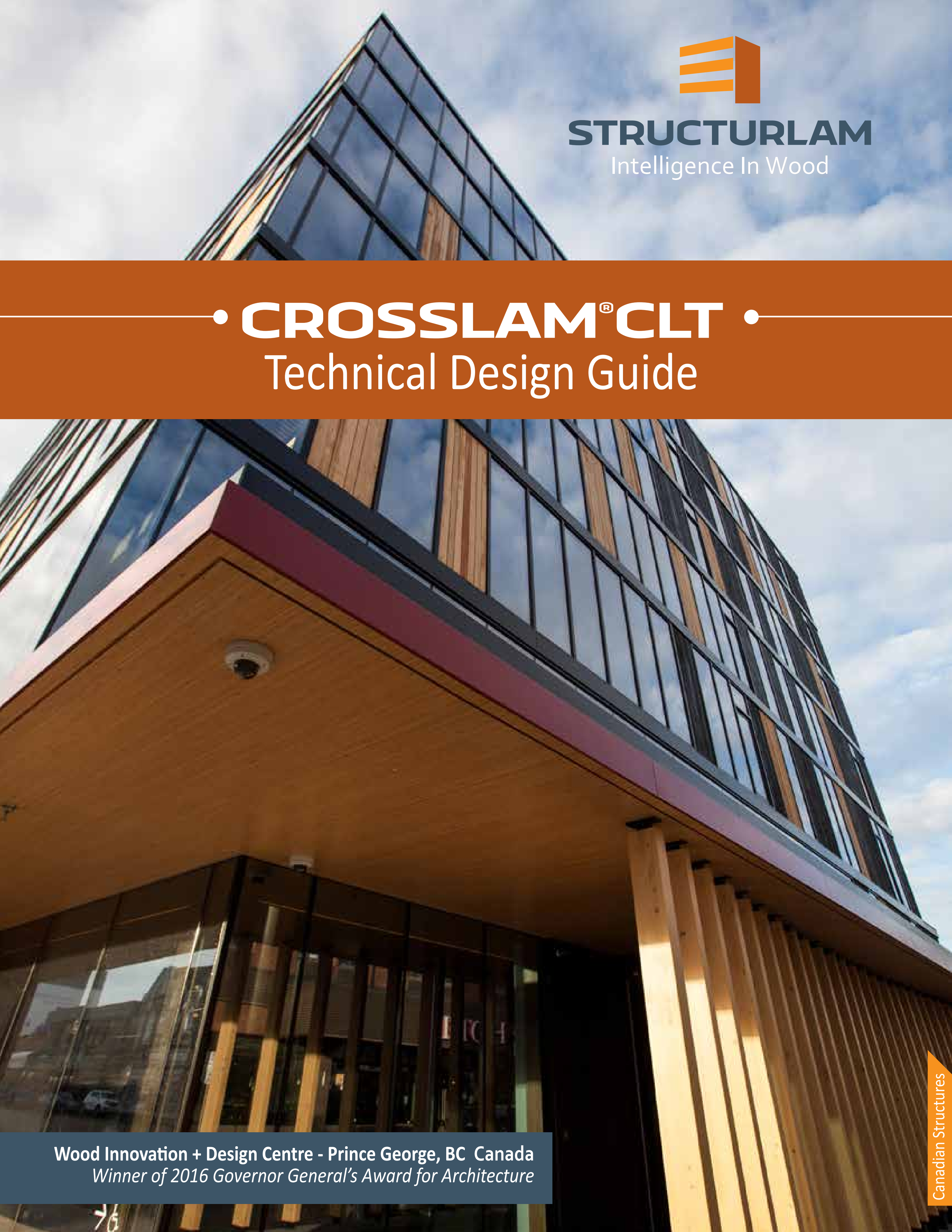


STRUCTURLAM
Intelligence In Wood

CROSSLAM® CLT
Technical Design Guide

Wood Innovation + Design Centre - Prince George, BC Canada
Winner of 2016 Governor General's Award for Architecture

Canadian Structures

Shoreline Medical Center - Seattle WA

Introduction - CrossLam® CLT

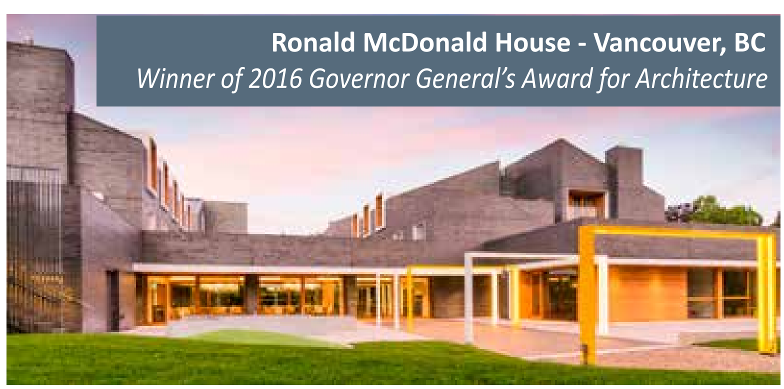
Structurlam Products LP was founded in 1962. In that year, the earth's population was less than half of what it is today. Sustainability was an unknown concept and wood construction had been replaced by concrete and steel everywhere except single family homes. The team at Structurlam had a different idea. 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 modelling 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.

Fast forward to 2011. The population of the world reached seven billion and sustainability was now universally understood. Wood use in construction was increasing as the realization that wood, as the only renewable construction material, was taking hold. It was in this environment that Structurlam opened the first cross laminated timber (CLT) plant in North America and introduced our product CrossLam® CLT to the market. Commercial construction was changed forever.

CrossLam® CLT, as we call our proprietary CLT panel, is a revolutionary product. It can be used for floors, walls and roofs. CrossLam® CLT is a direct replacement for concrete but is significantly lighter. It spans two directions with precision accuracy, is carbon negative and uses wood from only sustainably managed forests. CrossLam® CLT opens the door to a new, ecological way to construct the buildings of the twenty-first century.

The technical information in this guide supports efficient and affordable design when specifying CrossLam® CLT. A truly efficient structure is conceived of and designed with CLT panels from the start. 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.

Bill Downing
President, Structurlam Products LP



Ronald McDonald House - Vancouver, BC
Winner of 2016 Governor General's Award for Architecture

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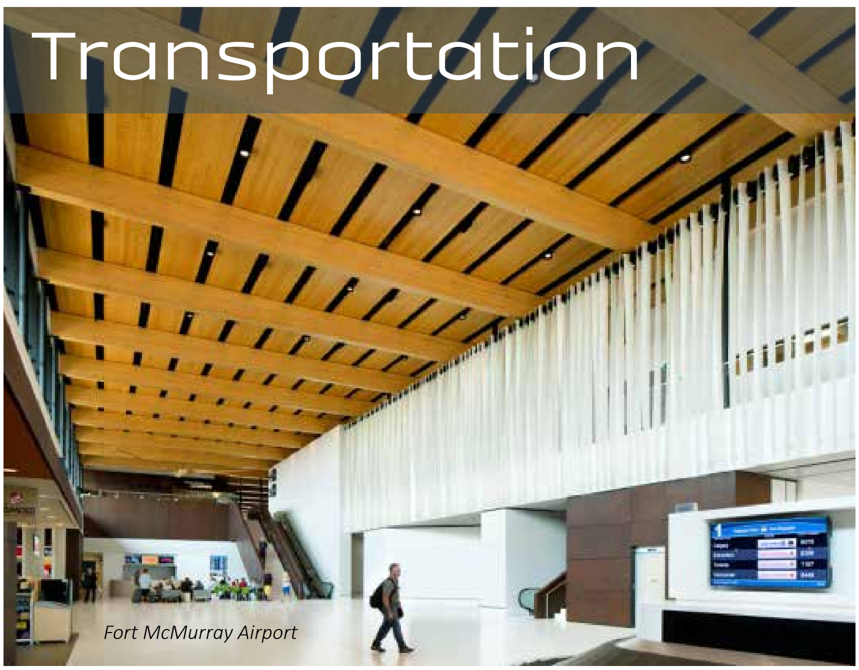
Brock Commons - University of British Columbia, Canada
2016 - The World's Tallest Wood Building

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 production machining. One of the biggest benefits with a mass timber building as compared to other types of structures is the ability to prefabricate the entire project. 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 modelling 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; glulam, CrossLam® CLT, steel connections, and associated hardware. By building the project virtually first, potential problems can be found by our highly trained detailers. This stage often takes three times longer than the actual time to produce the components and the construction team needs to be aware of this up front. By doing the hard work in the model first, the site runs smoothly.

