Structurlam Products Ltd.

CrossLam™

CROSS LAMINATED TIMBER PANELS

Presented by: Kris Spickler

HEAVY TIMBER PACKAGES   Glulam + Parallam PSL+ Solid Sawn

Cross Laminated Timber

CLT Technical Information – Specific to Structurlam **CrossLam**™

Material

- Western Wood Species: Engelmann Spruce, Lodge Pole Pine, Balsam Fir, Douglas Fir
- Grading: SPF #2 and better w/ Visual grades and Douglas Fir
- Moisture content: 12 % +/- 2 %
- Bonding adhesive: Polyurethane - Formaldehyde-free adhesive, finger jointing and surface bonding

Layer construction

- Manufactured in 3, 5, 7 and 9 multilayer constructions with different strip thicknesses.
- It is basically possible to achieve any desired overall thicknesses and constructions through combination of 19 mm to 35 mm layers.

Processing possibilities

- Produce ready-to-assemble packed components; in addition to CNC fabrication of joints, drilling, openings as well as window and door openings and electrical milling.

Structural Benefits

•Lower material weight at comparable strength (6 times lighter than concrete).

•Seismic performance.

•Panels span in both directions.

•Dimensional stability with minimal shrinkage in building height.

•Versatility and ability to integrate with other materials.

Structural – Strength & Stability

Structural – Versatility

Schedule – Rapid Assembly

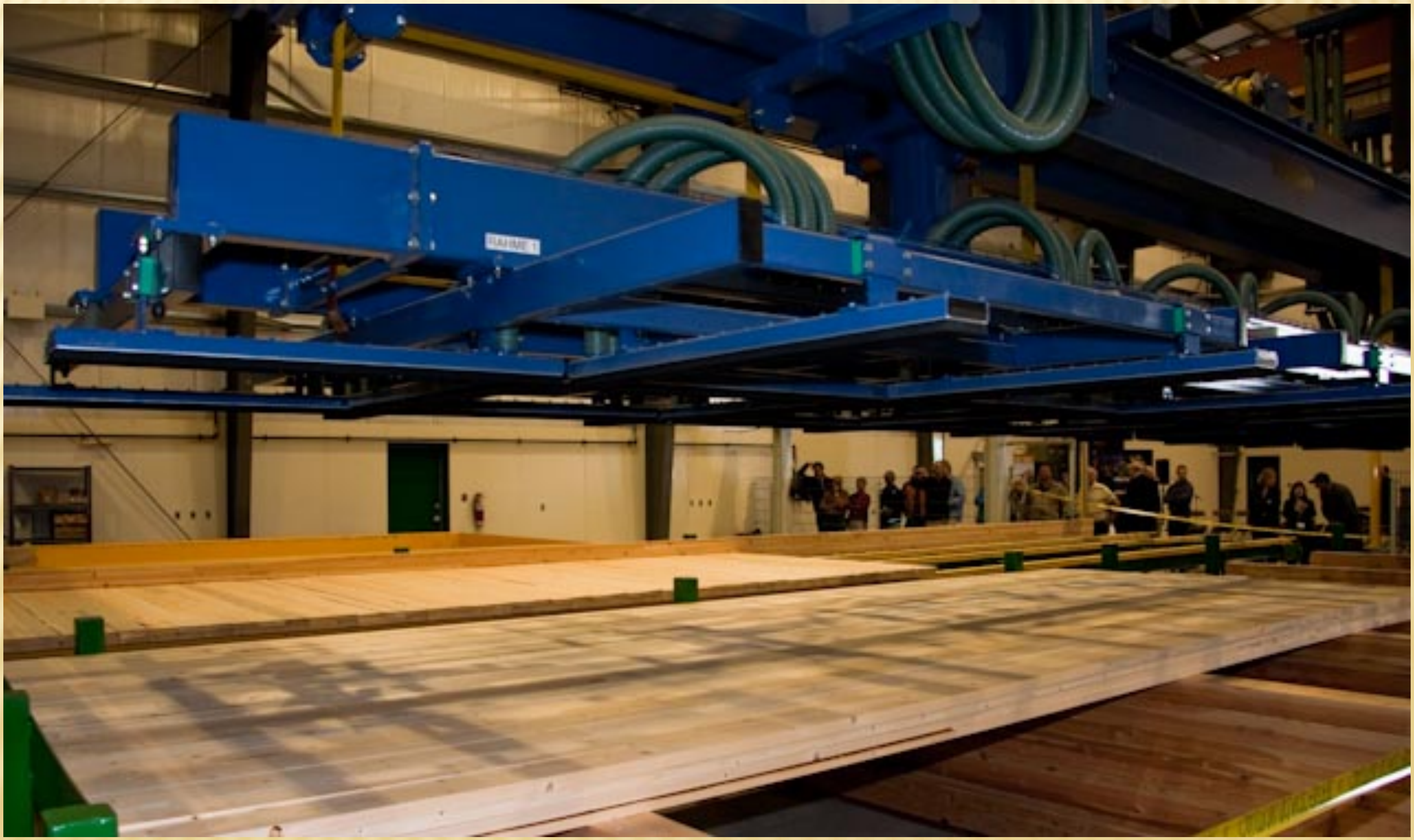
Environmental – Forest Health

Using sustainably managed resources including Engelmann Spruce , Lodge pole Pine, Balsam Fir, which has historically been underutilized, including mountain pine beetle-killed wood.

Environmental - Natural Materials

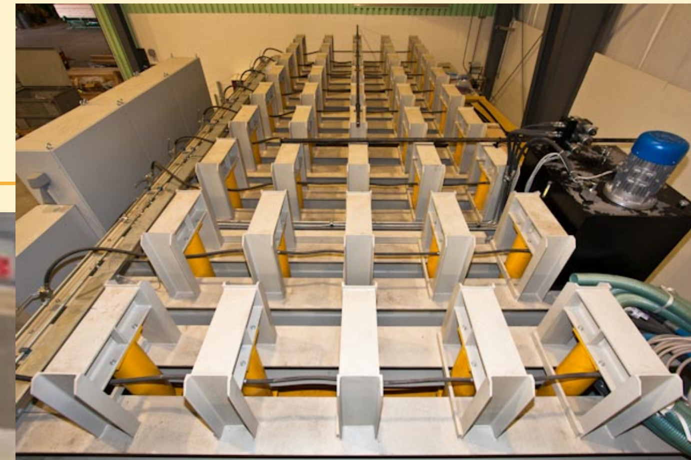
CLT Production

Gantry Crane to lift layers



Gantry Crane and panels

CLT Press and Glue Applicator



Glued CrossLam Panel

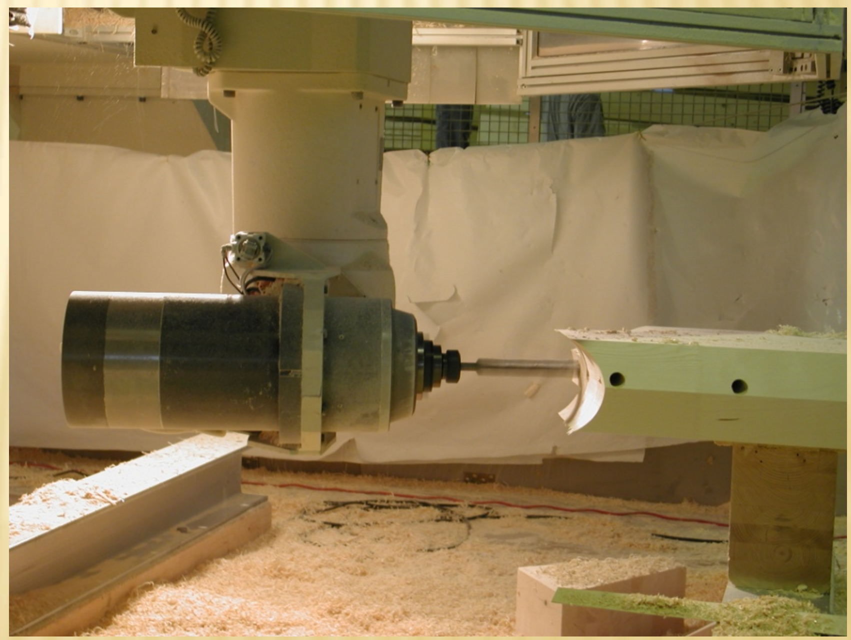
Rex Big Master Planer

- Feed speed up to 660 ft/min
- Maximum Width (8.5’)

French 5 Axis Creno Gantry style CNC

CNC Production

French 5 Axis Creno CNC



Panel Sizes

CrossLam Panel Dimension Increments (in mm)										
Width		**Length**								
2438	X	5645	6580	7515	8450	9385	10320	11255	12190
3048	X	5645	6580	7515	8450	9385	10320	11255	12190

The press measures 3048 x 12190. Placement of pressure bars allows for panels at one of two widths by one of eight lengths.

Panel lengths not specified above will be cut out of a larger panel.

Panels of odd widths will be nested and optimized from standard width panels.

