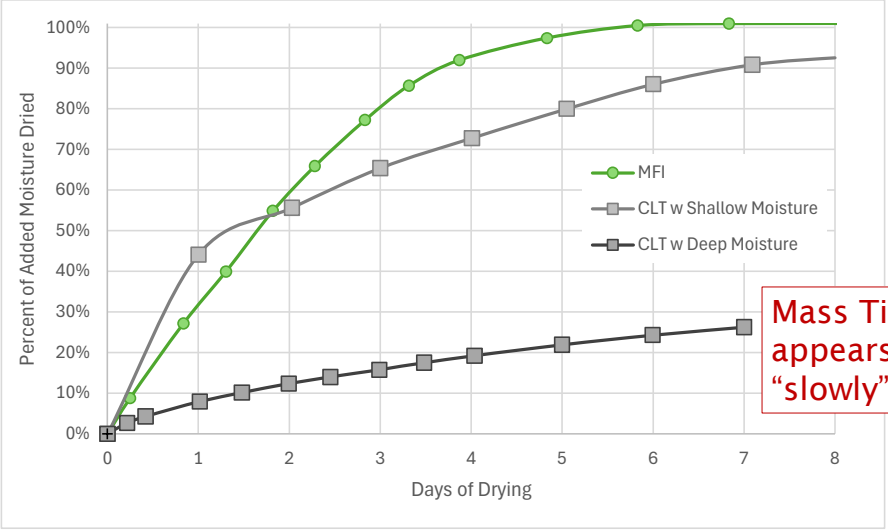
Drying of MFI vs CLT w “deep” moisture (no Assist)



Mass Timber appears to dry “slowly”

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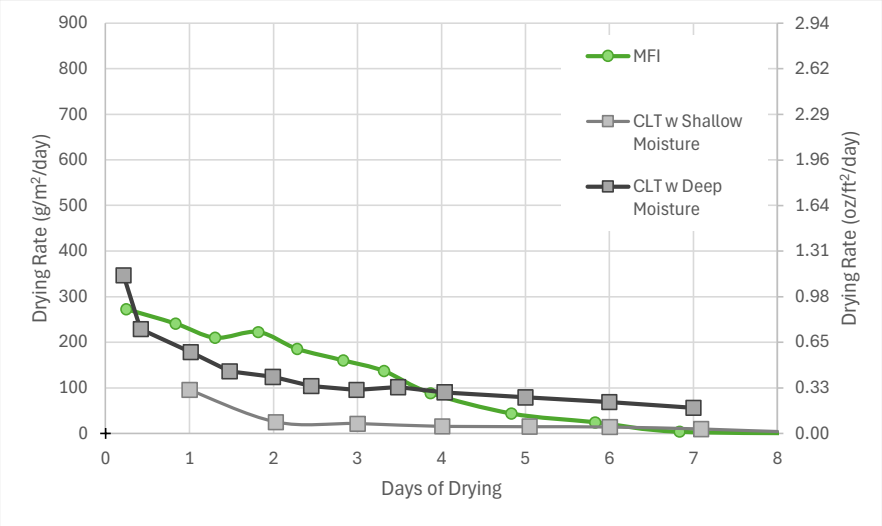
Drying Rate of MFI vs CLT w “deep” moisture (no Asssist)



