UBC

Increased Strength of Hem-Fir (N) Expands Structural Application in Heavy Timber Construction

Frank Lam
Tom Chao Zhang

University of British Columbia
Vancouver, BC Canada

November 24, 2022

Canadian Wood Council
Conseil canadien du bois

PACIFIC HEMFIR
WOOD THAT WORKS

3rd largest Canadian university

2022	Vancouver	Okanagan	Total
Undergraduates	47400	10806	58206
Graduate	11368	1183	12551
Faculty	6466	668	7134
Staff	10779	1020	11819

2022 Academic Ranking of World Universities placed UBC 44th in the world.
2022 Times Higher Education Rankings placed UBC 37th in the world.

UBC places among the top 20 public universities in the world

Climate change is the defining challenge of our generation

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2022

Sustainable Timber Built Environment Group/Cluster

Learning Objectives

- Understand how in-grade testing works and why it matters
- Review the impact of in-grade testing on the strength properties of Hem-fir (N) timbers
- Recognize the technical performance, sustainability and versatility of Hem-fir (N) timbers in different applications
- Explore potentials of new applications for Hem-fir (N) with comparisons to other large dimension wood products

Hem-fir (N)

Western hemlock (*Tsuga heterophylla*) is the most abundant tree species on the coast of British Columbia. A smaller volume of Western hemlock stands can also be found in the interior of BC.

Western hemlock is commonly harvested together with amabilis fir (*Abies amabilis*) and sold as a commercial species group as Hem-fir (N). For the Japanese export market Hem-fir (N) is called Canada Tsuga.

Hem-fir (N) is one of the most important timber resource in BC.

Source: www.gov.bc.ca

Hem-fir (N)

Hem-fir (N) has good strength and stiffness properties making it well suited for structural applications as horizontal components.

The density range of Hem-fir (N) is also well suited for ease of nailing and screw installation while achieving very good withdrawal and lateral resistance.

In non-structural applications Western hemlock has excellent working properties. It is a very desirable species for applications as mouldings, interior woodworking, joinery, veneered interior paneling, furniture, doors, floors, and windows.

Western hemlock is non-resinous. It has good treatability properties including takes any stains or finishes extremely well.

Hem-fir (N) Timber

In Canadian Code for Engineering Design in Wood CSA O86.1, “Beams and Stringers Timber” refers to sawn wood that is 114 mm or more in the smaller dimension with visual grades of Select Structural, No. 1 and No. 2 under the grading rules of National Lumber Grades Authority (NLGA)

Why investigate the strength properties of Hem-fir (N) timber?

Myra Canyon Trestle Bridge Fire 2003

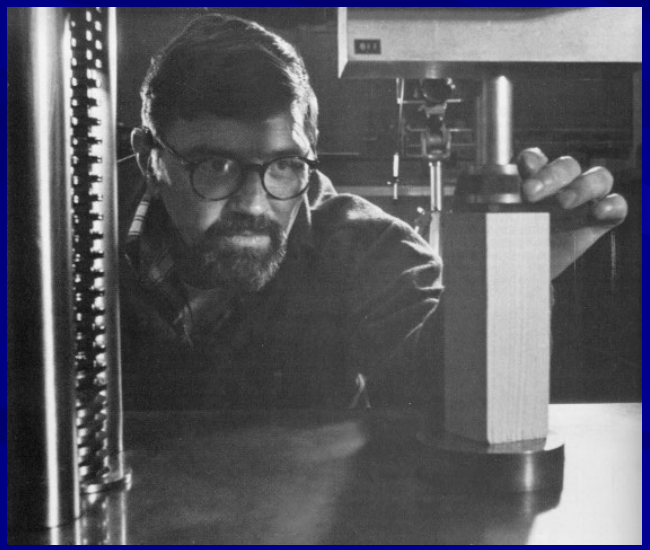
Kinsol Trestle 44 metres high and 188 metres long

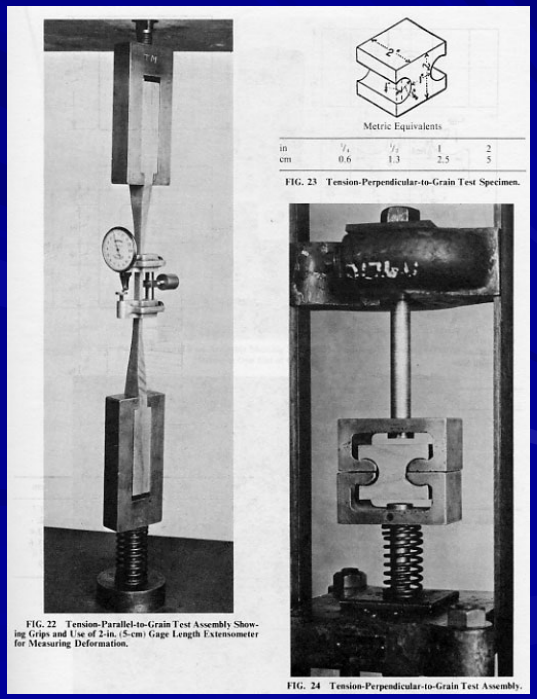
Engineers were reluctant to use Hem-fir (N) timber citing low strength properties in codes.

This does not align with UBC's database on full size testing of Hem-fir (N) post and timber material for applications in Japan!!

