KLH®

MADE FOR BUILDING
BUILT FOR LIVING

STRUCTURAL PRE-ANALYSIS TABLES

100% KLH® ORIGINAL

IMPRINT

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CONTENT

DESIGN GUIDE FOR USE IN THE U.S.

KLH® Cross Laminated Timber (CLT) panels are built up using layers of wood boards, with each successive layer arranged perpendicular to the adjacent ones. These layers are glued together with environmentally friendly PUR adhesive to form strong, solid wood panels which can be used for floor, roof, and wall construction. CLT, as a wood product, is naturally green and sustainable, and structures can often be built more quickly than structures using other materials.

In addition, the total carbon footprint, including shipment by container from Europe, compares favorably with panels delivered by rail or truck, and our prices are very competitive. Panels are delivered to the job site sequenced and numbered for easy erection, with all openings and other details having been precisely made in the factory using CNC technology. Panels can be easily placed and connected with a relatively small crew using simple tools and standard, readily available fasteners. KLH®-CLT is manufactured in Austria of European Spruce lumber. Our lumber supply is PEFC certified, with FSC® C119602 certified lumber available on request, and all products are manufactured to ANSI/APA PRG 320 standards.

KLH® was the first manufacturer in the world to produce CLT on a large-scale basis. At last count, KLH®-CLT has been used in over 35,000 projects over the world.

This brochure is designed for engineers who are considering CLT or are currently designing a structure with CLT. Therefore, you'll find numerous technical topics, including design aids, material properties, and more. Other brochures are available, both in print and online, that are more general in purpose and are intended to introduce CLT to potential clients, architects, contractors, and developers.

After you've read through this brochure, we invite you to turn to KLH®, the industry leader in CLT. Please call or email us to begin a conversation about the many benefits offered by KLH®-CLT. We stand ready to provide design assistance, 3D modeling, cost estimates, and any other information and services that your design/construction team requires.

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01 PRODUCT DESCRIPTION

KLH® CROSS-LAMINATED TIMBER

KLH® cross-laminated timber is produced from layers of Austrian spruce lumber that are arranged crosswise on top of each other, with each layer glued to the adjacent layers under 12,500 psf pressure to form large, solid wood elements (panels). The cross-wise arrangement of the longitudinal and transverse layers reduces swelling and shrinkage of the wood in the plane of the panel. Also, the arrangement of the layers results in strong elements capable of significant load carrying capacity over relatively long spans. The lumber used to produce KLH®-CLT panels is dried to a moisture content of 12% (+/- 2%) prior to producing the panels.

GLUING

Solvent- and formaldehyde-free PUR adhesive is used to glue the adjacent layers together. The glue is applied automatically and uniformly over the entire adhered surfaces, thus achieving a high level of adhesion under the high manufacturing pressure. All lumber comprising the laminations is carefully sorted prior to manufacturing of the built-up panels.

CNC CUTTING

Precise factory cutting according to specific design requirements takes place using state-of-the-art CNC technology. Cutting accuracy is generally +/- 5/64˝ (2 mm), resulting in extremely precise finished panels with minimal waste. In addition to panel overall dimensions, window, door, and other openings can easily be prefabricated prior to delivery to the job site.

SURFACE QUALITY

KLH®-CLT panels are available in non-visible (NVQ), industrial visible (IVQ), and domestic visible (DVQ) surface qualities. The DVQ level includes gluing the sides of the boards together in the outer most, visible surface lamination. IVQ and DVQ surfaces are sanded.

ASSEMBLY

CLT panels can be erected quickly and efficiently by relatively small crews using simple tools and connectors. A crane is used to raise the panels into position. Holes, channels, or other surface features, such as those required for utility lines or electrical wiring, can be cut on site, or prefabricated. Erection consists of connecting wall, floor, and roof panels together to quickly build a fully enclosed structure. Of course, CLT panels also work particularly well in combination with wood post-and-beam frameworks.

Lifting of KLH® TL panel

Erection Murray Grove in London I UK

TECHNICAL DESCRIPTION

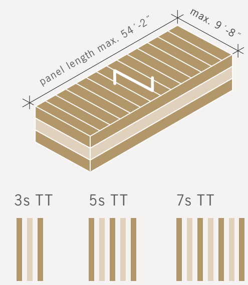
PRODUCT	Solid wood panels with crosswise glued laminations
PRODUCT NAME	KLH® Cross-Laminated Timber
USES	Structural elements for walls, floors, and roofs
WOOD TYPE	Austrian spruce (other wood species on request)
PANEL BUILD-UPS	3-, 5-, 7-, and 8-laminations
LAMINATIONS	Lamination thicknesses 0.79″ - 1.57″ Sorted for quality and finger-jointed
PANEL GRADE	CV3M1
GLUE	Formaldehyde-free PUR adhesive
LAMINATION PRESSURE	12,500 psf, minimum
MOISTURE CONTENT	12% (+/- 2%) at delivery
MAXIMUM DIMENSIONS	Length 54′-2″ / width 9′-8″ / thickness 1′-8″
AVAILABLE WIDTHS	7′-10″ / 8′-2″ / 8′-11″ / 9′-8″
SURFACE QUALITIES	Non-visible (NVQ) / Industrial visible (IVQ) / Domestic visible (DVQ)
WEIGHT	For structural calculations, 35 pcf Shipping weight, 31 pcf
DIMENSIONAL CHANGE WITH MOISTURE CONTENT	In-plane: 0.02% per 1% change in moisture content Out-of-plane: 0.24% per 1% change in moisture content
NOMINAL CHAR RATE	1.5 in./hr.
EFFECTIVE CHAR DEPTH	1.9 in. after 1 hour All lamination thicknesses = 1-$^{3}/_{8}$″
FIRE DESIGN	According to NDS 2015 and CLT Handbook, US Ed.
FLAME SPREAD INDEX	Classification B
CERTIFICATION	ANSI/APA PRG 320-2018

02 STANDARD PANEL TYPES AND STRUCTURES

AVAILABLE WIDTHS: 7´-10˝ / 8´-2˝ / 8´-11˝ / 9´-8˝
MAXIMUM DIMENSIONS: LENGTH 54´-2˝ / WIDTH 9´-8˝ / THICKNESS 1´-8˝

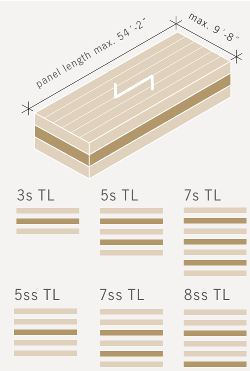
Covering layer in the transverse panel direction TT

Panel Type	Thickness (in.)	Lamination Thickness in CLT Layup (in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
60 3s TT	2.36	0.79	0.79	0.79				
70 3s TT	2.76	0.79	1.18	0.79				
80 3s TT	3.15	1.18	0.79	1.18				
80 3s TT (V2)	3.15	0.79	1.57	0.79				
90 3s TT	3.54	1.18	1.18	1.18				
100 3s TT	3.94	1.18	1.57	1.18				
100 3s TT (V2)	3.94	1.57	0.79	1.57				
105 3s TT	4.13	1.38	1.38	1.38				
110 3s TT	4.33	1.57	1.18	1.57				
120 3s TT	4.72	1.57	1.57	1.57				
100 5s TT	3.94	0.79	0.79	0.79	0.79	0.79		
110 5s TT	4.33	0.79	0.79	1.18	0.79	0.79		
120 5s TT	4.72	1.18	0.79	0.79	0.79	1.18		
120 5s TT (V2)	4.72	0.79	1.18	0.79	1.18	0.79		
130 5s TT	5.12	1.18	0.79	1.18	0.79	1.18		
140 5s TT	5.51	1.18	0.79	1.57	0.79	1.18		
140 5s TT (V2)	5.51	0.79	1.57	0.79	1.57	0.79		
140 5s TT (V3)	5.51	1.57	0.79	0.79	0.79	1.57		
150 5s TT	5.91	1.18	1.18	1.18	1.18	1.18		
150 5s TT (V2)	5.91	1.57	0.79	1.18	0.79	1.57		
160 5s TT	6.30	1.57	0.79	1.57	0.79	1.57		
175 5s TT	6.89	1.38	1.38	1.38	1.38	1.38		
180 5s TT	7.09	1.57	1.18	1.57	1.18	1.57		
200 5s TT	7.87	1.57	1.57	1.57	1.57	1.57		
180 7s TT	7.09	1.18	0.79	1.18	0.79	1.18	0.79	1.18



