Exposing the Potential of Heavy Timber Construction

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WoodWorks – Wood Products Council

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Wood in Educational Buildings
Indian Mountain Student Arts & Innovation Center
Lakeville, CT
Architect: Flansburgh Architects
Engineer: Roome & Guarracino
Photo: Robert Benson Photography

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

Course Description

Offering a mix of both the practical and inspirational, this presentation focuses on the use of heavy timber in applications such as offices and schools, as well as civic, industrial, mid-rise/multi-residential and other building types. Included will be a review of non-structural provisions in the *International Building Code* and a discussion of structural component and connection methods available. Example projects ranging from typical to unique will be used to illustrate the range of modern timber design solutions available and their ability to provide unlimited aesthetic opportunities for almost any building type.

Learning Objectives

1. Identify opportunities available through non-structural provisions of the *International Building Code* (IBC), including maximum height and area for exposed heavy timber-frame structures.
2. Discover the common design elements and connection options for heavy timber framing.
3. Examine the commonalities and differences of award-winning heavy timber structures.
4. Become aware of non-traditional uses for heavy timber that offer unique design solutions.

Outline

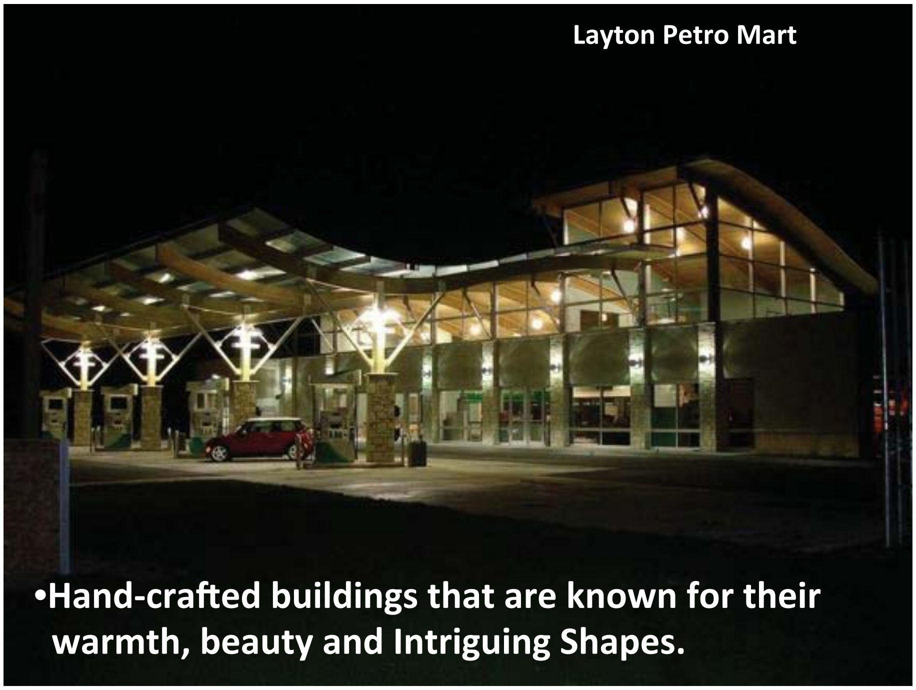
- Heavy Timber Code Requirements
- Design Elements
- Unique Design Solutions
- Case Studies
- Technical Resources

Timber Frame Construction

- One of the oldest known forms of construction
- Post & Beam or Timber Framed structures date back before the early Greeks.
- Increased interest because of the allowable height/area and fire resistance advantages.
- Offers innovative commercial building solutions

Butler Building Built in 1906

Benefits of Timber Framing



Outline

- Heavy Timber Code Requirements
- Design Elements
- Unique Design Solutions
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Type IV – Heavy Timber Code Requirements

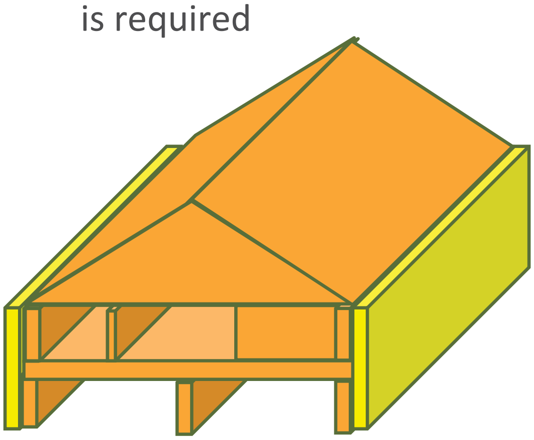
Why is heavy timber in the code?

- Historical Practice
- Fire Resistance

Photos provided by:
Structural Wood Corporation

Type IV Construction – IBC 602.4

Exterior walls are of noncombustible materials and interior building elements are of solid or laminated wood without concealed spaces. FRT wood or Cross Laminated Timber*-2015 IBC is permitted in exterior walls, where 2hr fire rating or less is required



*Exterior surface of CLT is protected by FRT sheathing or ½" gypsum

- Non combustible Exterior walls
- Interior walls-solid wood or 1 hour rated

- Fire Retardant Treated exterior walls or Cross laminated Timber (CLT)-2015 IBC are allowed if fire rating is 2hr or less

- Heavy Timber

Heights and Areas – IBC Table 503

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
	STORIES(S) AREA (A)									
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	3	5	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
M	S	UL	11	4	2	4	2	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000

Height Modification – IBC 504

IBC 504.2 Where a building is equipped throughout with an approved sprinkler system… (NFPA 13)

- maximum height is increased by 20 feet
- maximum number of stories is increased by one.
  - <u>EXCEPT</u> for I-2 occupancy of Type IIB, III and V construction and H occupancies **or** where sprinklers are used as substitution for 1hr fire resistance.

Can be combined w/ frontage area increase - 506.2
Can be combined w/ sprinkler area increase - 506.3

Area Modification – IBC 506

(Equation 5-1)

$$A_a = A_t + [A_t \times I_f] + [A_t \times I_s]$$

A_a = Allowable area per story (sq. ft.)

A_t = Tabular area per story (sq. ft.)

I_f = Area increase factor due to frontage (IBC 506.2)

I_s = Area increase factor due to sprinkler protection (IBC 506.3)

Is=2 if 2 stories or more, Is=3 for 1 story

Sprinkler Increases

- Up to 3x the tabulated area for building w/ more than one story
- Up to 4x the tabulated area for a building no more than one story
- The larger increased area might allow excluding sprinklers in a project

Automatic Sprinkler Increase – 506.3

IBC 506.3 – Floor Areas in Table 503 is permitted to be increased by an additional :

- I_s = 2 for buildings with more than one story above grade plane [$A_a = A_t + 2A_t + I_f (A_t) = \mathbf{3A_t} + I_f (A_t)$]
- I_s = 3 for buildings with no more than one story above grade plane. [$A_a = A_t + 3A_t + I_f (A_t) = \mathbf{4A_t} + I_f (A_t)$]

Can be combined with height and story increases - 504.2.

Exception

- Not permitted for H-1, H-2, and H-3 occupancies
- Not permitted where sprinklers substitute for 1hr construction

Frontage Increase for Area- IBC 506.2

Allowable size of building may increase where open frontage is provided.

(Equation 5-2)

$$I_f = [F/P - 0.25]\ W/30$$

F = Building perimeter that fronts on a public way or open space having 20 feet open minimum width (feet).

P = Perimeter of entire building (feet).

W = Width of public way or open space, not to exceed 30 feet

Maximum Building Area – 506.4

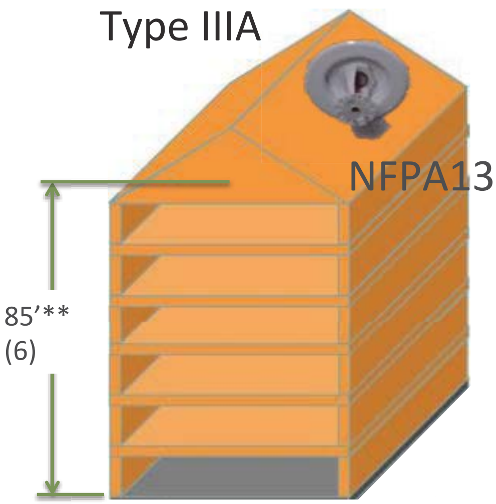
Single Occupancy Area determination

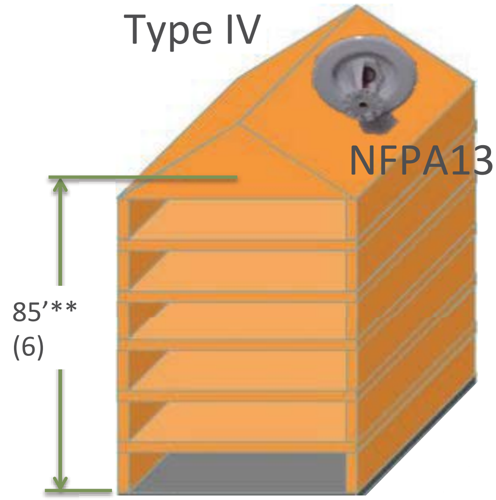
- Two stories above grade: Max. overall allowable area = A_a x 2
- Three stories or more above grade: Max. overall area = A_a x 3
- No Story shall exceed A_a

