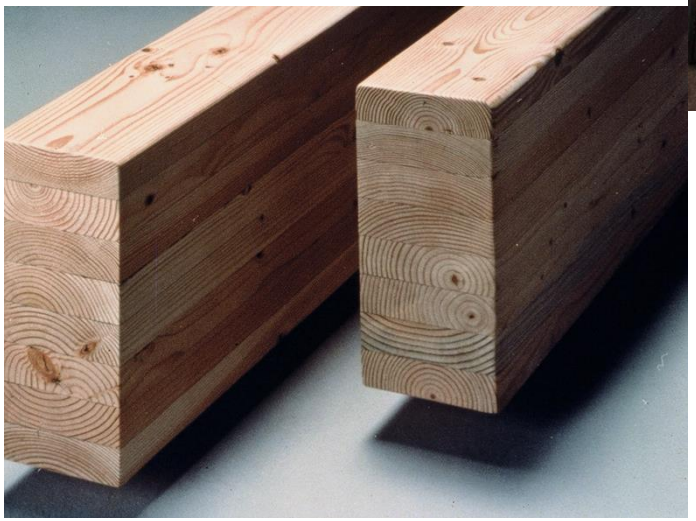


AMERICAN WOOD COUNCIL

Introduction to Mass Timber Construction

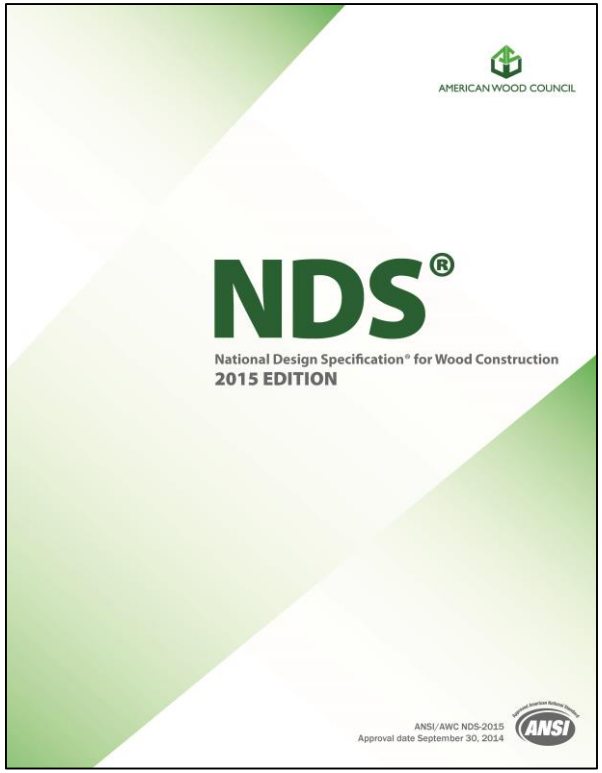
Paul Coats, PE, CBO
Southeast Regional Manager
American Wood Council

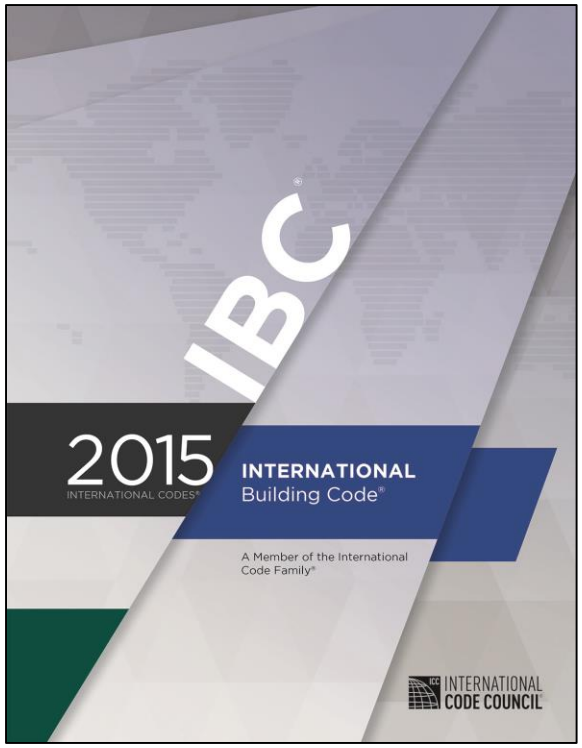
CONTINUING EDUCATION AIA

NCSEA STRUCTURAL ENGINEERS CONTINUING EDUCATION
Diamond Reviewed

ICC PREFERRED EDUCATION PROVIDER

American Wood Council





AWC is committed to ensuring a resilient, safe, and sustainable built environment.

Copyright Materials

Description

Cross-laminated timber (CLT) has been in use worldwide for over 15 years, but most notably in Europe. Building with CLT has increased in popularity for many reasons including: just-in-time fabrication and job site delivery, speed and efficiency in construction, reduced job site noise and on-site labor force, substitution of high embodied materials with a renewable resource that sequesters carbon, and creating a living or work space that has the aesthetics of exposed wood.

The recent introduction of CLT in the *2015 National Design Specification® for Wood Construction* (NDS®) and the *2015 International Building Code* has opened up an exciting new chapter in wood construction. The use of CLT alone or in combination with other mass timber elements, such as glued-laminated timber (GLT), nail-laminated timber (NLT), or structural composite lumber (SCL), is becoming more common in buildings complying with the current code. There is also an effort underway by the International Code Council (ICC) to recognize the use of mass timber elements in taller, combustible construction through the work of the ICC Tall Wood Ad Hoc Committee. This presentation will provide an introduction to CLT including relevant design standards and code references. Examples of various mass timber buildings around the world will be provided and potential future code provisions relating to mass timber will also be discussed.

Learning Objectives

At the end of this program, participants will be better able to

1. Define cross-laminated timber
2. Identify code and standard updates relevant to CLT and other mass timber elements
3. Recognize notable mass timber structures around the world
4. Understand how wood performs in fire conditions
5. Comprehend current tall wood building code developments and resources

Cross-laminated Timber (CLT)

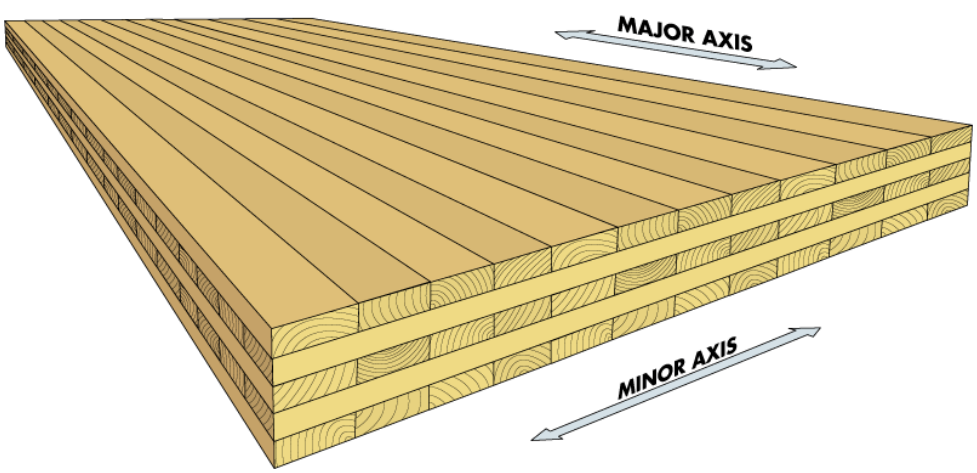
Photo provided by FPInnovations

Mass Timber Concept - History of CLT

- 1985 1st CLT patent - France
- 1993 1st CLT projects - Switzerland and Germany
- 1995-1996 Improved press technology
- 1998 1st multi-story res building - Austria
- Early 2000's
  - CLT use (Europe) increased significantly
  - Green building movement driven
  - Better efficiencies, product approvals, improved marketing and distribution channels
  - Over 500 CLT buildings in England
- Recent - US and Canadian use of CLT

