Cross Laminated Timber in the United States
Opportunity for Hardwoods?

The Future of the Hardwood Lumber Industry Conference
November 3, 2016

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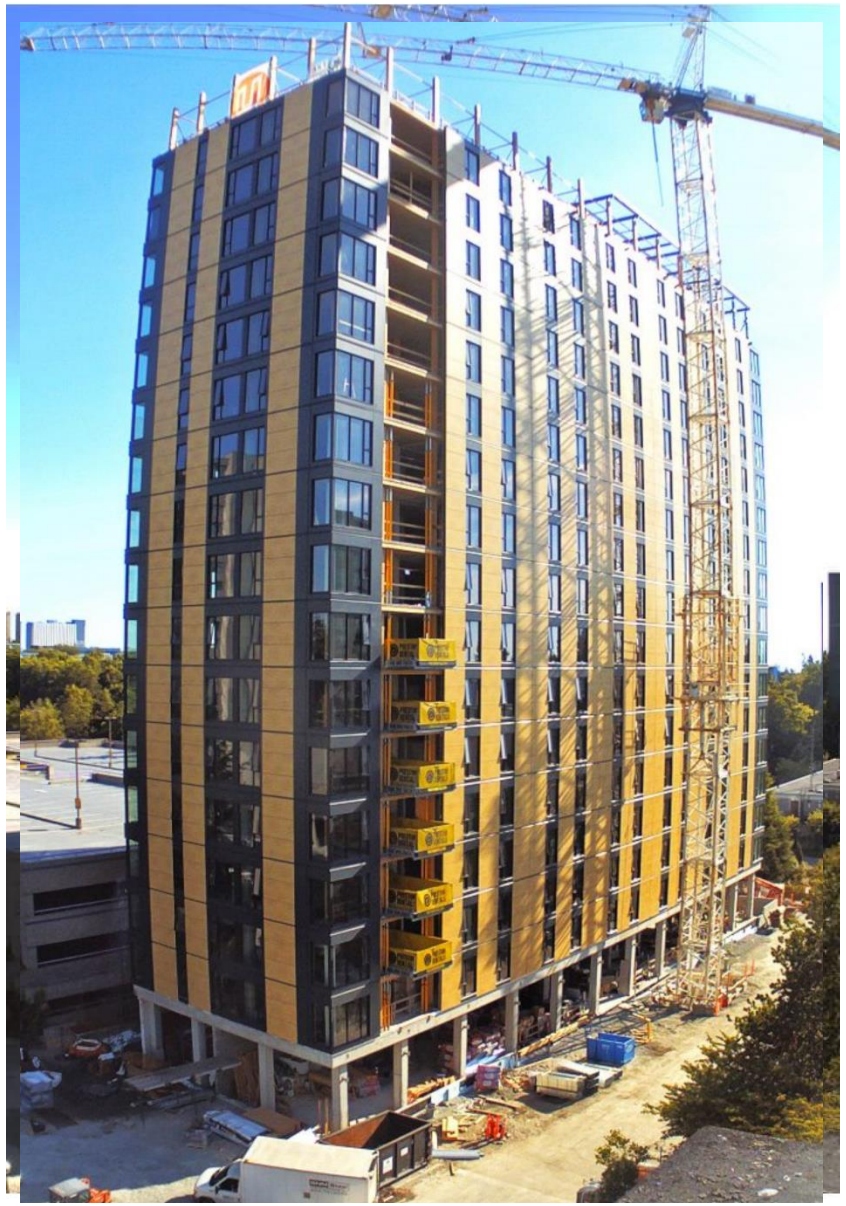
UNIVERSITY OF MINNESOTA
Driven to Discover℠

CLT Benefits

- Generate economic opportunities
- Reduce CO_2 emissions, fossil fuel consumption, increase energy efficiency
- Increase the use of renewable materials
- Create high value-added uses for wood.
- Increase the economic value of forestlands
- Architectural freedom
- Faster, cleaner construction
- Potential incremental volume 5BBF

Credit: MGA http://mg-architecture.ca/

NOTABLE PROJECTS IN NORTH AMERICA



Acton Ostry Architects Inc.

