Canadian Wood Council

G063

On-site Moisture Management of Wood Construction

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Course Description

This presentation aims to help designers and construction companies/builders assess the potential for moisture-related issues arising during the construction phase of a wood building project and identify the appropriate actions to mitigate such risk. Information on wetting and drying potential, and solutions and available resources related to on-site moisture management as well as design measures will be discussed.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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

Learning Objectives

- Wood's basic physical properties related to moisture management;
- Categories of wood materials/built-up assemblies;
- Wetting and drying performance of different assemblies;
- Different level of on-site moisture protection;
- Design solutions to facilitate drying performance

On-site Moisture Protection?

- Identify potential moisture-related issues during the construction phase
  - A building isn't protected against weather until the envelope is fully protected
- Provide appropriate measures to mitigate the moisture risk



Outline

- Basics about wood-water relations
- Moisture-related risk
- Wetting and drying performance of wood products/assemblies
- On-site moisture protection
- Summary

On-site Moisture Protection?

- Typically about preventing wetting during construction
  - Potential risks: decay, mould, swelling, corrosion..
- In extremely dry environment it could mean protection to reduce dimensional changes
  - Potential risks: checking, cupping, warping…

Basics about wood-water relations
Moisture-related risk
Wetting and drying performance of wood products/assemblies
On-site moisture protection

Wood and Water

- In freshly cut wood (green wood):
  - Liquid water in cell cavity (“free water” or “capillary water”), evaporates first during drying
  - Water in cell walls (“bound water” or “hygroscopic water”), more difficult to dry
- Fibre saturation point
  - Cells walls are fully saturated with water but no liquid water in cell cavity
  - Moisture content around 30%

Wood and Water

- Measuring MC with a moisture meter
  - Typical measurement range for solid wood: 6-25%
  - Measurement less accurate beyond this range; on composites or treated wood

capacitance-based meter (e.g., Wagner)

resistance-based meter (e.g., Delmhorst)

Wood and Water

- Wood moisture content (MC)
  - The amount of moisture in wood, expressed as a percentage of the mass of the wood *(after oven drying at 103°C)*
  - MC measured with a portable moisture meter or sensors during construction

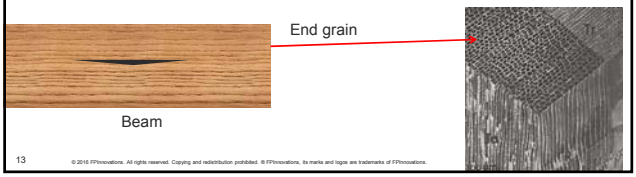
Wood and Water

- Wetting?
  - Exposure to a moisture source, wood reaches a risky MC, typically close to or above 30%
- Liquid water is a major cause of wetting
  - Rain, ground water, melting snow, condensation
  - Water once absorbed quickly increases local MC
- Risk of construction moisture is high in a coastal climate

Wood and Water

Pathways of liquid water into wood:

- Most rapidly through end grain
  - Exposed by end cuts, notching etc.
- Much slowly through other surfaces
- Checking may create water traps



Wood and Water

- In addition to liquid water, wood interacts with vapour in the air (i.e., sorption)
  - Wood gains moisture in high humidity environment
    - Also a source of wetting, but a slower process
  - Wood loses moisture in low humidity environment
    - It is the means of drying (evaporation)
    - An important aspect of keeping wood dry

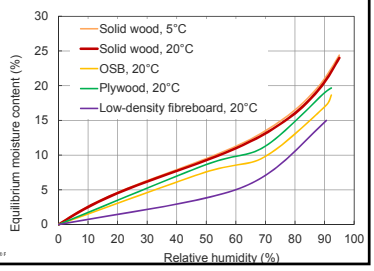
Wood and Water

Wood products have different wetting potential:

- Dimensional lumber/solid-sawn timber
  - Wood species, amount of sapwood vs. heartwood
  - Overall Canadian softwoods not permeable
- Engineered wood
  - Solid wood-based, or composites
  - Voids, end grain exposure, adhesive, wax…
- Build-up assemblies
  - e.g., nail-laminated timber, with small gaps inside
- Finishing/wrapping: water repellant, tarp…

