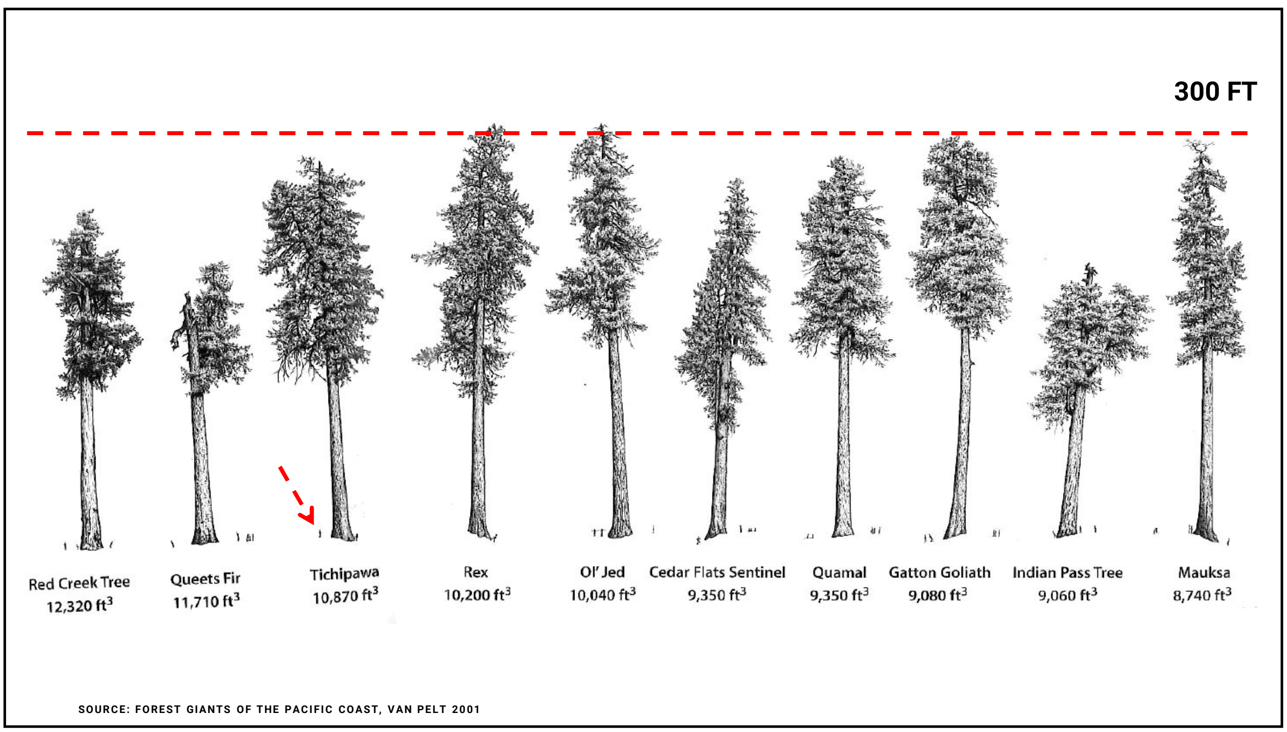
MASS TIMBER IN PRACTICE

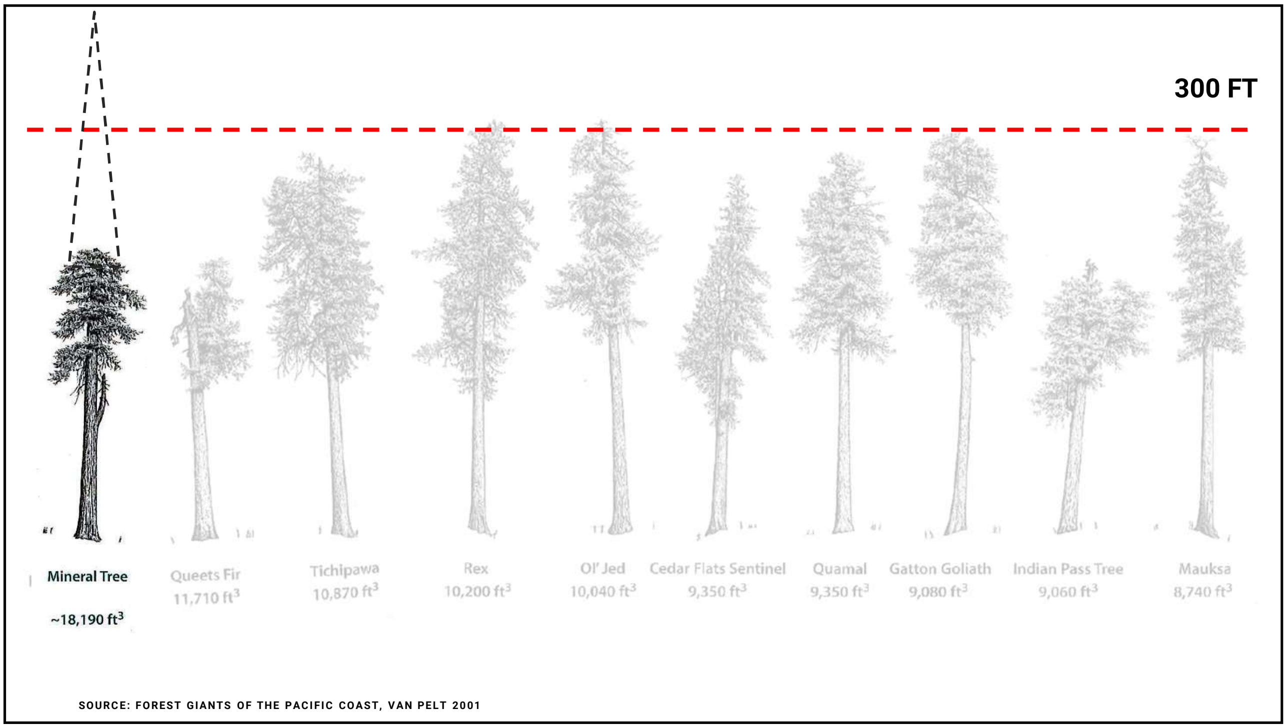
Progress in Educational Buildings and the Building Code

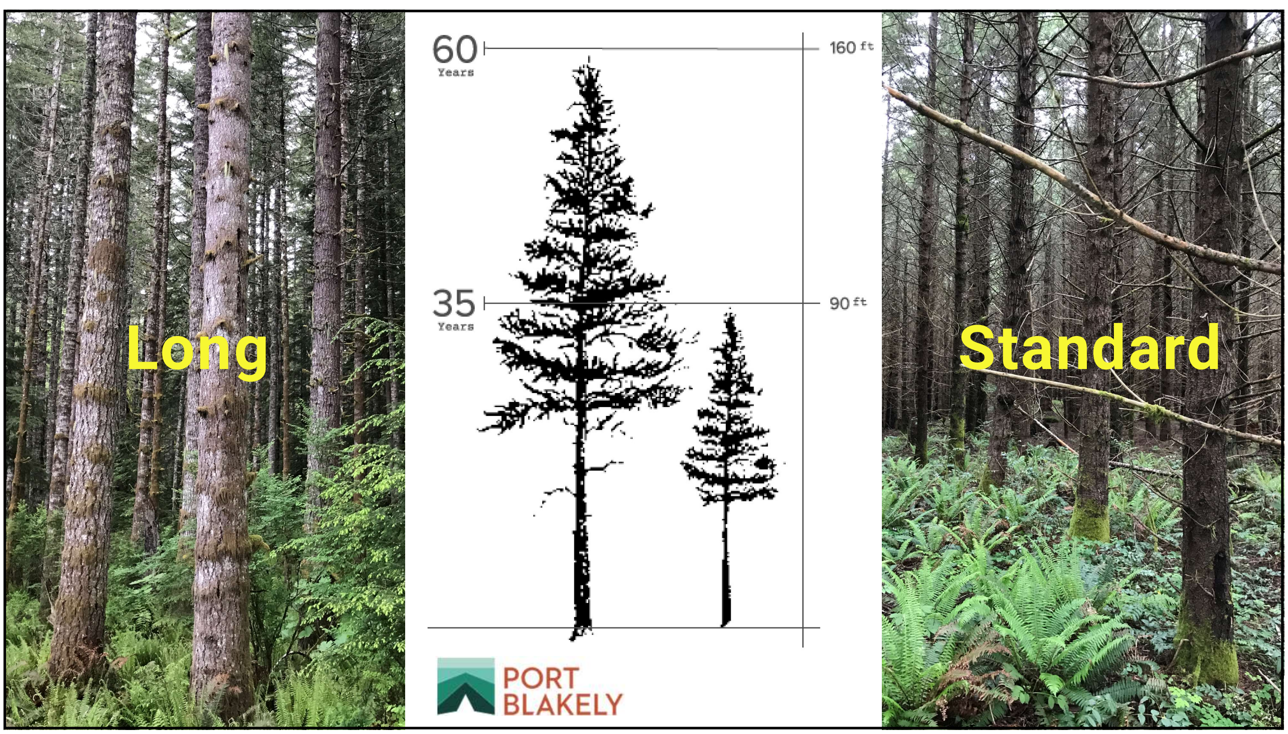
Joe Mayo, AIA LEED AP
Mahlum Architects

The Pacific Northwest

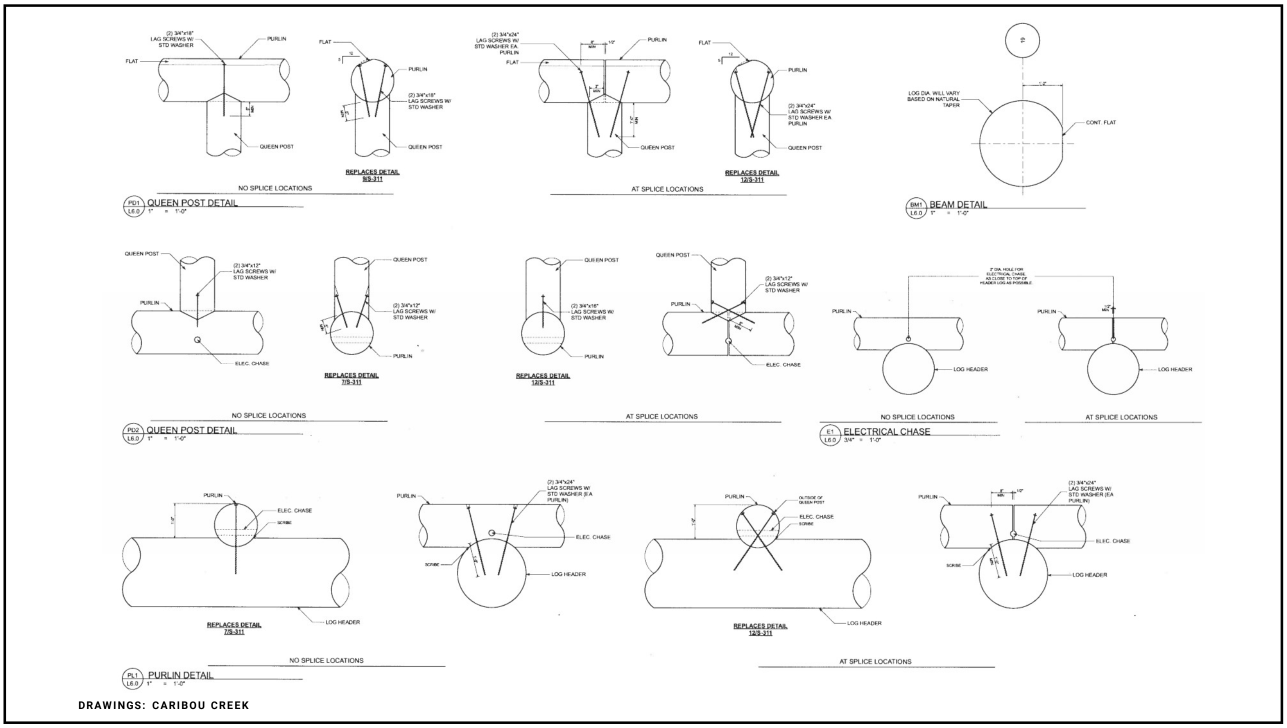
Can a building embody a culture? (in the age of climate change)

