

Katerra CLT Product Definition

Updated September 2019

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Introduction

This document defines Kattera's cross-laminated timber (CLT) product line for use in commercial building projects in the United States. The document is intended for use by representatives of architecture, building engineering, and construction to properly design, specify, and construct buildings using Kattera CLT. The definition herein represents the product line currently available from the Kattera CLT Factory in Spokane Valley, WA as it comes online in 2019.

1. Kattera CLT Overview

Kattera has built a world-class mass timber operation, spanning research, architecture, engineering, sourcing, manufacturing, logistics, and construction.

We control and optimize the entire building process, taking a technology-first approach and investing in R&D and continuous innovation at each step of the value chain. Kattera's team includes globally recognized leaders and best-in-class partners, and our production capacity and service capabilities are unmatched. The result is a portfolio of CLT structural products and full-scale building systems that will continue to expand and add value over time.

1.1 Katerra CLT Definition

Katerra CLT is a premanufactured, prefabricated, engineered solid wood building material composed of Katerra-specified lumber (aka laminations) stacked crosswise at 90-degree angles in multiple layers (aka plies) and bonded together under high pressure using structural adhesives.

The large format size, cross-layer makeup, and high strength-to-weight ratio position Katerra CLT as a natural, high-performance substitute for conventional concrete, masonry, and steel, as well as wood truss and joist floors.

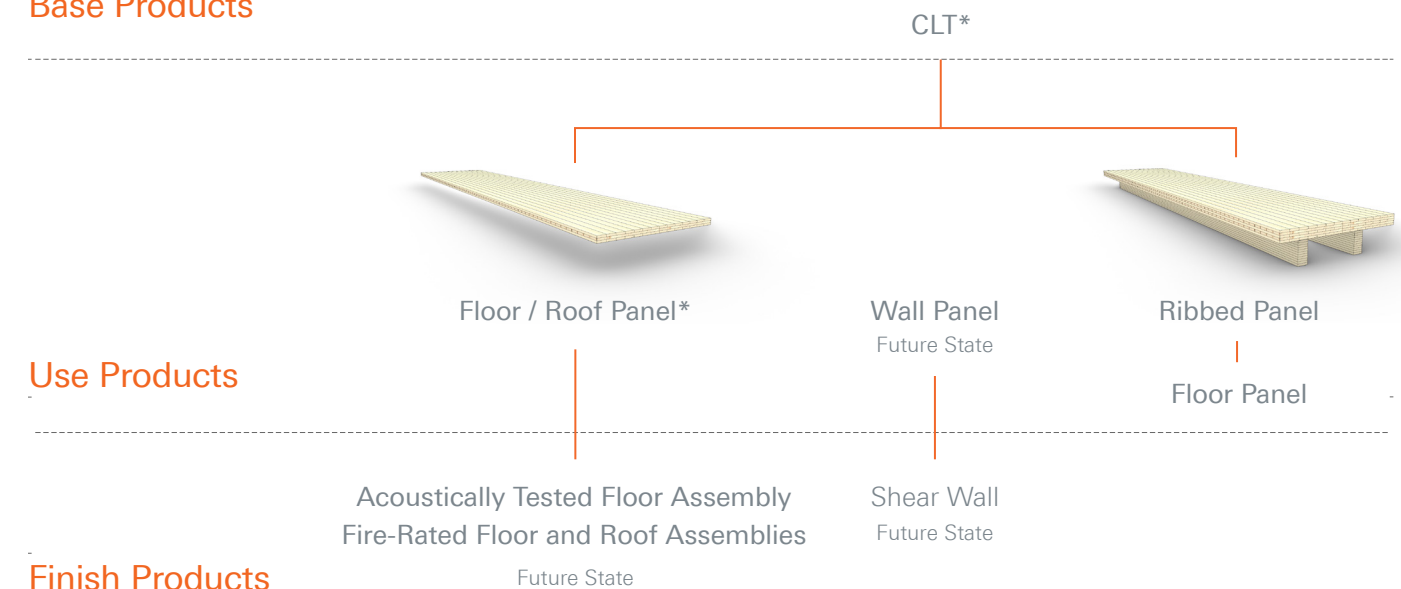
Produced at Katerra’s Spokane Valley factory, Katerra CLT is manufactured and tested for its intended use in compliance with the 2018 International Building Code (IBC) and all relevant reference standards including ANSI/APA PRG 320 (2018) for ready use in the United States. Complete certification for use in Canada is anticipated for late 2019.

