WoodWorks

The Case for Cross Laminated Timber

Opportunities and Challenges for a New Class of Timber Product

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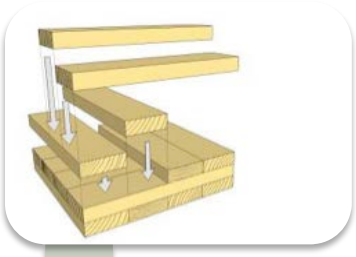
What is Cross Laminated Timber (CLT)?



- Layers of dimension lumber stacked crosswise and glued on their wide faces. Adhesives follow requirements of Glulam beams.
- Width/thickness of laminations vary (2 1/2-9 1/2" wide, 5/8 -2" thick).
- Lumber is ~12% MC prior to manufacture .

- Two way slab with odd number of layers identifying primary strength direction.
- Manufactured panels are typically 8-10' wide and up to 20" thick and up to 64' long.

- Finished panels are planed, sanded, cut to size. Then openings are cut with precise CNC routers.
- Third party inspection at factory.

- Custom engineered for material efficiency.
- Custom designed for project.

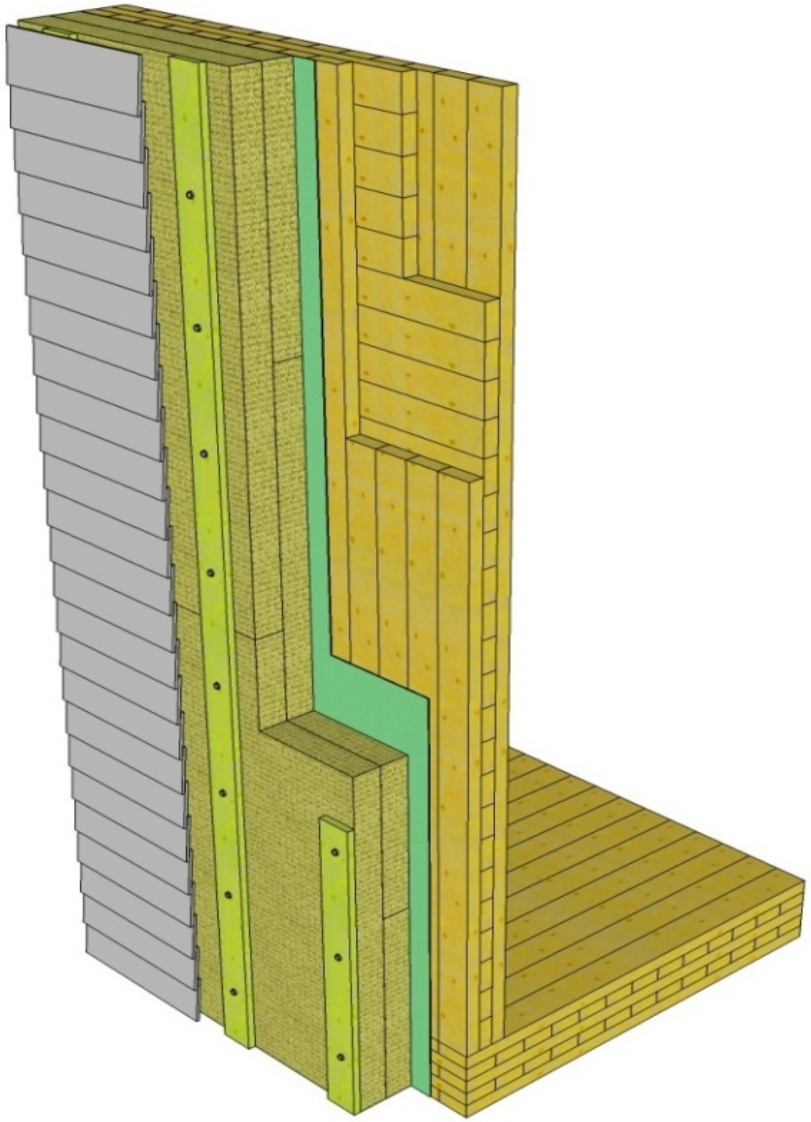
Large Timber Structures

- Incorporating timber plate elements
- Including large timber elements such as solid sawn, LVL, LSL, glulam, and CLT
- A structural system resisting both vertical and lateral loads

The new mass timber movement is motivated by….

