COCIS Research into Mass Timber Systems – Cross Laminated Timber

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DATE: ***04/12/2019***

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1 CLT - Compliance criteria

Outlined in Table below is the complete list of essential requirements, test methods and compliance criteria for CLT contained in BS EN 16351, which should carried out prior to obtaining European Technical Approval. (NOTE: all mechanical properties of CLT can also be derived from calculations).

Table - Initial type testing for cross laminated timber

Characteristic	Symbol	Assessment method	Test Standard	No. of tests	Notes/Compliance Criteria
1. Mechanical properties perpendicular to the plane of cross laminated timber					
1.1 Modulus of Elasticity	$E_{0,mean}$	Bending test	BS EN 16351:2015 & BS EN 408:2010	7-15	No. of test depend on the width of specimens. Test setup as per BS EN 16351:2015 cl. F3.1
1.2 Bending Strength	$f_{m,k}$				
1.3 (Rolling) Shear stiffness	$G_{9090,mean}$	Shear test	BS EN 16351:2015 &/or EN 789:2004	7-15	Number of test depend on the width of specimens Two possible test set ups
1.4 (Rolling) Shear strength	$f_{v,9090,k}$				
1.5 Compressive Strength	$f_{c,90,k}$	Compression test	BS EN 408:2010	30	-
1.6 Tensile Strength	$f_{t,90,k}$	Tension test	BS EN 408:2010	30	-
2. Mechanical properies in plane of cross laminated timber					
2.1 Modulus of Elasticity	$E_{0,mean}$	Bending test	BS EN 16351:2015 & BS EN 408:2010	7-12	Number of test depend on the width of specimens Test setup as per BS EN 16351:2015 cl. F4.1
2.2 Bending Strength	$f_{m,k}$				
2.3 Shear stiffness	$G_{090,mean}$	Bending test	BS EN 16351:2015 & BS EN 408:2010	20	Test setup as per BS EN 16351:2015 cl. F4.4
2.4 Shear strength	$F_{v,090,k}$	Shear test	BS EN 16351:2015 & BS EN 408:2010	20	Test setup as per BS EN 16351:2015 cl. F4.2
2.5 Compressive Strength	$f_{c,0,k}$	Compression test	BS EN 408:2010	30	-
2.6 Tensile Strength	$f_{t,0,k}$	Tension test	BS EN 408:2010	30	-
3. Bonding strength of cross laminated timber					
3.1 Bonding Strength of glue lines between layers	*Delam* (%)	Delamination test	BS EN 16351:2015	10	Declared as Pass Delam or Pass Shear
	f_v	or Shear test	BS EN 16351:2015	10	
4. Resistance to fire of cross laminated timber					
4.1 Geometrical data	L, t, w	Measurement	BS EN 16351:2015 & EN 14081–1	3	Charring rate (of layers), declared based on species used and strength class
4.2 Density of timber	ρ	Assess, check or test	BS EN 16351:2015 & EN 14081–1	3	
4.3 Species	-	Check	BS EN 16351:2015	-	
5. Reaction to fire of cross laminated timber					
5.1 Reaction to Fire	-	Check	EN 14081–1	-	Declared based on fire class of layers or tests
	-	or Fire test	EN 13501-1	-	
6. Dimensional stability of cross laminated timber					
6.1 Moisture deformation factor or Species	k_{cor}	Check	BS EN 16351:2015	-	Check that species listed in BS EN 16351 are used
7. Release / content of dangerous substances					
7.1 Formaldehyde emission	E1, E2	Check or test	BS EN 16351:2015	-	Declared as formaldehyde release class (E1 or E2)
8. Durability of bonding strength & against biological attack					
8.1 Species	-	Check	BS EN 16351:2015	-	-
8.2 Adhesive characteristic	-	Check or test	BS EN 16351:2015		Usually provided by adhesive/preservative manufacturer
8.4 Preservative treatment	-	Check or test	BS EN 16351:2015		

- CLT - Mechanical resistance

According to BS EN14080:2013 mechanical resistance covers the following essential characteristics of the cross laminated timber:

- Bending strength,
- Compressive strength,
- Tensile strength,
- Shear strength,
- Modulus of elasticity,
- Density.