Once the design work is complete, the model is used to create manufacturing lists for CrossLam® CLT and glulam. Shop drawings for panels and steel connectors are generated from the 3D model, and digital files are sent to our



Fort McMurray Airport

Ronald McDonald House

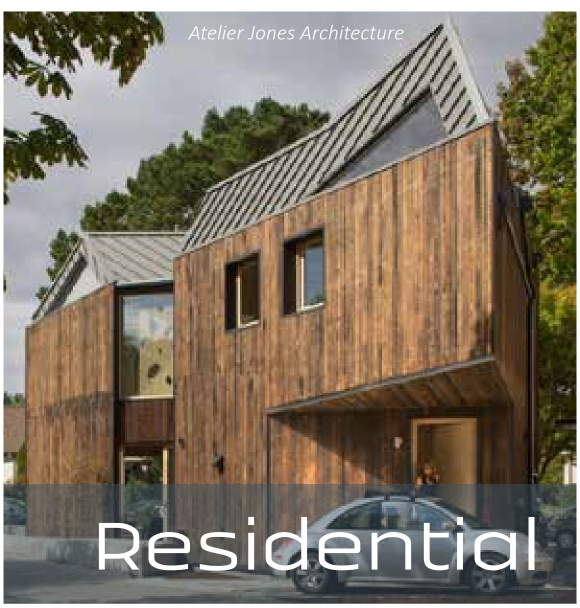
CNC machines for fabrication. Finally, our 3D model is used to develop a material list for efficient purchasing of steel and hardware components. Loading diagrams are then created to optimize freight and assembly drawings are produced to provide instruction for quick and efficient erection.

Design teams who leverage our fabrication services get 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 in CrossLam® CLT. While this is possible, it is always better to design with the structural system of choice. With CrossLam® CLT, optimum sizes are 2.4 m x 12.19 m and 3 m x 12.19 m. 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.

Earth Sciences Building, UBC

Faction Projects Building



Atelier Jones Architecture

BC Passive House Manufacturing Facility
Winner of 2016 Governor General's Award for Architecture

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

Achieving building efficiencies can be greatly enhanced if the project is designed from the beginning with standard CrossLam® CLT panel sizes such as 2.4 m or 3 m by 12.19 m. This maximizes the utilization of CrossLam® CLT to produce cost effective structures.

Structural Strength + 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 from design to erection are cost-effective alternatives to traditional steel and concrete. A well designed Crosslam® CLT system can be less expensive than steel and concrete. It can also be competitive with standard light wood framing systems in specific applications. By using a Crosslam® CLT system a compressed construction schedule is realized and overall project costs are further reduced.

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.

Strengths of the CrossLam® CLT System

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 fibre used in CrossLam® CLT is traceable from certified forests to the consumer. FSC Chain of Custody Certification is available from Structurlam should your project have this requirement.

Code Acceptance

In Canada, CLT is now part of the *Supplement to the National Building Code of Canada (NBC)*. The CSA-O86 Technical Committee has approved the adoption of CLT in the 2016 Supplement to the CSA-O86. This supplement will form a part of the 2014 edition of the CSA-O86 that is referenced by the 2015 edition of the NBC. The adopted package includes: 1) CLT as a structural member; 2) CLT connections; and 3) CLT as a lateral-load resisting system. For code acceptance, all CLT products must be manufactured to the standards of ANSI/APA PRG 320-2012.

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-L314C. These standards outline the requirements and test methods for qualification and quality assurance for CLT and are the same across North America.

Design Development + 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 saving and structural advantages of CrossLam® CLT construction. We offer design and fabrication services at a variety of levels.

DESIGN SUPPLY

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

MANUFACTURING DESIGN ASSIST

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

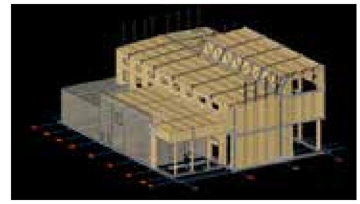
TRADITIONAL BID

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

FABRICATION

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

CrossLam® CLT Fabrication



Structurlam's CrossLam® CLT is fabricated using the latest 3D modelling software. Data is transferred directly to our CNC machines - the most sophisticated milling machinery in North America, allowing us to achieve very tight tolerances.

CrossLam® CLT projects begin with your drawings from which we develop a 3D model that is used to design panels and connectors. Our model also allows our experts to identify design optimizations to help you save money. 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, and assembly drawings for quick and efficient erection.

CrossLam® CLT Delivery, Storage + Handling

Structurlam has taken every reasonable precaution to protect your CrossLam® CLT panels during shipment to the project site. However, when not properly handled and protected, panels are subject to surface marring and damage, water staining, sun damage, and checking. We recommend you follow the guidelines outlined in our CrossLam® CLT Storage and Handling Guide available on our website or through our office.

CrossLam® CLT Installation

Detailed preconstruction planning can help to ensure installation of CrossLam® CLT is easy and efficient. We recommend you ensure there is sufficient space available to:

- Prepare panels for installation;
- Apply treatments if required;
- Add on-site hardware if required; and
- Re-sort panels according to the install sequence.

Shoreline Medical Center

CrossLam® CLT panels can be shipped with lifting hardware installed and ready for quick installation. Please contact our office to learn more about this option. All rigging and hoisting of panels should be done in a safe manner and the lifting device should have the capacity to unload panels from the truck and place them in the desired location.

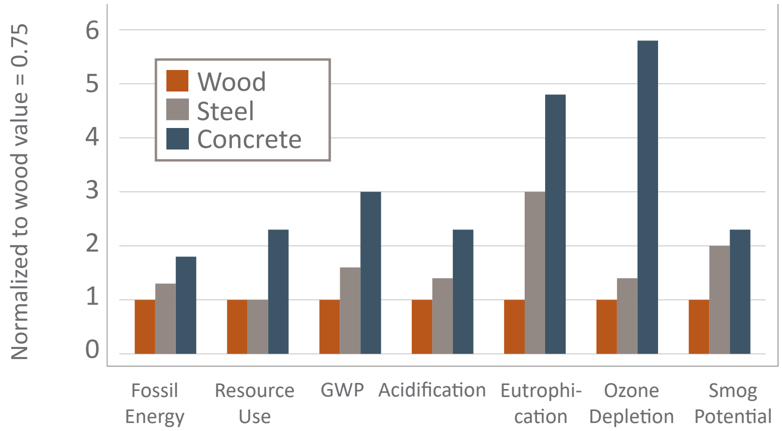
CrossLam® CLT vs. Concrete

Mass timber systems are significantly lighter than concrete both on the planet and on your project. CrossLam® CLT is up to five times lighter than concrete and has an installation time that can be up to 3 times faster than cast-in-place concrete, with many erectors installing up to 1,400 square metres per day. CrossLam® CLT is cost comparative to concrete and allows for construction in areas with poor soil conditions. As more CLT is designed into the building, the overall weight of the building drops and lower building costs are achieved.

CrossLam® CLT stores CO_2 as a carbon sink. Life Cycle Assessments (or LCA) of building materials show the carbon footprint of wood is lower than steel or concrete when compared with seven key environmental measures (see chart "Comparing Environmental Impact of a Wood, Steel and Concrete Home").

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/why-wood/wood-responsible-choice/life-cycle-assessment.

Comparing Environmental Impact of a Wood, Steel and Concrete Home



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

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

Floor Vibration Control Comparison

Floor performance can be subjective depending on the application and the expectations of the user. As such, floor vibration should be designed accordingly. The research in this area is ongoing; however the preferred design method to controlling vibrations in CLT floors is based on CSA 086-14, Clause 8, Appendix Section. 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 (mm)	Concrete Slab (mm)	Vibration Controlled Span (m)
87 V	87	135	3.2
105 V	105	150	3.7
139 V	139	190	4.5
175 V	175	215	5.1
191 V	191	235	5.6
243 V	243	260	6.4
245 V	245	275	6.6
315 V	315	315	7.6

2.4 kPa live load plus self weight plus 1.0 kPa miscellaneous deadload

Indicates CrossLam® CLT thickness advantage

CrossLam® CLT Applications

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 37 square metres (400 ft^2) per lift.


Faction Projects Building

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 87 mm and as thick as 315 mm resulting in a maximum possible roof span of 12.19 m with appropriate loading. CrossLam® CLT roofs are quickly installed allowing projects to approach lockup and a water tight state in a short amount of time.


Tall Tree Integrated Health

Walls

CrossLam® CLT wall panels are cost-competitive alternatives to pre-cast concrete systems. They are lighter than pre-cast 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.


BC Passive House

Shear Walls + Diaphragms

CrossLam® CLT panels offer a solution for building designs with lateral loads such as those generated by wind or earthquakes. Shear transfer between adjacent panels is achieved through a variety of metal connector systems and plywood splines that are attached with screws or nails.

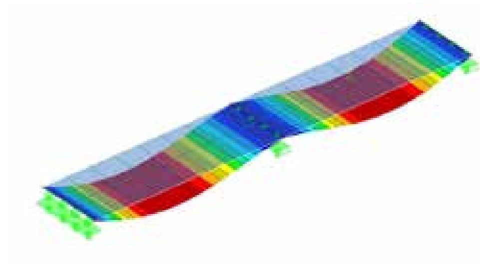
Cores + Shafts

CrossLam® CLT panel cores and shafts erect quicker and easier than comparable steel and concrete designs while still providing lateral bracing. CLT can be used as structural bearing or shearwalls and can have 2-hour fire rated elevator and stair shafts.