- Demand for lower impact structures
- Manufacturing Technology
- Material Technology
- Advances in Pre-fabrication
- Sophisticated Suppliers

How to use CLT - Assembly



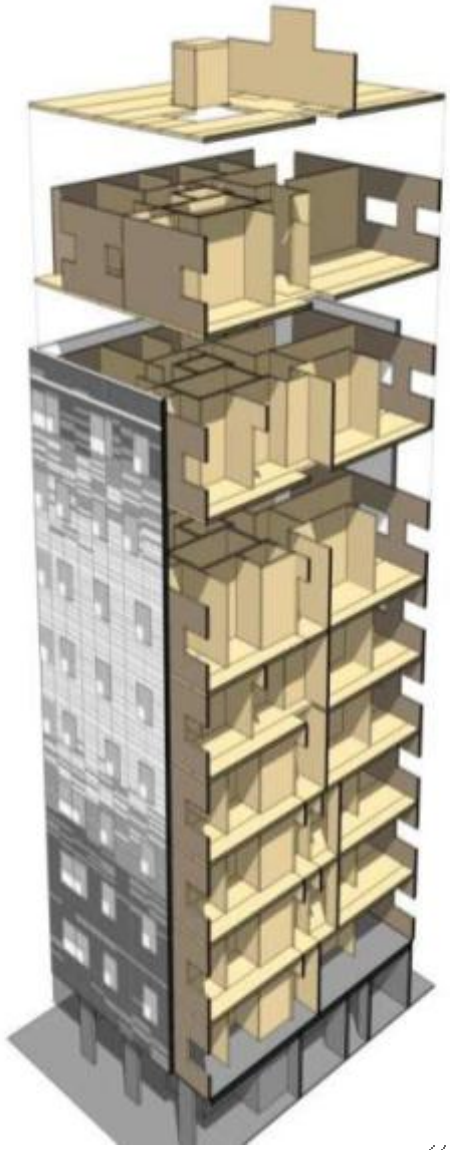
Reduced Embodied Carbon

Volume of wood used	950 m^3
Carbon sequestered and stored (CO_2e)	760 metric tons
Avoided greenhouse gases (CO_2e)	320 metric tons
Total potential carbon benefit (CO_2e)	1,080 metric tons

Carbon savings from the choice of wood in this one building are equivalent to:

1,615 passenger vehicles off the road for a year

Enough energy to operate a home for 803 years



Stadhaus, London, UK
Architect: Waugh Thistleton Architects
Photo credit: Waugh Thistleton Architects

Minimal Waste

Fire Test Results

4.5 in

6.9 in

9.6 in

WALL ASSEMBLIES

# of Plies	CLT Thickness (mm)	Gypsum Board Protection	Load (kN/m)	Load Ratio (%)	Failure Mode	Fire Resistance (min)
3	114	2 x 12.7 mm (1/2")	333	52	Structural	106
5	175	Unprotected	333	25	Structural	113
5	105	Unprotected	72	21	Structural	57

FLOOR ASSEMBLIES

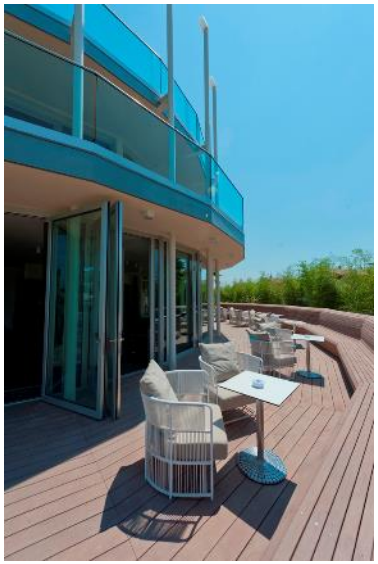
# of Plies	CLT Thickness (mm)	Gypsum Board Protection	Load (kPa)	Load Ratio (%)	Failure Mode	Fire Resistance (min)
3	114	2 x 12.7 mm (1/2")	2.7	23	No failure *	77 *
5	175	Unprotected	11.8	38	Integrity	96
3	105	1 x 15.9 mm (5/8")	2.4	43	Integrity	86
5	175	1 x 15.9 mm (5/8")	8.1	100	Integrity	124
7	245	Unprotected	14.6	100	Structural	178

* Test was stopped due to equipment limitations. Failure was not reached.

Structural Flexibility

75% Lighter Weight Than Concrete

- 180K sqft
- Luxury Hotel
- Construction time was 3 mo. vs. 2 yr. w/ concrete
- Wall system was 2” thinner with CLT



Aqualux Hotel, Bardolino, Italy
Architect: Rama Architettura

- Completed in 2012
- 10 stories
- ~ 105 ft. tall, > 18.6 K sqft.
- 3 million in R&D
- Poor soils required a much lighter building