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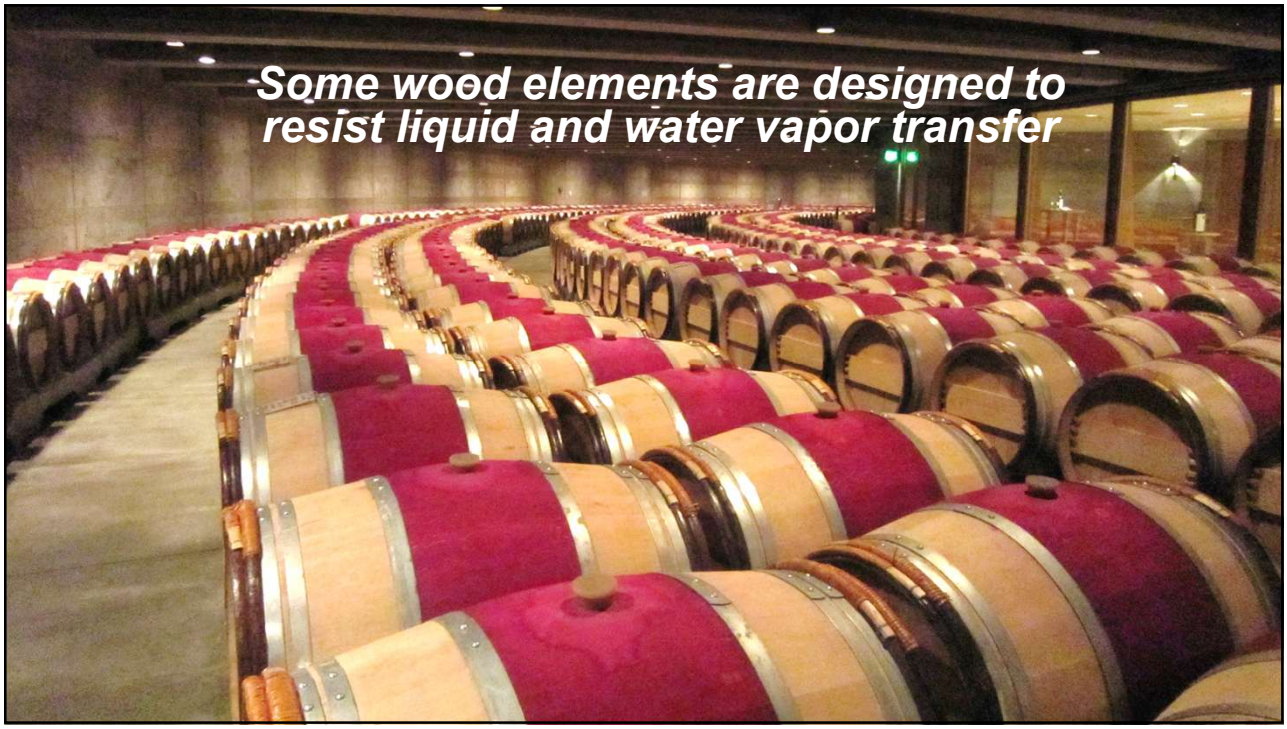

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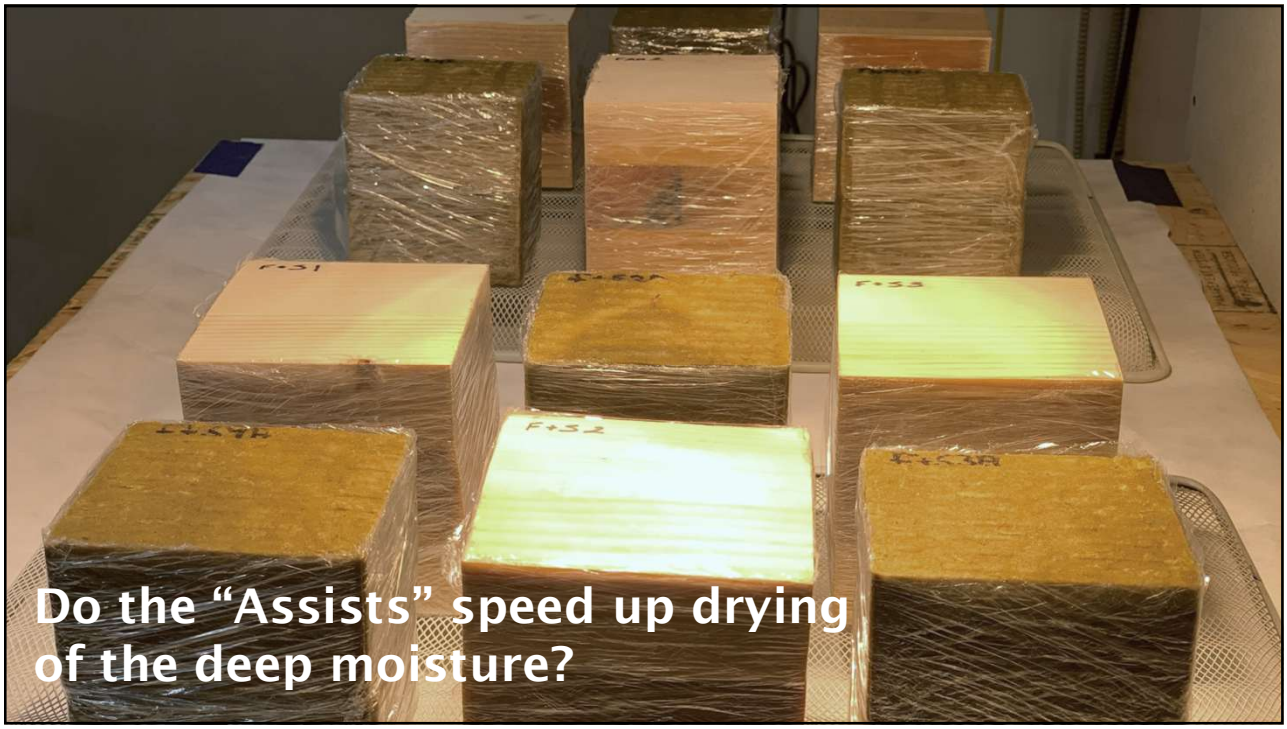