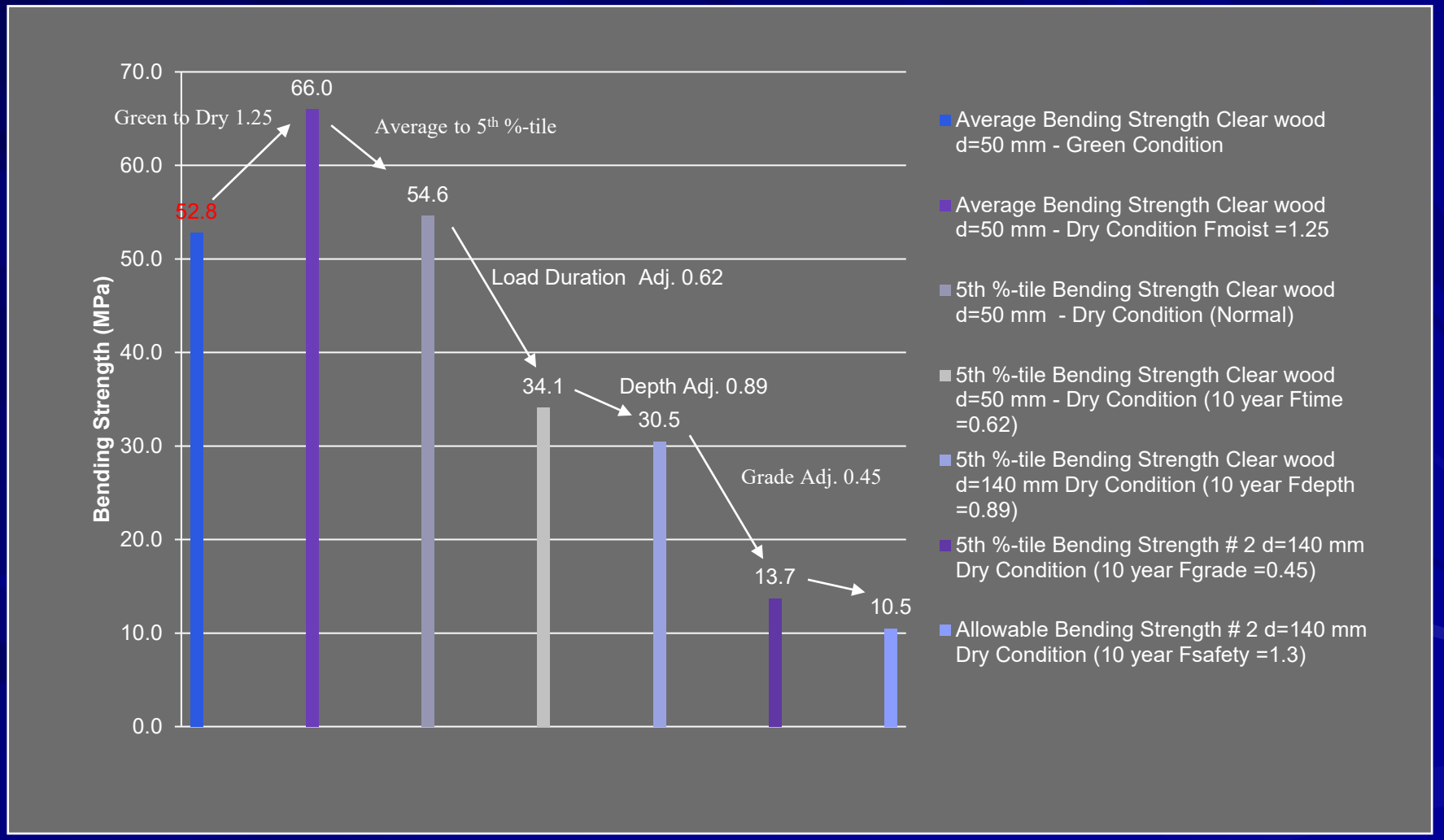
Structural Wood Products Property Studies

- Traditional Clear Wood Methods (1900's to 1960's)
  - Small clear and Full-size comparisons
  - Clear wood property tests standardized
  - Allowable Stresses: lumber, plywood, glulam





Small Clear Test Concept – from Test Results to Allowable Stress



Structural Wood Products Property Research

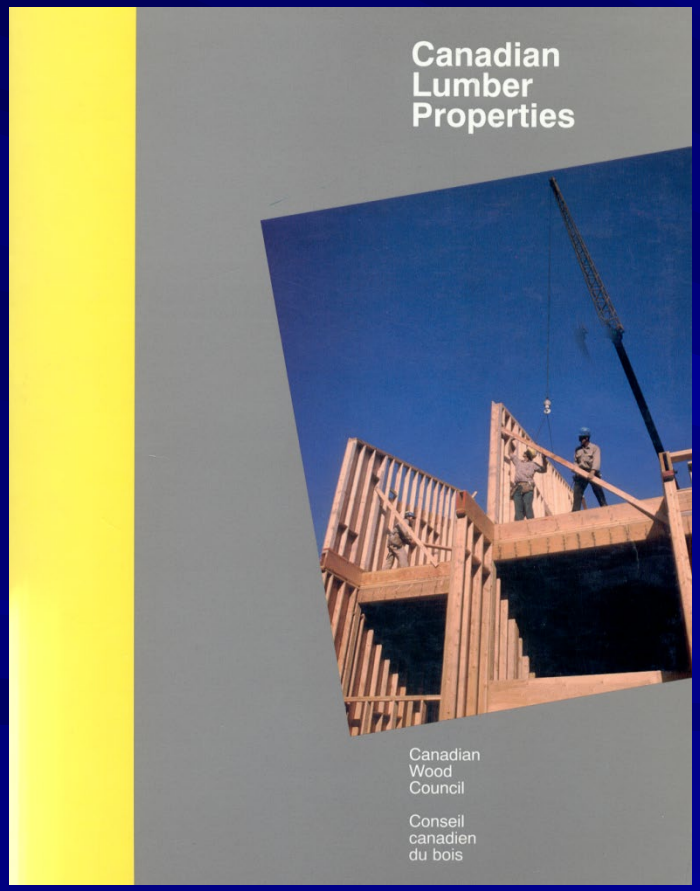
- In-Grade (Full-Size) Testing Methods (1960's to now)
  - National Standards adopted (1970's – 1980's)
  - ISO Standards – (1980's – 2005)
    - Standards for sampling, testing and evaluation of characteristic properties
  - Test products as-produced and used in construction
  - Represents actual material behavior in structures
  - Allowable Stress Design
  - Load and Resistance Factor Design
    - Reliability-Based Design Methods