Covering layer in the longitudinal panel direction TL

Panel Type	Thickness (in.)	Lamination Thickness in CLT Layup (in.)	(in.)	(in.)
60 3s TL	2.36	0.79	0.79	0.79
70 3s TL	2.76	0.79	1.18	0.79
80 3s TL	3.15	1.18	0.79	1.18
80 3s TL (V2)	3.15	0.79	1.57	0.79
90 3s TL	3.54	1.18	1.18	1.18
100 3s TL	3.94	1.57	0.79	1.57
100 3s TL (V2)	3.94	1.18	1.57	1.18
105 3s TL	4.13	1.38	1.38	1.38
110 3s TL	4.33	1.57	1.18	1.57
120 3s TL	4.72	1.57	1.57	1.57



* not available in DVQ

KLH

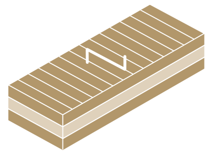
STANDARD PANELS AND STRUCTURES

Covering layer in the longitudinal panel direction TL

Panel Type	Thickness (in.)	Lamination Thickness in CLT Layup (in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
100 5s TL	3.94	0.79	0.79	0.79	0.79	0.79		
110 5s TL	4.33	0.79	0.79	1.18	0.79	0.79		
120 5s TL	4.72	1.18	0.79	0.79	0.79	1.18		
120 5s TL (V2)	4.72	0.79	1.18	0.79	1.18	0.79		
130 5s TL	5.12	1.18	0.79	1.18	0.79	1.18		
130 5s TL (V2)	5.12	0.79	1.18	1.18	1.18	0.79		
140 5s TL	5.51	1.57	0.79	0.79	0.79	1.57		
140 5s TL (V2)	5.51	0.79	1.57	0.79	1.57	0.79		
150 5s TL	5.91	1.57	0.79	1.18	0.79	1.57		
150 5s TL (V2)	5.91	1.18	1.18	1.18	1.18	1.18		
150 5s TL (V3)	5.91	0.79	1.57	1.18	1.57	0.79		
160 5s TL	6.30	1.57	0.79	1.57	0.79	1.57		
160 5s TL (V2)	6.30	0.79	1.57	1.57	1.57	0.79		
170 5s TL	6.69	1.57	1.18	1.18	1.18	1.57		
170 5s TL (V2)	6.69	1.18	1.57	1.18	1.57	1.18		
175 5s TL	6.89	1.38	1.38	1.38	1.38	1.38		
180 5s TL	7.09	1.57	1.18	1.57	1.18	1.57		
180 5s TL (V2)	7.09	1.18	1.57	1.57	1.57	1.18		
190 5s TL	7.48	1.57	1.57	1.18	1.57	1.57		
200 5s TL	7.87	1.57	1.57	1.57	1.57	1.57		
160 5ss TL	6.30	1.18+1.18	1.57	1.18+1.18				
140 7s TL	5.51	0.79	0.79	0.79	0.79	0.79	0.79	0.79
160 7s TL	6.30	0.79	1.18	0.79	0.79	0.79	1.18	0.79
180 7s TL	7.09	0.79	1.57	0.79	0.79	0.79	1.57	0.79
180 7s TL (V2)	7.09	1.18	0.79	1.18	0.79	1.18	0.79	1.18
200 7s TL	7.87	0.79	1.57	0.79	1.57	0.79	1.57	0.79
210 7s TL	8.27	1.18	1.18	1.18	1.18	1.18	1.18	1.18
220 7s TL	8.66	1.18	1.57	1.18	0.79	1.18	1.57	1.18
220 7s TL (V2)	8.66	1.57	0.79	1.57	0.79	1.57	0.79	1.57
230 7s TL	9.06	1.18	1.57	1.18	1.18	1.18	1.57	1.18
240 7s TL	9.45	1.18	1.57	1.18	1.57	1.18	1.57	1.18
245 7s TL	9.65	1.38	1.38	1.38	1.38	1.38	1.38	1.38
260 7s TL	10.24	1.57	1.57	1.18	1.57	1.18	1.57	1.57
180 7ss TL	7.09	1.18+1.18	0.79	0.79	0.79	1.18+1.18		
200 7ss TL	7.87	1.18+1.18	0.79	1.57	0.79	1.18+1.18		
210 7ss TL	8.27	1.18+1.18	1.18	1.18	1.18	1.18+1.18		
220 7ss TL	8.66	1.57+1.57	0.79	0.79	0.79	1.57+1.57		
220 7ss TL (V2)	8.66	1.18+1.18	1.18	1.57	1.18	1.18+1.18		
230 7ss TL	9.06	1.57+1.57	0.79	1.18	0.79	1.57+1.57		
240 7ss TL	9.45	1.57+1.57	0.79	1.57	0.79	1.57+1.57		
250 7ss TL	9.84	1.57+1.57	1.18	1.18	1.18	1.57+1.57		
260 7ss TL	10.24	1.57+1.57	1.18	1.57	1.18	1.57+1.57		
280 7ss TL	11.02	1.57+1.57	1.57	1.57	1.57	1.57+1.57		
300 8ss TL	11.81	1.57+1.57	1.18	1.57+1.57	1.18	1.57+1.57		
320 8ss TL	12.60	1.57+1.57	1.57	1.57+1.57	1.57	1.57+1.57		

03 DESIGN CAPACITIES

3.1 FOR TT PANELS



according to NDS 2015 and CLT Handbook, US ed.

Table 1. Allowable Design Properties[a] for lumber laminations used in KLH®-CLT (for use in the U.S.)

CLT Grade	Major strength direction						Minor strength direction					
	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{s,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{v,90}$ (psi)	$F_{s,90}$ (psi)
CV3M1	975	1.6	550	1450	175	55	975	1.6	550	1450	175	55

For SI: 1 psi = 0.006895 Mpa

[a] Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by KLH® based on the actual layup used in manufacturing the CLT panel (see Table 2).

Table 2. Allowable Design Capacities[a] for KLH®-CLT (for use in the U.S.)

CLT Grade	Layup #	Thickness (in.)	Lamination thickness (in.) in CLT layup							Major strength direction				Minor strength direction			
			=	⊦	=	⊦	=	⊦	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ [c] (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,90}$ (10^6 lbf/ft)	$V_{s,90}$ [c] (lbf/ft)
CV3M1	60 3s TT	2.36	0.79	0.79	0.79					743	20	0.34	1123	101	0.78	0.34	274
CV3M1	70 3s TT	2.76	0.79	1.18	0.79					969	31	0.37	1362	227	2.64	0.51	453
CV3M1	80 3s TT	3.15	1.18	0.79	1.18					1350	49	0.51	1453	101	0.78	0.37	231
CV3M1	80 3s TT V2	3.15	0.79	1.57	0.79					1205	44	0.40	1607	403	6.25	0.71	630
CV3M1	90 3s TT	3.54	1.18	1.18	1.18					1672	69	0.52	1684	227	2.64	0.52	410
CV3M1	100 3s TT	3.94	1.18	1.57	1.18					2008	92	0.54	1922	403	6.25	0.68	590
CV3M1	100 3s TT V2	3.94	1.57	0.79	1.57					2124	97	0.71	1788	101	0.78	0.40	192
CV3M1	105 3s TT	4.13	1.38	1.38	1.38					2276	109	0.60	1965	309	4.19	0.60	479
CV3M1	110 3s TT	4.33	1.57	1.18	1.57					2540	127	0.68	2013	227	2.64	0.54	367
CV3M1	120 3s TT	4.72	1.57	1.57	1.57					2973	163	0.69	2245	403	6.25	0.69	547
CV3M1	100 5s TT	3.94	0.79	0.79	0.79	0.79	0.79			1710	78	0.69	2004	874	20.33	0.69	1053
CV3M1	110 5s TT	4.33	0.79	0.79	1.18	0.79	0.79			1996	100	0.85	2158	1140	30.94	0.71	1286
CV3M1	120 5s TT	4.72	1.18	0.79	0.79	0.79	1.18			2724	149	0.85	2339	874	20.33	0.71	1010
CV3M1	120 5s TT V2	4.72	0.79	1.18	0.79	1.18	0.79			2214	121	0.74	2499	1588	49.24	1.03	1391
CV3M1	130 5s TT	5.12	1.18	0.79	1.18	0.79	1.18			3115	185	1.03	2514	1140	30.94	0.74	1239
CV3M1	140 5s TT	5.51	1.18	0.79	1.57	0.79	1.18			3534	226	1.22	2676	1417	43.95	0.77	1473
CV3M1	140 5s TT V2	5.51	0.79	1.57	0.79	1.57	0.79			2730	174	0.81	2996	2499	96.88	1.42	1730
CV3M1	140 5s TT V3	5.51	1.57	0.79	0.79	0.79	1.57			3889	248	1.03	2669	874	20.33	0.74	963
CV3M1	150 5s TT	5.91	1.18	1.18	1.18	1.18	1.18			3849	263	1.03	3006	1967	68.63	1.03	1579
CV3M1	150 5s TT V2	5.91	1.57	0.79	1.18	0.79	1.57			4381	300	1.22	2854	1140	30.94	0.77	1189
CV3M1	160 5s TT	6.30	1.57	0.79	1.57	0.79	1.57			4901	358	1.42	3027	1417	43.95	0.81	1419
CV3M1	175 5s TT	6.89	1.38	1.38	1.38	1.38	1.38			5239	418	1.20	3507	2678	108.99	1.20	1843
CV3M1	180 5s TT	7.09	1.57	1.18	1.57	1.18	1.57			5860	481	1.36	3515	2363	91.60	1.08	1766
CV3M1	200 5s TT	7.87	1.57	1.57	1.57	1.57	1.57			6842	624	1.37	4008	3497	162.68	1.37	2106
CV3M1	180 7s TT	7.09	1.18	0.79	1.18	0.79	1.18	0.79	1.18	5529	454	1.54	3317	2604	121.15	1.11	2336