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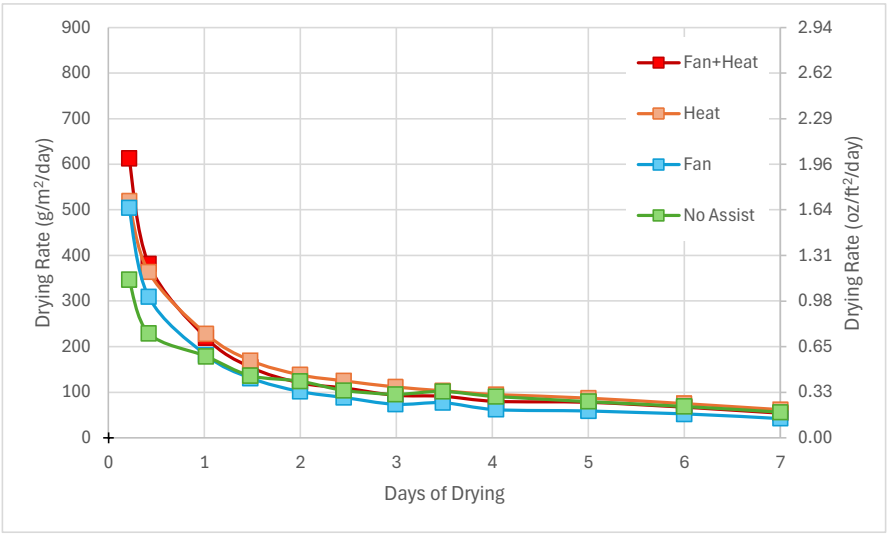
Drying Rate of CLT w “deep” moisture vs Assist



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Measured MC_{wt} by Meter after 6 days

	Sample 1	Sample 2	Sample 3
No Assist	26.8	29.0	19.0
Fan	18.7	22.6	22.4
Heat	23.1	16.0	19.6
Fan + Heat	15.7	17.1	18.9

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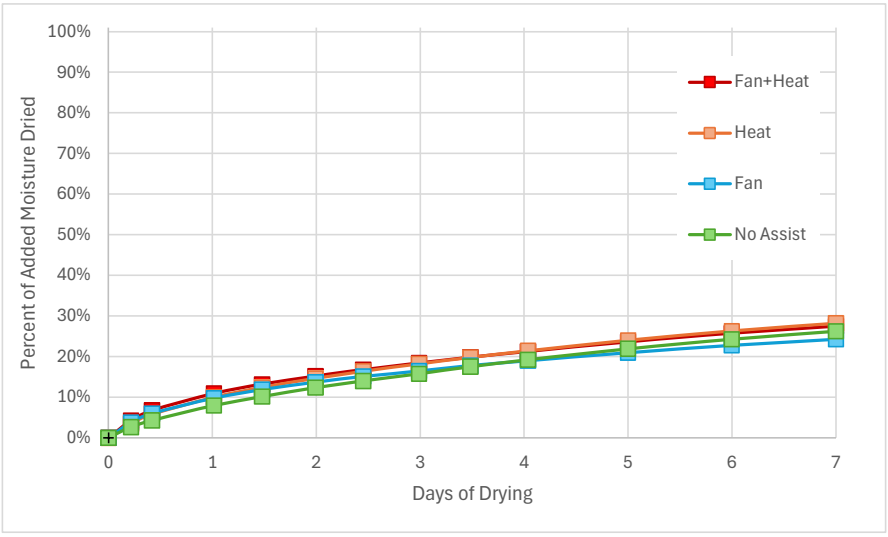
Drying of CLT w “deep” moisture vs Assist