CLT vs. GLT

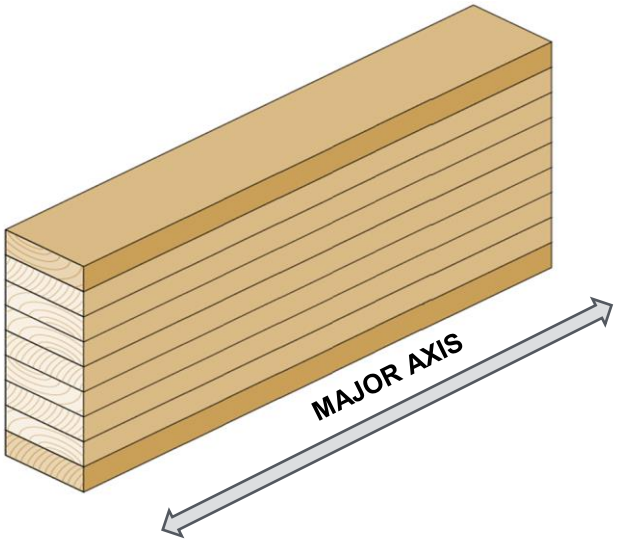
Cross Laminated Timber



Thick Orthotropic Plate

Graphics provided by WoodWorks

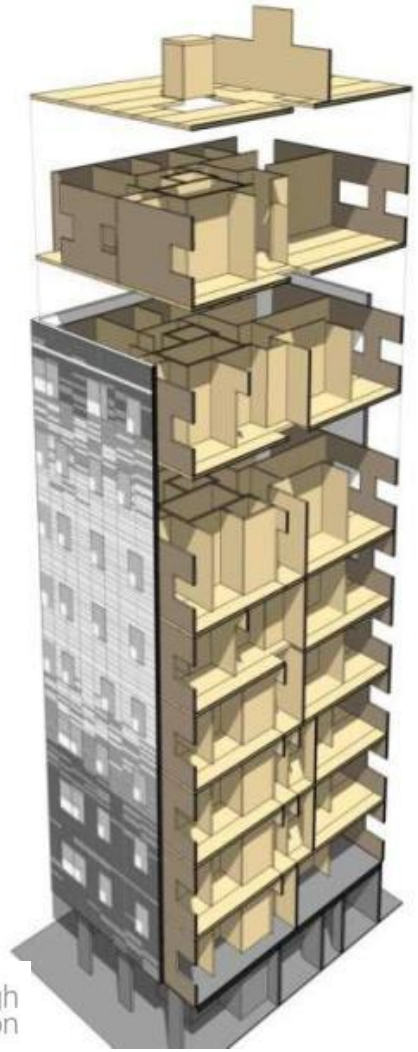
Glued Laminated Timber



Beam-like member

Graphics provided by APA

Climate Change



Stradthaus – 24 Murray Grove
London infill project
29 flats
4x less weight than concrete
~1/2 construction time of precast concrete (saved 22 weeks 30%)
Saves 300 metric tons of CO2
21 years of building energy usage

THE CASE FOR Tall Wood BUILDINGS How Mass Timber Offers a Safe, Economical, and Environmentally Friendly Alternative for Tall Building Structures FEBRUARY 22, 2012 PREPARED BY: mgb ARCHITECTURE + DESIGN; Equilibrium Consulting; LMDG Ltd; BTY Group

Mass Timber – US

Elementary School, Franklin, West Virginia

Source: LignaTerra

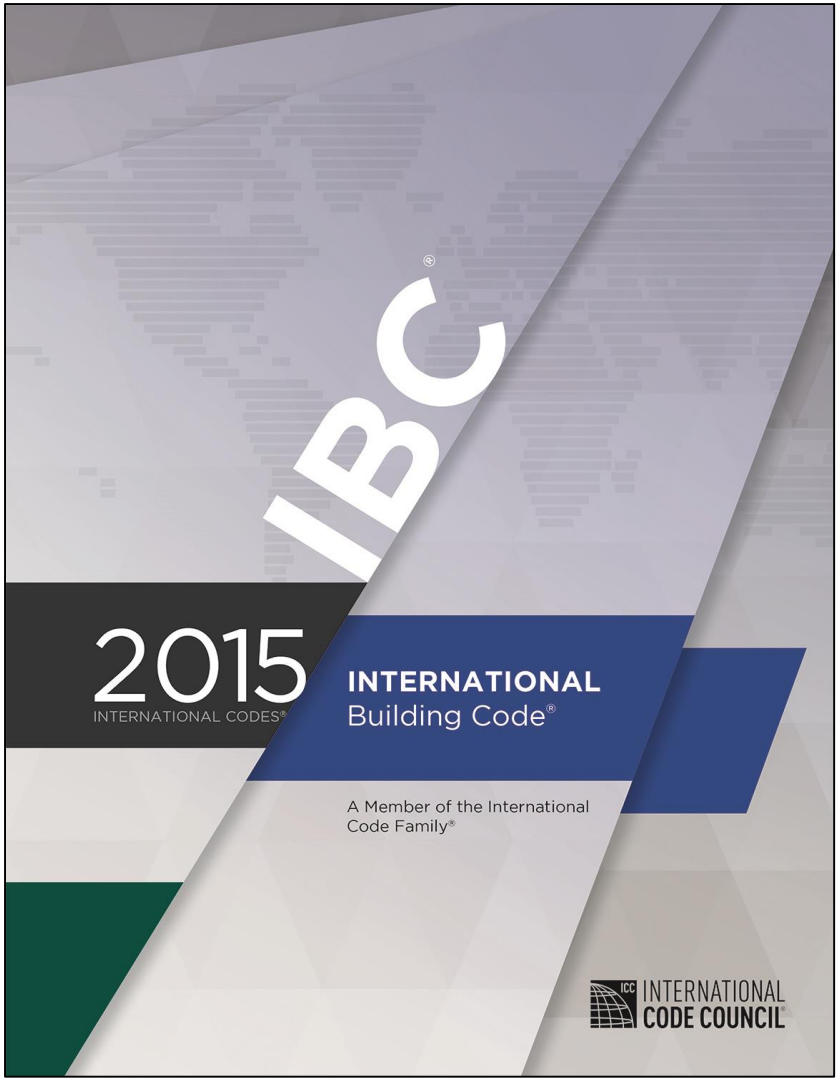
Mass Timber – US

Private Army Hotel
Redstone Arsenal Huntsville, AL

Source: LignaTerra

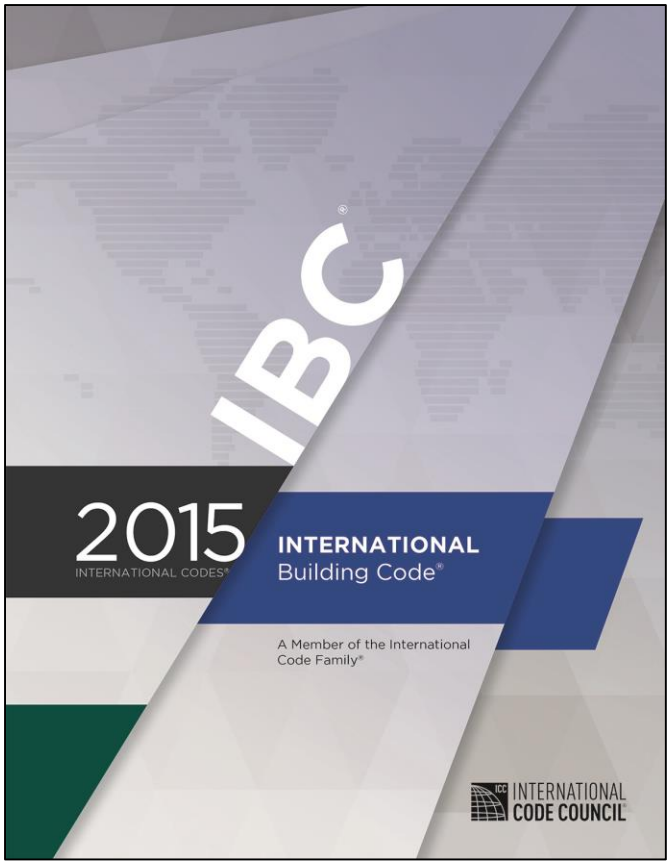
Four stories 58,000 sq ft
Architect: Lend Lease

