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Cross-Laminated Timber (CLT) panels Fact Sheet

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What are CLT panels?

CLT panels are comprised of lumber or composites layers with boards stacked crosswise at 90-degree angles and glue together. See Figure 1. An odd number of layers, three to seven per panel, is common to fabricate CLT panels. Some of the companies in Europe are manufacturing up to nine layers.

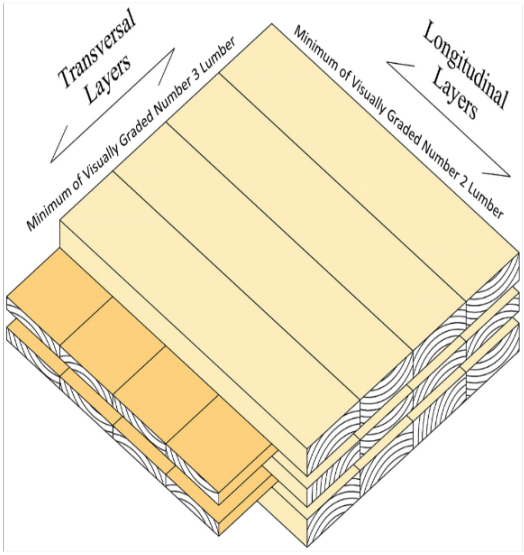

Figure 1: Structural grade CLT layups. Source: (Fragiacomo et al., 2012)

History

CLT was invented in the early 1990s in central Europe and is now considered an alternative construction material to mid and high-rise buildings across the globe. Based on uses, CLT panels are two types: structural or non-structural. Structural CLT panels are used in structural construction and manufactured under the criteria specified by APA-PRG 320 standard in North America. However, non-structural CLTs can be manufactured from any lumber species and types that satisfy the user requirements. Non-structural CLT panels are commonly used as access mats as an alternative to bolted mats. Table 1 shows a list of CLT manufacturing facilities in the USA.

Table 1: List of CLT manufacturers in the US

Company Name	City	State	Products
DR Johnson	Riddle	OR	All CLTs
SmartLAM	Columbia Falls	MT	All CLTs
SmartLAM	Dothan	AL	All CLTs
Freres Lumber	Lyons	OR	All CLTs
Sterling	Phoenix	IL	CLT Mats only
Sterling	Lufkin	TX	CLT Mats only
Spartan Mat	Peach Bottom	PA	CLT Mats only
Structurlam	Conway	AR	All CLTs
Mercer Mass Timber	Spokane Valley	WA	All CLTs
Vaagen Timbers	Colville	WA	All CLTs
Texas CLT	Magnolia	AR	All CLTs
Viking Mat Company	Eden Prairie	MN	CLT Mats only
Yak Mat	Columbia Falls	MS	CLT Mats only

North American Standard

In North America, CLT mills only qualify to produce CLT panels for structural applications after getting certified through the ANSI/APA-PRG 320 standard. The Engineered Wood Association grants the qualification, and each mill should certify both process and product for commercial production of CLT panels for structural application.

Lumber requirements

Sawn lumber for CLT manufacturing must be from softwood species with a specific gravity greater than 0.35. The American Lumber Standards Committee (ALSC) must qualify softwood species under PS 20 for manufacturing structural CLT panels. Lumber to be used in CLT manufacturing must be kiln-dried to a moisture content of 12±3%. Cross-laminated timber layers parallel to the outside layer must be a minimum of visually graded Number 2 and visually graded Number 3 for the perpendicular layers. The thickness of individual lumber must be 15.9 mm to 50.8 mm. The common lumber choice is 60.96 mm to 241.3 mm in width. Table 2 shows the approved CLT layouts and Table 3 lists the technical specifications of each approved CLT grade in the ANSI/APA-PRG 320 standard.

CLT Panel Manufacturing

Figure 2: Fingered jointed lumber.

The production process of the CLT panels starts with a quality check of the available lumber regarding sizes, moisture content, and lumber grade. First, the lumber is bonded lengthwise using finger joints (Figure 2).