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N

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

[b] The CV3M1 grade uses Austrian spruce lumber in both major and minor strength directions.

[c] $V_{s,0}$ and $V_{s,90}$ are calculated as $F_{s,0}(Ib/Q)_{eff,0}$ and $F_{s,90}(Ib/Q)_{eff,90}$ as per NDS Table 10.3.1

3.2 FOR TL PANELS

according to NDS 2015 and CLT Handbook, US ed.

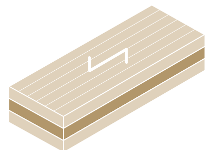


Table 1. Allowable Design Properties[a] for lumber laminations used in KLH®-CLT (for use in the U.S.)

CLT Grade	Major strength direction						Minor strength direction					
	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{s,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{v,90}$ (psi)	$F_{s,90}$ (psi)
CV3M1	975	1.6	550	1450	175	55	975	1.6	550	1450	175	55

For SI: 1 psi = 0.006895 Mpa

[a] Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by KLH® based on the actual layup used in manufacturing the CLT panel (see Table 2).

Table 2. Allowable Design Capacities[a] for KLH®-CLT (for use in the U.S.)

CLT Grade	Layup #	Thickness (in.)	Lamination thickness (in.) in CLT layup							Major strength direction				Minor strength direction			
			=	⊦	=	⊦	=	⊦	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ [c] (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,90}$ (10^6 lbf/ft)	$V_{s,90}$ [c] (lbf/ft)
CV3M1	60 3s TL	2.36	0.79	0.79	0.79					743	20	0.34	1123	101	0.78	0.34	274
CV3M1	70 3s TL	2.76	0.79	1.18	0.79					969	31	0.37	1362	227	2.64	0.51	453
CV3M1	80 3s TL	3.15	1.18	0.79	1.18					1350	49	0.51	1453	101	0.78	0.37	231
CV3M1	80 3s TL V2	3.15	0.79	1.57	0.79					1205	44	0.40	1607	403	6.25	0.71	630
CV3M1	90 3s TL	3.54	1.18	1.18	1.18					1672	69	0.52	1684	227	2.64	0.52	410
CV3M1	100 3s TL	3.94	1.57	0.79	1.57					2124	97	0.71	1788	101	0.78	0.40	192
CV3M1	100 3s TL V2	3.94	1.18	1.57	1.18					2008	92	0.54	1922	403	6.25	0.68	590
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CV3M1	110 3s TL	4.33	1.57	1.18	1.57					2540	127	0.68	2013	227	2.64	0.54	367
CV3M1	120 3s TL	4.72	1.57	1.57	1.57					2973	163	0.69	2245	403	6.25	0.69	547

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N

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

[b] The CV3M1 grade uses Austrian spruce lumber in both major and minor strength directions.

[c] $V_{s,0}$ and $V_{s,90}$ are calculated as $F_{s,0}(Ib/Q)_{eff,0}$ and $F_{s,90}(Ib/Q)_{eff,90}$ as per NDS Table 10.3.1

Table 2. Allowable Design Capacities[a] for KLH®-CLT (for use in the U.S.) (continued)

CLT Grade	Layup #	Thickness (in.)	Lamination thickness (in.) in CLT layup							Major strength direction				Minor strength direction			
			=	⊦	=	⊦	=	⊦	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ [c] (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,90}$ (10^6 lbf/ft)	$V_{s,90}$ [c] (lbf/ft)
CV3M1	100 5s TL	3.94	0.79	0.79	0.79	0.79	0.79			1710	78	0.69	2004	874	20.33	0.69	1053
CV3M1	110 5s TL	4.33	0.79	0.79	1.18	0.79	0.79			1996	100	0.85	2158	1140	30.94	0.71	1286
CV3M1	120 5s TL	4.72	1.18	0.79	0.79	0.79	1.18			2724	149	0.85	2339	874	20.33	0.71	1010
CV3M1	120 5s TL V2	4.72	0.79	1.18	0.79	1.18	0.79			2214	121	0.74	2499	1588	49.24	1.03	1391
CV3M1	130 5s TL	5.12	1.18	0.79	1.18	0.79	1.18			3115	185	1.03	2514	1140	30.94	0.74	1239
CV3M1	130 5s TL V2	5.12	0.79	1.18	1.18	1.18	0.79			2501	148	0.88	2646	1967	68.63	1.02	1618
CV3M1	140 5s TL	5.51	1.57	0.79	0.79	0.79	1.57			3889	248	1.03	2669	874	20.33	0.74	963
CV3M1	140 5s TL V2	5.51	0.79	1.57	0.79	1.57	0.79			2730	174	0.81	2996	2499	96.88	1.42	1730
CV3M1	150 5s TL	5.91	1.57	0.79	1.18	0.79	1.57			4381	300	1.22	2854	1140	30.94	0.77	1189
CV3M1	150 5s TL V2	5.91	1.18	1.18	1.18	1.18	1.18			3849	263	1.03	3006	1967	68.63	1.03	1579
CV3M1	150 5s TL V3	5.91	0.79	1.57	1.18	1.57	0.79			3018	206	0.94	3138	2988	127.41	1.38	1953
CV3M1	160 5s TL	6.30	1.57	0.79	1.57	0.79	1.57			4901	358	1.42	3027	1417	43.95	0.81	1419
CV3M1	160 5s TL V2	6.30	0.79	1.57	1.57	1.57	0.79			3328	243	1.08	3258	3497	162.68	1.36	2182
CV3M1	170 5s TL	6.69	1.57	1.18	1.18	1.18	1.57			5333	413	1.19	3343	1967	68.63	1.05	1537
CV3M1	170 5s TL V2	6.69	1.18	1.57	1.18	1.57	1.18			4600	357	1.08	3501	2988	127.41	1.36	1917
CV3M1	175 5s TL	6.89	1.38	1.38	1.38	1.38	1.38			5239	418	1.20	3507	2678	108.99	1.20	1843
CV3M1	180 5s TL	7.09	1.57	1.18	1.57	1.18	1.57			5860	481	1.36	3515	2363	91.60	1.08	1766
CV3M1	180 5s TL V2	7.09	1.18	1.57	1.57	1.57	1.18			5023	412	1.22	3653	3497	162.68	1.36	2145
CV3M1	190 5s TL	7.48	1.57	1.57	1.18	1.57	1.57			6308	547	1.22	3837	2988	127.41	1.36	1879
CV3M1	200 5s TL	7.87	1.57	1.57	1.57	1.57	1.57			6842	624	1.37	4008	3497	162.68	1.37	2106
CV3M1	160 5ss TL	6.30	1.18 x 2	1.57	1.18 x 2					5398	394	1.03	2905	403	6.25	0.74	462
CV3M1	140 7s TL	5.51	0.79	0.79	0.79	0.79	0.79	0.79	0.79	3025	193	1.03	2631	2012	78.01	1.03	1915
CV3M1	160 7s TL	6.30	0.79	1.18	0.79	0.79	0.79	1.18	0.79	3515	256	1.08	3080	3205	149.09	1.36	2265
CV3M1	180 7s TL	7.09	0.79	1.57	0.79	0.79	0.79	1.57	0.79	4021	330	1.14	3539	4575	248.29	1.73	2601
CV3M1	180 7s TL V2	7.09	1.18	0.79	1.18	0.79	1.18	0.79	1.18	5529	454	1.54	3317	2604	121.15	1.11	2336
CV3M1	200 7s TL	7.87	0.79	1.57	0.79	1.57	0.79	1.57	0.79	4789	437	1.21	3896	5766	357.64	2.13	2960
CV3M1	210 7s TL	8.27	1.18	1.18	1.18	1.18	1.18	1.18	1.18	6807	652	1.55	3946	4528	263.27	1.55	2873
CV3M1	220 7s TL	8.66	1.18	1.57	1.18	0.79	1.18	1.57	1.18	6983	701	1.56	4220	5681	352.35	1.71	3041
CV3M1	220 7s TL V2	8.66	1.57	0.79	1.57	0.79	1.57	0.79	1.57	8714	874	2.13	4005	3212	174.29	1.21	2741
CV3M1	230 7s TL	9.06	1.18	1.57	1.18	1.18	1.18	1.57	1.18	7536	791	1.59	4393	6274	413.44	1.87	3226
CV3M1	240 7s TL	9.45	1.18	1.57	1.18	1.57	1.18	1.57	1.18	8110	888	1.62	4578	6895	481.08	2.04	3398
CV3M1	245 7s TL	9.65	1.38	1.38	1.38	1.38	1.38	1.38	1.38	9266	1035	1.80	4604	6163	418.11	1.80	3352
CV3M1	260 7s TL	10.24	1.57	1.57	1.18	1.57	1.18	1.57	1.57	10576	1254	1.76	5011	6895	481.08	2.04	3353