Mechanical resistance of CLT can be determined on the basis of either geometrical data (e.g. cross-sectional sizes of laminations and layups) and baseline material properties or laboratory tests. Shown below is the diagram outlining all possible mechanical resistance verification procedures for CLT in accordance with BS EN 16351:2015.

Verification of Mechanical Resistance of CLT:

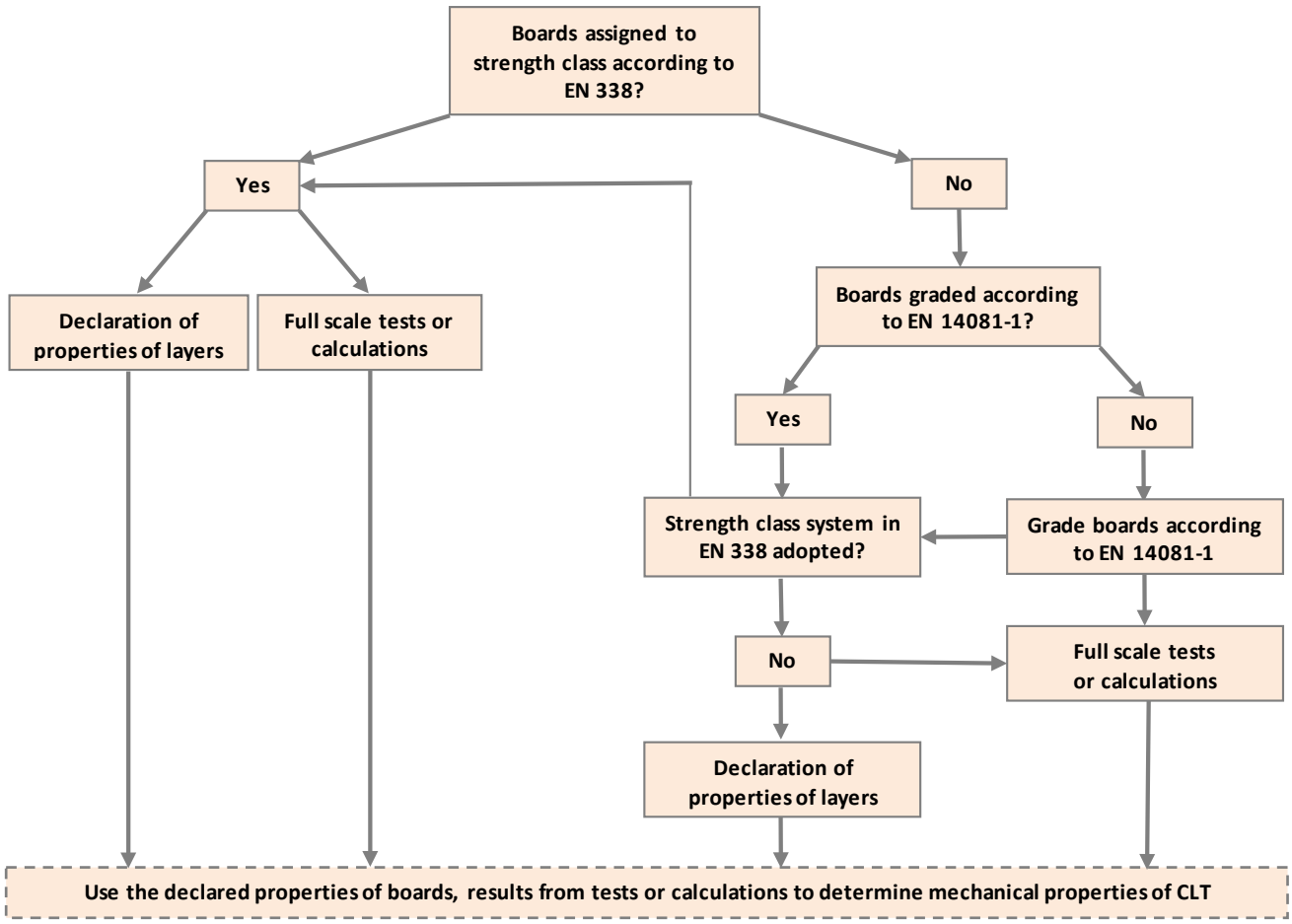


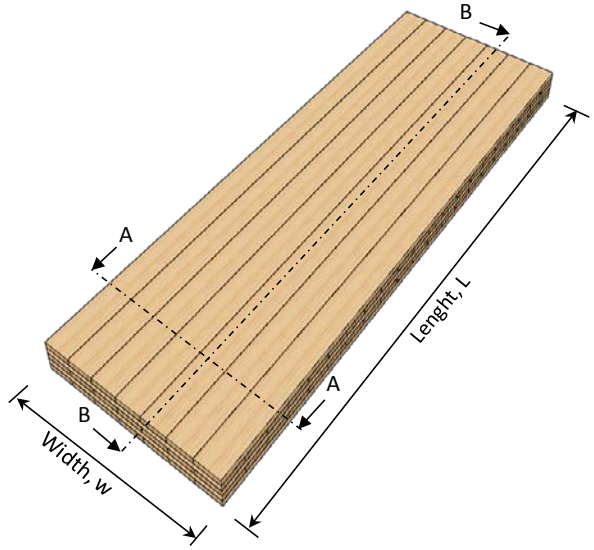
Figure – Procedures for determination mechanical resistance of CLT to BS EN 16351:2015

2 UK CLT – Possible configurations

Using grading settings for UK timber in conjunction with the requirements contained in BS EN 16351 it is possible to assign key mechanical and non-mechanical properties of CLT made from UK grown timber by declaring appropriate lamella properties (strength classes). Shown below are some examples of possible CLT lay-ups with all corresponding properties listed in BS EN 16351. Presented in the first two tables are properties of the panels consisting of layers made of laminations of one strength class (C16 for UK Sitka Spruce and C20 for UK Larch) the remaining two examples demonstrate estimated properties