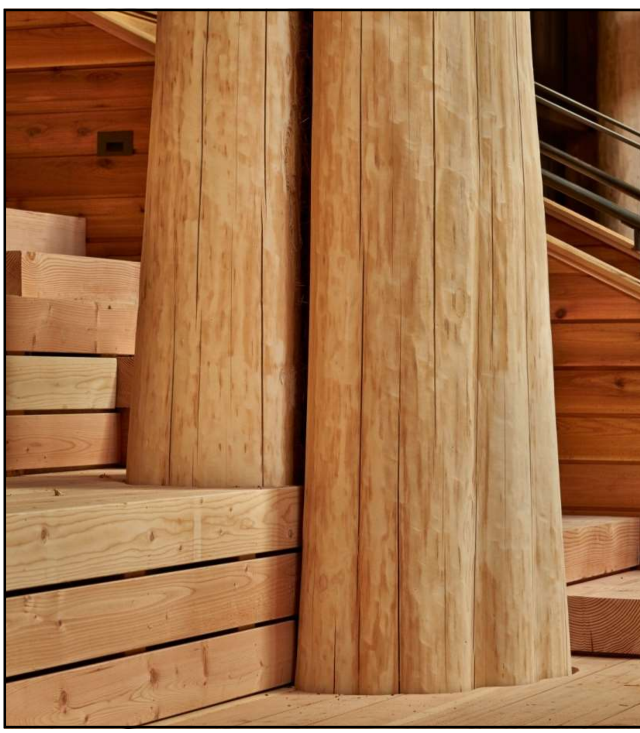


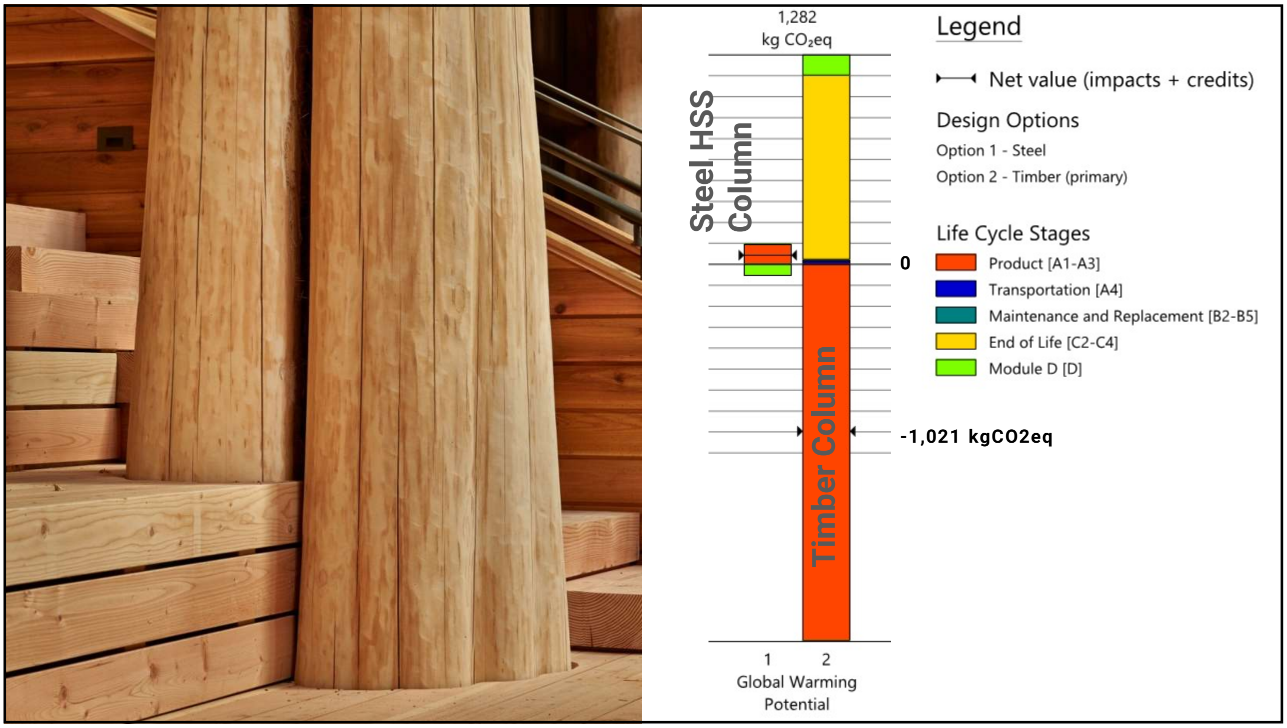

300 FT
Mineral Tree
~18,190 ft3
Queets Fir
11,710 ft3
Tichipawa
10,870 ft3
Rex
10,200 ft3
Ol' Jed
10,040 ft3
Cedar Flats Sentinel
9,350 ft3
Quamal
9,350 ft3
Gatton Goliath
9,080 ft3
Indian Pass Tree
9,060 ft3
Mauksa
8,740 ft3
SOURCE: FOREST GIANTS OF THE PACIFIC COAST, VAN PELT 2001

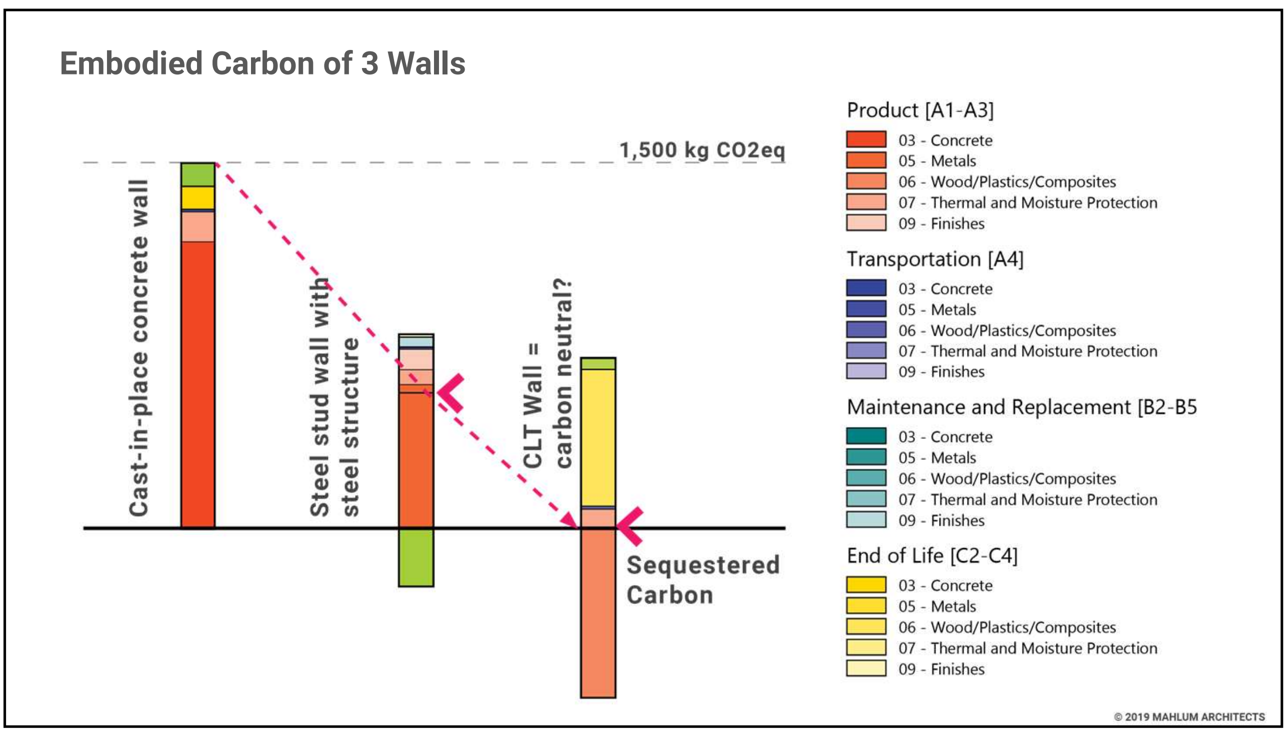

Long
60 Years
160 ft
35 Years
90 ft
PORT BLAKELY
Standard


© MAHLUM


NO SPLICE LOCATIONS
AT SPLICE LOCATIONS
QUEEN POST DETAIL
BEAM DETAIL
QUEEN POST DETAIL
ELECTRICAL CHASE
PURLIN DETAIL
DRAWINGS: CARIBOU CREEK




1,282
kg CO₂eq
Steel HSS Column
Timber Column
0
-1,021 kgCO2eq
1
2
Global Warming Potential
Legend
Net value (impacts + credits)
Design Options
Option 1 - Steel
Option 2 - Timber (primary)
Life Cycle Stages
Product [A1-A3]
Transportation [A4]
Maintenance and Replacement [B2-B5]
End of Life [C2-C4]
Module D [D]


Embodied Carbon of 3 Walls
1,500 kg CO2eq
Cast-in-place concrete wall
Steel stud wall with steel structure
CLT Wall = carbon neutral?
Sequestered Carbon
Product [A1-A3]
03 - Concrete
05 - Metals
06 - Wood/Plastics/Composites
07 - Thermal and Moisture Protection
09 - Finishes
Transportation [A4]
03 - Concrete
05 - Metals
06 - Wood/Plastics/Composites
07 - Thermal and Moisture Protection
09 - Finishes
Maintenance and Replacement [B2-B5
03 - Concrete
05 - Metals
06 - Wood/Plastics/Composites
07 - Thermal and Moisture Protection
09 - Finishes
End of Life [C2-C4]
03 - Concrete
05 - Metals
06 - Wood/Plastics/Composites
07 - Thermal and Moisture Protection
09 - Finishes
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Richard Woodcock Center for Education

How do we actually use CLT?

2015-2016

At-a-Glance

Location:
Western Oregon University, Monmouth, Oregon

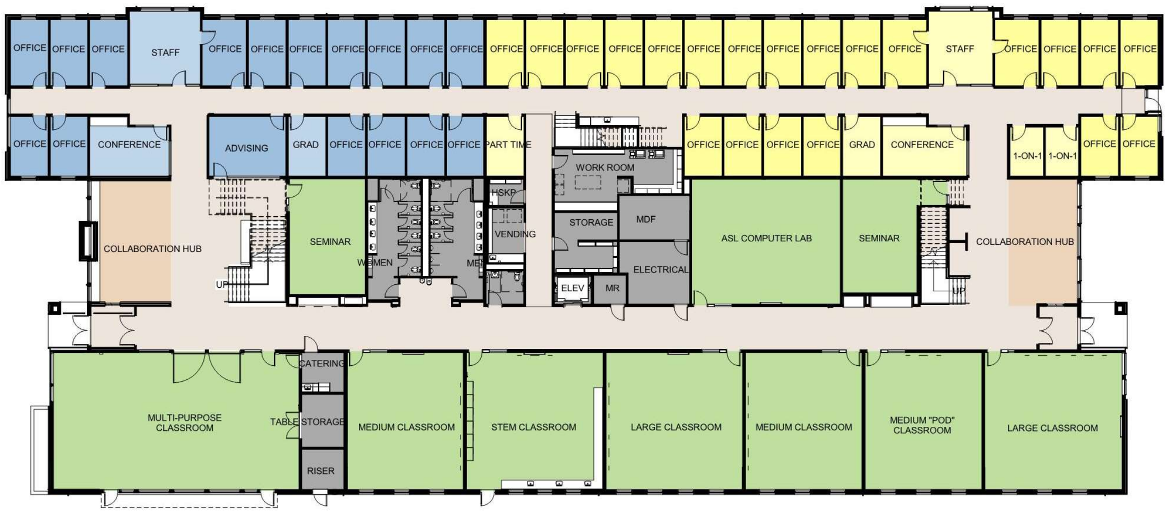
Area:
52,000 SF

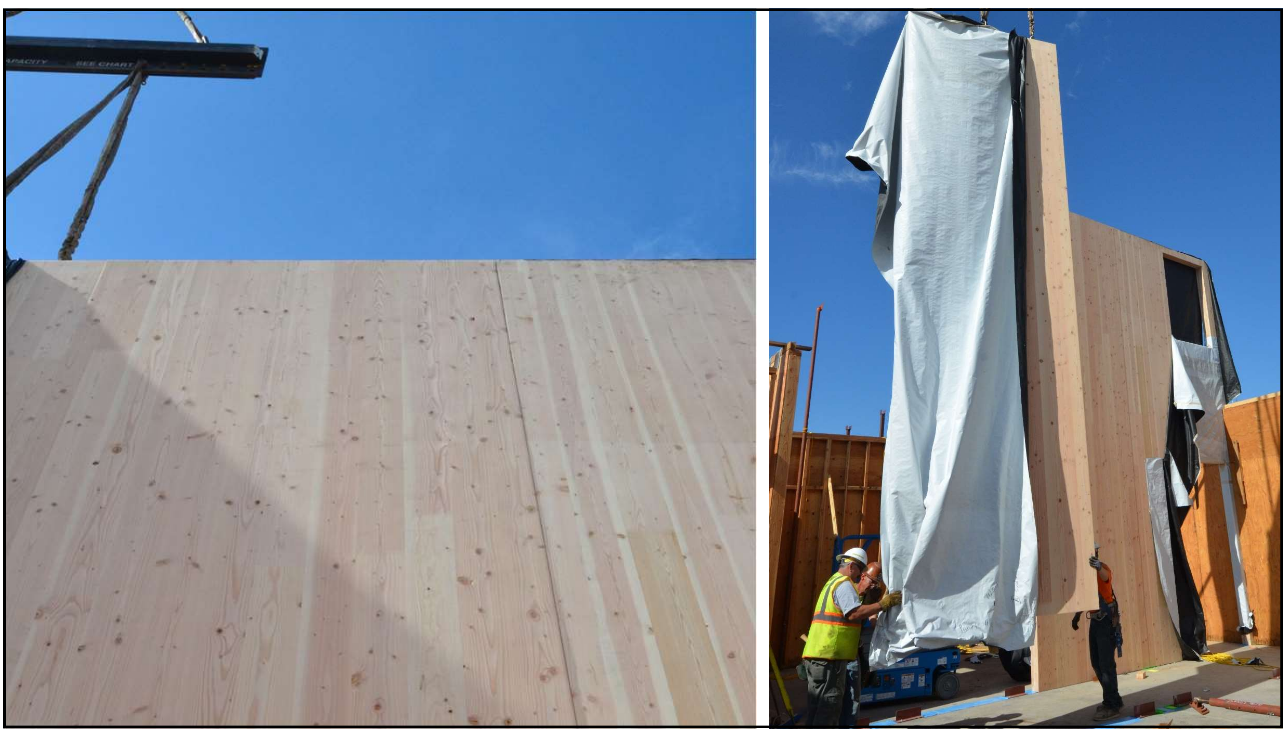
Height:
2-stories (~45' tall)