FLEXURAL DESIGN CAPACITIES

Table 2. Allowable Design Capacities(a) for KLH®-CLT
(for use in the U.S.) (continued)

CLT Grade	Layup #	Thickness (in.)	Lamination thickness (in.) in CLT layup							Major strength direction				Minor strength direction			
			=	⊦	=	⊦	=	⊦	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ [(c)] (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,90}$ (10^6 lbf/ft)	$V_{s,90}$ [(c)] (lbf/ft)
CV3M1	180 7ss TL	7.09	1.18 x 2	0.79	0.79	0.79	1.18 x 2			6697	550	1.42	3328	874	20.33	0.81	864
CV3M1	200 7ss TL	7.87	1.18 x 2	0.79	1.57	0.79	1.18 x 2			8100	739	1.85	3707	1417	43.95	0.89	1305
CV3M1	210 7ss TL	8.27	1.18 x 2	1.18	1.18	1.18	1.18 x 2			8750	838	1.54	4003	1967	68.63	1.11	1444
CV3M1	220 7ss TL	8.66	1.57 x 2	0.79	0.79	0.79	1.57 x 2			10166	1020	1.85	3994	874	20.33	0.89	767
CV3M1	220 7ss TL V2	8.66	1.18 x 2	1.18	1.57	1.18	1.18 x 2			9482	951	1.73	4190	2363	91.60	1.14	1670
CV3M1	230 7ss TL	9.06	1.57 x 2	0.79	1.18	0.79	1.57 x 2			11041	1158	2.08	4191	1140	30.94	0.93	975
CV3M1	240 7ss TL	9.45	1.57 x 2	0.79	1.57	0.79	1.57 x 2			11945	1307	2.33	4380	1417	43.95	0.98	1189
CV3M1	250 7ss TL	9.84	1.57 x 2	1.18	1.18	1.18	1.57 x 2			12800	1459	1.92	4662	1967	68.63	1.18	1346
CV3M1	260 7ss TL	10.24	1.57 x 2	1.18	1.57	1.18	1.57 x 2			13728	1628	2.13	4855	2363	91.60	1.21	1567
CV3M1	280 7ss TL	11.02	1.57 x 2	1.57	1.57	1.57	1.57 x 2			15555	1986	2.05	5337	3497	162.68	1.48	1926
CV3M1	300 8ss TL	11.81	1.57 x 2	1.18	1.57 x 2	1.18	1.57 x 2			17729	2426	3.01	5571	4046	219.59	1.38	2472
CV3M1	320 8ss TL	12.60	1.57 x 2	1.57	1.57 x 2	1.57	1.57 x 2			19605	2861	2.83	6055	5669	351.60	1.62	2839

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N

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

(b) The CV3M1 grade uses Austrian spruce lumber in both major and minor strength directions.

(c) $V_{s,0}$ and $V_{s,90}$ are calculated as $F_{s,0}(Ib/Q)_{eff,0}$ and $F_{s,90}(Ib/Q)_{eff,90}$ as per NDS Table 10.3.1

3.3 IN-PLANE SHEAR CAPACITY

Table 3. Allowable In-Plane Shear Stress for KLH®-CLT
(For Use in the U.S.)

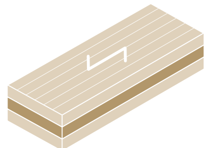
Grade	Layup (lams.)	Thickness, t_p (in.)	$F_{v,e,0}$ (psi)	$F_{v,e,90}$ (psi)
CV3M1	3	2.36 – 4.72	250	275
CV3M1	5	3.94 – 7.87	280	240
CV3M1	7	5.51 – 11.02	280	240
CV3M1	8	11.81 – 12.60	280	240

- $F_{v,e,0}$ is allowable stress in the major strength direction.
- $F_{v,e,90}$ is allowable stress in the minor strength direction.
- Allowable stress values shall be applied to the CLT thickness, t_p.
- 3 lamination values based on test results from 100 3s TL V2 panels.
- 5, 7, and 8 lamination values based on test results from 160 5s TL panels.
- Testing performed at the Composite Materials and Engineering Center at Washington State University, Pullman, WA, an IAS Accredited Testing Laboratory (TL-246).
- Research report satisfies IBC Section 1703.4 for determining the characteristic strength.
- Characteristic strength obtained from testing is divided by 2.1 to obtain allowable stress values.

Supermarket roof in Graz I Austria

04 KLH® FLOOR PANELS

4.1 FLOORS WITH LIGHT FINISHES, L = 40 PSF



according to NDS 2015 and CLT Handbook, US ed.

Preliminary Sizing of CLT Floor Panels with light finishes
D = 15 psf + panel self weight
L = 40 psf, C_D = 1.0

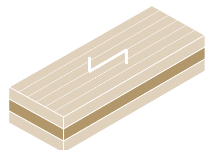
Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions		Single span		Two equal spans	
					Live load Δ_L		Live load Δ_L
		Vibration Control (ft)	Allowable Moment (ft)	Long term Δ_T = L/240 (ft)	@ Allowable Moment span	Long term Δ_T = L/240 (ft)	@ Allowable Moment span
60 3s TL	2.36	**8.20**	9.78	**7.90**	L/272	10.71	L/655
70 3s TL	2.76	**9.13**	11.11	**9.05**	L/286	12.27	L/689
80 3s TL	3.15	**10.29**	12.98	10.48	L/286	14.19	L/688
90 3s TL	3.54	**11.18**	14.34	11.62	L/297	15.76	L/715
100 3s TL	3.94	**12.23**	16.00	12.97	L/303	17.55	(6)
105 3s TL	4.13	**12.51**	16.48	13.35	L/308	18.12	(6)
120 3s TL	4.72	**13.83**	18.60	15.07	L/320	20.45	(6)
100 5s TL	3.94	**11.49**	14.34	12.07	L/338	16.32	(6)
120 5s TL	4.72	**13.55**	17.80	14.72	L/337	19.91	(6)
130 5s TL	5.12	**14.32**	18.92	15.74	L/350	21.27	(6)
140 5s TL	5.51	**15.42**	20.92	17.18	L/346	23.25	(6)
150 5s TL	5.91	**16.19**	22.03	18.19	L/360	24.62	(6)
160 5s TL	6.30	**16.94**	23.12	19.19	L/372	25.92	(6)
160 5ss TL	6.30	**17.27**	24.26	19.67	L/350	26.67	(6)
170 5s TL	6.69	**17.44**	23.98	19.90	L/381	26.94	(6)
175 5s TL	6.89	**17.44**	23.63	19.89	L/402	26.95	(6)
180 5s TL	7.09	**18.13**	24.89	20.82	L/398	28.17	(6)
180 7s TL	7.09	**16.23**	20.66	18.34	L/473	24.83	(6)
200 7s TL	7.87	**17.36**	22.17	19.85	(5)	26.89	(6)
220 7s TL	8.66	**19.73**	26.44	22.97	L/481	31.10	(6)
240 7s TL	9.45	**20.87**	28.03	24.49	(5)	33.19	(6)
245 7s TL	9.65	**21.80**	29.86	25.73	(5)	34.85	(6)
210 7ss TL	8.27	**20.86**	29.75	24.50	L/404	33.19	(6)
240 7ss TL	9.45	**23.50**	34.02	28.02	L/426	37.87	(6)
280 7ss TL	11.02	**25.83**	37.79	31.24	L/465	42.36	(6)
320 8ss TL	12.60	**28.39**	41.44	34.65	(5)	46.90	(6)