1.2 Katerra CLT Products

Katerra is developing an entire line of CLT and CLT-related products for manufacture, organized in the graphic below. This document focuses on defining the Katerra CLT Flat Panel base product and its derivative use products, CLT Flat Roof and Floor Panel.

Each Katerra CLT product includes a variety of thicknesses and layer combinations (layups) resulting in a catalog of sizes. End users may select the layup that best meets the building’s product-specific structural, fire, acoustics, and environmental performance requirements.

Base Products



Use Products

Finish Products

*Defined in this document

2. Katerra CLT Product Definition

Katerra CLT Flat Panels offer maximum nominal dimensions of 12 ft width by 60 ft length and 9-ply, 12.4 in thickness. CLT Flat Panels are primarily intended for use as the structural substrate for floor and roof assemblies, but they are also suited for bearing or shear walls in the appropriate code-compliant application.

2.1 CLT Flat Panel Applications

Building Construction Type (2018 IBC)	Katerra Project Type Examples	Building Product Component
I – Not Permitted ¹	Garden Chassis (Residential)	1-way spanning Floor/Roof panels on light-framed wood walls
II – Not Permitted ¹	Podium (Residential)	1-way spanning Floor/Roof panels on light-gauge steel walls
III – Permitted	Student Housing	Floor plate component in ribbed panels
IV – Permitted	Commercial Office	Bearing walls
V – Permitted		Shear walls (low-seismic only)

¹ CLT is allowed as a part of Heavy Timber roof construction in accordance with the International Building Code (2018 IBC).

The initial Katerra CLT panel is primarily intended for one-way slab span behavior in the panels strong direction for out-of-plane loads and acts as the floor/roof diaphragm without the addition of plywood sheathing. The bottom side of suitably-sized floor panels may be visually exposed to achieve a 1- or 2-hour fire resistance rating through charring of the wood.

The width of laminations (boards) in outer visible layers and inner layers of panels are nominally 6 in. Architectural and Industrial Appearance surface classifications are available, where Architectural Appearance surface classification may be specified on one, both, or neither of the broad surfaces of the panel. Our CLT is compatible with a number of different surface treatments (i.e., painted, stained, sealed, etc.), which should be evaluated on a project-by-project basis.

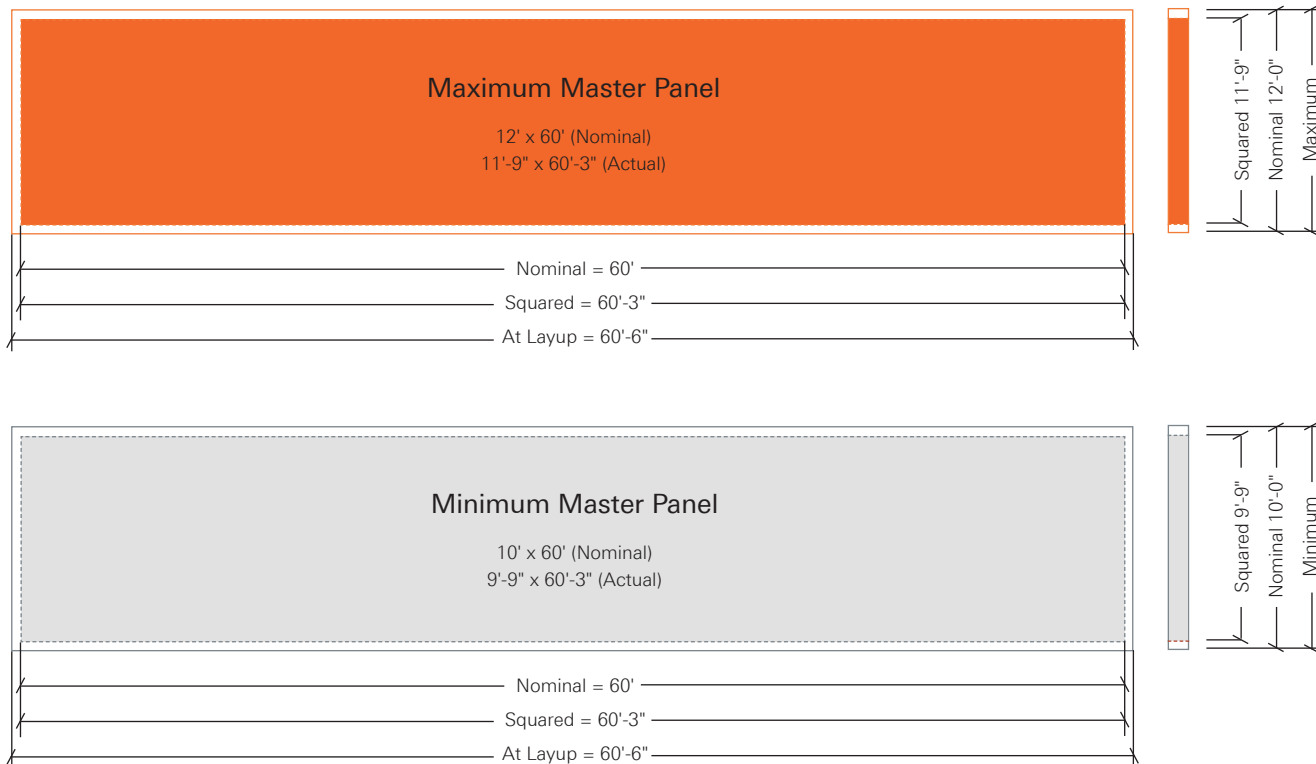
Longitudinal boards are end-jointed (finger-jointed) at random lengths to create continuous 60 ft long boards from which the master panel is layed up. Endjoints are cut parallel to the wide face of laminations, thus the fingers will be visible on the narrow face of boards. Transverse boards are continuous and do not contain finger joints.