Panel Finishes

UP	Unplaned
P	Planed
VOSJ	Visible one side, J-grade
VBSJ	Visible both sides, J-grade
VOSDF	Visible one side, Douglas Fir

Ready to ship

READY TO SHIP

Lift in Place

Rampa Lifting connectors

CLT Panel tool

Electrical applications

Concrete topping over conduit

Framed out pony wall

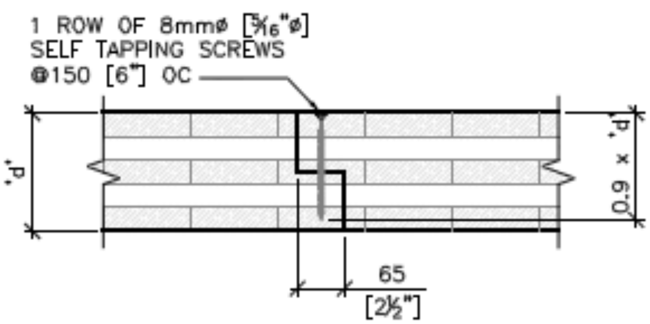
PLUMBING APPLICATIONS

Field routed behind cabinets

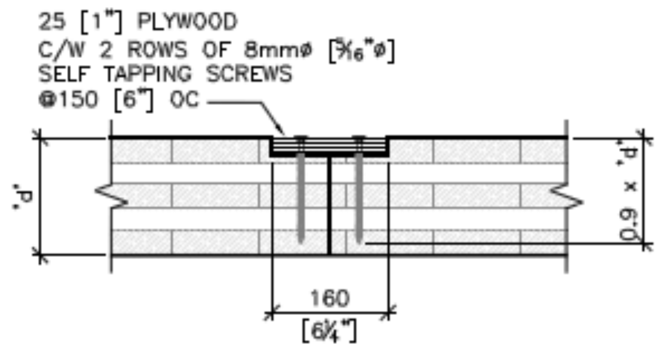
Field cut out behind cabinet

Typical Panel Connectors

connections floor/roof panel joints



JT1 - JOINT SECTION



JT2 - JOINT SECTION

NOTE:

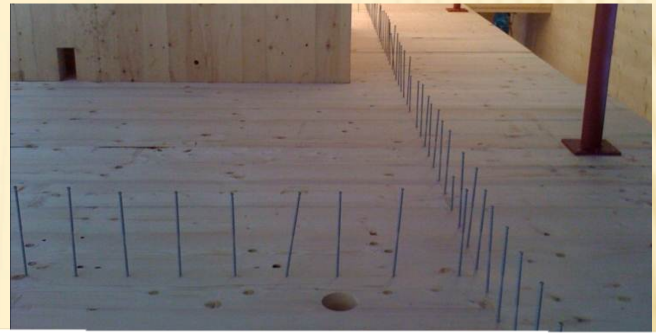
ALL PANEL JOINTS TO HAVE SEALANT.
TYP UNO.
SEE ARCH FOR DETAILS.

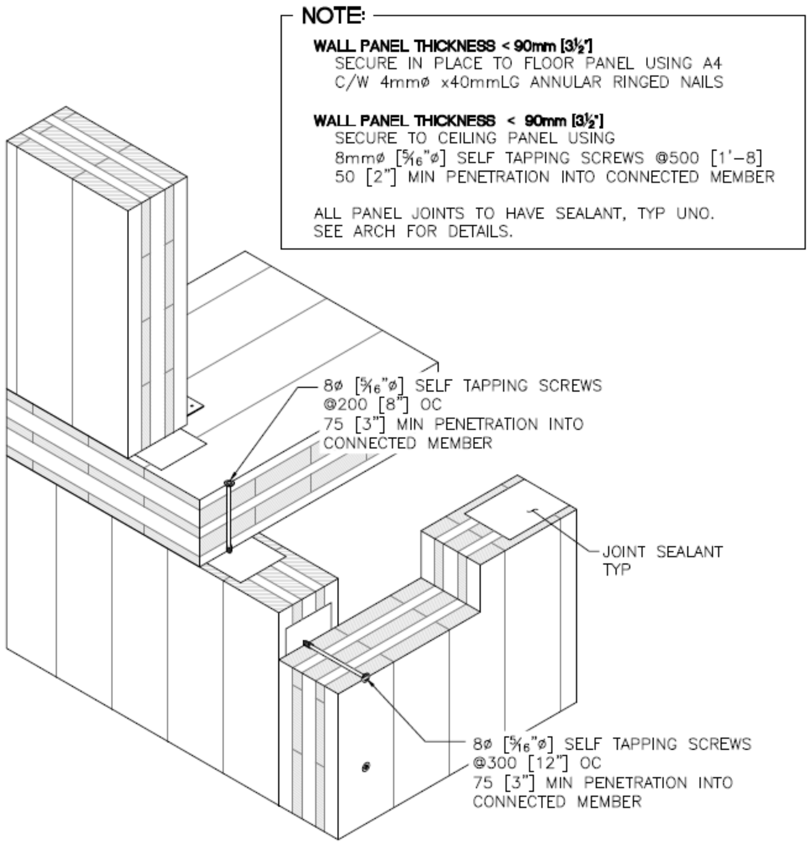
TYPICAL FLOOR/ROOF PANEL JOINTS PARALLEL TO MAIN LAYERS