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Considering Mass Timber Test Results

As a "material"

→Mass Timber has significant but *varied capillarity*
(faster along the grains and slower against the grains)

→Mass Timber has a relatively low vapor permeance

This means that

→Water near the surface dries quickly

→Deeper or "encapsulated" water is very slow to dry

→"Assists" speed up drying of shallow water but *not* *deep* water

Many people are surprised by this

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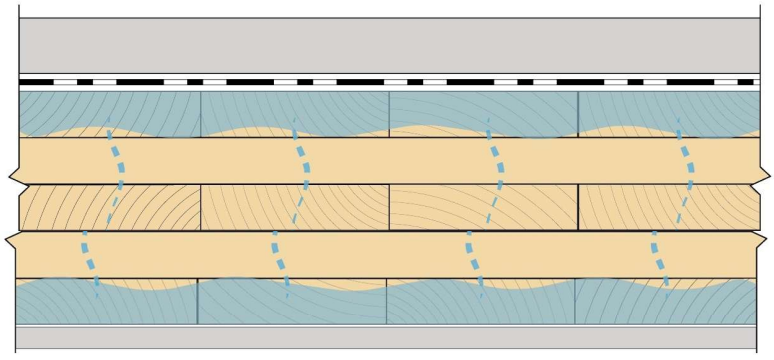
Biggest moisture risk?
Deep or Encapsulated Moisture !



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Hygrothermal Simulation of Real World Wetting & Drying

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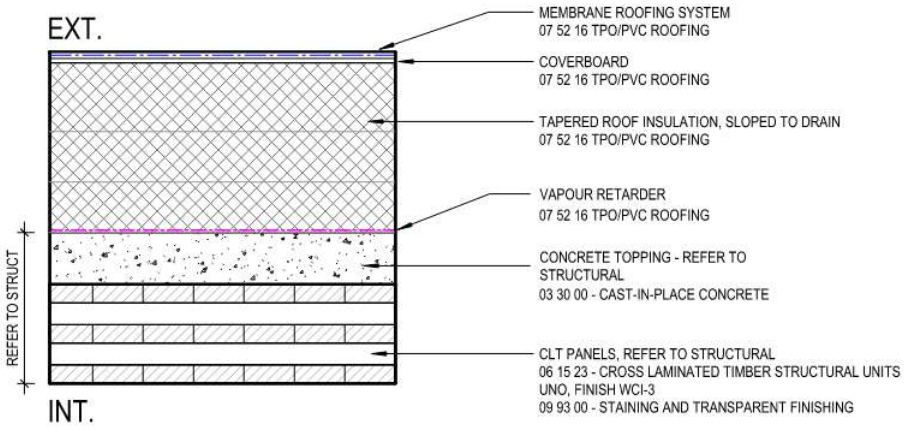
Roof Assembly



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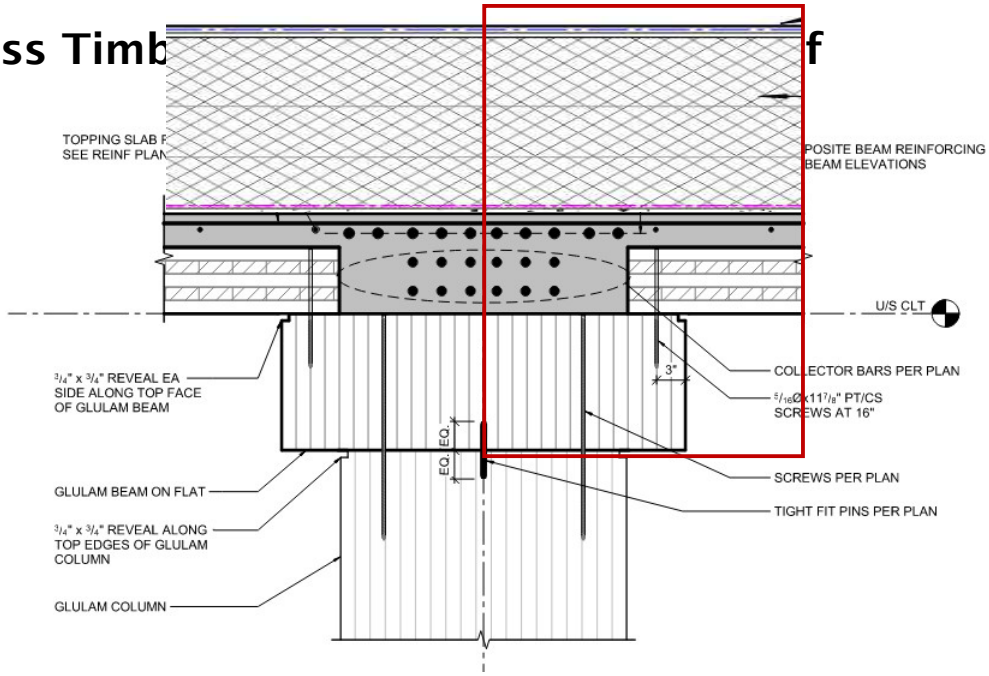
Mass Timb f