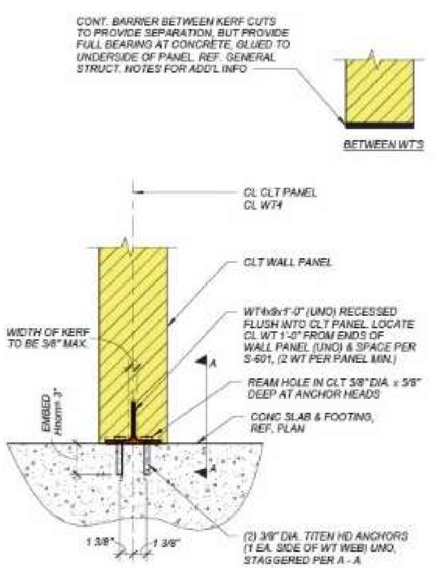
Occupancy: **B**

Construction:
Type VB

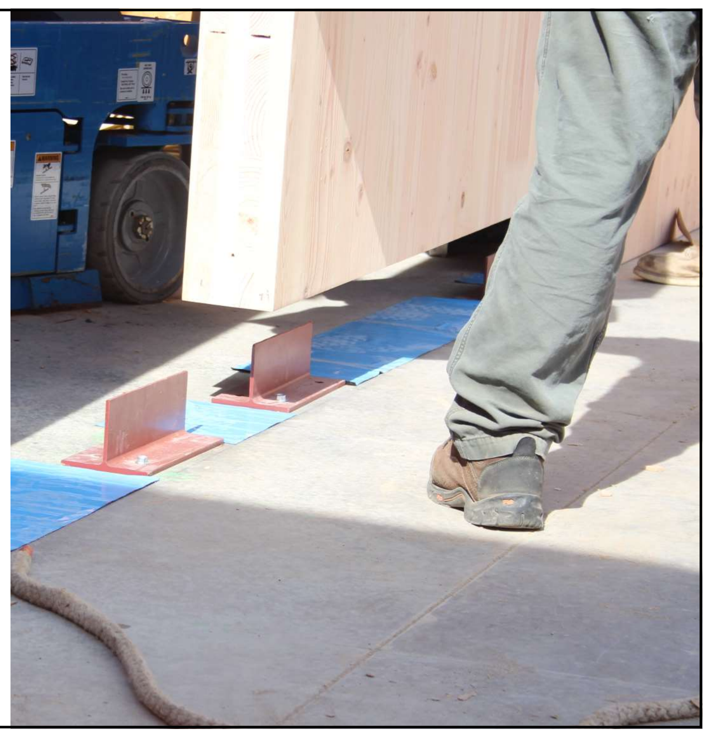
First Level Floor Plan

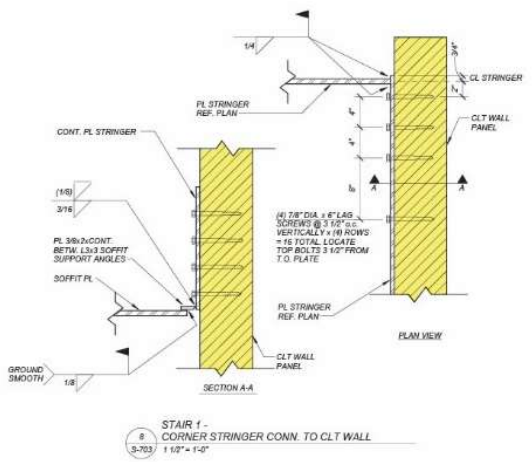






DRAWINGS: EQUILIBRIUM ENGINEERS

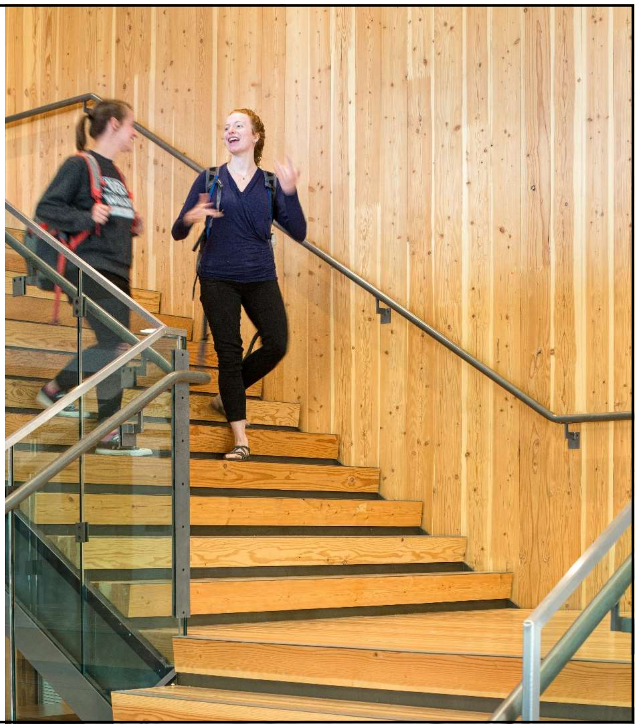




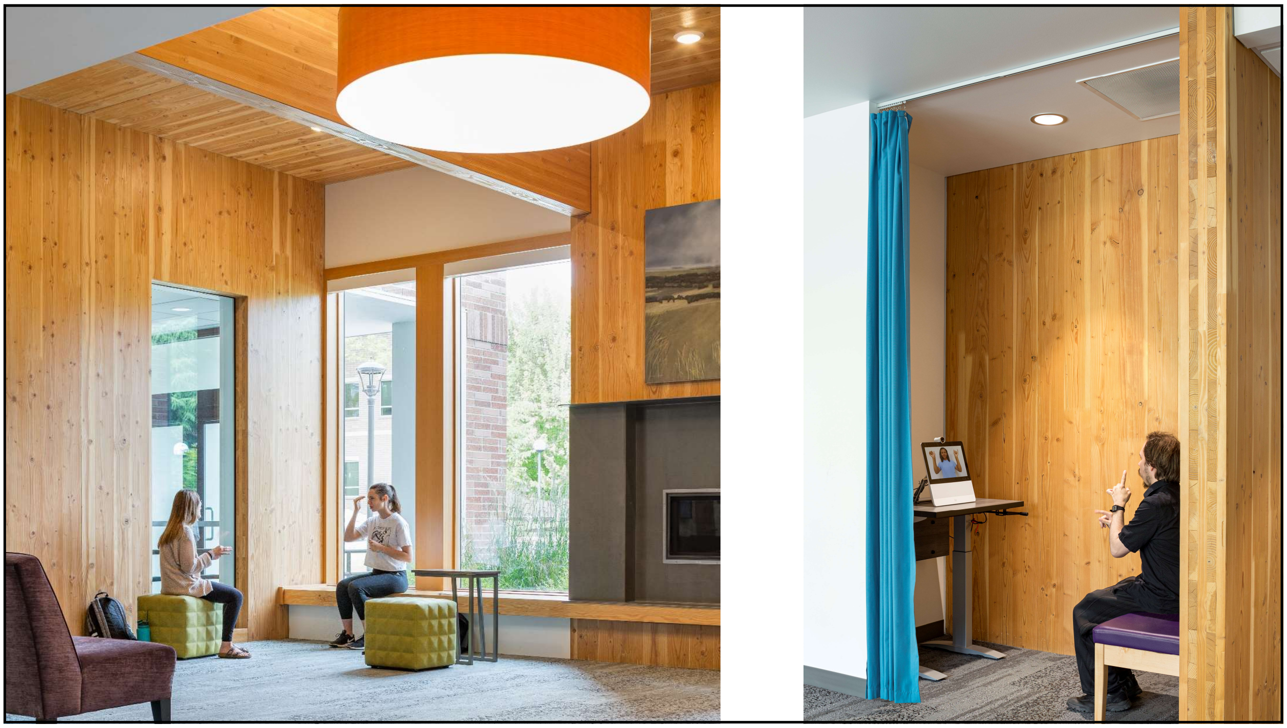
ABOVE: EQUILIBRIUM ENGINEERS

ABOVE: MAHLUM

PHOTO: DJ JOHNSON



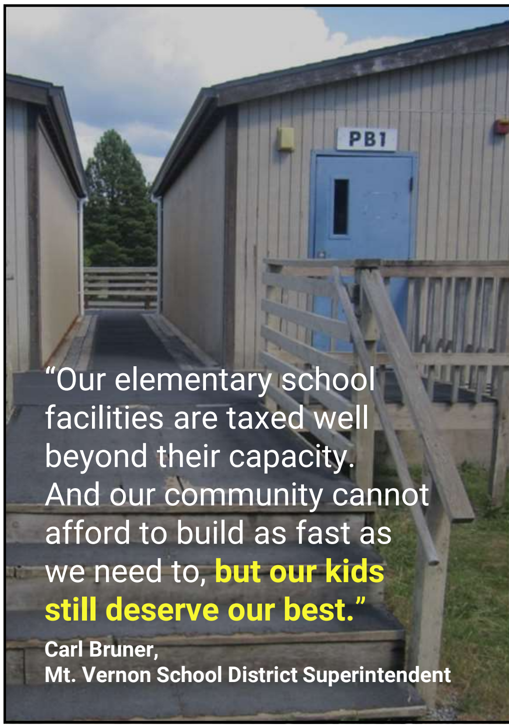

Challenges



CLT Pilot Program Classrooms

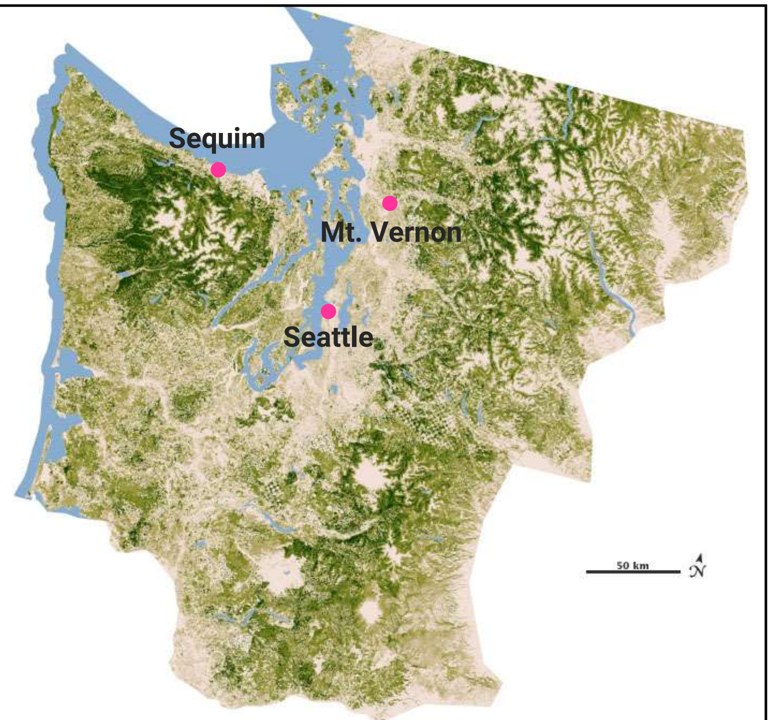
Can a small project be a catalyst to revitalize Washington State's rural economy?

2016-2017



"Our elementary school facilities are taxed well beyond their capacity. And our community cannot afford to build as fast as we need to, **but our kids still deserve our best."**

Carl Bruner,
Mt. Vernon School District Superintendent



At-a-Glance

3 unique school districts and sites

Provided appropriation:
About $250K per classroom
(Comparable to a portable)

Provide improved learning environment and durability

Reduce K-3 class size
(Students per teacher ratio)

Utilize as much CLT as possible

Test Progressive Design-Build Project Delivery Method

Fast-track schedule:
13 months to design, document and build 3 classroom buildings