CrossLam® CLT Design Considerations

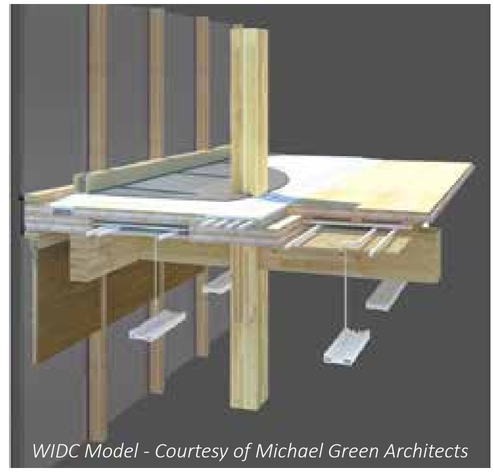
Deflection

Elastic deflection and permanent deformation for CrossLam® CLT slab elements should not exceed the total load deflection limit as specified in CSA 086-14, Clause 8, Appendix Section. Deflections and long term creep factors are taken into account for Canadian design standards.



Service Integration

Building penetrations for mechanical, electrical, and plumbing services (MEP) 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.



WIDC Model - Courtesy of Michael Green Architects

Material Optimization

By involving Structurlam in the early stages of your project, you can be sure that you are getting the most out of every CrossLam® CLT panel. For the best utilization of materials, we suggest designing in full billet sizes, 3 m x 12.190 m. Incorporating standard panel sizes into your design will most certainly reduce your product waste.

Atelier Jones Architecture

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 preferred design method proposed to controlling vibrations in CLT floors is based on CSA 086-14, Clause 8, Appendix Section which explicitly details simple span applications.

Acoustic Performance

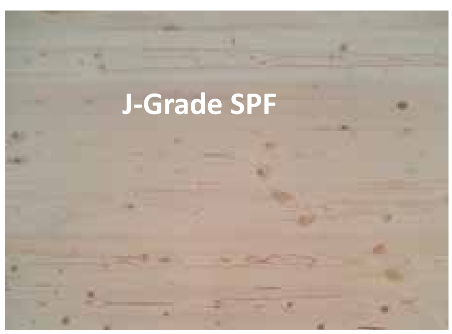
CLT walls and floors contribute to the overall sound isolation characteristics of the completed building. Sound transmission is affected by the components in wall and floor assemblies. Airtight construction and specifically engineered connections can help reduce sound transmission by mitigating flanking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

Elkford Community Conference Centre

CrossLam® CLT Panel Characteristics

Maximum Panel Size:	3 m x 12.19 m
Maximum Thickness:	315 mm
Minimum Thickness:	87 mm
Production Widths:	2.4 m & 3 m
Moisture Content:	12% (+/-3%) at time of production
Glue Specifications:	Purbond polyurethane adhesive
Glue Type:	Weatherproof, formaldehyde free foaming PUR
Species:	SPF, Douglas-fir
Lumber Grades:	SPF #2& Btr, SPF #3, Dfir L3, MSR 2100
Stress Grades:	V2M1, V2M1.1, V2.1, E1M3, E1M4, E1M5
Manufacturing Certification:	APA PRG 320 Product Report PR-L314c
Density:	± 485 kg/m^3 (SPF)
Dimensional Stability:	Longitudinal and Transverse 0.01% per % Δ in MC Thickness 0.2% per % Δ in MC
Smoke Development Classification:	30
Flame Spread Rating:	40
Specific Heat Capacity:	1.6 kJ/kg K dependent on moisture content
Thermal Conductivity:	RSI Value: 0.84 per 100 mm (K·m2/W)
	R Value: 1.2 per inch (h·ft2·°F /Btu)
CO_2 Sequestration:	220 kg/m^3
Dimensional Tolerances:	
Thickness:	2 mm or 2% of CLT thickness, whichever is greater
Width:	3 mm of the CLT width
Length:	6 mm of the CLT length
Squareness:	Panel face diagonals shall not differ by more than 3 mm
Straightness:	Deviation of edges from a straight line between adjacent panel corners shall not exceed 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	SPF, "J" Grade (Japanese Grade), Douglas-fir (L3 Grade)	SPF #2& Btr, MSR 2100
Sanded Face	80 grit	N/A
	Allowable Fibre Characteristics	
Shake and Checks	Several up to 61 cm long, none through	As per NLGA #2, SPF #2& Btr
Stain	Up to a max of 5% blue stain, heart stain allowed	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		
		

Introducing The New CrossLam® CLT Series

The V Series: Composed exclusively from #2& Btr visually graded 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.

CrossLam® CLT Name Convention

Panel Series | Panel Finish | Name | Position#

191 VJ-1 RP 16

Panel Thickness in mm

Grade Indicator
V = V series: V2M1, V2M1.1, V2.1
E = E series: E1M4, E1M5

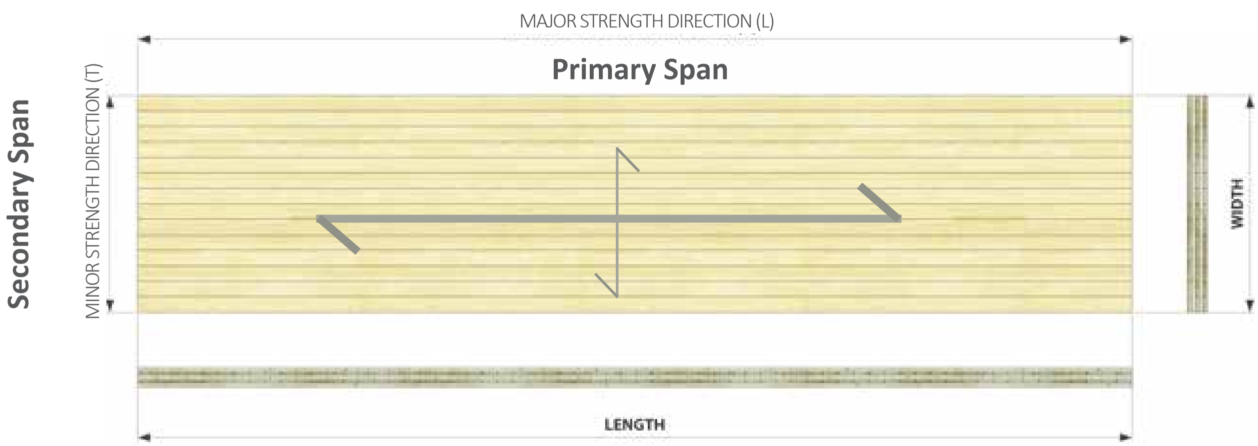
J-1 : One Side SPF J Grade, Visual Grade
D-1 : One Side Dfir Lumber, Visual Grade

J-2 : Two Sides SPF J Grade, Visual Grade
D-2 : Two Sides Dfir Lumber, Visual Grade
No Label: Non Visual Industrial Panel

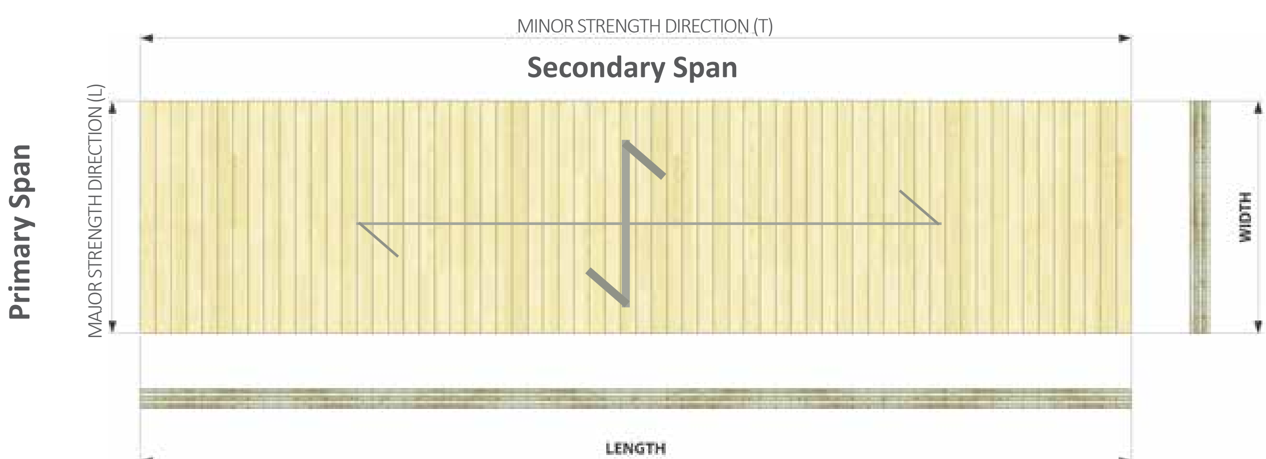
CrossLam® CLT Name Designations:

EC - Elevator Core
FP - Floor Panel
RP - Roof 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 (mm)									Panel Depth (mm)
					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	35	17	35							87
139 V					35	17	35	17	35					139
191 V					35	17	35	17	35	17	35			191
243 V					35	17	35	17	35	17	35	17	35	243
105 V	V2M1.1			SPF #2& Btr	35	35	35							105
175 V					35	35	35	35	35					175
245 V					35	35	35	35	35	35	35			245
315 V					35	35	35	35	35	35	35	35	35	315
87 E	E1M4	MSR 2100 1.8E SPF	MSR 2100 1.8E SPF	SPF #3& Btr	35	17	35							87
139 E					35	17	35	17	35					139
191 E					35	17	35	17	35	17	35			191
243 E					35	17	35	17	35	17	35	17	35	243
105 E	E1M5			SPF #2& Btr	35	35	35							105
175 E					35	35	35	35	35					175
245 E					35	35	35	35	35	35	35			245
315 E					35	35	35	35	35	35	35	35	35	315

L = Longitudinal Layer (Major Layer)
T = Tangential Layer (Minor Layer)

Spandral panels cannot be produced in any layups with 17 mm thick lamellas.