Table 2: CLT panels grade and specification details

CLT Grades	Specification details.
E1	1950f-1.7E Machine Strength Rated (MSR) Spruce-Pine-Fir (SPF) in all parallel layers and No. 3 SPF in all perpendicular layers
E2	1650f-1.5E MSR Douglas Fir-Larch lumber in all parallel layers and No. 3 Douglas Fir-Larch lumber in all perpendicular layers
E3	1200f-12E MSR, Northern Species, Eastern Softwoods or Western Woods in all parallel layers and No. 3, Northern Species, Eastern Softwoods or Western Woods all perpendicular layers
E4	All Parallel layers: 1950f -1.7E MSR Southern pine lumber and All Perpendicular layers: No. 3 Southern pine lumber
E5	All Parallel layers: 1950f -1.7E MSR Hem-fir lumber and All Perpendicular layers: No. 3 Hem-fir lumber
V1	All Parallel layers: No. 2 Douglas Fir-Larch and All Perpendicular layers: No. 3 Douglas Fir-Larch lumber
V1(N)	All Parallel layers: No. 2 Douglas Fir-Larch (North) and All Perpendicular layers: No. 3 Douglas Fir-Larch lumber (North)
V2	All Parallel layers: No. 1/No. 2 SPF lumber and All Perpendicular layers: No. 3 SPF lumber
V3	All Parallel layers: No. 2 Southern pine lumber and All Perpendicular layers: No. 3 Southern pine lumber
V4	All Parallel layers: No. 2 SPF lumber and All Perpendicular layers: No. 3 SPF lumber
V5	All Parallel layers: No. 2 Hem-fir lumber and All Perpendicular layers: No. 3 Hem-fir lumber
S1	2250f-1.5E LVL in all longitudinal and transverse layers
S2	1900f.1.3E LSL in all longitudinal and transverse layers
S3	1750f-1.3E OSL in all longitudinal and transverse layers

Table 3: Design values of CLT panels based on grade and number of layers. Adopted from (APA-PRG 320, 2018)

CLT grade	Layers	Strength Value							
		Major Strength Direction				Minor Strength Direction			
		FbSeff,0 N -mm/m	Eleff, 0 N-mm^2/m	GA eff, 0 (N/m of width)	Vs,0 (kNhn of width)	FbSeff,90 N -mm/m	Eieff 90 N-mm^2/m	GA, eff 90 (N/m of width)	Vs,90 (kNhn of width)
E1	3	42	1,088	7.3	35	1.4	32	9.1	12
	5	98	4,166	15	58	12	837	18	95
	7	172	10,306	22	82	29	3,220	27	58
E2	3	36	958	8	44	0.94	36	8.2	15
	5	83	3,674	16	74	8.2	930	16	44
	7	146	9,097	24	103	19	3,569	25	74
E3	3	26	772	5.3	30	0.92	23	6.4	10
	5	60	2,956	11	50	8	605	13	30
	7	106	7,313	16	70	18	2,325	19	50
E4	3	36	958	8	37	1.4	36	8.2	12
	5	83	3,674	16	62	12	930	16	37
	7	146	9,097	24	87	29	3,569	25	62
E5	3	15	1,023	8	44	0.94	36	8.7	15
	5	35	3,922	16	74	8.2	930	17	44
	7	61	9,708	24	103	19	3,571	26	74
V1	3	18	884	7.2	35	1.4	32	7.5	12
	5	41	3,388	14	58	12	837	15	95
	7	72	8,388	22	82	29	3,213	23	58
V1(N)	3	17	1,023	8	37	1.4	36	8.7	12
	5	38	3,922	16	62	12	930	17	37
	7	67	9,708	24	87	29	3,571	26	62
V2	3	51	1,226	8.9	43	6.9	47	8.9	14

Continued from previous Table									
CLT grade	Layers	Strength Value							
		Major Strength Direction				Minor Strength Direction			
		FbSeff,0 N -mm/m	Eleff, 0 N-mm^2/m	GA eff, 0 (N/m of width)	Vs,0 (kN/n of width)	FbSeff,90 N -mm/m	Eieff 90 N-mm^2/m	GA, eff 90 (N/m of width)	Vs,90 (kNhn of width)
	5	117	4,704	18	71	60	1,226	18	43
	7	207	11,647	27	99	138	4,704	27	71
V3	3	43	1,059	7.7	49	5.8	41	7.7	16
	5	99	4,064	15	81	51	1,059	15	49
	7	175	10,064	23	113	116	4,064	23	81
V4	3	0.4	1,059	7.7	37	5.4	41	7.7	12
	5	91	4,064	15	62	47	1,059	15	37
	7	161	10064	23	87	107	4,064	23	62
V5	3	42	1,088	7.3	35	1.4	32	9.1	12
	5	98	4,166	15	58	12	837	18	95
	7	172	10,306	22	82	29	3,220	27	58
S1	3	51	1,226	8.9	43	6.90	47	8.9	14
	5	117	4,706	18	71	60	1,226	18	43
	7	207	11,647	27	99	138	4,706	27	71
S2	3	43	1,059	7.7	49	5.80	41	7.7	16
	5	99	4,064	15	81	51	1,059	15	49
	7	175	10,064	23	113	116	4.064	23	81
S2	3	43	1,059	7.7	49	5.80	41	7.7	16
	5	99	4,064	15	81	51	1,059	15	49
	7	175	10,064	23	113	116	4.064	23	81

After finger-jointing, the lumber is dressed (surfaced) all four sides to ensure the required width and thickness and are trimmed to the desired length according to the designed dimension for parallel and perpendicular layers (Figure 3). All panels are assembled using a similar technique to plywood production: first, the bottom layer is placed on glue bench and the machine spreads the adhesive on top before laying adjacent perpendicular layers. See Figure 4.