Structural Wood Products Property Research

- Engineering Properties of Canadian Structural Lumber
- Douglas fir, Hemlock, Spruce-Pine-Fir, Yellow Cedar, Sitka Spruce

UBC- Madsen (70's)
Forintek Canada Corp. (80's)
UBC- Barrett, Lam (90's)

Structural Wood Products Property Research



Engineering Properties of BC Coast Species

by

J. David Barrett
and
Frank Lam

Department of Wood Science
University of British Columbia
Vancouver, BC

March 2003

Structural Wood Products Property Research

- Engineering Properties of Canadian Timber
- Douglas fir, Hemlock,

UBC- Lam , Barrett (90's to now)

Structural Wood Products Property Research

- In-grade testing of larger dimension timber products with member thickness greater than 100 mm is very costly; very limited in-grade data exist on their strength properties.

- In the early 1980's UBC conducted an in-grade testing program by proof loading on Douglas fir "Beam and Stringer" timber of Select Structural and No. 1 grades to establish their design strengths for the code.

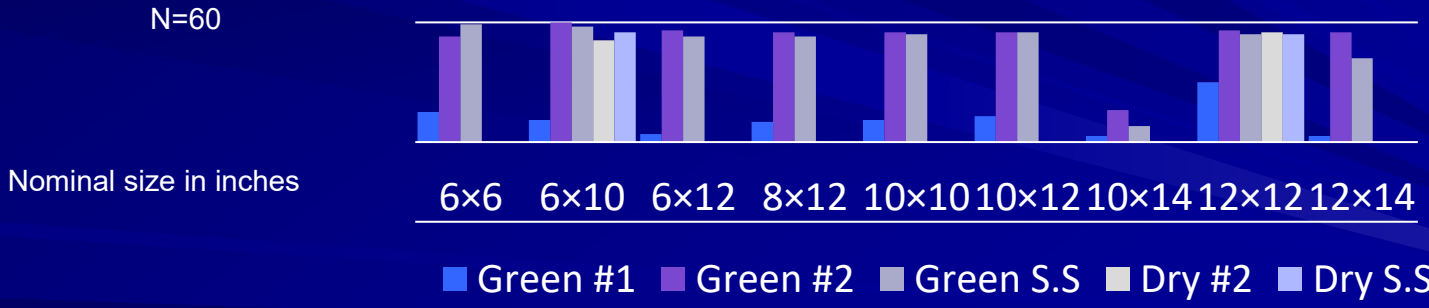
- In–grade testing on large dimension Hem-Fir (N) and Spruce-Pine-Fir timber was not performed . Timber design strengths for these species were conservatively derived by relating their small clear strength properties to those of Douglas fir-Larch.

Latest In-grade Program on Hem-fir (N) Timber

Over 400 m^3

	Sample Size	6×6	6×10	6×12	8×12	10×10	10×12	10×14	12×12	12×14
Green	No. 1	15	11	4	10	11	13	3	30	3
	No. 2	**53**	**60**	**56**	**55**	**55**	**55**	16	**56**	**55**
	S.S	**59**	**58**	**53**	**53**	**54**	**55**	8	**54**	42
Dry	No. 2		51						**55**	
	S.S		**55**						**54**	

N=60



E-rating

Knot Mapping

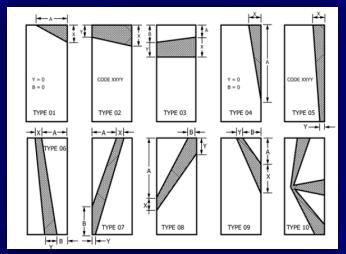
Bending Test

Failure Mapping

MC/SG Test

MOE/MOR

Moisture Content
Specific Gravity

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10X12
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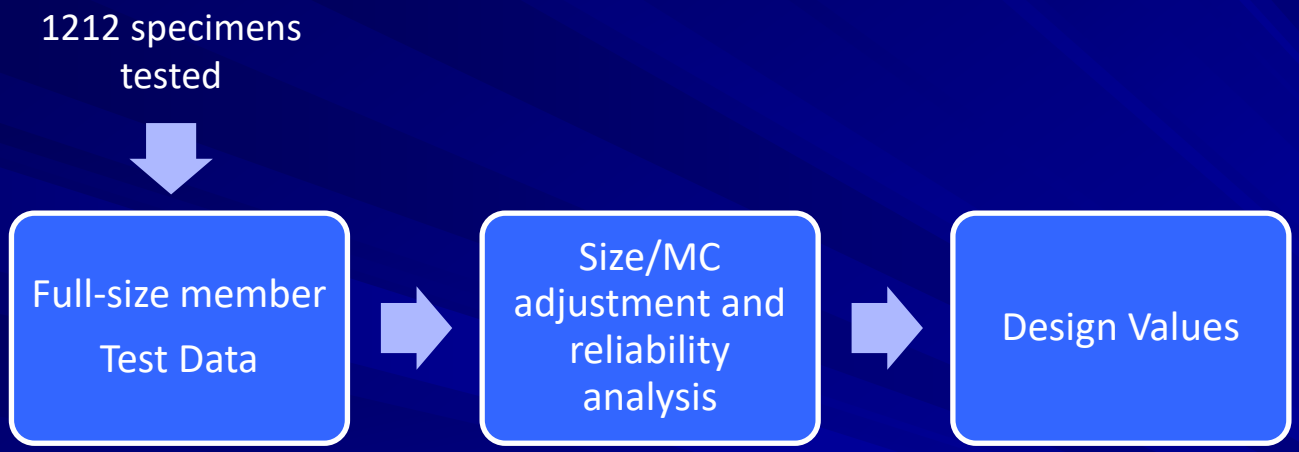
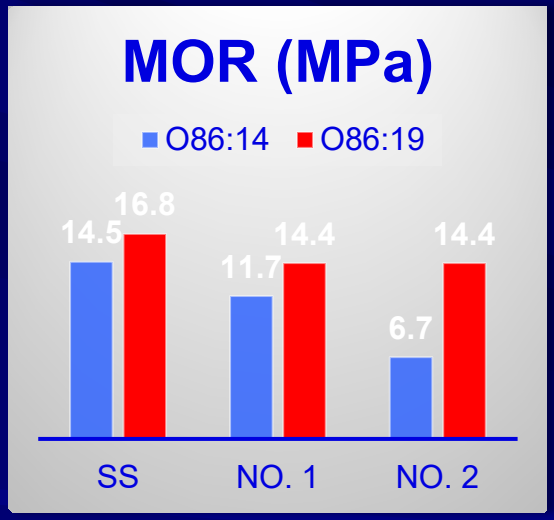