NTS

EQUILIBRIUM CONSULTING INC.
CONSULTING STRUCTURAL ENGINEERS

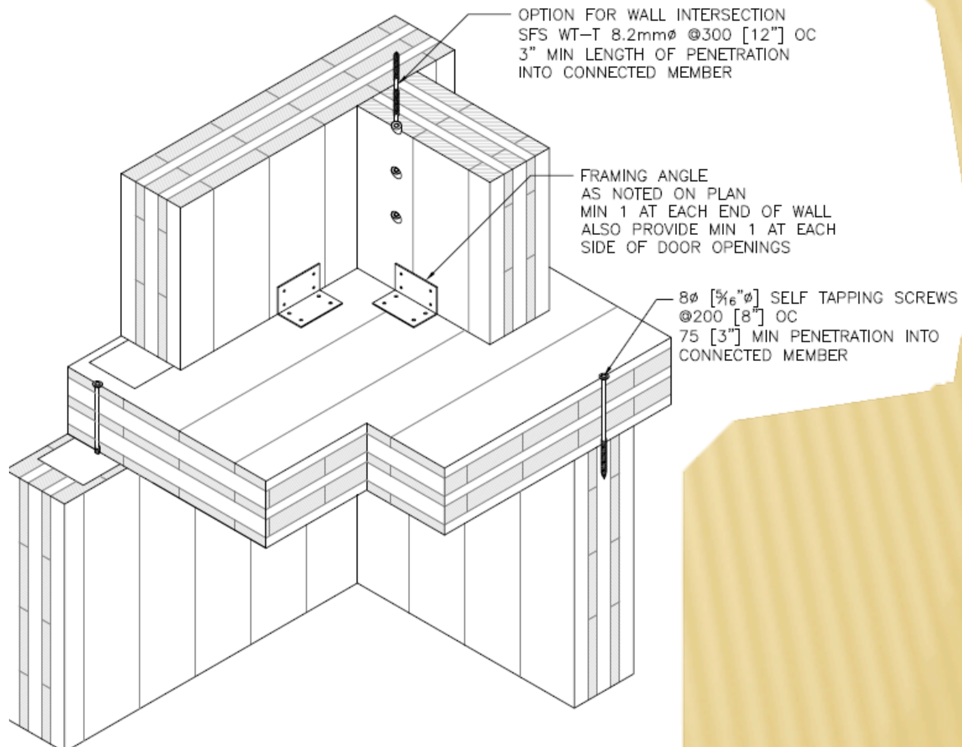
connections CLT to CLT





TYPICAL WALLTO FLOOR CONNECTION II

NTS

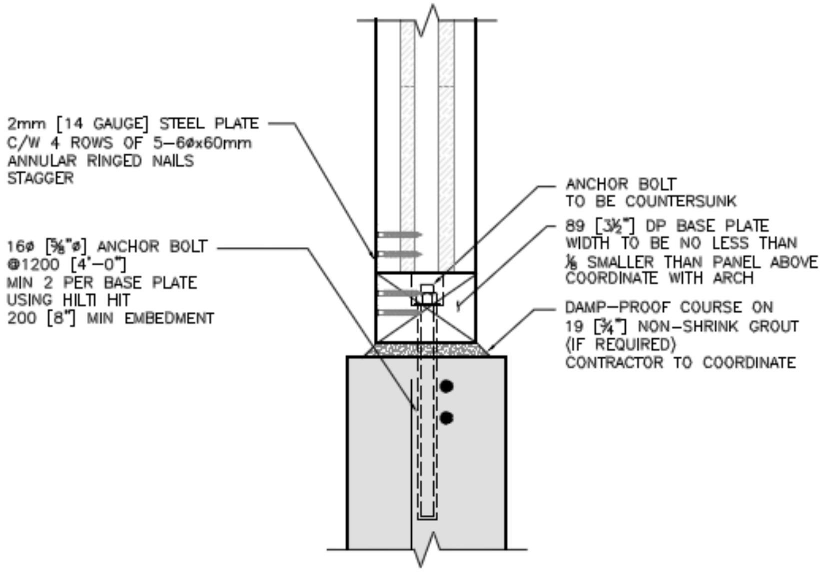


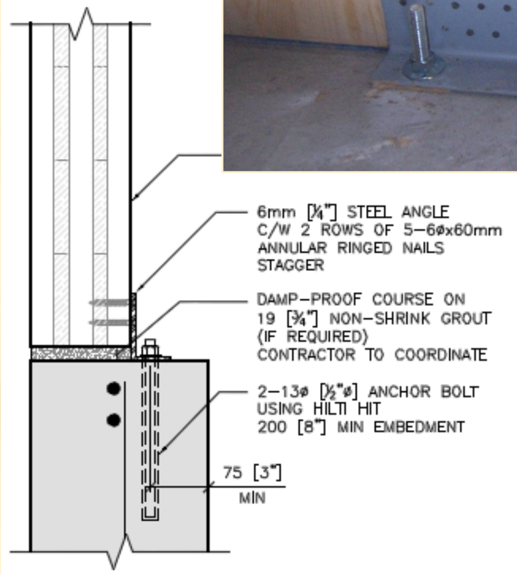
TYPICAL WALLTO FLOOR CONNECTION I

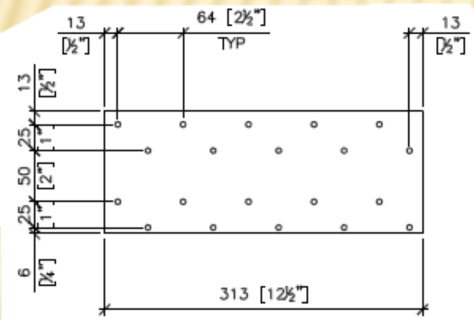
NTS

EQUILIBRIUM CONSULTING INC.
CONSULTING STRUCTURAL ENGINEERS

connections concrete

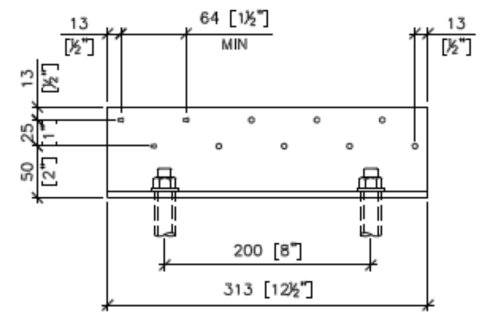






TYPICAL BASE PLATE CONNECTION

NTS

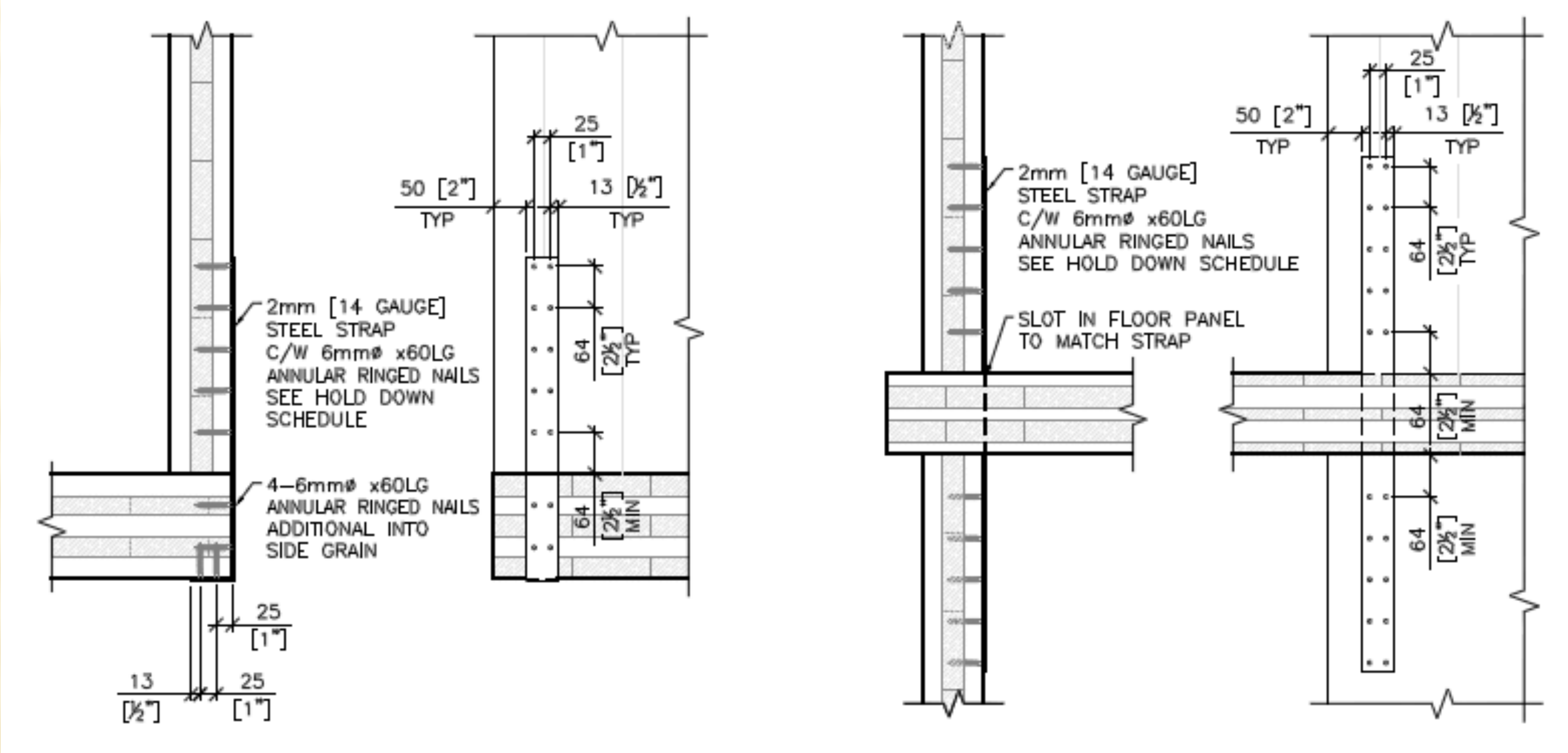


TYPICAL CONCRETE CONNECTION

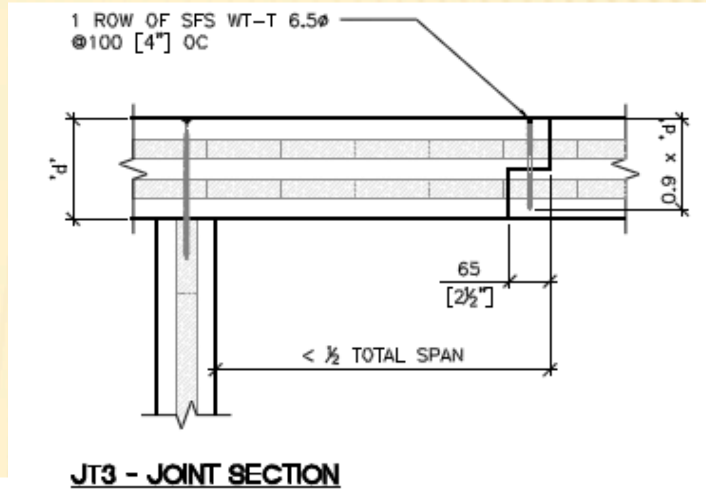
NTS

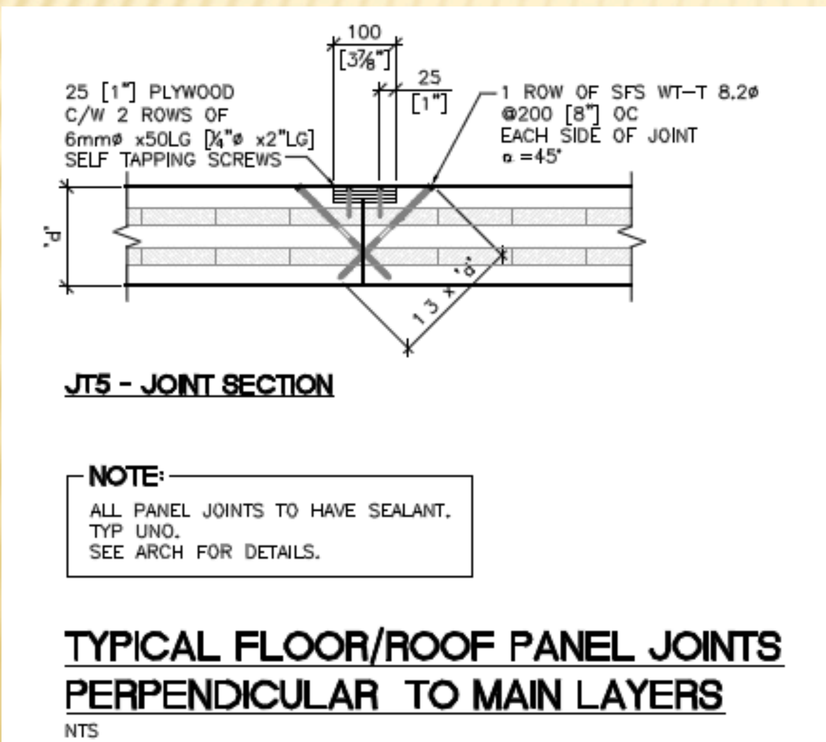
EQUILIBRIUM CONSULTING INC.
CONSULTING STRUCTURAL ENGINEERS

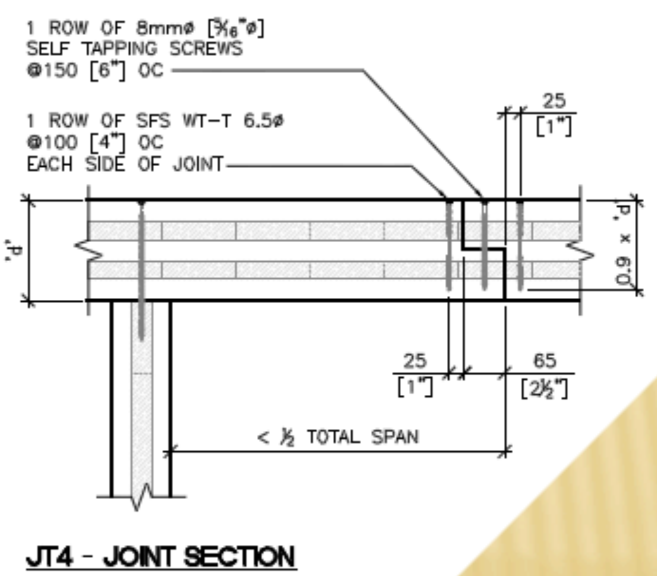
connections hold downs



connections floor/roof panel joints







Cross Laminated Timber Design

$$l \leq \frac{1}{9.15} \frac{(EI_{eff}^{1m})^{0.293}}{(\rho A)^{0.123}}$$

l = vibration controlled span (m)