Finished panels are accurately fabricated from full master panels to the user-specified size, shape, and level of detail by state-of-the-art CNC machines to provide precise field fit. Section 2.10 presents a summary of representative subtractive fabrication capabilities in the factory for edge connections. Consult with manufacturing on a project basis to review the manufacturability of the proposed CLT panelization, holes, and edge cut fabrication at early design stages.

2.2 CLT Flat Panel Characteristics

Characteristics	Features	
Master Panel Format Size	Length Width	Actual max/min 60'-3" (60 ft nominal) Actual max 11'-9" (12 ft nominal) Actual min 9'-9" (10 ft nominal) Notes: 1. The maximum and minimum widths presented above are based on the use of 10 ft and 12 ft long laminations at layup and trimming the master panel to square after pressing. 2. Consult with manufacturing for custom master panel widths between the stated maximum and minimum widths.

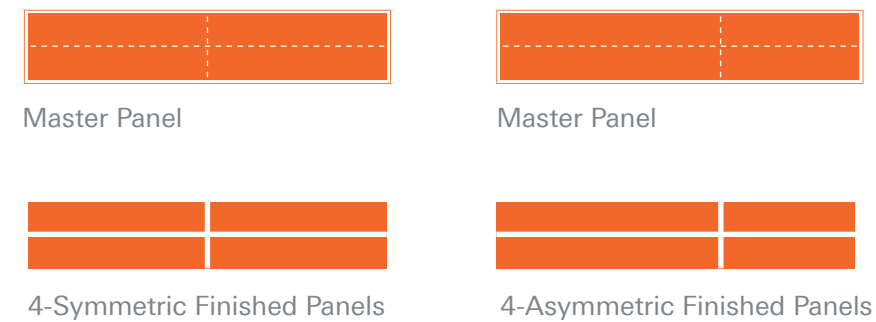
Actual Size versus Nominal Size of Master Panel



2.2 CLT Flat Panel Characteristics (Continued)

Standard Finished Panel Format Lengths and Widths Cut from Master Panel	Lengths	60'-0" 30'-0" 20'-0" 15'-0" 10'-0" 8'-0"	Notes: 1. The subdivisions presented at left are symmetric. Asymmetric subdivisions can be manufactured. The designer is cautioned to subdivide master panels in ways that result in a high rate of master panel utilization. 2. Selection of finished panel width and length to be informed by logistics, erection, design, etc.
	Widths (12 ft)	11'-9" 5'-9"	
	Widths (10 ft)	9'-9" 4'-9"	
Panel Thickness	(See layups in Section 2.3)		
Laminations	Layers (plies) Orientation Thickness Width	3, 5, 7, and 9 Adjacent layers are perpendicular Post-planed: approx. 1.08–1.38 in (see layups below) Post-planed: approx. 5.31 in	
Species / Species Group	All panels are comprised of a single species combination		
Adhesives	Face bonding End-joints	1-component polyurethane (formaldehyde-free) 2-component melamine formaldehyde with RF curing	