Ronald McDonald House

Structural Panel Properties

Table 2 - CrossLam® CLT Limit States Design (LSD) Bending Resistances [(1)]

CLT Series	CLT Grade	Weight lbs/ft²	Weight kg/m²	Major Strength Direction					Minor Strength Direction				
				$F_bS_{eff,0}$ (10^6 N-mm/m)	$EI_{eff,0}$ (10^9 N-mm²/m)	$GA_{eff,0}$ (10^6 N/m)	$M_{r,0}$ (kNm/m)	$V_{r,0}$ (kN/m)	$F_bS_{eff,90}$ (10^6 N-mm/m)	$EI_{eff,90}$ (10^9 N-mm²/m)	$GA_{eff,90}$ (10^6 N/m)	$M_{r,90}$ (kNm/m)	$V_{r,90}$ (kN/m)
105 V	V2M1.1	9.0	43.9	20.9	883	7.5	16.0	31.5	2.4	34	7.5	1.8	10.5
175 V		15.0	73.2	48.1	3390	15.0	36.8	52.5	20.9	883	15.0	16.0	31.5
245 V		21.0	102.4	85.1	8395	22.5	65.1	73.5	48.1	3390	22.5	36.8	52.5
315 V		27.0	131.7	132.0	16741	30.0	101.0	94.5	85.1	8395	30.0	65.1	73.5
87 V	V2.1	7.5	36.4	14.8	517	7.5	11.3	26.1	0.4	4	4.6	0.3	5.1
139 V		11.9	58.1	34.1	1907	14.9	26.1	41.7	4.8	215	8.7	3.7	20.7
191 V		16.3	79.8	60.6	4659	22.3	46.4	57.3	11.0	855	13.0	8.4	36.3
243 V		20.8	101.6	94.4	9230	29.8	72.2	72.9	19.3	2147	17.3	14.8	51.9
105 E	E1M5	9.7	47.5	53.8	1153	7.7	41.2	31.5	2.4	34	9.6	1.8	10.5
175 E		16.1	78.6	123.7	4416	15.3	94.7	52.5	20.9	884	19.2	16.0	31.5
245 E		22.5	109.7	218.6	10923	23.0	167.2	73.5	48.2	3398	28.9	36.9	52.5
315 E		28.8	140.8	338.8	21766	30.7	259.2	94.5	85.4	8427	38.5	65.4	73.5
87 E	E1M4	8.2	40.0	38.0	675	7.8	29.1	26.1	0.3	4	5.6	0.3	5.1
139 E		13.0	63.6	87.7	2487	15.5	67.1	41.7	4.8	215	11.3	3.7	20.7
191 E		17.8	87.1	155.9	6073	23.2	119.3	57.3	11.1	860	16.9	8.5	36.3
243 E		22.7	110.7	242.7	12026	31.0	185.6	72.9	19.5	2165	22.3	14.9	51.9

Table 3 - CrossLam® CLT Specified Strengths + Modulus of Elasticity [(1)]

CLT Grade	Major Strength Direction						Minor Strength Direction					
	$f_{b,0}$ (MPa)	E_0 (MPa)	$f_{t,0}$ (MPa)	$f_{c,0}$ (MPa)	$f_{cp,0}$ (MPa)	$f_{s,0}$ (MPa)	$f_{b,90}$ (MPa)	E_{90} (MPa)	$f_{t,90}$ (MPa)	$f_{c,90}$ (MPa)	$f_{cp,90}$ (MPa)	$f_{s,90}$ (MPa)
V2M1.1	11.8	9500	5.5	11.5	5.3	0.5	11.8	9500	5.5	11.5	5.3	0.5
V2.1	11.8	9500	5.5	11.5	5.3	0.5	7	9000	3.2	9	5.3	0.5
E1M5	30.4	12400	17.7	19.9	6.5	0.5	11.8	9500	5.5	11.5	5.3	0.5
E1M4	30.4	12400	17.7	19.9	6.5	0.5	7	9000	3.2	9	5.3	0.5

Notes:

1. Tabulated values are Limit States Design values and not permitted to be increased for the lumber size adjustment factor in accordance to CSA O86-14.
2. The CLT grades are developed based on CSA 086-14 and ANSI/APA PRG 320. 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 of the CLT panel (see tables above).
4. Values are calculated per 1 metre wide section of panel.

Table 4 - CrossLam® CLT Roof Panel Load Table, maximum span (mm)

	CrossLam® CLT Series	ROOF SNOW LOAD (kPa)					
		1.1	1.6	2.2	2.9	3.3	8.5
SINGLE SPAN	87 V	4250	4000	3800	3600	3500	2550[a]
	87 E	4600	4350	4100	3900	3800	3000
	105 V	4950	4700	4450	4250	4100	3000[a]
	105 E	5350	5100	4850	4650	4550	3550
	139 V	6250	6000	5700	5450	5300	3800[a]
	139 E	6750	6450	6150	5900	5750	4600
	175 V	7350	7050	6700	6450	6300	4500[a]
	175 E	7900	7600	7250	6950	6800	5450
	191 V	8100	7750	7450	7100	7000	5050[a]
	191 E	8700	8350	8000	7700	7550	6100
	245 V	9400	9100	8750	8400	8250	5900[a]
	245 E	10150	9800	9450	9050	8900	7300
	243 V	9800	9450	9100	8700	8550	6250[a]
	243 E	10500	10150	9750	9400	9250	7550
	315 V	11350	11000	10600	10200	10100	7300[a]
	315 E	12150	11850	11450	11050	10850	9000
DOUBLE SPAN	87 V	5650	5050[a]	4500[a]	4050[a]	3850[a]	2550[a]
	87 E		5800	5500	5200	5100	3000[b]
	105 V		5900[a]	5300[a]	4700[a]	4500[a]	3000[a]
	105 E					6000	3600[b]
	139 V				6000[a]	5750[a]	3800[a]
	139 E						4700[b]
	175 V						4500[a]
	175 E						5800[b]
	191 V						5050[a]
	191 E	Double span is governed by maximum panel length of 12.19 m --> use max value of 6,095 or design as simple span using table values above.					
	245 V						5900[a]
	245 E						
	243 V						
	243 E						
	315 V						
	315 E						

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

Notes:

1. For structural panel properties - see page 18. Span table assumes dry service conditions.
2. The following factors were used for calculations: KD = 1.0; KS = 1.0; KT = 1.0; KH = 1.0.
3. Snow load is based on BCBC 2012 with the following factors: IS = 1.0 for ULS; IS = 0.9 for SLS; CW = 1.0; CS = 1.0; Ca = 1.0.
4. Spans shown represent distance between the centerlines of supports and are to be used for preliminary design only.
5. Span table above includes panel self weight plus 0.5 kPa miscellaneous dead load.
6. Engineer to ensure that L/180 deflection limit is appropriate for intended use.
7. Ponding or ceiling finishes may require higher deflection limits.
8. Spans are assumed to be equal for double span panels.
9. Total panel length is limited to 12.19 m due to fabrication process.
10. CLT is NOT an isotropic material. Therefore the presented values must only be used for bending of panels in the longitudinal (major) axis.
11. For applications with deflection limits or loading different than what is indicated above, contact your Structurlam technical representative.

