STRUCTURLAM
MASS TIMBER CORPORATION

Intelligence In Wood

Mass Timber Design Guide

CrossLam® CLT | GlulamPLUS® | Mass Timber Building Systems

U.S. VERSION

Penticton Lakeside Resort, Penticton, BC, Canada

Mica Heli-Ski Lodge, Mica, BC, Canada

Beautifully engineered to change an entire industry.

At Structurlam, it's been our goal for more than 50 years to innovate and push the boundaries of our industry in order to create new limits of what it means to build with wood. Through our experience in bringing buildings to life, we've been proud to be part of developing and producing structures in exciting and efficient new ways.

In fact, as the industry moved toward concrete and steel in commercial buildings, we stayed true to ourselves. We understood the advantages of building with wood and of laminating lumber into beams that could be used in larger structures. We embraced new technology, such as 3D modeling and robotic machinery, to fabricate complete mass timber packages. This allowed us to introduce wood into buildings where it was never considered in the past.

The result is an array of high-performance mass timber structures that are environmentally friendly, cost-effective and aesthetically stunning. As the mass timber industry has evolved, Structurlam has pioneered the use of cutting-edge technology and systems to bring your project from concept to reality. From prefabrication of structural elements to erection on-site, BIM modeling permits the use of mass timber to be highly precise, efficient and cost competitive.

By working with us, you're always assured engineering expertise and design efficiency that reduces time and cost on-site. No job is too simple or too complex, and we'll always work to help you build whatever you dream. So go out there and be creative.

Commercial
Mission Office, Kelowna, BC, Canada

The Structurlam Advantage

Structurlam is more than a fabricator of the highest-quality engineered wood products. We operate at the front lines of innovation in mass timber design, engineering, 3D modeling and precision manufacturing. One of the biggest benefits with mass timber buildings as compared to other types of structures is the ability to prefabricate the entire structure. This saves precious time and money on-site because the installation process becomes more efficient. Since the 1990s, Structurlam has been leveraging state-of-the-art 3D modeling software to virtually construct each building before it is produced. Our team begins with the two-dimensional drawings and creates a 3D model. This model includes all of our components: GlulamPLUS®, CrossLam® CLT, steel connections and associated hardware. Virtual construction allows our highly-trained detailers to detect potential problems and prevent issues in the field. The work to build the model often takes three times longer than the actual time to produce the components, but it's necessary for a smooth assembly process on-site.

Once the design work is complete, the model is used to create manufacturing lists for CrossLam® CLT and GlulamPLUS®. Shop drawings for beams, columns, panels and steel connectors are generated from the 3D model, and digital files are sent to our CNC machines for fabrication. Finally, our 3D model is used to develop a material list for efficient purchasing of steel and hardware components. Loading diagrams are then created to optimize freight and assembly drawings are produced to provide instruction for quick and efficient installation.

Design teams who leverage our fabrication services receive aesthetically appealing buildings with optimized structural performance and rapid assembly; where every piece fits and no detail is missed. Because mass timber structures are relatively new, many of our first-time customers come to us with a concrete building already designed and ask us to offer an option with Structurlam Mass Timber solutions using GlulamPLUS® and CrossLam® CLT. While this is possible, it is always better to design with the structural system of choice. With CrossLam® CLT, optimum sizes are 7'10.5" x 40' and 9'10.5" x 40'. This is the best way to ensure an efficient design, optimal panel spans and layout and the most cost-effective structure.

Structurlam brings cohesion and coordination to project teams, facilitating success from design to installation.

Transportation
Fort McMurray Airport, F. McMurray, AB, Canada

Educational
Okanagan College, Kelowna, BC, Canada

Multi-Family
Virtuoso, Vancouver, BC, Canada

Industrial
BC Passive House Factory, Pemberton, BC, Canada

Winner of 2016 Governor General's Award for Architecture

Healthcare
Ronald McDonald House, Vancouver, BC, Canada

Winner of 2016 Governor General's Award for Architecture

Carbon 12, Portland, OR , USA

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CROSSLAM® CLT

GlulamPLUS®

MASS TIMBER BUILDING SYSTEMS

CrossLam® CLT

When it came to developing a CLT panel for the North American construction market, we wanted to create something revolutionary. As a North American manufacturer, we understand the construction process in our region and are uniquely suited to deliver solutions that serve it. So, we put our decades of experience to the test and the result is CrossLam® CLT, our proprietary CLT panel built specifically for North America using North American lumber. Engineered to be a direct replacement for concrete, but significantly lighter, CrossLam® CLT can be used for floors, walls and roofs. It spans two directions with precision and accuracy, is carbon negative and uses wood from only sustainably managed forests. In fact, CrossLam® CLT opens the door to a new, ecological way to construct the buildings of the 21st century.

When you conceive and design a project with CLT panels from the start, you can build truly efficient, affordable and environmentally sound structures. The technical information in this guide is compiled to support you in developing designs that specify CrossLam® CLT. If you have questions and need help, let our qualified team of technical representatives and support staff help you specify the right panel for your project.

Earth Sciences Building, UBC, Vancouver, BC, Canada

Strengths of the CrossLam® CLT System

PREFABRICATION

CrossLam® CLT is manufactured with CNC machines in a factory environment where close tolerances and rigorous quality control are easily achieved. Our efficient CAD workflow ensures complete coordination between design, manufacturing and on-site construction.

STANDARDIZED SIZING

Building efficiencies are achieved when the project is designed from the beginning with standard CrossLam® CLT panel sizes such as 7’10.5” or 9’10.5” by 40’. This maximizes the utilization of CrossLam® CLT by reducing material costs and waste.

STRUCTURAL STRENGTH AND STABILITY

The CrossLam® CLT system is structurally comparable to steel and concrete but lighter. Projects utilizing the CrossLam® CLT system can have smaller, less expensive foundations and are ideally suited for poor soil conditions.

COST EFFICIENCY

Construction projects that leverage the CrossLam® CLT system achieve cost efficiencies through the combination of material and installation costs and the associated benefits of using a prefabricated system that is structural and architectural. The compressed construction schedule of a well-designed Crosslam® CLT system provides a less expensive option to steel and concrete. CrossLam® CLT can also be competitive with standard light wood framing systems in specific applications.

REDUCED CONSTRUCTION TIME

In comparison to concrete structures, CrossLam® CLT projects are installed in a shorter period of time due to the nature of prefabrication and dry materials. Mass timber components arrive on-site as a kit of parts, require less storage and can be shipped for just-in-time scheduling to facilitate quick assembly in dense urban areas.

Architects and Designers can design with freedom.

Engineers receive a strong, stable building.

General Contractors receive a predictable experience on-site.

Owners receive a green building that is on budget and on time.

LIGHT ENVIRONMENTAL IMPACT

Life Cycle Assessment studies show that CrossLam® CLT has a lighter overall environmental footprint than other building materials. CrossLam® CLT also stores carbon and produces fewer greenhouse gas emissions during manufacture. The wood fiber used in CrossLam® CLT is traceable from certified forests to the consumer. FSC and SFI Chain-of-Custody Certifications are available from Structurlam should your project have this requirement.

STANDARDS

CrossLam® CLT is certified to meet the requirements of the Standard for Performance Rated CLT ANSI/APA PRG-320 and the APA Product Report PR-L314. These standards outline the requirements and test methods for qualification and quality assurance for CLT and are the same across North America.

CODE ACCEPTANCE

The 2015 International Building Code (IBC) and 2015 National Design Specification (NDS) recognize CLT as a structural system; however, it must be manufactured according to the ANSI/APA PRG-320 2012 Standard for Performance Rated Cross-Laminated Timber. The IBC approves the use of CLT in exterior/interior walls, floors and roofs for Type IV Construction and Chapter 10 of the NDS references design values, design equations and overall engineering design specific to the use of CLT. The Structurlam ICC-ES Report affirms *“CrossLam® CLT panels comply with requirements noted in Section 2303.1.4 of the 2015 IBC for allowable stress design in accordance with IBC Section 2301.2(1) and Chapter 10 of the 2015 NDS.”*

CrossLam® CLT Applications

Mission Office, Kelowna, BC, Canada

Tall Tree Integrated Health, Victoria, BC, Canada

BC Passive House Factory, Pemberton, BC, Canada

Structurlam Mass Timber Corporation Factory Addition, Okanagan Falls, BC, Canada

Elevator Core Shaft

FLOORS

CrossLam® CLT panels are ideally suited for modern floor systems because they are two-way span capable and ship to site as ready-to-install components, greatly simplifying building construction and increasing job site productivity. Our expanded array of CrossLam® CLT products helps to ensure an optimized structural solution that allows you to install up to 400 square feet per lift.

ROOFS

CrossLam® CLT panels easily provide overhanging eaves while efficiently spanning a variety of roof layouts. The enhanced thermal properties of CLT contribute to a much more efficient envelope assembly. Panels can be as thin as 3.43" and as thick as 12.42", resulting in a maximum possible roof span of 40' with appropriate loading. CrossLam® CLT roofs are quickly installed, allowing projects to approach lockup and a watertight state in a short amount of time.

WALLS

CrossLam® CLT wall panels are cost-competitive alternatives to precast concrete systems. They are lighter than precast concrete and can be handled with greater ease. When used as a system, CrossLam® CLT wall and roof panels allow more flexibility and efficiency for all types of building design. As vertical and horizontal load-bearing elements, CrossLam® CLT panels extend the design envelope for industrial projects and allow designers to use one structural system for their entire project.

SHEAR WALLS AND DIAPHRAGMS

CrossLam® CLT panels may be utilized as the lateral force-resisting systems for both wind and seismic loads. The white paper, Horizontal Diaphragm Design Example by Spickler, K., Close, M., Line, P., and Pohll, M., provides a design method to determine the strength of a CLT horizontal diaphragm and deflection due to lateral wind or seismic loads. Visit structurlam.com to download a copy of this white paper. More information about shear walls can also be found in the U.S. CLT Handbook.

CORES AND SHAFTS

CrossLam® CLT panel cores and shafts erect quicker and easier than comparable steel and concrete designs while still providing lateral bracing. Elevator and stair shafts can achieve two-hour fire resistance ratings.

Shoreline Medical Center, Seattle, WA, USA

CrossLam® CLT Panel Characteristics

MAXIMUM PANEL SIZE:	9’10.5" x 40' (3000 x 12192 mm)
MAXIMUM THICKNESS:	12.42" (315 mm)
MINIMUM THICKNESS:	3.43" (87 mm)
PRODUCTION WIDTHS:	7'10.5" and 9'10.5" (2400 mm and 3000 mm)
MOISTURE CONTENT:	12% (+/-3%) at time of manufacturing
GLUE SPECIFICATIONS:	Purbond polyurethane adhesive
GLUE TYPE:	Weatherproof, formaldehyde-free foaming PUR
SPECIES:	SPF, Douglas fir
LUMBER GRADES:	SPF #2& Btr, SPF MSR 2100, SPF #3, Dfir #2& Btr Square Edge
STRESS GRADES:	V2M1.1, V2.1, E1M4, E1M5
MANUFACTURING CERTIFICATION:	APA PRG-320 Product Report PR-L314
DENSITY:	30.3 lbs/ft^3 (shipping weight at time of manufacturing)
DIMENSIONAL STABILITY:	Longitudinal and Transverse 0.01% per % Δ in MC. Thickness 0.2% per % Δ in MC
THERMAL CONDUCTIVITY:	R value: 1.2 per inch (h·ft2·°F /Btu)
CO_2 SEQUESTRATION:	37.4 lbs/ft^3 (subject to local manufacturing and distances)

DIMENSIONAL TOLERANCES	
THICKNESS:	1/16" (2 mm) or 2% of CLT thickness, whichever is greater
WIDTH:	1/8" (3 mm) of the CLT width
LENGTH:	1/4" (6 mm) of the CLT length
SQUARENESS:	Panel face diagonals shall not differ by more than 0.125" (3 mm)
STRAIGHTNESS:	Deviation of edges from a straight line between adjacent panel corners shall not exceed 1/16" (2 mm)

CrossLam® CLT Appearance Classification

	VISUAL	NON-VISUAL
INTENDED USE	Where one or both faces are left exposed	Where both faces are covered by another material
FACE LAYER - V SERIES	SPF #2& Btr “J” Grade (Appearance Grade), Douglas fir (#2 Square Edge)	SPF #2& Btr
FACE LAYER - E SERIES	SPF MSR 2100 Square Edge	SPF MSR 2100
SANDED FACE	80 grit Note: Final finishing prep work must be completed on-site, including cleaning and touch-up of panels	N/A

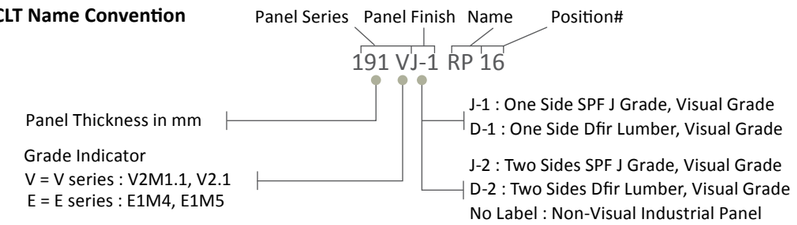
	ALLOWABLE FIBER CHARACTERISTICS	
SHAKE AND CHECKS	Several up to 24” long, none through	As per NLGA #2, SPF #2& Btr
STAIN	Up to a max of 5% blue stain, heart stain allowed Note: E Series panels have no blue stain restrictions	Allowed, not limited
KNOTS	Firm & Tight (NLGA #2)	NLGA #2
PITCH STREAKS	Not limited	Not limited
WANE ON FACE	None	Allowed
SIDE PRESSURE	Yes	None
SURFACE QUALITY	 SPF J-GRADE	 SPF NON-VISUAL
	 DOUGLAS FIR	 SPF NON-VISUAL

The CrossLam® CLT Series

The V Series: Composed exclusively from #2& Btr structural lumber.

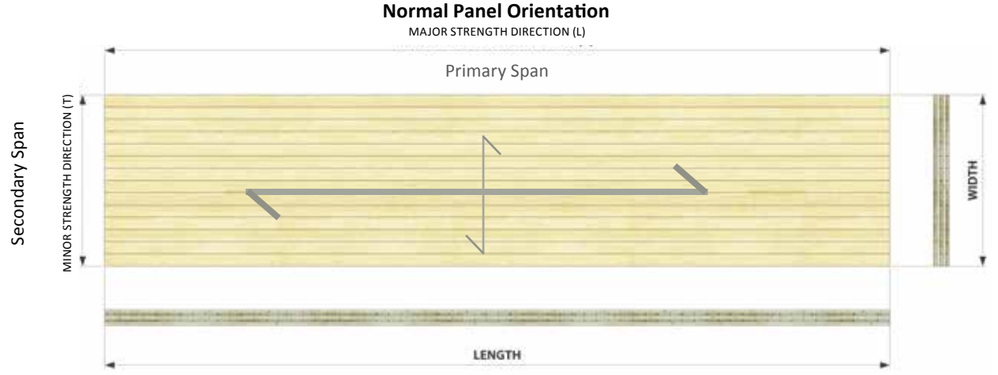
The E Series: Contains MSR E-rated lumber for all major strength direction layers. The lumber for the E series panels does cost slightly more, but it allows a thinner panel to span further. This is more cost effective in certain spans. However, it is important to note that E1 panels are not available with a visual grade or with a Dfir face layer. **This panel is recommended for non-visual uses only.**

CrossLam® CLT Name Convention



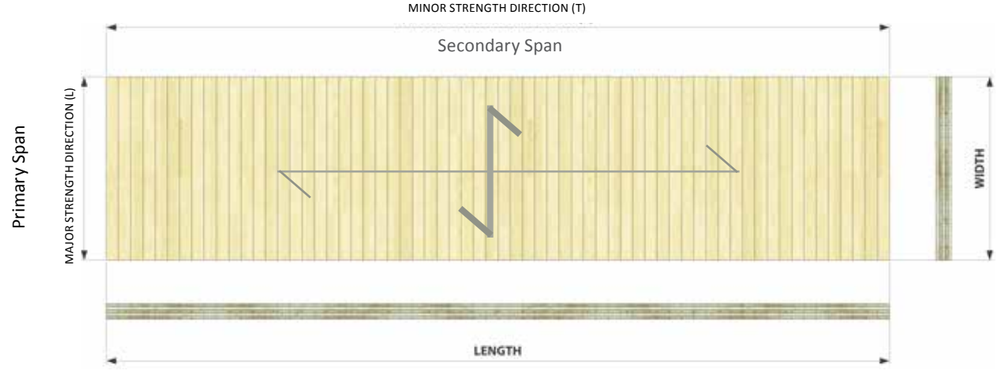
CrossLam® CLT Name Designations: EC - Elevator Core Panel RP - Roof Panel FP - Floor Panel WP - Wall Panel

Normal Panel Orientation



Spandrel Panel Orientation

(only available in 105, 175, 245 and 315 panels)



No side pressure available and visual application not recommended.

Table 1 - CrossLam® CLT Panel Layups

CROSSLAM® CLT SERIES	GRADE	FACE LAYERS	MAJOR LAYER (L)	MINOR LAYER (T)	LAYER THICKNESS (in)									PANEL DEPTH (in)
					L	T	L	T	L	T	L	T	L	
87 V	V2.1	SPF #2& Btr J-Grade Dfir L3	SPF #2& Btr	SPF #3& Btr	1.38	**0.67**	1.38							3.43
139 V					1.38	**0.67**	1.38	**0.67**	1.38					5.48
191 V					1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38			7.53
243 V					1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38	9.58
105 V	V2M1.1			SPF #2& Btr	1.38	1.38	1.38							4.14
175 V					1.38	1.38	1.38	1.38	1.38					6.90
245 V					1.38	1.38	1.38	1.38	1.38	1.38	1.38			9.66
315 V					1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	12.42
87 E	E1M4	MSR 2100 1.8E SPF	MSR 2100 1.8E SPF	SPF #3& Btr	1.38	**0.67**	1.38							3.43
139 E					1.38	**0.67**	1.38	**0.67**	1.38					5.48
191 E					1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38			7.53
243 E					1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38	**0.67**	1.38	9.58
105 E	E1M5			SPF #2& Btr	1.38	1.38	1.38							4.14
175 E					1.38	1.38	1.38	1.38	1.38					6.90
245 E					1.38	1.38	1.38	1.38	1.38	1.38	1.38			9.66
315 E					1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	12.42

L = Longitudinal Layer (Major Layer)

T = Tangential Layer (Minor Layer)

Spandrel panels cannot be produced in any layups with 0.67" thick lamellas.