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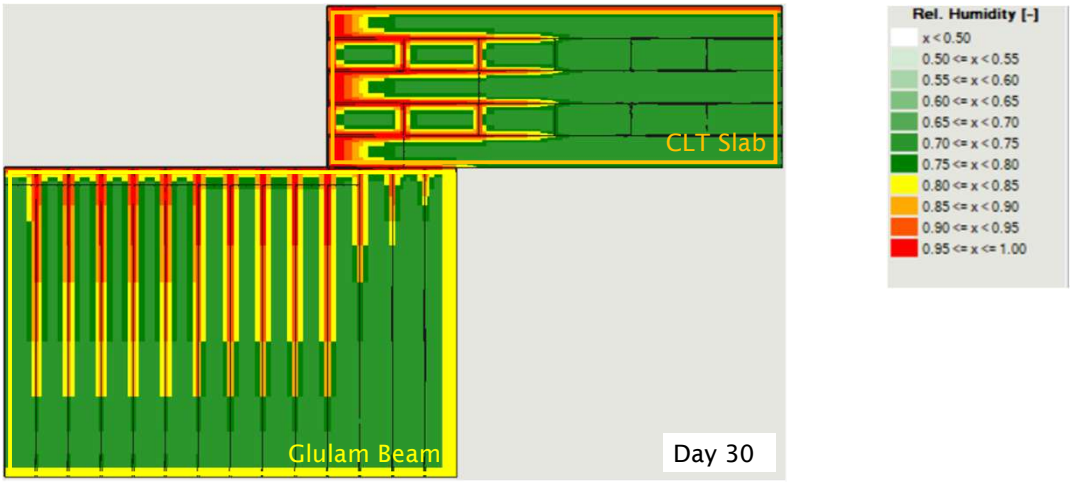
Rain Wetting of Unprotected CLT Slab & Glulam Beam



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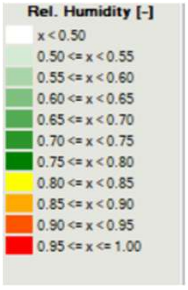
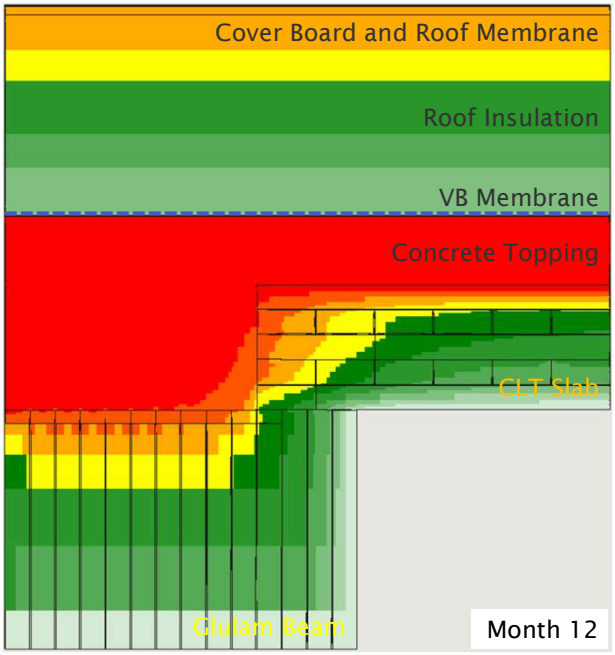
Drying of Unprotected CLT Slab & Glulam Beam