Examples of Finished Panels Cut from a Master Panel



2.2 CLT Flat Panel Characteristics (Continued)

Master Panel Tolerances at the Time of Manufacturing	Thickness	+/- 1/16" or 2% of panel thickness, whichever is greater
	Width	+/- 1/8"
	Length	+/- 1/8"
	Squareness	1/8" max – (difference in length two panel face diagonals measured between corners)
	Straightness	1/8" max – (deviation of edges from a straight line between adjacent panel corners)
Finish Panel CNC Tolerances	Fabrication tolerances using factory CNC equipment will generally be +/- 1/16"	
Moisture Content	12% +/- 3% (at the time of manufacture)	
Surface Classification Options	Industrial Appearance (IA)	Architectural Appearance (AA)
Density	Dependent on species used (Reference the National Design Specification (NDS) for Wood Construction)	
Use Conditions	Dry (Ref PRG 320 – Section 1 – Scope)	
Panel Orientation	Longitudinal layers (long boards) are parallel to the long dimension of the master panel.	
Edge Sealer	Panel edges and cutouts with exposed lamination end grain is coated with a clear factory applied end-grain sealer.	

2.3 CLT Flat Panel Layups

	CLT Layup Designation ¹	CLT Thickness (in)	Lamination Thicknesses in CLT Layup (in) ^{2,3}												
			=	⊥	=	⊥	=	⊥	=	⊥	=				
3-ply 	K3-0320	3.24	1.08	1.08	1.08										
	K3-0350	3.54	1.08	1.38	1.08										
	K3-0380	3.84	1.38	1.08	1.38										
	K3-0410	4.14	1.38	1.38	1.38										
5-ply 	K5-0540	5.40	1.08	1.08	1.08							1.08	1.08		
	K5-0600	6.00	1.08	1.38	1.08							1.38	1.08		
	K5-0630	6.30	1.38	1.08	1.38							1.08	1.38		
	K5-0660	6.60	1.32	1.32	1.32							1.32	1.32		
7-ply 	K7-0970	9.66	1.38	1.38	1.38							1.38	1.38	1.38	1.38
9-ply 	K9-1120	11.22	1.38	1.08	1.38							1.08	1.38	1.08	1.38
	K9-1240	12.42	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38				

Layup Availability: ■ Estimate for release Q3 2019; ■ Estimated for release Q4 2019; ■ Estimated for release Q1 2020

¹ "CLT Layup" is classified as a "CLT-Grade" in the PRG-320 standard

² "=" indicates laminates are parallel to the longitudinal axis of the panel;
 "⊥" indicates laminates are perpendicular to the longitudinal axis of the panel

³ See Section 3.3 for associated design values for each CLT layup designation

2.4 Appearance Classifications

Katerra produces two appearance classifications for its CLT floor/roof product line to achieve the project's visual appearance requirements. An Architectural Appearance (AA) surface classification may be specified for the broad faces of a panel on a single face, both faces, or no faces. Unless otherwise specified, the top side of all Katerra CLT floor/roof panels have an Industrial Appearance (IA) classification, and the bottom side of all panels have an Architectural Appearance (AA), where top side is defined by the orientation of the panel as installed in the field. The following table presents the visual characteristics of each surface classification.^{1,2}

Characteristic	Industrial Appearance (IA)	Architectural Appearance (AA)
Surface finish	Sanded 80 grit	Sanded 80 grit
Color and texture	Not specified	Well-balanced color and texture
Blue/Brown stain	Permitted	Up to 5% of area max permitted
Knots (i.e., intergrown, spike, loose)	At edge: 1-7/8" max dia At centerline: 2-7/8" max dia	At edge: 1" max dia
Knot holes	1-1/2" max dia	At centerline: 1" max dia
Resin pockets	Permitted	3/4" max dia.
Pith	Permitted	Occasionally permitted, 3/8" x 3" max, or the equivalent in square inches
Bark ingrowth	Permitted	Occasional pith up to a length of 36" permitted
Wane	1/3 the thickness and 1/3 the width full length, or equivalent on each face, provided wane does not exceed 2/3 the thickness or 1/2 the width for up to 1/4 the length.	Not permitted
Compression wood	Permitted	To some extent permitted

2.4 Appearance Classifications (Continued)

Characteristic	Industrial Appearance (IA)	Architectural Appearance (AA)
Insect damage	Occasionally permitted	Not permitted
Decay (unsound wood)	Honeycomb or peck are limited to 1/6 the width. Any other unsound wood is limited to a spot 1/12 the width and 2" in length or smaller.	Not permitted
Wood shake, splits, checks (at manufactured MC reference)	Permitted	Occasional surface cracks permitted, occasional end shakes, up to 2" length
Sapwood	Permitted	Permitted
Edge gluing	No	Only upon request
Edge joint gaps	Less than 1/8"	Less than 1/16"

¹ The specified surface qualities are only valid for the outer layer(s) at the time of manufacturing, and therefore are not applicable to the end grain (narrow faces) of the panel.