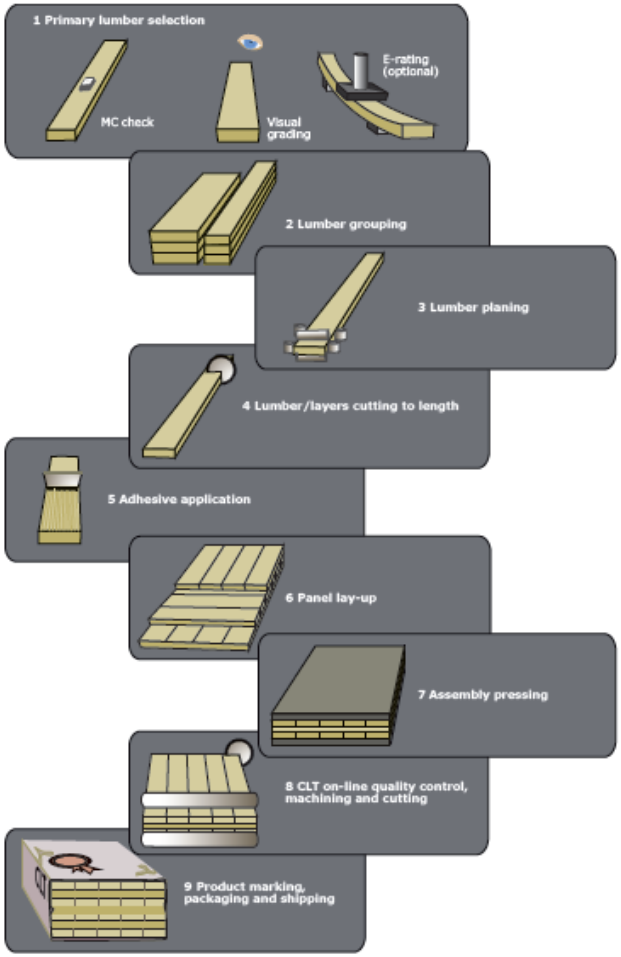
Forte', Victoria Harbor, Melbourne, Australia
Architect: Lend Lease

Forte', Victoria Harbor, Melbourne, Australia
Architect: Lend Lease

Product Availability

- Three North American producers of structural CLT
- ~425,000 ft^3 of annual production capacity (structural CLT)
- 2-3 US Companies pursuing manufacturing facilities
- Non-commodity based product
- Standardized manufacture but custom fabrication

Building Code -Product Standard



APA/ANSI PRG 320

- 7 stress classes
- Quality assurance testing
- Identification marking

CLT Grade	CLT Thick-ness (in.)	Lamination Thickness in CLT Lay-up (in.)							Major Strength Direction			Minor Streng Direction		
		=	⊥	=	⊥	=	⊥	=	$F_bS_{eff,0}$ (lb.-ft./ft.)	$EI_{eff,0}$ (10^6 lb.-in.^{2}/ft.)	$GA_{eff,0}$ (10^6 lb./ft.)	$F_bS_{eff,90}$ (lb.-ft./ft.)	$EI_{eff,90}$ 10^6 lb.-in.^{2}/ft.)	
E1	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.46	160	3.1	
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	0.92	1,370	81	
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,375	1,089	1.4	3,125	309	
E2	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	165	3.6	
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,825	389	1.1	1,430	95	
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,600	963	1.6	3,275	360	
E3	4 1/8	1 3/8	1 3/8	1 3/8					2,800	81	0.35	110	2.3	
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			6,400	311	0.69	955	61	

Code Approvals – Product Reports

Table 1. Allowable Design Properties[a] for Nordic X-Lam (for use in the U.S.)

CLT Grade	Major Strength Direction						Minor Strength Direction					
	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{s,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{v,90}$ (psi)	$F_{s,90}$ (psi)
E1	1,950	1.7	1,375	1,800	135	45	500	1.2	250	650	135	45

For SI: 1 psi = 0.006895 MPa

[a] Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Table 2).

Table 2. The Allowable Bending Capacities[a] for Nordic X-Lam Listed in Table 1 (for use in the U.S.)

CLT Grade[b]	Layup #[c]	Thick-ness (in.)	Lamination Thickness (in.) in CLT Layup							Major Strength Direction				Minor Strength Direction			
			=	⊥	=	⊥	=	⊥	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.²/ft)	$GA_{eff,0}$ (10^6 lb/ft)	$V_{s,0}$ (lb/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.²/ft)	$GA_{eff,90}$ (10^6 lb/ft)	$V_{s,90}$ (lb/ft)
E1	78-3s	3 1/8	1 1/64	1 1/16	1 1/64					2,525	48	0.34	1,070	95	1.4	0.47	380
	105-3s	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.46	1,430	160	3.1	0.61	495
	131-5s	5 1/8	1 1/64	1 1/16	1 1/64	1 1/16	1 1/64			5,800	184	0.69	1,470	785	35	0.94	1,090
	175-5s	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	0.92	1,970	1,370	81	1.2	1,430
	220-7s	8 1/4	1 3/8	1 1/16	1 3/8	1 1/16	1 3/8	1 1/16	1 3/8	15,975	853	1.4	2,400	2,160	184	1.5	1,580
	244-7l	9 5/8	1 3/8x2	1 3/8	1 3/8	1 3/8	1 3/8x2			23,700	1,404	2.0	3,200	1,370	81	1.9	1,430
	314-9l	12 3/8	1 3/8x2	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8x2		36,700	2,794	2.4	3,875	3,125	309	2.5	1,960

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448N

[a] Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS.

[b] The CLT grades are developed based on ANSI/APA PRG 320, as permitted by the standard.

[c] The layup designation refers to the panel thickness (in mm), the number of layers, and the layup combination ("s" for standard perpendicular layers, and "l" for doubled outermost parallel layers).

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

Questions?

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