Interior Environment: Flexibility

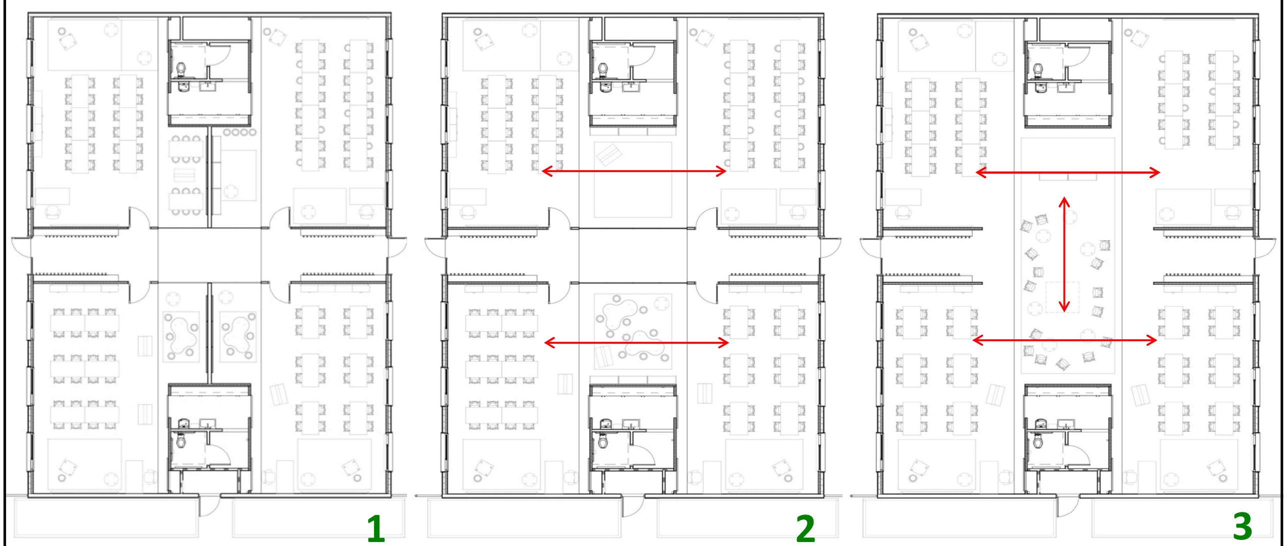
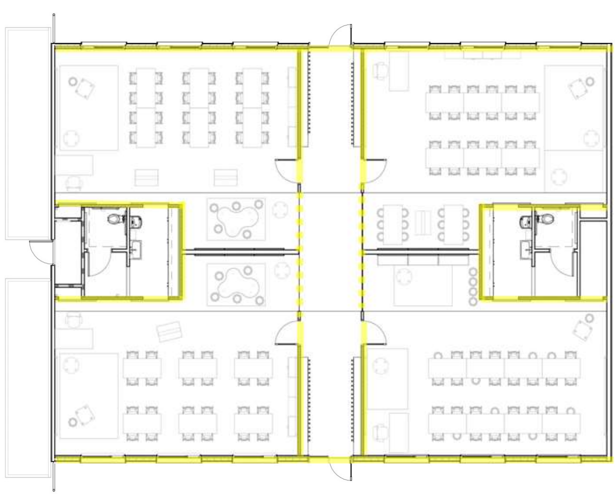


IMAGE: MAHLUM

CLT Elements



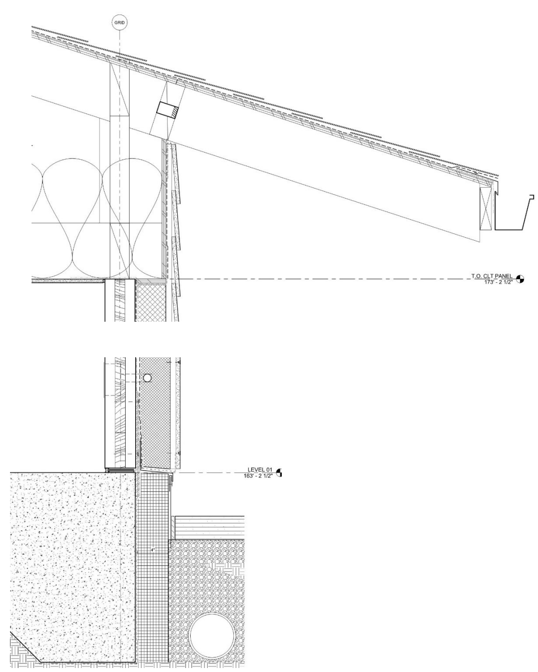
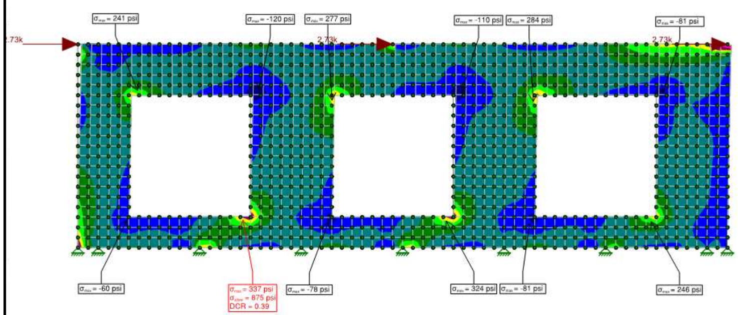


IMAGE: MAHLUM

Structural: CLT as Lateral Force Resisting System



2

SHEAR WALLS AND DIAPHRAGMS

Resistance to lateral loads from wind and earthquakes in CLT structures is made through wall and floor panels designed as shear walls and diaphragms. Unlike typical wood-frame shear wall and diaphragm systems, which have design unit shear strength prescribed based on a specific construction (AWC, 2008), the design shear strength of CLT shear walls and diaphragms is determined directly based on principles of engineering mechanics using provisions of the National Design Specification (NDS) for Wood Construction (AWC, 2012) for connection design (see Chapter 5 entitled *Connections in cross-laminated timber buildings*) and CLT panel design (see Chapter 3 entitled *Structural design of cross-laminated timber elements*). The unit shear strength of the CLT shear wall and CLT diaphragm will vary by factors such as fastener size, spacing, and location as well as the shear strength of the CLT panel itself. Deflection estimates based on principles of engineering mechanics or derived from testing should account for all sources of deflection including panel bending, panel and/or connector shear, and fastener deformation.

Capacity design principles are recommended for design of CLT for seismic resistance to ensure predictable yielding in CLT wall panels and interconnection of CLT elements through fastener yielding, wood crushing, or a combination thereof prior to onset of undesirable brittle wood failure modes. This approach recognizes that wall panel-to-panel and panel-to-floor connections provide the primary source of yielding, while the wood wall panels themselves remain essentially elastic. Special seismic detailing of the CLT seismic force resisting system includes the following:

See page 3

a) Fastener Requirements. Fasteners loaded in shear are designed such that the expected fastener yield mode is Mode III or Mode IV as defined in the NDS.

b) CLT Member Design at Connections. The nominal connection capacity determined in accordance with Item c) is used as the minimum design demand for any wood member limit states.

c) Nominal Connection Capacity. The nominal connection capacity in shear is determined in accordance with the following:

For dowel type fasteners -- $n \times Z(K_F)(l)(C_M)(C_t)(C_{eg})$ where n is the number of fasteners; Z is the reference lateral design value for a single fastener; and K_F, l, C_M, C_t, and C_{eg} are adjustment factors specified in the NDS for format conversion, time effect, wet service, temperature and end grain, respectively.

d) Fastener Withdrawal. Where a connector relies directly on fastener withdrawal for load resistance, testing shall demonstrate that the fasteners can develop substantial yielding in the connector prior to full fastener withdrawal.

IMAGE: COUGHLIN PORTER LUNDEEN

Local Wood

Interfor Mill, Port Angeles, Washington

IMAGE: INTERFOR MILL


PHOTO: FORTERRA


PHOTO: MAHLUM

PHOTOS: WALSH

PHOTO: MAHLUM

Cost: State-Wide Study (2017)

WASHINGTON STATE OFFICE OF THE SUPERINTENDENT OF PUBLIC INSTRUCTION
K-12 CAPITAL FACILITIES COST STUDY

4.2 WASHINGTON STATE COST RANGE BY SCHOOL TYPE

Based on the cost range by space program, a statewide average range of construction costs were developed for each school type. Construction costs exclude Washington State sales tax, site costs, and indirect costs. A project allowance has been added to the table below to reach the total project cost that includes a range of typical site costs and indirect costs. Costs outside of the typical range for special or extraordinary conditions are not included.

NEW DIRECT CONSTRUCTION*	Elementary		Middle		High	
	Low Cost/GSF	High Cost/GSF	Low Cost/GSF	High Cost/GSF	Low Cost/GSF	High Cost/GSF
Washington State Average	$230	$309	$246	$326	$265	$344
Add Site Costs Allowance	10.0%	12.0%	10.0%	15.0%	10.0%	15.0%
Add Indirect Costs Allowance	25.0%	30.0%	30.0%	35.0%	30.0%	35.0%
	$316	**$450**				

Cost: CLT Classrooms vs Portables (2017)

CLT CLASSROOMS COST DATA

	CLT Classrooms w/o site utilities (west side projects in Washington)	CLT Classrooms w/ site utilities (west side projects in Washington)	Traditional Modular (estimate)
Project Cost	$2,758,000	$2,978,000	-
Markups	$137,900	$148,900	-
Total	$2,895,900	$3,126,900	-
Per Building	$965,300	$1,042,300	-
Per Classroom	$241,325	$260,575	~$250,000
Cost/SF (building)	$247.51	$267.26	-

VIDEO: YOUTUBE
BETHEL SCHOOL DISTRICT

Western Washington University

Can CLT expedite housing construction?