Notes:

(1) Spans controlled by allowable moment include panel self weight
(2) Vibration control calculation as per chapter 7, CLT Handbook, US Ed.
(3) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(4) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(5) Floor live load Δ_L < L/480
(6) Floor live load Δ_L < L/720
(7) Vibration controlled span is the same for single and two span conditions where all spans = L
(8) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(9) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

4.2 FLOORS WITH 2 IN. N.W. CONCRETE, L = 40 PSF



according to NDS 2015 and CLT Handbook, US ed.

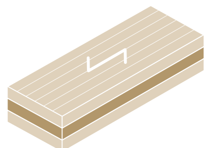
Preliminary Sizing of CLT Floor Panels with 2“ n.w. concrete
D = 40 psf + panel self weight
L = 40 psf, C_D = 1.0

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions		Single span		Two equal spans	
					Live load Δ_L		Live load Δ_L
		Vibration Control (ft)	Allowable Moment (ft)	Long term Δ_T = L/240 (ft)	@ Allowable Moment span	Long term Δ_T = L/240 (ft)	@ Allowable Moment span
60 3s TL	2.36	**8.20**	8.29	**6.70**	L/438	9.12	(6)
70 3s TL	2.76	**9.13**	9.40	**7.69**	L/463	10.48	(6)
80 3s TL	3.15	**10.29**	11.00	**8.96**	L/462	12.17	(6)
90 3s TL	3.54	**11.17**	12.19	**9.95**	L/474	13.54	(6)
100 3s TL	3.94	**12.23**	13.64	**11.15**	(5)	15.14	(6)
105 3s TL	4.13	**12.51**	14.07	**11.49**	(5)	15.63	(6)
120 3s TL	4.72	**13.83**	15.92	**13.03**	(5)	17.74	(6)
100 5s TL	3.94	**11.49**	12.23	**10.38**	(5)	14.09	(6)
120 5s TL	4.72	**13.55**	15.25	**12.73**	(5)	17.28	(6)
130 5s TL	5.12	**14.32**	16.24	**13.66**	(5)	18.52	(6)
140 5s TL	5.51	**15.42**	18.00	**14.93**	(5)	20.27	(6)
150 5s TL	5.91	**16.19**	18.99	**15.89**	(5)	21.52	(6)
160 5s TL	6.30	**16.94**	19.96	**16.79**	(5)	22.75	(6)
160 5ss TL	6.30	**17.27**	20.95	**17.18**	(5)	23.37	(6)
170 5s TL	6.69	**17.44**	20.75	**17.43**	(5)	23.67	(6)
175 5s TL	6.89	**17.44**	20.46	17.45	(5)	23.71	(6)
180 5s TL	7.09	**18.13**	21.58	18.27	(5)	24.82	(6)
180 7s TL	7.09	**16.23**	17.92	**16.11**	(5)	21.87	(6)
200 7s TL	7.87	**17.36**	19.29	17.50	(5)	23.75	(6)
220 7s TL	8.66	**19.73**	23.09	20.34	(5)	27.61	(6)
240 7s TL	9.45	**20.87**	24.56	21.78	(5)	29.55	(6)
245 7s TL	9.65	**21.80**	26.18	22.88	(5)	31.08	(6)
210 7ss TL	8.27	**20.86**	25.93	21.65	(5)	29.41	(6)
240 7ss TL	9.45	**23.50**	29.81	24.93	(5)	33.77	(6)
280 7ss TL	11.02	**25.83**	33.31	27.94	(5)	37.99	(6)
320 8ss TL	12.60	**28.39**	36.74	31.21	(5)	42.33	(6)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Vibration control calculation as per chapter 7, CLT Handbook, US Ed.
(3) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(4) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(5) Floor live load Δ_L < L/480
(6) Floor live load Δ_L < L/720
(7) Vibration controlled span is the same for single and two span conditions where all spans = L
(8) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(9) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

4.3 FLOORS WITH 2 IN. N.W. CONCRETE, L = 65 PSF



according to NDS 2015 and CLT Handbook, US ed.

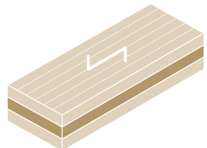
Preliminary Sizing of CLT Floor Panels with 2" n.w. concrete
D = 40 psf + panel self weight
L = 50 psf + 15 psf (partitions), C_D = 1.0

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions		Single span		Two equal spans	
		Vibration Control (ft)	Allowable Moment (ft)	Long term Δ_T = L/240 (ft)	Live load Δ_L @ Allowable Moment span	Long term Δ_T = L/240 (ft)	Live load Δ_L @ Allowable Moment span
60 3s TL	2.36	8.20	**7.28**	**6.30**	L/391	8.59	(6)
70 3s TL	2.76	9.13	**8.30**	**7.24**	L/405	9.88	(6)
80 3s TL	3.15	10.29	**9.74**	**8.44**	L/403	11.49	(6)
90 3s TL	3.54	11.17	**10.79**	**9.39**	L/413	12.80	(6)
100 3s TL	3.94	12.23	**12.08**	**10.53**	L/420	14.32	(6)
105 3s TL	4.13	12.51	**12.48**	**10.84**	L/421	14.79	(6)
120 3s TL	4.72	**13.83**	14.18	**12.31**	L/429	16.79	(6)
100 5s TL	3.94	11.49	**10.86**	**9.81**	L/464	13.33	(6)
120 5s TL	4.72	13.55	**13.55**	**12.05**	L/457	16.37	(6)
130 5s TL	5.12	**14.32**	14.45	**12.94**	L/471	17.56	(6)
140 5s TL	5.51	**15.42**	16.05	**14.16**	L/458	19.25	(6)
150 5s TL	5.91	**16.19**	16.95	**15.06**	L/473	20.45	(6)
160 5s TL	6.30	**16.94**	17.87	**15.95**	(5)	21.61	(6)
160 5ss TL	6.30	**17.27**	18.75	**16.29**	L/451	22.20	(6)
170 5s TL	6.69	**17.44**	18.55	**16.55**	(5)	22.51	(6)
175 5s TL	6.89	**17.44**	18.30	**16.58**	(5)	22.55	(6)
180 5s TL	7.09	**18.13**	19.32	**17.37**	(5)	23.62	(6)
180 7s TL	7.09	16.23	**16.03**	**15.31**	(5)	20.81	(6)
200 7s TL	7.87	17.36	**17.30**	**16.65**	(5)	22.63	(6)
220 7s TL	8.66	**19.73**	20.76	**19.38**	(5)	26.34	(6)
240 7s TL	9.45	**20.87**	22.15	**20.75**	(5)	28.22	(6)
245 7s TL	9.65	**21.80**	23.65	21.85	(5)	29.69	(6)
210 7ss TL	8.27	**20.86**	23.29	**20.61**	(5)	28.03	(6)
240 7ss TL	9.45	**23.50**	26.85	23.79	(5)	32.26	(6)
280 7ss TL	11.02	**25.83**	30.15	26.71	(5)	36.36	(6)
320 8ss TL	12.60	**28.39**	33.34	29.90	(5)	40.60	(6)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Vibration control calculation as per chapter 7, CLT Handbook, US Ed.
(3) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(4) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(5) Floor live load Δ_L < L/480
(6) Floor live load Δ_L < L/720
(7) Vibration controlled span is the same for single and two span conditions where all spans = L
(8) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(9) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

4.4 FLOORS WITH 2 IN. N.W. CONCRETE, L = 100 PSF



according to NDS 2015 and CLT Handbook, US ed.