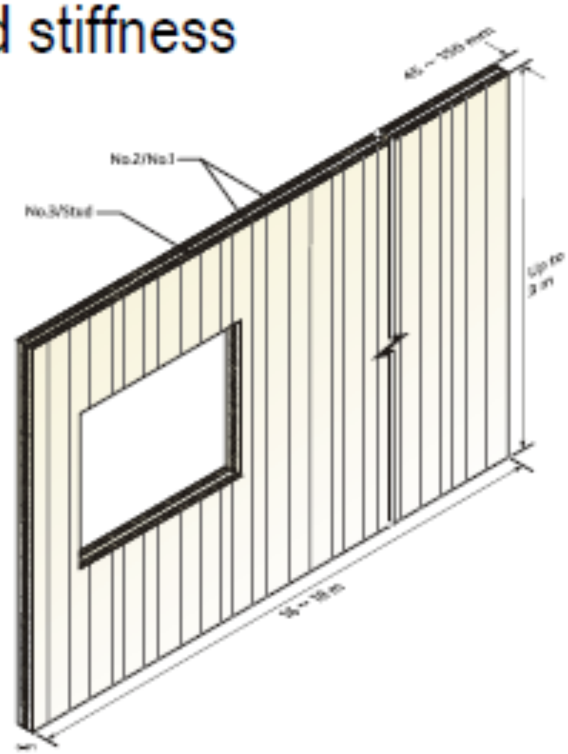
ρ = density (kg/m^3)

A = area of 1 m wide CLT (m^2)

EI_{eff}^{1m} = effective apparent stiffness in span direction of 1 m wide CLT (N-m^2)

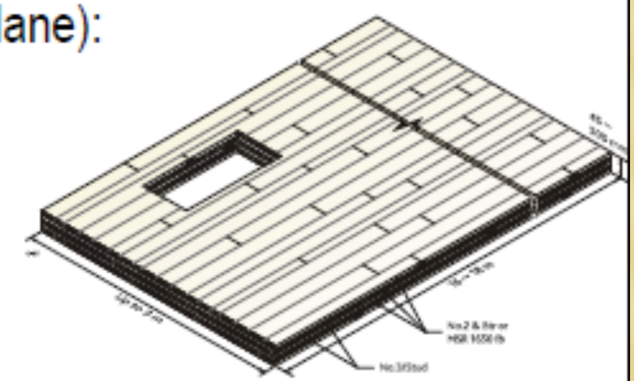
Wall Design

- Load-bearing capacity
- In-plane and out-of-plane strength and stiffness
- Fire performance
- Acoustic performance
- Durability in service



Floor Design

- Short-term and long-term behaviour (out-of-plane):
  - bending and shear strength
  - instantaneous deflection
  - long-term deflection (creep deformation)
  - long-term strength for permanent loading
- Vibration (for floor)
- Compression perpendicular to grain strength (bearing)
- In-plane strength and stiffness (diaphragms)
- Fire performance
- Acoustic performance
- Durability in service



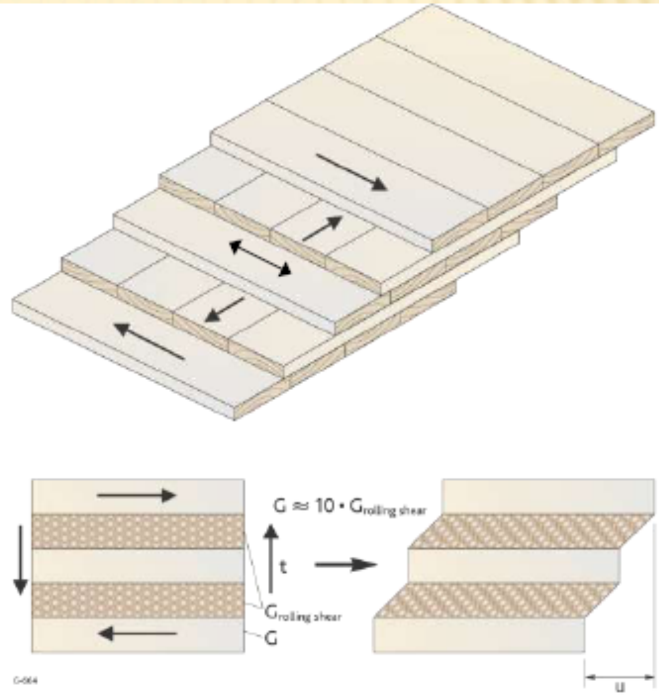
Panel Design

1) Mechanically Jointed Beams Theory (Gamma Method)

- Based on Annex B of Eurocode 5 (EN 1995:2004)
- Developed for beams connected together with mechanical fasteners with stiffness *k* uniformly spaced at distance *s*
- Only layers acting in the direction of loading are used
- Shear deformation of longitudinal layers is neglected
  - For span-to-depth ratio ≥ 30

Shear Deformation

- Shear Modulus Perpendicular to Grain
  - *Rolling Shear Modulus G_R*
- Shear Strength Perpendicular to Grain
  - *Rolling Shear Strength $F_{v,R}$*



- In general, the shear deformation of CLT panels may be neglected for floor elements having a span-to-depth ratio of about 30

Vibration Design

$$l \leq \frac{1}{9.15} \frac{(EI_{eff}^{1m})^{0.293}}{(\rho A)^{0.123}}$$

l = vibration controlled span (m)

ρ = density (kg/m^3)

A = area of 1 m wide CLT (m^2)

EI_{eff}^{1m} = effective apparent stiffness in span direction of 1 m wide CLT (N-m^2)

Suggested spans for damping

CLT thickness (mm)	FPInnovations' design method proposed span (m)	CLTdesigner proposed span for 1% damping and no topping floors (m) (Schickhofer, 2010)
100	3.58	3.53
120	3.76	3.75
140	4.50	4.43
160	4.80	4.76
180	5.16	5.14
200	5.68	5.67
220	5.84	5.89
240	6.09	6.17

Vibration and Creep Considerations

Vibration Control

As a rule of thumb use:
99mm panel - 12.25’ span or L/d of 33
169mm panel - 17.0’ or L/d of 28
235mm panel – 21.0’ or L/d of 25

Creep Adjustment

25% reduction in shear stiffness for elastic limit
50% reduction in shear stiffness for permanent deformation

Floor CLT Panel Table

Floor CLT Panel Design Table	Occupation type	Residential	Classroom/Office	Assembly
	Live Load (kPa)	1.9	2.4	4.8
	superimposed dead (kPa)	0.5	0.5	0.5
	Topping (mm)	38	38	38
SIMPLE SPAN	4.0 m	114-3s	114-3s	190-5s
	6.0 m	190-5s	190-5s	266-7s
	8.0 m	266-7s	266-7s	342-9s
TWO SPAN CONTINUOUS	4.0 m	114-3s	114-3s	114-3s
	6.0 m	190-5s	190-5s	190-5s
	8.0 m	190-5s	266-7s	266-7s
Note:	1. CLT panel is made of SPF No.1 38x140 lumber.			

Floors:

Bottom of the CLT floor is typically finished with drywall sheathing or left exposed.

Most materials applied on top of panels are light weight concrete topping or wood chips with acoustical insulation layer, and cement screed on top.

CLT Cross-Laminated Timber

floor panel load table

CLT Floor Panel Load Table

MAX. SPAN (mm)		FLOOR LIVE LOAD (kPa, unfactored)				
		1.9	2.4	3.6	4.8	7.2
	PANEL TYPE	RESIDENTIAL	OFFICE/CLASSROOM	MECHANICAL ROOM	ASSEMBLY	LIBRARY
single span	CLT-3ply-99	**3490**	**3490**	3220	2980	2650
	CLT-5ply-169	**4920**	**4920**	**4920**	4730	4220
	CLT-7ply-239	**6200**	**6200**	**6200**	**6200**	5720
	CLT-9ply-309	**7370**	**7370**	**7370**	**7370**	7180
double span	CLT-3ply-99	**3700**	**3700**	3650	3350	2920
	CLT-5ply-169	**5150**	**5150**	**5150**	**5150**	4650
	CLT-7ply-239	**6500**	**6500**	**6500**	**6500**	6350
	CLT-9ply-309	**7800**	**7800**	**7800**	**7800**	**7800**
triple span	CLT-3ply-99	**3725**	**3725**	3500	3220	2850
	CLT-5ply-169	**5250**	**5250**	**5250**	5100	4500
	CLT-7ply-239	**6550**	**6550**	**6550**	**6550**	6150
	CLT-9ply-309	**7825**	**7825**	**7825**	**7825**	7750

Notes:

1. Material is S-P-F No.1/No.2 for all laminations.
2. Outer laminations are 32mm thick; inner laminations are 35mm thick.
3. Specified modulus of elasticity and strength in major strength direction:
   E_0 = 9500 MPa; $f_{b,0}$ = 11.8 MPa; $f_{v,0}$ = 1.5 MPa; $f_{vr,0}$ = 0.5 MPa; $f_{c,0}$ = 11.5 MPa; $f_{t,0}$ = 5.5 MPa (ref: Table 5.3.1A of CSA-O86-09).
4. Specified modulus of elasticity and strength in minor strength direction:
   E_{90} = 9500 MPa; $f_{b,90}$ = 11.8 MPa; $f_{v,90}$ = 1.5 MPa; $f_{vr,90}$ = 0.5 MPa; (ref: Table A3 ANSI/APA PRG 320 -75% Draft January 2011).
5. Dead load includes panel self-weight plus 1.0 kPa flooring load.
6. **Bold** text indicates span governed by vibration; regular text indicates span governed by dead plus live load deflection limit of L/300.
7. All spans are assumed to be equal for multi-span panels.
8. Spans shown represent distance between the centerlines of supports.
9. Maximum spans shown are only to be used for preliminary design.
10. Engineer to ensure that L/300 deflection limit is appropriate for intended use.
11. The following factors were used for calculations: K_D = 1.0; K_s = 1.0; K_T = 1.0; K_H = 1.0.