Brock Commons Phase 1

- University of British Columbia Point Grey campus
- Student residence
- 18 stories, 173 ft (53 m)
- 162,700 ft^2 (15,115m^2)
- LEED Gold certification
- In construction (scheduled 2017)

July 28, 2016
August 15, 2016

http://www.actonostry.ca/project/brock-commons-phase-1/

T3-Hines

- Minneapolis, Minnesota.
- 7 stories, 85 ft (26 m).
- 220 000 ft^2 (20 400 m^2)
- High-end office space.
- Post and beam with NLT.
- Under Construction.

http://goo.gl/BsRW5t

http://www.startribune.com/developer-breaks-ground-on-modern-all-timber-office-building-in-north-loop-minneapolis/318684551/

Franklin Elementary School

- Franklin, West Virginia.
- 300 students.
- Carbon stored: 1 014 tons.
- Completed January 2015.

http://www.msesarchitects.com/projects/franklin-elementary-school/

http://www.msesarchitects.com/projects/franklin-elementary-school/

Candlewood Hotel

- Redstone, Alabama.
- 4 stories, 58 000 ft^2
- 92 rooms.
- Army's privatized lodging.
- Completed 2014.

LendLease

http://goo.gl/t1GvfM

LendLease

Source: Google Maps

North American CLT Manufacturers

HARDWOOD CLT

Birch CLT - Austria

- Hasslacher Norica Timber / TU Graz
- Birch (*Betula pendula*)
- $\rho_{12\%MC}$ = 594 kg/m^3 (37 lb/ft^3)
- n=20, 5-ply, x-section ~24x8 in, MUF
- Tested according EN 1995-1-1
  - MOE = 15,524 MPa (COV=4.3%)
  - MOR = 38 MPa (COV=11.6%)
  - Tensile strength of joints 55.7 MPa
  - Compressive strength ⊥ =5.8 MPa[2]

Jeitler, G.; Augustin, M.; Schickhofer, G.: Mechanical properties of glued laminated timber and cross laminated timber produced with the wood species birch , Proceedings of the World Conference on Timber Engineering (WCTE 2016), August 22-25, 2016, Vienna, Austria, Publisher: Vienna University of Technology, Austria,

Birch CLT House, Austria

HASSLACHER NORICA TIMBER

Jeitler, G.; Augustin, M.; Schickhofer, G.: Mechanical properties of glued laminated timber and cross laminated timber produced with the wood species birch , Proceedings of the World Conference on Timber Engineering (WCTE 2016), August 22-25, 2016, Vienna, Austria, Publisher: Vienna University of Technology, Austria,

Beech CLT - Switzerland

- Bern University of Applied Sciences
- European beech (*Fagus sylvatica*)
- ρ = 690 kg/m^3 (43 lb/ft^3)
- n=13, 120 mm (4¾ in), layers=vary
- Values higher than spruce CLT, especially rolling shear (~5x), bending (1.7x) and compression perpendicular to grain (~5x).

Franke, S.: Mechanical properties of beech CLT, CD-ROM Proceedings of the World Conference on Timber Engineering (WCTE 2016), August 22-25, 2016, Vienna, Austria, Eds.: J. Eberhardsteiner, W. Winter, A. Fadai, M. Pöll, Publisher: Vienna University of Technology, Austria

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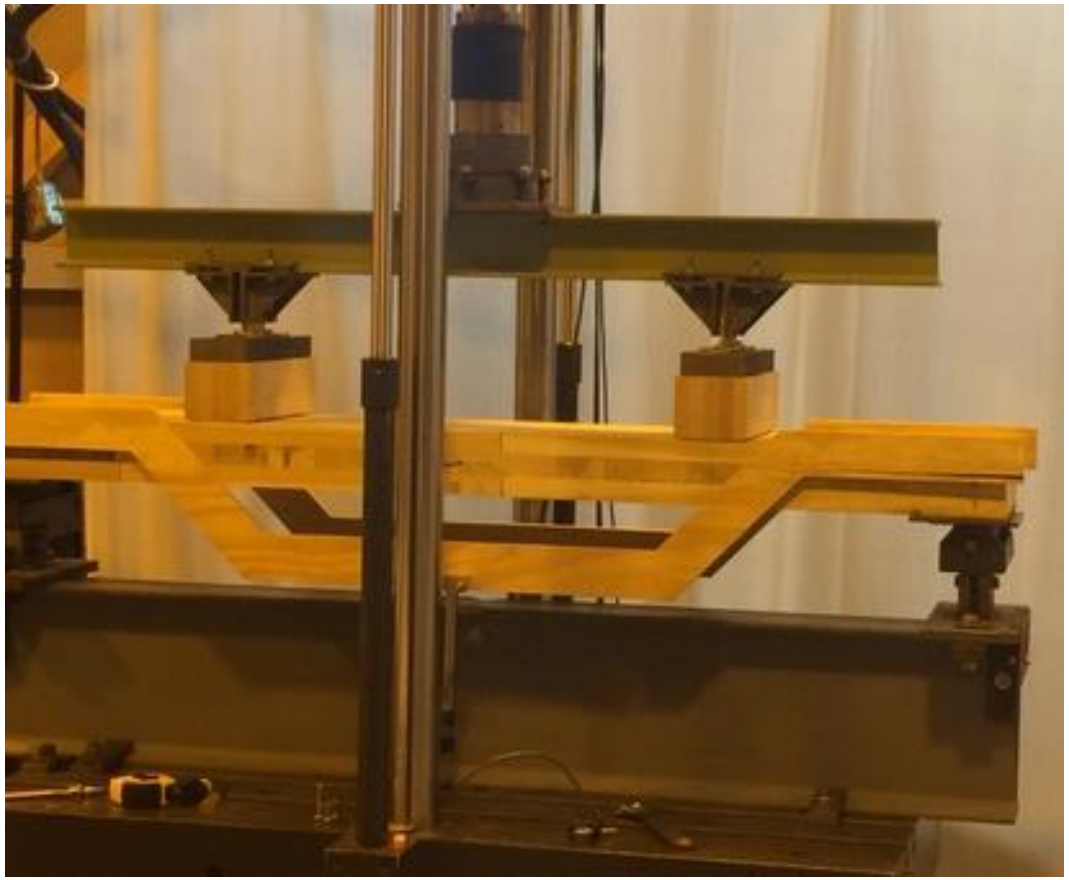
Yellow-Poplar CLT - USA