Preliminary Sizing of CLT Floor Panels with 2“ n.w. concrete
D = 40 psf + panel self weight
L = 100 psf, C_D = 1.0

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

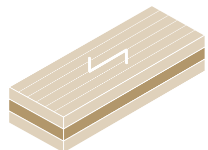
Panel Type	Thickness (in)	Both span conditions		Single span		Two equal spans	
		Vibration Control (ft)	Allowable Moment (ft)	Long term Δ_T = L/240 (ft)	Live load Δ_L @ Allowable Moment span	Long term Δ_T = L/240 (ft)	Live load Δ_L @ Allowable Moment span
60 3s TL	2.36	8.20	**6.35**	**5.87**	L/373	8.02	(6)
70 3s TL	2.76	9.13	**7.25**	**6.74**	L/385	9.22	(6)
80 3s TL	3.15	10.29	**8.52**	**7.88**	L/382	10.75	(6)
90 3s TL	3.54	11.17	**9.45**	**8.76**	L/390	11.97	(6)
100 3s TL	3.94	12.23	**10.61**	**9.85**	L/395	13.42	(6)
105 3s TL	4.13	12.51	**10.95**	**10.13**	L/395	13.85	(6)
120 3s TL	4.72	13.83	**12.43**	**11.52**	L/403	15.75	(6)
100 5s TL	3.94	11.49	**9.51**	**9.17**	L/440	12.49	(6)
120 5s TL	4.72	13.55	**11.91**	**11.29**	L/428	15.37	(6)
130 5s TL	5.12	14.32	**12.71**	**12.13**	L/441	16.50	(6)
140 5s TL	5.51	15.42	**14.14**	**13.29**	L/427	18.08	(6)
150 5s TL	5.91	16.19	**14.93**	**14.15**	L/442	19.23	(6)
160 5s TL	6.30	16.94	**15.73**	**15.00**	L/454	20.35	(6)
160 5ss TL	6.30	17.27	**16.51**	**15.28**	L/420	20.88	(6)
170 5s TL	6.69	17.44	**16.39**	**15.56**	L/453	21.19	(6)
175 5s TL	6.89	17.44	**16.18**	**15.58**	L/476	21.23	(6)
180 5s TL	7.09	18.13	**17.08**	**16.35**	L/469	22.25	(6)
180 7s TL	7.09	16.23	**14.18**	**14.40**	(5)	19.61	(6)
200 7s TL	7.87	17.36	**15.33**	15.67	(5)	21.35	(6)
220 7s TL	8.66	19.73	**18.43**	18.28	(5)	24.88	(6)
240 7s TL	9.45	20.87	**19.68**	**19.60**	(5)	26.71	(6)
245 7s TL	9.65	21.80	**21.00**	**20.65**	(5)	28.08	(6)
210 7ss TL	8.27	20.86	**20.65**	**19.42**	L/461	26.46	(6)
240 7ss TL	9.45	**23.50**	23.88	**22.48**	L/475	30.52	(6)
280 7ss TL	11.02	**25.83**	26.89	**25.27**	(5)	34.46	(6)
320 8ss TL	12.60	**28.39**	29.86	**28.37**	(5)	38.58	(6)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Vibration control calculation as per chapter 7, CLT Handbook, US Ed.
(3) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(4) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(5) Floor live load Δ_L < L/480
(6) Floor live load Δ_L < L/720
(7) Vibration controlled span is the same for single and two span conditions where all spans = L
(8) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(9) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

05 KLH® ROOF PANELS

5.1 ROOFS WITH L = 20 PSF

according to NDS 2015 and CLT Handbook, US ed.



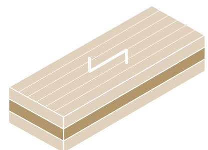
Preliminary Sizing of CLT Roof Panels
D = 10 psf + panel self weight
L = 20 psf, C_D = 1.25

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions	Single span		Two equal spans	
				Live load Δ_L		Live load Δ_L
		Allowable	Long term	@ Allowable	Long term	@ Allowable
		Moment	Δ_T = L/180	Moment span	Δ_T = L/180	Moment span
		(ft)	(ft)		(ft)	
60 3s TL	2.36	14.18	**10.17**	L/183	**13.72**	(5)
70 3s TL	2.76	16.00	**11.60**	L/197	**15.67**	(5)
80 3s TL	3.15	18.57	**13.36**	L/200	**18.03**	(5)
90 3s TL	3.54	20.41	**14.77**	L/211	**19.94**	(5)
100 3s TL	3.94	22.65	**16.36**	L/218	**22.06**	(5)
105 3s TL	4.13	23.26	**16.85**	L/225	**22.79**	(5)
120 3s TL	4.72	26.06	**18.94**	L/239	**25.58**	(5)
100 5s TL	3.94	**20.30**	**15.23**	(4)	20.52	(5)
120 5s TL	4.72	24.95	**18.45**	(4)	**24.89**	(5)
130 5s TL	5.12	**26.39**	**19.64**	(4)	26.48	(5)
140 5s TL	5.51	29.05	**21.37**	(4)	**28.85**	(5)
150 5s TL	5.91	30.46	**22.55**	(4)	**30.45**	(5)
160 5s TL	6.30	**31.83**	**23.73**	(4)	31.95	(5)
160 5ss TL	6.30	33.41	**24.38**	(4)	**32.93**	(5)
170 5s TL	6.69	**32.89**	**24.57**	(4)	33.16	(5)
175 5s TL	6.89	**32.34**	**24.55**	(4)	33.13	(5)
180 5s TL	7.09	**34.01**	**25.61**	(4)	34.55	(5)
180 7s TL	7.09	**28.24**	**22.59**	(4)	30.48	(5)
200 7s TL	7.87	**30.07**	**24.32**	(4)	32.85	(5)
220 7s TL	8.66	**35.63**	**28.02**	(4)	37.81	(5)
240 7s TL	9.45	**37.54**	**29.75**	(4)	40.15	(5)
245 7s TL	9.65	**39.92**	**31.22**	(4)	42.14	(5)
210 7ss TL	8.27	**40.21**	**29.96**	(4)	40.45	(5)
240 7ss TL	9.45	**45.56**	**33.99**	(4)	45.83	(5)
280 7ss TL	11.02	**50.03**	**37.71**	(4)	50.95	(5)
320 8ss TL	12.60	**54.33**	**41.51**	(4)	56.03	(5)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(3) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(4) Roof live load Δ_L < L/240
(5) Roof live load Δ_L < L/360
(6) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(7) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

5.2 ROOFS WITH S = 25 PSF



according to NDS 2015 and CLT Handbook, US ed.

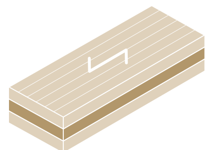
Preliminary Sizing of CLT Roof Panels
D = 20 psf + panel self weight
S = 25 psf, C_D = 1.15

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions	Single span		Two equal spans	
		Allowable Moment (ft)	Long term Δ_T = L/180 (ft)	Snow load Δ_S @ Allowable Moment span	Long term Δ_T = L/180 (ft)	Snow load Δ_S @ Allowable Moment span
60 3s TL	2.36	**11.48**	**8.93**	(4)	12.07	(5)
70 3s TL	2.76	**12.99**	**10.22**	(4)	13.82	(5)
80 3s TL	3.15	**15.15**	**11.82**	(4)	15.97	(5)
90 3s TL	3.54	**16.71**	**13.11**	(4)	17.73	(5)
100 3s TL	3.94	**18.62**	**14.59**	(4)	19.72	(5)
105 3s TL	4.13	**19.16**	**15.05**	(4)	20.35	(5)
120 3s TL	4.72	**21.57**	**16.97**	(4)	23.00	(5)
100 5s TL	3.94	**16.69**	**13.57**	(4)	18.32	(5)
120 5s TL	4.72	**20.65**	**16.55**	(4)	22.35	(5)
130 5s TL	5.12	**21.92**	**17.69**	(4)	23.87	(5)
140 5s TL	5.51	**24.20**	**19.32**	(4)	26.08	(5)
150 5s TL	5.91	**25.45**	**20.43**	(4)	27.58	(5)
160 5s TL	6.30	**26.67**	**21.55**	(4)	29.05	(5)
160 5ss TL	6.30	**28.00**	**22.12**	(4)	29.92	(5)
170 5s TL	6.69	**27.64**	**22.35**	(4)	30.21	(5)
175 5s TL	6.89	**27.21**	**22.35**	(4)	30.18	(5)
180 5s TL	7.09	**28.65**	**23.35**	(4)	31.55	(5)
180 7s TL	7.09	**23.79**	**20.60**	(4)	27.83	(5)
200 7s TL	7.87	**25.46**	**22.27**	(4)	30.08	(5)
220 7s TL	8.66	**30.31**	**25.76**	(4)	34.80	(5)
240 7s TL	9.45	**32.07**	**27.44**	(4)	37.15	(5)
245 7s TL	9.65	**34.14**	**28.82**	(4)	38.95	(5)
210 7ss TL	8.27	**34.13**	**27.49**	(4)	37.17	(5)
240 7ss TL	9.45	**38.92**	**31.38**	(4)	42.35	(5)
280 7ss TL	11.02	**43.07**	**35.01**	(4)	47.36	(5)
320 8ss TL	12.60	**47.08**	**38.76**	(4)	52.36	(5)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(3) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(4) Roof snow load Δ_S < L/240
(5) Roof snow load Δ_S < L/360
(6) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(7) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