1212 specimens tested
Full-size member Test Data
Size/MC adjustment and reliability analysis
Design Values

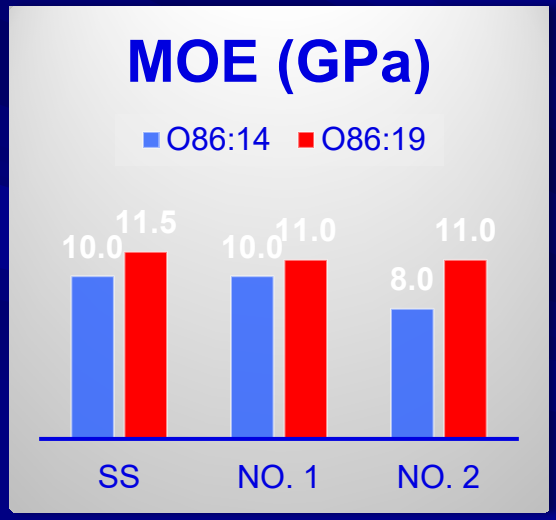
CSA O86-2019

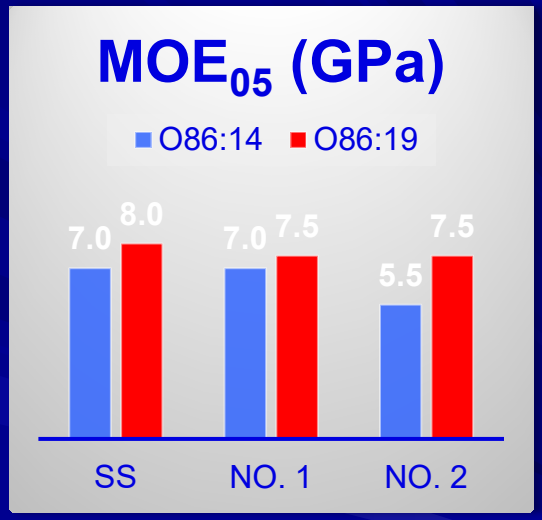
Table 6.6
Specified strengths and moduli of elasticity for beams and stringers, MPa
(See Clauses 6.3.1.1, 6.5.2.2, 6.5.5.2.5, 10.5.3–10.5.5, 10.6.3.1, 10.6.3.6, 12.4.4.4, 12.4.4.5, and 14.3.)

				Compression			Modulus of elasticity	
Species combination	Grade	Bending, f_b*	Longitudinal shear, f_v	Parallel to grain, f_c	Perpendicular to grain, f_{cp}	Tension parallel to grain, f_t	E*	E_{05}*
Douglas Fir-Larch	SS	19.5	1.5	13.2	7.0	10.0	12 000	8000
	No. 1	15.8		11.0		7.0	12 000	8000
	No. 2	9.0		7.2		3.3	9500	6000
Hem-Fir	SS	16.8	1.2	13.0	4.6	7.4	11 500	8000
	No. 1	14.4		12.4		6.3	11 000	7500
	No. 2	14.4		12.4		6.3	11 000	7500
Spruce-Pine-Fir	SS	13.6	1.2	9.5	5.3	7.0	8500	6000
	No. 1	11.0		7.9		4.9	8500	6000
	No. 2	6.3		5.2		2.3	6500	4500
Northern Species	SS	12.8	1.0	7.2	3.5	6.5	8000	5500
	No. 1	10.8		6.0		4.6	8000	5500
	No. 2	5.9		3.9		2.2	6000	4000