Note: For 3D Modeling please use metric thickness in mm per the panel name, or exact decimal inches converted from the metric value.


Carbon 12, Portland, OR, USA

Structural Panel Properties

Table 2 - CrossLam® CLT Allowable Design Capacities [1]

CLT GRADE	MAJOR LAYER	WEIGHT lbs/ft²	MAJOR STRENGTH DIRECTION					MINOR STRENGTH DIRECTION				
			$F_bS_{eff,0}$ (lbs-ft/ft)	$EI_{eff,0}$ (10^6lbs-in²/ft)	$GA_{eff,0}$ (10^6lbs/ft)	$M_{allow,0}$ (lbs-ft/ft)	$V_{allow,0}$ (lbs/ft)	$F_bS_{eff,0}$ (lbs-ft/ft)	$EI_{eff,90}$ (10^6lbs-in²/ft)	$GA_{eff,90}$ (10^6lbs/ft)	$M_{allow,90}$ (lbs-ft/ft)	$V_{allow,90}$ (lbs/ft)
V2.1	87 V	7.5	1444	56	0.5	1444	1220	37	0.4	0.30	32	240
	139 V	11.9	3329	206	1.0	3329	1770	537	21	0.60	457	850
	191 V	16.3	5917	503	1.4	5917	2290	1216	83	0.91	1034	1080
	243 V	20.8	9212	995	1.9	9219	2800	2133	209	1.20	1814	1320
V2M1.1	105 V	9.0	2042	96	0.5	2042	1440	277	3.7	0.53	235	495
	175 V	15.0	4701	366	1.1	4701	1980	2403	96	1.10	2042	1440
	245 V	21.0	8315	906	1.6	8315	2500	5531	366	1.60	4701	1970
	315 V	27.0	12896	1806	2.1	12896	3025	9782	906	2.10	8315	2470
E1M4	87 E	8.2	3465	72	0.5	3465	1220	37	0.4	0.38	32	240
	139 E	13.0	7983	264	1.0	7983	1770	537	21	0.77	457	945
	191 E	17.8	14183	645	1.5	14183	2280	1216	83	1.10	1034	1200
	243 E	22.7	22075	1278	2.0	22075	2800	2133	209	1.50	1814	1460
E1M5	105 E	9.7	4900	123	0.5	4901	1430	277	3.7	0.66	235	495
	175 E	16.1	11261	469	1.1	11261	1980	2403	96	1.30	2042	1590
	245 E	22.5	19897	1161	1.6	19897	2500	5531	366	2.00	4701	2180
	315 E	28.8	30837	2314	2.1	30838	3000	9782	906	2.60	8315	2750

Table 3 - CrossLam® CLT Allowable Design Properties for Laminations [1]

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} (10^6psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{V,90}$ (psi)	$F_{s,90}$ (psi)
V2.1	875	1.4	450	1150	135	45	500	1.2	250	650	135	45
V2M1.1	875	1.4	450	1150	135	45	875	1.4	450	1150	135	45
E1M4	2100	1.8	1575	1875	160	50	500	1.2	250	650	135	45
E1M5	2100	1.8	1575	1875	160	50	875	1.4	450	1150	135	45

Notes:

1. *Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS.*
2. *The CLT grades are developed based on APA Product Report PR-L314. Please refer to specific grade layups for complete panel information.*
3. *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 tables above).*
4. *Values are calculated per one-foot wide section of panel.*
5. *The panel weight is based on SPF lumber values in the 2015 NDS.*

Table 4 - CrossLam® CLT Floor Panel Load Table, maximum span (ft)

	CROSSLAM® CLT SERIES	FLOOR LIVE LOAD (psf)									
		40 RESIDENTIAL		50 OFFICE/CLASSROOM		75 MECHANICAL ROOM		100 ASSEMBLY/STORAGE		150 LIBRARY	
		VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240
SINGLE SPAN	87 V	**10.58**	12.33	**10.58**	11.95	10.58	**10.56**	10.58	**9.71**[a]	10.58	**8.18**[a]
	87 E	**11.37**	13.33	**11.37**	12.67	**11.37**	11.43	11.37	**10.55**	11.37	**9.33**
	105 V	**12.04**	14.58	**12.04**	13.86	**12.04**	12.51	12.04	**11.48**[a]	12.04	**9.69**[a]
	105 E	**12.93**	15.77	**12.93**	15.00	**12.93**	13.54	12.93	**12.51**	12.93	**11.07**
	139 V	**14.65**	18.68	**14.65**	17.81	**14.65**	16.15	14.65	**14.49**[a]	14.65	**12.27**[a]
	139 E	**15.75**	20.17	**15.75**	19.24	**15.75**	17.47	**15.75**	16.19	15.75	**14.41**
	175 V	**16.78**	22.24	**16.78**	21.23	**16.78**	18.93[a]	**16.78**	17.01[a]	16.78	**14.45**[a]
	175 E	**18.01**	24.01	**18.01**	22.93	**18.01**	20.88	**18.01**	19.38	18.01	**17.28**
	191 V	**18.30**	24.65	**18.30**	23.56	**18.30**	21.10[a]	**18.30**	18.99[a]	18.30	**16.16**[a]
	191 E	**19.65**	26.58	**19.65**	25.43	**19.65**	23.21	**19.65**	21.58	19.65	**19.29**
	245 V	**20.98**	29.30	**20.98**	27.81[a]	**20.98**	24.48[a]	**20.98**	22.12[a]	20.98	**18.91**[a]
	245 E	**22.50**	31.57	**22.50**	30.27	**22.50**	27.74	**22.50**	25.85	**22.50**	23.16
	243 V	**21.68**	30.34	**21.68**	29.08	**21.68**	25.79	**21.68**	23.30	21.68	**19.92**
	243 E	**22.91**	32.67	**22.91**	31.33	**22.91**	28.73	**22.91**	26.80	**22.91**	24.04
	315 V	**24.86**	35.47[a]	**24.86**	33.49[a]	**24.86**	29.69[a]	**24.86**	26.95[a]	24.86	**23.18**[a]
	315 E	**26.66**	38.72	**26.66**	37.23	**26.66**	34.29	**26.66**	32.07	**26.66**	28.86
DOUBLE SPAN	87 V	**10.58**	13.59[a]	**10.58**	12.62[a]	**10.58**	10.88[a]	10.58	**9.71**[a]	10.58	**8.18**[a]
	87 E	**11.37**	18.23	**11.37**	17.16	**11.37**	15.51	**11.37**	14.35	**11.37**	12.65[a]
	105 V	**12.04**	15.98[a]	**12.04**	14.86[a]	**12.04**	12.85[a]	12.04	**11.48**	12.04	**9.69**
	105 E	**12.93**		**12.93**		**12.93**	18.42	**12.93**	17.04	**12.93**	14.98[a]
	139 V	**14.65**	19.96[a]	**14.65**	18.61[a]	**14.65**	16.17[a]	14.65	**14.49**[a]	14.65	**12.27**[a]
	139 E	**15.75**		**15.75**		**15.75**		**15.75**		**15.75**	17.43[b]
	175 V						**18.93**[a]		**17.01**[a]		**14.45**[a]
	175 E										
	191 V								**18.99**[a]		**16.16**[a]
	191 E										
	245 V										**18.91**[a]
	245 E										
	243 V										
	243 E										
	315 V										
	315 E										

MAXIMUM VALUE IS 20 FT

Span is governed by maximum panel length of 40 ft.
Use max value of 20 ft or design as simple span using table values above.

[a] Represents governing value Mr and [b] represents governing value Vr

Notes:

1. *For structural panel properties - see page 16. Span table assumes dry service conditions.*
2. *CLT is NOT an isotropic material. Presented values must only be used for bending of panels in the major strength axis.*
3. *Spans shown represent distance between the center lines of supports and are to be used for preliminary design only.*
4. *Span table above includes panel self weight, plus 15 psf miscellaneous dead load.*
5. *Engineer to ensure that L/240 deflection limit is appropriate for intended use.*
6. *Spans are assumed to be equal for double span panels.*
7. *Total panel length is limited to 40 ft due to fabrication process.*
8. *Values in **BOLD SHADING** correspond to a span governed by allowable bending stress, allowable shear stress or by vibration.*
9. *Table values are to be used for preliminary design only.*
10. *Values for double spans include a 20 percent increase based on CSA 086-14.*
11. *Deflection L/240 is considered for total load.*

Table 5 - CrossLam® CLT Floor Panel Load Table, with 2" concrete topping maximum span (ft)

	CROSSLAM® CLT SERIES	FLOOR LIVE LOAD (psf)									
		40 RESIDENTIAL		50 OFFICE/CLASSROOM		75 MECHANICAL ROOM		100 ASSEMBLY/STORAGE		150 LIBRARY	
		VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240	VIBRATION	DEFLECTION L/240
SINGLE SPAN	87 V	**8.79**	11.19	**8.79**	10.75	**8.79**	9.88	**8.79**	9.00[a]	8.79	**7.75**[a]
	87 E	**9.44**	12.11	**9.44**	11.64	**9.44**	10.71	**9.44**	10.00	9.44	**8.97**
	105 V	**10.17**	13.26	**10.17**	12.74	**10.17**	11.72	**10.17**	10.65[a]	10.17	**9.18**[a]
	105 E	**10.91**	14.35	**10.91**	13.79	**10.91**	12.69	**10.91**	11.86	10.91	**10.64**
	139 V	**14.65**	17.06	**14.65**	16.43	**14.65**	14.78[a]	14.65	**13.46**[a]	14.65	**11.63**[a]
	139 E	**15.75**	18.45	**15.75**	17.77	**15.75**	16.42	15.75	**15.38**	15.75	**13.87**
	175 V	**16.78**	20.38	**16.78**	19.39[a]	**16.78**	17.35[a]	16.78	**15.83**[a]	16.78	**13.71**[a]
	175 E	**18.01**	22.02	**18.01**	21.24	**18.01**	19.65	**18.01**	18.43	18.01	**16.64**
	191 V	**18.30**	22.64	**18.30**	21.62[a]	**18.30**	19.36[a]	18.30	**17.69**[a]	18.30	**15.33**[a]
	191 E	**19.65**	24.44	**19.65**	23.59	**19.65**	21.87	**19.65**	20.55	19.65	**18.59**
	245 V	**20.98**	26.32[a]	**20.98**	25.05[a]	**20.98**	22.53[a]	20.98	**20.65**[a]	20.98	**17.97**[a]
	245 E	**22.50**	29.16	**22.50**	28.18	**22.50**	26.19	**22.50**	24.64	22.50	**22.34**
	243 V	**21.68**	27.74[a]	**21.68**	26.39[a]	**21.68**	23.74[a]	**21.68**	21.75[a]	21.68	**18.92**[a]
	243 E	**23.28**	30.19	**23.28**	29.19	**23.28**	27.14	**23.28**	25.56	23.28	**23.19**
	315 V	**24.86**	31.80[a]	**24.86**	30.35[a]	**24.86**	27.44[a]	**24.86**	25.24[a]	24.86	**22.06**[a]
	315 E	**26.66**	35.95	**26.66**	34.81	**26.66**	32.48	**26.66**	30.64	**26.66**	27.87
DOUBLE SPAN	87 V	**10.55**	11.83[a]	**10.55**	11.17[a]	10.55	**9.91**[a]	10.55	**9.00**[a]	10.55	**7.75**[a]
	87 E	**11.33**	16.42	**11.33**	15.80	**11.33**	14.55	**11.33**	13.41[a]	**11.33**	11.54[a]
	105 V	**12.20**	13.95[a]	**12.20**	13.18[a]	12.20	**11.72**[a]	12.20	**10.65**[a]	12.20	**9.18**[a]
	105 E	**13.09**	19.48	**13.09**	18.75	**13.09**	17.29	**13.09**	15.86[a]	**13.09**	13.67[a]
	139 V	17.58	**17.51**[a]	**17.58**	**16.58**[a]	17.58	**14.78**[a]	17.58	**13.46**[a]	17.58	**11.63**[a]
	139 E	**18.90**		**18.90**		**18.90**		**18.90**		18.90	**15.67**[b]
	175 V				**19.39**[a]		**17.35**[a]		**15.83**[a]		**13.71**[a]
	175 E										
	191 V						**19.36**[a]		**17.69**[a]		**15.33**[a]
	191 E										
	245 V										**17.97**[a]
	245 E										
	243 V										**18.92**[a]
	243 E										
	315 V										
	315 E										

MAXIMUM VALUE IS 20 FT

Span is governed by maximum panel length of 40 ft.
Use max value of 20 ft or design as simple span using table values above.

[a] Represents governing value Mr and [b] represents governing value Vr

Notes:

1. *For structural panel properties - see page 16. Span table assumes dry service conditions.*
2. *CLT is NOT an isotropic material. Presented values must only be used for bending panels in the major strength axis.*
3. *Spans shown represent distance between the center lines of supports and are to be used for preliminary design only.*
4. *Span table above includes panel self weight, 20 psf for concrete topping, plus 15 psf miscellaneous dead load.*
5. *Engineer to ensure that L/240 deflection limit is appropriate for intended use.*
6. *Spans are assumed to be equal for double span panels.*
7. *Total panel length is limited to 40 ft due to fabrication process.*
8. *Values in **BOLD SHADING** correspond to a span governed by allowable bending stress, allowable shear stress or by vibration.*
9. *Table values are to be used for preliminary design only.*
10. *The non-structural flooring is assumed to provide an enhanced vibration effect on double spans. Values include a 20 percent increase.*
11. *Deflection L/240 is considered for total load.*
12. *For floors with concrete topping, where the concrete is applied directly to the CLT panel, weight of concrete is ignored in the calculation of vibration-controlled span limit, provided the area density of the topping is not greater than twice the bare CLT floor area density.*

Duke University, Durham, NC , USA

Tall Tree Integrated Health Centre, Victoria, BC, Canada

Table 6 - CrossLam® CLT Roof Panel Load Table, maximum span (ft)

	CROSSLAM® CLT SERIES	ROOF SNOW LOAD (PSF, UNFACTORED)										125% NON-SNOW LOAD	
		20		30		40		55		100		20	
		L/180	L/240	L/180	L/240	L/180	L/240	L/180	L/240	L/180	L/240	L/180	L/240
SINGLE SPAN	87 V	16.21	14.69	14.95	13.55	14.01	12.68	12.62[a]	11.70	9.91[a]	9.88	16.21	14.69
	87 E	17.51	15.87	16.17	14.65	15.15	13.72	14.00	12.67	11.85	10.70	17.51	15.87
	105 V	19.10	17.31	17.66	16.00	16.57	15.00	14.86[a]	13.86	11.72[a]	11.72	19.10	17.31
	105 E	20.62	18.68	19.09	17.29	17.92	16.22	16.58	15.00	14.06	12.69	20.62	18.68
	139 V	24.18	21.92	22.48	20.38	20.74[a]	19.18	18.61[a]	17.80	14.78[a]	14.78[a]	24.18	21.92
	139 E	26.04	23.61	24.25	21.98	22.86	20.71	21.24	19.24	18.15	16.42	26.04	23.61
	175 V	28.56	25.89	26.15[a]	24.16	24.05[a]	22.81	21.68[a]	21.23	17.35[a]	17.35[a]	28.56	25.89
	175 E	30.76	27.87	28.76	26.05	27.19	24.62	25.34	22.93	21.74	19.65	30.76	27.87
	191 V	31.51	28.57	29.00[a]	26.73	26.72[a]	25.27	24.13[a]	23.56	19.36[a]	19.36[a]	31.51	28.57
	191 E	33.86	30.70	31.74	28.77	30.06	27.24	28.07	25.43	24.17	21.87	33.86	30.70
	245 V	36.12[a]	33.60	33.02[a]	31.60	30.61[a]	30.00	27.81[a]	27.81[a]	22.53[a]	22.53[a]	37.07	33.60
	245 E	39.84	36.11	37.54	34.01	35.67	32.31	33.44	30.27	28.96	26.19	39.84	36.11
	243 V	38.09[a]	34.79	34.81[a]	32.72	32.26[a]	31.06	29.31[a]	29.07	23.74[a]	23.74[a]	38.36	34.79
	243 E		37.32	38.79	35.16	36.88	33.42	34.59	31.33	30.00	27.14		37.32
	315 V			39.24[a]	38.55	36.60[a]	36.60[a]	33.49[a]	33.49[a]	27.44[a]	27.44[a]		
	315 E						39.55		37.23	35.91	32.48		
DOUBLE SPAN	87 V	17.55[a]	17.55[a]	15.59[a]	15.59[a]	14.17[a]	14.17[a]	12.62[a]	12.62[a]	9.91[a]	9.91[a]	18.30[a]	18.30[a]
	87 E				19.79		18.56	18.93	17.16	15.31[a]	14.57		
	105 V			18.26[a]	18.26[a]	16.64[a]	16.64[a]	14.86[a]	14.86[a]	11.72[a]	11.72[a]		
	105 E									18.10[a]	17.29		
	139 V							18.61[a]	18.61[a]	14.78[a]	14.78[a]		
	139 E												
	175 V									17.35[a]	17.35[a]		
	175 E												
	191 V									19.36[a]	19.36[a]		
	191 E												
	245 V												
	245 E												
	243 V												
	243 E												
	315 V												
	315 E												

MAXIMUM VALUE IS 20 FT

Span is governed by maximum panel length of 40 ft.