CLT Cross-Laminated Timber

floor panel with concrete topping load table

CLT Floor Panel Load Table with 2" (50mm) Concrete Topping

MAX. SPAN (mm)		FLOOR LIVE LOAD (kPa, unfactored)				
		1.9	2.4	3.6	4.8	7.2
	PANEL TYPE	RESIDENTIAL	OFFICE/CLASSROOM	MECHANICAL ROOM	ASSEMBLY	LIBRARY
single span	CLT-3ply-99	3350	3230	2990	2800	2520
single span	CLT-5ply-169	**4920**	**4920**	4730	4450	4030
single span	CLT-7ply-239	**6200**	**6200**	**6200**	6020	5480
single span	CLT-9ply-309	**7370**	**7370**	**7370**	**7370**	6890
double span	CLT-3ply-99	**3700**	**3700**	3420	3180	2820
double span	CLT-5ply-169	**5150**	**5150**	**5150**	5050	4500
double span	CLT-7ply-239	**6500**	**6500**	**6500**	**6500**	6150
double span	CLT-9ply-309	**7800**	**7800**	**7800**	**7800**	7700
triple span	CLT-3ply-99	**3725**	3600	3300	3070	2740
triple span	CLT-5ply-169	**5250**	**5250**	5200	4860	4360
triple span	CLT-7ply-239	**6550**	**6550**	**6550**	**6550**	5940
triple span	CLT-9ply-309	**7825**	**7825**	**7825**	**7825**	7450

Notes:

1. Material is S-P-F No.1/No.2 for all laminations.
2. Outer laminations are 32mm thick; inner laminations are 35mm thick.
3. Specified modulus of elasticity and strength in major strength direction:
   E_0 = 9500 MPa; $f_{b,0}$ = 11.8 MPa; $f_{v,0}$ = 1.5 MPa; $f_{vr,0}$ = 0.5 MPa; $f_{c,0}$ = 11.5 MPa; $f_{t,0}$ = 5.5 MPa (ref: Table 5.3.1A of CSA-O86-09).
4. Specified modulus of elasticity and strength in minor strength direction:
   E_{90} = 9500 MPa; $f_{b,90}$ = 11.8 MPa; $f_{v,90}$ = 1.5 MPa; $f_{vr,90}$ = 0.5 MPa; (ref: Table A3 ANSI/APA PRG 320 - 75% Draft January 2011).
5. Dead load includes panel self-weight plus 1.0 kPa flooring load, and weight of 2" (50mm) normal weight concrete topping.
6. **Bold** text indicates span governed by vibration; regular text indicates span governed by dead plus live load deflection limit of L/300.
7. All spans are assumed to be equal for multi-span panels.
8. Spans shown represent distance between the centerlines of supports.
9. Maximum spans shown are only to be used for preliminary design.
10. Engineer to ensure that L/300 deflection limit is appropriate for intended use.
11. The following factors were used for calculations: K_D = 1.0; K_s = 1.0; K_T = 1.0; K_H = 1.0.

Roof Design Table

Roof

CrossLam Roof Panel Load Table									
	MAX. SPAN (mm)		ROOF SNOW LOAD (kPa, unfactored)						
	PANEL TYPE	SIZE (mm)	1.1 PENTICTON	1.6 VANCOUVER	2.2 NANAIMO	2.9 PRINCE GEORGE	3.3 SQUAMISH	8.5 WHISTLER
single span	SLT3	99	4450	4120	3820	3550	3420	2510
	SLT5	169	6800	6360	5950	5570	5390	4050
	SLT7	239	8920	8420	7920	7450	7220	5520
	SLT9	309	10900	10330	9770	9230	8970	6940
double span	SLT3	99	5400	4950	4550	4200	4050	2900
	SLT5	169	8250	7650	7100	6600	6350	4650
	SLT7	239	10900	10150	9450	8850	8550	6350
	SLT9	309	13300	12500	11700	11000	10600	8000
triple span	SLT3	99	5160	4750	4400	4050	3900	2850
	SLT5	169	7900	7300	6800	6350	6100	4550
	SLT7	239	10350	9700	9100	8500	8200	6150
	SLT9	309	12650	11850	11200	10550	10200	7750

Notes:

1. Material is S-P-F No. 1/No. 2 for all laminations.
2. Outer laminations are 32mm thick; inner laminations are 35mm thick.
3. Specified modulus of elasticity and strength in major strength direction:
   $E_0 = 9500$ MPa; $f_{b,0} = 11.8$ MPa; $f_{v,0} = 1.5$ MPa; $f_{vr,0} = 0.5$ MPa; $f_{c,0} = 11.5$ MPa; $f_{t,0} = 5.5$ MPa
   (ref: Table 5.3.1A of CSA-O86-09).
4. Specified modulus of elasticity and strength in minor strength direction:
   $E_{90} = 9500$ MPa; $f_{b,90} = 11.8$ MPa; $f_{v,90} = 1.5$ MPa; $f_{vr,90} = 0.5$ MPa;
   (ref: Table A3 ANSI/APA PRG 320 - 75% Draft January 2011).
5. Dead load includes panel self-weight plus 0.5 kPa roofing load.
6. Maximum span is governed by dead plus snow load deflection limit of L/300.
7. All spans are assumed to be equal for multi-span panels.
8. Spans shown represent distance between the centerlines of supports.
9. Maximum spans shown are only to be used for preliminary design.
10. Engineer to ensure that L/300 deflection limit is appropriate for intended use.
11. The following factors were used for calculations: $K_D = 1.0$; $K_S = 1.0$; $K_T = 1.0$; $K_H = 1.0$.
12. Shear stiffness has been reduced by 50% to account for creep deformation.
13. Snow load is based on BCBC 2006 with the following factors:
    $I_s = 1.0$ for ULS; $I_s = 0.9$ for SLS; $C_w = 1.0$; $C_s = 1.0$; $C_a = 1.0$.

CLT Cross-Laminated Timber

wall panel axial load table

CrossLam Wall Pannel Load Table (Axial Loading Only)				
Panel	SLT3	SLT5	SLT7	SLT9
d (mm)	99	169	239	309
L (m)	P_r (kN/m)			
2.0	385	699	949	1179
2.5	332	650	904	1134
3.0	276	599	861	1093
3.5	223	547	818	1054
4.0	178	494	773	1014
4.5	143	442	728	975
5.0	114	392	681	934
5.5		345	633	893
6.0		303	587	851
6.5		265	541	808
7.0		232	496	764
7.5		203	454	721
8.0		177	415	678
8.5			378	637
9.0			344	596

Notes:

1. $P_r = \Phi F_{cb} A K_{zc} K_C$
2. Material is S-P-F No.1/No.2 for all laminations.
3. Outer laminations are 32mm thick; inner laminatins are 35mm thick.
4. Specified moduls of elasticity and strength in major strength direction:
   E_0 = 9500 Mpa; $f_{b,0}$ = 11.8 Mpa; $f_{v,0}$ = 1.5 Mpa; $f_{vr,0}$ = 0.5 Mpa; $f_{c,0}$ = 11.5 Mpa; $f_{t,0}$ = 5.5 Mpa
   (ref: Table 5.3.1A of CSA 086-09)
5. Specified moduls of elasticity and strength in minor strength direction:
   E_{90} = 9500 Mpa; $f_{b,90}$ = 11.8 Mpa; $f_{v,90}$ = 1.5 Mpa; $f_{vr,90}$ = 0.5 Mpa
   (ref: Table A3 ANSI/APA PRG 320-75% Draft January 2011)
6. Wind load has not been included.
7. Where the Pr values are not given, the slenderness ratio exceeds 50 (maximum permited; CSA 086-09)
8. 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
9. Eccentricity of axial load has not been included.
10. These values are to be used for preliminary design only.

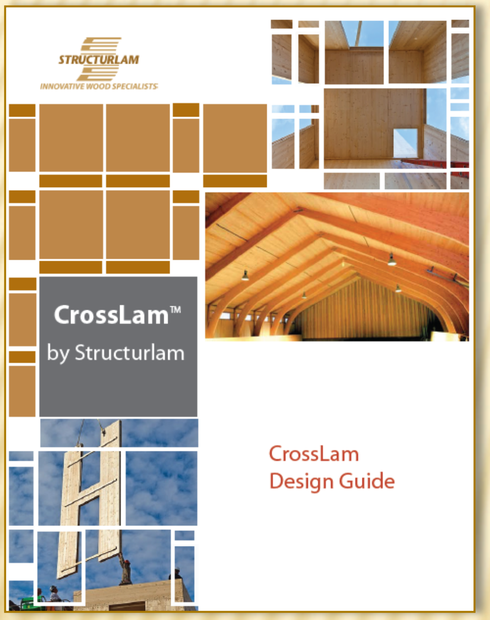
CLT Cross-Laminated Timber

wall panel in plane shear load table

CrossLam Wall Pannel Load Table (In-Plane Shear Loading Only)				
Panel	SLT3	SLT5	SLT7	SLT9
d (mm)	99	169	239	309
	V_r (kN/m)			
	95	190	285	380

Notes:

1. Computed values based on *"In-Plane Shear Capacity and Verification Methods"* by Prof. G. Schickhofer, University of Graz.
2. Material is S-P-F No.1/No.2 for all laminations.
3. Outer laminations are 32mm thick; inner laminatins are 35mm thick.
4. Specified moduls of strength: $f_{v,clt,k}$ = 5.0 Mpa; $f_{T,clt,k}$ = 2.5 Mpa
   (ref: *"BSPhandbuch Holz-Massivbauweise in Brettsperrholz" Technical Univercity of Graz*)
5. The following factors were used for calculations: k_{mod} = 0.8; γ_m = 1.25.
6. Minimum width of wood used in lay-up is 89mm.
7. Values are for SLT panel only, not for shear connectors.
8. These values are to be used for preliminary design only.