Compared to previous design values

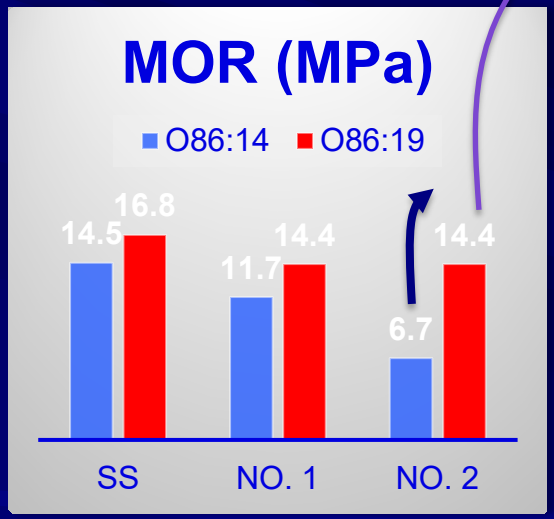






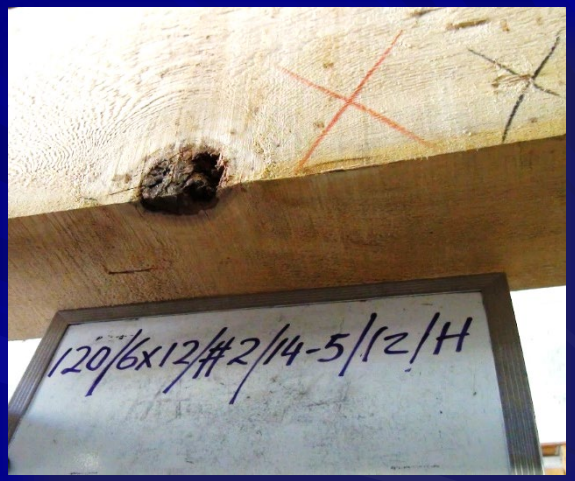
Why such a drastic change?

Compared to previous design values

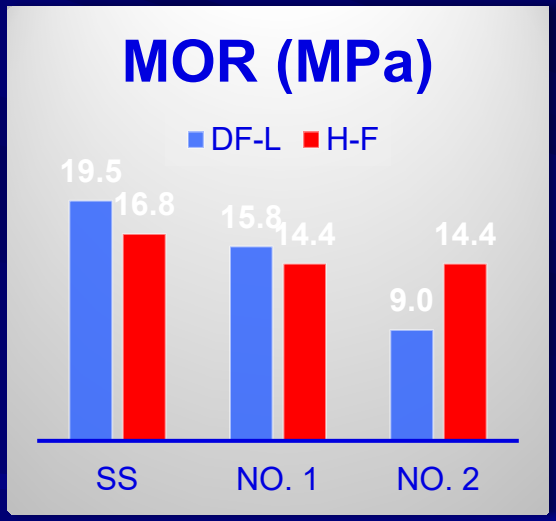


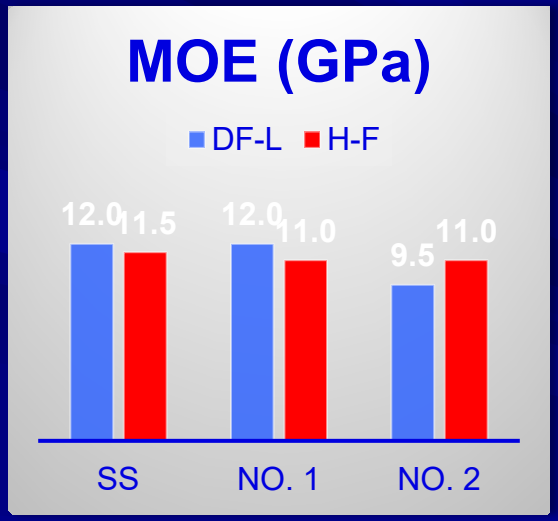
1) Results based on In-grade testing.

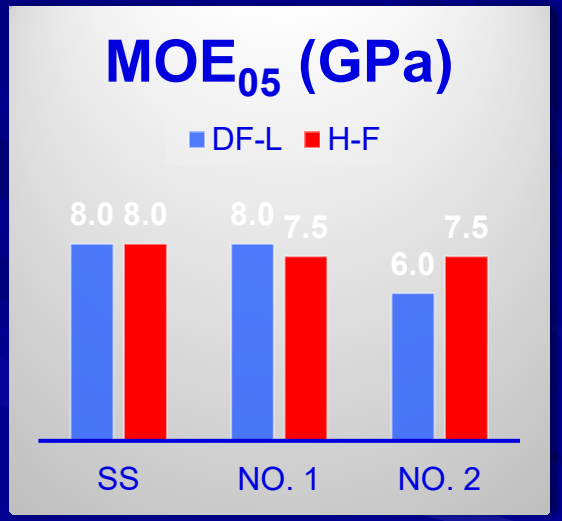
2) A large number of specimens were downgraded from Select Structural to #2 due to **small unsound** knot.



Compared to Douglas Fir-Larch design values







Summary

Grade	CSA O86:14			CSA O86:19		
Unit (MPa)	Bending	Modulus of elasticity		Bending	Modulus of elasticity	
	f_b	E	E_{05}	f_b	E	E_{05}
SS	14.5	10,000	7,000	**16.8**	**11,500**	**8,000**
No. 1	11.7	10,000	7,000	**14.4**	**11,000**	**7,500**
No. 2	6.7	8,000	5,500	**14.4**	**11,000**	**7,500**

Potential Applications of Hem-fir (N) Timber - Outdoors

Outdoors Structures

Treatability:
Compared to Douglas Fir, the cell structures of Hem-fir (N) is more permeable in terms of chemical treatments; thus, offering more durability protection when treated.