Wood and Water

- Sorption curve: equilibrium moisture content at given RH and temperature
  - RH is a major factor for EMC
  - Material matters



Wood and Water

Typical MC ranges at manufacture (*Introduction to Wood Design*)

Material/assembly	MC range
Dimension lumber, "S-Dry" (including "KD")	15-19%
Solid-sawn timbers	Subject to supply agreement, typically above 30% (fibre saturation point) for green timber posts
Glued-laminated solid wood products, such as glulam, cross-laminated timber (CLT)	11-15%
Sheathing panels, such as plywood, OSB, fiberboard	6-12%
Structural composite products, such as parallel strand lumber, laminated strand lumber, oriented strand lumber, laminated veneer lumber (LVL)	6-12%
Large built-up members: Nail-laminated timber (NLT)	6-19%

Basics about wood-water relations

Moisture-related risk

Wetting and drying performance of wood products/assemblies

On-site moisture protection

Wood and Water

Equilibrium moisture content in different climates (*CWC*)

Location in Canada		Average EMC (%)	Winter EMC (%)	Summer EMC (%)
West coast	indoors	10 – 11	8	12
	sheltered outdoors	15 – 16	18	13
Prairies (e.g., Alberta)	indoors	6 – 7	5	8
	sheltered outdoors	11 – 12	12	10
Central (e.g., Ontario, Quebec)	indoors	7 – 8	5	10
	sheltered outdoors	13 – 14	17	10
East coast	indoors	8 – 9	7	10
	sheltered outdoors	14 – 15	19	12

Moisture-related Risk

- Decay causes structural damage
- Conditions favourable for decay
  - Moisture content: 40-80%
    - Threshold of MC for decay to initiate: 26%
    - It typically requires liquid water for decay fungi to grow
    - **Keeping wood dry** is usually the most effective and practical means to prevent decay
  - Temperature: 21-32˚C
  - …

Decay Hazard Map

- Decay requires moisture and warm condition
- Climate indexes have been developed to link wood decay and climate mathematically
- Scheffer Climate Index used to predict continental above-ground decay hazard
  - Based on mean monthly temperature and rainy days
  - Developed in 1971 by Ted Scheffer of Oregon State U.

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Moisture-related Risk

- Mould growth conditions
  - Relative humidity of surrounding air ≥ 80%
  - Warm temperature
- Staining
  - Iron staining a commonly-seen type
    - It requires moisture and iron contamination
- Mould and staining
  - Do not cause structural damage

Decay Hazard Map

- Map based on climate normals 1970-2000
- Climate change has impact

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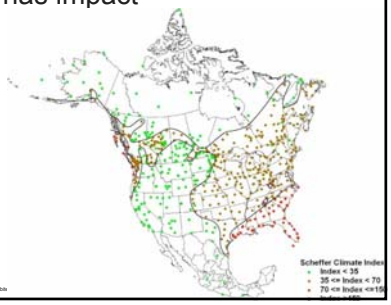

Moisture-related Risk

Shrinkage/swelling

- Shrinkage/swelling the root cause for checking, cupping, warping…
- Wood shrinks or swells with MC change
  - When MC is below 30% (i.e., *fibre saturation point*)

Moisture-related Risk

- Shrinkage/swelling amount depends on material/species, grain orientation, MC change
  - Transverse (cross section): 0.25% per 1% MC change
  - Longitudinal direction: negligible
  - Engineered wood often has reduced shrinkage/swelling
- Differential movement becomes a larger issue in mid-rise wood-frame construction
  - Chapter 5, Mid-rise Wood-Frame Construction Handbook

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Principles for Design/Construction

- For very dry environment, use
  - Products with good dimensional stability
  - Wood with low initial MC to reduce dimensional change
  - End sealing and coating etc. to slow down drying
  - Humidification may become necessary

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Principles for Design/Construction