- VT, WVU
- 6/4 #2 Common Yellow-poplar
- SG = 0.48-0.50
- n = 24, 72x12x4.2 in, 3-ply, PF
- Tested according PRG320
- Bending stiffness and strength, and resistance to delamination exceeded required values
- Forms adequately strong and durable adhesive bonds

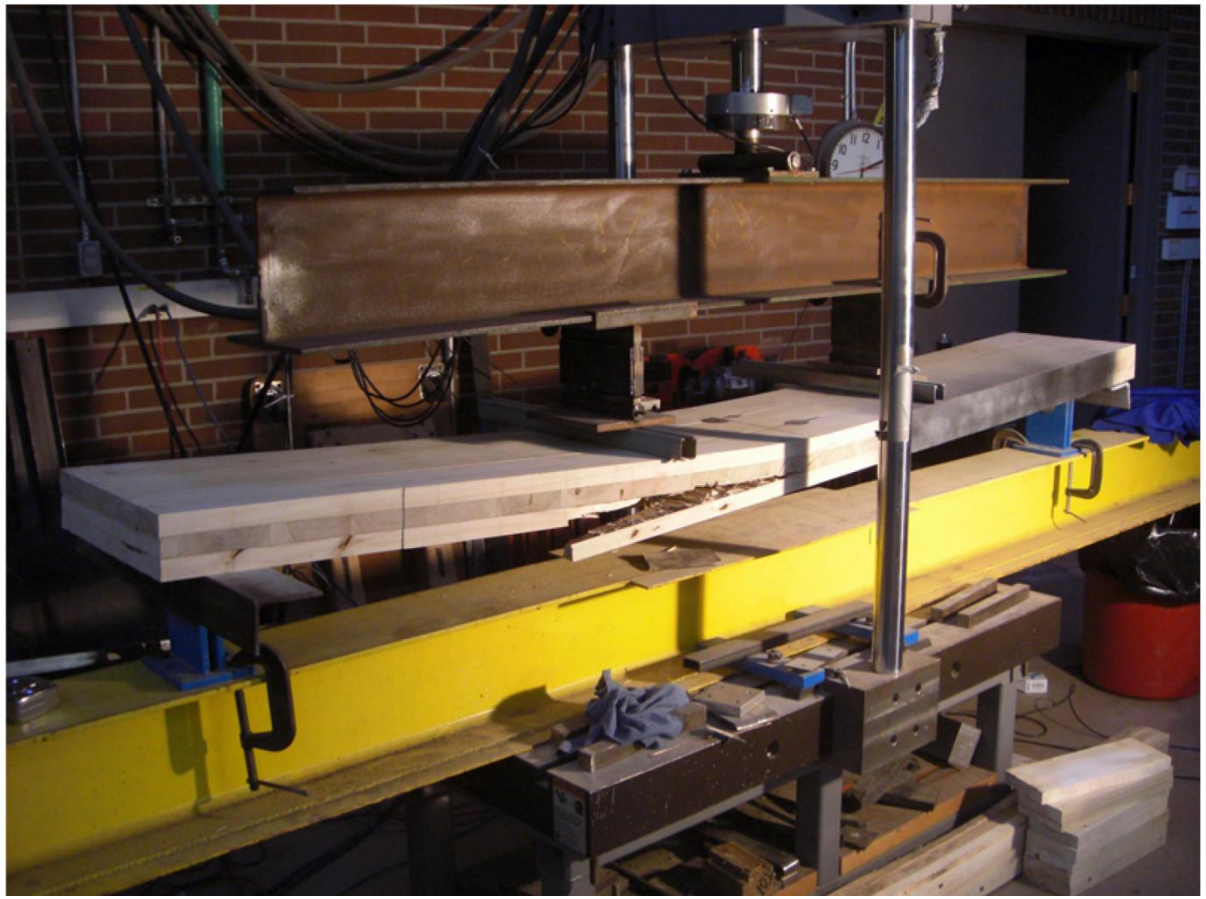


Mohamadzadeh, M., & Hindman, D. (2015). Mechanical Performance of Yellow-Poplar Cross Laminated Timber