Potential Applications of Hem-fir (N) Timber - Outdoors

Timber Deck

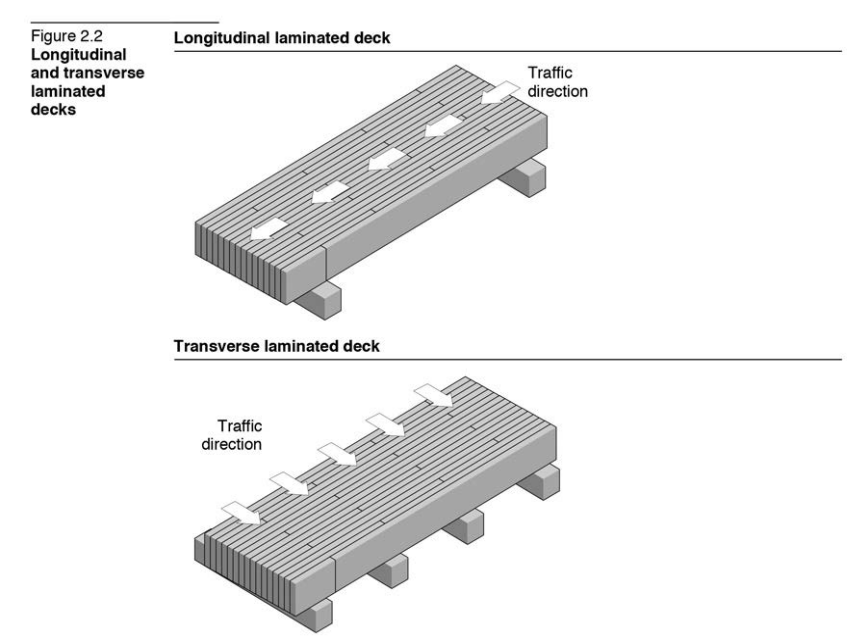
Potential Applications of Hem-fir (N) Timber - Outdoors

Decking for Footbridges

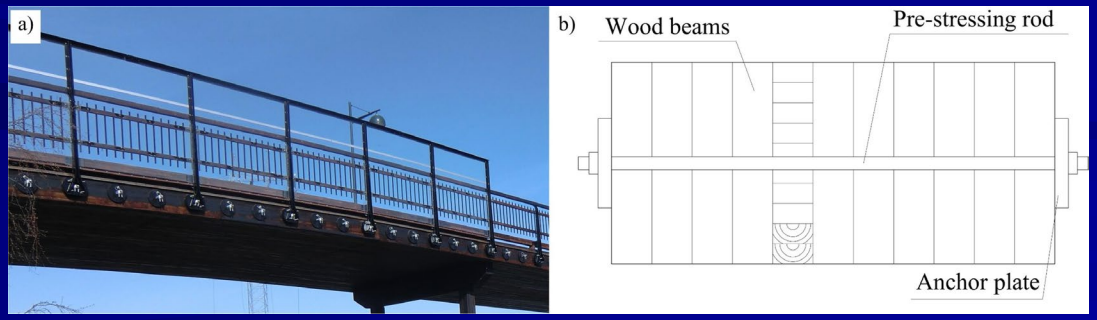
Structurecraft

Potential Applications of Hem-fir (N) Timber - Outdoors

Stress laminated Timber Deck



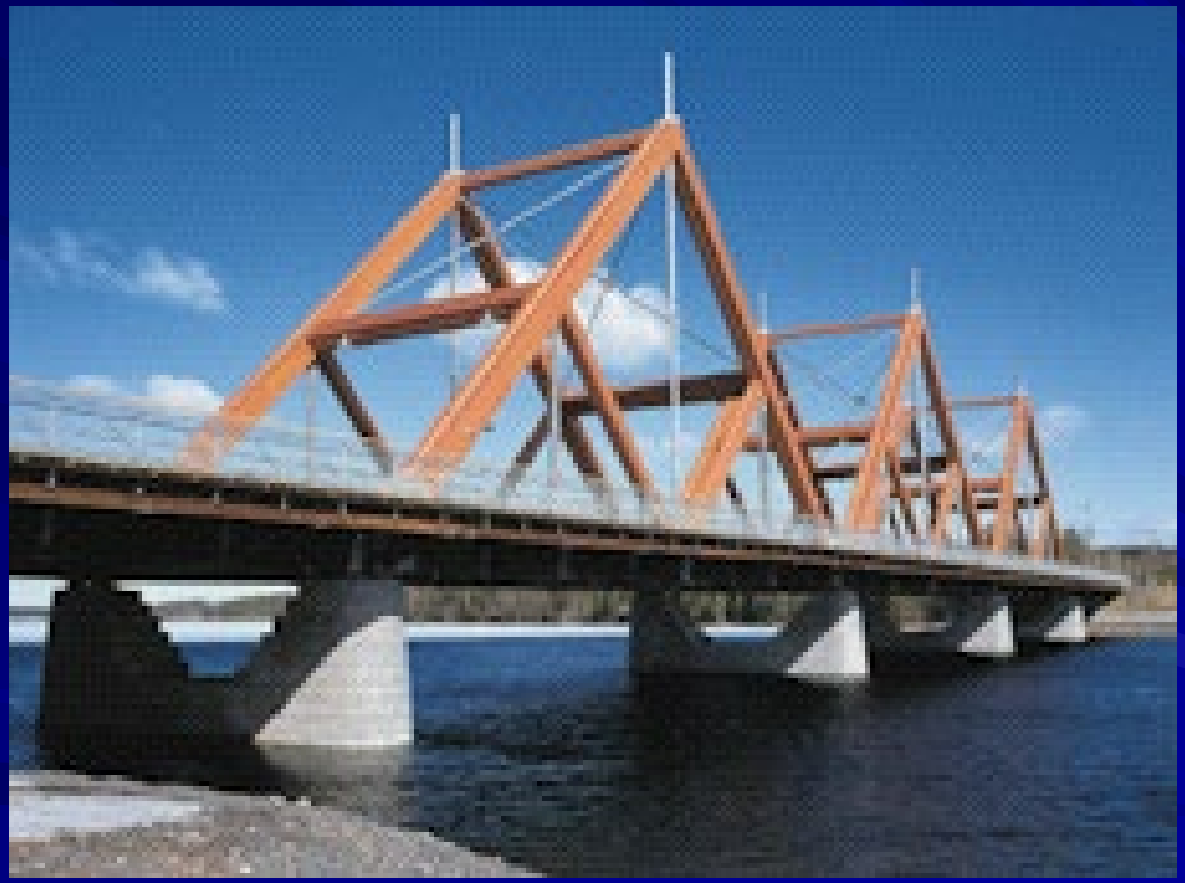
OHBDC (1983). Ontario Highway Bridge Design Code 1983, Ontario Ministry of Transportation and communications.