Table 5 - CrossLam® CLT Floor Panel Load Table, maximum span (mm)

CrossLam® CLT Series		FLOOR LIVE LOAD (kPa)									
		1.9 RESIDENTIAL		2.4 OFFICE / CLASSROOM		3.6 MECHANICAL ROOM		4.8 ASSEMBLY/ STORAGE		7.2 LIBRARY	
		Vibration	L/180	Vibration	L/180	Vibration	L/180	Vibration	L/180	Vibration	L/180
SINGLE SPAN	87 V	**3250**	3550	**3250**	3400	3250	**3150**	3250	**2950**	3250	**2650**[a]
	87 E	**3460**	3850	**3460**	3700	3460	**3450**	3460	**3250**	3460	**2950**
	105 V	**3700**	4150	**3700**	4000	**3700**	3750	3700	**3500**	3700	**3150**[a]
	105 E	**3960**	4500	**3960**	4350	**3960**	4050	3960	**3800**	3960	**3450**
	139 V	**4480**	5350	**4480**	5150	**4480**	4800	**4480**	4550	4480	**4000**[a]
	139 E	**4780**	5750	**4780**	5600	**4780**	5250	**4780**	4950	4780	**4500**
	175 V	**5150**	6300	**5150**	6100	**5150**	5750	**5150**	5400	5150	**4750**[a]
	175 E	**5500**	6850	**5500**	6600	**5500**	6200	**5500**	5900	5500	**5360**
	191 V	**5600**	7000	**5600**	6800	**5600**	6350	**5600**	6050	5600	**5300**[a]
	191 E	**5970**	7550	**5970**	7350	**5970**	6900	**5970**	6550	**5970**	6000
	245 V	**6440**	8250	**6440**	8050	**6440**	7550	**6440**	7200	6440	**6250**[a]
	245 E	**6880**	8950	**6880**	8700	**6880**	8200	**6880**	7800	**6880**	7150
	243 V	**6630**	8600	**6630**	8350	**6630**	7850	**6630**	7450	6630	**6550**[a]
	243 E	**7070**	9250	**7070**	9000	**7070**	8500	**7070**	8100	**7070**	7450
	315 V	**7600**	10100	**7600**	9850	**7600**	9300	**7600**	8850	**7600**	7650[a]
	315 E	**8160**	10900	**8160**	10600	**8160**	10050	**8160**	9600	**8160**	8850
DOUBLE SPAN	87 V	**3900**	4450[a]	**3900**	4100[a]	3900	**3550**[a]	3900	**3150**[a]	3900	**2650**[a]
	87 E	**4150**	5100	**4150**	4950	**4150**	4600	**4150**	4300	4150	**3300**[b]
	105 V	**4450**	5200[a]	**4450**	4850[a]	4450	**4200**[a]	4450	**3750**[a]	4450	**3150**[a]
	105 E	**4750**	6000	**4750**	5800	**4750**	5400	**4750**	5050	4750	**3950**[b]
	139 V	**5380**		**5380**		5380	**5300**[a]	5380	**4750**[a]	5380	**4000**[a]
	139 E	**5740**		**5740**		**5740**		**5740**		5740	**5150**[b]
	175 V								**5600**[a]		**4750**[a]
	175 E										
	191 V										**5300**[a]
	191 E										
	245 V										
	245 E										
	243 V										
	243 E										
	315 V										
	315 E										

Double span is governed by maximum panel length of 12.19 m --> Use max value of 6,095 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 18. 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. The following factors were used for calculations: KD = 1.0; KS = 1.0; KT = 1.0; KH = 1.0.
4. Spans shown represent distance between the centerlines of supports and are to be used for preliminary design only.
5. Span table above includes panel self weight, 1.2 kPa for concrete topping (where indicated), plus 1.0 kPa miscellaneous dead load.
6. Engineer to ensure that L/180 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 12.19 m due to fabrication process.
9. Values in **BOLD** correspond to a span governed by allowable bending stress, allowable shear stress or by vibration.

Table 6 - CrossLam® CLT Floor Panel Load Table, with 50 mm concrete topping maximum span (mm)

	CrossLam® CLT Series	FLOOR LIVE LOAD (kPa)									
		1.9 RESIDENTIAL		2.4 OFFICE / CLASSROOM		3.6 MECHANICAL ROOM		4.8 ASSEMBLY/ STORAGE		7.2 LIBRARY	
		Vibration	L/180	Vibration	L/180	Vibration	L/180	Vibration	L/180	Vibration	L/180
SINGLE SPAN	87 V	**2750**	3050	**2750**	2950	**2750**	2800	2750	2700	2750	**2500**
	87 E	**2930**	3300	**2930**	3250	**2930**	3050	**2930**	2950	2930	**2700**
	105 V	**3150**	3600	**3150**	3500	**3150**	3350	**3150**	3200	3150	**2950**
	105 E	**3400**	3900	**3400**	3800	**3400**	3650	**3400**	3450	3400	**3200**
	139 V	**3900**	4650	**3900**	4550	**3900**	4350	**3900**	4150	3900	**3800[a]**
	139 E	**4200**	5050	**4200**	4950	**4200**	4700	**4200**	4500	**4200**	**4200**
	175 V	**5150**	5500	**5150**	5400	**5150**	**5150**	5150	**4950**	5150	**4500[a]**
	175 E	**5500**	6000	**5500**	5900	**5500**	5600	5500	**5350**	5500	**5000**
	191 V	**5600**	6150	**5600**	6050	**5600**	5750	5600	**5500**	5600	**5000[a]**
	191 E	**5970**	6700	**5970**	6550	**5970**	6250	**5970**	6000	5970	**5600**
	245 V	**6440**	7350	**6440**	7200	**6440**	6850	**6440**	6600	6440	**5900[a]**
	245 E	**6880**	7950	**6880**	7800	**6880**	7450	**6880**	7150	6880	**6700**
	243 V	**6630**	7650	**6630**	7450	**6630**	7150	**6630**	6850	6630	**6200[a]**
	243 E	**7070**	8250	**7070**	8100	**7070**	7750	**7070**	7450	7070	**6950**
	315 V	**7600**	9050	**7600**	8850	**7600**	8500	**7600**	8200	7600	**7250[a]**
	315 E	**8160**	9800	**8160**	9600	**8160**	9200	**8160**	8850	**8160**	8300
DOUBLE SPAN	87 V	**3300**	3850[a]	**3300**	3600[a]	**3300**	**3200[a]**	3300	**2900[a]**	3300	**2500[a]**
	87 E	**3510**	4400	**3510**	4300	**3510**	4100	**3510**	3900	3510	**2950[b]**
	105 V	**3800**	4450[a]	**3800**	4250[a]	**3800**	**3800[a]**	3800	**3450[a]**	3800	**3000[a]**
	105 E	**4080**	5200	**4080**	5050	**4080**	4800	**4080**	4600	4080	**3550[b]**
	139 V	**4700**	5750[a]	**4700**	5400[a]	**4700**	4850[a]	4700	**4400[a]**	4700	**3800[a]**
	139 E	**5040**		**5040**		**5040**		**5040**	6000	5040	**4650[a]**
	175 V						**5700[a]**		**5200[a]**		**4750[a]**
	175 E										**5750[a]**
	191 V								**5800[a]**		**5000[a]**
	191 E										
	245 V										**5500[a]**
	245 E										
	243 V										
	243 E										
	315 V										
	315 E										

Double span is governed by maximum panel length of 12.19 m --> Use max value of 6,095 or design as simple span using table values above.

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

Notes:

1. The non-structural concrete flooring is assumed to provide an enhanced vibration effect on the double spans. Values include a 20% increase.
2. CLT is NOT an isotropic material. Presented values must only be used for bending of panels in the major strength axis.
3. For structural panel properties - see page 18. Span table assumes dry service conditions.
4. The following factors were used for calculations: KD = 1.0; KS = 1.0; KT = 1.0; KH = 1.0.
5. Spans shown represent distance between the centerlines of supports and are to be used for preliminary design only.
6. Span table above includes panel self weight, 1.2 kPa for concrete topping (where indicated), plus 1.0 kPa miscellaneous dead load.
7. Engineer to ensure that L/180 deflection limit is appropriate for intended use.
8. Spans are assumed to be equal for double span panels.
9. Total panel length is limited to 12.19 m due to fabrication process.
10. Values in **BOLD** correspond to a span governed by allowable bending stress, allowable shear stress or by vibration.