- Controlling MC is the key
- Keep wood dry to prevent decay, mould, fastener corrosion, through:
  - Minimize wetting during construction/in service
  - Allow drying out once wetting occurs
- Achieve durability under anticipated wet conditions, use:
  - Preservative-treated, or naturally durable wood

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Basics about wood-water relations
Moisture-related risk
Wetting and drying performance of wood products/assemblies
On-site moisture protection

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Wetting and Drying Performance

Covering three separate but related studies:

- Measure MC of dimensional lumber during wood-frame construction as baseline
- Wetting and drying of simulated small roofs built with different products (OSB, plywood, LVL, CLT)
- Wetting and drying of simulated "nail laminated plate" (with or without sheathing or protective membrane)

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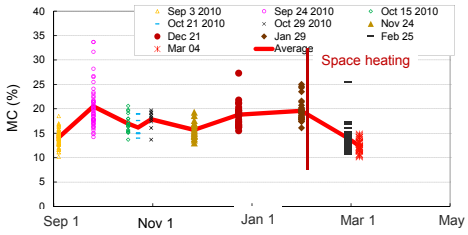
Lumber MC Change: 4-Storey Building

- Framed in the winter
- Studs on ground floor, chest height
  - Average MC around 20% prior to space heating



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Wood MC in Wood-Frame Construction

- MC is an important parameter for predicting vertical movement (shrinkage) in mid-rise wood-frame buildings
- MC data collected is a baseline for on-site moisture management

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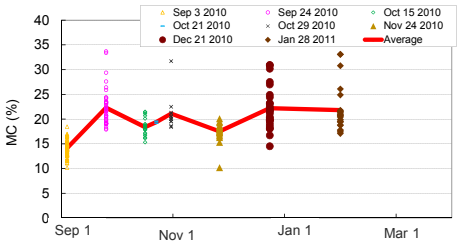
Lumber MC Change: 4-Storey Building

- Framed in the winter
- Sill plates
  - MC higher than 20% prior to space heating



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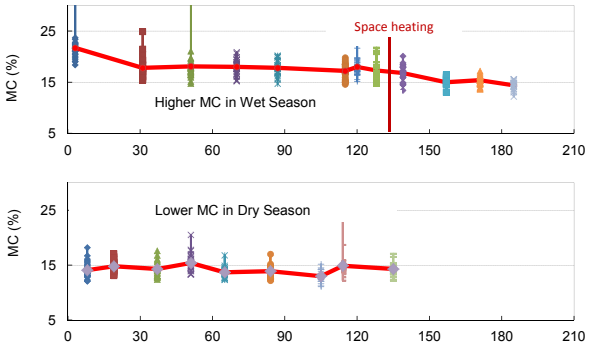
Lumber MC Change: 5-Storey Building

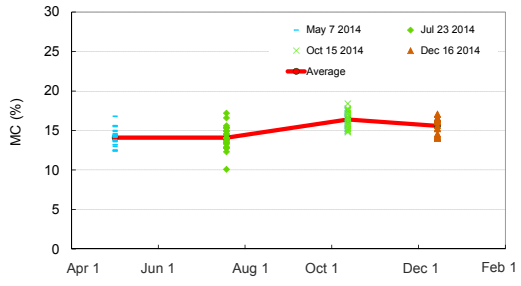


Changes in MC at chest height of studs, first floor

Wetting and Drying Performance of Simulated Roof

- Pre-wetted wood, built into different assemblies
  - Covered with an impermeable membrane, or felt + asphalt shingle
  - With and without 3" closed-cell spray foam underneath
- Drying under different conditions
  - In an unheated storage shed
    - Simulate condition of new construction just sheltered by roof
    - Assess effect of space heating (on one side) on drying
  - In heated lab

Lumber MC Change: 6-Storey Building



Lower MC, around 15%, when framed and sheltered in dry season

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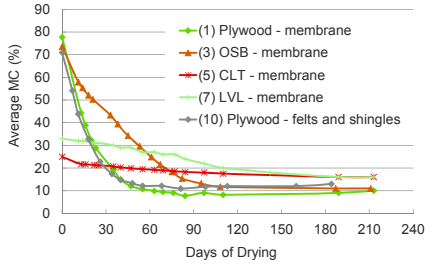
Wetting and Drying Performance of Simulated Roof