2019-Current

At-a-Glance

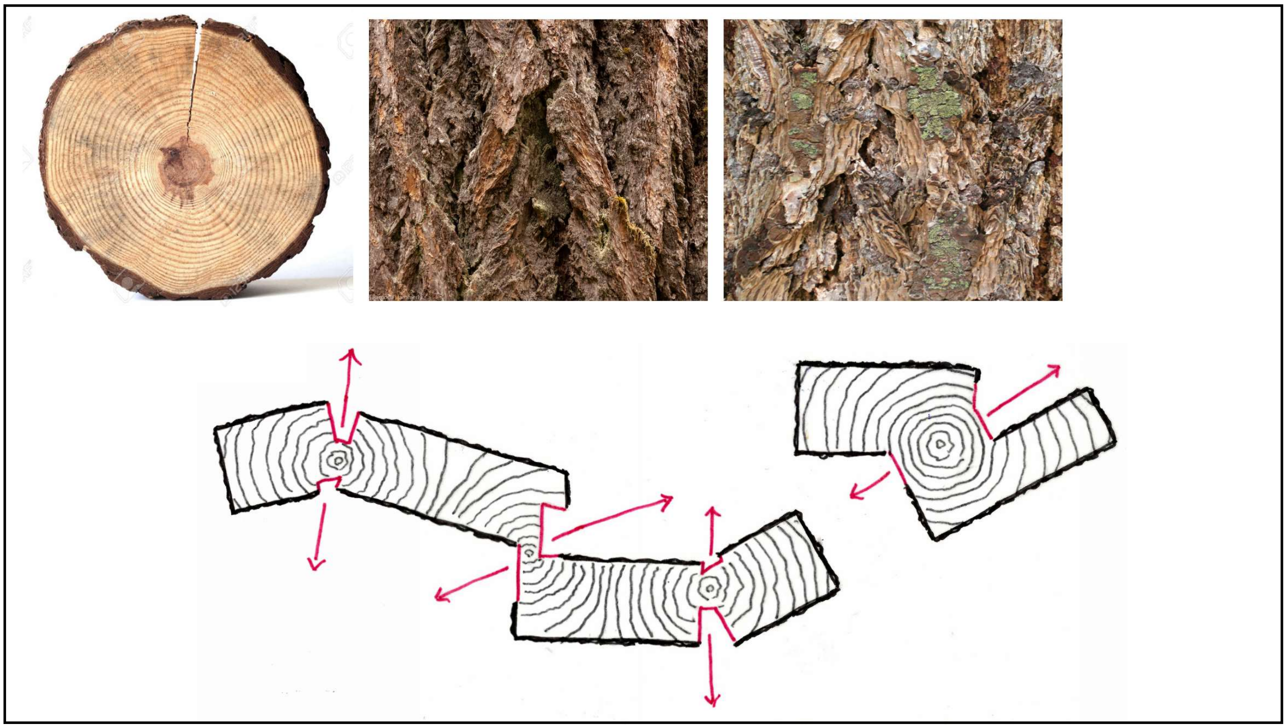
Location:
Bellingham, Washington

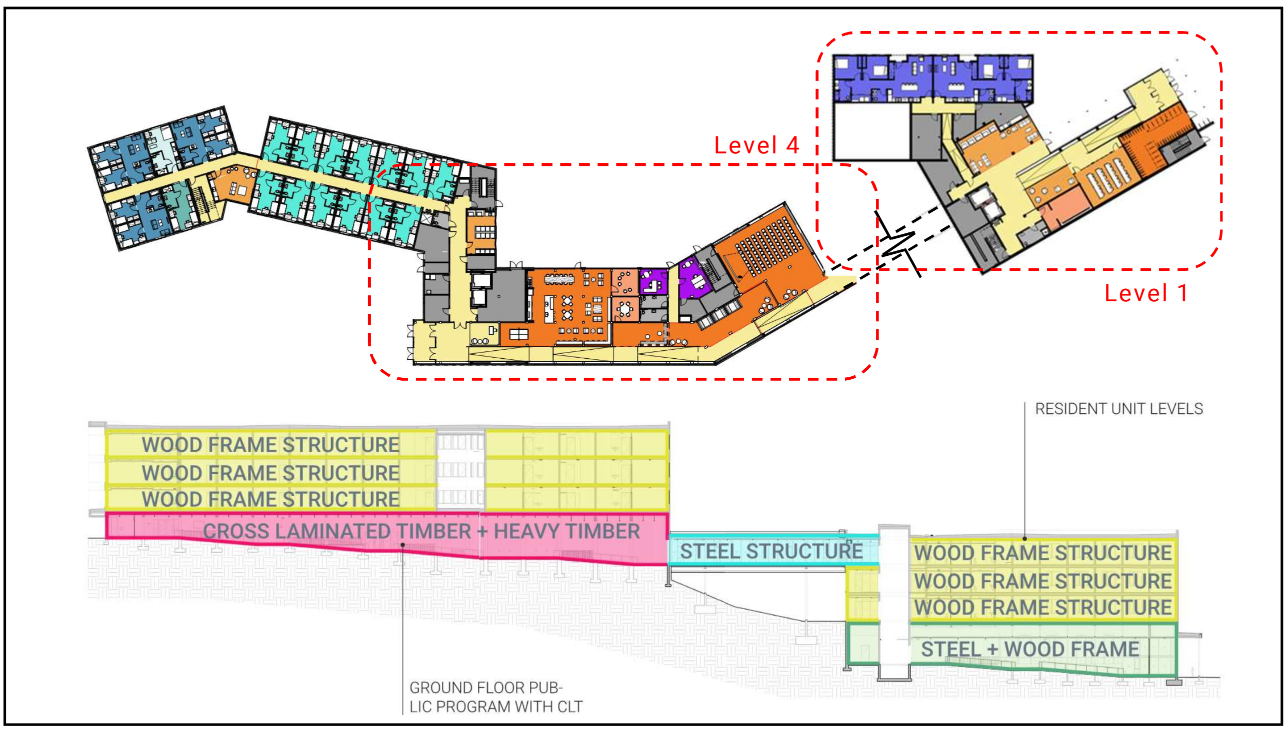
Area:
110,300 SF

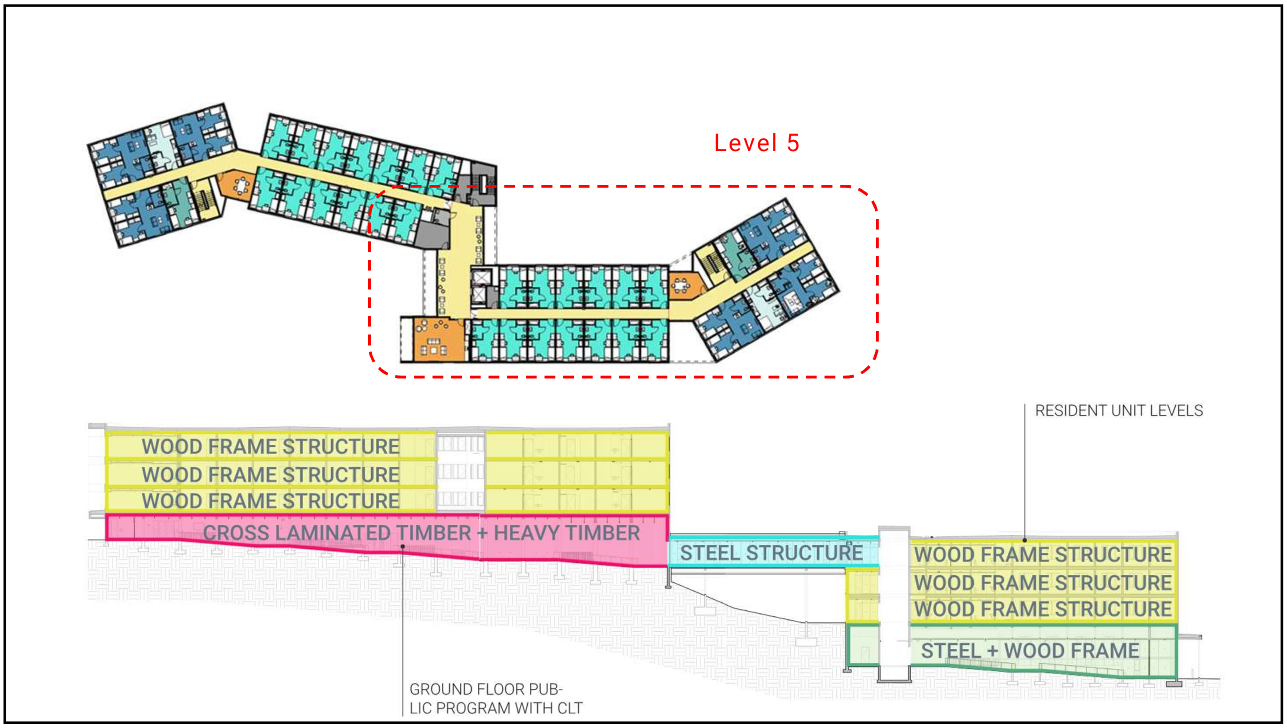
Height:
7-stories (~55-60' tall)

Occupancy: **R-2**

Construction Type: **VA**

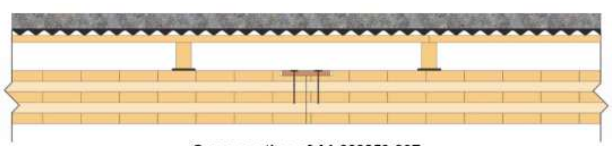



Level 4
Level 1
RESIDENT UNIT LEVELS
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
CROSS LAMINATED TIMBER + HEAVY TIMBER
STEEL STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
STEEL + WOOD FRAME
GROUND FLOOR PUB-
LIC PROGRAM WITH CLT


Level 5
RESIDENT UNIT LEVELS
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
CROSS LAMINATED TIMBER + HEAVY TIMBER
STEEL STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
WOOD FRAME STRUCTURE
STEEL + WOOD FRAME
GROUND FLOOR PUB-
LIC PROGRAM WITH CLT

Tested Assembly: STC 59 (1.5” concrete)
Proposed Assembly: STC 56 (1.5” gypcrete)

HOUSING



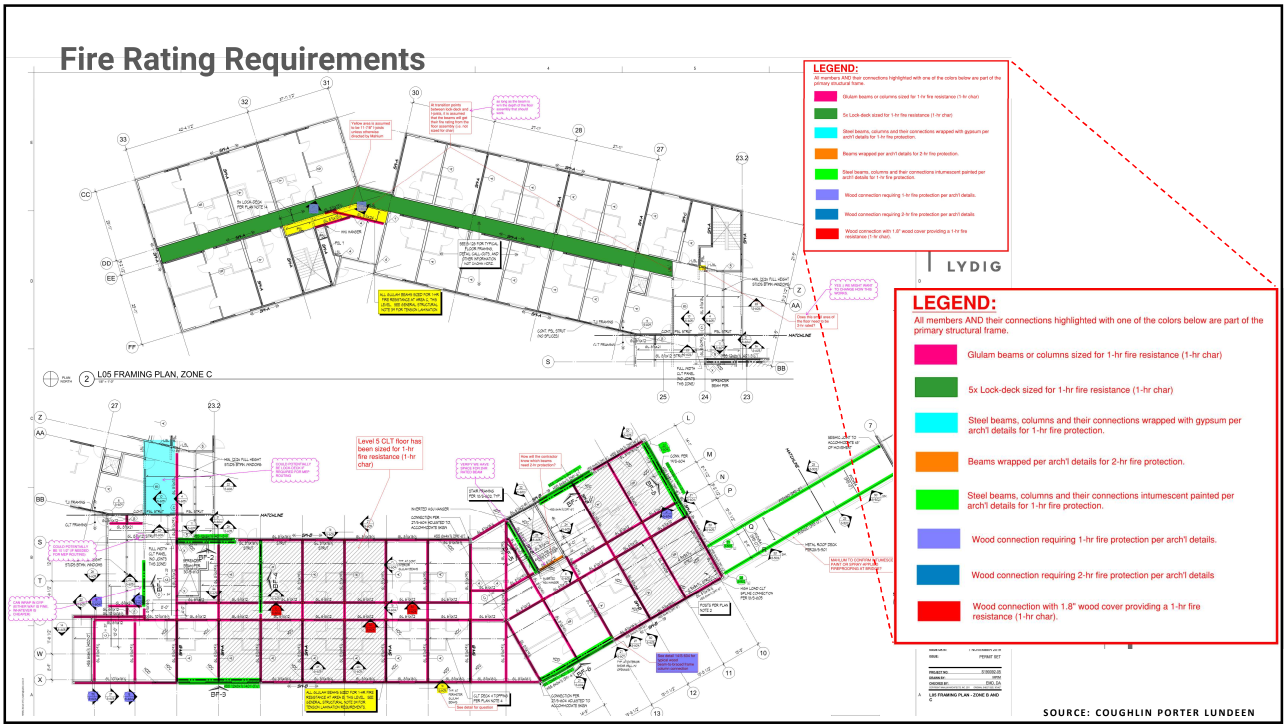
Cross-section of A1-008253-30F

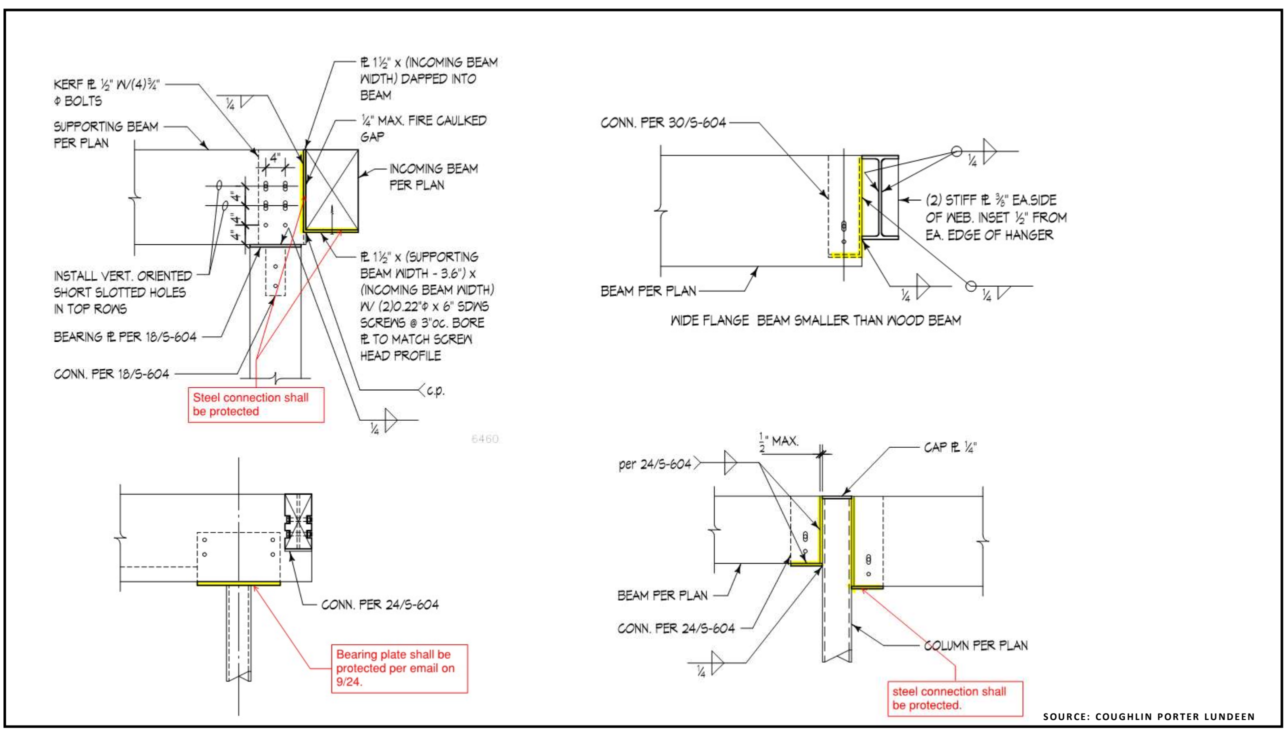
LOUNGE

Specimen Properties

Element	Actual thickness (mm)	Mass (kg)	Mass/length, area or volume
38 mm Precast Concrete Slab	38	1 905	98.6 kg/m^2
17 mm Regupol® SonusWave™	17	157	8.1 kg/m^2
18 mm OSB Tongue and Groove Sheeting	18	202	10.5 kg/m^2
38 mm x 64 mm Wood Battens	64	47	0.3 kg/m
10 mm Rubber Membrane	10	21	7.7 kg/m^2
131 mm CLT 5 ply	131	1 343	69.3 kg/m^2
Total	**278**	**3 675**	**190.2 kg/m^2**

SOURCE: A3 ACOUSTICS


Fire Rating Requirements
L05 FRAMING PLAN, ZONE C
Level 5 CLT floor has been sized for 1-hr fire resistance (1-hr char)
LYDIG
LEGEND:
All members AND their connections highlighted with one of the colors below are part of the primary structural frame.
Glulam beams or columns sized for 1-hr fire resistance (1-hr char)
5x Lock-deck sized for 1-hr fire resistance (1-hr char)
Steel beams, columns and their connections wrapped with gypsum per arch'l details for 1-hr fire protection.
Beams wrapped per arch'l details for 2-hr fire protection.
Steel beams, columns and their connections intumescent painted per arch'l details for 1-hr fire protection.
Wood connection requiring 1-hr fire protection per arch'l details.
Wood connection requiring 2-hr fire protection per arch'l details
Wood connection with 1.8" wood cover providing a 1-hr fire resistance (1-hr char).
SOURCE: COUGHLIN PORTER LUNDEEN


KERF PL ½" W/(4)¾" Φ BOLTS
SUPPORTING BEAM PER PLAN
PL 1½" x (INCOMING BEAM WIDTH) DAPPED INTO BEAM
¼" MAX. FIRE CAULKED GAP
INCOMING BEAM PER PLAN
INSTALL VERT. ORIENTED SHORT SLOTTED HOLES IN TOP ROWS
BEARING PL PER 18/S-604
CONN. PER 18/S-604
PL 1½" x (SUPPORTING BEAM WIDTH - 3.6") x (INCOMING BEAM WIDTH) W/ (2)0.22"Φ x 6" SDWS SCREWS @ 3"oc. BORE PL TO MATCH SCREW HEAD PROFILE
c.p.
Steel connection shall be protected
CONN. PER 30/S-604
(2) STIFF PL ⅜" EA.SIDE OF WEB. INSET ½" FROM EA. EDGE OF HANGER
BEAM PER PLAN
WIDE FLANGE BEAM SMALLER THAN WOOD BEAM
CONN. PER 24/S-604
Bearing plate shall be protected per email on 9/24.
per 24/S-604
½" MAX.
CAP PL ¼"
BEAM PER PLAN
CONN. PER 24/S-604
COLUMN PER PLAN
steel connection shall be protected.
SOURCE: COUGHLIN PORTER LUNDEEN

Kellogg Middle School

First Acoustic DLT Installation in the U.S.