Hovanec, D. (2015). Effect of Wood Characteristics on Adhesive Bond Quality of Yellow-Poplar for Use in Cross-Laminated Timbers. West Virginia University

Hybrid Poplar CLT - USA

- Oregon State University
- FSC-certified plantation hybrid poplar (Pacific Albus)
- SG = 0.347, No.2&Btr
- n=10, 100x16x3¼ in, 3-ply, PF
- Tested for PRG-320 compliance
- Met/exceeded shear and bending strength for CLT. Did not meet stiffness (MOE) needed



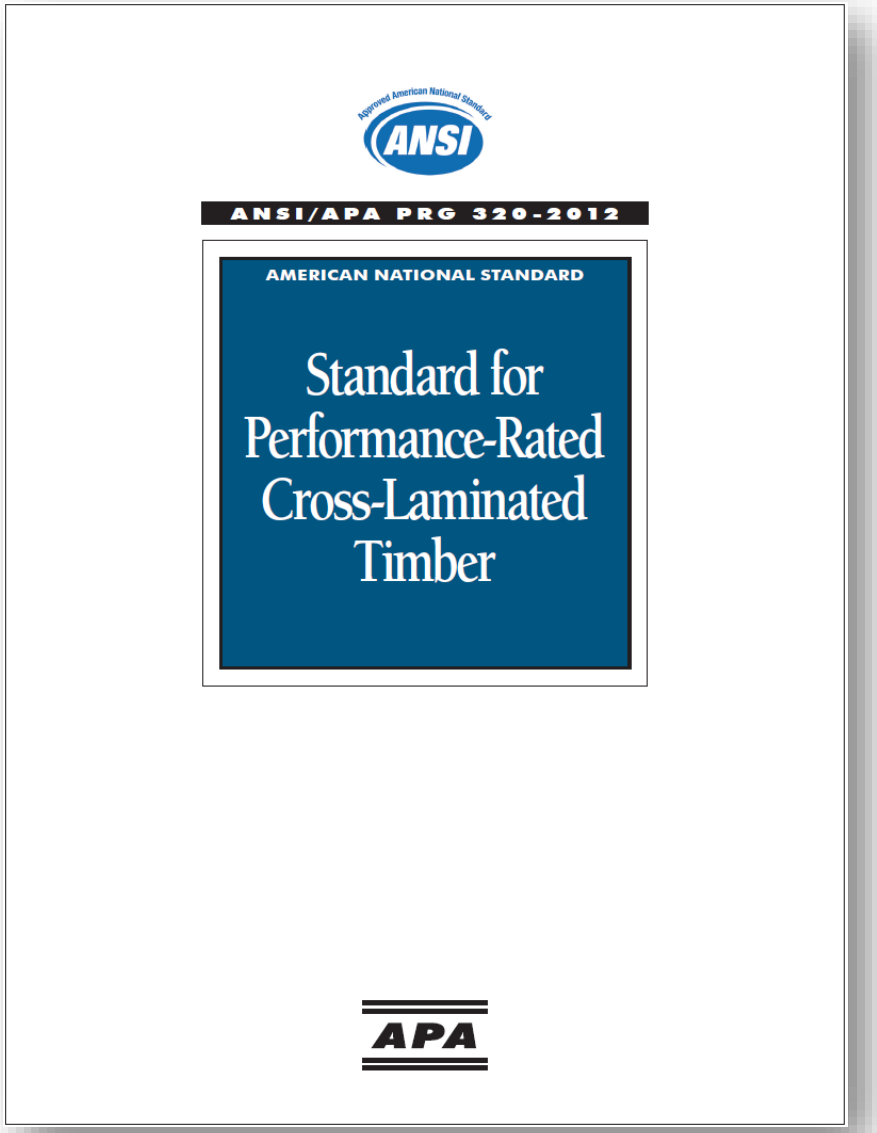
Kramer, A., Barbosa, A., & Sinha, A. (2014). Viability of Hybrid Poplar in ANSI Approved Cross-Laminated Timber Applications. Journal of Materials in Civil Engineering, 26(7)

HARDWOOD CLT IN THE U.S.
MAJOR ISSUES

"This standard provides requirements and test methods for qualification and quality assurance for performance rated cross-laminated timber (CLT) intended for use in construction applications."