Panel Layouts

Name	Layers	Depth (mm)	Inner Lams (mm)	Outer Lams (mm)
SLT3	3 layers	99	inner lams 35	outer lams 32
SLT5	5 layers	169	inner lams 35	outer lams 32
SLT7	7 layers	239	inner lams 35	outer lams 32
SLT9	9 layers	309	inner lams 35	outer lams 32

Max Panel Size 3.0m x 12.2m (10.0’ X 40.0’)

Max Thickness 309 mm

Production Widths 1.2 m & 2.4 m (4.0’ X 8.0’)

Moisture Content 12% (+/-2%) at time of production

Glue Specifications Purebond polyurethane adhesive

Wood Species SPF No.1/No.2, other species available upon request

Surface Qualities Planed 4 sides

Squareness Panel face diagonals shall not differ by more than 3.2mm

Straightness Deviation of edges from a straight line between adjacent panel corners shall not exceed 1.6 mm

Dimensional Tolerances

Thickness: +/- 1.6mm (1/16 in) or 2% of the CrossLam thickness whichever is greater

Width: +/- 1.6 mm (1/16 in) per foot (305 mm) of CrossLam width

Length: +/- 3.2 mm (1/8 in) up to 6100 mm (20 ft) and +/- 3.2 mm (1/8 in) for each additional 6100 mm (20 ft) in length

Technical Approvals

CrossLam meets the requirements of the following standards:

- CLT Plant Qualification Standard – draft- by FPInnovations
- Standard for Performance Rated CLT ANSI/APA PRG 320 – draft – by APA

Codes

- ANSI/APA PRG 320 Standard for Performance Rated CLT

This Standard provides requirements and test methods for qualification and quality assurance for performance-rated cross-laminated timber (CLT), which is manufactured from solid-sawn lumber intended for use in construction applications. Product performance classes are also specified.

The development of this consensus American National Standard was achieved by following the *Operating Procedures for Development of Consensus Standards* of *APA – The Engineered Wood Association*, approved by the American National Standards Institute (ANSI).

- FPInnovations CLT Plant Qualification Standard & Design recommendations

- Submitted IBC inclusion in 2015

Keys to successful CLT plan check and approval

- ANSI APA PRG320 Standard
- Specification, details included in plan
- Complete engineering calculations
- Submitted under the Alternate System section of the code
- Test data to match standard

Fire Safety

- The fire performance of CLT is better than any other wood building system.
- The low surface area and the airtight environment compared to standard wood construction also helps to inhibit fire growth in a contained space by limiting the available fuel.
- Even a normal installed panel does not allow fire to burn through which encapsulates the flame in a single area, suffocating it.
- Another great attribute is the solid thermal mass. This allows one side of the panel to be close to 1000 degrees Celsius while the other side is room temperature.
- FP Innovations latest fire tests showed a 7 layer unprotected floor panel under full loading condition survived 2 hours and 58 minutes before failure.

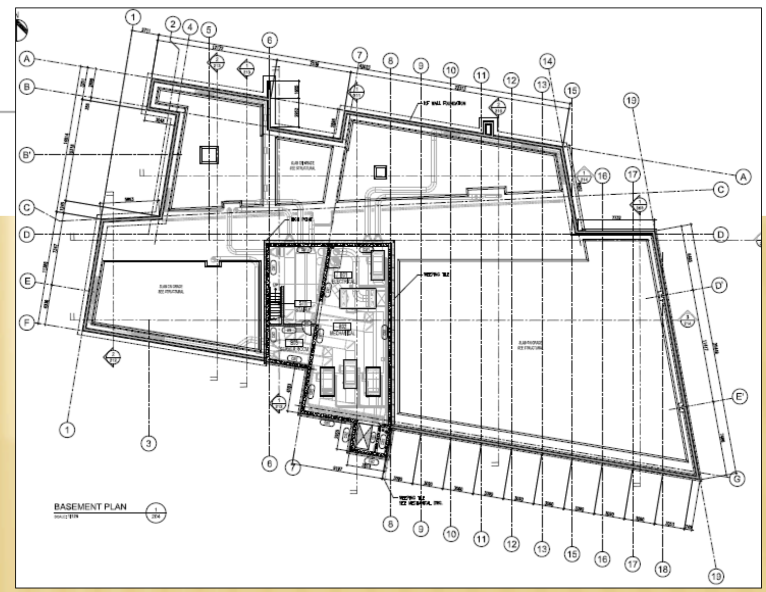
Cross Laminated Timber Earthquake Test Video

- http://www.youtube.com/watch?v=T08KRyVhyeo&feature=BFa&list=PL0C748D60E698719A&index=13

North American Commercial Projects

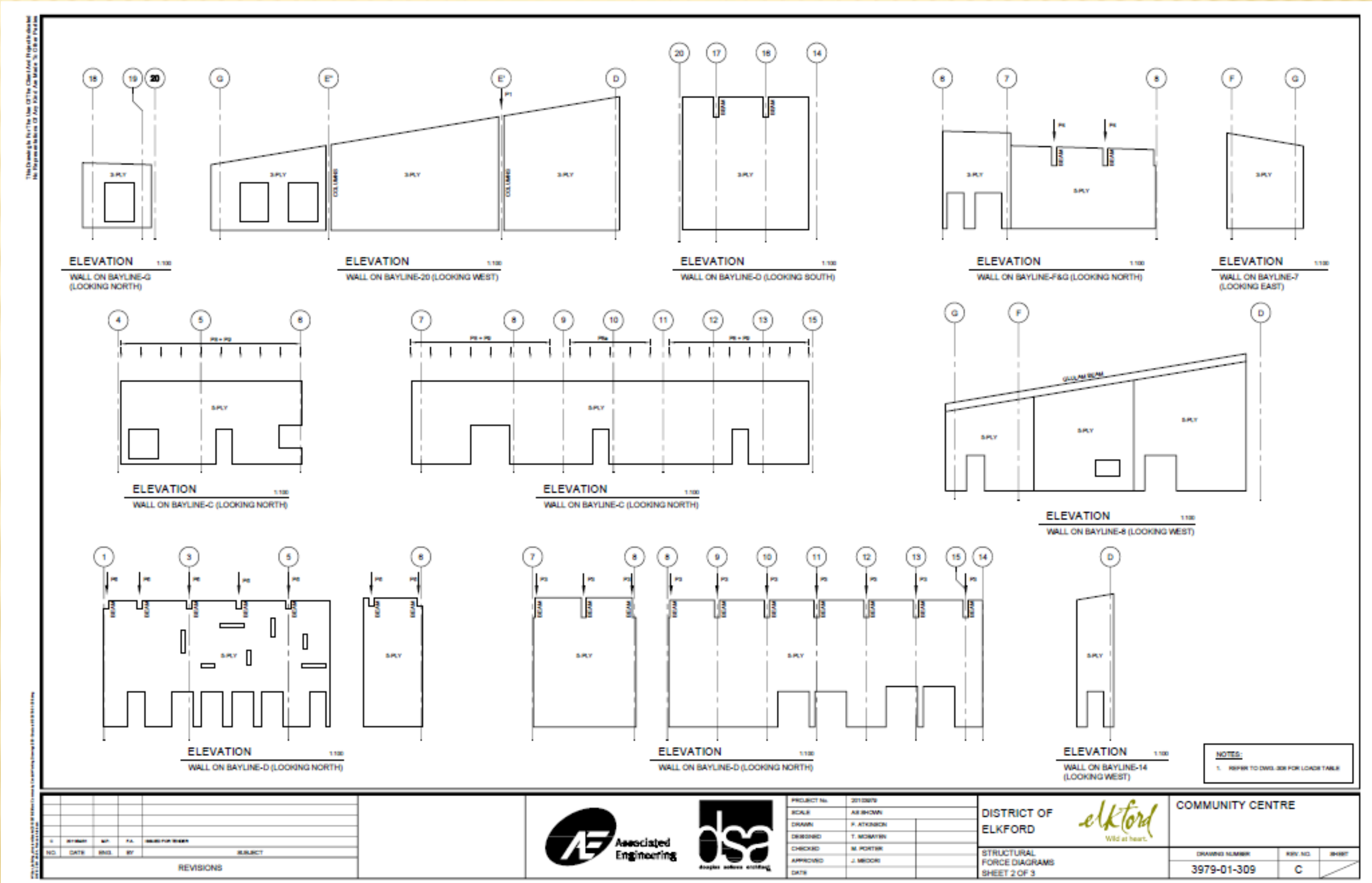
- USB Child Care Services Building
- UBC Earth System Science Building
- Elkford Community Center
- North Vancouver School District Outdoor Center
- Promega GMP Facility
- Fort McMurray Airport