Exceptions

- Unlimited area buildings
- Buildings with NFPA 13R sprinkler system

Opportunity for Office Occupancy (B)





Occupancy	IIIA (ft²)*	IV (ft²)*
B	85,500 +21,375(max frontage)	108,000 +27,000(max frontage)

*Areas reflect PER STORY max. Total building max may limit area further.
**ASCE7 12.2-1 limits wood shear wall seismic systems to 65' in height in SDC D,E,F

Fire Resistance Rating -IBC Table 601

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls									
Exterior[f, g]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Outside of Type IV Construction

Heavy Timber Roofs can be used
- in ANY type of construction except IA

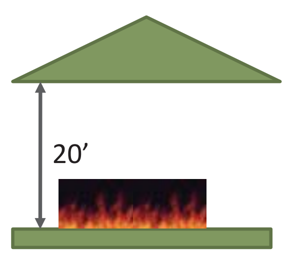
Exposed Wood Roofs can be used
- in Type IIB, IIIB and VB
- in Type IIA, IIIA, VA where roof is >20' from floor below
- or when sprinklers are substituted for 1hr rated const.

Exposed Wood Floors can be done
- in Type IIIB and VB
- or when sprinklers are substituted for 1 hr. rated const.

Table 601 Footnotes – "b"

Fire protection of structural members shall not be required, where every part of the roof construction is 20 feet or more above any floor immediately below.

- FRT wood allowed: For Type I, II, III, and V roof framing



Except in group F-1, H, M, and S-1 occupancies

Table 601 Footnotes – "c"

Heavy Timber roof can be used where fire rating is 1hr or less

- Applies to any type of construction except Type IA.

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Roof construction and secondary members (see Section 202)	$1^1/_2$ [b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

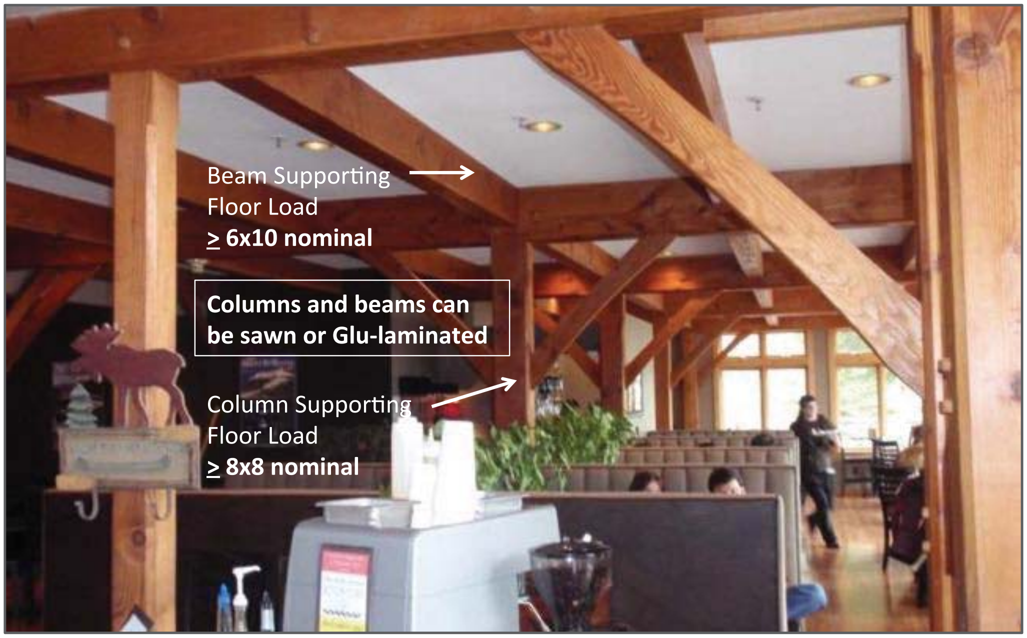
Table 601 Footnotes – "d"

Sprinkler system can be substituted for a 1hr fire rating

- For Type IIA, IIIA, and VA
- Substitution can NOT be used
  - if sprinkler is used for allowable height or area increase
  - for exterior wall fire rating requirements.
  - for required occupancy separation

Minimum Sizes – Floor Framing

IBC Section 602.4 (Table 602.4) address minimum sizes



Minimum Sizes – Roof Framing

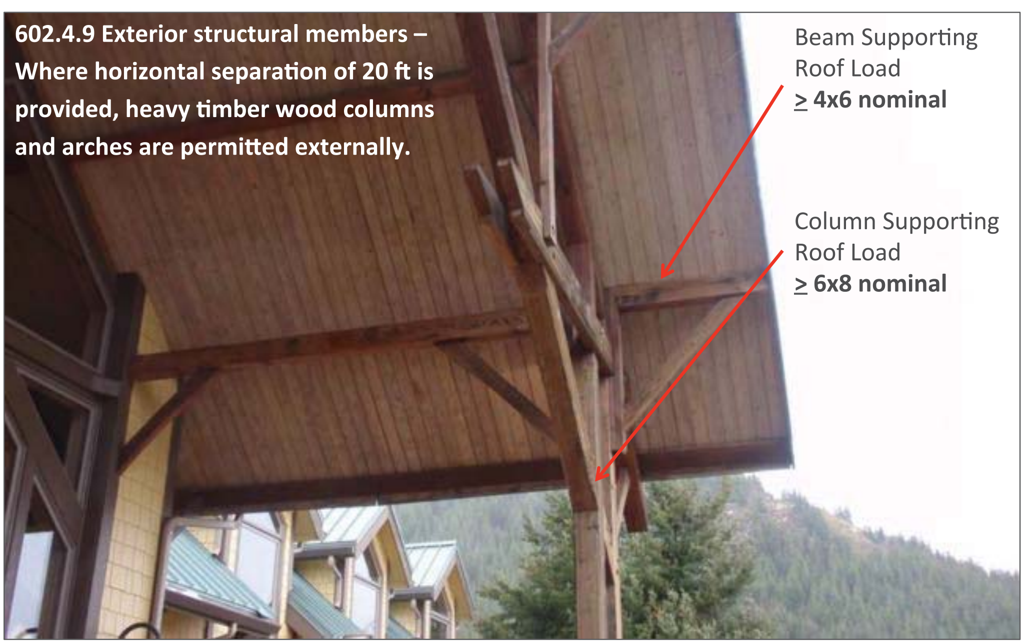


Photo of Hoffstadt Bluff Visitor's Center

Minimum Sizes – Roof Framing

Often 7/16" sheathing may be applied over 2x deck to increase diaphragm strength

Photo of Hoffstadt Bluff Visitor's Center

Arch Sprung From the Ground

Images Provided by Structural Wood Corporation

Arches supporting roof loads from top of wall shall be ≥ **4x6**

Timber Arches supporting roof loads and springing from floor ≥ **6x8** at bottom & **6x6** at top

Equivalent Glued Laminated Net Size

Table 602.4
Wood member Size Equivalents

Minimum Nominal Solid Sawn Size		Minimum Glued-laminated Net Size		Minimum Structural Composite Lumber Net Size	
Width, Inch	Depth, Inch	Width, Inch	Depth, Inch	Width, Inch	Depth, Inch
8	8	6 ¾	8 ¾	7	7 ½
6	10	5	10 ½	5 ¼	9 ½
6	8	5	8 ¼	5 ¼	7 ½
6	6	5	6	5 ¼	5 ½
4	6	3	6 7/8	3 ½	5 ½

Structural Requirements

- Columns-IBC 2304.10.1
  - Continuous or superimposed throughout all stories
  - Intersecting beams shall be closely fitted to column faces
  - Adjoining beams shall be cross tied to each other across joints
  - Wood bolsters shall not be placed on tops of columns unless the columns support roof loads only

Bolster

Structural Requirements

- Floor framing-IBC 2304.10.2
  - Approved wall plate boxes or hangers are required where beams, girders or trusses rest on masonry or concrete walls
  - Intermediate beams supporting floors shall rest on the tops of girders or shall be supported by ledgers securely fastened to the girder or **by approved metal hangers**
- Roof framing-IBC 2304.10.3
  - Every girder and at least every other alternate roof beam shall be anchored to its supporting member
  - Anchors shall be steel or iron bolts of sufficient strength to resist vertical roof uplift loads

Structural Requirements

- Floor decking-IBC 2304.10.4
  - A gap ≧ ½" shall be provided between the decking and wall to allow for expansion of the decking.
  - Molding attached to the wall shall cover the gap and shall not obstruct the movement of the decking
- Roof decking-IBC 2304.10.5
  - Where roof decks are supported by walls, the decks shall be anchored to the walls to resist uplift forces per Chapter 16.
  - Anchors shall be steel or iron bolts of sufficient strength to resist vertical roof uplift loads

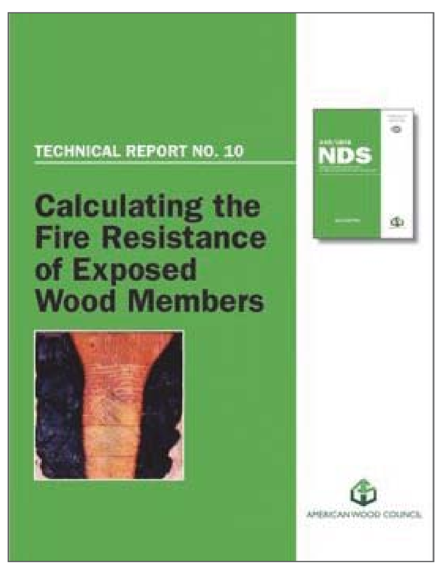
Type IV – Heavy Timber-Fire Requirements

In a variety of ways the building code does recognize the ability for Heavy Timber to resist fires through charring.