5.3 ROOFS WITH S = 40 PSF



according to NDS 2015 and CLT Handbook, US ed.

Preliminary Sizing of CLT Roof Panels
D = 20 psf + panel self weight
S = 40 psf, C_D = 1.15

Allowable spans for KLH®-CLT in major strength direction
Single span = L and two equal spans each = L
Governing span in **bold** font

Panel Type	Thickness (in)	Both span conditions	Single span		Two equal spans	
		Allowable Moment (ft)	Long term Δ_T = L/180 (ft)	Snow load Δ_S @ Allowable Moment span	Long term Δ_T = L/180 (ft)	Snow load Δ_S @ Allowable Moment span
60 3s TL	2.36	**10.12**	**8.40**	(4)	11.37	(5)
70 3s TL	2.76	**12.99**	**10.22**	(4)	13.82	(5)
80 3s TL	3.15	**13.41**	**11.16**	(4)	15.10	(5)
90 3s TL	3.54	**16.71**	**13.11**	(4)	17.73	(5)
100 3s TL	3.94	**16.55**	**13.81**	(4)	18.68	(5)
105 3s TL	4.13	**17.05**	**14.25**	(4)	19.32	(5)
120 3s TL	4.72	**19.26**	**16.12**	(4)	21.82	(5)
100 5s TL	3.94	**14.84**	**12.87**	(4)	17.38	(5)
120 5s TL	4.72	**18.43**	**15.72**	(4)	21.25	(5)
130 5s TL	5.12	**21.92**	**17.69**	(4)	23.87	(5)
140 5s TL	5.51	**21.68**	**18.36**	(4)	24.85	(5)
150 5s TL	5.91	**22.85**	**19.48**	(4)	26.29	(5)
160 5s TL	6.30	**23.99**	**20.55**	(4)	27.75	(5)
160 5ss TL	6.30	**25.17**	**21.09**	(4)	28.55	(5)
170 5s TL	6.69	**27.64**	**22.35**	(4)	30.21	(5)
175 5s TL	6.89	**24.53**	**21.32**	(4)	28.83	(5)
180 5s TL	7.09	**25.85**	**22.32**	(4)	30.15	(5)
180 7s TL	7.09	**23.79**	**20.60**	(4)	27.83	(5)
200 7s TL	7.87	**23.04**	**21.32**	(4)	28.82	(5)
220 7s TL	8.66	**30.31**	**25.76**	(4)	34.80	(5)
240 7s TL	9.45	**29.19**	**26.35**	(4)	35.68	(5)
245 7s TL	9.65	**31.10**	**27.69**	(4)	37.46	(5)
210 7ss TL	8.27	**30.94**	**26.33**	(4)	35.62	(5)
240 7ss TL	9.45	**35.43**	**30.14**	(4)	40.69	(5)
280 7ss TL	11.02	**39.41**	**33.70**	(4)	45.62	(5)
320 8ss TL	12.60	**43.28**	**37.41**	(4)	50.57	(5)

Notes:
(1) Spans controlled by allowable moment include panel self weight
(2) Deflections based on EI_{app} as per chapter 3, CLT Handbook, US Ed.
(3) Long term loading deflection Δ_T based on K_{cr} = 2.0 as per NDS 2015 Section 3.5.2
(4) Roof snow load Δ_S < L/240
(5) Roof snow load Δ_S < L/360
(6) Allowable moment controlled span based on $M_{max} = +wL^2/8$ for single span condition and $M_{max} = -wL^2/8$ over interior support for two span condition
(7) E.O.R. must verify structural adequacy of CLT panel chosen for actual project load and span conditions

06 ADDITIONAL DESIGN PROCEDURES

6.1 FIRE DESIGN PROCEDURE FOR CLT PANELS

Step 1:
Determine the effective char depth for a given fire duration using the procedures illustrated in Chapter 16 of the National Design Specification for Wood Construction (NDS), 2015 Ed. For all laminations of equal thicknesses, see Table 16.2.1B for a summary of effective char depth based on lamination thicknesses and fire duration. For CLT panels of unequal lamination thicknesses, refer to the CLT Handbook, U.S. Ed., for modified procedures for calculating the effective char depth.

Step 2:
Calculate the reduced section properties of remaining unburned wood using principles of engineering mechanics. Worked examples are provided in the CLT Handbook, U.S. Ed.

Step 3:
Calculate the member strength after charring using the procedure described in NDS Section 16.2.2. Adjustment factors applied to the various strength properties are given in Table 16.2.2.

Step 4:
Verify that the member strengths are greater than the load effects due to service loads.

Step 5:
Verify the integrity of CLT joints using the procedure specified in Chapter 8 of the CLT Handbook, U.S. Ed.

6.2 DEFLECTION OF HORIZONTAL CLT PANELS DUE TO OUT-OF-PLANE LOADS

Deflection shall be calculated according to NDS 3.5, including time-dependent deformation (creep). Deflection calculations shall be performed using the apparent bending stiffness $(EI)_{app,}$ which reduces the effective bending stiffness $(EI)_{eff}$ to account for the effects of shear deformation, as per NDS 10.4.

6.3 VIBRATION ANALYSIS OF CLT PANELS DUE TO OUT-OF-PLANE LOADS

Vibration limit states may be calculated using the simplified equation in the CLT Handbook, U.S. Ed., or any rational procedure approved by the engineer.

6.4 CLT AS COMPRESSION MEMBERS WITH OR WITHOUT SIMULTANEOUS OUT-OF-PLANE LOADING

For CLT loaded in plane as a compression member, such as a bearing wall, the column stability factor CP shall be calculated as per NDS 3.7 using $(EI)_{app\text{-}min} = 0.5184(EI)_{app}$ and applied to the reference compression design value parallel to grain, $Fc(A_{parallel})$, as per NDS 10.3.7, along with all other applicable adjustment factors as per NDS Table 10.3.1. For cases involving simultaneous out-of-plane loading, such as wind load, refer to the procedures specified in NDS 3.9.

6.5 CLT IN-PLANE BENDING

The engineer should use a rational method to calculate the bending capacity of CLT members used for in-plane loading situations, such as lintels or cantilevered walls. For example, only horizontal laminations might be considered as effective for bending resistance, with shear checked using the values for in-plane shear reported in section 3.3.

6.6 FASTENERS

The procedures specified in NDS Chapters 11-12 for fastener design may be used for CLT construction, giving attention to how the fasteners are oriented relative to the direction of grain of the laminations involved in the connection.

6.7 FIRE PERFORMANCE TESTING AT SOUTHWEST RESEARCH INSTITUTE (SWRI ®)

ASTM E119-16 STANDARD TEST METHODS FOR FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS

60-minute Fire Resistance Rating

5-ply 130 mm thick CLT, load bearing roof assembly, SwRI Project No. 01.23472.01.001, June 6, 2018
5-ply 160 mm thick CLT, load bearing floor assembly, SwRI Project No. 01.23472.01.004, June 29, 2018

ASTM E84-16 STANDARD TEST METHOD FOR SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS

Flame Spread Index and Smoke Developed Index, Classification B

5-ply 130 mm thick CLT, SwRI Project No. 01.23472.02.001, April 17, 2018

ASTM E2768-11 STANDARD TEST METHOD FOR EXTENDED DURATION SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS (30 MIN TUNNEL TEST)

Flame Spread Index and Smoke Developed Index, Classification B

5-ply 130 mm thick CLT, SwRI Project No. 01.23472.02.001a

Support during erection in Wiener Neustadt I Austria

Single Family house in Klagenfurt | Austria

Home in Scappoose, Oregon | USA

07 GENERAL STRUCTURAL NOTES

01 Cross-Laminated Timber panels shall be manufactured in conformance with the latest edition of ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber.