Use max value of 20 ft or design as simple span using table values above.

[a] Represents governing value Mr and [b] represents governing value Vr

Notes:

1. *For structural panel properties - see page 16. Span table assumes dry service conditions.*
2. *CLT is NOT an isotropic material. Presented values must only be used for bending panels in the major strength axis.*
3. *Spans shown represent distance between the center lines of supports and are to be used for preliminary design only.*
4. *Span table above considers panel self weight and 10 psf for miscellaneous dead load. [Ref: International Building Code 2012 - art.1607.5].*
5. *Ponding or ceiling finishes may require higher deflection limits.*
6. *Engineer to ensure that deflection limit is appropriate for intended use.*
7. *Spans are assumed to be equal for double span panels.*
8. *Total panel length is limited to 40 ft due to the fabrication process.*
9. *Table values are to be used for preliminary design only.*
10. *L/180 is total load deflection limit; L/240 is snow load deflection limit.*
11. *For applications with deflection limits or loading different than what is indicated above, contact your Structurlam technical representative.*

Table 7 - CrossLam® CLT Wall Panel Load Table (Axial Loading Only)

PR (kips)		L (ft)													
PANEL NAME	PANEL SIZE (in)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
87 V	3.43	36.80	35.13	30.69	23.28	16.77	12.32	9.34								
87 E	3.43	58.64	54.15	43.26	30.61	21.62	15.81	11.97								
105 V	4.14	37.07	36.24	34.36	30.52	24.81	19.31	15.06	11.95							
105 E	4.14	59.35	57.21	52.11	42.94	32.92	25.04	19.38	15.33							
139 V	5.48	55.94	55.17	53.58	50.51	45.09	37.78	30.63	24.79	20.26	16.79	14.10				
139 E	5.48	90.04	88.15	83.99	75.83	63.41	50.55	40.04	32.08	26.11	21.59	18.11				
175 V	6.90	56.13	55.73	54.98	53.72	51.65	48.36	43.64	38.03	32.52	27.69	23.66	20.35	17.64	15.41	
175 E	6.90	90.52	89.56	87.69	84.39	78.84	70.53	60.57	50.93	42.69	35.96	30.56	26.20	22.68	19.79	
191 V	7.53	74.88	74.36	73.40	71.80	69.18	65.02	59.00	51.69	44.37	37.86	32.39	27.88	24.18	21.13	18.60
191 E	7.53	120.83	119.61	117.24	113.09	106.11	95.53	82.51	69.64	58.48	49.33	41.94	35.98	31.14	27.18	23.91
245 V	9.66	75.05	74.78	74.30	73.56	72.47	70.90	68.66	65.50	61.27	56.13	50.54	45.06	40.02	35.57	31.69
245 E	9.66	121.26	120.62	119.48	117.65	114.87	110.73	104.73	96.66	87.07	77.11	67.74	59.43	52.26	46.15	40.96
243 V	9.58	93.76	93.37	92.68	91.59	89.96	87.55	84.05	79.12	72.72	65.41	58.01	51.16	45.10	39.86	35.38
243 E	9.58	151.48	150.57	148.90	146.19	142.00	135.62	126.42	114.50	101.28	88.42	76.91	67.02	58.66	51.62	45.69
315 V	12.42	93.93	93.73	93.37	92.84	92.10	91.09	89.75	87.95	85.57	82.46	78.50	73.73	68.39	62.82	51.62
315 E	12.42	151.90	151.42	150.58	149.31	147.49	144.95	141.45	136.69	130.35	122.36	113.06	103.14	93.34	84.16	75.84

Notes:

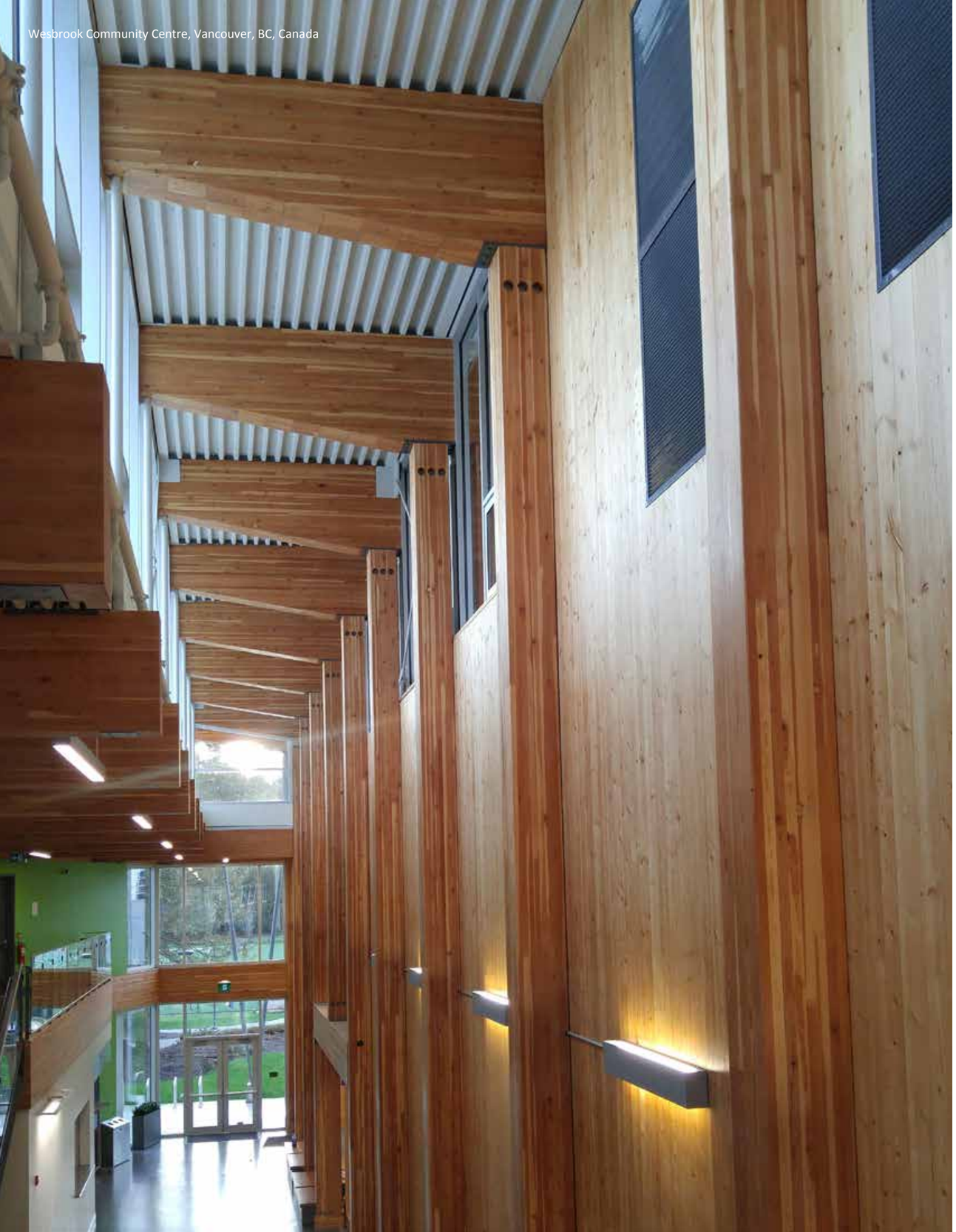
1. *For panel properties - see page 16.*
2. *Table assumes dry service conditions.*
3. *$P_r = F_{c\,parallel} A C_D C_M C^T C_P$, where the Pr values are not given, the slenderness ratio exceeds 50.*
4. *The following factors were used for calculations: C_D=1.0, C_M=1.0, C_T=1.0.*
5. *Table values are to be used for preliminary design only.*
6. *Eccentricity of axial load and wind loading has not been included.*
7. *Axial load table assumes outer laminations to be vertical.*
8. *For applications with loading different than what is indicated above, contact your Structurlam technical representative.*

Table 8 - CrossLam® CLT In-Plane Shear Loading

CROSSLAM® CLT SERIES															
87 V	87 E	105 V	105 E	139 V	139 E	175 V	175 E	191 V	191 E	245 V	245 E	243 V	243 E	315 V	315 E
Vr (lbs/ft)															
10656	10656	15869	15869	15869	15869	23428	23428	23428	23428	23428	23428	23428	23428	23428	23428

Notes:

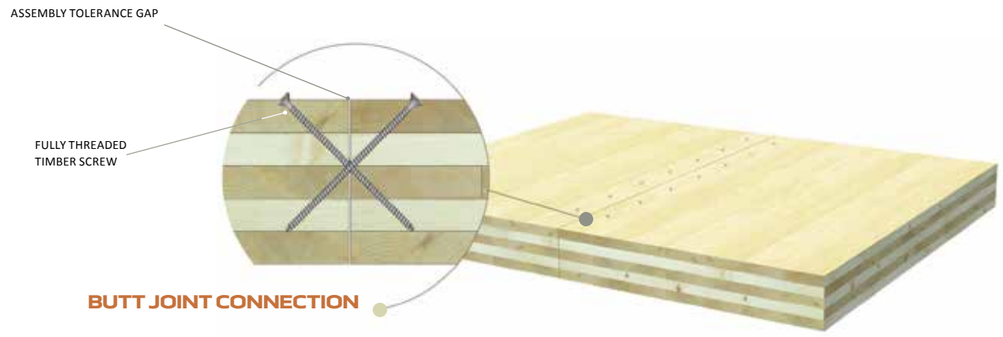
1. *For panel properties - see page 16.*
2. *Table values are to be used for preliminary design only.*
3. *Table values for 87 V and 87 E are computed based on "In- Plane Shear Capacity and Verification Methods" by Prof. G. Schickhofer, University of Graz.*
4. *Other table values are based on the in-plane shear resistance test conducted by the Advanced Building Sytems Department at FPInnovations. The panels were tested according to the test requirements of the ICC/ES AC455 acceptance criteria (Section 4.3) that refers to the method of ASTM D5456-14.*
5. *Values are for CrossLam® CLT panel only, not for shear connectors.*
6. *For applications with loading different than what is indicated above, contact your Structurlam technical representative.*



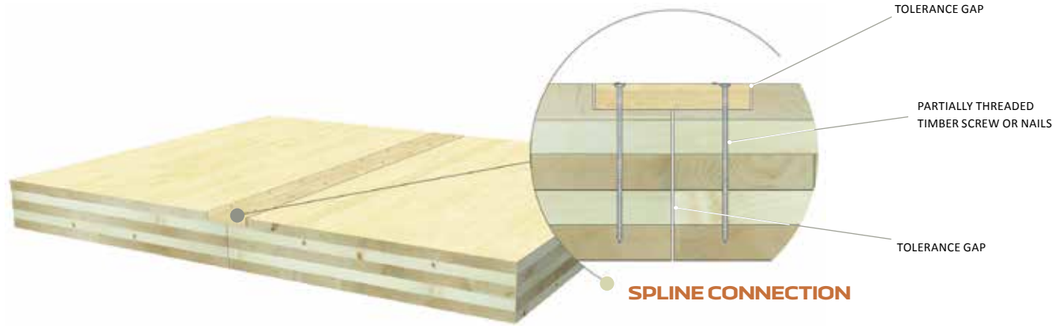
Wesbrook Community Centre, Vancouver, BC, Canada

CrossLam® CLT Connection Details - Floor to Roof Panel Joints

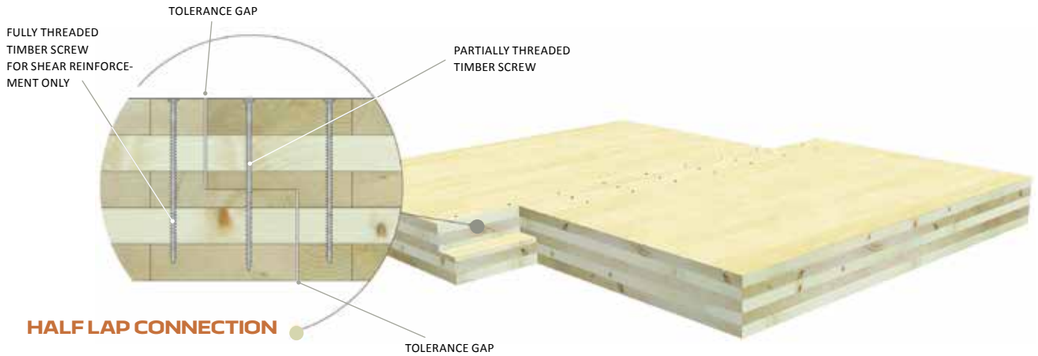
Structurlam will work with your team to identify the most cost-effective connection system for your structure. The following details show typical connection details used in CrossLam® CLT buildings.



BUTT JOINT CONNECTION

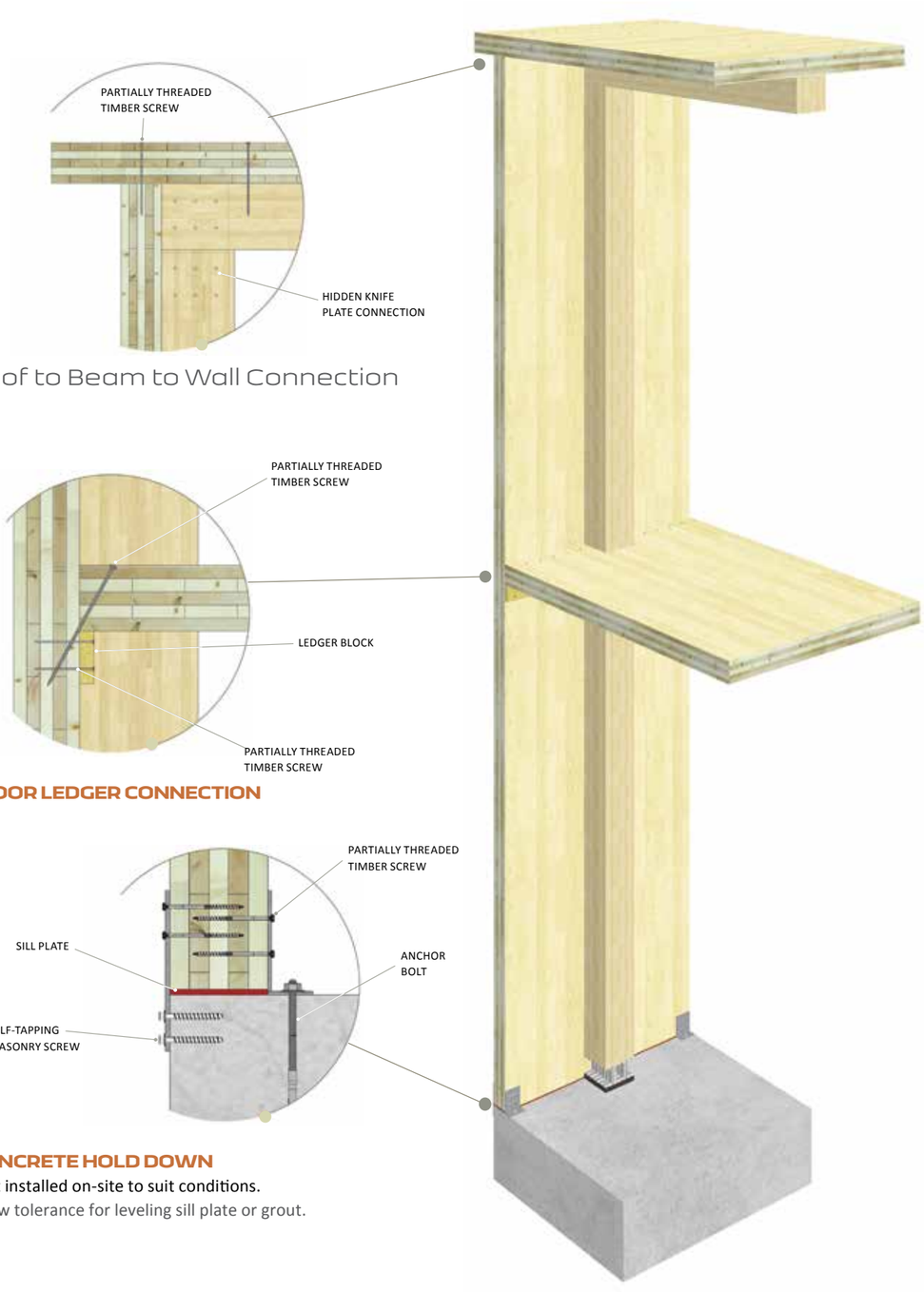


SPLINE CONNECTION



HALF LAP CONNECTION

Flat Roof to Beam to Wall Connections



Roof to Beam to Wall Connection

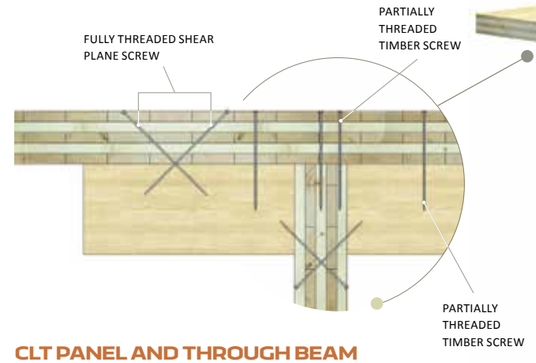
FLOOR LEDGER CONNECTION

CONCRETE HOLD DOWN

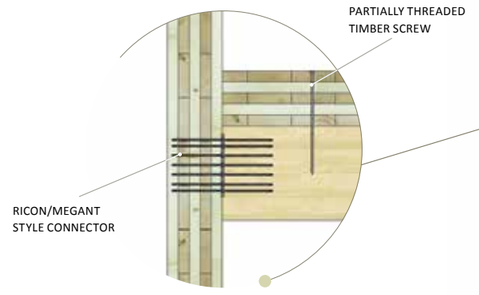
Post installed on-site to suit conditions.