Achieving One Hour Equivalency for Protected Construction

NDS Chapter 16
Fire Design of Wood Members

OR →

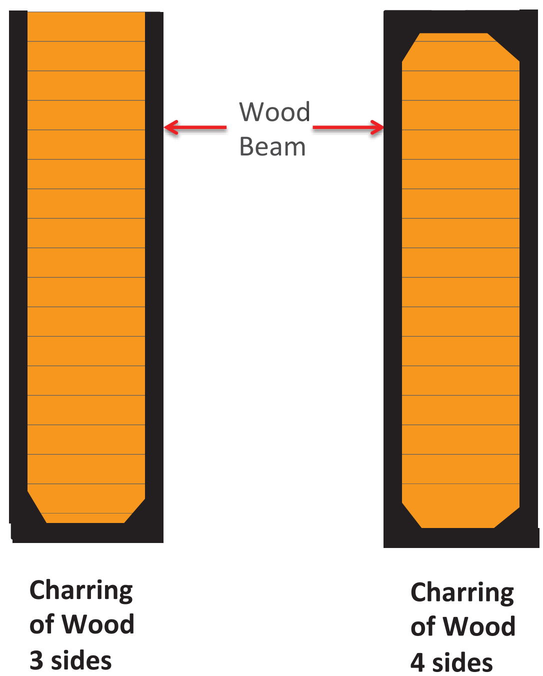


TR 10

Available from AWC website

Equations for Calculating Fire Endurance

- Assumptions
  - Nominal assumed char rate=1.5"/hr.
  - Uses ultimate strength for design check
- Reduced section checked for capacity vs. demand



Key Component 1 – Char Rate

ACCOUNTS FOR NON-CHARRED STRENGTH RED'N

$$\beta_{eff} = \frac{1.2\beta_n}{t^{0.187}}$$

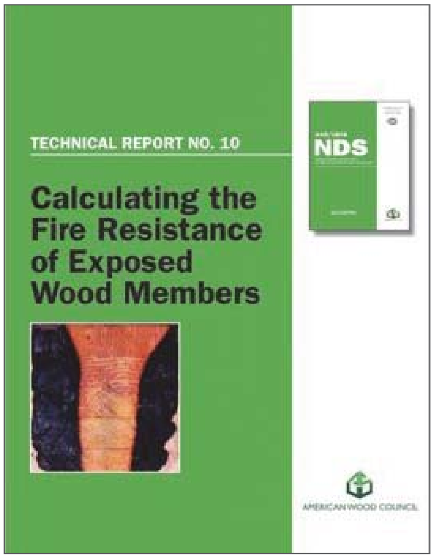
CHAR SLOWS WITH TIME- NON LINEAR

β_{eff} = Effective char rate (in/hr), adjusted for exposure time, t

β_n = Nominal char rate (in/hr), linear char rate based on a 1-hour exposure (1.5"/hr.)

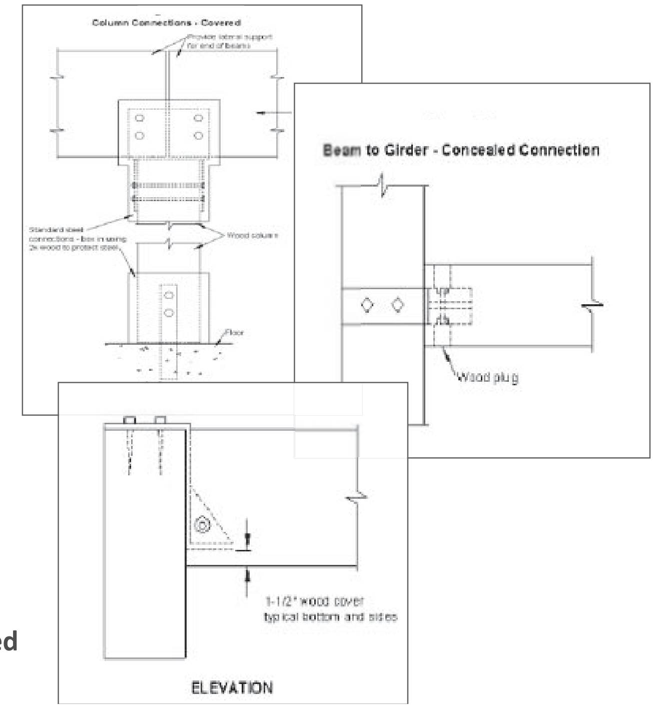
t = Exposure time (hrs)

Protecting Steel Connections



TR 10 EXCERPTS

- 1 hr. Protection-1 ½" wood, approved covering or coating



Outline

- Heavy Timber Code Requirements
- Design Elements
- Unique Design Solutions
- Case Studies
- Technical Resources

Beams-Solid Sawn & Engineered Lumber Products

Glued Laminated Timber

Glued Laminated Beams

Available in:

Framing/Industrial Grades – Intended for non-exposed conditions

Architectural Grade– Intended for exposed members.

Premium Grade also available

Structural Composite Lumber

- Bonded wood veneers
- Plies
- Strands

Columns-Solid Sawn & Multi-Ply Sections

- IBC section 602.4.3-Columns- solid sawn or glue-laminated members only.
- Nailed built-up columns in accordance with NDS Commentary section 15.3 are not allowed

Multi-Ply Columns OK for unprotected Construction

Multi-Ply Nailed Columns ≠ Solid Section

Heavy Timber Roof

Heavy timber framework at entries serve as focal points.

Photo by Universal Forest Products

Tongue and Groove Decking

- **AWC:WCD2-Horizontally applied tongue and groove decking**
  - **Simple span**
  - **Simple-2 span Continuous**
  - **3 or more spans Continuous**
  - **Controlled random lay-up**

Diaphragm Options

- Horizontally applied tongue and groove decking
  Low allowable diaphragm shear values, Aspect Ratio (A/R)=2:1
- Diagonally applied tongue and groove decking
  Single layer- moderate shear values, A/R=3:1

  Double layer- high shear values, A/R=4:1
- Wood Structural Panel Sheathing Over Decking
  Acts as blocked diaphragm, high shear values, A/R=4:1

Structural Panels Over Decking

Panel Installation Requirements

- Panel Edges must not coincide with decking joints
- Panel edges must be attached to common member
- Minimum fastener penetration must be provided
- Maximum 4:1 aspect ratio is allowed.
- A complete load path must be provided for forces

Additional information can also be found in:

- APA Form TT-097 Designing Diaphragms Over Existing Board Floors or Roofs
- ATC 7 Guidelines For The Design of Horizontal Wood Diaphragms