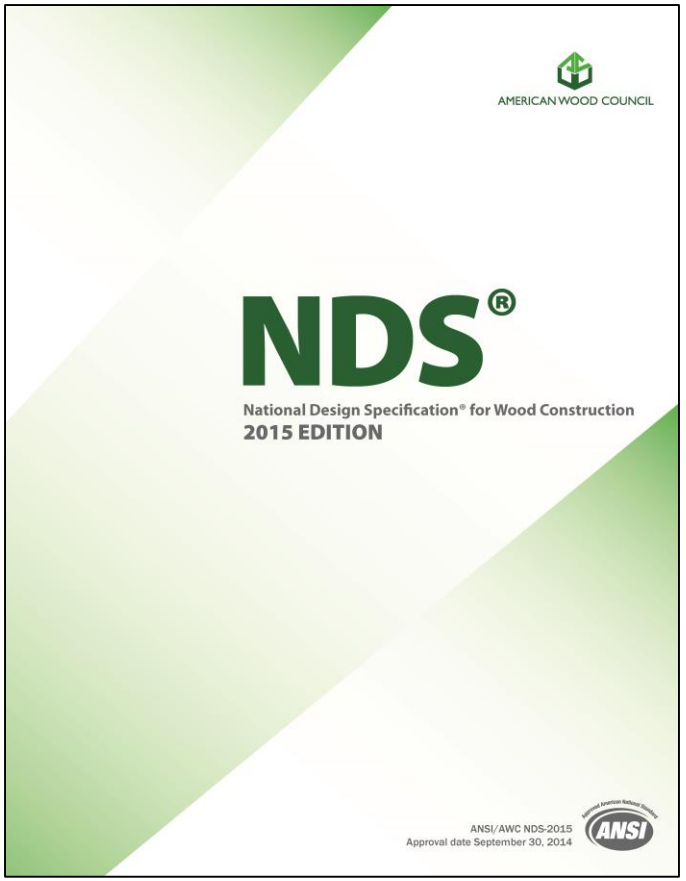
Building Codes



Governing Codes for Wood Design

2015 IBC references in 2015 NDS

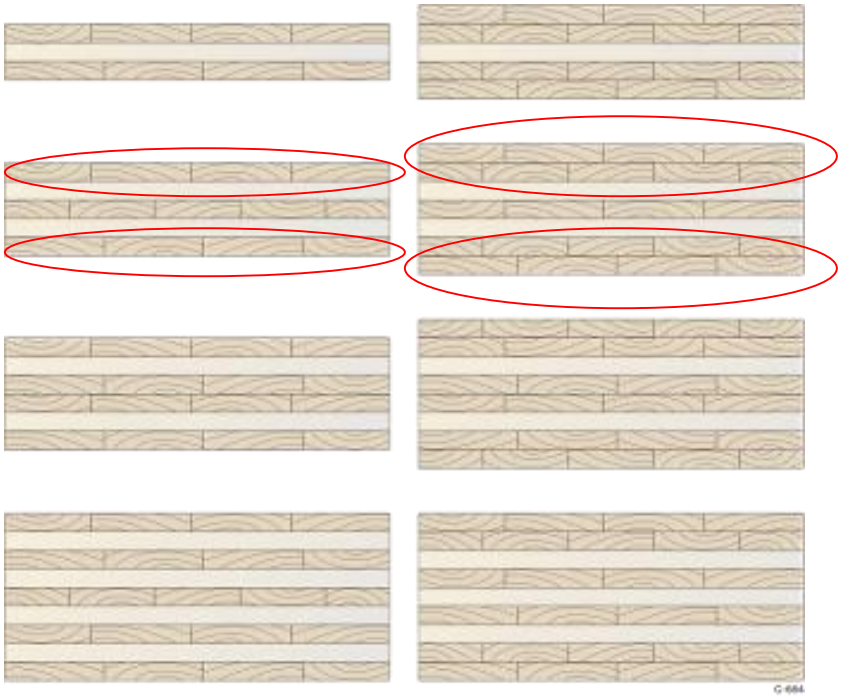


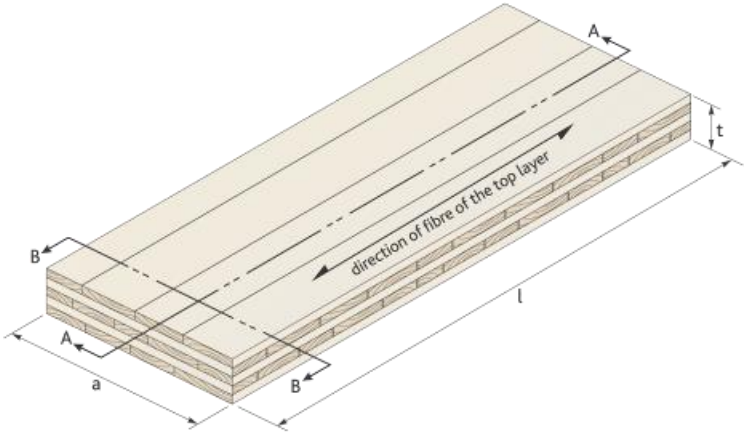


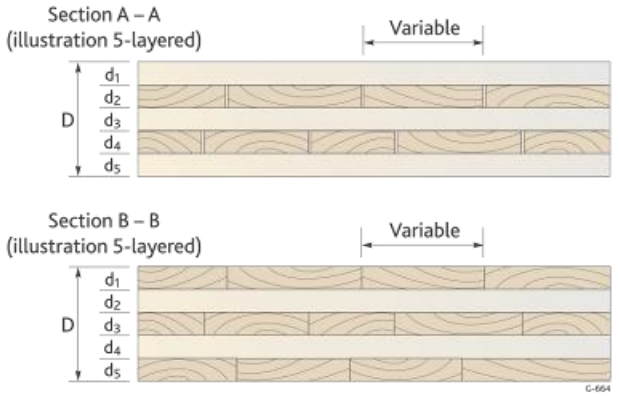
Chapter 10 – Cross-Laminated Timber

1, 2, 3, 4 transverse layers

Single or multiple surface layers







Laminations: 5/8”-2” sawn lumber or SCL
Panel thickness: 20” max
In-Service MC: 16%

Graphics provided by FPInnovations

Chapter 10 – Cross-Laminated Timber

New

10.1 General

10.1.1 Application

10.1.1.1 Chapter 10 applies to engineering design with performance-rated cross-laminated timber.

10.1.1.2 Design procedures, reference design values and other information provided herein apply only to performance-rated cross-laminated timber produced in accordance with ANSI/APA PRG-320.

10.1.2 Definition

Cross-Laminated Timber (CLT) – a prefabricated engineered wood product consisting of at least three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross-oriented and bonded with structural adhesive to form a solid wood element.

10.1.3 Standard Dimensions

10.1.3.1 The net thickness of a lamination for all layers at the time of gluing shall not be less than 5/8 inch or more than 2 inches.

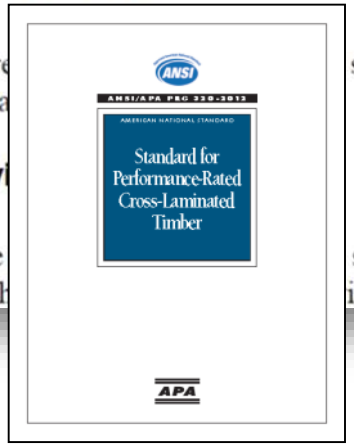
10.1.3.2 The thickness of cross-laminated timber shall not exceed 20 inches.

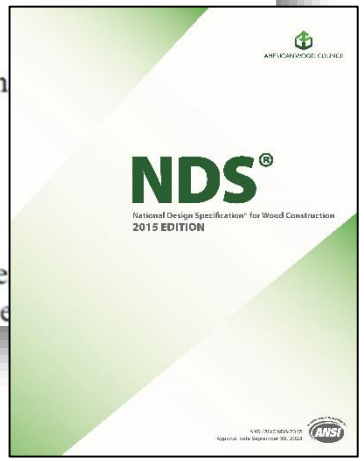
10.1.4 Specification

All require… sh… fied in accorda…

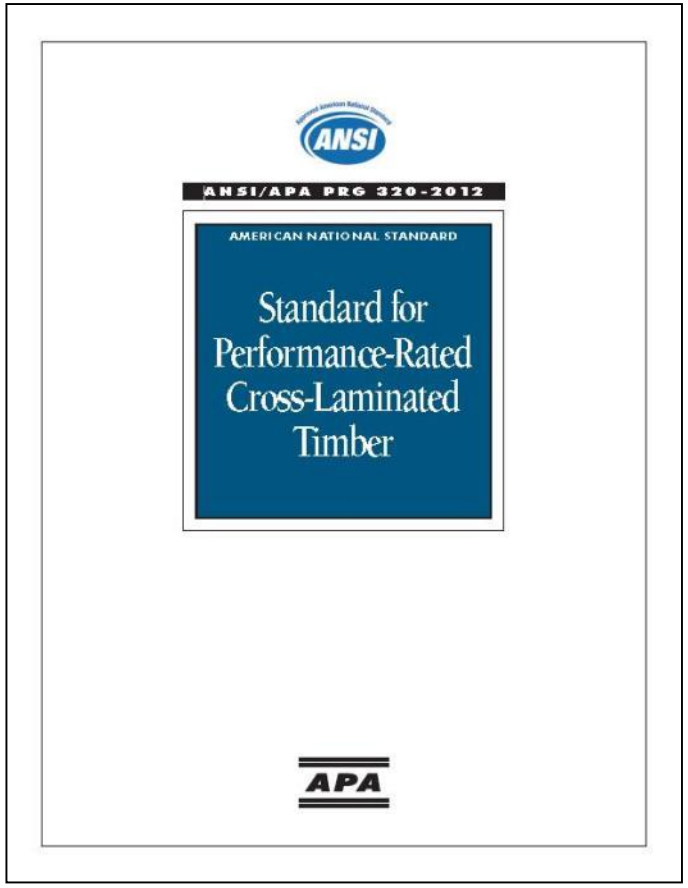
10.1.5 Servi…

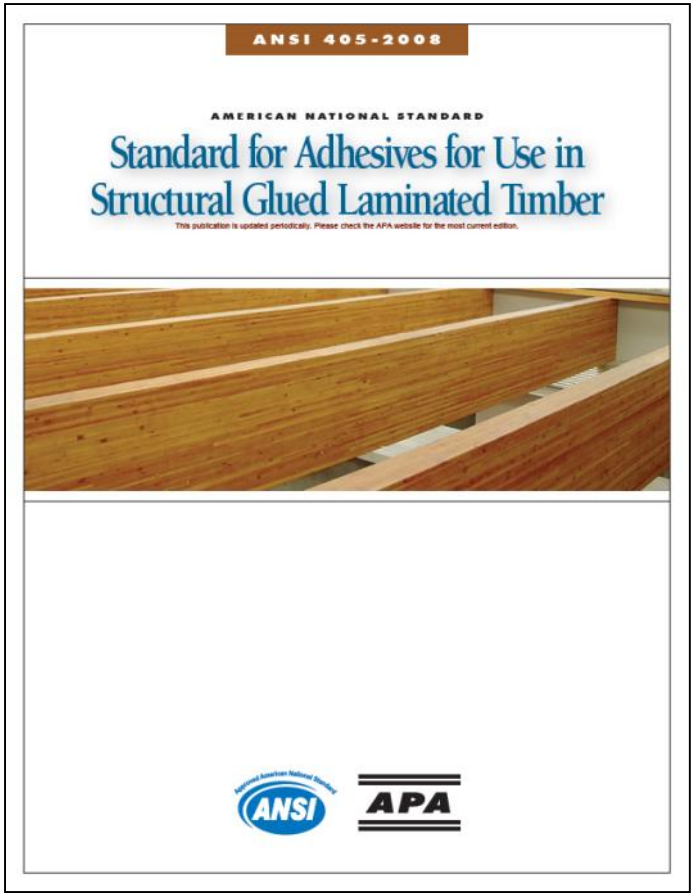
Reference … se… tions, where th… ice…





GLT and CLT Adhesives





Product Marking

Marks contain the following:

a) CLT grade qualified

b) CLT thickness or identification

c) Mill name or identification number

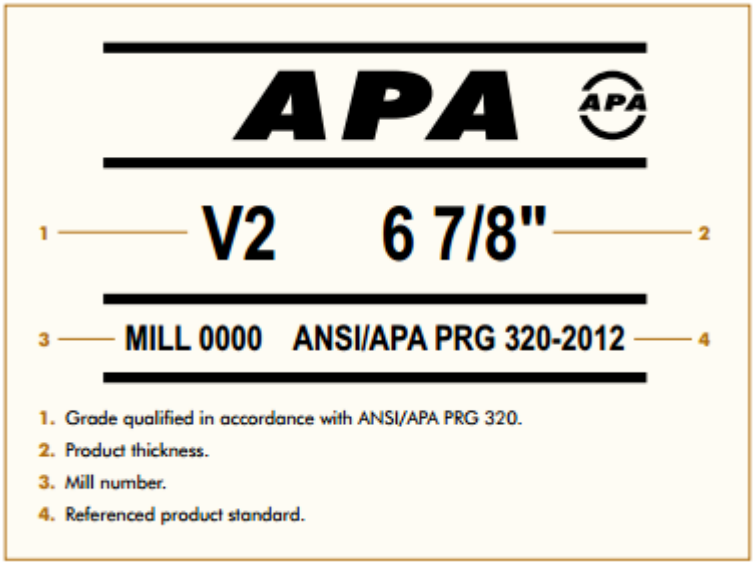
d) Approved agency name or logo

e) "ANSI/APA PRG 320"

f) Manufacturer's designation

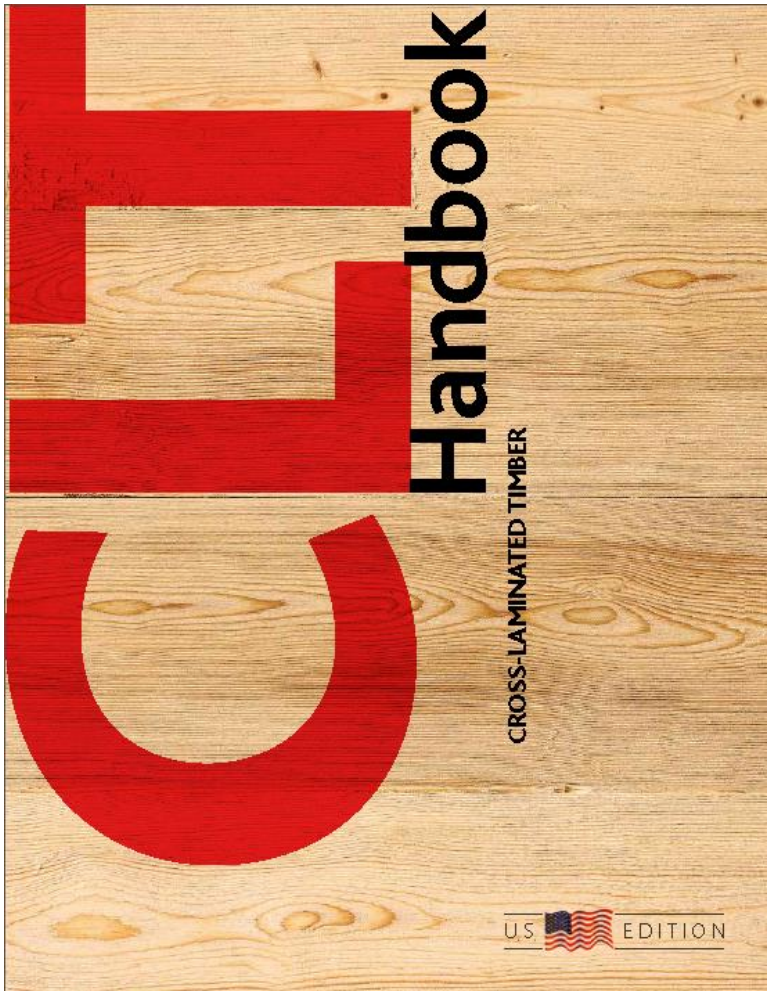
g) "Top" stamped on top face

(For unbalanced layups)



CLT Handbook

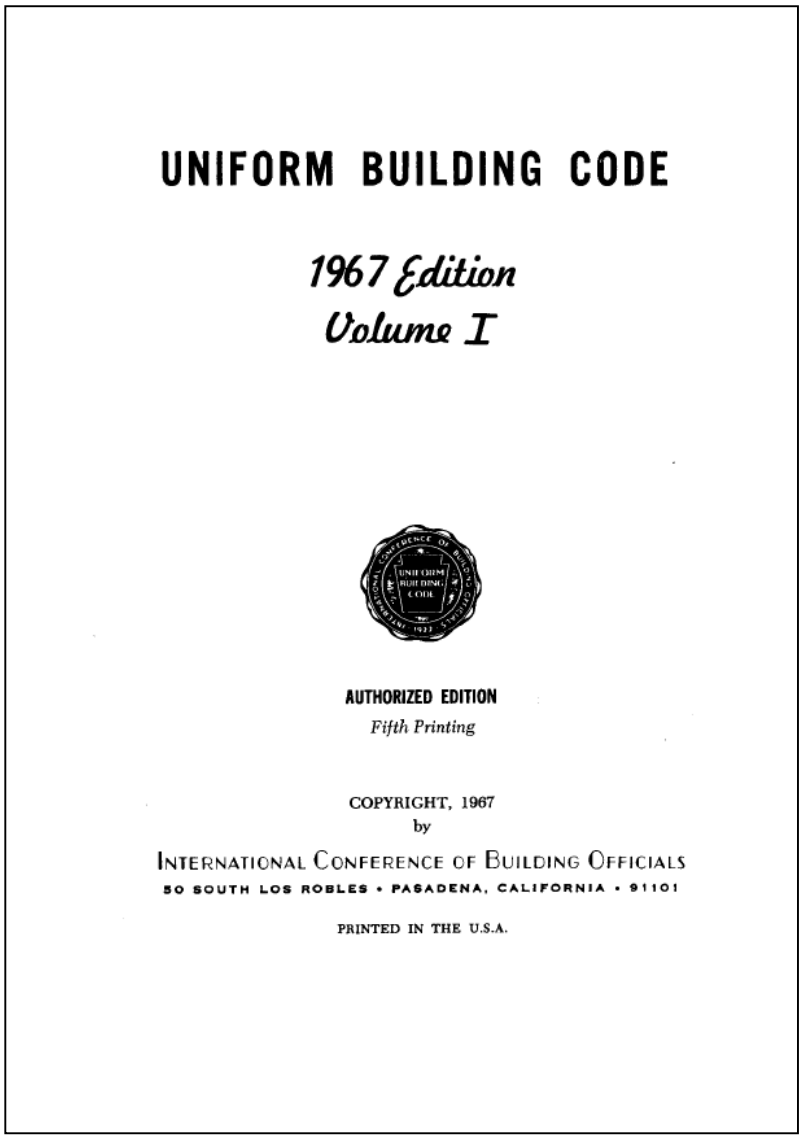
- **Additional information on issues not yet covered in NDS or IBC**
  - Energy
  - Sound
  - Vibration
  - Enclosures
  - Handling



Nail Laminated Timber (NLT)

Photo courtesy of Structurecraft

Nail-Laminated Timber



UNIFORM BUILDING CODE

1967 Edition
Volume I

AUTHORIZED EDITION
Fifth Printing

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS
50 SOUTH LOS ROBLES • PASADENA, CALIFORNIA • 91101

PRINTED IN THE U.S.A.

(g) **Mechanically Laminated Floors and Decks.** A laminated lumber floor or deck built up of wood members set on edge, when meeting the following requirements, may be designed as a solid floor or roof deck of the same thickness, and continuous spans may be designed on the basis of the full cross section using the simple span moment coefficient.

Laminations shall be driven up and spiked closely together with a row of nails near each edge at spaced intervals and staggered vertically. Nail spacing in each row shall not exceed eighteen inches (18") for two-inch by eight-inch (2" x 8") nominal width and be proportional for other plank widths. Nail length shall be not less than two and one-half times the net thickness of each lamination.