Allow tolerance for leveling sill plate or grout.

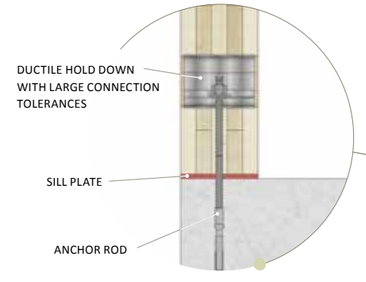
Flat Roof to Wall Connections



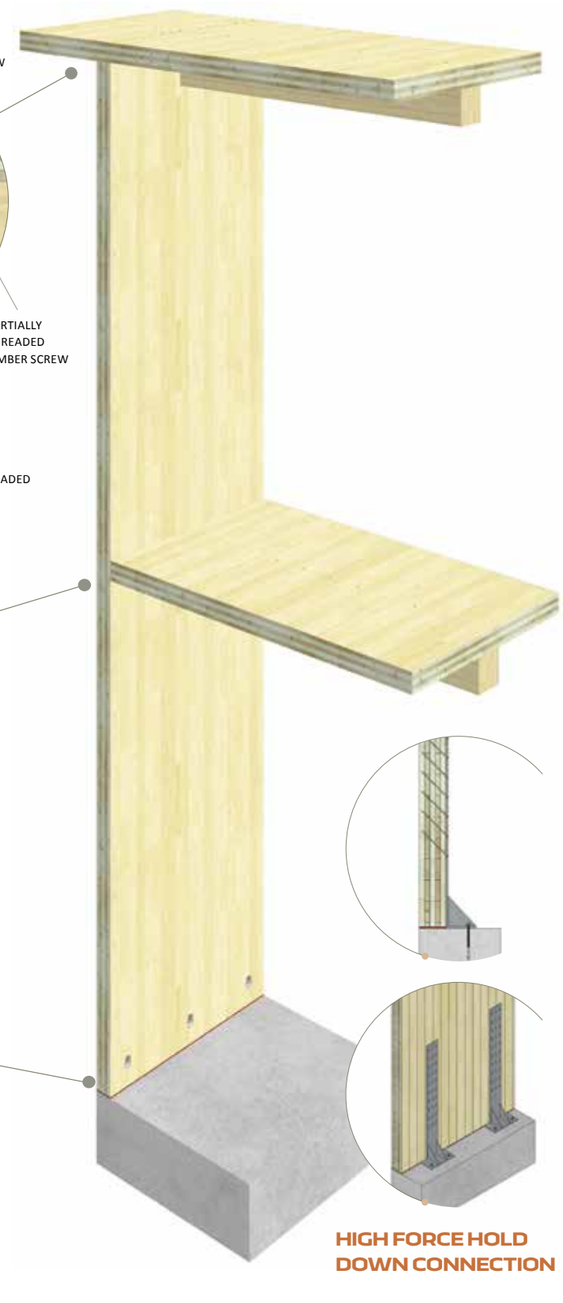
CLT PANEL AND THROUGH BEAM ROOF CONNECTION



CLT WALL AND FLOOR CONNECTION

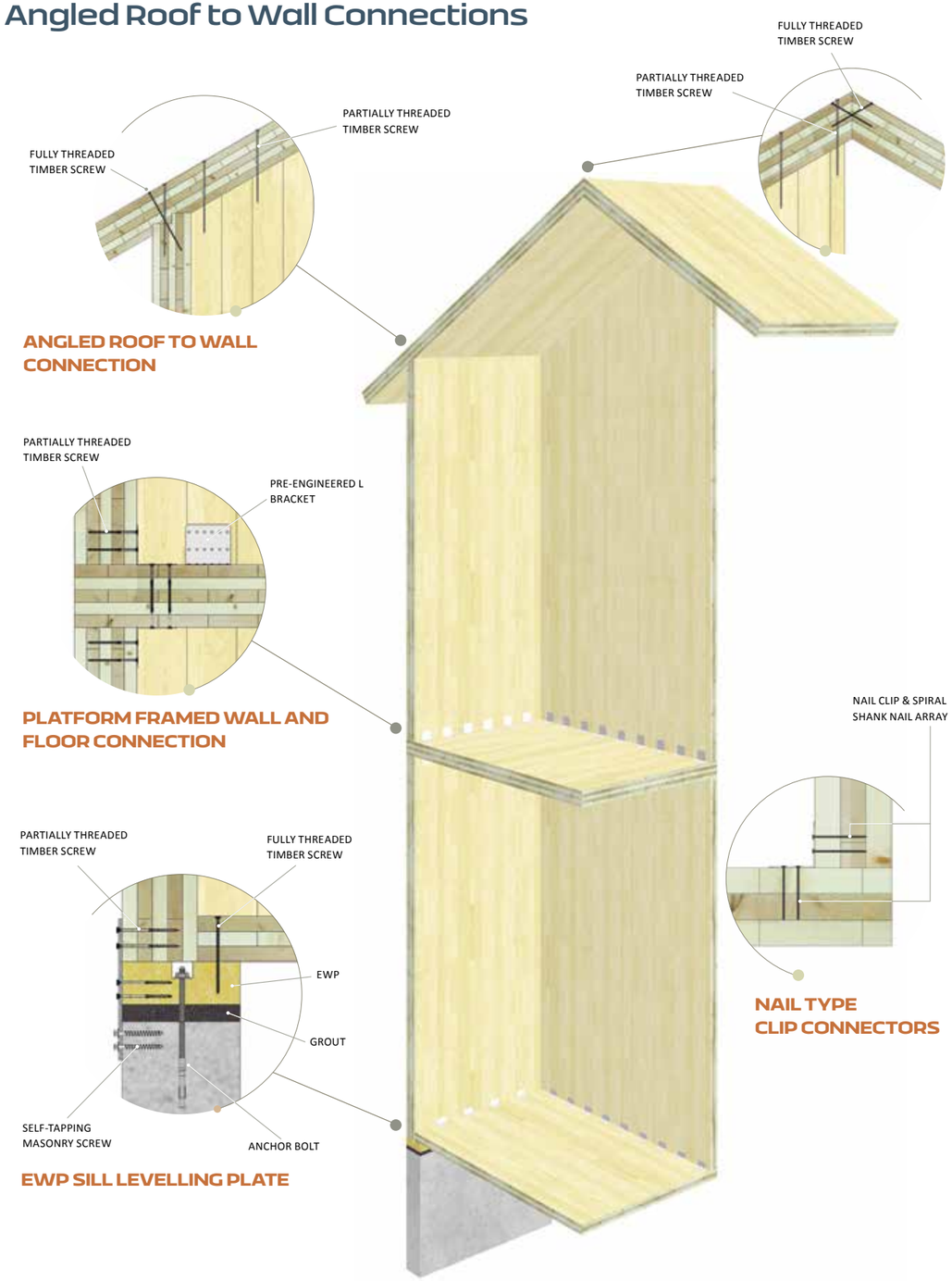


CLT HOLD DOWN CONNECTION



HIGH FORCE HOLD DOWN CONNECTION

Angled Roof to Wall Connections



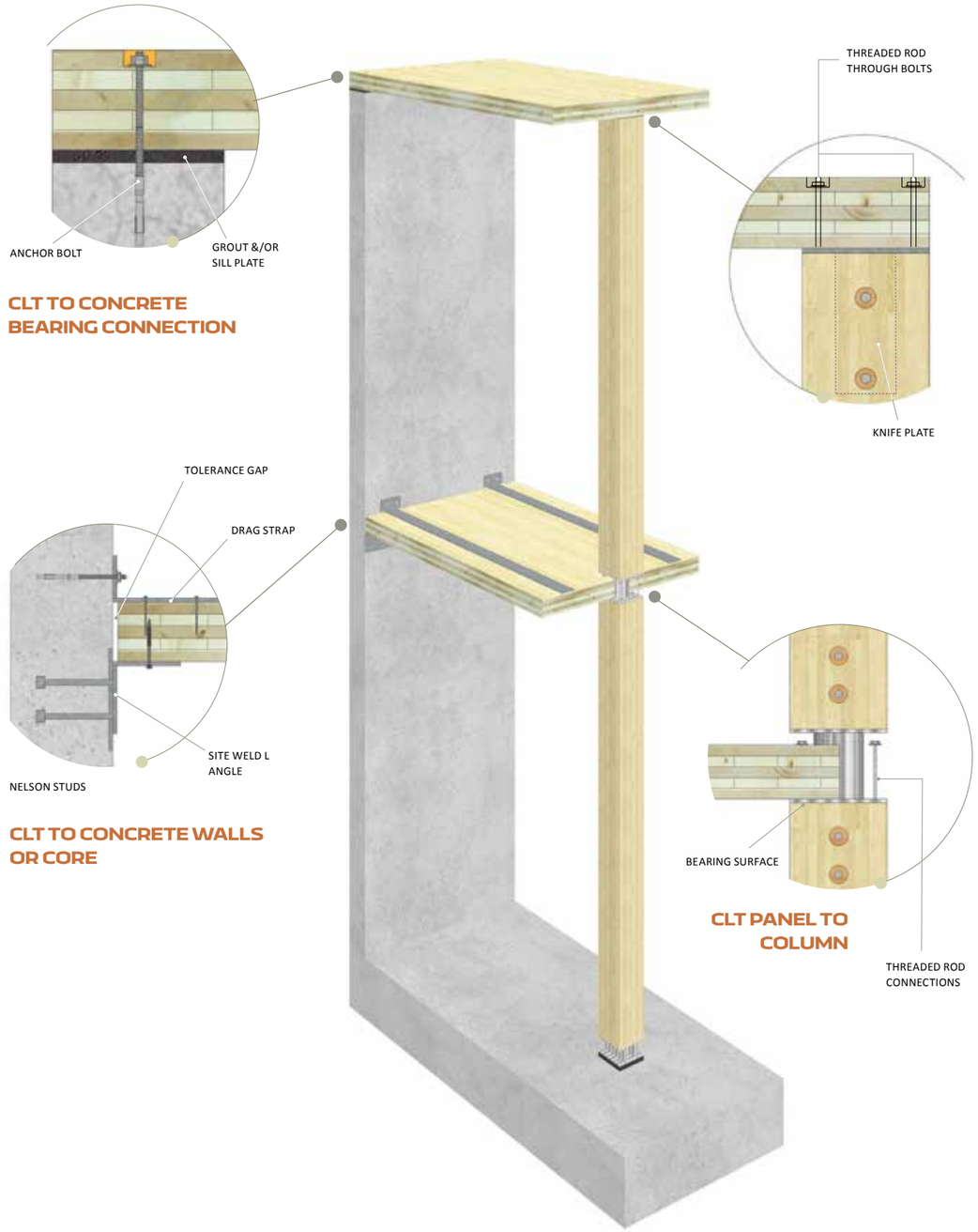
ANGLED ROOF TO WALL CONNECTION

PLATFORM FRAMED WALL AND FLOOR CONNECTION

NAIL TYPE CLIP CONNECTORS

EWP SILL LEVELLING PLATE

Wall to Concrete Connections



CLT TO CONCRETE BEARING CONNECTION

CLT TO CONCRETE WALLS OR CORE

CLT PANEL TO COLUMN

Duke University, Durham, NC, USA

Mica Heli-Ski Lodge, Mica, BC, Canada

Crosslam® CLT Frequently Asked Questions

1 WHERE IS CLT REFERENCED IN THE BUILDING CODE?

CLT is now included as a structural system in both the 2015 International Building Code (IBC) for Type IV Construction (Heavy Timber) and the 2015 National Design Specification (NDS) for Wood Construction. Chapter 10 of the NDS applies to CLT manufactured to ANSI/APA standards which states "CLT shall be manufactured in accordance with ANSI/APA PRG-320 2012 Standard for Performance Related Cross Laminated Timber."

2 CAN CLT SPAN IN TWO DIRECTIONS?

CLT is manufactured to span in two directions. The unique structural properties of CrossLam® CLT give it strength in both major and minor axis directions. The minor strength span direction needs to be calculated separately as CLT is not isotropic.

3 HOW ARE PANELS CONNECTED?

There are a variety of connection systems for CLT panels that provide excellent engineering solutions and are fast and simple to use on the job site. Please refer to pages 23-27 in the CrossLam® CLT Design Guide for more connection information.

4 CAN WE RUN MECHANICAL, ELECTRICAL AND PLUMBING (MEP) THROUGH THE CLT PANEL?

Unlike concrete, the installation of MEP services is easy when building with CLT panels. Services can be field located on-site and cut with power tools by the installer. Should MEP services need factory prefabrication, locations must be determined during the shop drawing phase before manufacturing of CLT begins. This information must be provided to Structurlam in a fabrication-level 3D model with solid opening volumes to be cut out of the CLT model.

5 CAN ALL CROSSLAM® CLT PANELS BE USED IN VISUAL APPLICATIONS?

No. E1 panels are not available with a visual grade or with a Dfir face layer. They cannot be used in visual applications in standard visual applications, but can be used understanding their lower-quality grading requirement. Spandrel panels do not have edge pressure on the laminations and are not tight at time of manufacture. They cannot be used for visual applications.

6 WHAT IS THE INSULATION VALUE OF CLT?

The insulation value of CLT is as follows:

- R Value: 1.2 per inch ($h \cdot ft^2 \cdot °F/Btu$)

CLT also has significant thermal mass acting as a thermal battery for both heating and cooling loads.

7 CAN WE USE CLT IN EXTERIOR APPLICATIONS?

The 2015 NDS states that CLT must only be used in dry service conditions where the moisture content in service is less than 16 percent. Soffits usually meet this requirement.

8 CAN CLT BE USED IN SOFFIT APPLICATIONS?

A soffit application is considered to be a dry service application, so this is an acceptable detail for CrossLam® CLT. Be sure to detail the ends of the panels with protective fascia and metal flashing materials to protect CLT from the elements.

9 CAN WE EXPOSE THE PANEL EDGE?

It is permissible to expose the CrossLam® CLT panel edge when used in an interior dry service application. It is not permissible to expose the panel edge in an exterior application detail. See FAQ #8. Edge sealer can be supplied as a recommended additional surface protection.

10 WHAT ARE THE FIRE RESISTANCE RATINGS OF CLT?

Please see Chapter 8 - Fire Performance of Cross Laminated Timber Assemblies in the U.S. CLT Handbook published by the American Wood Council and FPInnovations. When used with glues compliant with PRG-320 2018 or newer CLT has the same fire protection properties as solid wood. FRR is primarily a function of the moment capacity of the panel based on load and span.

11 WHAT ARE THE ACOUSTIC RATINGS - STC, IIC, FSTC AND FIIC FOR CLT?

Currently, all assemblies are calculated according to the specific application. Please see Chapter 9 - Sound Insulation in the U.S. CLT Handbook published by the American Wood Council and FPInnovations. Page 61 of this guide contains possible demonstration sample values for CLT assembly acoustic performance.

12 CAN CLT BE USED IN SHEAR WALL APPLICATIONS?

Yes. Shear walls and diaphragms must be designed in accordance with ANSI/AWC SDPWS-2015, Special Design Provisions for Wind and Seismic.

13 CAN CLT PANELS BE USED AS A VAPOR BARRIER?

The U.S. CLT Handbook Chapter 10 states that CLT panels may meet requirements for both vapor retarders and vapor barriers. These findings are subject to the thickness of CLT, properly sealed connections and lifelong movement of wood products.

14 CAN OTHER BUILDING MATERIALS BE APPLIED TO CROSSLAM® CLT PANELS?

Yes, but not during the CLT manufacturing process. Foam insulation, butyl peel and stick membranes (blue-skin), drywall, acoustic materials and many other building materials can be applied to CrossLam® CLT panels in a post-manufacturing environment.

15 CAN COATINGS BE APPLIED TO CROSSLAM® CLT?

Yes. Coatings are field applied. Coatings are NOT applied to CrossLam® CLT during manufacturing.

16 DO YOU APPLY SEALER TO THE EDGE OF THE CROSSLAM® CLT PANELS TO PREVENT CHECKING?

Applying a sealer to the end of CrossLam® CLT panels is not a standard practice as it can affect other coating and finishing systems. However, if desired, Structurlam does offer this service at an additional cost.

17 IS YOUR CROSSLAM® CLT PANEL EDGE-GLUED?

No. Structurlam does not edge-glue CrossLam® CLT panels. Our state-of-the-art press technology has an edge pressure system to minimize gaps between the lamellas. This system also controls face checking on CrossLam® CLT panels.

18 CAN WE DO OUR OWN SHOP DRAWINGS?

Yes, you can do your own shop drawings. Structurlam can provide design standards that are compatible with our manufacturing requirements. We accept single piece shop drawings as well as the following file formats: IFC, STP, STL or 3dz (CadWork).

19 IS TRUCKLOAD SEQUENCING AVAILABLE BEFORE SHIPPING TO THE JOB SITE?

Truckload sequencing is an added service that we offer. It is recommended for projects in urban areas where a staging area is not available. Load sequencing must be requested during the shop drawing process.

20 DOES STRUCTURLAM OFFER A WARRANTY ON PANELS?

Yes, warranty information can be found in the **Structurlam Sales Terms & Conditions.** Please refer to our website or contact your local Structurlam Mass Timber specialist.

Duke University, Durham, NC, USA

GLULAMPLUS®
BY STRUCTURLAM

Structurlam GlulamPLUS® uses the highest-quality, sustainably-harvested, interior-grown Douglas fir fiber, coupled with clear adhesive and a hand-sanded finish to create North America's most beautiful glulam beams and columns. Combined with a wide size range, stringent QC process, CNC framing to exacting tolerances and other time-saving options like factory installed connections and factory applied stain, GlulamPLUS® beams and columns stand above all others.

In the last few years, glulam has become a key component as the backbone of mass timber structures. One of the greatest advantages of GlulamPLUS® is that it can be manufactured in a wide range of shapes, sizes and configurations to match your vision.