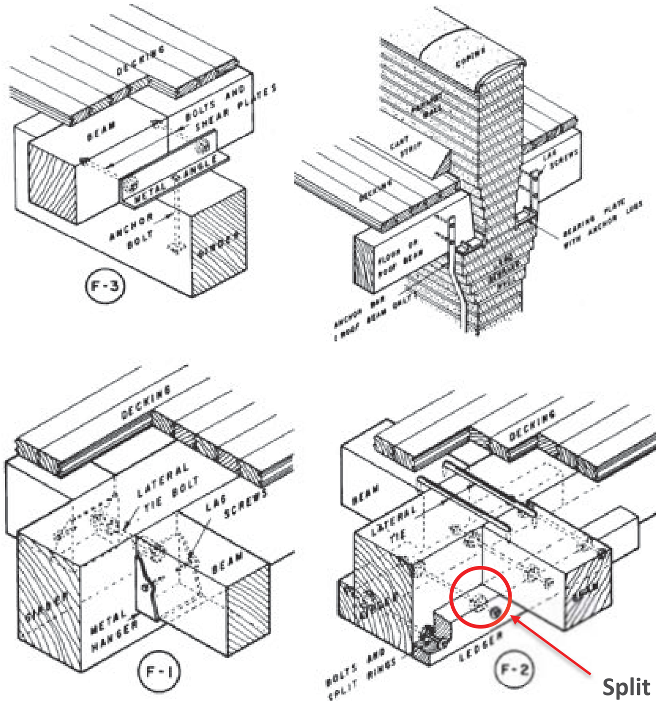
Large Roof With Structural Panels

Photo by Universal Forest Products

Timber Connections

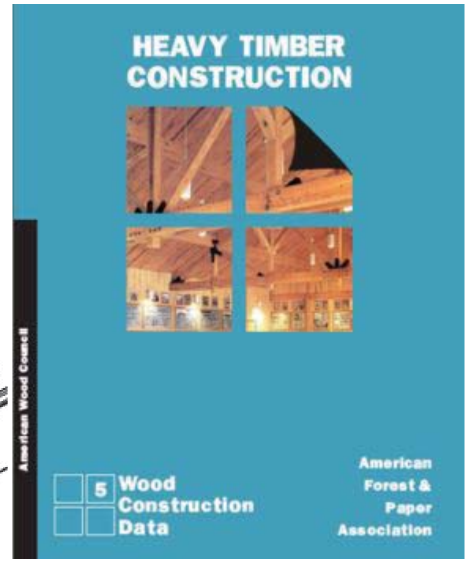
- Steel Plate/Bolted Connections
- Split Rings
- Shear Plates
- Timber Rivets
- Modern Joinery
- Modern/innovative Heavy Timber Connections

Heavy Timber Standard Prescriptive Details



Split rings

WCD5



IBC section 2304.10-Heavy Timber

Exposed Steel Plate/Bolted Connections

Solid sawn members w/ bolted steel plate members connections

- Avoid cross grain shrinkage by using slotted holes
- Provide drainage holes in bucket type connections

Steel Plate Connections

- Shop layout of entire assembly
- Use the steel plates as bolt hole templates

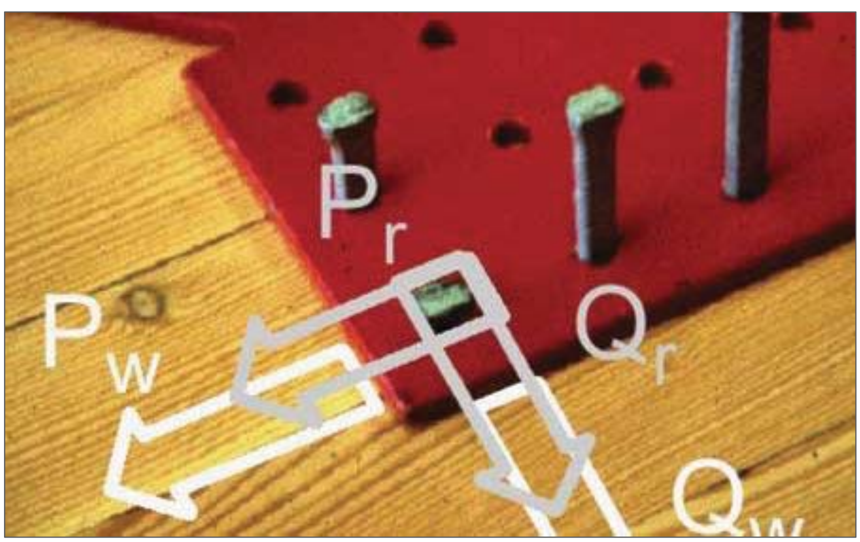
Split Rings-Wood to Wood Connections

- Act as large diameter bolts (bearing area)
- Split in ring allows for shrinkage
- Note-malleable iron washer for bolt to wood connection

Shear Plates-Steel to Wood Connections

- Act as large diameter bolts (bearing area)
- Commonly used in steel plated glue-lam trusses

Timber Rivets



- Oval shaped nails with narrow side parallel to grain
- Allows closer spacing of rivets-reduces splitting

Modern Joinery

- Computer program downloads cuts to saw
- Allows precision joints

Joinery

- Craftsmanship provides the true beauty of Timber frame structures

- Some joints still require handcrafting

Joinery-Typical Traditional Examples

HALF-LAP DOVETAIL COLLAR TIE

COMMON RAFTERS AT RIDGE

Modern Heavy Timber Connections

Competitiveness of a timber structure may be determined by the efficiency of the connections used.

Connections:

- Easy to design
- Aesthetically attractive
- Good serviceability (e.g., shrinkage, ductility, etc.)
- Cost-effective & availability
- Fire resistant (as required)

Use of CNC Technology for Connections

- Computer Numerically Controlled (CNC) connections
- Ability to fabricate joints with precision

Innovative/Proprietary Connection Systems

- Long self-tapping screws

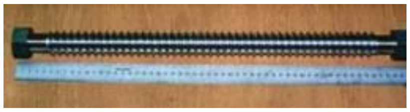
- Grid plates

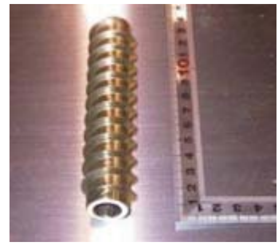
- Embedded end connections

- Embedded kerf plates

Innovative Lag Screw Bolt (LSB) Connection System

Developed in 1994 & has been modified in various forms

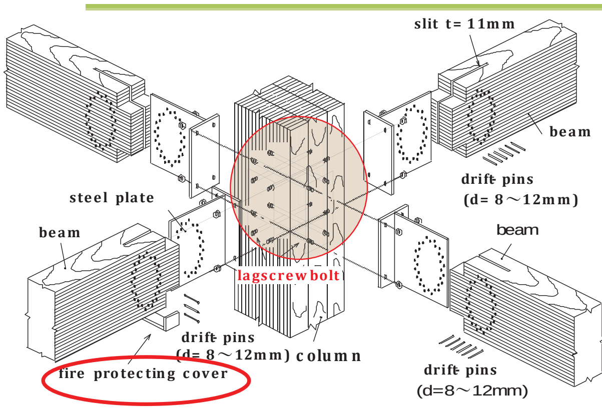




Source: Komatsu/Japan

http://www.ewpa.com/Archive/2004/jun/Paper_083.pdf -(theory)
http://www.timberdesign.org.nz/files/00155%20Makoto%20Nakatani.pdf- (testing)

LagScrewBolt (LSB) System



By inserting LSBs from both surfaces of a post, a two way semi-rigid connection can be achieved

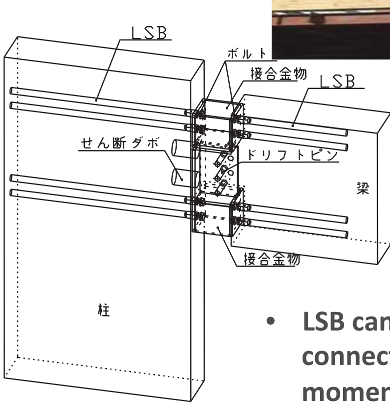
- **LSB extend full width and depth of column**
- **Short end bolts allow for installation in tight places**
- **Shaft provides bearing capacity of a bolt**
- **Threads provide pull-out capacity of a screw**