A single span deck shall have all laminations full length.

A continuous deck of two spans shall have not more than every fourth lamination spliced within quarter points adjoining supports.

A continuous deck of more than two spans shall have not more than every third lamination spliced within quarter points adjoining supports.

Joints shall be closely butted over supports or staggered across the deck but within the adjoining quarter spans.

No lamination shall be spliced more than twice in any span.

Nail-Laminated Timber

- **2304.8.3 Mechanically laminated decking.**
- **2304.8.3.1 General.**
- **2304.8.3.2 Nailing.**
- **2304.8.3.3 Controlled random pattern.**

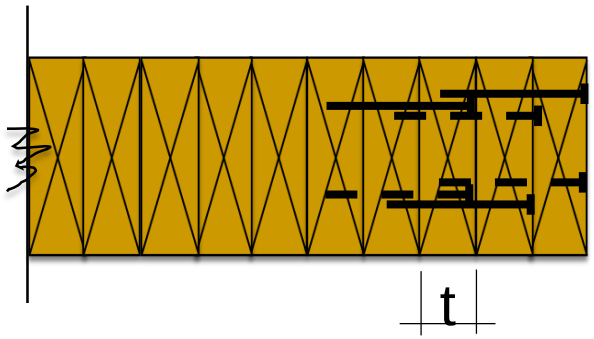
Nail $length_{min}$ = 2.5 x $t_{lamination}$

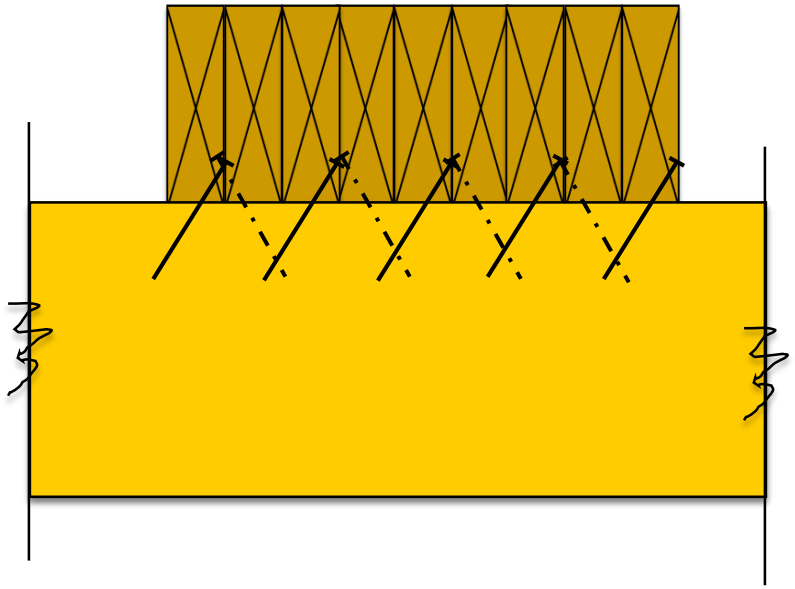
Nail spacing

≤ 30″ o.c.* 48″ span

≤ 18″ o.c.* > 48″ span

*nail placement alternates between top and bottom





Warner Drive – Culver City, CA

- Nail-Laminated Timber – 2x12 vertical mechanically-connected w/nails
- NDS principles of mechanics

Architect: Profeta Royalty Architecture
Structural Engineer: Structural Focus
Completed: 2011

Nail-Laminated Timber

- **Clay Creative**
  - Portland, Oregon
    - Mixed-Use
    - 72,000 SF
    - 6 Story (5 over 1 plus 1 level partial below grade parking)

Developer: Killian Pacific
Architect: Mackenzie
Structural Engineer: Kramer Gehlen & Associates
Completion: 2016

Nail-Laminated Timber

- **The Hudson**
  - Vancouver, WA
    - Mixed-Use
    - 45,000 SF
    - 3 story

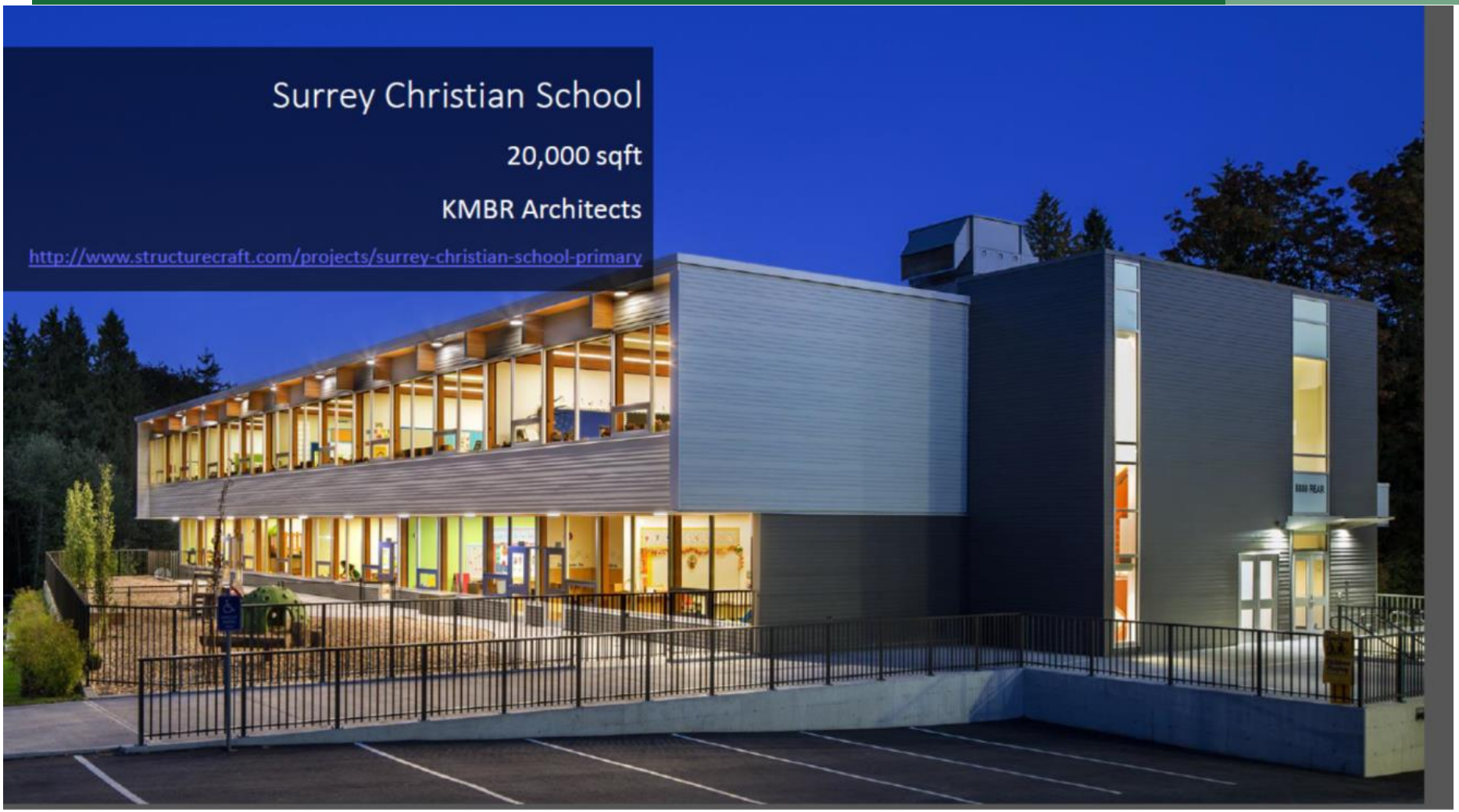
Developer: Killian Pacific
Architect: Mackenzie
Completion: 2016


ORIGINAL
NEW YORK
SELTZER

Nail-Laminated Timber

Resource: StructureCraft

Nail-Laminated Timber



Resource: StructureCraft

General Contractor: **Companion**
Location: **Surrey, British Columbia, Canada**
Design Assist, Fabrication and Installation: **StructureCraft**
Completion: **2013**

Glued-laminated Timber (GLT)


BLUE STAR

Glued-laminated Timber

- **One North**
  - Portland, Oregon
    - Mixed Use
    - East Bldg. 43,000 SF
    - West Bldg. 43,000 SF

Development Team: Karuna Properties II, LLC; Nels Gabbert, LLC; Kaiser Group Inc.; Owen Gabbert, LLC
Contractor: R&H Construction
Architect: Holst Architecture
Structural Engineer: Froelich Consulting Engineers
Completion: 2016

Glued-laminated Timber

Structural Composite Lumber (SCL)