The strength and beauty of GlulamPLUS® allow you to expose the bones of your building. Our customers typically incorporate these structural elements as a high-grade visual component in impressive applications, such as vaulted ceilings and soaring open spaces. GlulamPLUS® beams and columns, when combined with mass timber systems such as CrossLam® CLT floors and roof decks, can be a key component of an earth-friendly building that offers a beneficial indoor environment.

Structurlam has a long history of developing project delivery systems to help ensure your project is delivered on time and in full. GlulamPLUS® allows your project to be erected quicker on-site, producing an economic and beautiful structure made from sustainable material.

This guide was created to help you design and specify GlulamPLUS® for your project. If you have any questions, please reach out to our qualified team of technical Mass Timber Specialists and support staff to help you complete your project.

Ballard Library, Seattle, WA, USA

GLULAMPLUS® ADVANTAGES:

- North American code approved
- Range of shapes and sizes
- Superior wood fiber and appearance
- Hand-sanded, high-quality finish
- Prefabricated kit of parts, CNC-framed to tight tolerances
- Top-notch project delivery experience
- BIM modeling options
- Shop-assembled connections
- Rigorous quality control process

MANUFACTURING/FIBER

Fiber: Interior Douglas Fir (Pseudotsuga menziesii var. glauca)

Glue: Melamine (standard) or Phenol Resorcinol (optional)

FSC Certification: Available upon request
(Additional costs may apply)

SFI Certification: Available upon request
(Additional costs may apply)

Moisture Content: 7%-15%

Density: 34 lbs/ft^3, 560 kg/m^3

Certifications: ANSI/AITC 190.1, ANSI 117, CSA 0122, CSA-0177 and JAS program for glulam

AVAILABLE SIZES

Max length standard: 60’ (18.3 m)

Max length specialty: 110’ (33.5 m)

Max depth standard: 48” (1219 mm)

Max depth specialty: 96” (2438 mm)

Minimum depth: 4.5” (114 mm)

	INDUSTRIAL FINISH WIDTH		ARCHITECTURAL FINISH WIDTH	
NOMINAL SIZE	IMPERIAL (IN)	METRIC (MM)	IMPERIAL (IN)	METRIC (MM)
2x4	3 1/8	79	3 1/8	76
2x6	5 1/8	130	5 1/8	127
2x8	6 7/8	175	6 3/4	170
2x10 SL	8 5/8	219	8 1/2	216
2x12 SL	10 3/8	263	10 1/4	260
2x14 SL	12 3/8	314	12 1/4	311
2x16 SL	14 3/8	365	14 1/4	362
2x18 SL	16	406	15 7/8	403

Note: Industrial-sized members are industrial visual quality. They also carry industrial framing tolerances and are not squared to the same accuracy as architectural finish members. Mass timber packages with specialty steel connections or pre-engineered connections must be quality finish and 1/4" (6.4 mm) undersized in width to properly fit on-site. GlulamPLUS® depth will also be undersized by 1/2" (13 mm) for architectural quality or tight tolerances for pre-framed applications.

Arches

GlulamPLUS® has the ability to be formed into many unique and complex shapes, resulting in stunning structures that tame complex geometry to their form. Structurlam's GlulamPLUS® arches are custom made for each project and available in a variety of formats. Arched Structurlam members are unique to glulam and provide a significant advantage over steel or concrete alternatives.

LAMINA THICKNESS		TANGENT ENDS MINIMUM		CURVED END MINIMUM	
IMPERIAL (IN)	METRIC (MM)	RADII (FT)	RADII (M)	RADII (FT)	RADII (M)
1.50	38	27.6	8.4	35.4	10.8
0.75	19	9.2	2.8	12.5	3.8

Note: Any arch within 3 ft (1 m) radii of the minimum radii is subject to substantial spring back and will not exhibit perfect geometry. Talk to your technical sales representative for more information.

Shane Homes YMCA at Rocky Ridge, Calgary, AB, Canada

Finishes

ARCHITECTURAL

Members may contain natural growth characteristics allowed in specified grades of lamstock. Sides shall be planed to specified dimensions and sanded smooth. Tight knots and stain are permitted to appear on finished surface. Loose knots, knotholes, wane and pitch pockets shall be replaced with sound stock or non-shrinking waterproof filling material (wood putty).

INDUSTRIAL

Members may contain natural growth characteristics allowed in specific grades of lamstock. Sides shall be planed true to specified dimensions. Occasional planing misses are permitted. Wood inserts and filling are not required.

Structural Design Values and Grades

ALLOWABLE STRESSES (PSI)							
COMBINATION	TEN./ F_{BX}	COMP./ F_{BX}	F_{VX}	E_X	$E_{C//}$	E_{C1}	F_T
Unbalanced Layups							
EWS 24F-V4/DF	2400	1850	265	1.8×10^6	1650	650	1100
Balanced Layups							
EWS 24F-V8/DF	2400	2400	265	1.8×10^6	1650	650	1100

** SOURCE ANSI 190.1*

COLUMN LAYUP DESIGNATIONS AND DESIGN STRESSES* (PSI)							
SPECIES AND LAYUP COMBINATION	LAM GRADE	F_c	E	F_{BX}	F_{BY}	F_{VX}	F_{VY}
DF – Comb. No. 2	12	1900	1.7×10^6	1700	1800	240	210

** All stress values are in psi and assume 4 or more laminations (up to 15 inches) without special tension laminations. Numerous other species and layup combinations are available. See Glulam Design Properties, Form Y117, for more information.*

** SOURCE ANSI 190.1*

CAMBER STANDARDS:

Four standard cambers are available. Any cambers falling outside these standards are custom processed and carry additional fabrication costs as arches. Standard cambers carry no additional costs. Camber cannot be used with complex multi-point connection or pre-engineered tight tolerance connections. Cambers should only be used when simple bucket or knife plate connections are used on each end of the beam.

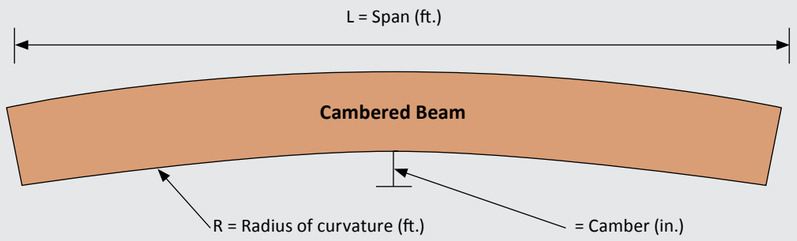
Camber 1: Radius 1310'

Camber 2: Radius 1833'

Camber 3: Radius 2620'

Camber 4: Radius 3274'

BEAM CAMBER PARAMETERS



SOURCE APA: The Engineered Wood Association

Storage and Handling of GlulamPLUS® Building Products

QUALITY ASSURANCE AND STANDARDS

Structurlam provides glulam products that meet the current ANSI/APA190.1 and Japanese standards through daily QC testing, bimonthly third-party audits and annual internal reviews. However, QC is applied to a lot more than just the products we make and the standards they are made to. It is also performed in all aspects of our Mass Timber packages as our Quality Assurance and Product Application Assurance (PAA) systems. The finished products all have a Quality Assurance process to ensure that what has been included in the 3D model perfectly matches what is sent to site. This includes QC checks when creating the model and multiple steps as the product is manufactured.

DETAILS

Our GlulamPLUS® package incorporates full 3D BIM modeling that is required for our precise CNC machines to frame the glulam. This fully framed glulam is test fit with steel connections typically supplied by Structurlam for mass timber to mass timber connections. This ensures a quick and simple installation on-site reducing risks and unknowns.

FINISHES

Wood finishes are a necessary component of preserving your products at the most critical phase of service. Bare wood products highlight the natural beauty of wood, as wood behaves as the natural material it is, by checking, swelling and changing color over time. GlulamPLUS® beams and columns are coated with a standard sealer, which, in addition to proper efforts for storage and handling during construction, can help to account for these factors.

Telus Gardens, Vancouver, BC, Canada

WEATHER CONDITIONS

Glulam beams, columns and arches are susceptible to adverse weather conditions and precautions must be taken to protect them. Rain and moisture will cause staining of glulam members. If bolts are used with steel connections, ensure they are free of oil. Otherwise this will cause staining. Using galvanized bolts and connectors will prevent this. Any unprotected structural steel that can rust could also drip onto the glulam members and cause staining. Ensure the protective poly is kept on the glulam members until the roof is installed.

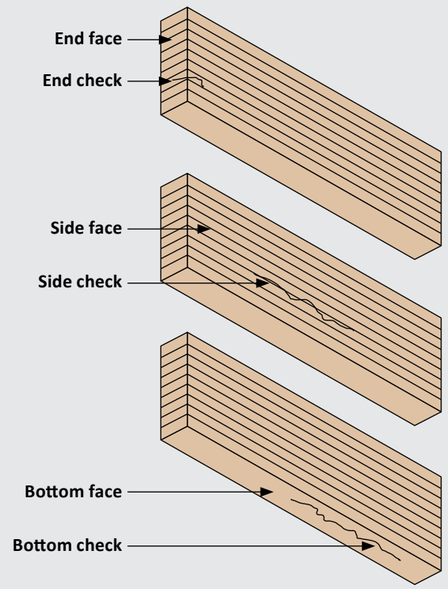
SUDDEN APPLICATION OF HEAT

Sudden application of heat to buildings can rapidly change the moisture content of glulam beams, columns and arches, producing an adverse affect on the structural integrity and cause adverse checking to glulam building products. It is important that care is taken during transit, storage and throughout all stages of construction to avoid rapid changes in the moisture content of glulam building products. Ambient building temperature should be gradually increased in the structure over a two- to three-week period, up to normal temperatures. This will ensure a gradual change in the moisture content of the glulam building products. The slower the moisture content in the wood equalizes with the moisture content in the air, the better. It is important to not direct any forced air heating systems onto the glulam structural members. Regulate all heating units remembering that hot air rises and temperatures at the ceiling can reach much higher temperatures where glulam structural members are often located. Adequate venting should also be provided to maintain normal relative humidity in the building and monitor if necessary. It is recommended to apply the final finish to the glulam member before heat is applied as this will help to regulate the change in moisture content.

CHECKING

Checking is a natural occurrence in glulam and is due to dimensional changes and the internal release of fiber stresses as the wood takes on or expels moisture from the ambient air humidity. If you believe excessive checking is occurring, please consult your Structurlam representative. Allowing for gradual acclimation to the relative environmental conditions to ensure slow humidity changes during construction, occupation and throughout the building's service life can help to mitigate checking.

CHECKING



In bending members (beams, rafters, girders, etc.), checks are commonly observed in the face of the bottom lamination, in the side of the members and at the end of the members.

SOURCE APA: The Engineered Wood Association

Mass Timber Building Systems

The future of multi-story commercial and residential building is here and it's made from an organic compound that is as strong as steel, sequesters carbon dioxide and is 100 percent renewable. Nature's carbon fiber engineering dream, Wood, is the material of the future. For more than five decades, Structurlam has been at the forefront of engineered timber, developing systems that include products and components like CrossLam® CLT and GlulamPLUS®, making mass timber structures possible.

Structurlam is more than a fabricator of high-quality engineered wood products and building systems: We're an innovator of mass timber design, engineering, 3D modeling and precision manufacturing. By applying these technologies to wood—the only renewable structural material available—you can prefabricate your entire project. This saves precious time and money on-site, mitigating design risks and accelerating construction schedules. That is a benefit you won't see with any other building material.

The technical information presented in this guide describes a variety of structural systems commonly used in the construction of mass timber buildings and is intended to guide architects, engineers, designers, contractors and developers in their designs. For further guidance and expertise, please contact our qualified team of technical representatives and support staff. We would be happy to be of further assistance to your project.

UBC Brock Commons, Vancouver, BC, Canada

Design Development and Service Options

Structurlam is a world-renowned fabricator of complex structural timber components. Our team of design and manufacturing professionals carefully integrates 3D computer models with CNC controlled milling machines to produce world-leading projects. Our goal is to help design teams make the most of their projects by leveraging the cost savings and structural advantages of mass timber construction. We offer design and fabrication services at a variety of levels.

DESIGN SUPPLY

- Full Engineering or Specialty Engineering
- Partner with Architect to retain original design intent
- Complete detailing and drafting services (steel connections and hardware)
- Supply of mass timber members per Structurlam shop drawings

MANUFACTURING DESIGN ASSIST

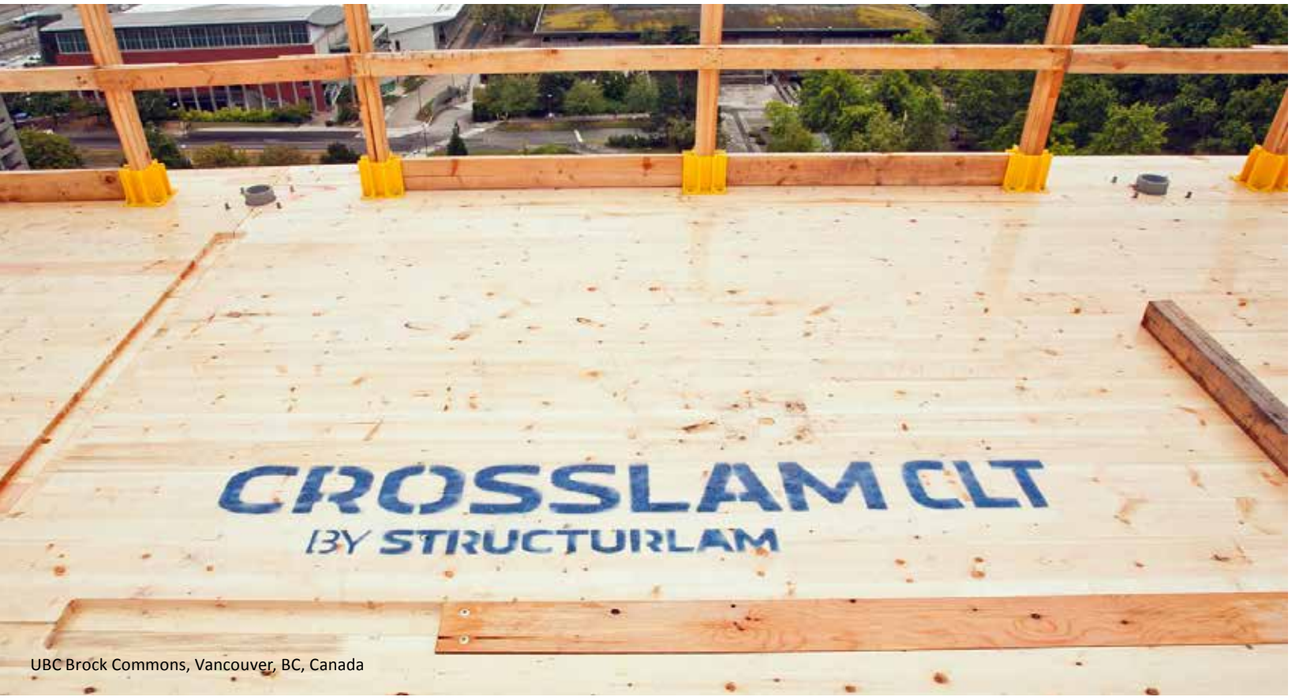
- Assist the EOR and Architect with achieving cost optimization
- Complete detailing and drafting services (steel connections and hardware)
- Supply of mass timber members per Structurlam shop drawings

TRADITIONAL BID

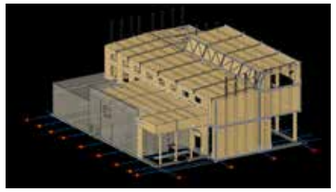
- Complete detailing and drafting services (steel connections and hardware)
- Supply of mass timber members per Structurlam shop drawings

FABRICATION ONLY

- Supply of mass timber members per single piece shop drawing or fully detailed 3D model



UBC Brock Commons, Vancouver, BC, Canada



CrossLam® CLT and GlulamPLUS®, Mass Timber Fabrication

Structurlam's Mass Timber package is fabricated using the latest 3D modeling software. Data is transferred directly to our CNC machines—the most sophisticated milling machinery in North America, allowing us to achieve tight fabrication tolerances.

CrossLam® CLT projects begin with your drawings, from which we develop a 3D BIM model that is used to design panels and connectors. Our model also allows our experts to identify optimized design alternatives to increase constructability and reduce overall costs. Shop drawings for panels and steel connectors are generated from the 3D model, and digital files are sent to our CNC machines for fabrication. Finally, our 3D model is used to develop a material list for efficient purchasing, loading diagrams to optimize freight as well as assembly drawings for quick and efficient installation.

CrossLam® CLT Delivery, Storage and Handling

Structurlam takes every reasonable precaution to protect your mass timber package components during shipment by wrapping panels in 100 percent recyclable plastic. However, when not properly handled and protected, panels and beams are subject to surface marring and damage, water staining, sun damage and checking. We recommend you follow the guidelines outlined in our CrossLam® CLT and GlulamPLUS® Storage and Handling Guide available on our website or through our office.


Shoreline Medical Center, Seattle, WA, USA

CrossLam® CLT Installation

Detailed pre-construction planning can help to ensure installation of CrossLam® CLT is easy, safe and efficient. Depending on the project site, we recommend that sufficient space be available to:

- Prepare panels or GlulamPLUS® system for installation
- Re-sort panels according to the install sequence
- If required, apply treatments
- If required, add on-site hardware

Truckload sequencing is a standard feature of the Structurlam Mass Timber package. The exact sequencing is established during the shop drawing process. In order to maintain safe shipment, some panels may be delivered out of sequence in order to properly balance the load. Please contact our office to learn more about truckload sequencing. All lifting equipment, rigging and hoisting devices are designed by the installer's erection engineer taking into account all site conditions.