Elkford Community Centre



http://www.youtube.com/ahc1893

Elkford Community Centre

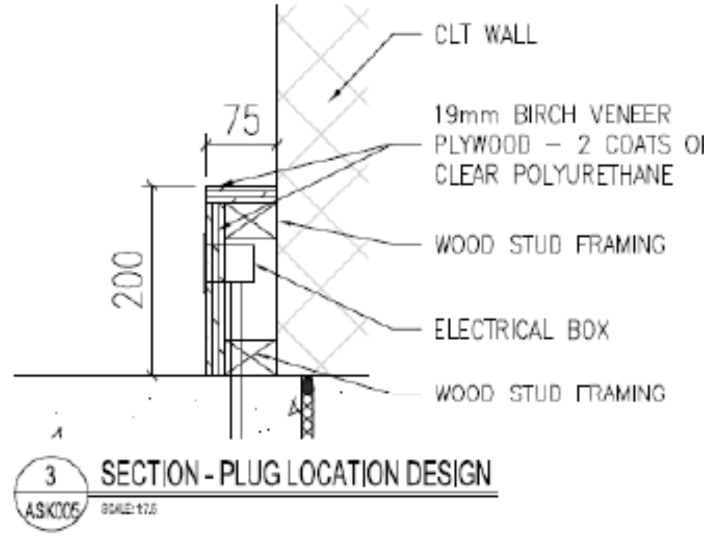


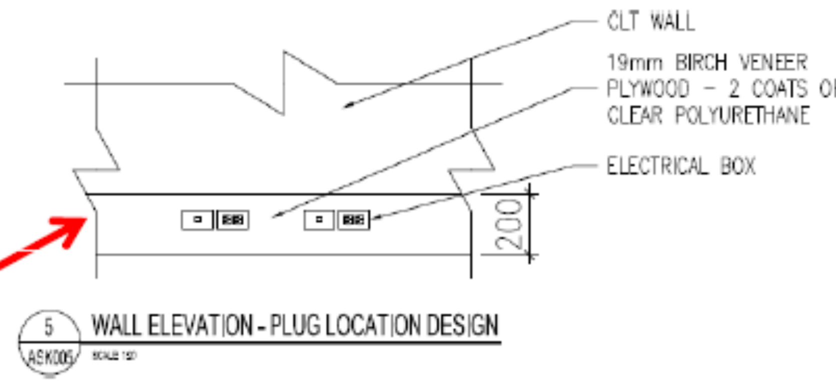
LIFTING THE CROSSLAM PANELS INTO PLACE

• Several options for electrical outlets on CLTs

• Furred out wall with drywall & wood cap

• Outlets incorporated into wood baseboard





• Outlets incorporated into wood baseboard

Elkford Community Centre

Elkford AHC-CLT-exclusive movie.mov

ELKFORD COMMUNITY CENTRE

UBC Earth System Science Building

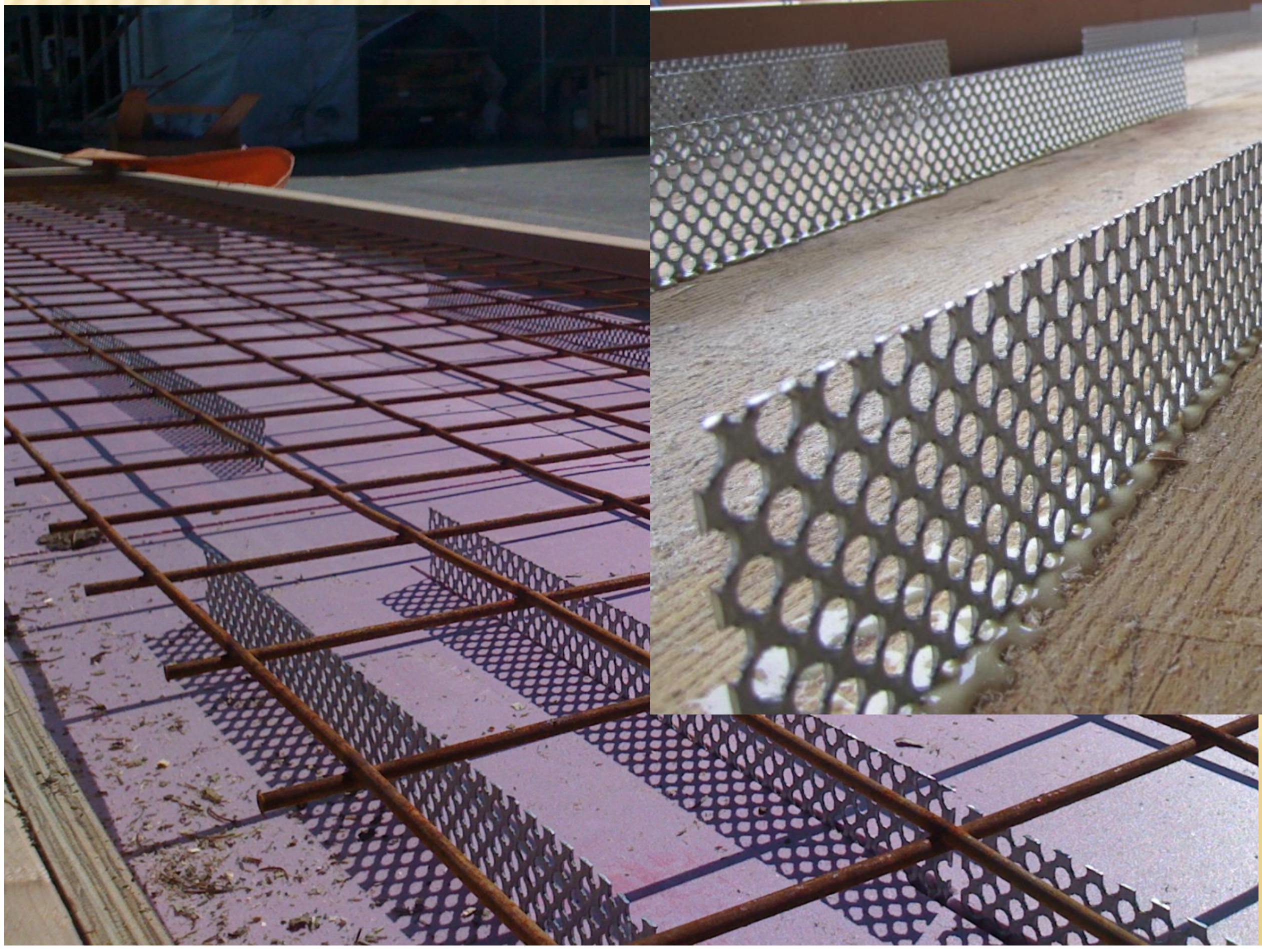
UBC Earth System Science Building

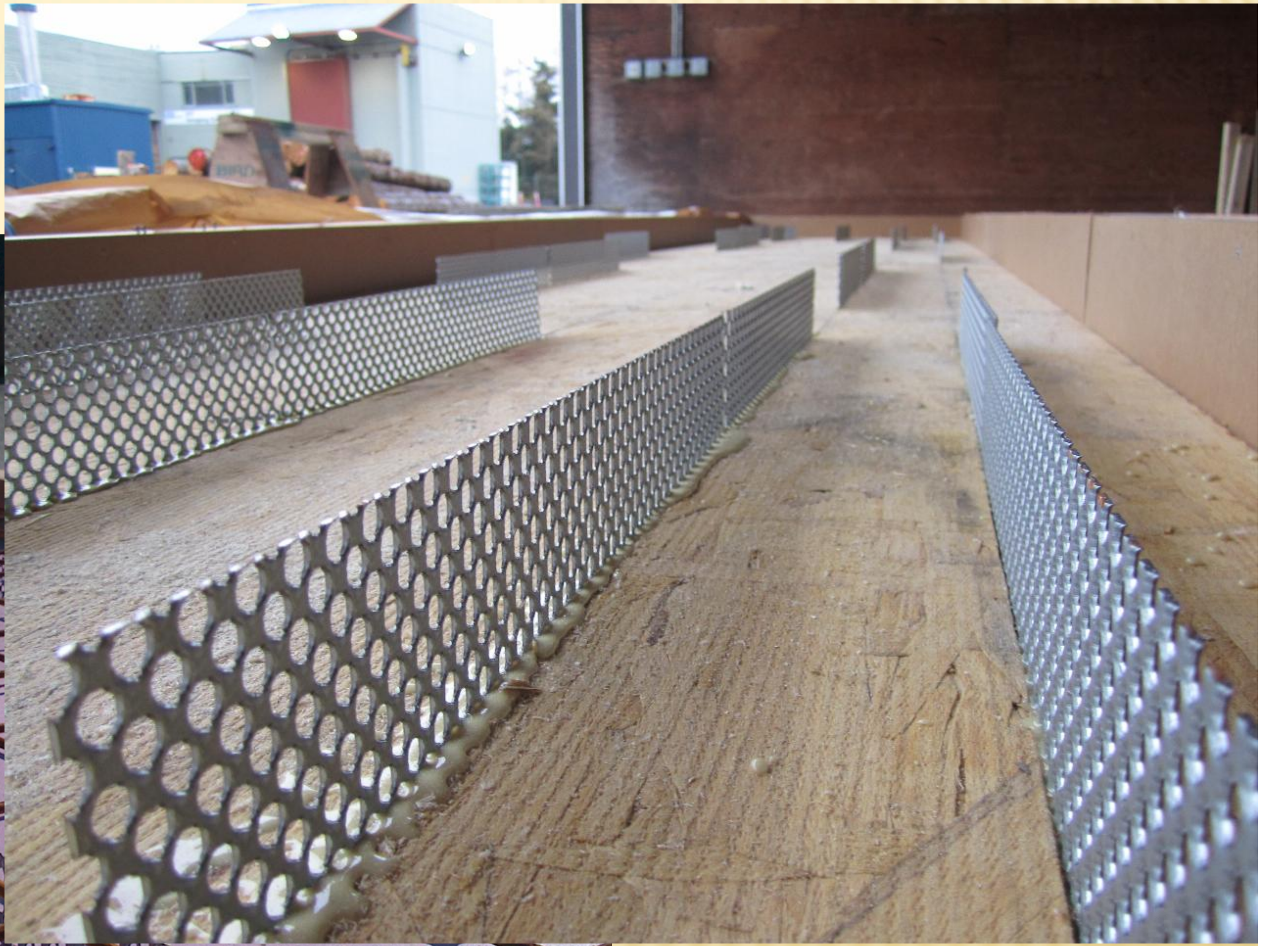
Lateral load resisting glulam frames

UBC EARTH SYSTEM SCIENCE BUILDING