2017-Current

At-a-Glance

Location:
Shoreline, Washington

Area:
152,000 SF (separated into two buildings)

Height:
2-stories (~45' tall)

Occupancy: **E**

Construction: **Type IIB**

NRC = 0.70

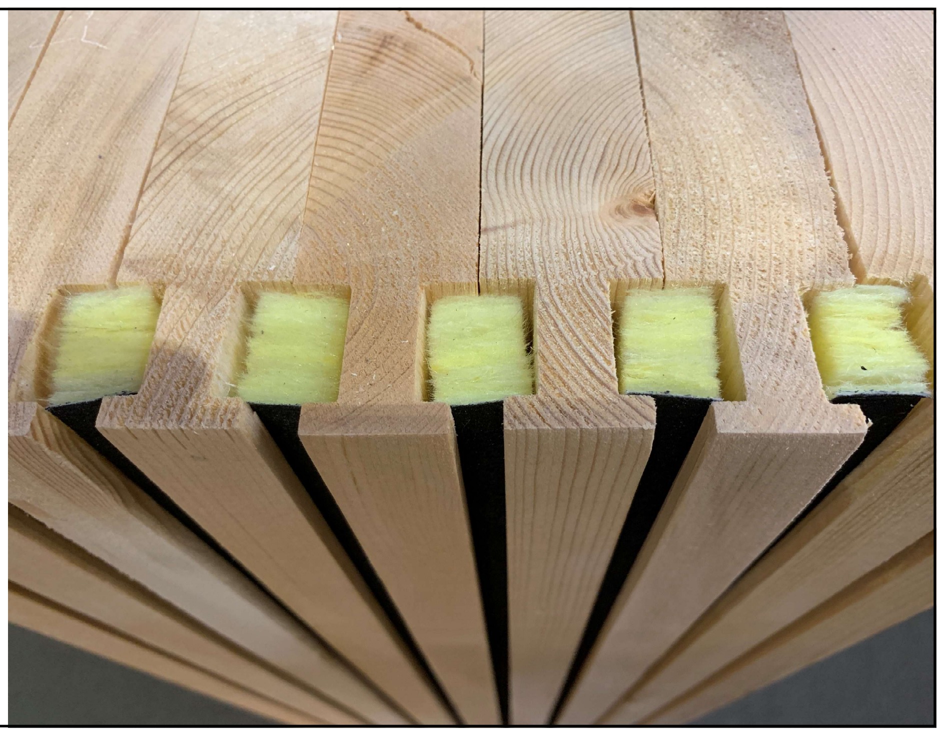


PHOTO: MAHLUM


RENDERING: MAHLUM


RENDERING: MAHLUM


PHOTO: MAHLUM

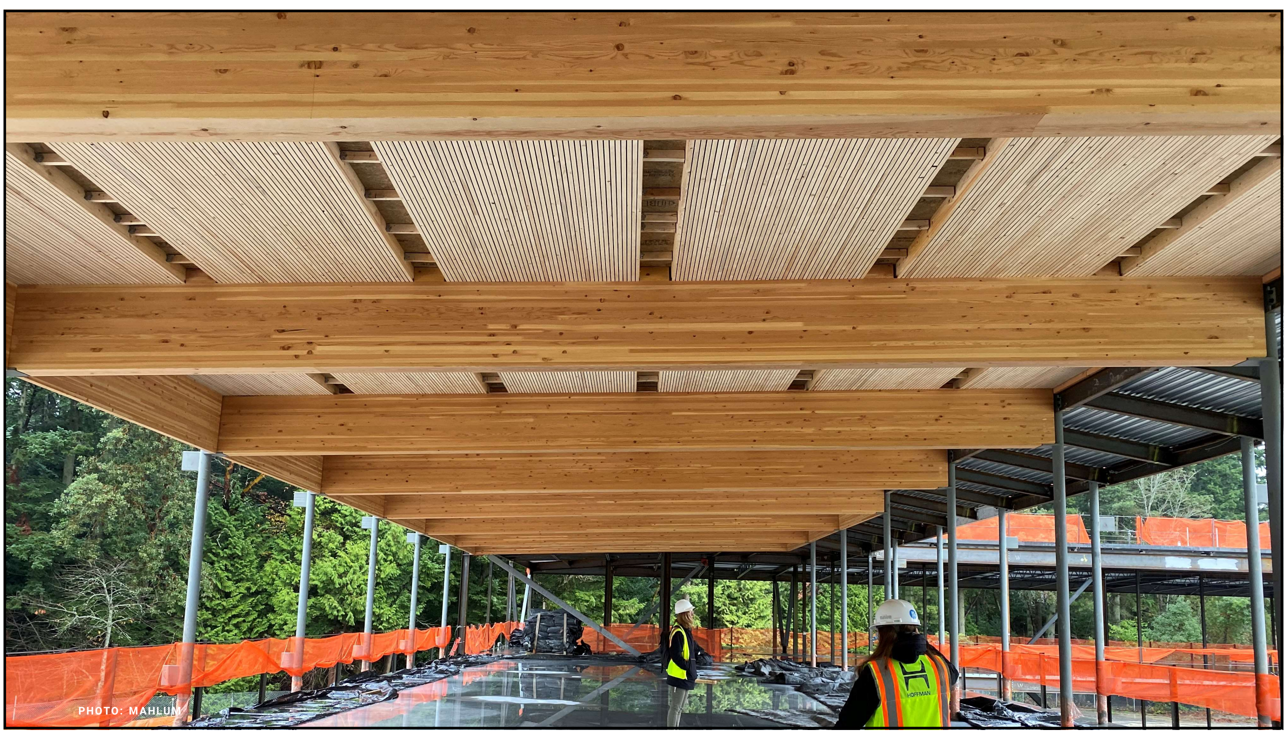


PHOTO: MAHLUM

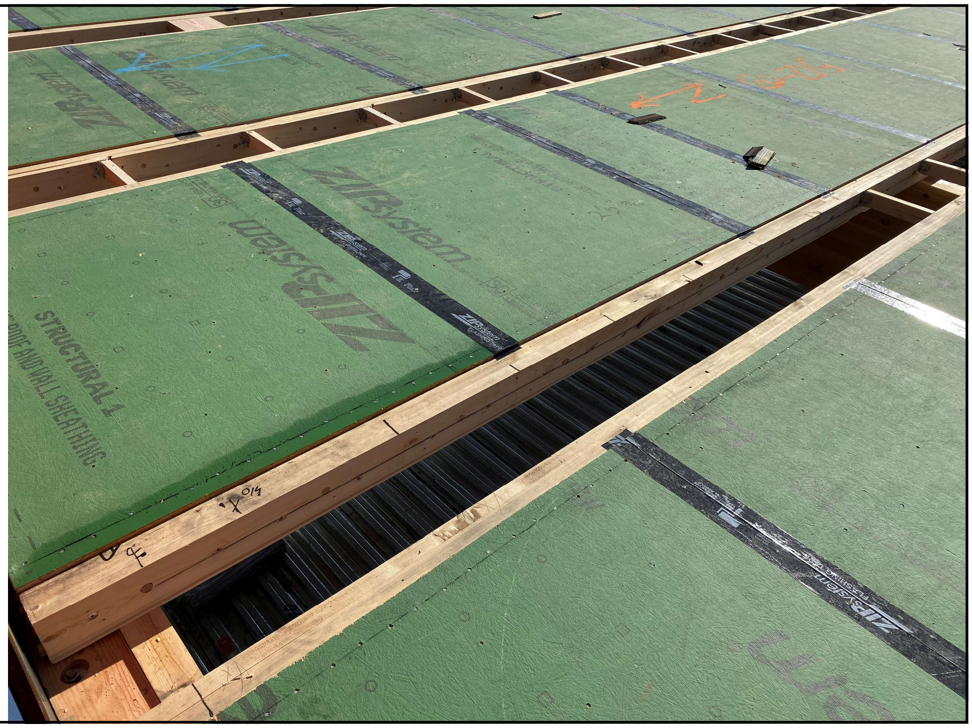
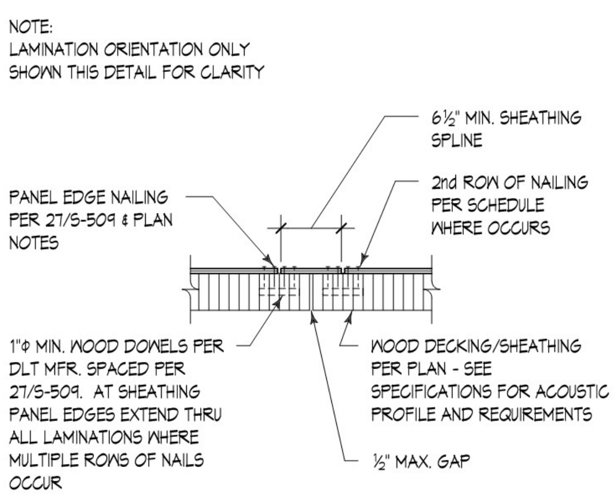


PHOTO: MAHLUM



DLT DECKING SPLICE

DRAWING: COUGHLIN PORTER LUNDEEN

Design

DIAPHRAGM SHEATHING NAILING SCHEDULE				
ZONE	PANEL EDGE NAILING SPACING		SWG SCREW SPACING	WOOD DOWEL SPACING
	a	b		
	6"oc	6"oc	12"oc	18"oc
	3"oc	4"oc	12"oc	15"oc
	2½"oc	2½"oc	7½"oc	10"oc
	(2) ROWS @ 3"oc	(2) ROWS @ 4"oc	6"oc	8"oc

CHART: COUGHLIN PORTER LUNDEEN

Shop Drawing

DIAPHRAGM SHEATHING NAILING SCHEDULE			SCREW REINFORCING SCHEDULE	
ZONE	PANEL EDGE NAILING SPACING	SCREW SPACING	SCREW REINFORCING AT SPLINE ASSY VG (FT-CL) Ø5/16" x 9 1/2"	SCREW REINFORCING AT BUILDING EDGE ASSY VG (FT-CL) Ø3/8" x 11 3/4"
	A			
	6" O.C	12" O.C	11" O.C. @45 DEG ALTERNATE	18" O.C. @90 DEG INTO SIDE OF PANEL. SCREWS TO BE ALIGNED WITH DOWELS
	3" O.C	12" O.C	9" O.C. @45 DEG ALTERNATE	
	2-1/2" O.C	7-1/2" O.C	5" O.C. @45 DEG ALTERNATE	
	(2) ROWS @ 3" O.C	6" O.C	10" O.C. @45 DEG ALTERNATE	

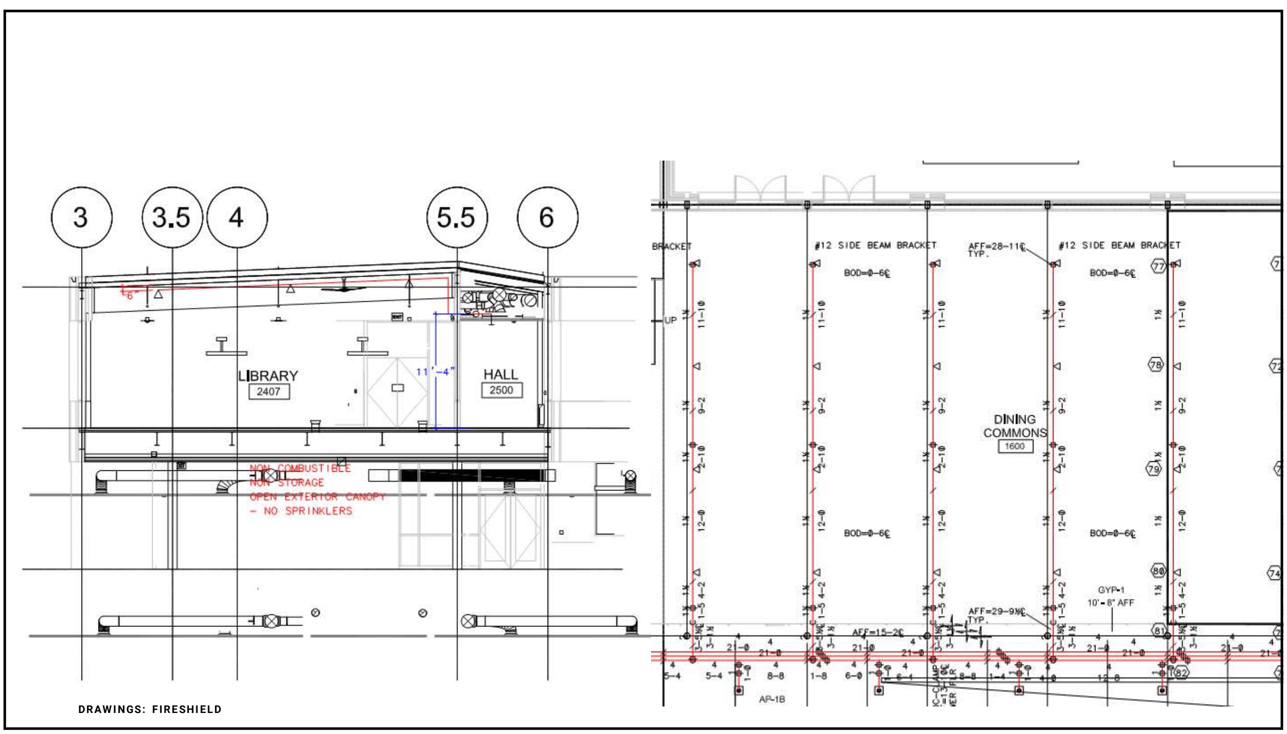
NOTES:

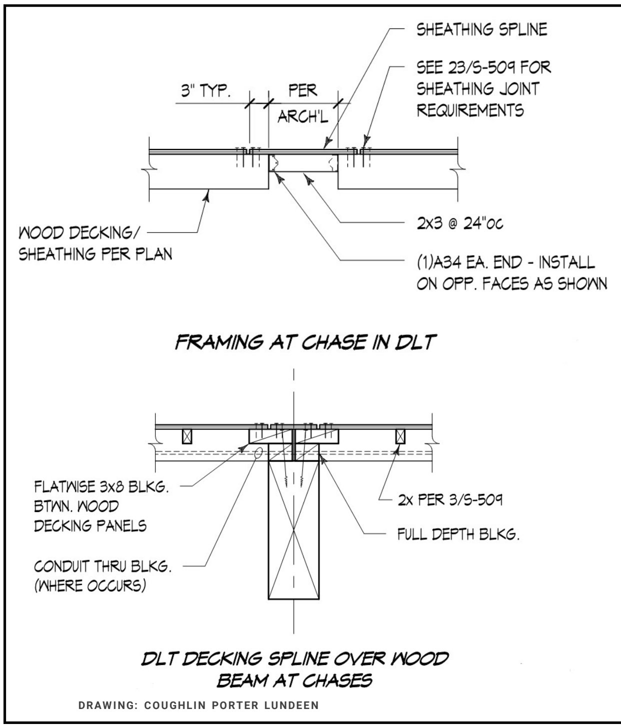
1. NAIL SHEATHING AT ALL PANEL EDGES W/ 10d SPACED PER THE DIAPHRAGM SHEATHING SCHEDULE. FIELD NAIL ALL PANELS W/ 10d @ 12" O.C EA WAY.
2. SWG SCREWS SHALL BE INSTALLED IN THE CENTER OF DLT LAMINATIONS

DRAWING: STRUCTURCRAFT

CHART: STRUCTURCRAFT


PHOTOS: MAHLUM


3
3.5
4
5.5
6
LIBRARY
2407
HALL
2500
11'-4"
NON COMBUSTIBLE
NON STORAGE
OPEN EXTERIOR CANOPY
- NO SPRINKLERS
BRACKET
#12 SIDE BEAM BRACKET
AFF=28-11¢
TYP.
BOD=0-6¢
DINING
COMMONS
1600
GYP-1
10'-8" AFF
AFF=29-9½¢
AFF=15-2¢
AP-1B
DRAWINGS: FIRESHIELD



Lakeridge Junior High School

DLT and WholeTrees

2018-Current

At-a-Glance

Location:
Lake Oswego, Oregon

Area:
141,000 SF (separated into four buildings)

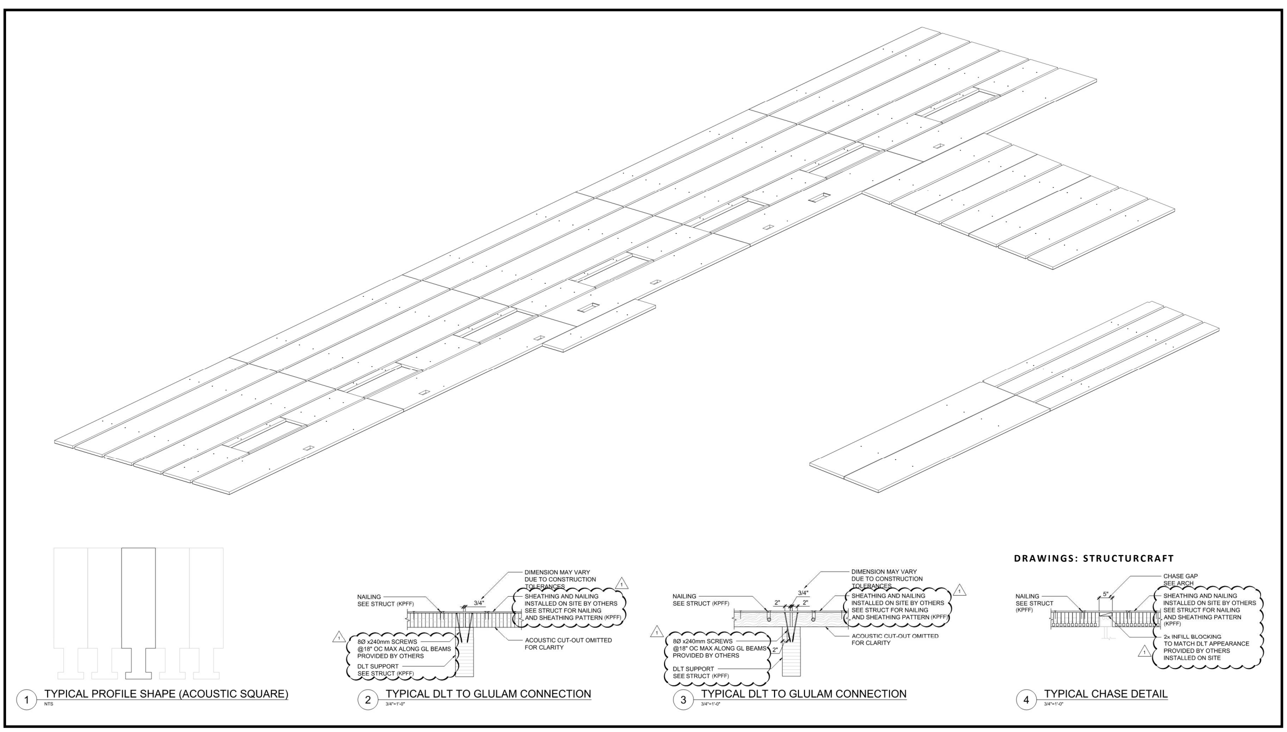
Height:
2-stories

- ~32’ tall classroom bars
- 36’ tall Gym

Occupancy: **E**

Construction: **Type VB**


RENDERING: MAHLUM


DRAWINGS: STRUCTURCRAFT
1 TYPICAL PROFILE SHAPE (ACOUSTIC SQUARE)
NTS
2 TYPICAL DLT TO GLULAM CONNECTION
3/4"=1'-0"
DIMENSION MAY VARY DUE TO CONSTRUCTION TOLERANCES
NAILING SEE STRUCT (KPFF)
3/4"
SHEATHING AND NAILING INSTALLED ON SITE BY OTHERS SEE STRUCT FOR NAILING AND SHEATHING PATTERN (KPFF)
8Ø x240mm SCREWS @18" OC MAX ALONG GL BEAMS PROVIDED BY OTHERS
DLT SUPPORT SEE STRUCT (KPFF)
ACOUSTIC CUT-OUT OMITTED FOR CLARITY
3 TYPICAL DLT TO GLULAM CONNECTION
3/4"=1'-0"
DIMENSION MAY VARY DUE TO CONSTRUCTION TOLERANCES
NAILING SEE STRUCT (KPFF)
3/4"
2"
2"
SHEATHING AND NAILING INSTALLED ON SITE BY OTHERS SEE STRUCT FOR NAILING AND SHEATHING PATTERN (KPFF)
8Ø x240mm SCREWS @18" OC MAX ALONG GL BEAMS PROVIDED BY OTHERS
2"
DLT SUPPORT SEE STRUCT (KPFF)
ACOUSTIC CUT-OUT OMITTED FOR CLARITY
4 TYPICAL CHASE DETAIL
3/4"=1'-0"
NAILING SEE STRUCT (KPFF)
5"
CHASE GAP SEE ARCH
SHEATHING AND NAILING INSTALLED ON SITE BY OTHERS SEE STRUCT FOR NAILING AND SHEATHING PATTERN (KPFF)
2x INFILL BLOCKING TO MATCH DLT APPEARANCE PROVIDED BY OTHERS INSTALLED ON SITE