Photo provided by Truss Joist

Photo provided by Weyerhaeuser

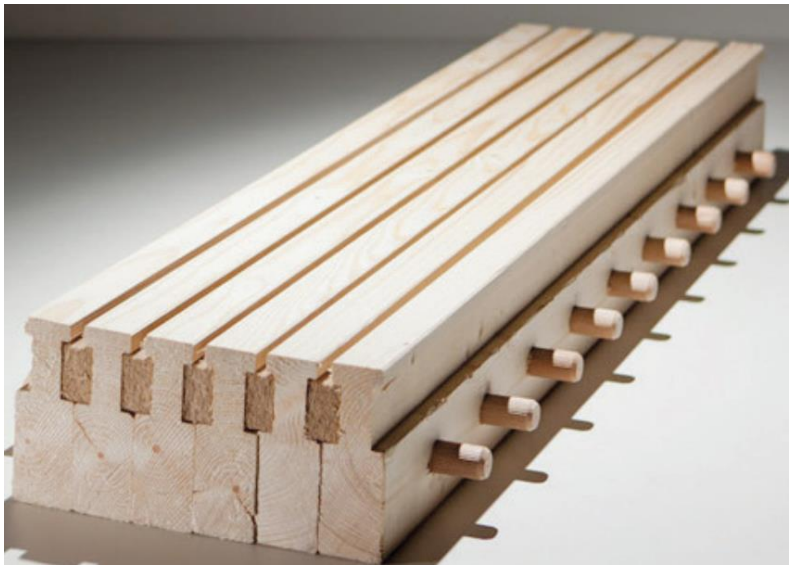
- PSL
  - parallel strand lumber
- LSL
  - laminated strand lumber
- LVL
  - laminated veneer lumber
- OSL
  - oriented strand lumber

Photo provided by Structurecraft

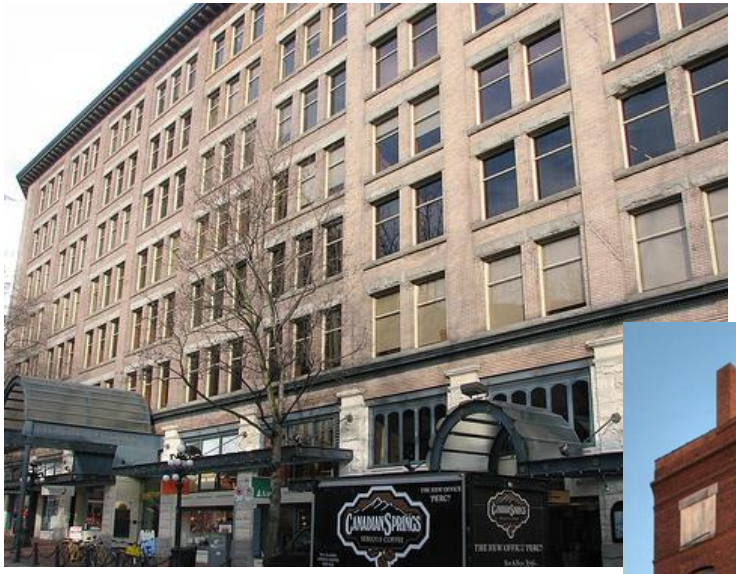
Photo provided by Wood Solutions

Other Innovations

- **Dowel Laminated Timber**
- **Wood-Concrete Composites**



Historical Tall Wood

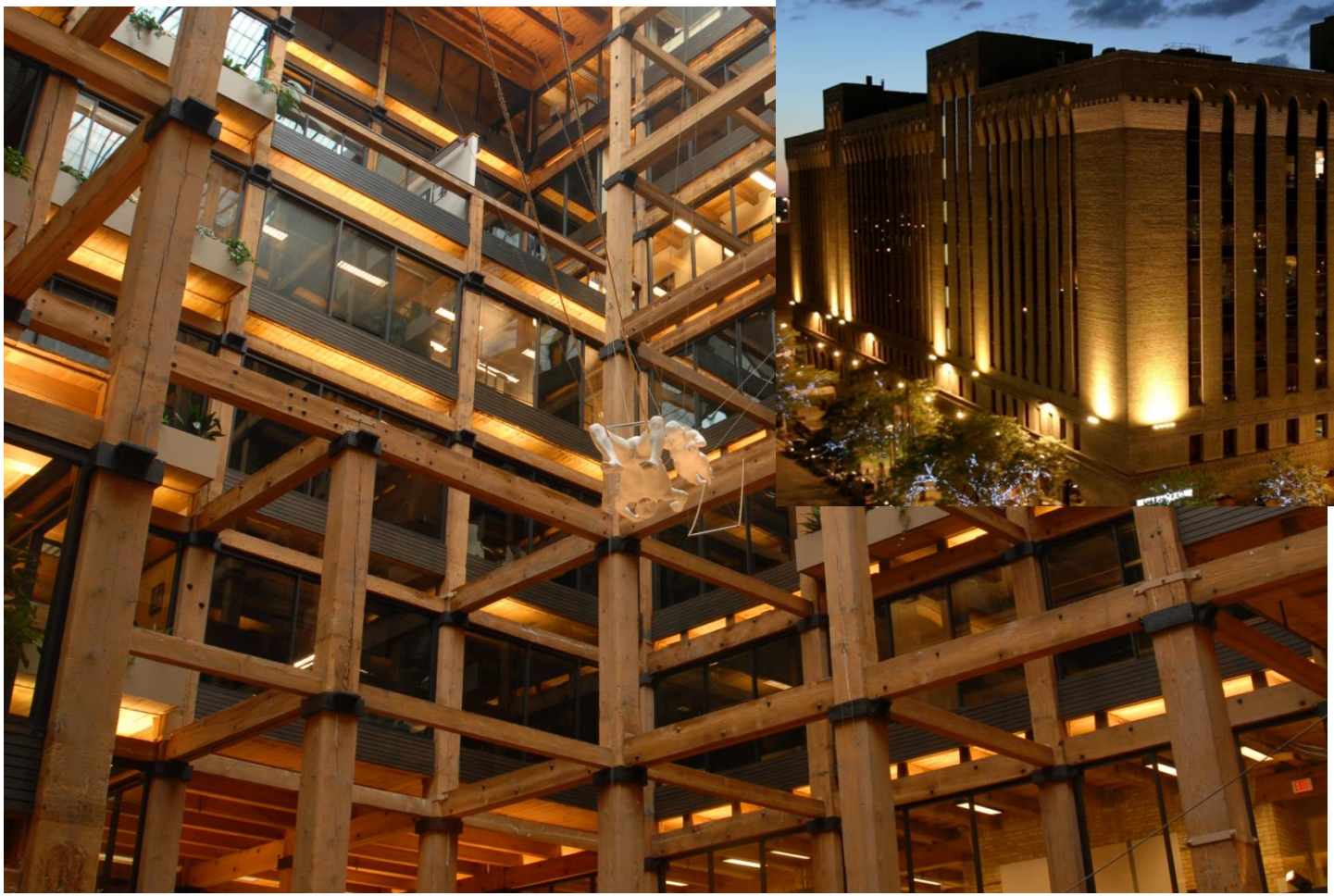


Kelly, Douglas and Co. Warehouse; Vancouver , BC (c. 1905)

The Purse Building, Dallas, TX, (c. 1905)

Leckie Building, Vancouver, BC (c. 1908)

Butler Brothers Building – Minneapolis - 1906



From *Designing for Durability* – reThinkWood.com
Building interior: Preservation Alliance of Minnesota; Building exterior: Butler Square

US Projects

- **Framework**
  - Portland, Oregon
    - 12 Story
      - Currently tallest Wood Building in US
    - Street-level retail, office, workforce housing and community space
    - U.S. Tall Wood Building Prize Competition winner *

Photo provided by Next Portland

http://www.nextportland.com/2016/07/21/framework-dz1/

* Sponsored by the U.S. Department of Agriculture, the Softwood Lumber Board and the Binational Softwood Lumber Council

Mass Timber – US

Mixed retail/office space

Minneapolis, Minnesota

- T3 Project
- 7 Stories
  - https://vimeo.com/162580838

US Projects

Carbon 12

- Portland, Oregon
  - 8 Stories
  - Residential tower

http://www.nextportland.com/2015/05/14/carbon12/

Canadian Projects

The Arbora

- Québec, Canada
  - 8 Stories
  - 434 Residential condo, townhouse and rental units

The Arbora

Canadian Projects

Brock Commons

- Vancouver, British Columbia, Canada
  - 18 Stories
  - Mixed use student housing

Tall Wood Worldwide

reTHINK WOOD®

TALL WOOD GALLERY

Over the past several years, a number of tall wood projects have been completed around the world, demonstrating successful applications of new wood and mass timber technologies. Here are several of the most recent projects.

If you know of any new tall wood projects, please let us know at info@reThinkWood.com.