² Like all wood products, the above stated qualities are at the time of manufacturing and subject to crack and joint formation as a result of normal drying to the equilibrium moisture content of the location and conditions wherein the product is finally installed. Refer to the Katerra CLT Product Care Manual for recommendations for protection during transportation, site storage, and installation.

2.5 Design and Mechanical Properties of Laminations¹

CLT Grade ²		V2 (SPF)	
Orientation	—	Longitudinal layers	Transverse layers
Species	—	S-P-F ³	S-P-F ³
Stress class	Visually graded ²	No. 2	No. 3
Specific gravity	SG	0.42	0.42
Bending at extreme fiber	Fb (psi)	875	500
Shear parallel to grain	Fv (psi)	135	135
Rolling shear	Fs (psi)	45	45
Compression parallel to grain	Fc (psi)	1,150	650
Compression perpendicular to grain	Fcp (psi)	425	425
Tension parallel to grain	Ft (psi)	450	250
Modulus of elasticity	E (psi)	1,400,000	1,200,000

¹ All values are NDS Reference Design Values and minimum requirements for Katerra CLT

² Visual grading rules as established by National Lumber Grades Authority (NLGA) 2017 Edition.

³ Species group Spruce-Pine-Fir (S-P-F)

2.6 Fire Performance

Characteristic	Standard	Value ¹
Fire resistance rating	ASTM E119	Floor and Roof 1-hr, Floor 2-hr
Char rate	—	TBD
Spread of flame and smoke index rating	ASTM E84	Class B
Through-penetration fire stopping	ASTM E814	1- and 2-hour

¹ CLT product has been tested per the reference standards in third-party accredited laboratories. Consult Katerra's CLT product management team for specific products tested and performance requirements that have been met.

2.7 Acoustic Performance of Bare CLT¹

Characteristic	Standard	Value
Airborne Sound Transmission Class (STC)	ASTM E90	K5-0540: STC = 41" ²
Impact Insulation Class (IIC)	ASTM E492	K5-0540: IIC = 27" ²

¹ CLT may need to be integrated into an assembly with supplemental materials to achieve desired acoustic performance.

² CLT product has been tested per the reference standards in third-party accredited laboratories. Consult Katerra's CLT product management team for specific products tested and performance requirements that have been met.

2.8 Thermal Performance

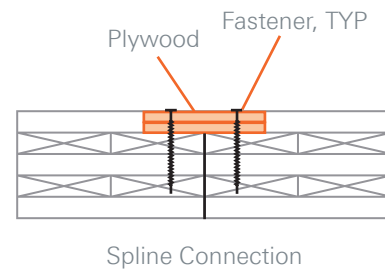
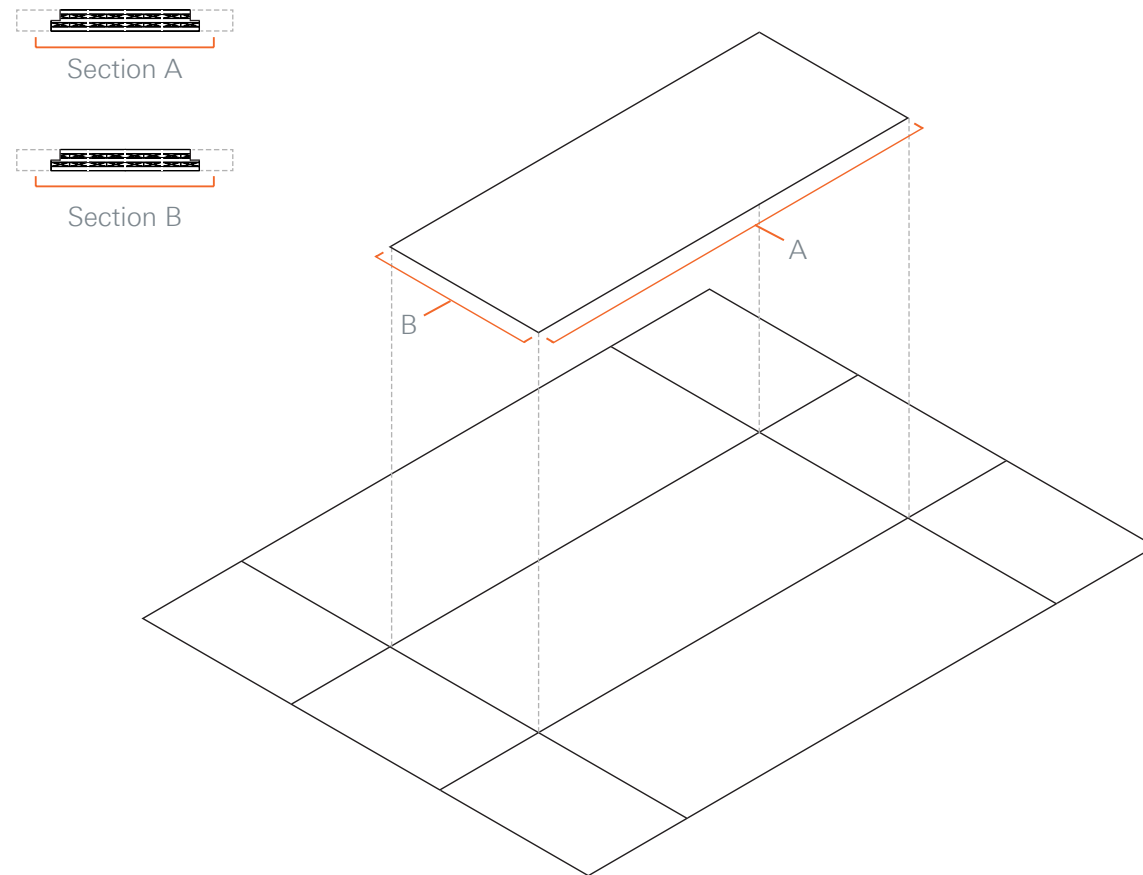
Characteristic	Standard	Value
Thermal conductivity (U)	TBD	TBD
Thermal resistance (R)	TBD	TBD
Airtightness	TBD	TBD