Source: Komatsu/Japan

Alternative System for Large Scale Timber Construction

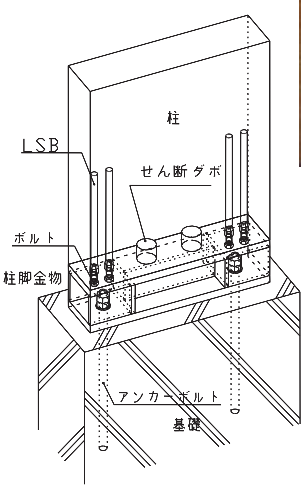
- Easy to install on-site

Source: Komatsu/Japan



- LSB can create semi-rigid connections-similar to a moment frame

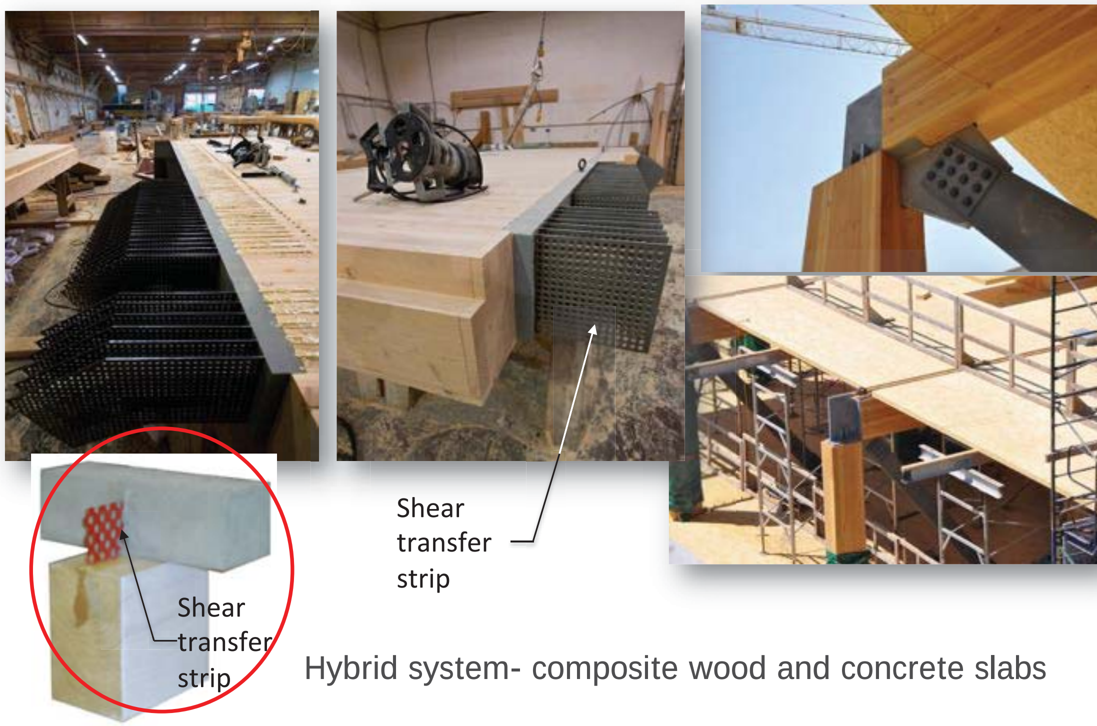
LagScrewBolt (LSB) System



- Semi-rigid connections can also be achieved at the column base
- LSB allow installation of bolts in tight spaces

Source: Komatsu/Japan

Innovative Connection Systems



Hybrid system- composite wood and concrete slabs

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- Heavy Timber Code Requirements
- Design Elements
- **Unique Design Solutions**
  - Wood Podiums
  - Gas Stations
  - Heavy Timber Braced Frames
  - Post Frame Construction
  - CLT-Mass Timber
- Case Studies
- Technical Resources

Wood Podiums

SEAOC 2012 CONVENTION PROCEEDINGS

All-wood Podiums in Mid-rise Construction

Michelle Kam-Biron, S.E.
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Karyn Beebe, P.E., LEED AP
APA
San Diego, CA

Abstract

Concern for the environment and climate change as well as the economic downturn of the past few years have created a demand for sustainable multi-family housing. According to the Washington, D.C.-based National Association of Home Builders Multifamily Production Index (MPI), a leading indicator for the multi-family market, the apartment and condominium housing market has shown steady improvement for six consecutive quarters. However, today's economic and environmental realities have led the building industry to re-evaluate the way we design and build multi-story buildings.

Mid-rise podium construction, consisting of two to four stories of wood framing above a concrete first story (the "podium") and often incorporating additional subterranean concrete levels, is common throughout North America and in levels of residential units built on top of one or two levels of parking or other non-residential occupancies below. In this paper, we are defining wood podium as the level (or transfer level) between the two or more stories of wood-framed residential occupancy and the lower non-residential occupancy which is traditionally constructed of concrete. In an article titled, "What to Build Now," by Michael Russo, Dan Withee, AIA, LEED AP, and partner with Withee Malcolm Architects LLP in Torrance, CA states, "Wood podium is basically tuck-under apartments on steroids."

The projects described in this paper have parking, retail, and restaurant space on their first level. The podium is composed of gypcrete (or light weight concrete) topping over wood structural panels supported by I-joists and glued laminated (glulam) beams. Both design teams made a conscientious effort to not utilize concrete or steel framing.

ALL-WOOD PODIUMS

Although a podium structure typically refers to wood-frame construction over concrete, a handful of designers have lowered their costs even further by designing the podium in wood.

"When determining the cost of a structure, there are a lot variables, including most notably time, materials and labor," said Karyn Beebe, P.E., of APA. "Using wood instead of concrete lowers the mass of the building, which results in more economical podium shear walls and foundations. Using the same material for the entire structure may also mean lower design costs, and the construction team experiences savings in the form of fewer trades on site, which means less mobilization time, greater efficiency because framing is repeated on all of the levels, easier field modifications, and a faster schedule."

Architect Dan Withee, AIA, LEED AP, of Withee Malcolm Architects designed an 85-unit wood podium project in San Diego. He estimated that a concrete podium can cost $15,000 per parking space compared to $9,500 for wood podium.[4]

- **Multiple stories of wood construction over 1 or 2 story concrete podiums are common**
- **Code also allows the use of multiple stories of wood framing over a Type IV wood podium**

Multi-Story Wood Construction

A cost-effective and sustainable solution for today's changing housing market

Parking Beneath Group R – IBC 510.4

Possibility of a Type IV podium where a number of stories starts above parking when:

- Occupancy above is R and below is S-2
- Lower floor is open Type IV parking with grade entrance
- Horizontal assembly between 1st and 2nd floor shall be
  - Type IV
  - Have 1 hr. fire resistance rating when sprinklered
  - Have 2 hr. fire resistance rating when not sprinklered
- overall height is still limited to occupancy

APA Case Study: All Wood Podiums N110

Galt Place

- Location: Galt, CA.
- Type VA
- 2 stories over all wood podium
- Architect: Michael Malinowski

Oceano at Warner Center

- Location: Woodland Hills, CA.
- Type VA
- 3 stories over all wood podium
- Architect: R C Alley III

- Less massive than concrete
- Enhanced constructability
- Cost savings

Outline

- Heavy Timber Code Requirements
- Design Elements
- Unique Design Solutions
- **Unique Design Solutions**
  - Wood Podiums
  - Gas Stations
  - Heavy Timber Braced Frames
  - Post Frame Construction
  - CLT-Mass Timber
- Case Studies
- Technical Resources

Gas Station Canopies – IBC 406.7.2

Canopies - Shall be of noncombustible materials:

- Fire-retardant-treated wood
- Wood of Type IV sizes
- or, construction providing 1-hour fire resistance.

Combustible materials used in or on a canopy shall be:

- Shielded from the pumps by a noncombustible element of the canopy
- or, wood of Type IV sizes

Gas Stations

- Shielded condition

- Heavy timber condition

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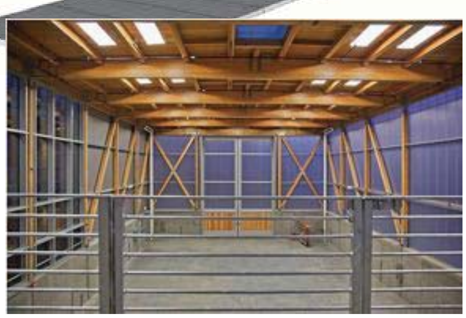
Heavy Timber Braced Frames (HTBF)

Heavy timber braced frames are becoming a preferred alternative vertical/lateral resisting system due to cost, performance and aesthetics.

- **R=3, Ie=1.25 for this project**
- **Over-strength, system=2.0, braces=2.5**
- **Overall effect → R=1 (remains elastic, no ductility)**

Simpson Strong Tie Materials Demo Lab – 1st approved HTBF approved under 2007 CBC and ASCE 7-05

- SEAOC 2010 Convention paper: http://www.arce.calpoly.edu/news-events/documents/heavy-timber-braced-frames.pdf
- Structure Magazine Article: http://www.structuremag.org/article.aspx?articleID=1221
- **5000 sf. facility utilizing HT braced frames as the primary LFRS**



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Post Frame Construction

- **Previously used in agricultural buildings**
- **Adapted and commonly used in commercial structures**

Features

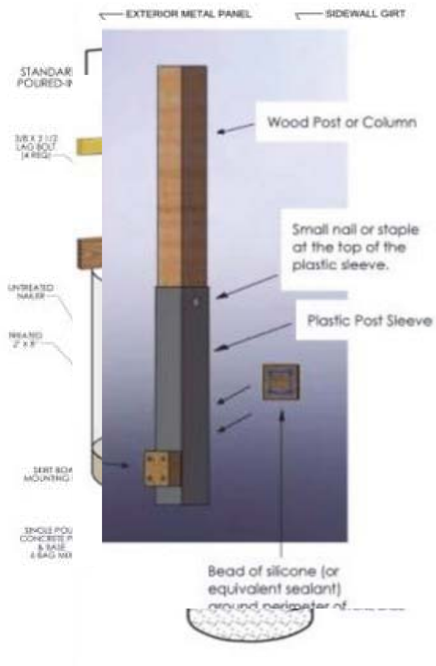
- Wood side wall posts
- Pitched Trusses
- Wide bay spacing (8ft to 12ft +)
- Large clear spans (100 ft +)
- Embedded wood posts or concrete piers
- Walls, roof usually type V construction