Click on the building images below for more details.

http://www.rethinkwood.com/tall-wood-mass-timber/tall-wood-gallery

45

Heavy Timber Fire Resistance Rating

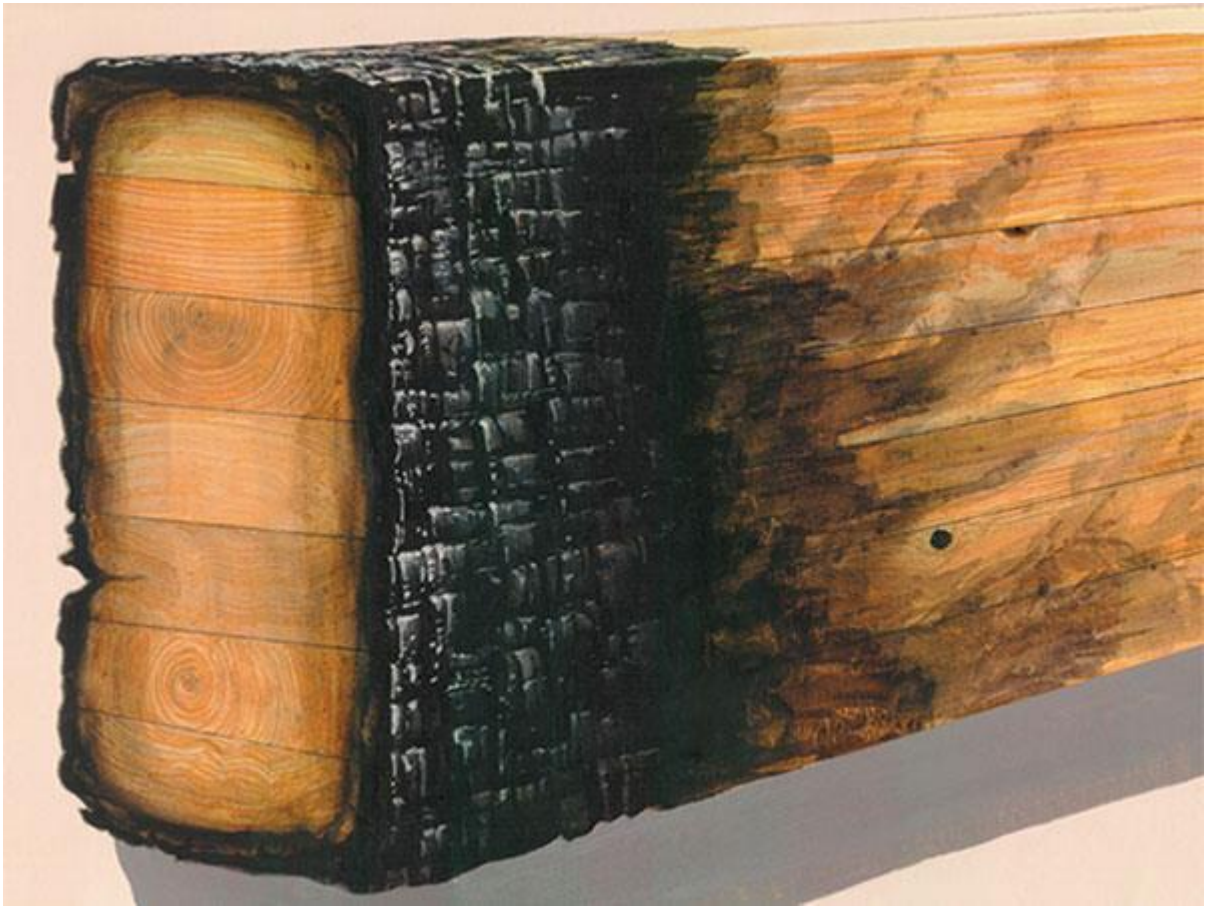
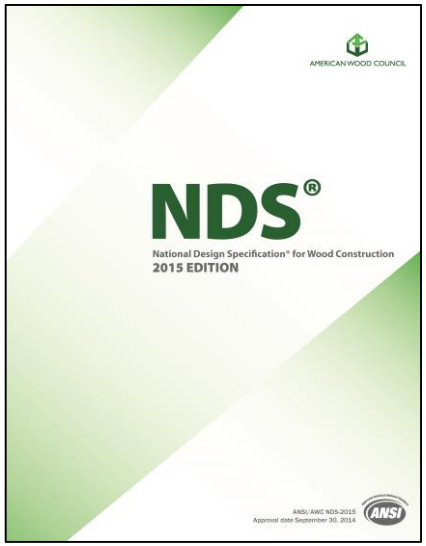
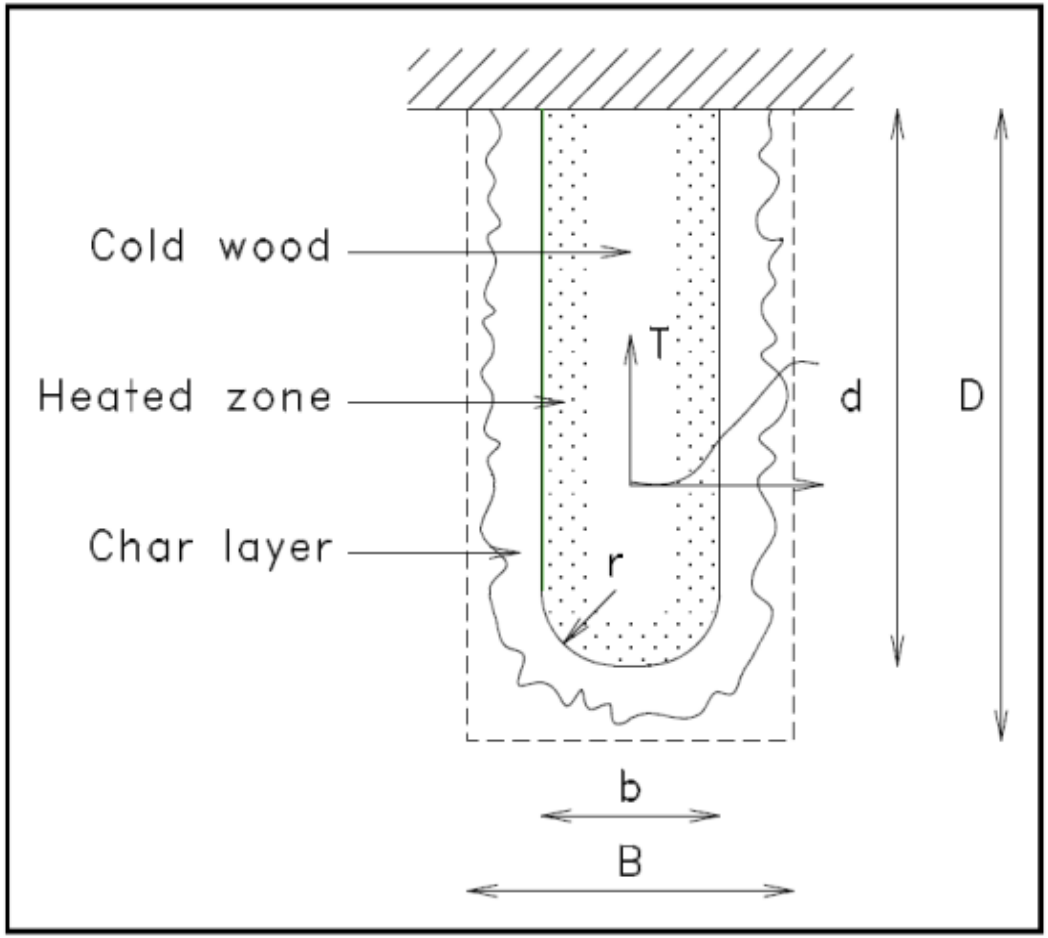


Photo by Structure Magazine

NDS Chapter 16 – Calculated Resistance

- **Fire resistance of exposed wood members may be calculated using the provisions of NDS Chapter 16**

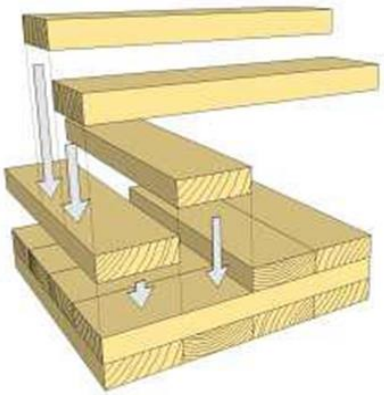




Predictable

Fire Design of Exposed Wood Members

New $$a_{char} = 1.2\left[n_{lam}\, h_{lam} + \beta_n \left(t - \left(n_{lam}\, t_{gi}\right)\right)^{0.813}\right]$$



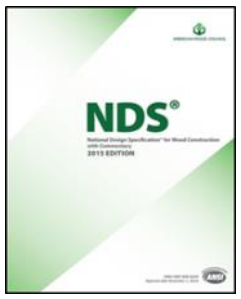
Cross-laminated Timber-Effective Char Depth

$$t_{gi} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$$

t_{gi} = time for char front to reach glued interface (hr.)

h_{lam} = lamination thickness (in.)

$$n_{lam} = \frac{t}{t_{gi}}$$



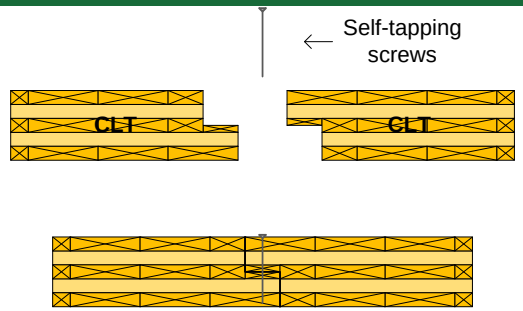
n_{lam} = number of laminations charred (rounded to lowest integer)

t = exposure time (hr.)