- Materials have different wetting/drying potential
- Plywood, covered with impermeable membrane or roof felt/shingles, had similar drying rates



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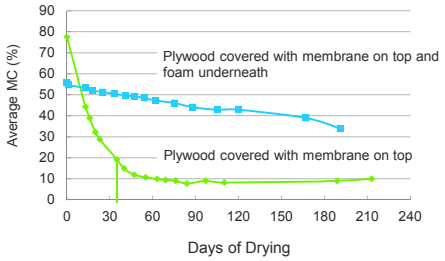
Wetting and Drying Performance of Simulated Roof



Wet plywood, sandwiched between impermeable roofing membrane and closed-cell spray foam, did not dry

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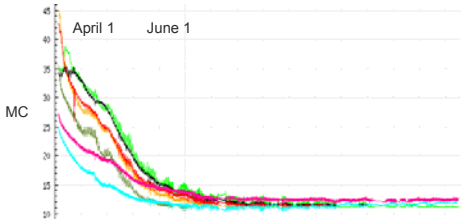
Wetting and Drying Performance of Simulated Roof

- Severely wetted plywood dried under reversed temperature differential
  - 19 mm thick, with a moisture pin sensor installed in each ply
  - Covered with an impermeable membrane on top
  - MC dropped below 20% within 2 months



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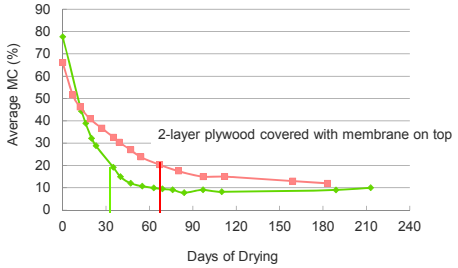
Wetting and Drying Performance of Simulated Roof



Double-layer plywood deck, sometimes specified for structural performance, reduced drying

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Wetting and Drying Performance of NLT

- Wetting
  - Exterior
  - Controlled wetting by hourly water spray
- Drying
  - Exterior
  - In shed
    - With/without space heating on one side
- Evaluate potential protection method
  - Sheathing (plywood)
  - Protective membrane
    - Building paper
    - Permeable plastic membrane
    - Impermeable self-adhesive membrane

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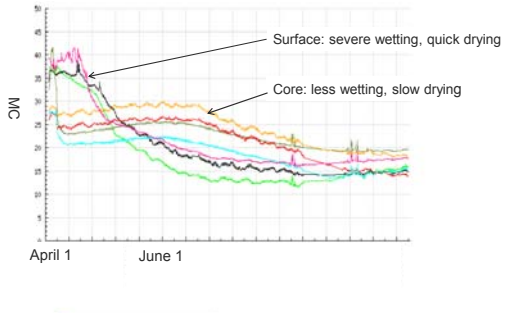
Wetting and Drying Performance of NLT



Bare NLT without sheathing or membrane on top, wetted in lab and dried in shed

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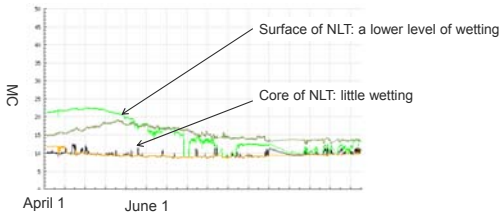
Wetting and Drying Performance of NLT



NLT covered with plywood and building paper on top, wetted in lab and dried in shed

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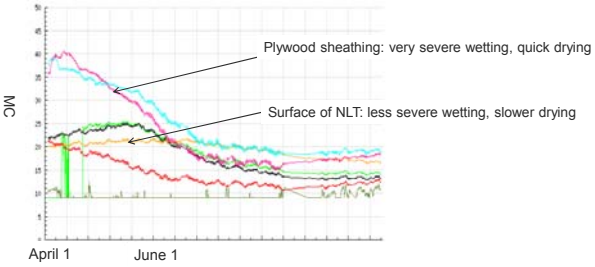
Wetting and Drying Performance of NLT



NLT covered with plywood sheathing on top, wetted in lab and dried in shed

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Basics about wood-water relations
Moisture-related risk
Wetting and drying performance of wood products/assemblies
On-site moisture protection

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On-site Moisture Protection

"Standard" wood-frame construction in N.A.