Innovative Foundation

- Asphalt and polyethylene wrap
- Poured-in-place concrete pier
- Blow-molded plastic
- Pre-cast reinforce concrete columns
- HDPE plastic barrier
- Polyethylene post sleeve

More information:

www.postframeadvantage.com



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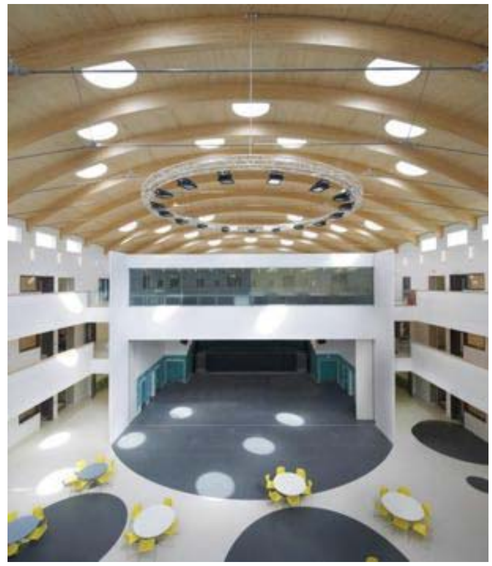
CLT is part of a new class of product… "Mass"ive Timber

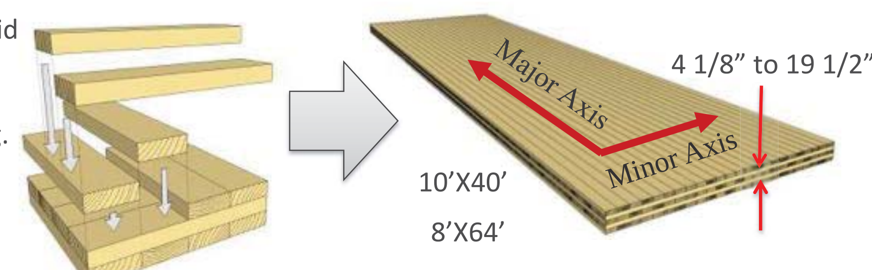
- CLT, LVL, LSL and glulam beams
- Plate elements of mass timber - less surface area to volume ratio
- Improved fire performance characteristics
- Efficient utilization of smaller diameter trees
- Mass Timber elements can be used for both vertical and lateral resisting system



The Brief Open Academy, Norfolk England
Design Team: Sheppard Robson, Romboll uK
Photo credit: KLH

What is Cross Laminated Timber (CLT)?

- 3 layers min. of solid sawn lams
- 90 deg. cross-lams
- Similar to pw. sht'g.



Photos provided by FPInnovations

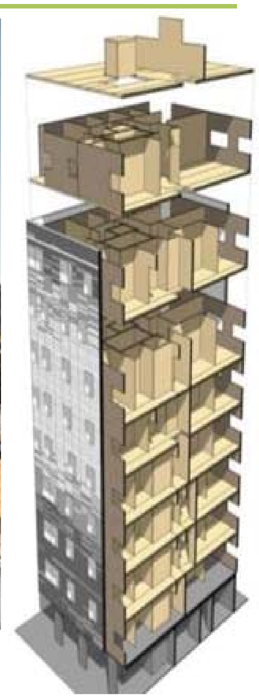
Mass-”Timber”-Forte’, Melbourne, Australia

- Tallest modern timber building
  - 10 stories total
- 9 stories of CLT over 1 story concrete podium
- Prefabricated CLT panels
- All CLT load-bearing walls, floor slabs, and elevator and stair shafts

Architect: Lendlease
Photo credit: Lendlease

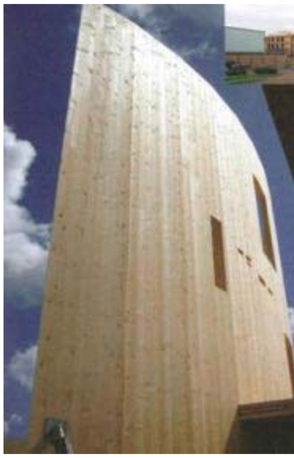
Mass-”Timber”-Treet, Bergen, Norway

- Currently under construction
- Once complete will be tallest modern timber building
  - 14 stories total, 173 feet tall
- Scheduled completion Autumn 2015
- Unique glulam and CLT module construction



Architect: Arco
Engineer: Sweco

Structural Flexibility





- Large clear spans
- Curved shapes
- Solid CLT shafts
- Wood podiums
- Cantilever stairs-no posts
- Long cantilever roof overhangs

Office Buildings using CLT Construction

- **Short construction time**
- **Similar to concrete tilt-up buildings**

Case Study-CLT Milestone in Montana

The Long Hall

- First CLT project in the US, using a US CLT supplier.
- Type VB–CLT walls and floor, glue-lam roof beams and decking
- 2 stories, mixed use
- 5 days to erect, 3 months from foundation to occupancy
- Cost effectiveness- short construction time and keeping CLT panels as interior finish

Designer: Datum Design Drafting
Engineer: CLT Solutions
Photo: gravityshots.com

Location: Whitefish, MT

Solid Timber Shaft Walls

- Eliminates using concrete or masonry
- Short construction time
- Saves money

Enhancing Structural Flexibility with CLT

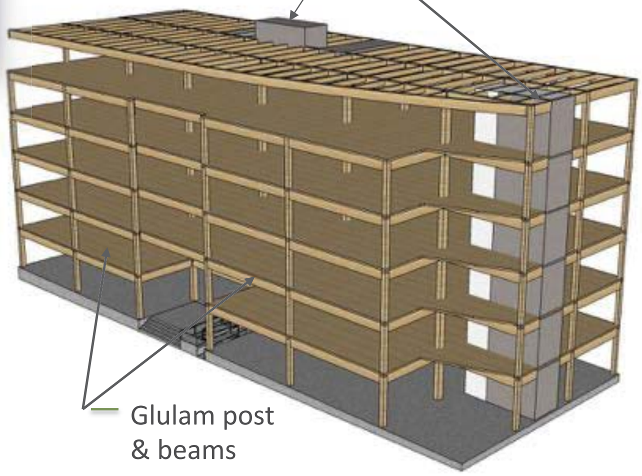
Heavy Timber Frame Mid-rise Building, Quebec City

- Posts and beams support gravity loads
- Concrete cores resist lateral loads

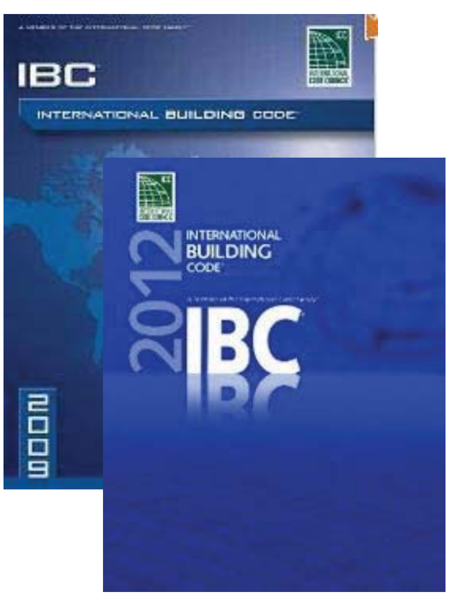
CLT shafts could be substituted for the concrete cores

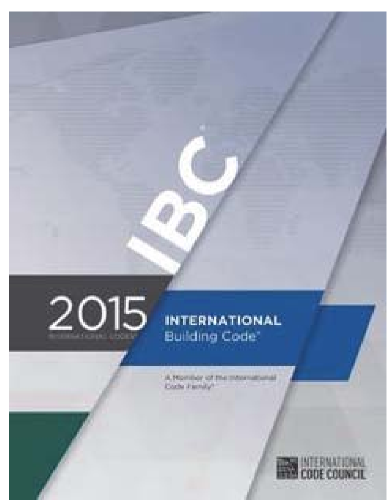
CLT floor and roof panels could be used as solid rigid diaphragm elements

6-storey glulam post-and-beam structure with reinforced concrete cores (CSN FondAction)



Is CLT recognized by the building Code?





2015 IBC? YES!

Section 602.4-Heavy Timber and section 2303.1.4.