2.9 Water Vapor Transmission of Bare CLT

Characteristic	Standard	Value
Permeance, desiccant method	ASTM E96, Dry Cup	TBD
Permeance, water method	ASTM E96, Wet Cup	TBD

2.10 Typical Panel-to-Panel Connection Configurations

Katerra has the capabilities to pre-fabricate CLT Flat Panels for quick and accurate onsite installation using state-of-the-art CNC equipment located in its Spokane Valley manufacturing facility. Used as floor or roof panels, we recommend the following panel-to-panel connections configurations to ensure strength, stiffness, fire, vibration, and acoustic performance requirements of the application are met.



Note:

1. Sketches are not to scale.
2. The detailed specifics and design of the connections is subject to coordination and may vary depending on the application.

2.11 Environmental Voluntary Certification

Katerra will pursue third-party voluntary environmental certification of Katerra CLT to demonstrate transparency in its materials and manufacturing process, as well as quantify the embodied environmental impacts of Katerra CLT. In accordance with the certification standard, this effort will commence once the factory has been in operation for a minimum of 12 months.

The environmental label certification Katerra will pursue is a product- and process-specific Type III Environmental Product Declaration to ISO 14025 *Environmental labels and declarations – Type III environmental declarations – Principles and procedures (EPD)*. Type III EPDs provide quantified and third-party reviewed environmental information on the cradle-to-gate life cycle of a product to enable comparisons between products fulfilling the same function. Lifecycle impact categories measured include the following:

- Global warming potential
- Ozone depletion potential
- Photochemical ozone creating potential
- Acidification potential
- Eutrophication potential
- Depletion of abiotic resources (elements, fossil fuels)

Sourcing 100 percent of our lamstock from well-managed forests is a basic Katerra requirement. All lamstock sourced from Canada will be SFI or PEFC certified at a minimum.

3. Component Characteristics

Katerra CLT is composed of two basic components, laminations and adhesives. The following provides a detailed description of each component.

3.1 Laminations

The laminations used in Katerra's CLT product line are shaped by raw materials with the desired mechanical and visual characteristics. The following presents the maximum allowable characteristics of the natural laminations from which Katerra CLT is manufactured. Some characteristics below are further limited by the selected surface classification of the CLT product for application.