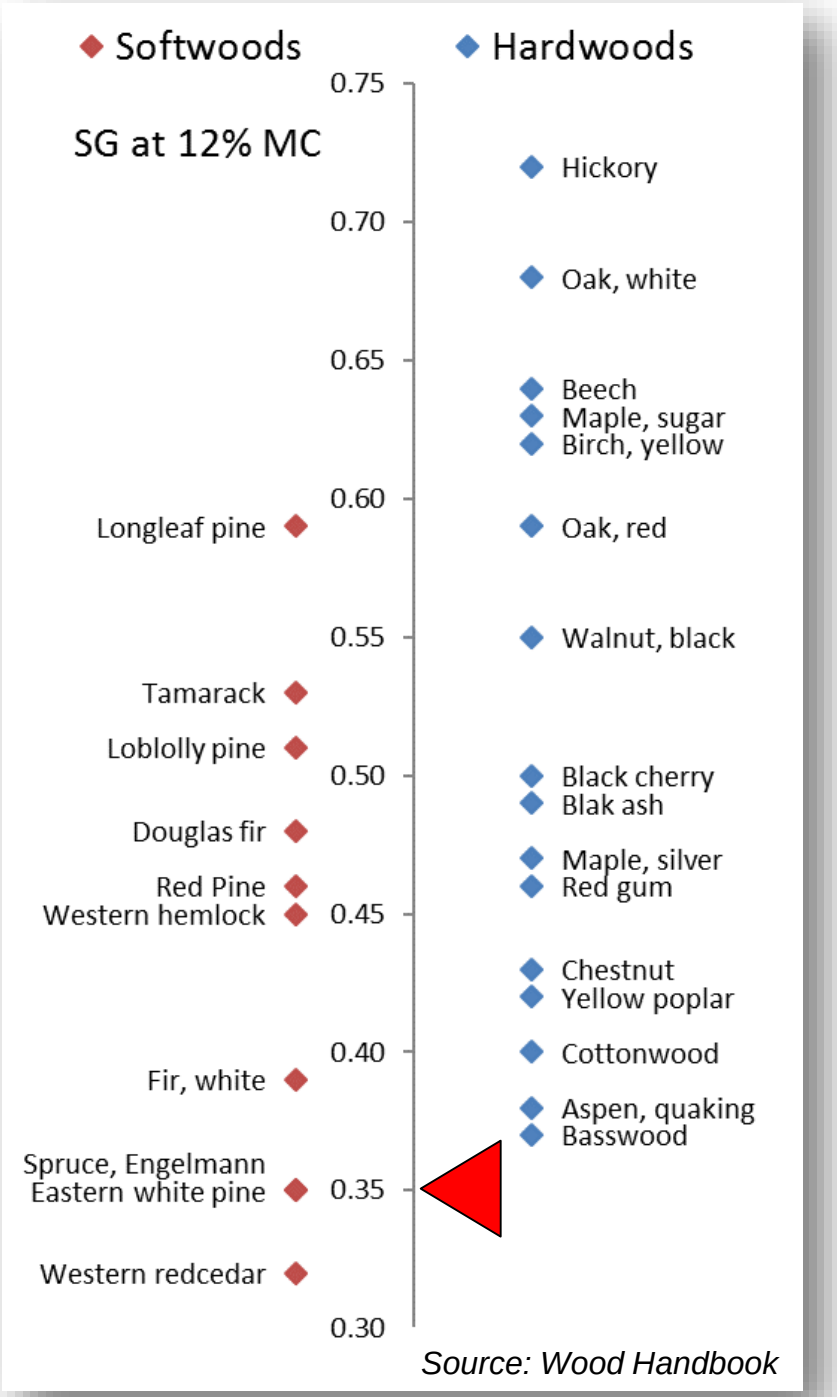
ANSI/APA PRG 320-2012

Standard for Performance-Rated Cross-Laminated Timber

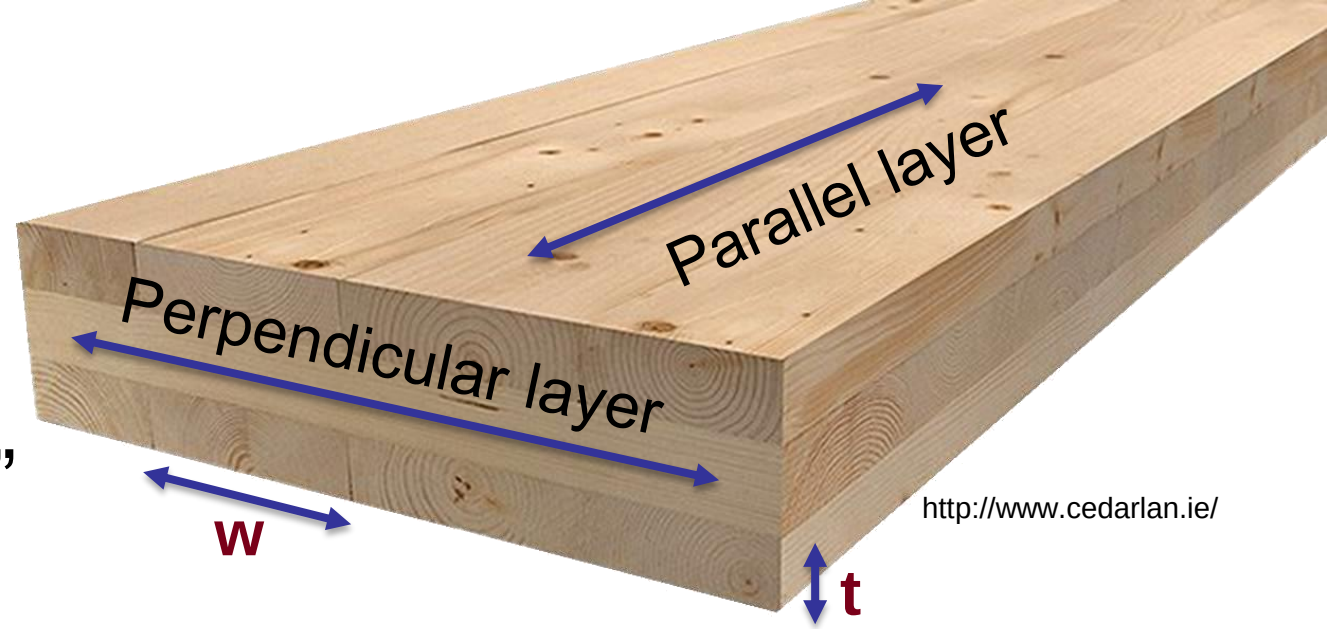


PRG320 - Material Considerations

- Any **softwood** recognized by ALSC
- Species: SG ≥ 0.35
  1 per layer
- Grades: #2&btr (//) , #3&btr (⊥)
- MC: 12 ± 3%
- Most hardwoods have SG > 0.35
- Hardwoods typically dried to low MCs