Branching Column: 2973

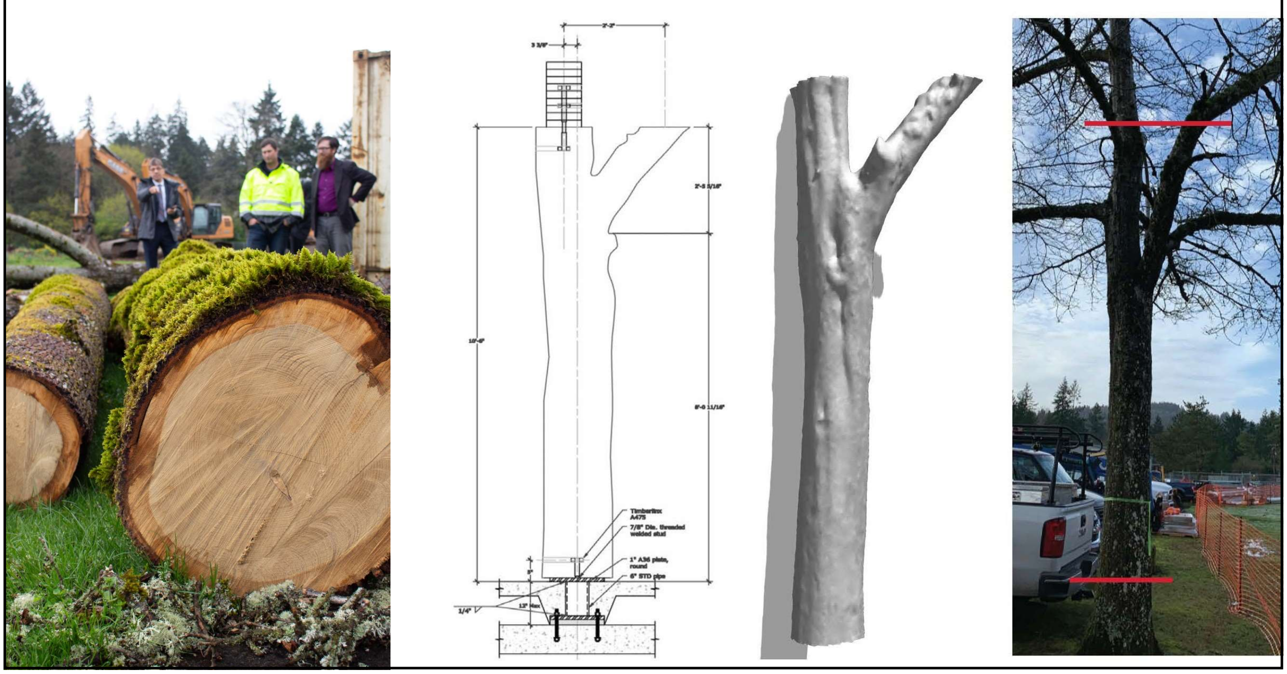
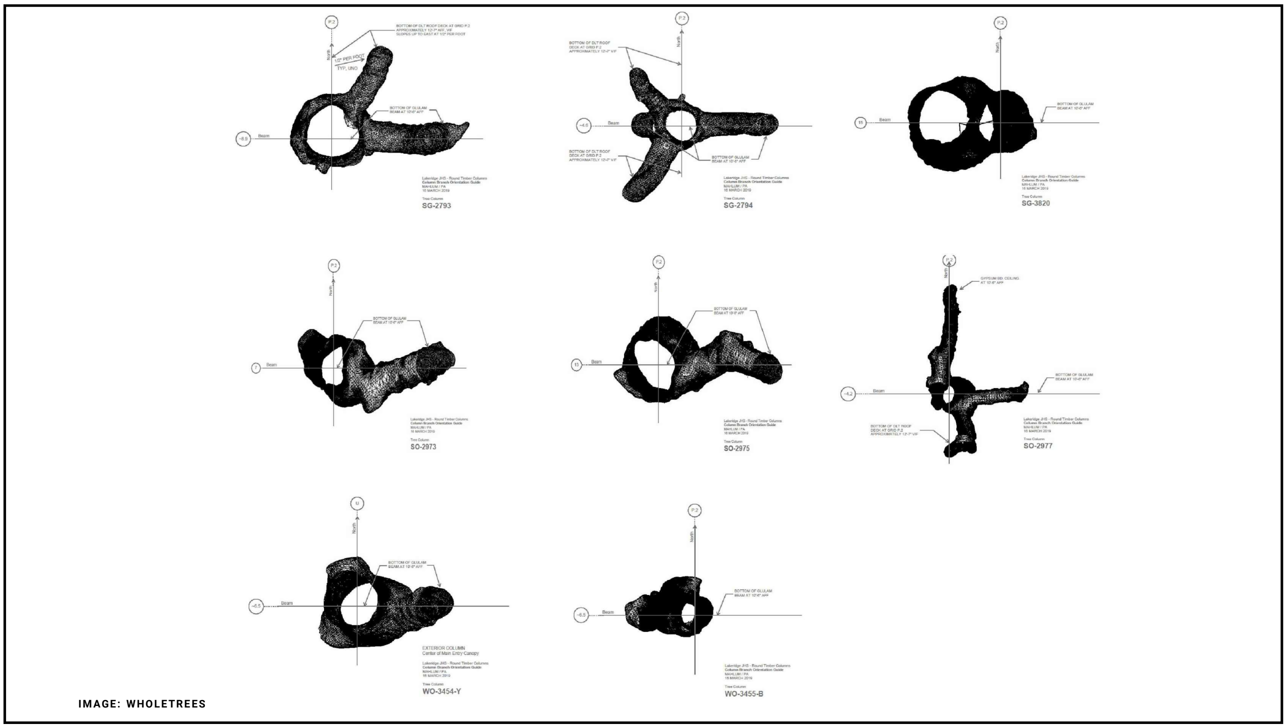
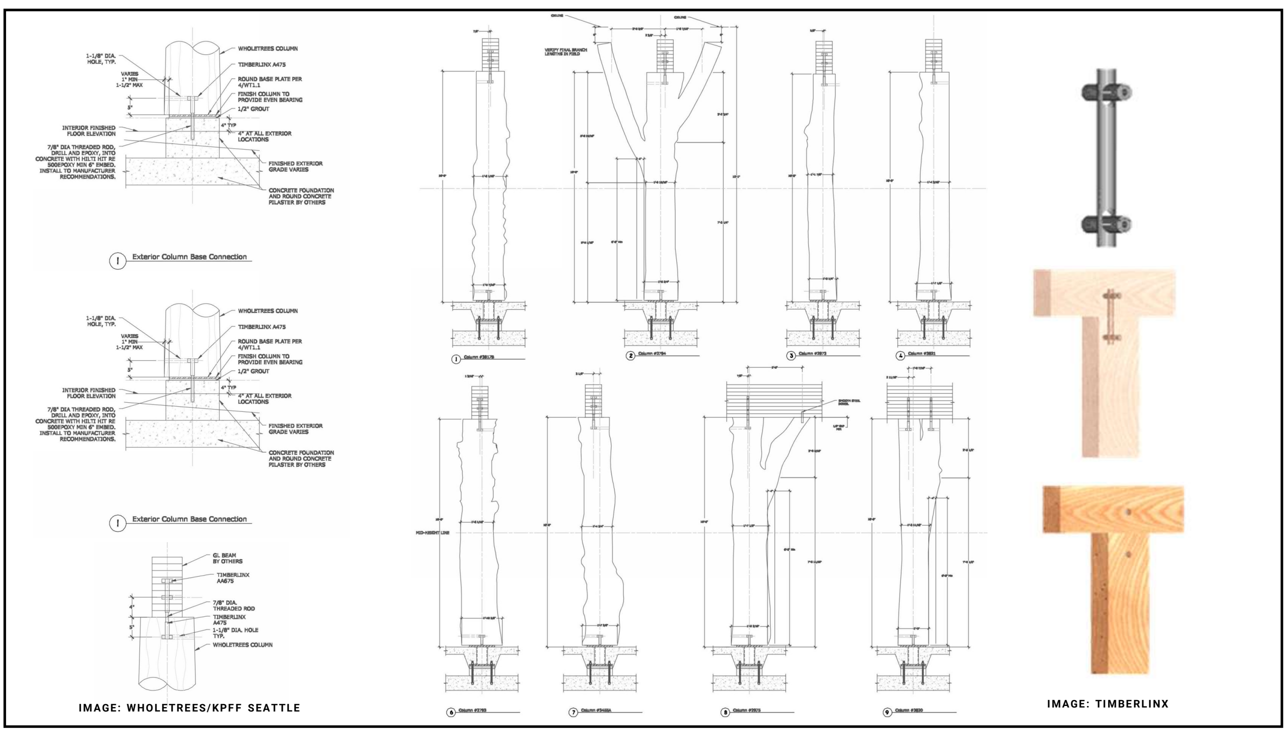
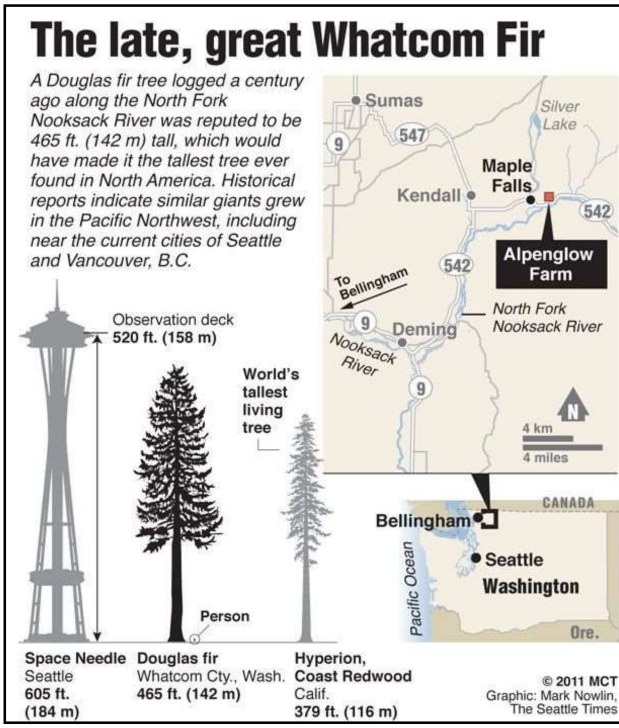
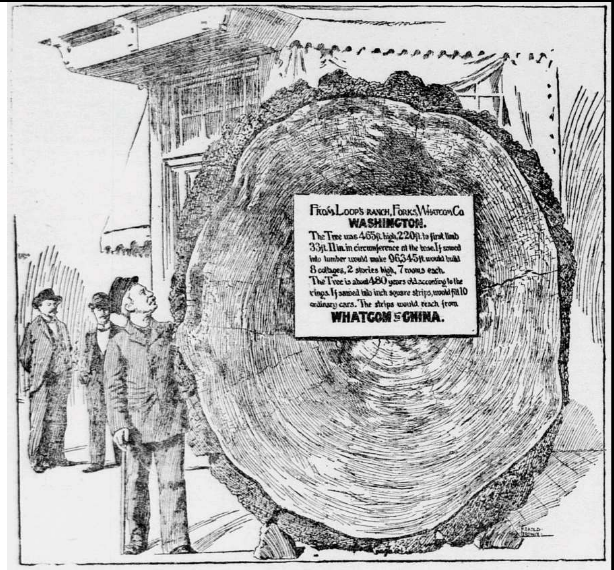


IMAGE: WHOLETREES


SG-2793
SG-2794
SG-3820
SO-2973
SO-2975
SO-2977
WO-3454-Y
WO-3455-B
IMAGE: WHOLETREES


WHOLETREES COLUMN
TIMBERLINX A47S
Exterior Column Base Connection
Exterior Column Base Connection
IMAGE: WHOLETREES/KPFF SEATTLE
IMAGE: TIMBERLINX





The Lumbermen Declare That This Tree, Sawed Into Fine Strips, Would Reach to China From New Whatcom.

IMAGE: WIKIPEDIA

Mass Timber Building Codes

How can we grow the impact of mass timber in Washington State?

ICC Tall Wood Building Committee (established December 2015)
13 Proposals

1. **TWB Proposed code changes: January 2018**
2. **ICC Committee Action Hearing: April, 2018**
3. **ICC Public Comment Hearing: October, 2018**
4. **Passed as Proposed by ICC Membership Vote: December, 2018**

   977 votes cast
   > Votes cast than ever
   71% in favor, 29% against

IMAGE: BUILD WITH STRENGTH CAMPAIGN

State-Wide Code Change Proposal

SBCC Washington State Building Code Council

FORTERRA
FOR THE PEOPLE. FOR THE LAND. FOREVER.

Winter 2018	Spring 2018	Winter 2018	July 2019	July 2020
WA State Legislature passes **ESB 5450** ICC TWB Committee releases proposed code language	Submitted code change proposal to SBCC SBCC Process and Public Hearings	SBCC Approves code change proposal Pre-adopts 2021 IBC provisions created by TWB	Provisions available for 2015 WA IBC	Provisions available for 2018 IBC

New Mass Timber Codes

Type IV-A
18-story max

Type IV-B
12-story max

Type IV-C
9-story max

Type IV-HT
Don't forget!

Concealed spaces allowed with provisions

All adhesives must be heat resistant (PRG-320 2018)

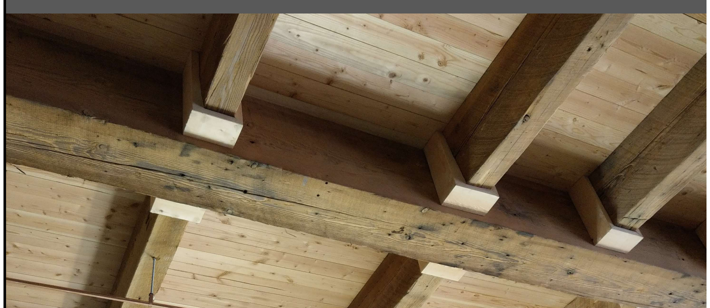
Connections must be fire protected

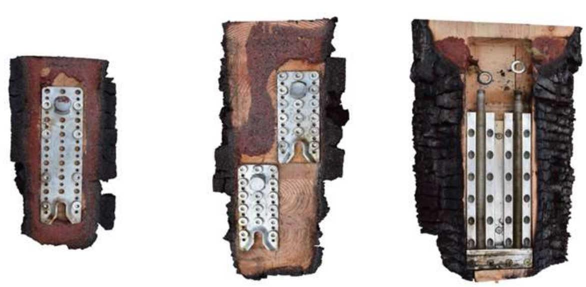
Exterior walls must be protected

Tall mass timber requires protection during construction

Special Inspections

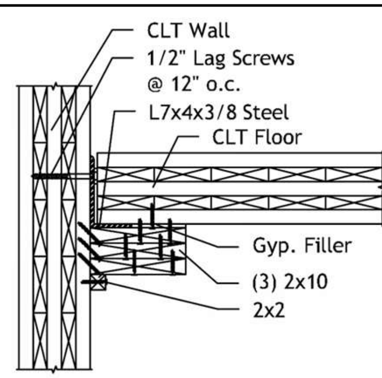
Fire Protection of Connections

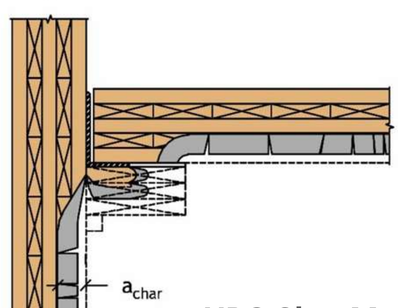




Proprietary Connection Systems

SOURCE: MYTICON





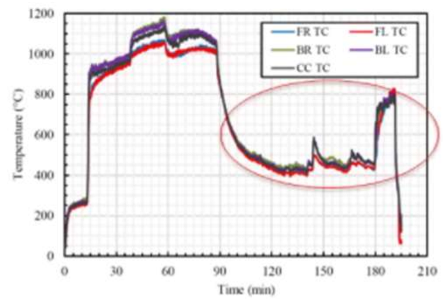
SOURCE: AWC

NDS Char Method

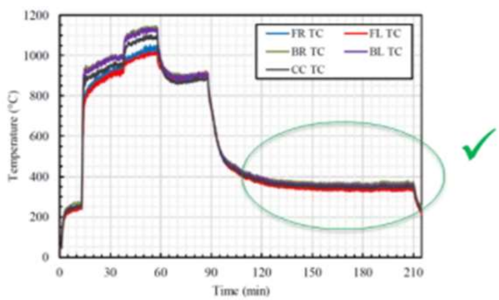
Adhesive Qualification Tests

PRG-320 test identifies acceptable performance

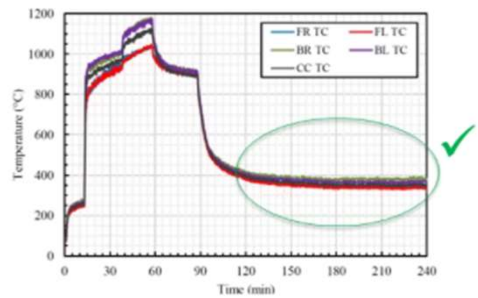
Performance similar to solid wood



Heat-delaminating PUR



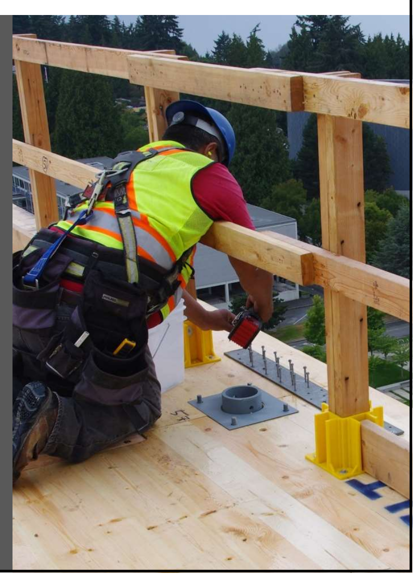
Melamine formaldehyde resin



Improved PUR

Regulatory

- Fire protection of connections – likely handled by Building Official
  - 2018 IBC 110.3.9 and 2021 Chapter 1
  - 2018 IBC 1705.1.1 allows AHJ to require special inspections
- Special Inspections – WABO is finalizing an exam so special inspectors can get registration for this
- Seattle Mass Timber Presubmission Checklist
  - ~2 mass timber presubmissions to date




Thank You!
Joe Mayo AIA LEED AP
jmayo@mahlum.com
PHOTO: MAHLUM