- Open and exposed construction
- Trend towards prefabricated open panels for multi-storey buildings

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On-site Moisture Protection

- Temporary roof becoming common in Europe
  - Fixed, or liftable
  - Construction protection/implementation standard first developed in Finland in 2012
  - It is now becoming an EU standard

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On-site Moisture Protection

- Basic protection is commonly seen
  - Many wood products wrapped for shipping
  - Many engineered wood has water repellent applied in factory (end grain, or entire surface)
  - Covering with tarp becomes common at site

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On-site Moisture Protection

- Temporary roof used in N.A. for building envelope retrofit
  - Due to occupancy and related insurances etc.
- But rare in new construction
  - Cost may be offset with improved efficiency and reduced need for remedial treatment

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On-site Moisture Protection

Comprehensive on-site protection provided in this 18-storey timber building

- Good coordination and sequencing
  - A high level of prefabrication to reduce on-site wetting
  - Materials delivered for just-in-time installation
  - Timbers installed in generally warm and dry season (June-August 2016)
  - Exterior walls/roof installed quickly to protect

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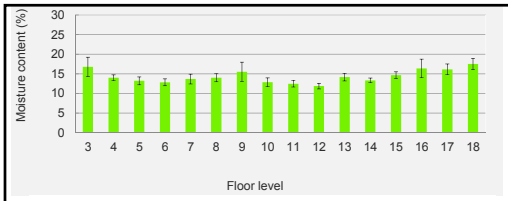
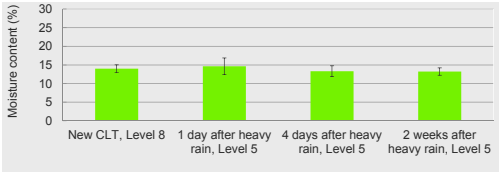


Average MC measured from CLT of different floor levels from June 24 to September 1, 2016



MC of CLT, measured from a newly installed floor (Level 8), and from Level 5 with different days after a heavy rain event

On-site Moisture Protection

- Additional on-site protection applied
  - CLT pre-coated with a water repellent
  - Joints/holes in CLT floor sealed with self-adhesive tapes immediately after installation
  - Second water repellent applied at site
  - Sink-style drains created on each floor
- Wetting was overall slow in CLT (SPF) floors based on site measurements

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Design to Promote Drying

- Drying potential varies with product/treatment
- Design has a large impact on drying, e.g.,
  - Use of built-up members
  - Using low-permeance products (e.g., low-permeance insulation, impermeable membrane)

Design to Promote Drying

- Design for drying is particularly important for mass timber assembly
  - e.g., interior ventilation cavity in mass timber roof

Plywood furring used to create an air space between plywood roof sheathing and CLT panels

Wood Innovation and Design Centre, Prince George, Canada

Photo source: Michael Green Architecture

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Summary

- Materials/assemblies, susceptible to wetting and poor drying, require better on-site protection + design
  - Some levels of protection can be provided by sheathing or a membrane, if a more advanced method (e.g., shelter) is not possible
  - Always design assemblies with good drying capacity, since protection against wetting is never perfect
- Guide for on-site Moisture Management of Wood Construction recently published by FPInnovations
  - Available at fpinnovations.ca; bchousing.org

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Summary

- MC of dimensional lumber in wood-frame construction remains on average
  - 20% during the wet season
  - 15% during the dry season
  - MC not permitted to be over 19% before enclosure
- Preventing wetting should have a higher priority over accelerating drying
  - Wetting mostly caused by liquid water sources
  - Drying is slow once water penetrates the wood or is trapped

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