CrossLam® CLT vs. Concrete

Mass timber systems produce a lighter-weight structure and a lighter carbon footprint than concrete. CrossLam® CLT is up to five times lighter than concrete and can be installed three times faster than cast-in-place concrete, with many erectors installing up to 15,000 square feet per day with a team of 4-6 people. CrossLam® CLT is also cost comparative to concrete and allows for construction in areas with poor soil conditions. As CLT replaces concrete in buildings, the overall weight of the structure is reduced, allowing for a reduced amount of rebar and lower total cost.

CrossLam® CLT sequesters CO_2 and allows a building to serve as a carbon sink over its lifetime. Life Cycle Assessment (LCA) of building materials shows the carbon footprint of wood is lower than steel or concrete when compared with seven key environmental measures (see chart "Environmental Impact of Wood, Steel and Concrete").

To learn more about the environmental footprint of Structurlam products, contact us for a copy of our Life Cycle Assessment and Environmental Product Declaration documents. You can read more about the LCA of wood by visiting http://www.naturallywood.com/wood-design/responsible-choice/life-cycle-assessment

Floor Vibration Control Comparison

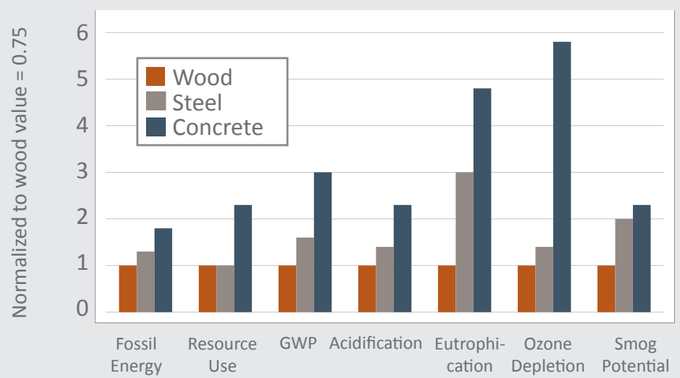
Floor vibration performance depends on the application and the expectations of the user. As such, floor vibration should be designed accordingly. The preferred design method to controlling vibrations in CLT floors is found in NDS 2015 and the US CLT Handbook. The chart below compares the thickness of CrossLam® CLT floors against concrete and at what level we are able to better control our vibration with CrossLam® CLT versus concrete.

CROSSLAM® CLT SERIES	CLT PANEL (IN)	CONCRETE SLAB (IN)	VIBRATION CONTROLLED SPAN (FT)
87 V	3.43	5.31	10.5
105 V	4.14	5.91	12.1
139 V	5.48	7.48	14.8
175 V	6.90	8.46	16.7
191 V	7.53	9.25	18.4
243 V	9.58	10.24	21.0
245 V	9.66	10.83	21.6
315 V	12.42	12.40	24.9

50 psf live load plus self weight plus 21 psf miscellaneous dead load

Indicates CrossLam® CLT thickness advantage

Environmental Impact of Wood, Steel and Concrete



Three hypothetical buildings (wood, steel and concrete) of identical size and configuration are compared. In all cases, impacts are lower for the wood design.

Source: *Dovetail Partners using the Athena Eco-Calculator (2014)*

Benefits of building with Structurlam's Mass Timber Products

EASE AND SPEED OF CONSTRUCTION

Due to the nature of prefabrication, mass timber components arrive on-site as a kit of parts, require less storage and can be shipped for just-in-time scheduling to facilitate quick assembly in dense urban areas. Prefabrication in Structurlam's facility allows complex cuts to be made with high precision and small tolerances, effectively reducing custom work on-site.

STRUCTURAL STRENGTH AND STABILITY

Thanks to the high strength-to-weight ratio of timber, projects utilizing mass timber systems typically have smaller, less expensive foundations and are ideally suited for poor soil conditions. CrossLam® CLT is made up of a series of perpendicular layers, adding strength to the system in multiple directions. As a result, CrossLam® CLT is an exemplary product compared to other mass timber products, making it ideal for both regular and architecturally complex structures. Due to the rigidity of CrossLam® CLT, panels create an effective lateral load-resisting system with exceptional performance in high seismic and wind events. The design principles for both GlulamPlus® and CrossLam® CLT can be referenced in NDS 2015 in the U.S. or CSA o86 in Canada.

THERMAL AND ENERGY PERFORMANCE

The material properties of mass timber help to manage the transfer of thermal energy through the building envelope by resisting air transfer, creating a highly insulated space. Due to the tight tolerances and precision of prefabrication in Structurlam's state-of-the-art manufacturing facility, joints between panels and members tend to fit together tighter, resulting in the improved energy efficiency of your building. The mass in the mass timber also acts as a thermal battery, helping the structure better regulate internal environmental conditions.

FIRE AND ACOUSTIC PERFORMANCE

Due to the mass of heavy timber products, impact, airborne and flanking sound transfer can be controlled effectively creating adequate acoustic performance in your building. Mass timber also performs exceptionally well in fire events due to its slow charring and self-insulating properties. Our Mass Timber products char at the same rate as solid wood products, providing effective fire protection.

COST EFFICIENCY

Mass timber buildings, when designed effectively, have similar material costs to concrete and steel alternatives. Cost efficiencies must be implemented via:

- Reduced schedule/financing
- Reduced foundation design, lightweight materials
- Mitigated on-site risks/issues
- Simplified fit and finish
- Ease of MEP installation
- Use of prefabrication and industrialized industry 4.0 construction practices

ENVIRONMENTAL SUSTAINABILITY

Timber-based building materials contain many environmental benefits when compared to conventional materials such as steel and concrete. A major benefit of mass timber is that it sequesters CO_2 over its life and, therefore, acts as a carbon sink, ultimately helping to mitigate one of the most pressing issues impacting our society today: global warming. If the harvesting, processing and replanting of trees is conducted responsibly, more CO_2 can be stored and less greenhouse gases are produced during the manufacturing process. In response to this pressing issue, Structurlam ensures that all wood fiber used in GlulamPlus® and CrossLam® CLT is traceable from certified and sustainably managed forests.


Prince George Airport, Prince George, BC, Canada

Mass Timber System Design Considerations

DEFLECTION

The deflection limits of CLT are specified in IBC Table 1604.3. Calculating deflection should conform to the U.S. CLT Handbook, 2013, Chapter 2. Creep is a critical factor that should be accounted for in any structural design. Please see the approach outlined in Chapter 6 of the U.S. CLT Handbook. The 2015 NDS contains design information on calculating deflection limits. Generally, the CLT floor plate will be governed by performance-based vibration analysis.

SERVICE INTEGRATION

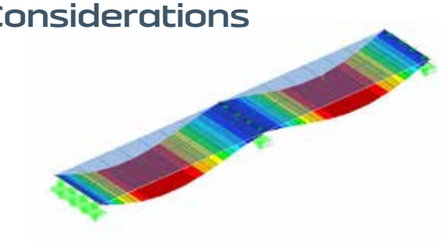
Building penetrations for mechanical electrical and plumbing (MEP) services are easier and more economical to install if their locations can be included in the design of the CLT panel. Penetrations can be cut in the factory, saving installation time and expense. MEP services not included before the manufacture of the panel can still be incorporated on-site using standard construction tools.

MATERIAL OPTIMIZATION

Involving Structurlam in the early stages of your project is the best way to ensure efficient utilization of CrossLam® CLT panels. To achieve material optimization, we suggest designing in full billet sizes, 9'10.5" x 40'. Incorporating standard panel sizes into your design will most certainly reduce your product waste.

VIBRATION

Maximum floor vibrations for CLT slab elements must be carefully analyzed when designing with CrossLam® CLT. Research in this area is ongoing; however, the proposed design method for controlling vibrations in CLT floors is

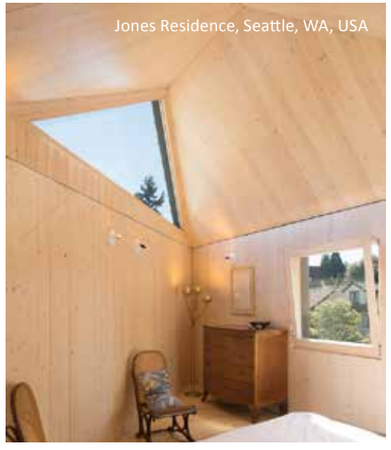


outlined in Chapter 7 of the U.S. CLT Handbook. Different system configurations of bearing walls or beam types will also affect the overall system vibration performance.

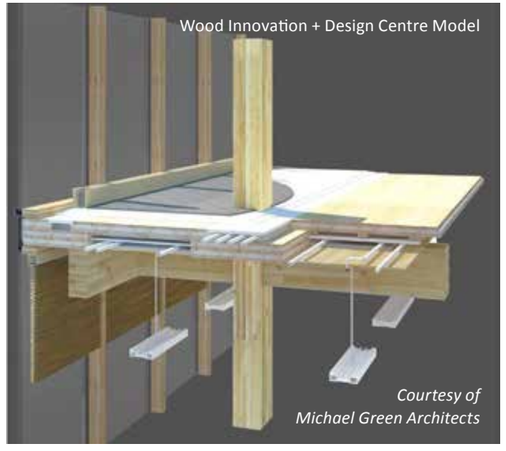
ACOUSTIC PERFORMANCE

CLT walls and floors contribute to the overall sound isolation characteristics of the completed building. Sound transmission is affected by the components in wall and floor assemblies. Airtight construction and specifically engineered connections can help reduce sound transmission by mitigating flanking transmission (sound energy that passes around, not through, panels). Chapter 9 of the U.S. CLT Handbook addresses sound insulation in CLT construction.

Elkford Community Conference Centre, Elkford, BC, Canada



Jones Residence, Seattle, WA, USA

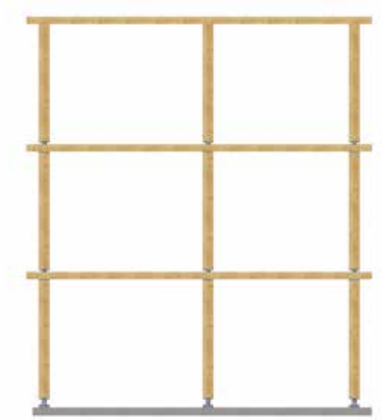


Wood Innovation + Design Centre Model

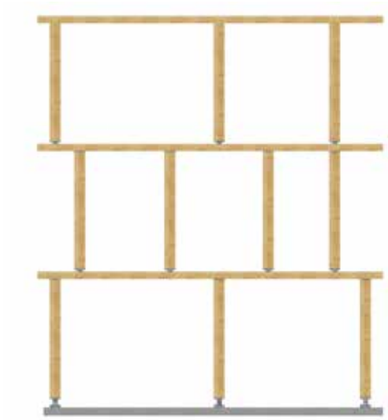
Courtesy of Michael Green Architects

Structural Considerations of Multi-Story Timber Buildings

Typically, multi-story mass timber buildings require that all loading paths are vertically and uniformly aligned throughout all stories of the structure. Any walls and columns that remain aligned in the same vertical plane throughout the building can be used to brace the building. This is important to consider in all mass timber building systems described in this guidebook, including the Post and Platform, Post-Beam-Panel and Hybrid Light-Wood Frame systems. Structures with load paths that do not align will require transfer slabs and transfer beams. While possible, these types of design are not cost-effective and add significant complication to mass timber structures. Base designs and concepts should always avoid these types of design situations, if possible.



Ideal structural layout with walls and columns vertically aligned



Unsuitable structural layout with complicated and staggered wall and column alignment

UBC Brock Commons, Vancouver, BC, Canada

UBC Brock Commons, Vancouver, BC, Canada

UBC Brock Commons, Vancouver, BC, Canada

Post and Platform System

The Post and Platform system is a common type of mass timber structural system made up of CrossLam® CLT floor panels resting directly above GlulamPLUS® columns. This system does not use any beams or secondary supporting members for the CrossLam® CLT panels. The panels work in a full two-way span system point supported on bearing columns. This system is ideal for many types of buildings including multi-story residential and office buildings. It can effectively be used in both hybrid material systems as well as full timber-based structures. This type of structure allows easy MEP routing, clear head heights and rapid deployment. It is ideally suited for hotels or smaller residential uses such as dormitories or micro apartments.

SYSTEM COMPOSITION

The Post and Platform system is made up of the following components *(See figure on page 46)*:

- GlulamPLUS® columns
- CrossLam® CLT panels
- Steel connectors (plates, screws, etc.)

Benefits

The Post and Platform System has been successfully used in high-profile mass timber projects due to a variety of benefits including the following:

EASE AND SPEED OF CONSTRUCTION

Connection design is typically less complex than other commonly used systems, making this a very advantageous system. The simple connections help to speed up and simplify the construction process and allow for less experienced builders to succeed in the construction of this type of building. Commonly used connections are discussed in further detail in on pages 47-48.

ARCHITECTURAL VALUE AND FLEXIBILITY

The Post and Platform system provides high architectural value due to the high quality of natural timber materials used as well as its ability to construct open spaces. This system is made up of a series of typical grids, allowing for the simple design of open concept living and workspaces. As a result, this system is ideal for the construction of hotels, dormitories, offices and multi-family residential buildings, among a variety of other suitable applications.

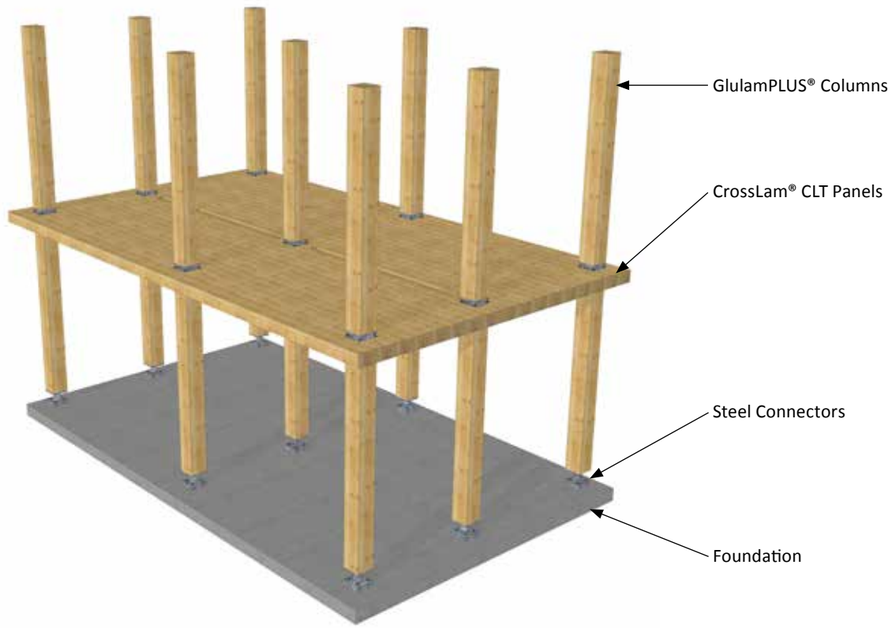
STRAIGHTFORWARD AND DEPENDABLE STRUCTURAL DESIGN

The Post and Platform System is highly advantageous due to its proven structural details, simplicity and its potential for consistency throughout the building if considered early in the architectural design of the building. An important consideration in the structural design of Post and Platform systems is the two-way span of the CrossLam® CLT. Due to its cross laminations, CrossLam® CLT is able to provide strength in two directions and therefore is a superior mass timber building system, which is ideal for this type of application.

COST EFFICIENCY

Due to the ease and speed of construction of a Post and Platform System, construction costs can be reduced considerably since this system has proven to take weeks, or even months, off the construction schedule.

Typical Post and Platform System Construction



CONNECTIONS

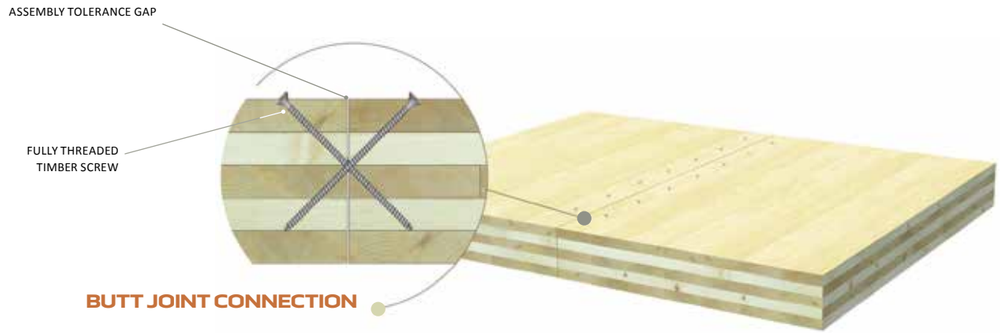
The following sections show typical connection details used in Post and Platform buildings. Structurlam will be happy to work with your team to identify the most economical and effective connection system for your building.

FLOOR PANEL JOINTS

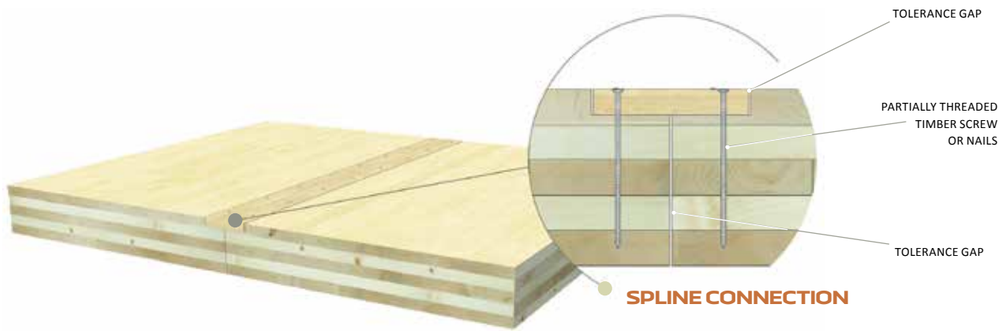
In the construction of mass timber buildings, the CrossLam® CLT panels can be joined using a variety of connections, including spline or butt joint connections as detailed below. In the case of both systems, the cutouts are prefabricated and prepared at Structurlam's manufacturing facility to simplify installation on-site.