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

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
L (m)	P_r (kN/m1)															
2.0	394	662	450	767	702	1203	712	1227	949	1636	933	1612	1172	2025	1140	1972
2.5	307	508	388	655	633	1079	670	1150	894	1536	895	1544	1121	1934	1101	1902
3.0	233	381	326	544	561	947	625	1069	836	1431	858	1478	1071	1843	1065	1839
3.5	175	283	268	443	487	816	578	983	775	1319	821	1410	1019	1749	1032	1779
4.0	132	212	218	356	417	692	528	894	711	1203	782	1340	965	1650	998	1718
4.5			176	286	354	582	478	804	646	1086	741	1266	909	1547	964	1656
5.0			142	229	297	486	429	717	581	972	699	1189	850	1441	929	1592
5.5					250	405	382	634	520	863	656	1111	791	1334	892	1525
6.0					209	338	339	558	462	762	612	1032	731	1227	854	1456
6.5					176	283	299	490	409	670	569	954	673	1123	816	1386
7.0							263	429	361	589	526	878	616	1023	776	1314
7.5							231	375	318	516	484	805	562	929	736	1242
8.0							203	329	280	453	445	735	512	842	696	1171
8.5							179	288	247	398	407	671	465	761	657	1100
9.0											372	611	421	688	618	1031

Notes:

1. For structural panel properties - see page 18.
2. Table assumes dry service conditions.
3. $P_r = \phi F_c A_{eff} K_{zc} K_c$. Where the P_r values are not given, the slenderness ration exceeds 43 (maximum permitted by CSA O86-14).
4. The following factors were used for calculations: K_d=0.65; K_s=1.0; K_T=1.0; K_H=1.0; K_e=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
V_r (kN/m1)															
54	54	95	95	108	108	190	190	163	163	285	285	217	217	380	380

Notes:

1. For structural panel properties - see page 18.
2. Table assumes dry service conditions.
3. The following factors were used for calculations: k_{mod} = 0.8; ym = 1.25.
4. Computed values based on "In-Plane Shear Capacity and Verification Methods" by Prof. G. Schickhofer, University of Graz.
5. Specified modulus of Strength: f_v,CLT,k = 5.0 Mpa; f_T,CLT,k = 2.5 Mpa, ref: "BSPhandbuch Holz-Massivbauweise in Brettsperrholz", Technical University of Graz.
6. Minimum width of wood used in layup is 89 mm.
7. Values are for CrossLam® CLT panel only, not for shear connectors.
8. Table values are to be used for preliminary design only.
9. For applications with loading different than what is indicated above, contact your Structurlam technical representative.

Table 9 - CrossLam® CLT Fire Resistance

Structurlam has completed fire testing under ULC S101/E119 for North American CLT. The following chart illustrates the remaining cross sectional depth in the event of a fire. Calculations are based on data from the Fire Performance section of the July 2014 CLT Handbook (Chapter 8-Fire Performance of CLT Assemblies). Structural resistance for a given fire resistance rating will need to be calculated by the EOR in accordance with ULS of the panels and regional codes. For difficult or unique circumstances it is recommended that a fire engineer and building code specialist be used.

		CrossLam® Remaining Sectional Depth (mm)						
CrossLam® CLT Covering	CrossLam® CLT Depth (mm)	Fire Exposure Time (mins)						
		30	45	60	90	120	150	180
Bare	87	63	50	34	9	0	0	0
	105	81	69	56	32	8	0	0
	139	115	102	86	61	32	8	0
	175	151	139	126	102	78	54	29
	191	167	154	138	113	84	60	31
	243	219	206	190	165	136	112	83
	245	221	209	196	172	148	124	99
	315	291	279	266	242	218	194	169
1 Layer Type X Gypsum 15.9 mm	87	87	75	63	34	9	0	0
	105	105	93	81	56	32	8	0
	139	139	127	115	86	61	32	8
	175	175	163	151	126	102	78	54
	191	191	179	167	138	113	84	60
	243	243	231	219	190	165	136	112
	245	245	233	221	196	172	148	124
	315	315	303	291	266	242	218	194
2 Layers Type X Gypsum 15.9 mm	87	87	87	87	63	34	9	0
	105	105	105	105	81	56	32	8
	139	139	139	139	115	86	61	32
	175	175	175	175	151	126	102	78
	191	191	191	191	167	138	113	84
	243	243	243	243	219	190	165	136
	245	245	245	245	221	196	172	148
	315	315	315	315	291	266	242	218

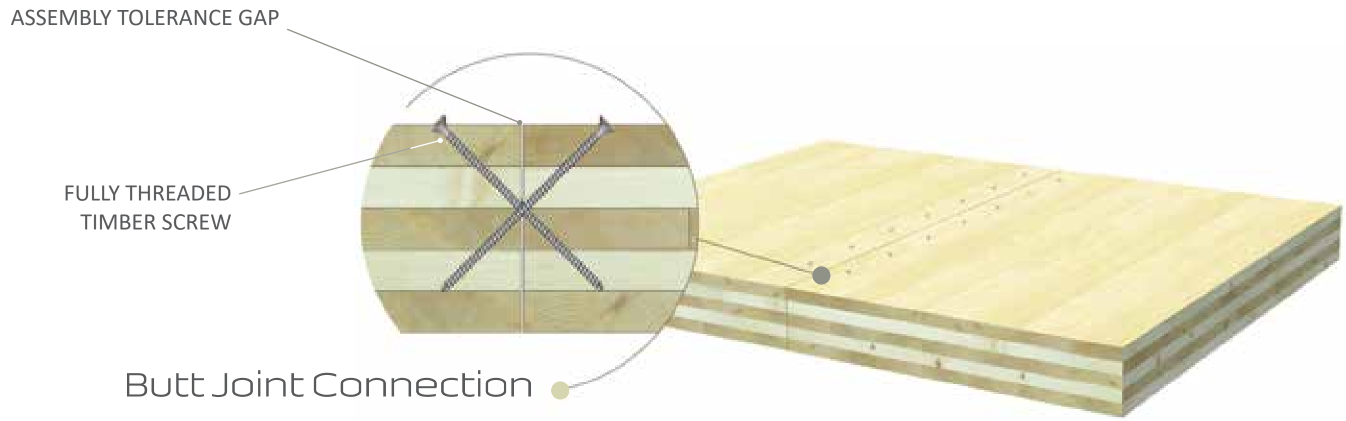
Notes:

1. Specific results for exact panel assemblies and their FRR are available in the report "Preliminary CLT Fire Resistance Testing", L Osborne, C Dagenais, N Benichou, July 2012. FPInnovations, National Research Council of Canada, Advanced Building Systems.
2. The above chart has been calculated using the June 2014 CLT Handbook Fire Design Guide.

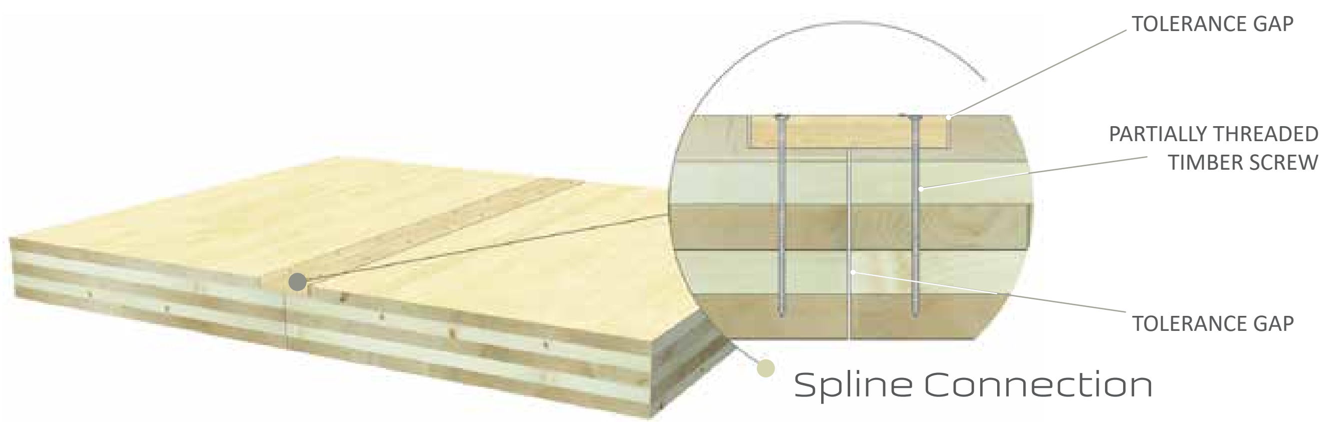
Wesbrook Community Centre - Vancouver BC

CrossLam® CLT Connection Details - Floor to Roof Panel Joints

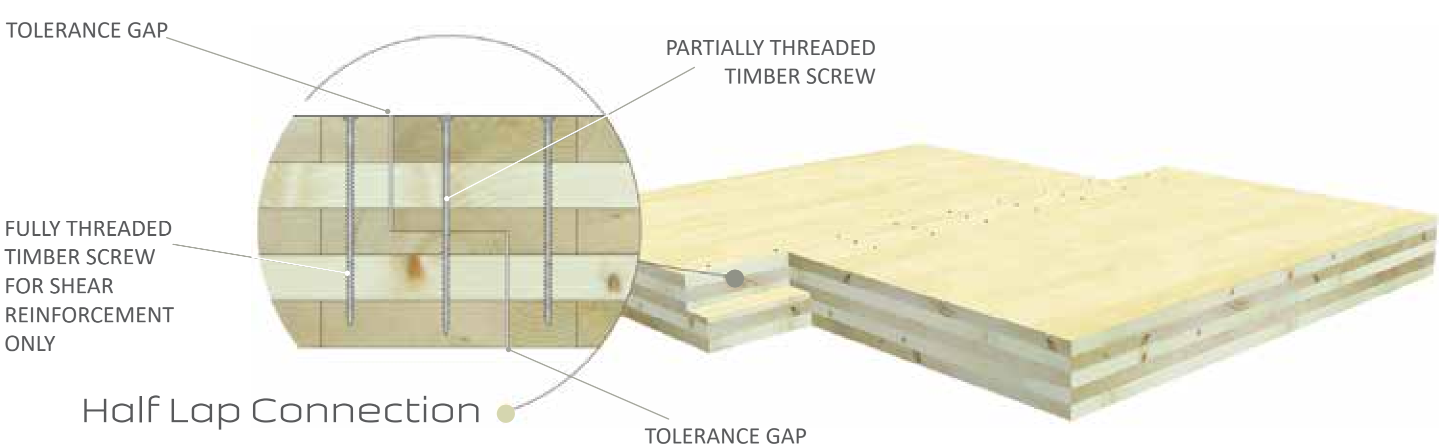
Structurlam will work with your team to identify the most cost-effective connection system for your structure. The following details show typical connection details used in CrossLam® CLT buildings.