PRG320 - Material Considerations

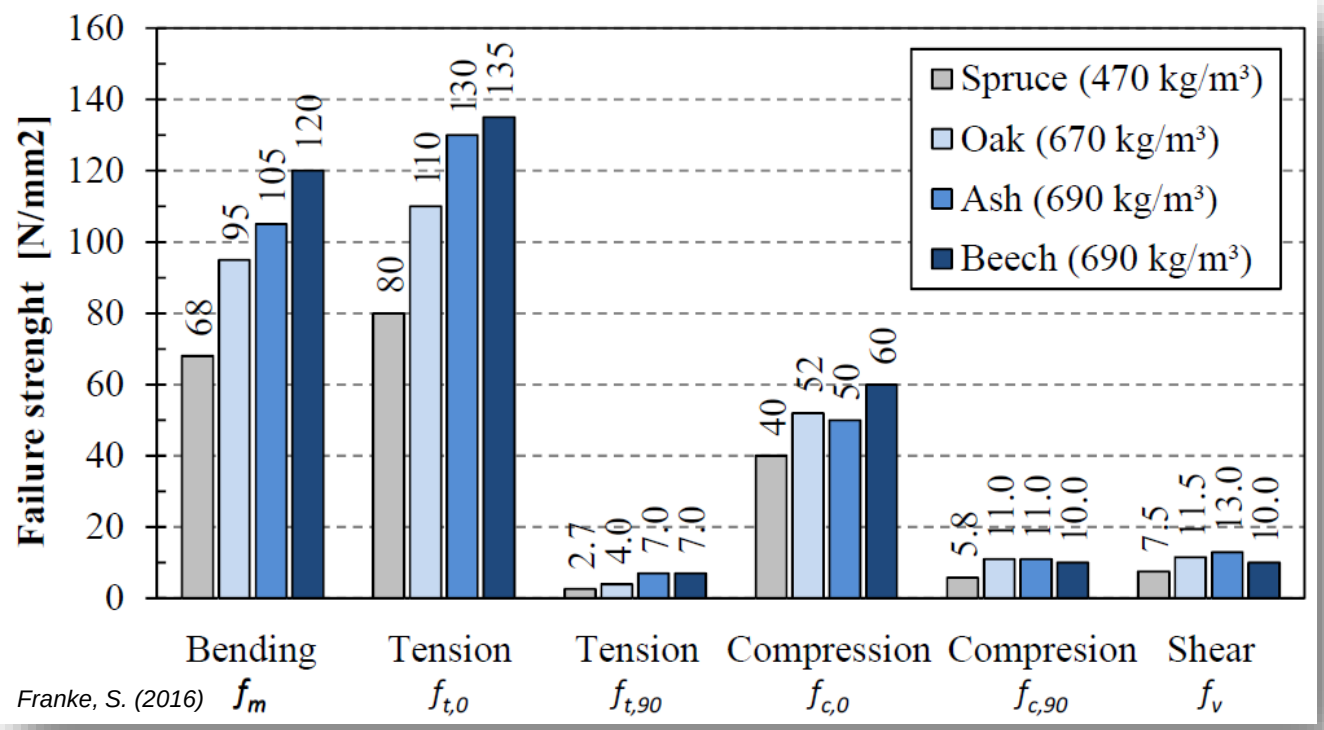


http://www.cedarlan.ie/

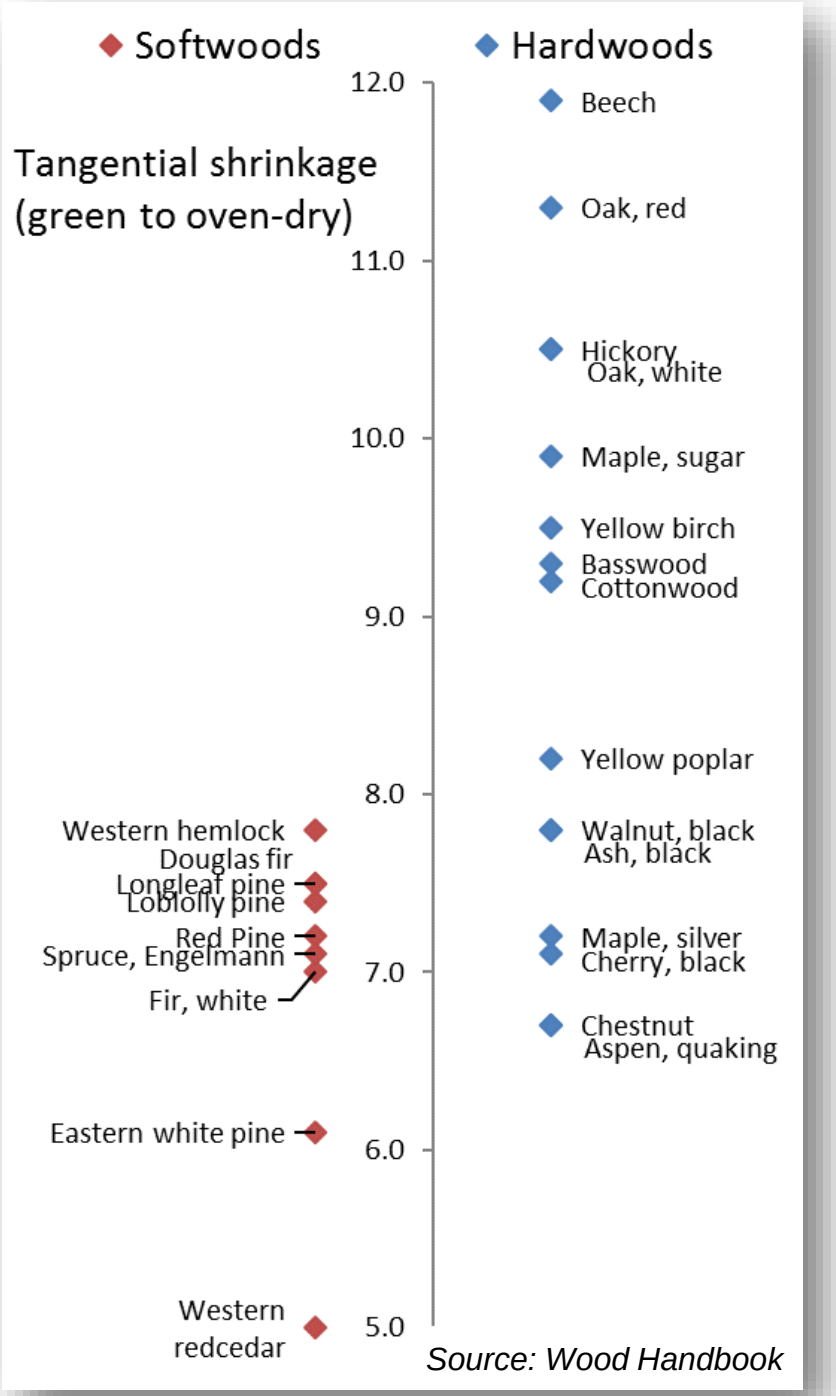
- Layer thickness: 5/8” ≤ **t** ≤ 2”
- Width of pieces:
  - Parallel layers w ≥ 1.75 × **t** (major strength)
  - Perpendicular layers w ≥ 3.5 × **t** (minor strength)
- For dimension lumber, this excludes:
  - Parallel: 2x2, 2x3; Perpendicular: 1x2,1x3, 2x2, 2x3, 2x4
- Hardwoods commonly sawn to 1” thickness