After applying adhesive, each panel is immediately pressed to form a solid CLT structure, see Figure 5. The pressing force must meet the specifications of the adhesive and lumber species. Equally distributed adequate pressure is essential over the whole CLT panel layer surface to guarantee a consistent bond line.

Figure 3: Lumber cut to CLT lengths after finger jointing.

Cross-laminated timber panels from the press come with excess adhesive on the edge of the panels. Therefore, this excess must be removed by edge trimming. Finally, all panels are dressed properly for finishing. CLT panels are customized according to the end-use by cutting, trimming, milling, and drilling to match the design specifications, see Figure 6.

CLT manufacturing's final step is product labeling using manufacturing, logistics, and on-site assembly information. The finished product is packaged to protect it from harsh weather conditions and prepared for shipping. All the assembly parts are collected at the installation site, where the structure will be constructed.

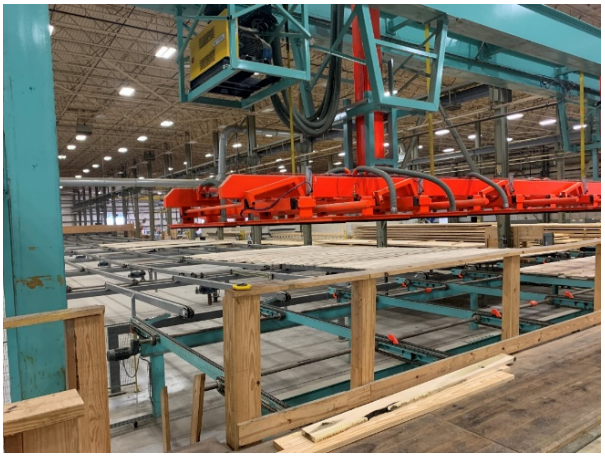

Figure 4: Vacuum stacking of the lumber for layups.

Advantages of CLT Panels

The sustainable nature of wood due to carbon sequestration and minimum embodied energy is the major environmental advantage of CLT panels compared to steel and concrete construction. Some studies concluded that an average of 26.5% reduction in global warming potential could be achieved with CLT construction compared to concrete and other construction materials (Vanova et al., 2021).

CLT panels have ease of factory prefabrication of the parts and design flexibility. This allows for precise openings for doors, windows, and other mechanical elements of the structure. Figure 7 shows the building Dalston Lane, the largest CLT structure in the World.

CLT panel construction helps to reduce onsite work and assembly. It is estimated to cut construction time by a minimum of 20% when compared to concrete construction. CLT construction also helps to reduce

waste on construction sites due to prefabrication practice (Augustus; Raymond, 2019).

Figure 5: CLT panel pull-out form press and ready for CNC work.

Figure 6: CNC machine working on the panel to cut into final dimension.

CLT panels have a thermal conductivity of 0.13 W/mK, better than steel and concrete structures, providing better insulation properties and CLT panels provide outstanding structural stability and stiffness. The cross-laminating of layers exhibits relatively high in-plane and out-of-plane strength, resulting in higher load-bearing capacity.

The strength and cross lamination make CLT capable of a two-way span, like reinforced concrete, providing the ease of transferring the load into two-structural directions. Higher seismic and fire resistance ability of CLT panels is the major advantage over traditional construction materials. The fibrous nature of wood and assembly connection of CLTs provides seismic flexibility. A charred layer is formed on the CLT surface during the fire, preventing oxygen from the outside and limiting the fire from spreading much.

Figure 7: Dalston Lane, the Largest CLT Building in the World. Source: (Schuler Timothy A., 2018)

Construction with CLT panels results in lower-weight buildings than traditional construction systems. As a result, it requires minimum foundation work for construction.

Disadvantages of CLT Panels

Currently CLT panels are more expensive than traditional construction such as steel or concrete. Its price depends on the need for transportation, foundation work, assimilation cost, and CLT grade. Transportation is a significant cost factor, so it is less attractive if the construction requires long-distance hauling. CLT panels could be more cost-effective for mid, and high-rise buildings only, so they will not be the primary choice for residential housing to compete with timber frame construction.

Limited availability and a long waiting time are other limitations as there are very few CLT industries in operation. CLT manufacturing requires huge lumber volumes and is adding additional demand for structural grade lumber.

Finally, obtaining desired acoustic insulation may be a problem and it requires the use of additional materials such as light concrete to increase acoustic insulation.

Acknowledgment

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