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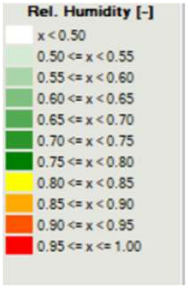
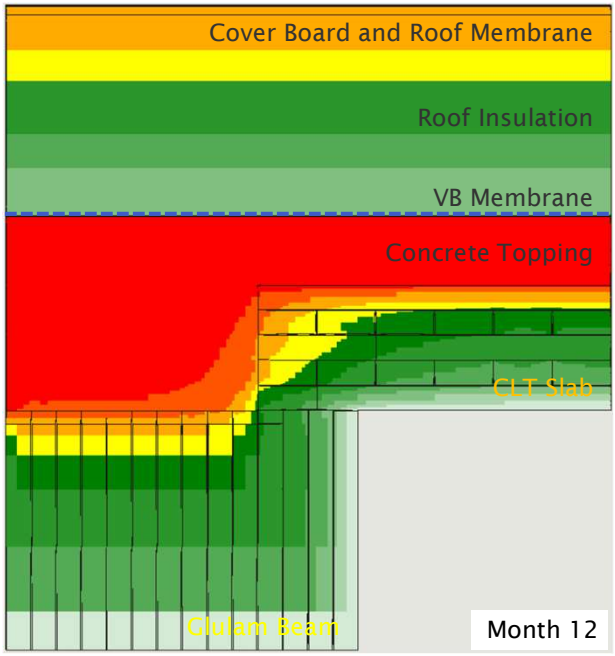
Drying of Unprotected CLT Slab & Glulam Beam Low Water Concrete





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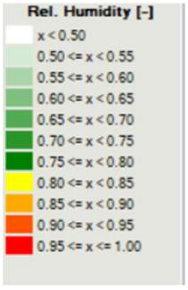
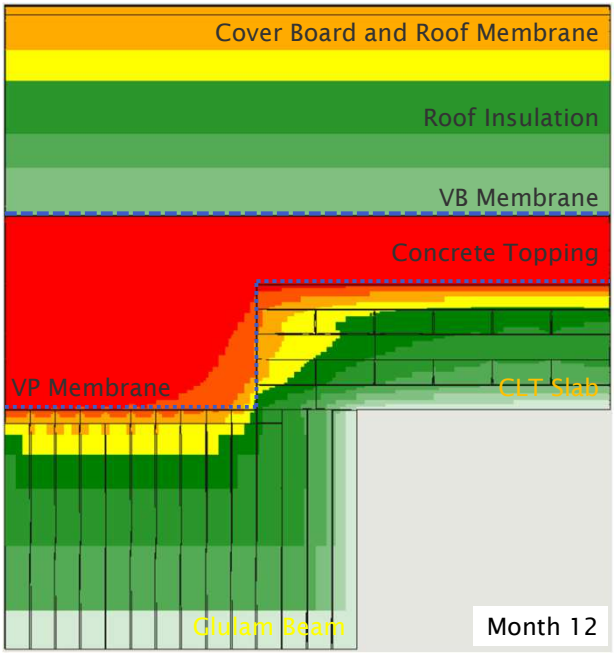
Drying of Protected CLT Slab & Glulam Beam w 30 Perm Membrane





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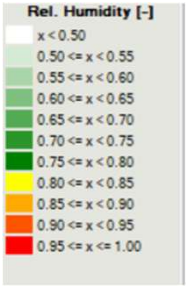
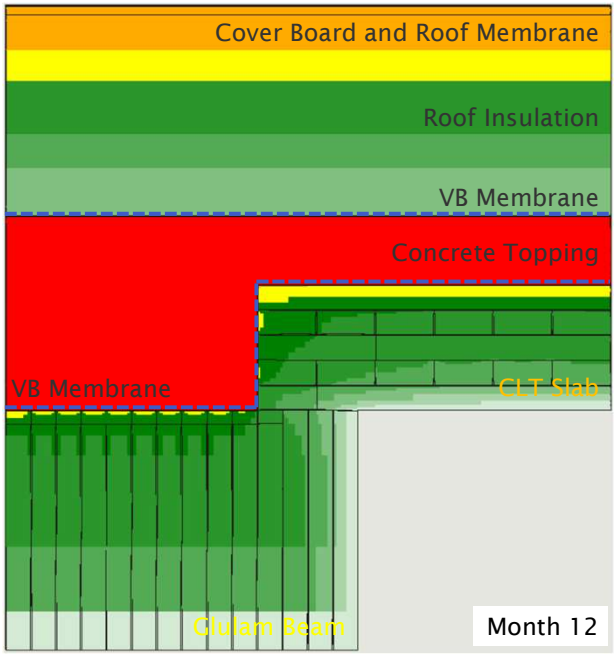
Drying of Protected CLT Slab & Glulam Beam w 0.5 Perm Membrane