Characteristic	Longitudinal Laminations	Transverse Laminations
Species/Group	Spruce-Pine-Fir (SPF)	Spruce-Pine-Fir (SPF)
Moisture content	12% (+/- 3%) average measure per lamination, with no measurement greater than 19% (no less than 5 measurements)	12% (+/- 3%) average measure per lamination, with no measurement greater than 19% (no less than 5 measurements)
Checks	Equal in length to 1 ½ times the width of the piece	Up to 1/6 the length of the piece
Grain	Medium – average of 4 or more annual ring per inch on either end of a piece measured on a representative radial line	Not Applicable
Knots	At-edge Wide Face = 1 7/8" Centerline Wide Face = 2 7/8" Holes = 1 ½" @ (2) lin. ft	At-edge Wide Face = 2 ¾" max Center Wide Face = 3 ¾" max Holes = 2" @ (1) lin. ft
End knots	Knots exceeding 3/8" dia are not permitted within 3 knot dia or 6", whichever is greater, of the end lamination	Not Applicable
Manufacture	Standard (E) – very heavy torn grain; raised grain; very heavy loosened grain; medium machine bite; machine gouge; medium machine offset; chip marks; knife marks; light wavy dressing; light mismatch	Standard (E) – very heavy torn grain; raised grain; very heavy loosened grain; medium machine bite; machine gouge; medium machine offset; chip marks; knife marks; light wavy dressing; light mismatch
Pitch and pitch streaks	Not limited	Not limited

3.1 Laminations (Continued)

Characteristic	Longitudinal Laminations	Transverse Laminations
Pockets, pitch, or bark	Not limited	Not limited
Shake	If at ends (see Splits). Away from ends through shakes up to 2' long, well separated. If not through, single shakes shall not exceed 3' long or 1/4 the length, whichever is greater.	If at ends (see Splits). Surface shakes permitted. Through shakes 1/3 length, scattered along.
Skips	Hit and miss, with a maximum of 5% of the pieces containing hit or miss or heavy skip 2' or less in length. Permit series of skips completely or partly surfaced or entirely rough not over 1/16" deep.	Hit and miss, with a maximum of 10% of the pieces containing heavy skips (not over 1/8" deep). Permit series of skips completely or partly surfaced or entirely rough not over 1/16" deep.
Slope of grain	1 in 8	1 in 4
Splits	Up to 1 1/2 times the width of the piece	Up to 1/6 the length of the piece
Stain	Stained sapwood. Firm heart stain or firm red heart. Not limited.	Stained wood not limited
Unsound wood	Excluding white speck – not permitted in thicknesses over 2". In 2" lumber, small spots or streaks of firm honeycomb or peck are limited to a spot of 1/12 the width and 2" in length or smaller.	Must not destroy the nailing edge. Spots or streaks limited to 1/3 the cross section at any point along the length.
Wane	1/3 thickness and 1/3 the width full length, or equivalent on each face, provided wane does not exceed 2/3 thickness or 1/2 the width for up to 1/4 the length	1/2 thickness and 1/2 the width full length, or equivalent on each face, provided wane does not exceed 7/8 thickness or 3/4 the width for up to 1/4 the length
Wane (Sorted) ¹	10% in any 4' long length along the lamination	
Warp	Light (for 2x6 at 8'+ long)	Medium (for 2x6 at 12' long) Firm
Bow (Sorted) ¹	≤ 2" over 12', ≤ 1" over 6' ²	

3.1 Laminations (Continued)

Characteristic	Longitudinal Laminations	Transverse Laminations
Bow (Sorted) ¹	≤ 2" over 12', ≤ 1" over 6' ²	
Crook (Sorted) ¹	≤ 0.037" over 12', ≤ 0.019" over 6'	
Cup (Sorted) ¹	≤ 0.0625"	
Twist (Sorted) ¹	≤ 0.5" over 12', ≤ 0.25" over 6'	
White speck and honeycomb	Firm, 1/3 the face or equivalent	Firm
Marking/ Identification ³	Grade stamped no less than No. 2	Grade stamped no less than No. 3

¹ "Sorted" indicates limits for entry into the process for layup.

² The indicated limit is for a uniform bow arc. Where bow is isolated to within 1/3 of the end of the lamination, the material shall not be permitted.

³ Reference NLGA grading rules for additional information.

3.2 Adhesives

Katerra CLT panels are face bonded together with a structural adhesive between each layup layer to create a composite solid wood element. Longitudinal boards are end-jointed together using a structural adhesive. The face bonding adhesive is formaldehyde-free and provides a visually clear bondline.

The structural face and end-joint adhesives are certified for use per the PRG-320 (2018) manufacturing standard.