CrossLam roof and floor system with glulam beams

Composite CrossLam / concrete decks using the HBV System





UBC Earth System Science Building

Stairway – partially unsupported CrossLam construction


RIVERSIDE
FIRST AID


RIVERSIDE


MANUFACTURED BY TOLKO


8800

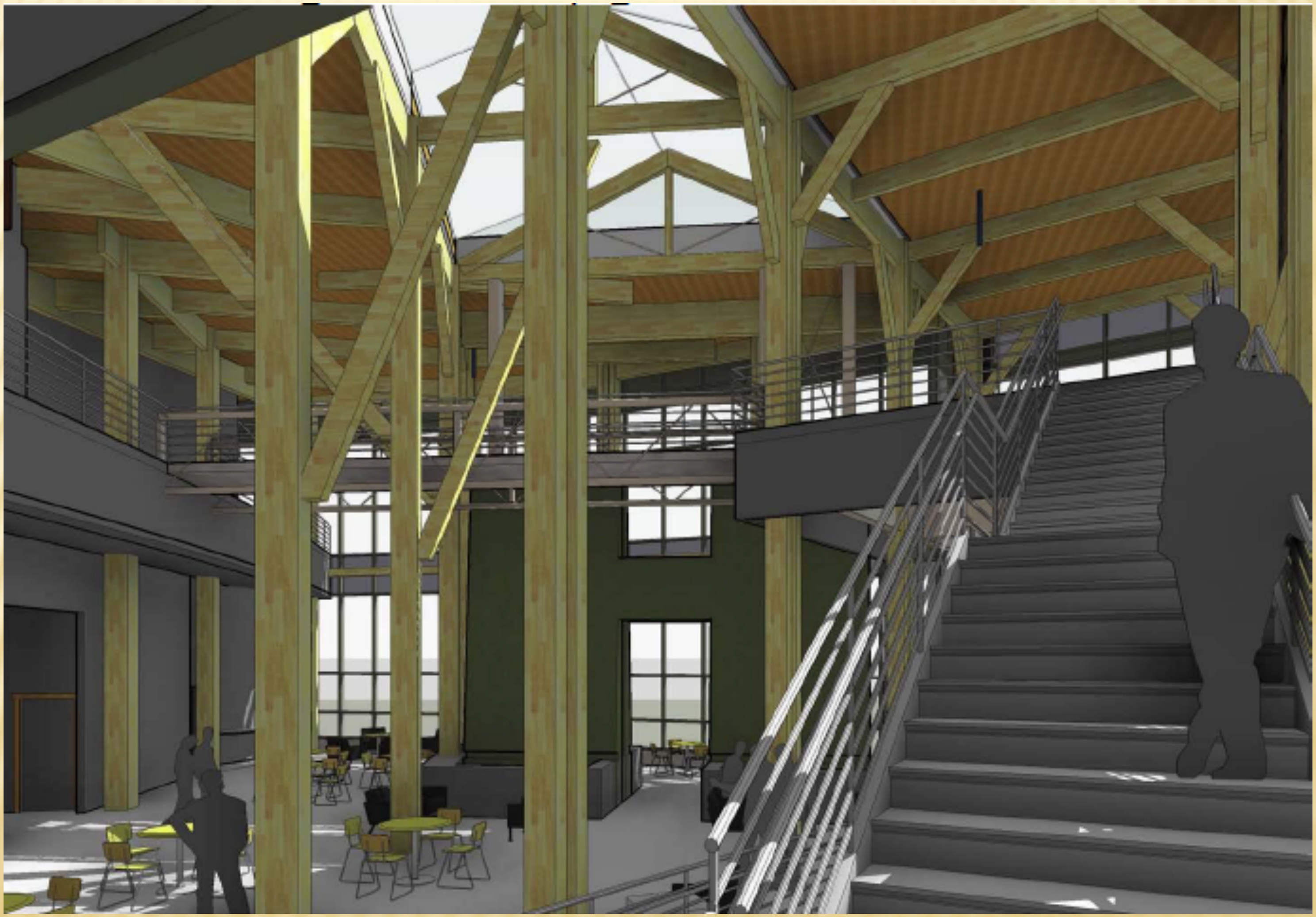
NORTH VANCOUVER OUTDOOR SCHOOL

INDUSTRIAL WATER TANK

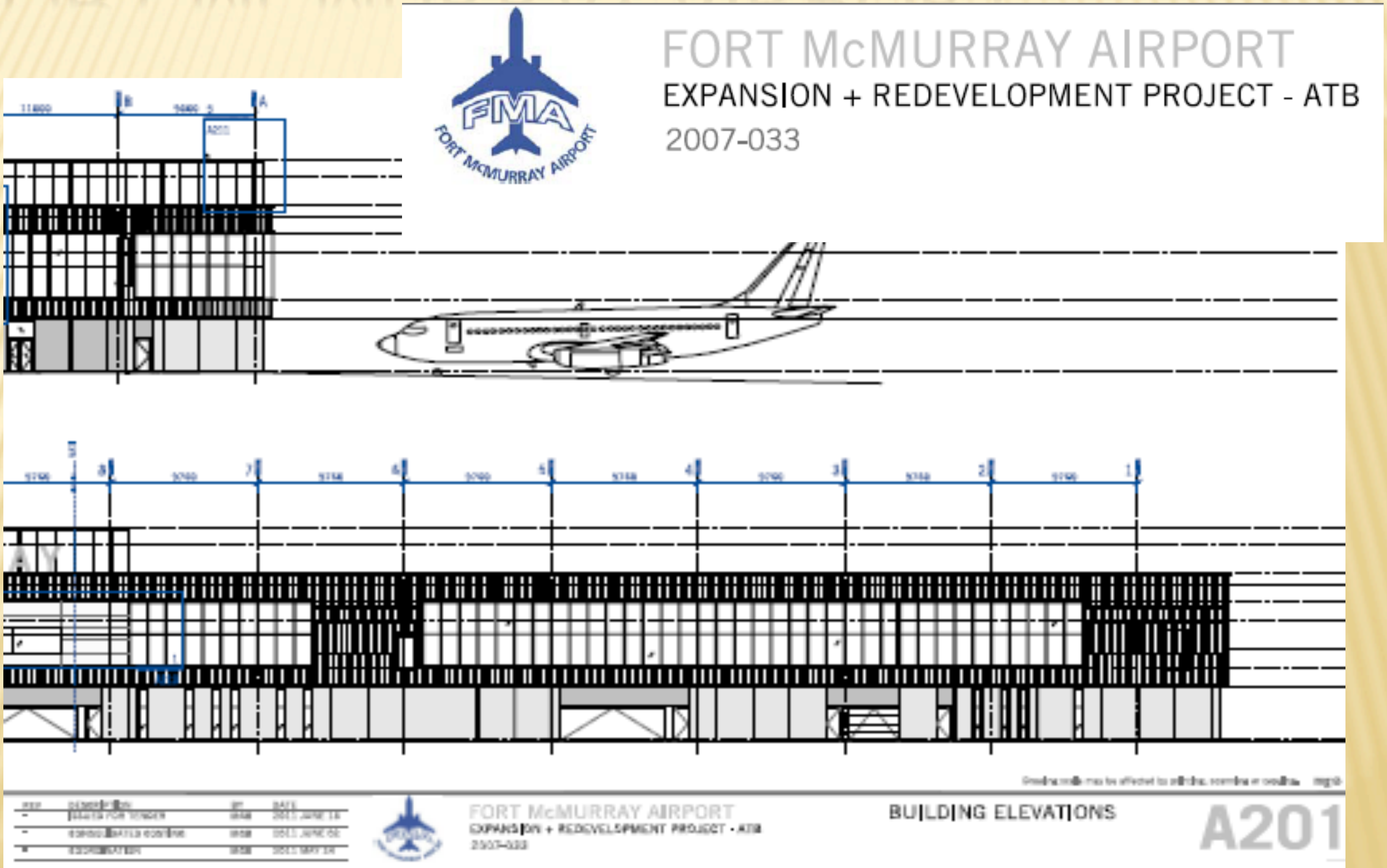
UBC Child Care Services Building

Promega GMP Facility Fitchburg, WI

Client Center Interior view



FORT MCMURRAY AIRPORT



Seattle AIA Mock up

THANK YOU

CrossLam™ Panels

STRUCTURLAM

INNOVATIVE WOOD SPECIALISTS

Glulam • Parallam® • Solid Timbers

Kris Spickler – Heavy Timber Specialist
Phone : 916-797-5588
E-mail : kris@structurlam.com