Additional detailed information is available at www.woodworks.org

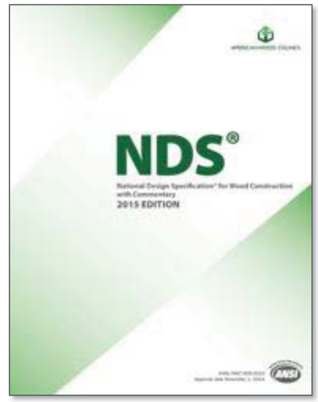
Fire Performance

- ASTM E119 Fire Endurance Test
  - 5-Ply CLT (6-7/8” thick)
  - 5/8” Type X GWB each side
  - 2 hour target
  - Actual 3 hours 6 minutes

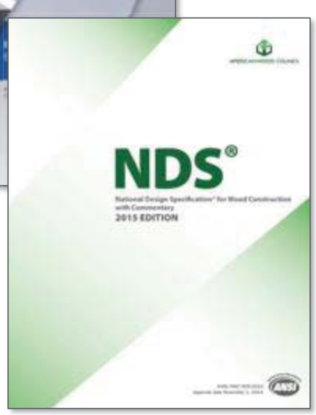
Highly Successful CLT Fire Test

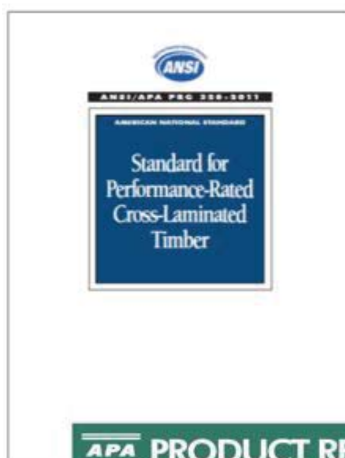
As part of a project to produce a U.S. design manual for cross-laminated timber (CLT), AWC conducted a very successful ASTM E119 fire endurance test on a CLT wall at NGC Testing Services in Buffalo, NY. The wall, consisting of a 5-ply CLT (approximately 7-inches thick), was covered on each side with a single layer of 5/8" Type X gypsum wallboard. The wall was loaded to the maximum attainable by the test equipment, although it remained significantly below the full design strength of the CLT specimen. It was then exposed to a standard fire that reaches over 1800 degrees Fahrenheit in the first 90 minutes of exposure. While only seeking a 2-hour rating, as required by the targeted building code provisions, the test specimen lasted 3 hours 6 minutes. This may open up additional possibilities in a few specialized locations where a 3-hour fire resistance rating might be required. The test culminated nearly a month of intense planning and cooperation by the North American wood products industry to get the test run in advance of the recent ICC hearings where an AWC-proposed code change to specifically recognize CLT was approved.

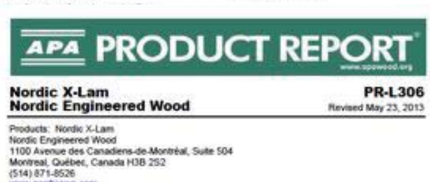
- 2015 NDS Chapter 16 includes char rates for CLT to achieve up to 2 hour fire rating



Product Standardization



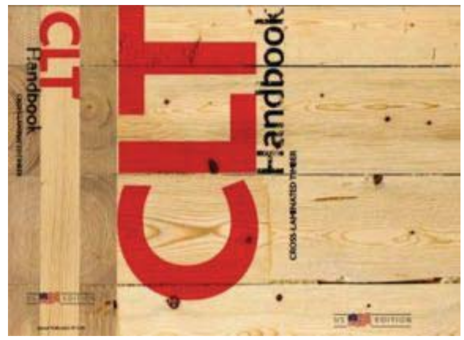




US CLT Handbook

1. Introduction
2. Manufacturing
3. Structural
4. Lateral
5. Connections
6. DOL and Creep
7. Vibration
8. Fire
9. Sound
10. Enclosure
11. Environmental
12. Lifting

www.masstimber.com



Outline

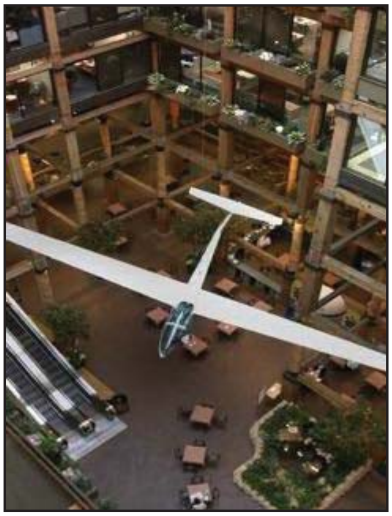
- Heavy Timber Code Requirements
- Design Elements
- Unique Design Solutions
- Case Studies
- Technical Resources

Outline – Case Studies

- Commercial, Offices
- HealthCare
- Schools
- Apartments/Lodges
- Churches
- Performing Arts Centers
- Aquatic Centers/Arenas

Butler Brothers Building,1906-1908, 9 stories, 500,000 s.f.

Architect: Harry W. Jones   Renovated 1974



- Atrium created to open the interior and provide natural lighting
- The Atrium was the key to marketability of the project

Case Study: Greenest Building in the World

Bullitt Center

- Location: Seattle, WA.
- Type IV construction
- 4 stories of wood over a 2 story concrete podium
- Net Zero Building
- Construction cost $360/sf.
- Goal- 250 year life expectancy

Architect: Miller Hull Partnership
Photo Credit: Miller Hull Partnership

Case Study: 1st US Commercial Bldg. “w/ NA CLT”

Promega GMP Facility-client & staff reception area

- Location: Madison, WI.
- Type IV construction
- 2 stories of heavy timber and CLT
- 52,000 sf. addition

.
Architect: Uihlein Wilson Architects

Case Study: Wood Innovation Design Center

Wood Innovation Design Center

- Location: Prince George, BC
- Glulam, LVL, and CLT structure
- 8 stories, 97 feet tall

Architect: Michael Green Architecture

Healthcare

Credit Valley Hospital, Ontario

Architect:

Tye Farrow of Farrow Partnership

- Main focus -create a serene atmosphere to the hospital
- Heavy timber achieved that goal

Photo: Peter Sellar, courtesy naturallywood.com

Case Study-Herrington Recovery Center

Location: Okonomowoc, WI

Architect: TWP Architecture
Photo: Curtis Waltzrington

- 3 story, 21,000 sf.
- Exposed glu-lam beams and decking
- Wood selected for its warmth, and healing effects

Photo: Tom Davenport

Case Study: CLT Framed School

Franklin Elementary School

- Location: Franklin, WV
- 2 stories- 45,200 sf.
- Structure erected in less than 3 months
- 1st CLT School in US
- Currently Under Construction – Scheduled completion Winter 2015

Architect: MSES Architects

Case Study: Earth Sciences Building

Earth Sciences Building, University of British Columbia

- Location: Vancouver, BC
- 5 stories- 158,770 sf.
- Exposed CLT roof panel and glulam column exterior canopy
- Wood chevron braces are lateral frame

Architect: Perkins + Will
Photos: www.naturallywood.com

Case Study: Positive Learning Environment

Duke Lower & Middle School

- Location: Durham, NC.
- Type VB
- 1 story – 79,204 sf.
- 5 new wood buildings, 4 existing

Architect: DTW Architects

- Glue-lam columns, girders, and arches
- exposed T&G decking
- Reason for using exposed wood framing
  - aesthetics
  - How the warmth and beauty of wood could influence the students.

Case Study: Integrating Nature with Mass Timber

Burr & Burton Academy – Mountain Campus

- Location: Peru, VT
- 1 story – 4,000 sf.
- LEED Platinum (83 points)
- Net Zero
- Has won 3 Sustainable Design Awards

Architect: Bensonwood

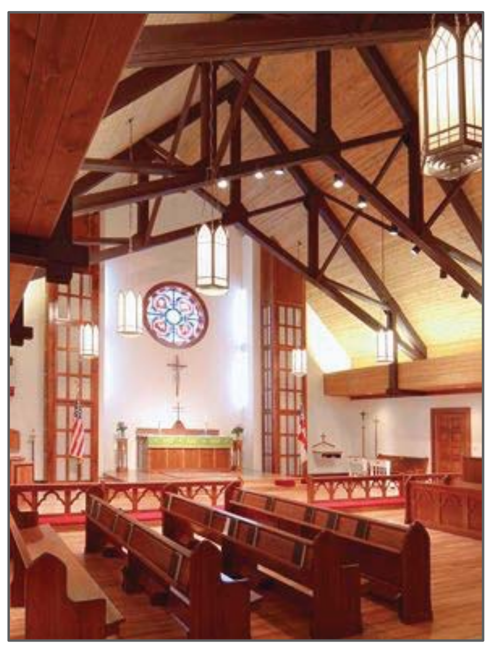
Case Study: Bridport House, London, UK

- Two blocks: 5 and 8 stories, 41 apartments total
- All CLT load-bearing walls, floor slabs, and elevator and stair shafts
- Light weight CLT structure accommodated existing storm sewer under site
- CLT construction time was 12 weeks: 50% faster than with other materials
- Carbon benefit: each apartment stores more than 30 tons of CO_2