Butt Joint Connection

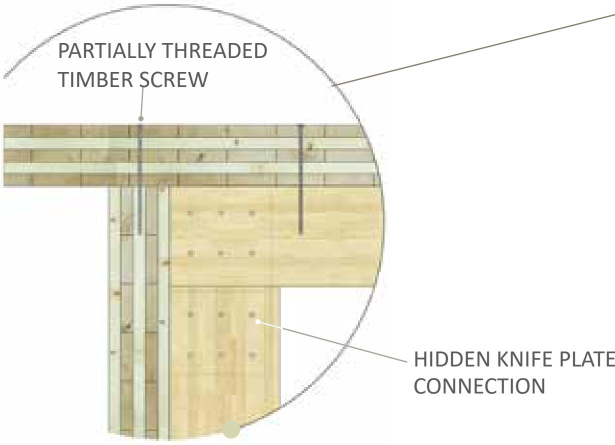


Spline Connection

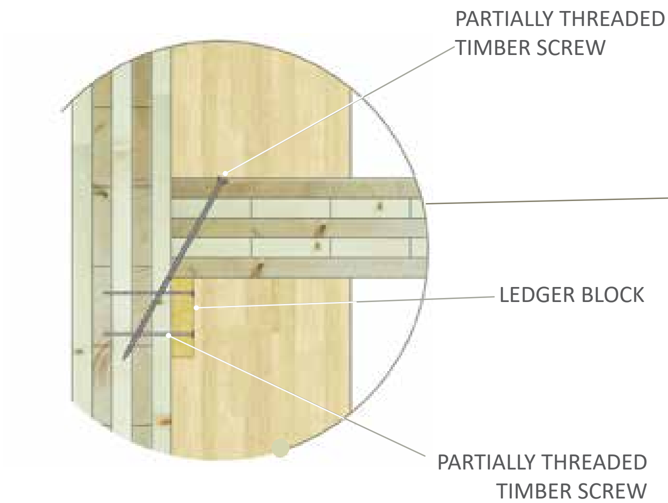


Half Lap Connection

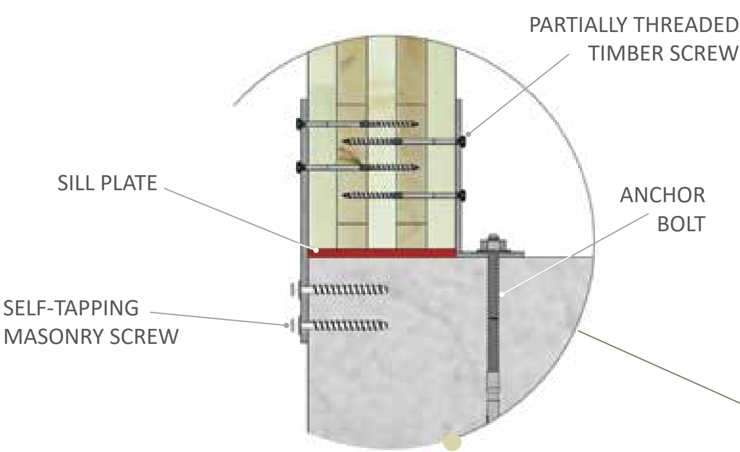
Flat Roof to Beam to Wall Connections



Roof to Beam to Wall Connection



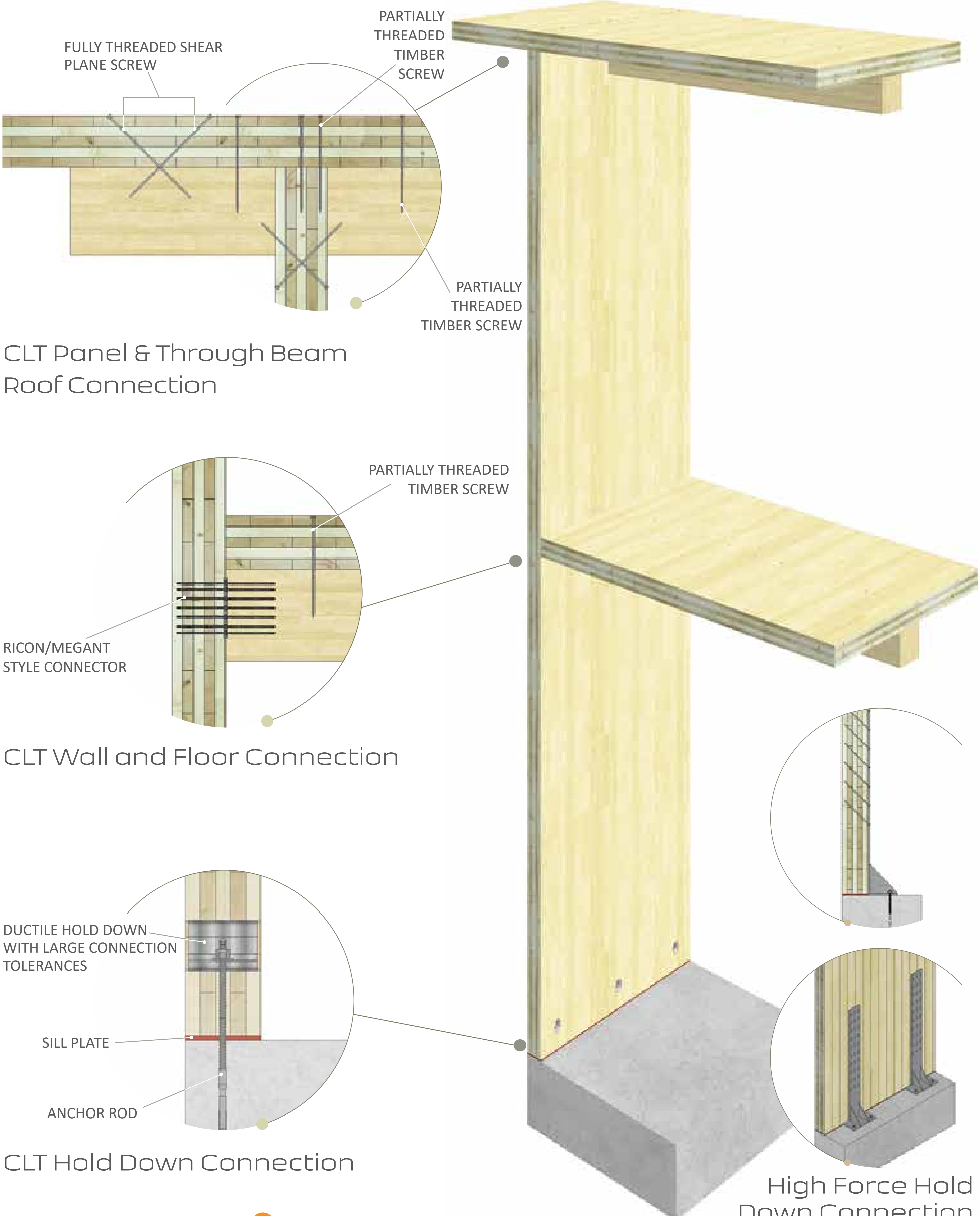
Floor Ledger Connection



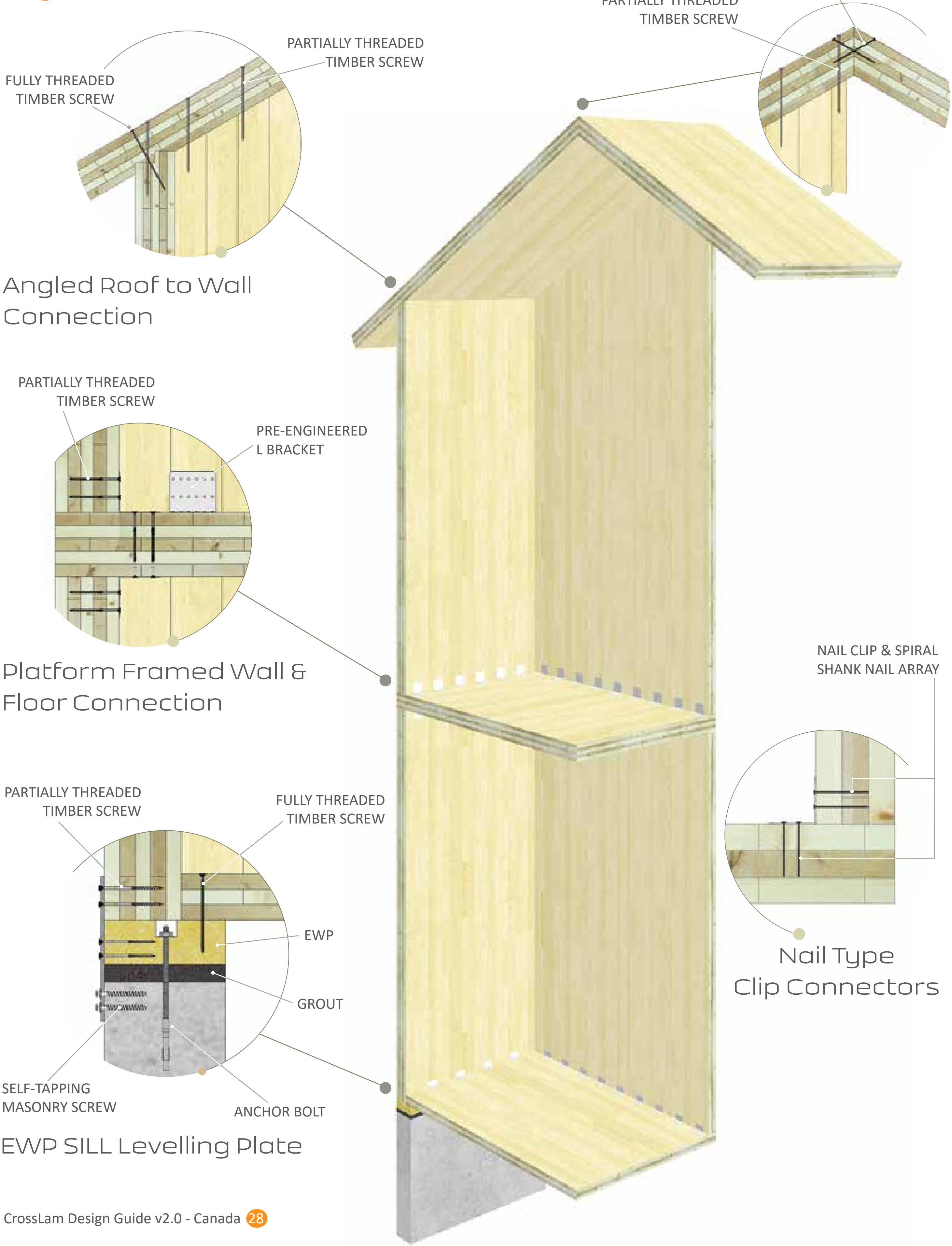
Concrete Hold Down

Post installed on-site to suit conditions.
Allow tolerance for leveling SILL plate or grout.

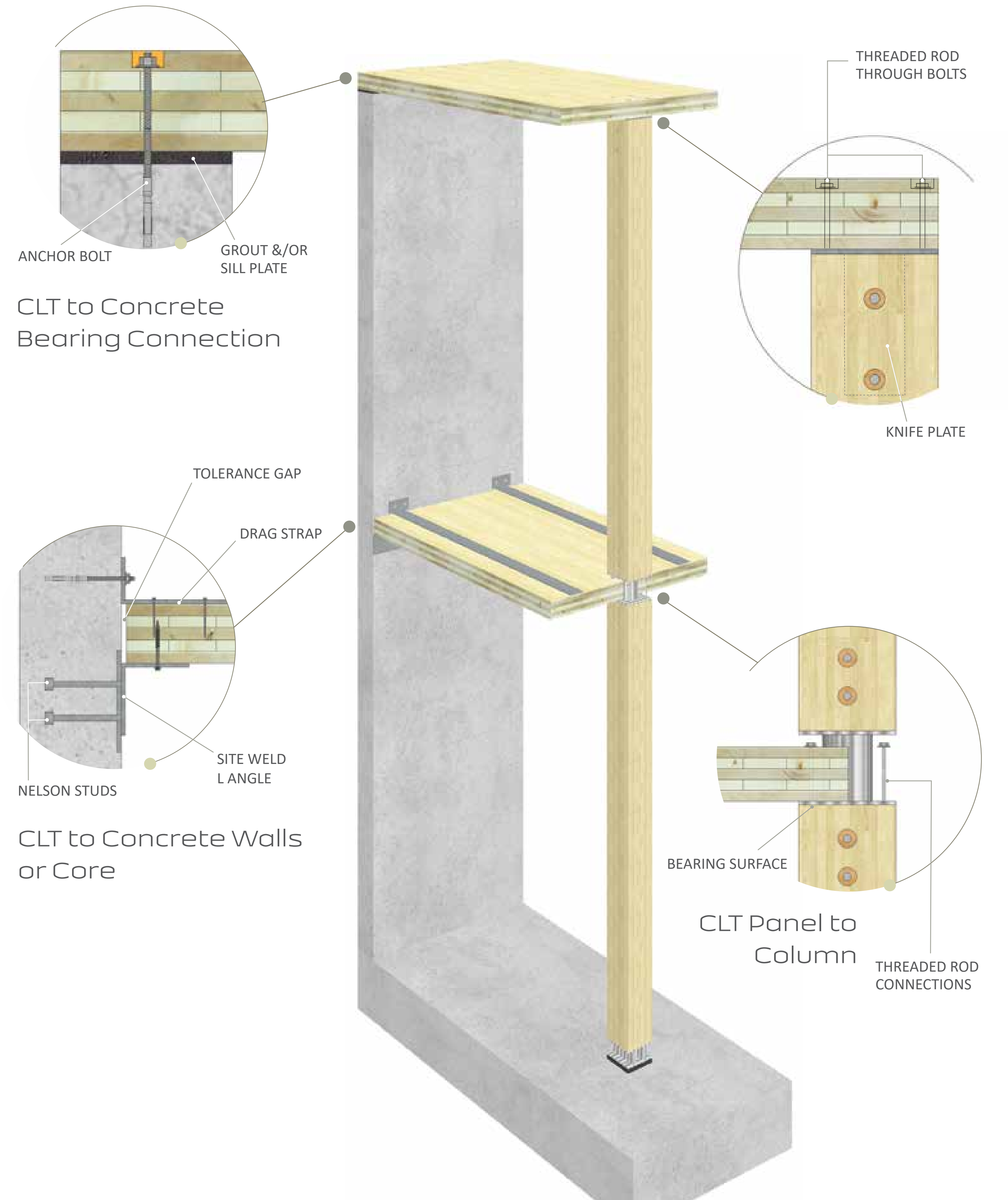
Flat Roof to Wall Connections



Angled Roof to Wall Connections



Wall to Concrete Connections



f.a.q.
frequently asked questions

1. Where is CLT referenced in the building code?

In Canada CLT is now part of the Supplement to the National Building Code (NBC). The CSA-O86 Technical Committee has approved the adoption of CLT in the 2016 Supplement to the CSA-O86. This supplement will form a part of the 2014 edition of the CSA-O86 that is referenced by the 2015 edition of the National Building Code of Canada. The adopted package includes; 1) CLT as a structural member, 2) CLT connections, and 3) CLT as a lateral-load resisting system. All manufacturers of CLT are required to meet the ANSI/APA standard PRG 320-2012. In the US, CLT is part of the ICC, 2015 International Building Code and ANSI/AWC NDS-2015.

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 25-29 in the CrossLam® CLT Design Guide for more connection information.

4. 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.

5. Is a truckload sequencing option available before shipping to the job site?

Truckload sequencing is an added feature that Structurlam can offer. It should be considered for projects in dense urban areas where a staging area is not available. The installer must confirm load sequencing during the shop drawing process.