Butt joints are advantageous because they are relatively simple in design, do not require much prefabrication and produce highly rigid connections with ductile failure modes; however, they require many timber screws, leading to more time and effort spent on-site.

Spline connections have become one of the most common panel connection systems because they are simple to frame and prefabricate and lead to simple installation on-site. Splines are typically cut from 3/4" (19 mm) or 1" (25 mm) plywood, with a width of around 5 1/2"-6" (140-150 mm), as determined by an engineer. They can be used with self-tapping timber screws or with nailed splines that tend to be more cost-effective if the loads are appropriate.



BUTT JOINT CONNECTION

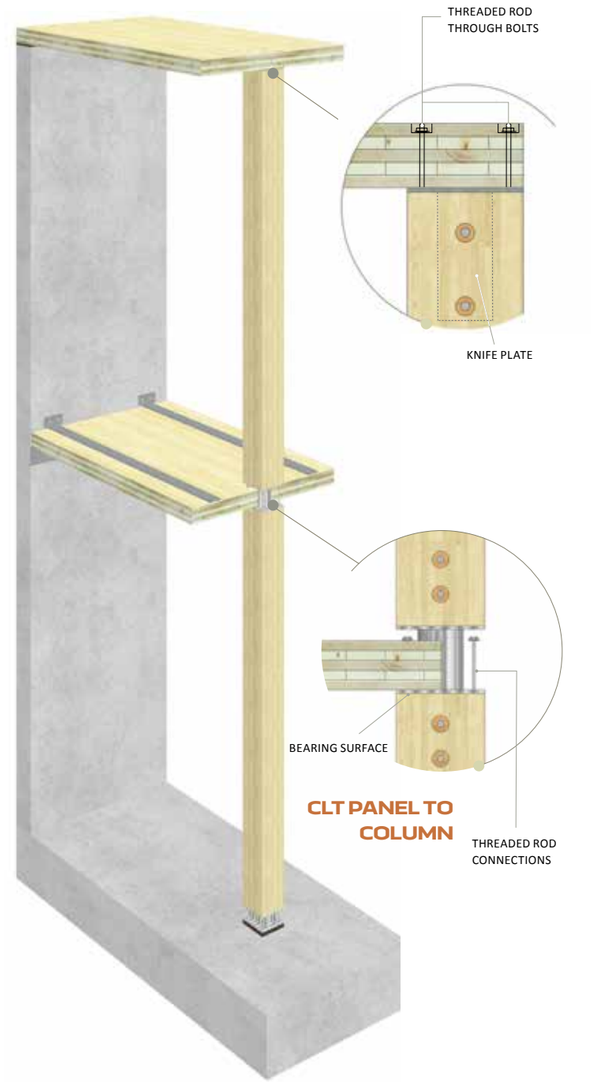


SPLINE CONNECTION

COLUMN TO PANEL CONNECTION

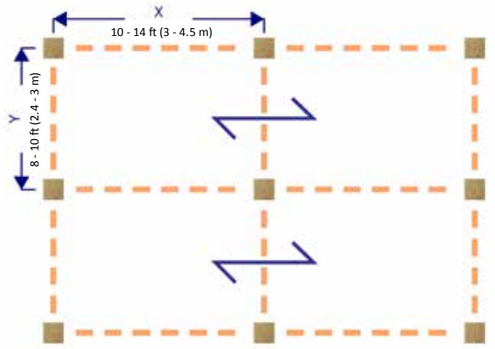
Typically, columns arrive on-site prefabricated with the steel connectors already in place. These columns can then be erected allowing the CrossLam® CLT panels to immediately be installed above, quickly creating a working surface for subsequent floors. The figure below shows typical CrossLam® CLT to GlulamPLUS® column connections that are commonly used in the construction of Post and Platform systems.

The column-to-column connection also incorporates the CLT bearing connection and must be checked for punching shear on the CLT panel, which tends to be a governing value in this type of connection.



TYPICAL GRIDS

The figure to the right shows the typical grid sizes used for Post and Platform mass timber building systems. The optimal grid sizes for this type of system are 7'10.5" and 9'10.5" (2.4 m-3 m) wide since this maximizes the utilization of CrossLam® CLT by reducing material costs and waste. Other sizes can be used; however, they may result in significant cost increases due to high waste. Due to the nature of pressing CrossLam® CLT, the maximum length of panel that can be pressed is 40' (12.19 m) and the maximum width that can be pressed is 7'10.5" (2.4 m) and 9'10.5" (3 m). This results in grid layouts that are ideal for hotels, micro-condos or student housing.



Typical Post and Platform System Grids

Carbon 12, Portland, OR, USA

Post-Beam-Panel System

POST-BEAM-PANEL SYSTEM

The Post-Beam-Panel system is another common type of mass timber structural system composed of CrossLam® CLT floor panels resting directly above GlulamPLUS® beams and columns. The beams and columns form the load-bearing structure of the building upon which the panels can be placed, effectively forming a platform for construction on subsequent floors. This system has been used effectively in several types of buildings including multi-story residential buildings, office buildings, industrial buildings and large assembly halls, and its principles can be used in both hybrid material and full timber-based structures.

SYSTEM COMPOSITION

This system is made up of the following components:

- GlulamPLUS® beams
- GlulamPLUS® columns
- CrossLam® CLT panels
- Steel connectors (plates, screws, etc.)

All are prefabricated to provide the highest degree of accuracy and to simplify and accelerate construction on-site.

First Tech Credit Union, Hillsboro, OR, USA

Benefits

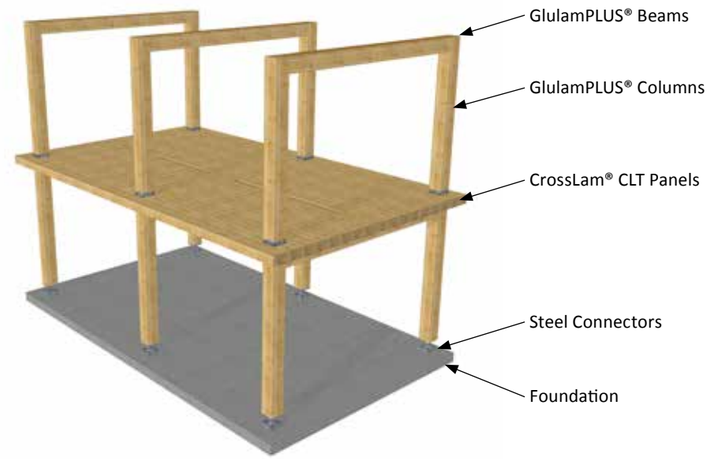
The Post-Beam-Panel mass timber structural systems are often used for office, commercial or residential applications. This type of construction method shows benefits in many areas including the following:

ARCHITECTURAL VALUE AND FLEXIBILITY

Due to the nature of the system, it is simple to expose the bones of the mass timber structure, providing high architectural value to the building. If it is desired to expose the GlulamPLUS® beams and/or CrossLam® CLT ceiling, MEP equipment is typically installed in the floor buildup of the panels rather than the ceiling side.

EASE AND SPEED OF CONSTRUCTION

Much like the Post and Platform system, this system leads to a relatively simple construction, helping to accelerate the erection of the building. Depending on the connection system used, prefabrication can drastically help simplify construction and meet precise tolerance requirements. Commonly used connections are discussed in further detail on page 52.



STRAIGHTFORWARD AND DEPENDABLE STRUCTURAL DESIGN

An additional benefit to this system is that the panels are required only to span in one direction, thus drastically simplifying the design of the structure. The beams also provide extra support to the panels, allowing thinner panels to span farther. It is beneficial to allow panels to span over several grids because it increases the stiffness of the panels, thus reducing vibration and deflection concerns.

COST EFFICIENCY

Material costs can be substantially reduced by using thinner panels in conjunction with the beams in the system. Also, simple pre-engineered or custom steel connectors can be used for the GlulamPLUS® beams and columns, which can help to simplify construction on-site, thus reducing installation time on-site. By accelerating the construction process, costs can be reduced dramatically.

Connections

BEAM TO COLUMN CONNECTIONS

There are several types of beam to column connections, which can be used in the design of Post-Beam-Panel systems including pre-engineered connectors and custom steel systems.

PRE-ENGINEERED CONNECTORS

Pre-engineered connectors are often preferred systems because they are typically time-saving for installation, as the connections can be factory installed and are simple to design using design tables or standardized values. There are different types of beam hangers such as concealed beam hangers, which help to achieve high fire-rating requirements and meet rotational compatibility during seismic and wind events.

CUSTOM STEEL

In certain applications, where pre-engineered connectors may not be feasible, custom steel connections are typically used. Custom steel connections are often required when there are common shapes and geometries. These types of connections may require more in-depth design and are less predictable than tested, pre-engineered connections.

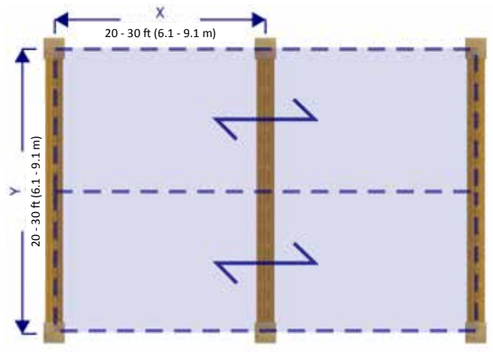
TYPICAL GRIDS

The figure to the right shows typical grid sizes used for Post-Beam-Panel mass timber building systems. Due to the nature of pressing CrossLam® CLT, the maximum length of panel, which can be pressed is 40' (12.19 m) and the maximum width that can be pressed is 7'10.5" (2.4 m) and 9'10.5" (3 m).

The use of augmented grids can create amazing structural efficiencies. An example would be a 30" (9.1 m) primary beam span in the Y direction and 15' (4.5 m) bay spacing in the X direction. Located on exterior bays of the building, this produces a large functional space.

Installation of beam using concealed pre-engineered beam connectors

Concealed pre-engineered beam to column connectors



Typical Post-Beam-Panel System Grids

Hybrid Light-Wood Frame

This system is a hybrid between typical light-wood frame and mass timber construction. Typically, only the shear walls and horizontal structure (floor and roof) are constructed using CrossLam® CLT while the rest of the structure is made up of typical light-wood frame construction principles. This is typically used for residential structures.

SYSTEM COMPOSITION

The Hybrid Light-Wood Frame system is made up of the following components:

- Light-wood frame walls
- CrossLam® CLT floor/roof panels
- GlulamPLUS® beams as required

Benefits

The Hybrid Light-Wood Frame system shows superiority over conventional light-wood frame systems with the following benefits:

EASE AND SPEED OF CONSTRUCTION

By using a hybrid light-wood frame system in your building, the ease and speed of construction can be improved drastically compared to a conventional light-wood frame building system. This is due to the nature of the installation of CrossLam® CLT. CrossLam® CLT can be easily installed, typically using a crane, and reduces time spent on installing joists and other components. This quickly allows access to subsequent floors for further construction to begin, ultimately accelerating the total construction schedule of your building. Experienced crews typically install more than 15,000 square feet of CrossLam® floor system per day.

MEP INSTALLATION

Due to the buildup of light-wood frame systems, most of the MEP infrastructure can be installed within the wall assembly. This is ideal for contractors and designers who are less familiar with mass timber construction because conventional practices can be used. MEP penetrations coordinated via 3D model can also be cut in Structurlam's factory, if desired, and the relevant information is supplied in time.

ACOUSTIC AND FIRE PERFORMANCE

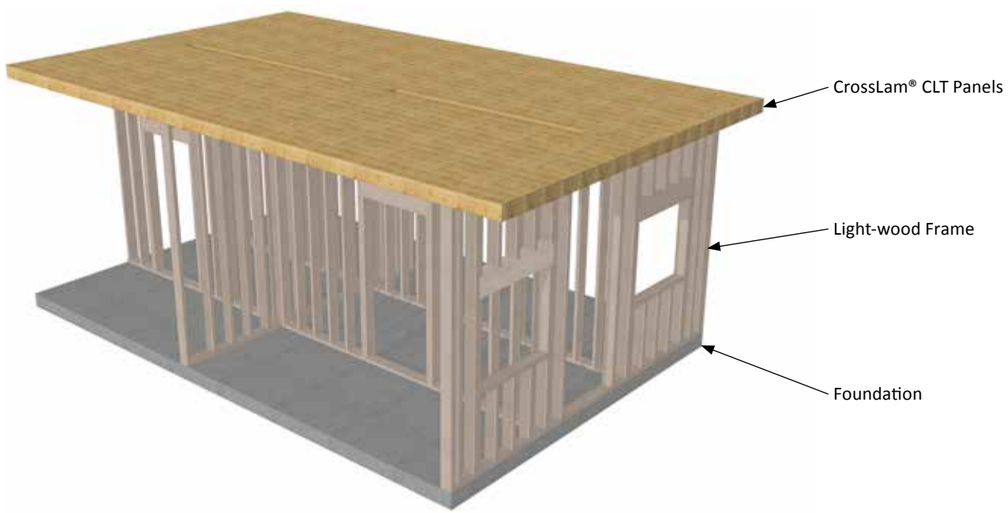
CrossLam® CLT has been proven to perform exemplary in fire and acoustic conditions. By using a Hybrid Light-Wood Frame construction system, it is expected for the fire and acoustic performance to be improved compared to conventional construction due to the material properties of CrossLam® CLT. Continuous solid CrossLam® CLT helps increase performance in both fire and acoustical applications. See pages 57-59 to learn more about the benefits of mass timber with respect to both acoustic and fire performance principles.

STRAIGHTFORWARD AND DEPENDABLE STRUCTURAL DESIGN

By using the Hybrid Light-Wood Frame construction system, the building performance is improved drastically compared to typical light-wood frame construction. The CrossLam® CLT helps to improve the robustness of the building, ultimately leading to an improvement in lateral (seismic and wind) and vertical loading design performance. Design processes are simple when slab edge plans are provided and bearing points are clearly identified.

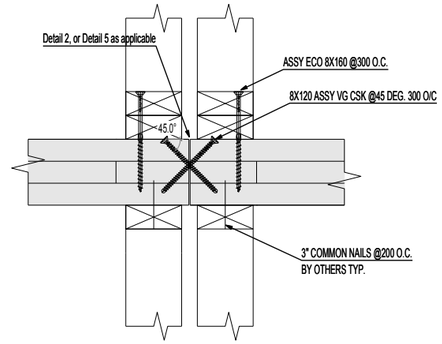
COST EFFICIENCY

Due to the extra robustness and improved performance of light-wood frame construction using mass timber elements, overall lifespan is expected to be improved, therefore reducing long-term maintenance costs. Also, due to the ability to expose mass timber, this system can be a key selling feature for building occupants and create greener, healthier living spaces. Installation time is reduced with a completely prefabricated product in comparison to traditional light framing methods.

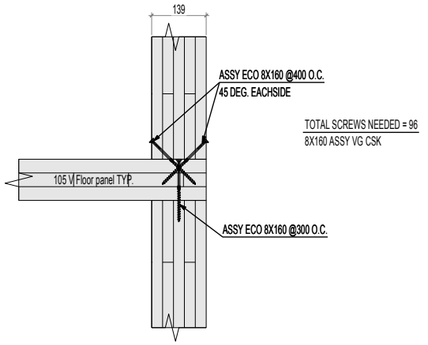


Sample Connections

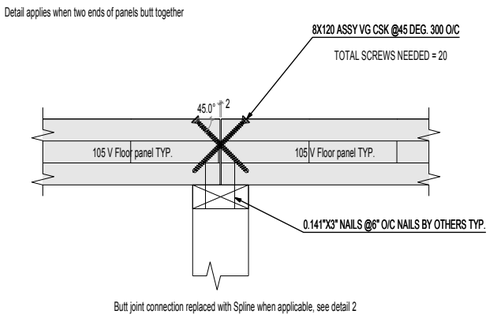
Mass timber connections in hybrid panel configurations on light frame or steel frame are easier than you think, and are generally comprised of self-tapping screws or nailed connections to other structural elements.



Platform frame light frame wall to floor to wall connection



Platform frame CLT wall to floor to wall connection



Panel to panel diaphragm over bearing connection

UBCO The Hangar, Kelowna, BC, Canada

Churchill Avenue 4-plex, Penticton, BC, Canada

Fire Design Principles

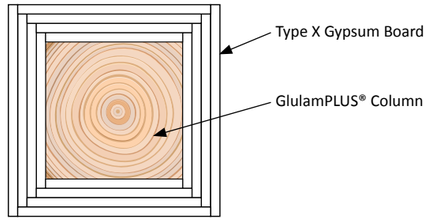
Fire resistance can be described as the ability for a material to continue to provide structural strength and resistance to heat or vapor transfer during a fire event. A fire resistance rating (FRR) refers to the time that a building component can withstand fire or heat and integrity failure. It is important to note that requirements regarding fire safety vary depending on building occupancy type and location; therefore, the specific requirements must be confirmed when designing the system. Mass timber systems can be designed using various performance principles to meet the required criteria including the following two methods:

- The Encapsulation Method
- The Char Method

THE ENCAPSULATION METHOD

This method encapsulates all structural mass timber components using Type X Gypsum Board and is the more conservative option between the two. Each additional board of 5/8" (16 mm) gypsum board adds approximately 30 minutes of extra fire resistance to the timber components. This system is designed for performance as it does not allow the mass timber to char.

Images Courtesy: Beam Craft



Encapsulation method with two-hour fire rating.

THE CHAR METHOD

The char method allows mass timber to be directly exposed to fire. Since the timber is fully exposed, extra lumber is added during the design phase to meet the fire resistance rating (FRR). This system is designed by determining the approximate depth to which the fire would penetrate and the remaining structural strength of the member after a certain exposure time.