Architect and photo credit:
Karakusevic Carson Architects

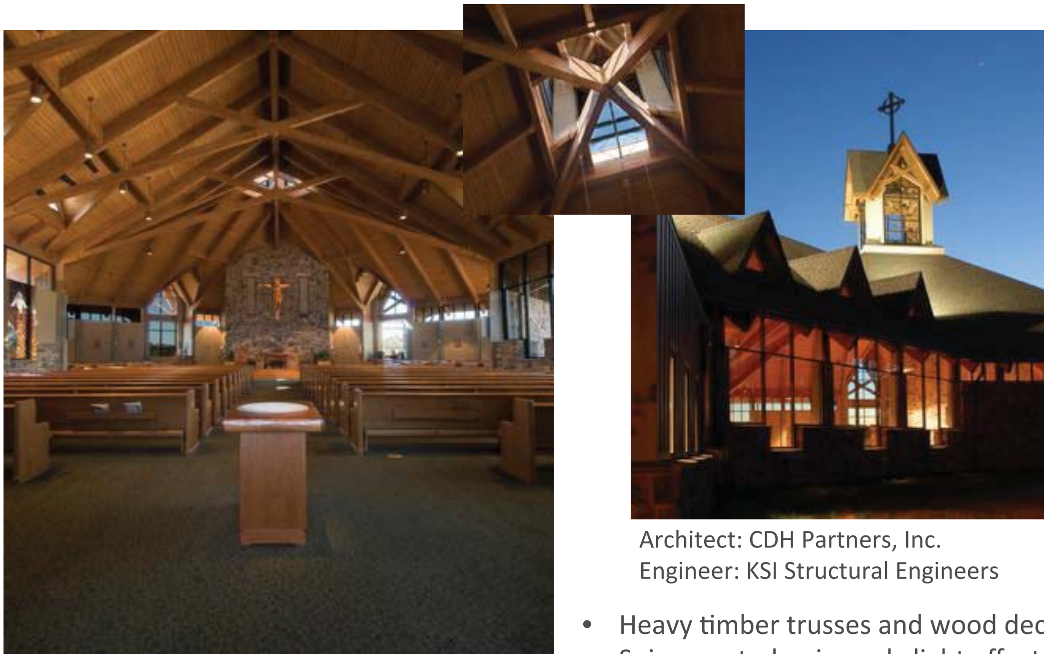
Churches

- Heavy timber is a common theme in churches and religious centers
- Provides warmth and beauty and a harmony with nature
- Project shown is multi-ply metal plate trusses to achieve aesthetic of heavy timber



Project by Foreman Seeley Fountain Architects

Churches



Christ the King Catholic Church -Hamilton, GA

Architect: CDH Partners, Inc.
Engineer: KSI Structural Engineers

- Heavy timber trusses and wood decking
- Spire created unique skylight effect

Case Study – Oakland Cathedral

Design Team: Skidmore Owings & Merrill, Craig W. Harman, Webcor Buildiers
Photo Credit: Timothy Hursley, Cesar Rubio, and John Blaustein

Cathedral of Christ the Light –Oakland, CA

- 108 ft high DF Glulam arches

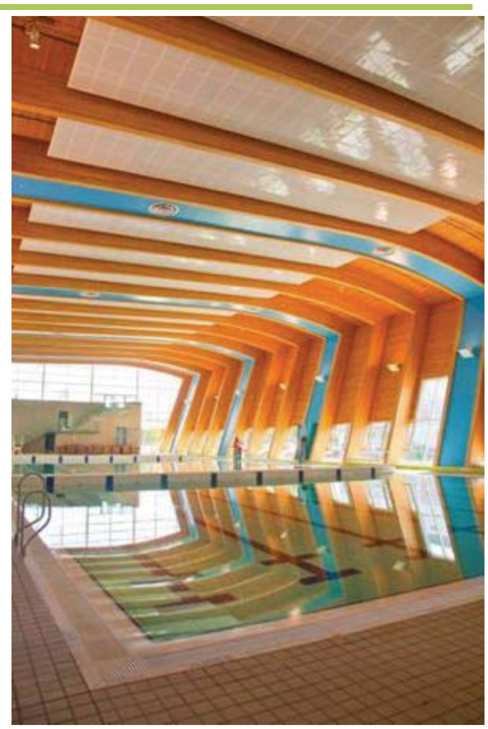
Case Study: Arena Stage at the Mead Center

Photo: Nic Lehoux
Architect: Bing Thom Architects

- Location: Washington, D.C.
- Expansion and renovation of a 200,000 sf. theater complex
- PSL timber columns supporting roof and glass facade
- Column capacity is 400 kips

Aquatic Centers

Percy Norman Aquatic Centre
British Columbia
Architect: Hughes Condon Marler
Photo: natuallywood.com
LEED Gold



- 66,500 sf. aquatic center
- 10 ½"x41 ½" glue-lams spanning 130 ft., spaced at 12' oc.
- 2 ½" T&G decking overlaid w/ pw sheathing
- 130 ft. span, the glulam columns and beams had to be assembled on-site.

.

Aquatic Centers

West Vancouver Aquatic Centre
Design Team: Hughes Condon Marler Architects, Fast and Epp Engineers
Photo Credit: Nic Leboux, Gary Otte, Martin Tessler

- Curved glulam beams and wishbone columns provide vertical and lateral support
- $7.5 Million total cost

University Laval Soccer Stadium, Quebec City

Richmond Olympic Oval, Richmond, B.C.

- Multi-purpose arena with 500,000 sf. floor area
- 330’ clear span arches w/ 2 way curvature roof covering 6 acres
- Proprietary Woodwave panel roof system spanned between the composite glue-lam arches

Credit: naturallywood.com
Design team: CannonDesign
Owner: City of Richmond

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WoodWorks – Resources for You

Technical Assistance
help@woodworks.org

- Code issues-H/A, fire protection
- Design assistance
- Wood design, use, and properties
- Product information

Wood Solutions Fairs

Case Studies

Education and Design Tools

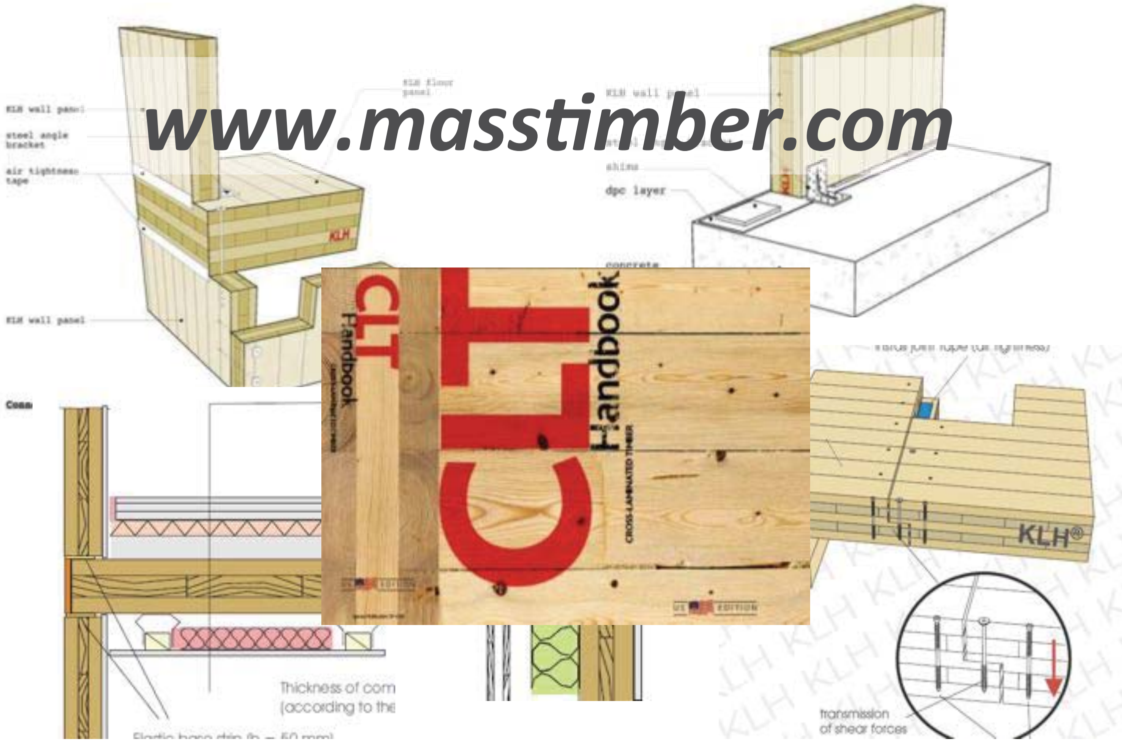
- **On-line webinars**
- **Design guides and standards**
- **Design software**
- **CAD & REVIT details**
- **On-line calculators**
- **Span Tables**

…and more at **woodworks.org**

Other Resources

- **American Wood Council - www.awc.org**
- **APA-Engineered Wood Association- www.apawood.org**
- **www.timberframeengineeringcouncil.org/**
- **Timber Framers Guild- www.tfguild.org/**
- **Timber Frame Business Council- www.timberframe.org**

For more information



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Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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