Fire Test

American Wood Council
ASTM E119 Fire Endurance Test

- 5-Ply CLT (approx. 7” thick)
- 5/8” Type X GWB each side
- Sought 2 hour rating
- RESULTS: 3 hours 6 minutes



Half-lapped – middle of panel

Residential Fire Load Demonstration

Room after 60 minutes

Room after drywall removed following the three-hour test

CLT : September 15, 2015

ICC Tall Wood Ad Hoc

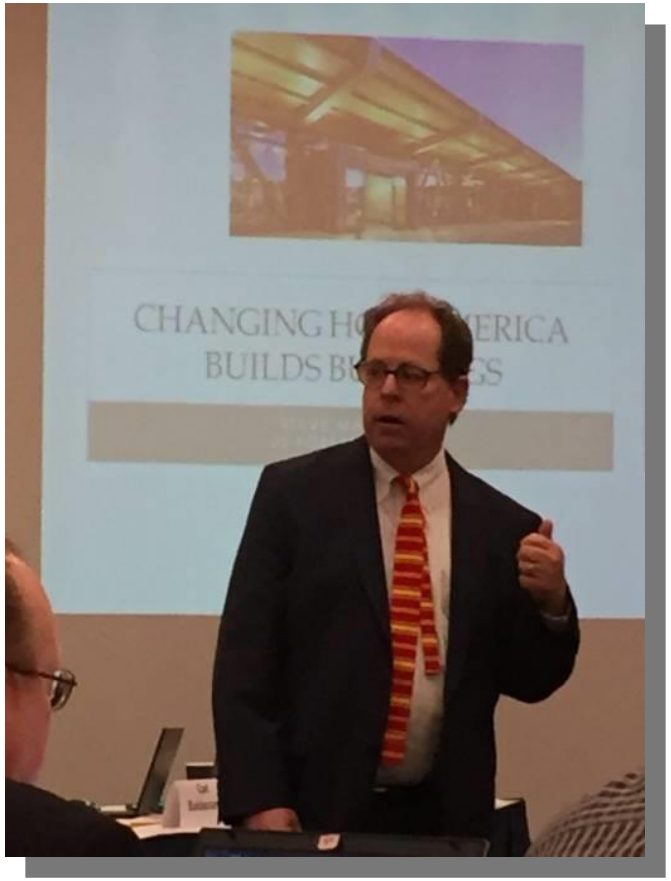
ICC NEWS RELEASE

For Immediate Release
Janurary 7, 2016
www.iccsafe.org

Contact: Trey Hughes
1-888-ICC-SAFE (422-7233), ext. 5237
thughes@iccsafe.org

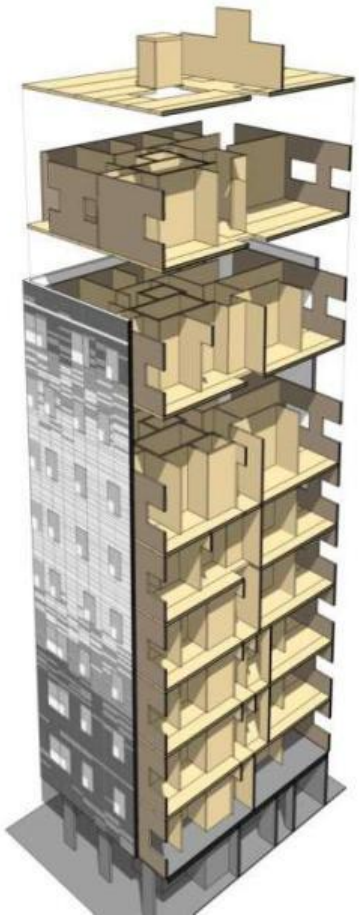
ICC Accepting Applications for Ad Hoc Committee on Tall Wood Buildings

The International Code Council (ICC) Board of Directors has established an ad hoc committee to explore the building science of tall wood buildings. Tall wood is a term used in the industry to identify wood construction which utilizes Cross Laminated Timber (CLT) in buildings of heights greater than six stories. CLT buildings with heights varying from seven to 12 stories are in the planning stages in Minneapolis, Portland, and New York City.



AWC Proposals

- Existing Type IV construction to remain
- New categories for CLT/Mass Timber
  - Examples based on Use Groups R1 and R2
  - Type IV C - 9 Stories meeting existing code requirements for HT except with 2-hour fire performance
  - 12 Stories meeting existing code requirements (except for non-combustibility) of Type IB construction
  - 20 Stories meeting existing code requirements (except for non-combustibility) of Type IA construction
  - Additional enhancements above current code requirements can be considered for each category



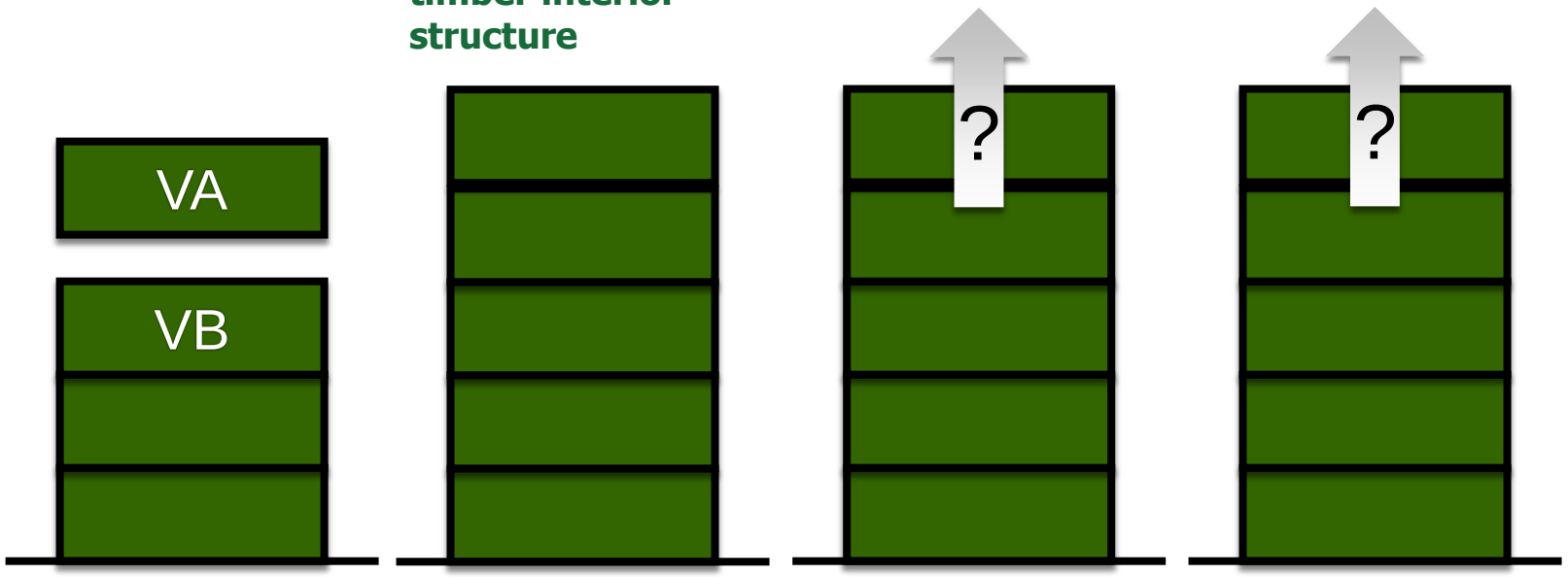
Sprinklered Group R (NFPA 13 sprinkler system)

- **Conventional light frame, unrated (Type VB) or 1-hour rated structure (Type VA)**

Type III (noncom or FRTW 2-hour exterior bearing walls; light frame interior structure)

Type IV (noncom or FRTW exterior walls; heavy timber interior structure

- **"Mass" Timber, fire resistance rated, minimum heavy timber dimensions, and partially protected with gypsum**
- **Mass timber, fire resistance rated and fully protected with gypsum**



Possible Fire Safety Distinctions for Mass Timber

Type IV:

-minimum heavy timber dimensions;

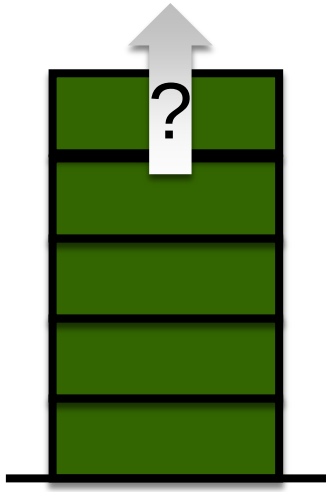
-no concealed spaces

Type IV-C:

-minimum heavy timber dimensions

-MINIMUM fire resistance ratings

-protected concealed spaces



Type IV-B:

-minimum heavy timber dimensions

-INCREASED fire resistance ratings

-protected concealed spaces

-PROTECTION required (gypsum covering, multiple layers, most surfaces)

12 STORIES ?

Type IV-A:

-minimum heavy timber dimensions

-MAXIMUM fire resistance ratings

-protected concealed spaces

-COMPLETE PROTECTION required (gypsum covering, multiple layers, for all surfaces)

20 STORIES ?

Ongoing testing

- National Fire Protection Research Foundation (at NIST test facilities)
- AWC testing (ATF facility)

Questions?

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

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