Engineering Structures
Volume 213, 15 June 2020, 110592

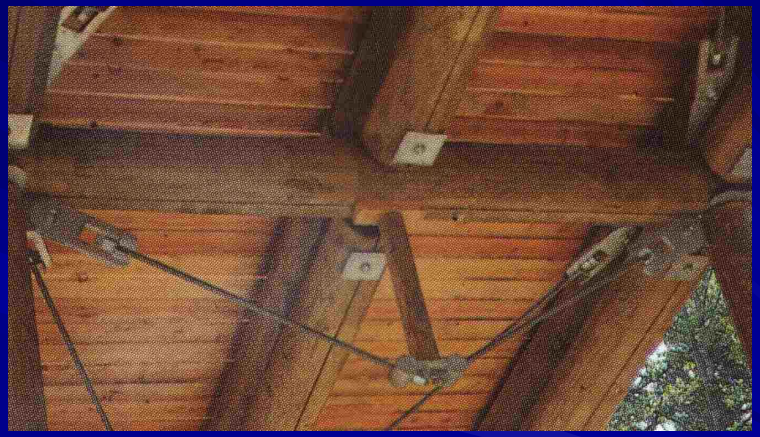
Decking for Vehicle Bridge

Vihantasalmi Bridge Finland

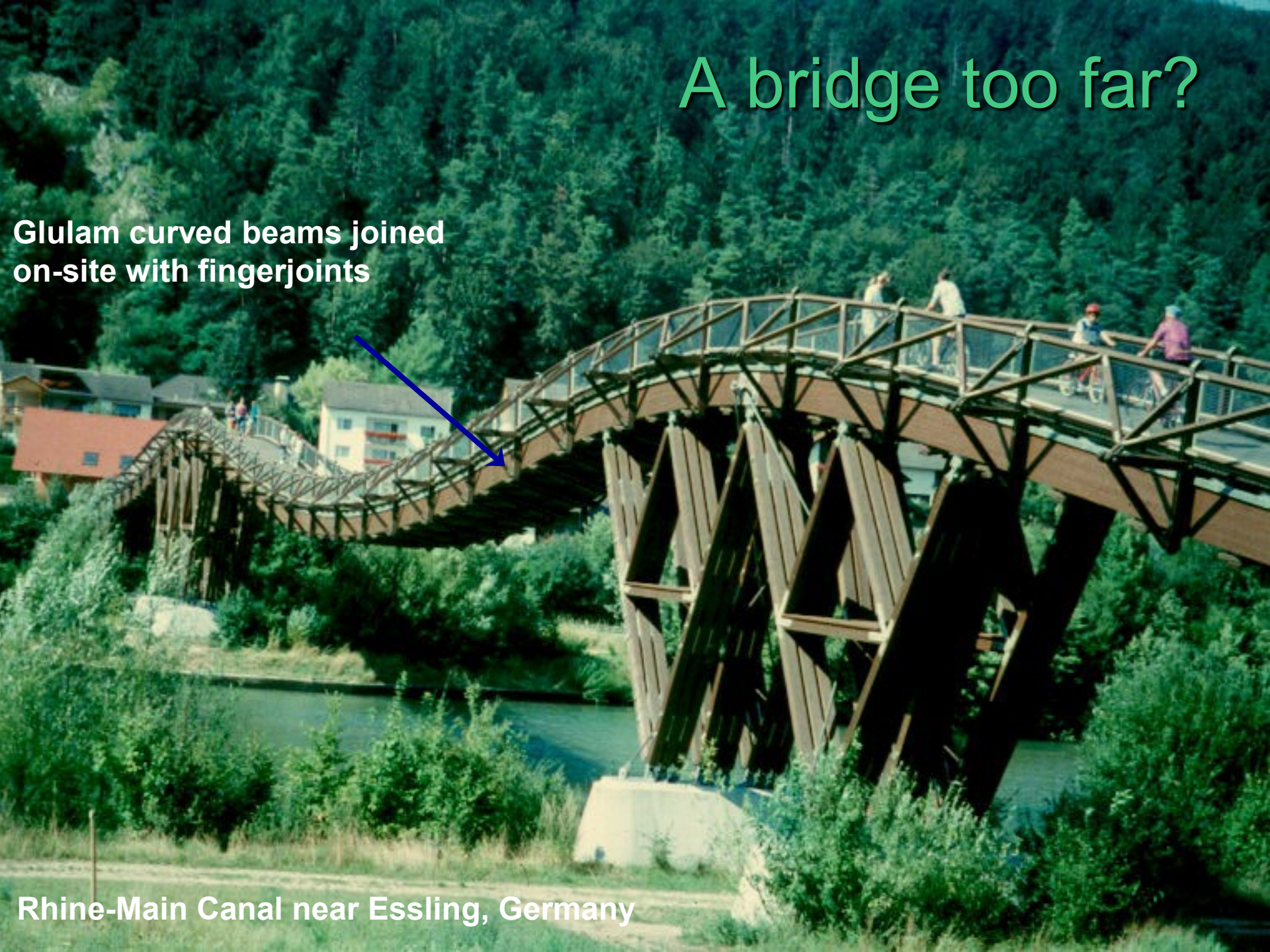


Pedestrian Bridge Ursanne

Pedestrian Bridge Vallorbe



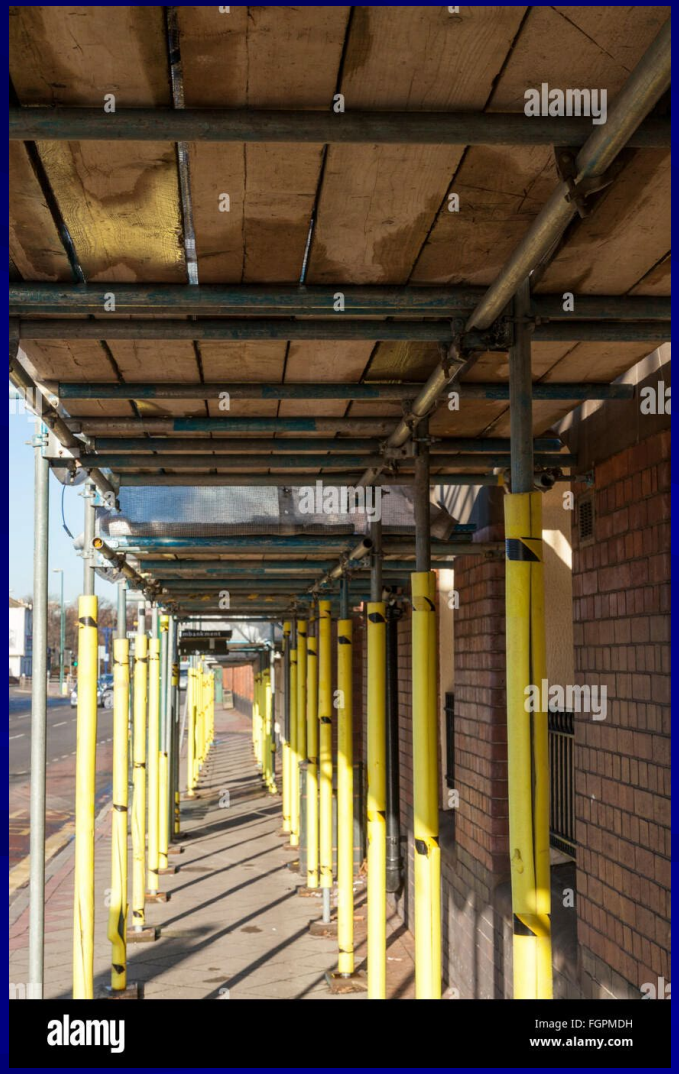
A bridge too far?



Cucumber Tower by Jan Vondrak Czech Republic

Source dezeen_ss_9

Roadside Construction Scaffolding Timber Deck



Potential Applications of Hem-fir (N) Timber - Indoors

Indoors Structures

Proper drying is needed to control moisture content and dimension stability.

Advanced drying techniques such as RF Vacuum drying can facilitate the drying process

Stress Relieve groove in Japanese Cypress post

Structural application of RF/V dried Sugi Timber in Japan

Solid Sawn Mass Timber Building using Douglas-fir

Source: www.canadawood.org

UBC C.K. Choi Building

Application of Hem-fir (N) timber in Whistler Public Library


MUSIC CDS
REFERENCE