Material Considerations

- Shrinkage (hardwoods ~30% higher)
- Adhesion issues
- Mechanical properties

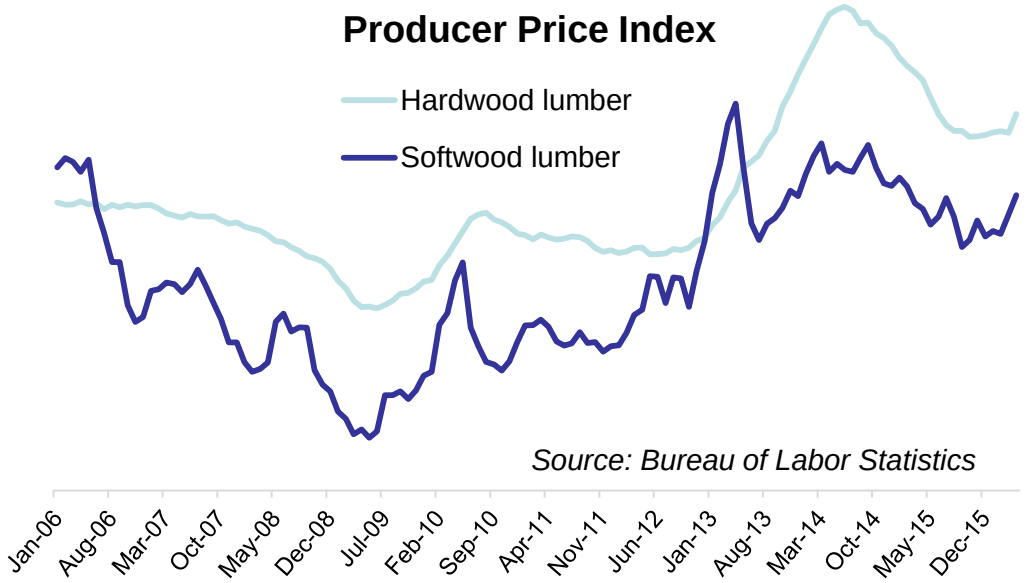


Franke, S. (2016)



Source: Wood Handbook

Cost Considerations



- Softwood lumber price: **$314**
  - #2&btr West SPF, KD (09.09.2016*)
- Hardwood lumber prices: **$510**
  - #2Com 4/4 poplar, KD (08.26.2016**)
- Wood is ~**50%** of CLT mfg. costs (glue is 10%)
- Europe: spruce CLT ~$700/$m^3$; beech ~$3,200/m^3
- CLT in general costs **10-15%** more than steel/concrete
  - However, structural frame is <20% of total building cost

* Random Lengths
** Hardwood Market Report

Hardwood CLT - Procurement Issues

- Is there enough wood to sustain a hardwood CLT industry?
- Average western dimension mill capacity ~180MMBF
- Considering width-thickness ratios, process factors, and lumber prices, some sizes and grades are favored.
- One large CLT plant (~24MMBF**) needs access to ~5 average dimension mills' supplies.
- However, average hardwood sawmill capacity ~6.7MMBF*
  - How much of mill's output suitable for CLT?

* Espinoza, O., Bond, B., & Buehlmann, U. (2011). Energy and the US hardwood industry - Part 1: Profile and impact of prices. Bioresources, 6(4), 3883-3898.
** Anderson, Roy (2016). Mass Timber Conference.

Summary

- Research/testing indicates that hardwood CLT for structural use is **technically feasible**
- Hardwood CLT, in general, has **better strength properties**.
  - Potential for smaller cross-sections, longer spans
- Major issues: **cost**, **procurement**, **gluing**, **grading**
- Inclusion in **ANSI/APA PRG320**
- Maybe **specific** uses; e.g., high loads, long spans, hybrids
- **Industry support** and long-term commitment needed!

Endless Stair


Endless Stair at Tate Modern ©dRMM


Endless Stair at Tate Modern ©dRMM


Endless Stair at Tate Modern ©dRMM

Slavid, R. (2013). Endless Stair. Retrieved from http://www.americanhardwood.org/news-events/endless-stair/

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http://www.cnn.com/2016/09/19/design/london-design-festival-the-smile-clt/index.html

Thanks!