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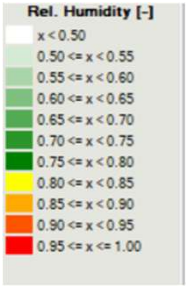
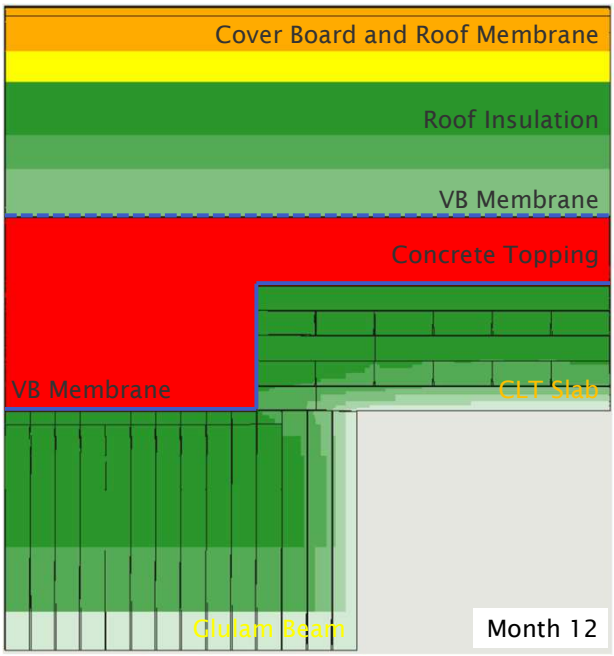
Drying of Protected CLT Slab & Glulam Beam w 0.015 Perm Membrane





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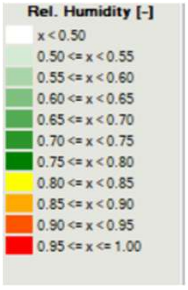
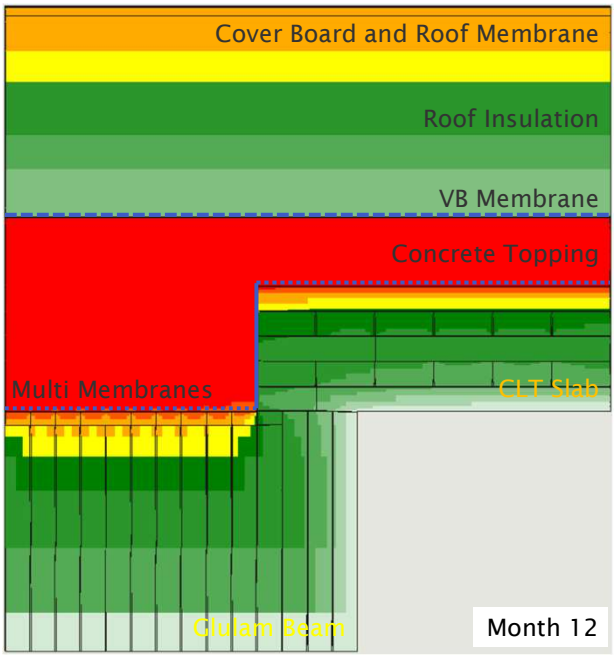
Drying of Protected CLT Slab & Glulam Beam w Multi Membranes





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Concluding Thoughts

- Plenty of industry guidance available
- Successful Mass Timber buildings take a little care
- Many designers, builders, trades don't appear to heed advice
- Mass timber is not like light wood framing / post & beam / concrete

- Disproportionate number of Mass Timber buildings experience moisture problems related to construction moisture

- Most significant problems: *Deep* or *Encapsulated* moisture

- Please help us get this through to industry stakeholders

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Discussion

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…Or Just Plan Ahead & Take Advantage of the Protection

Finland – use of climbing roof and overhead cranes – high degree of modular moisture sensitive components

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