CrossLam® CLT and GlulamPLUS® behave as mass timber and have a predictable charring rate of 1.5"/hr (0.65 mm/min). The char layer, which is formed during combustion, acts as an insulating layer for the inner layers thus protecting the structural members from a further loss of strength. The FRR of CrossLam® CLT and GlulamPLUS® is dependent on several factors including the member depth, span, applied loading and exposure. The most vulnerable components of this type of system tend to be the steel connectors due to the rapid reduction in steel's strength at high temperatures. To counteract this, it is required that all connectors be covered by a layer of timber or intumescent paint to protect the steel.

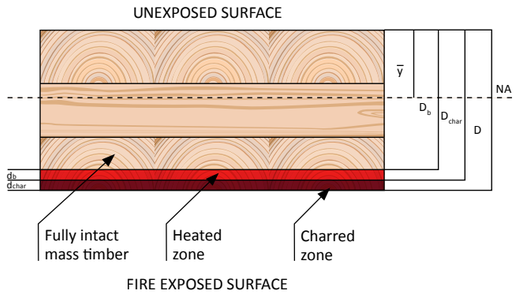
FRR performance is designed according to the local and NDS 2015 codes. Extensive testing has been completed to allow a codified approach to cover a variety of use scenarios.

Type IV Heavy Timber Construction of the 2015 IBC Chapter 6: CLT is allowed in the IBC 2015 under Type IV Construction – 602.4 Type IV construction (Heavy Timber, HT). The hourly fire resistance rating requirements for walls, floors and roofs are found in Table 601 of the IBC.

Char calculation method of the 2015 NDS: The NDS methodology uses wood-engineering-based mechanics to calculate the fire resistance of wood members and is referenced in Section 721.1 of the IBC. Effective charring rates calculated using the NDS methodology are also included in Section 721.2 of the IBC.

Execution of proprietary ASTM E-119 testing that is specific to the project assemblies: Standard Test Methods for Fire Tests of Building Construction Materials or UL 263, Standard for Fire Tests of Building Construction and Materials evaluate the duration for which CLT will contain a fire and maintain its structural integrity during exposure to fire.

CROSS SECTION OF FIRE-EXPOSED CROSS-LAMINATED TIMBER



Cross Section of Fire Exposed CrossLam® CLT Panel

FIRE STOPS AND SERVICE PENETRATIONS

A number of commercially available fire rated joint systems for concrete can achieve the same FT ratings when used in mass timber up to 2 hours. Detailing and fire caulking needs to be applied appropriately around the fire sleeve. This allows solid mass timber panels such as CrossLam® CLT to be a superior part of your fire protection system.

Wall assembly after testing showing the depth of charring on the exposed side. *NRC (2014) Fire Endurance of Cross-Laminated Timber Floor and Wall Assemblies for Tall Wood Buildings.*

Acoustic Principles

ACOUSTIC DESIGN PRINCIPLES

Sound and vibration control are directly associated with the comfort of building occupants. There are several different types of sound including airborne sound, impact sound and flanking sound that must be minimized and optimized to provide maximum comfort and livability within your building. Reverberation sound affects sound quality in a room but not rating values.

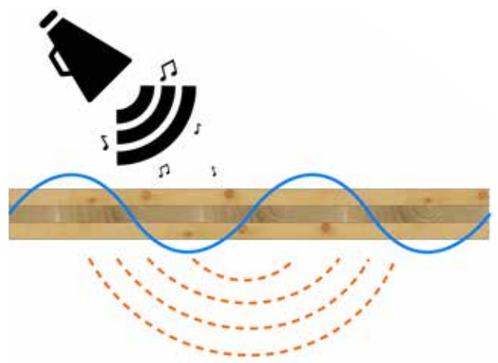
AIRBORNE SOUND (STC RATING)

Airborne sound is transmitted through the air such as through speech, televisions and stereo systems. These airborne waves cause the structural components to vibrate and therefore transmit sound to adjacent spaces.

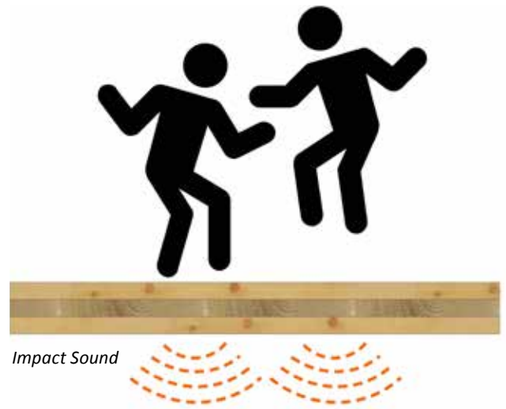
Airborne Sound Mitigation:

In order to mitigate the intensity of airborne sound from being transmitted into adjacent building spaces, architectural outfitting can be used. Fire, thermal and acoustic insulation can typically be combined where appropriate such as for walls, doors and windows. Techniques to reduce airborne sound often include the use of dense materials which tend to attenuate sound waves effectively such as:

- Floor: acoustic mat floor underlays or dropped ceilings
- Walls: dense wall insulation (i.e. rock mineral wool)



Airborne Sound



Impact Sound

IMPACT SOUND (ICC RATING)

Impact sound is a structure-borne sound, which is transmitted through a direct impact on solid elements such as through the walls and floors of a building. Examples of impact sound in a building include footsteps, falling objects and other sounds from your upstairs neighbors.

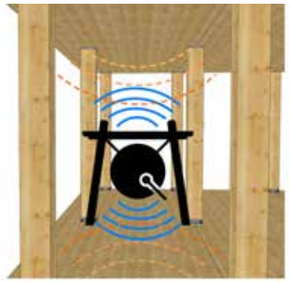
Impact Sound Mitigation:

To reduce the transmission of impact sound between building areas, it is effective to install damping materials on the impact surface such as some of the following:

- Carpet flooring
- Resilient underlay beneath flooring surface
- Suspended ceiling or raised floors

SOUND REVERBERATION

Reverberation is a longer lasting and degrading sound caused by the reflection from surfaces inside of a building. Varied surface shapes such as fluting or soft absorbing surfaces can help change the sound quality of a room and mitigate reverberation. This should not be confused with IIC (Impact) or STC (Sound Transmission) ratings.



Sound Reverberation

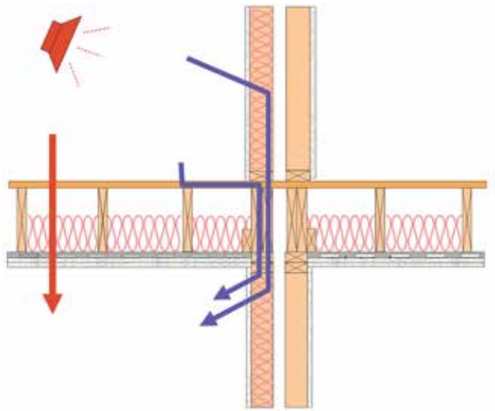

First Tech Credit Union, Hillsboro, OR, USA

FLANKING SOUND (STC AND ICC RATING)

Flanking sound occurs due to the transmission of both airborne and impact sound or vibration through building components into other non-intended portions of the building via uninsulated and indirect sound paths. For example, flanking sound transmission paths include windows and doors, ducts and shared structural building components such as floor panels. Conventional flanking sound mitigation techniques commonly see a 2-5 dB increase in field STC/ICC ratings.

Flanking Sound Mitigation:
Flanking sound must be mitigated on a project-specific basis and is minimized using sound insulation techniques such as window placement and building component insulation developed during the design stage. A certain degree of flanking sound can typically not be avoided; however, it can be minimized through:

- Design of less direct (i.e., longer and more complex) sound transmission paths
- Prioritization of discontinuity between units and building elements (i.e., avoid using one panel for more than one living unit without adding acoustic barriers)
- The buildup of multiple layers in the structural component cross-section
- Sound encapsulation techniques to remove direct structural paths (i.e., dropped ceilings)



Direct Path (red arrow) vs. Flanking Path (blue arrows) on floor surface

Estimated Airborne (STC-rating) and Impact (IIC-rating, in brackets) Sound Insulation of 175 V CLT with Various Floor Design Samples

CLT FLOOR 175 V [THICKNESS: 6.90 in (175 mm), MASS/AREA: 18.7 lb/ft^2 (91.4 kg/m^2)] STC (IIC)		BARE	GYPSUM BOARD CEILING: 2 LAYERS 1/2 in (12.7 mm) THICK TYPE X GYPSUM BOARD			
			DIRECTLY ATTACHED	1-1/2 in (38 mm) WOOD FURRING @ 24 in (600 mm)	AS HUNG CEILING ON METAL GRILLAGE 6 in (150 mm) BELOW CLT SURFACE	DIRECTLY ATTACHED TO CLT AND ADDITIONAL ACOUSTIC HUNG CEILING WITH 5/8 in (15.9 mm) THICK TYPE X ON METAL GRILLAGE 6 in (150 mm) UNDERNEATH
BARE		41 (25)	42 (25)	50 (36)	68 (56)	67 (55)
FLOOR TOPPINGS	1-1/2 in (38 mm) CONCRETE TOPPING ON 3/8 in (9.5 mm) CLOSED CELL FOAM	53 (36)	**53 (40)**	**59 (50)**	**76 (66)**	**74 (64)**
	1-1/2 in (38 mm) CONCRETE TOPPING ON 1/2 in (12.7 mm) WOOD FIBER BOARD	52 (35)	**53 (38)**	**59 (47)**	**76 (64)**	**73 (63)**
	1-1/2 in (38 mm) CONCRETE TOPPING ON 3/4 in (19 mm) RECYCLED FIBER FELT	59 (42)	**59 (46)**	**63 (45)**	**77 (61)**	**75 (60)**
	1-1/2 in (38 mm) CONCRETE TOPPING ON 1/2 in (12.7 mm) RUBBER NUGGETS ON FOIL	53 (46)	**53 (44)**	**59 (49)**	**73 (65)**	**70 (63)**
	1-1/2 in (38 mm) CONCRETE TOPPING ON 5/16 in (8 mm) SHREDDED RUBBER MAT	52 (38)	**52 (38)**	**58 (48)**	**76 (66)**	**74 (64)**
	1-1/2 in (38 mm) CONCRETE TOPPING ON 2/3 in (17 mm) SHREDDED RUBBER MAT	54 (44)	**54 (43)**	**60 (51)**	**76 (67)**	**73 (65)**
	1-1/2 in (38 mm) CONCRETE TOPPING NOT BONDED TO CLT	49 (28)	**49 (32)**	**56 (41)**	**75 (60)**	**74 (60)**
	2 LAYERS 1/2 in (12 mm) CEMENT BOARD ON 1/2 in (12.7 mm) WOOD FIBER BOARD	48 (46)	**48 (38)**	**54 (47)**	69 (63)	**68 (60)**
	1-1/2 in (38 mm) GYPSUM CONCRETE ON 3/8 in (9.5 mm) CLOSED CELL FOAM	50 (41)	**50 (41)**	**58 (49)**	72 (63)	**73 (63)**

Notes:

1. For all hung gypsum board ceilings: Cavity between furring and above hung ceiling filled with glass fiber batts (thickness 38 mm for furring and 5-1/2 in (140 mm) for hung ceiling).
2. White cells are measured STC ratings.
3. Blue cells are the predicted STC ratings from measured TL of bare element and measured TL improvement due to adding extra layers.

Source:

Acoustics: Sound insulation in mid-rise wood buildings (Report to Research Consortium for wood and wood-hybrid mid-rise buildings); Schoenwald, S.; Zeitler, B.; King, F.; Sabourin, I.

UBC Earth Sciences, Vancouver, BC, Canada

Structurlam Manufacturing Facility, Okanagan Falls, BC, Canada

Structurlam Project Execution

Our team of design and manufacturing specialists at Structurlam take pride in all their projects from preliminary consultation and design through to the manufacturing, shipment and installation of our products. We understand the many challenges of design and construction and make it our primary goal to ensure that all processes run as smoothly as possible.

DESIGN DEVELOPMENT AND SERVICE OPTIONS

Structurlam offers design and fabrication services at a variety of levels in order to ensure that our customers' needs and preferences are met to the highest standard. If engineering services are required, Structurlam can provide specialty structural engineering services through well-respected, award-winning engineering firms. If such services are not required, based on decades of experience and expertise as a high-quality engineered wood product manufacturer, Structurlam is able to provide input on manufacturing optimization to improve constructability.

DETAILING

As part of the Structurlam advantage, 3D modeling software is used to virtually construct each building before it is produced. This allows for the early detection of potential challenges and problems by our qualified detailers, effectively helping to ensure that installation on-site runs smoothly.

We begin by receiving 2D architectural and structural drawings or 3D models. From there, an accurate 3D model is made including all GlulamPLUS®, CrossLam® CLT, steel connections and associated hardware. Using these models, shop drawings for CrossLam® CLT panels, GlulamPLUS® and steel connectors are generated. Digital files are then sent to our CNC machines for fabrication. Finally, our 3D model is used to develop material lists for efficient purchasing of steel and hardware components.

SCHEDULE PROCESS:	
1	3D Geometry Modelling
2	[Optional] 2D Geometry Approval drawings
3.A	Issued for Fabrication (IFF) Steel model required (client to provide)
3.B	3D Connection modeling
3.C	Issued for Fabrication (IFF) MEP model required for penetrations (client to provide)
4	Offered for Approval (OFA) 2D Assembly drawings - Client Review
5	3D Fabrication model completion
6	Issued for Fabrication (IFF/IFC) 2D Assembly drawings
7	IFF/IFC Production Lists and metadata
8	IFF/IFC Single Piece Shop Quality Assurance Drawings
9	CLT panel Truck Load plans
10	CNC Coding
11	Fabrication processes

FABRICATION

Structurlam's products are fabricated using cutting-edge 3D modeling software. Data is transferred directly to our CNC machines allowing precise fabrication processes to proceed.

Structurlam Project Execution

DELIVERY, LOAD PLANNING AND HANDLING

An important consideration to make when designing your mass timber building is the transportation and delivery method of the prefabricated elements. Structurlam's family of mass timber products are typically shipped to site on flat deck semitrucks.

LOAD PLANNING

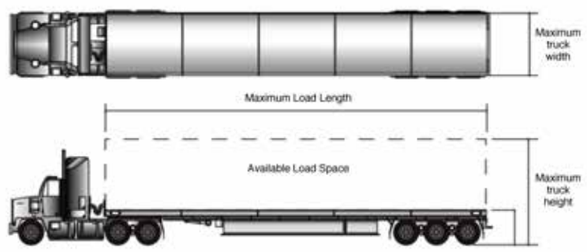
Typically, the panels and members will require sorting and staging on-site as the exact load order will not usually follow the exact installation order. If requested at the time of sale, Structurlam will create load-sequencing plans as determined through the shop drawing approval process, with the sequence typically following the installation order. In order to safely transport the load, some panels may be out of sequence. Using our detailed 3D modeling software, truck loading diagrams are created to optimize freight and shipment to site. Considerations that are important during this stage include:

- Vehicle width and length
- Vehicle weight
- Allowable load that can be transported on route to site
- Installation sequence (this must be requested during the shop drawing process)

Vehicle weight and dimensions must conform to jurisdictional limitations along the route of travel to site and therefore must be considered during the load planning stage.

HANDLING/FREIGHT PROTECTION

When not properly handled and protected, panels and members are subject to surface marring and damage, water staining, sun damage and checking. As a result, Structurlam takes every reasonable precaution to protect our products during shipment by individually wrapping panels in 100 percent recyclable materials. The panels are strapped together in bundles of two to three pieces stacked on top of each other. These bundles are separated by dunnage and panel protection on the truck for safe unloading using a forklift or crane. Please refer to the guidelines provided in our CrossLam® CLT Storage and Handling Guide available on our website or through our office for more information.



3D truck loading diagram

Installation

ON-SITE STORAGE

Detailed pre-construction planning can help to ensure installation of Structurlam products is easy, safe and efficient. Depending on the project site, we recommend that sufficient space be available to:

- Prepare panels for installation
- Re-sort panels according to the install sequence
- Apply treatments if required
- Install on-site hardware if required

LIMITED STORAGE

If on-site storage space is limited to re-sort panels, Structurlam must be notified during the shop drawing process to provide truckload sequencing services. In this case, CrossLam® CLT panels are sequenced on trucks such that they can be directly lifted into place off the truck in the shortest amount of time. It is important to ensure that suitable lifting equipment is available on-site. In order to safely transport the load, some panels may be out of sequence.

ASSEMBLY DRAWINGS

Load plan assembly drawings are produced using our 3D modeling software to provide instruction for fast and efficient erection on-site.

REFERENCES

CLT Handbook - Chapter 8, Canada, 2014.

CLT Handbook - Chapter 9, U.S., 2013.

Structurlam has seen exceptional growth in mass timber construction in recent years and expects these changes to continue as part of a construction paradigm shift. Mass timber in North America has slowly shifted from high-end, boutique, award-winning prefabricated structures to schedule-, cost- and quality-driven rectilinear office and residential structures.

Using wood as a renewable, structural material paired with advanced Industry 4.0 manufacturing systems, we see these prefabricated and fully coordinated structures create beautiful spaces that not only reflect the natural environment but also compete on costs and excel on schedules. Structurlam's Mass Timber systems with CrossLam® CLT and GlulamPLUS® will expand as market disrupters, representing a renewed frontier for construction.

Our service and product experience is ever-evolving to be the best in the industry. How can we help build your next project?

STRUCTURLAM
MASS TIMBER CORPORATION

Intelligence In Wood

Blue Mountain Golf Clubhouse, Hunest, South Korea

Structurlam's family of Mass Timber building products.

CrossLam® CLT: Cross-laminated timber panels used in floor, wall and roof structures

GlulamPLUS®: Structural EWP beam and column system

Steel Connections

3D BIM Models

Contact us to learn more.

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03/2019