02 Minimum allowable design properties for the lumber laminations used in the panels shall be grade CV3M1.

03 Exposed panel surfaces shall be finished as per the Architectural drawings.

04 Contractor to confirm all dimensions and details with Architectural drawings.

05 CLT panels shall consist of 3, 5, 7, or 8 layers of crosswise stacked spruce boards and glued together with approved adhesives. Lamination thickness may vary from 20 mm to 40 mm (25/32″ to 1-9/16″).

06 Panels shall not be fabricated until approval of the shop drawings by the E.O.R.

07 Panels shall be manufactured with lumber of maximum moisture content of 12% (+/-) 2%.

08 The Contractor shall cut no holes, slots, notches, grooves, etc. in the panels without written approval by the E.O.R.

09 CLT panels shall be installed in strict conformance with manufacturer's requirements

10 Store all panels off the ground and stacked using spacers to separate individual panels. Contractor is responsible for taking appropriate measures to minimize the likelihood of staining, cracking, distortion, warping or other types of damage to the panels.

11 Lift and support panels during construction only at designated points shown in the shop drawings.

12 Handle panels consistent with their shape to minimize damage.

13 Panels shall fit together properly, without trimming or cutting in the field. The Contractor shall report any problems with fit-up to the E.O.R.

14 CLT panels shall be adequately braced until all structural diaphragms and permanent bracing systems are installed and connected.

15 Floor and roof panels shall be oriented with the exterior layers perpendicular to the supports, u.o.n.

16 Structural steel components used to connect the panels to each other or the structural framework and, if supplied by the manufacturer, test fitted in the manufacturing facility prior to shipment.

17 The manufacturer shall provide instructions and prepare the panels for shipment in such a way as to facilitate erection.

18 Manufacturer shall affix labels to all panels.

19 Panel labels will include information on the surface qualities of each face.

20 Manufacturer shall submit product certificates to the A.O.R. and E.O.R. for review and written approval prior to fabrication.

08 SECTION 06130 HEAVY TIMBER CONSTRUCTION

PART 1 GENERAL

1.1 RELATED DOCUMENTS

A Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A Labor, materials, equipment, services, and transportation required to complete the work as shown on the Drawings and as specified herein.
1 Cross Laminated Timber (CLT) panels as indicated in the drawings.
2 Connectors, fasteners, and other installation accessories.
3 Erection.

1.3 REFERENCES

A ANSI/APA PRG 320-2018 Standard for Performance-Rated Cross-LaminatedTimber.
B NDS 2015 National Design Specification for Wood Construction.
C AITC 108: Standard for Heavy Timber Construction
D ANSI 405: Standard for Adhesives for Use in Structural Glued Laminated Timber

1.4 SUBMITTALS

A Product Data for each type of product indicated.
B Shop Drawings, including panel location plans, dimensions, shapes and sections, openings, support conditions, and connections.
1 Indicate lifting connections.
2 Indicate locations, tolerances, and details of anchorage to supporting structure.
3 Include and locate openings.
4 Indicate location of CLT panel by identification mark placed on panel.
5 Indicate relationship of CLT panels to adjacent materials.
6 Clearly indicate stress grade, service grade, and appearance grade of surfaces.
7 Provide three dimensional models of all interfaces and CLT panels, including all connections.
8 CLT supplier shall provide a fully accurate three-dimensional (3D) model of the interfaces (supports, abutments, etc.), CLT panels, and all connections prior to submission of shop drawings. Model to be generated using hsbcad (compatible with AutoCAD 2011).

C Sustainable Design Submittals
1 Manufacturer's product data for adhesives, sealants, paints, and coatings, including printed manufacturer's statement of VOC content.
2 Provide certificates indicating location of material manufacturer and point of extraction, harvest, or recovery for each raw material to Project, by rail, by inland waterway, by sea and by all other means. Include statement indicating cost for each regional material, and fraction by weight that is considered regional.
3 For non-recycled wood and wood based materials, provide itemized list of materials including manufacturer and vendor chain-of-custody certificates.
4 Vendors and organizations modifying materials and/or packaging of material must be FSC® Chain of Custody (CoC) certified, as determined by an FSC®-accredited certification body.
5 Certified Wood: Lamination stock shall be produced from wood obtained from forests certified by an FSC®-accredited certification body to comply with FSC® STD-01-001, "FSC® Principles and Criteria for Forest Stewardship."As an alternate, CLT lumber shall be certified to PEFC.

1.5 QUALITY ASSURANCE

A Material Standard: Certify CLT panels to APA/ANSI PRG 320.
B Manufacturer's Qualifications: Manufacturer shall comply with the National Design Specification for Wood Construction- NDS 2015, applicable to types of CLT panels indicated.

1.6 DELIVERY, STORAGE, AND HANDLING

A Support panels during shipment on non-staining material in same position as during storage.
B Store panels with adequate bracing and protect panels to prevent contact with soil. Separate panels with blocking so that air may circulate around all faces. Take all reasonable steps to prevent cracking, distortion, warping or other physical damage.
1 Place stored panels so that identification labels are clearly visible.
2 Handle and transport units in a position consistent with their shape and design in order to avoid excessive stresses that would cause cracking or damage.
3 Lift and support panels only at designated points shown on the Shop Drawings.
4 Cover top and sides with opaque moisture resistant membrane.
5 Maintain protection of panels at all times during construction.

PART 2 PRODUCTS

2.1 PRODUCT REQUIREMENTS

A Provide FSC® C119602-certified wood products, or a PEFC alternative.

2.2 MANUFACTURER

A Basis-of-Design manufacturer:

1 KLH. Contact Sebastian Popp, 30 Wall Street | 8th floor New York, NY 10005-2205, (971) 804-3794, sebastian.popp@klhusa.com

2.3 MATERIALS

A Wood Species: FSC® C119602- or PEFC-certified Austrian Spruce for lamination stock for panels.

B Adhesives: Provide adhesive products in compliance with ANSI A190.1, DIN 68141, and EN301 and EN302.

1 Acceptable Product: Purbond HB X172 by Henkel Corp.: na.henkel-adhesives.com.

2.4 FABRICATION

A Fabricate panels in accordance with ANSI/APA PRG 320.
Use multiple layers of 20 mm minimum to 40 mm maximum thick laminations.

B Manufacturer to be ISO 9001, 14001 certified.

C CLT Layup shall be Stress Grade CV3M1 as per Product listing.

D Joints: CLT panels shall be joined at panel edges using connections as indicated on the Drawings.

E Panels shall satisfy one of the following appearance classifications, as indicated on the Drawings.
See **www.klh.at/en/product/surface/** for a complete description of these classifications.

1 NSI (NVQ): Non-Visual Quality (very low surface quality, planed)

2 ISI (IVQ): Industrial Visual Quality (medium surface quality, sanded)

3 WSI (DVQ): Domestic Visual Quality (high surface quality, sanded, surface edges glued)

F Tolerances: +/- 2 mm for panels >1 m^2 @ 12% moisture content.

PART 3 EXECUTION

3.1 EXAMINATION

A Prior to fabrication, check all dimensions relating to this section of work. Report any discrepancies to the EOR.

B Prior to site erection, examine all site conditions and ensure an acceptable condition.

3.2 INSTALLATION

A Erect panels in accordance with final approved shop drawings.

B Make adequate provision for possible erection stresses.
Set panels level and plumb to correct positions. Securely brace panels and anchor in place to maintain plumb until permanently secured by finished structure.

C Fit panels closely and accurately, without trimming, cutting, or other modifications, unless approved in writing by the EOR.

D Site cutting or boring of panels, other than shown on the shop drawings, is not permitted without the written consent of the EOR.

3.3 CLEANING

A Clean exposed surface of panels after erection and completion of field touch up.

1 Perform cleaning procedures, if necessary, according to Manufacturer's written recommendations. Protect other work from staining or damage due to cleaning operations.

2 Do not use cleaning materials or processes that could damage the appearance of the panels or damage adjacent materials.

END OF SECTION 06130

NOTES

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