3.3 Design Values

Table 1:

Allowable Design Properties for Lumber Laminations Used in Katerra CLT											
Major Strength Direction						Minor Strength Direction					
$f_{b,0}$ (psi)	$E(10^5 \text{ psi})$	$f_{t,0}$ (psi)	$f_{c,0}$ (psi)	$f_{v,0}$ (psi)	$f_{s,0}$ (psi)	$f_{b,90}$ (psi)	$E(10^5 \text{ psi})$	$f_{t,90}$ (psi)	$f_{c,90}$ (psi)	$f_{v,90}$ (psi)	$f_{s,90}$ (psi)
875	1.4	450	1150	135	45	500	1.2	250	650	135	45

Note: Properties are based on visual grade S-P-F No. 1/No. 2, and No. 3 for major and minor strength directions, respectively.

3.3 Design Values (Continued)





Table 2 – Part 1: Allowable Design Values¹ for Katerra CLT

	CLT Layup Designation	CLT Thickness (in)	Lamination Thicknesses in CLT Layup (in)								
			=	⊥	=	⊥	=	⊥	=	⊥	=
3-ply 	K3-0320	3.2	1.08	1.08	1.08						
	K3-0350	3.5	1.08	1.38	1.08						
	K3-0380	3.8	1.38	1.08	1.38						
	K3-0410	4.1	1.38	1.38	1.38						
5-ply 	K5-0540	5.4	1.08	1.08	1.08	1.08	1.08				
	K5-0600	6.0	1.08	1.38	1.08	1.38	1.08				
	K5-0630	6.3	1.38	1.08	1.38	1.08	1.38				
	K5-0660	6.6	1.32	1.32	1.32	1.32	1.32				
7-ply 	K7-0970	9.7	1.38	1.38	1.38	1.38	1.38	1.38	1.38		
9-ply 	K9-1120	11.2	1.38	1.08	1.38	1.08	1.38	1.08	1.38		
	K9-1240	12.4	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38

¹ Reference NLGA grading rules for additional information.

3.3 Design Values (Continued)





Table 2 – Part 2: Allowable Design Values¹ for Katerra CLT

	CLT Layup Designation	CLT Thickness (in)	Major Strength Direction				Minor Strength Direction			
			$F_b S_{b,eff,0}$ (10 ⁶ lb-ft/ft)	$EI_{eff,0}$ (10 ⁶ lb-in ² /ft)	$GA_{eff,0}$ (10 ⁶ lb/ft)	$V_{s,0}$ (lb/ft)	$F_b S_{b,eff,90}$ (10 ⁶ lb-ft/ft)	$EI_{eff,90}$ (10 ⁶ lb-in ² /ft)	$GA_{eff,90}$ (10 ⁶ lb/ft)	$V_{s,90}$ (lb/ft)
3-ply 	K3-0320	3.24	1250	46	0.36	1170	95	1.50	0.41	390
	K3-0350	3.54	1460	59	0.37	1270	160	3.20	0.51	495
	K3-0380	3.84	1790	78	0.45	1380	95	1.50	0.42	390
	K3-0410	4.14	2050	96	0.46	1490	160	3.20	0.52	495
5-ply 	K5-0540	5.40	2875	176	0.72	1940	845	39	0.81	1170
	K5-0600	6.00	3350	227	0.74	2160	1200	66	1.00	1380
	K5-0630	6.30	4125	293	0.91	2270	985	50	0.84	1270
	K5-0660	6.60	4300	321	0.88	2380	1260	72	0.99	1430
7-ply 	K7-0970	9.66	8325	908	1.40	3475	3175	315	1.60	2480
9-ply 	K9-1120	11.22	11350	1437	1.80	4050	4000	486	1.70	3050
	K9-1240	12.42	12900	1810	1.80	4475	5625	782	2.10	3475

¹ Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS.

3.3 Design Values (Continued)

Table 3: Allowable Design Values¹ for Edgewise Shear of Katerra CLT in the US

	CLT Layup Designation	CLT Thickness (in)	Edgewise Shear Stress ²	
			$F_{v,e,0}$ (psi)	$F_{v,e,90}$ (psi)
3-ply 	K3-0320	3.24	*	*
	K3-0350	3.54	*	*
	K3-0380	3.84	*	*
	K3-0410	4.14	*	*
5-ply 	K5-0540	5.40	*	*
	K5-0600	6.00	*	*
	K5-0630	6.30	*	*
	K5-0660	6.60	*	*
7-ply 	K7-0970	9.66	*	*
9-ply 	K9-1120	11.22	*	*
	K9-1240	12.42	*	*

¹ The tabulated values are allowable (ASD) design values.

² The tabulated values shall be multiplied by the gross area (full thickness of the CLT x Length) to attain an allowable force for the element under consideration.

* Design values are pending testing to ASTM D5456 Annex A3 to fulfill the requirements of PRG 320 Section 8.5.6.