Hem-fir (N) in Whistler Audain Museum


AUDAIN ART MUSEUM

Hem-fir (N) timber in Pt. Robert Residence

Cost and Availability

- Industry has capacity to double Hem-fir Timber production and is looking for more market opportunities for this resource.

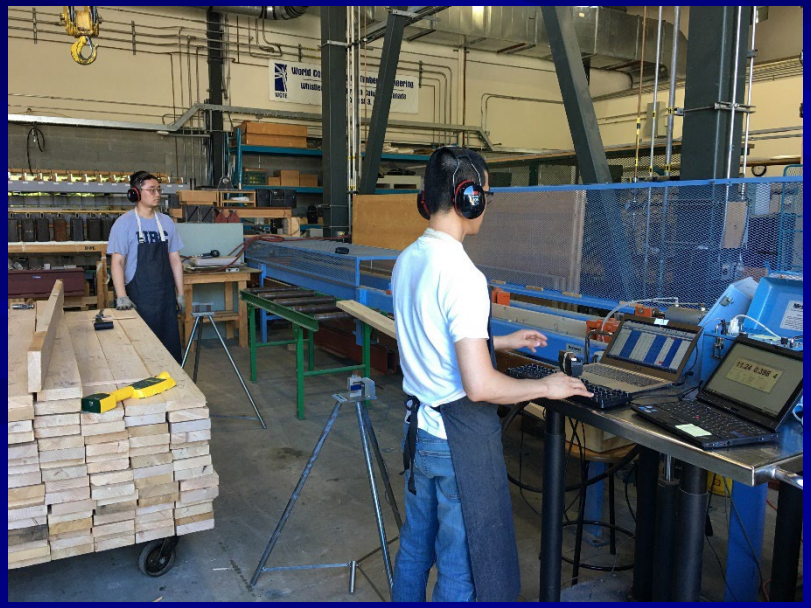
- Douglas fir has a price premium over Hem-fir (N). Depending on market conditions, Douglas fir timber can be ~30% more expensive.

New initiatives

Industry is looking at machine graded timber.

Industry is working on developing Hem-fir (N) lamstock for CSA 24f-E glulam beams.

Lamstock testing is underway at UBC. Hem-fir (N) glulam beams will be tested in 2023.



UBC

Contact Information

Dr. Frank Lam P.Eng. FIWSc, FIAWS
Senior Chair Professor Wood Building Design and Construction
Department of Wood Science
University of BC
2424 Main Mall
Vancouver BC
Canada
V6T 1Z4
Tel: 604 822-6526

email: frank.lam@ubc.ca

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Photo courtesy of Western Forest Products