6. What is the insulation value of CLT?

The insulation value of CLT is as follows in both metric and imperial units:

- RSI Value: 0.84 per 100 mm (K·m^2/W)
- R Value: 1.2 per inch (h·ft^2· °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?

As with all engineered wood products, CSA-O86 states that CLT must only be used in dry service conditions. Therefore CrossLam® CLT must not be used in exterior exposed applications.

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 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.

f.a.q.
frequently asked questions

10. What are the Fire Resistance Ratings, Flame Spread Rating, and Smoke Ratings of CLT?

Please see ratings as outlined on page 14 & 23 of the CrossLam® CLT Design Guide.

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 the CLT Handbook published by FP Innovations for assembly details and information (www.fpinnovations.ca).

12. Can CLT be used in shear wall applications?

Yes. Please refer to CSA-O86 for shear wall design procedures.

13. Can CLT panels be used as a vapour barrier?

The FPInnovations CLT Design Guide Chapter 10 states in 2.2.2 that CLT panels may meet requirements for both vapour retarders and vapour barriers. These findings are subject to enough 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 process.

16. Do you apply sealer to the end 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 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. Does Structurlam offer installation services for CrossLam® CLT panels?

Structurlam has a growing list of preferred installation partners that can assist you with the installation of CrossLam® CLT for your project.

STRUCTURLAM

Intelligence In Wood

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