of finished CLT assuming that UK grown Sitka spruce and Larches were to be graded to C24/C16 and C27/C16 combination respectively. In order to confirm the properties of CLT consisting of more than one strength class, a calculation exercise, using gamma and/or shear analogy methods (two most common analytical approaches accepted by CLT manufacturers and designers) is recommended.

Table – Possible specification of CLT made from UK Sitka Spruce (C16 grade)

CLT - UK Sitka Spruce

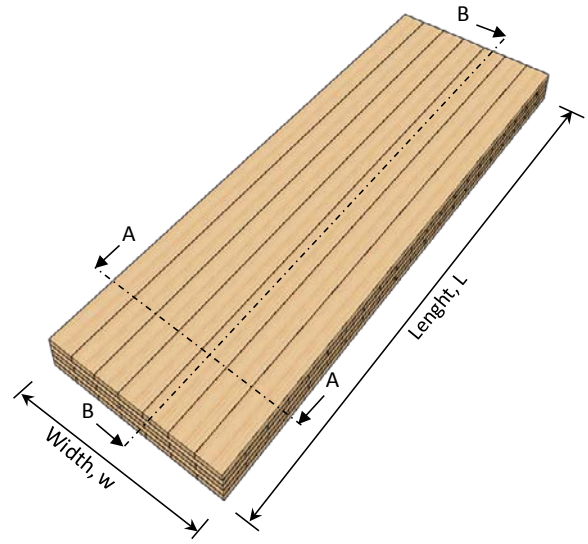


Utilisation of Sitka spruce graded to C16 = 100%

Cross laminated timber element		
Wood species:		UK Sitka Spruce
Number of layers:		3 to 9
Lay-up configuration		100% C16
Max width, w		≤ 3.5 m
Max length, L		≤ 13 m
Type of adhesive		Type 1
Formaldyde emission		E1
Reaction to fire:		D-s2, d0
Durability against biological attack:		2
Service classes:		1 and 2
Boards		
Thickness, t_l		6 to 45 mm
Width, b_l		40 to 300 mm
Ratio width to thickness		≥ 4:1
Moisture content to EN 13183-2:		6 to 15%
Mechanical resistance		
1. Perpendicular to cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	8000 N/mm²
Shear modulus	G_{mean}	500 N/mm²
Rolling shear modulus	$G_{R,mean}$	50 N/mm²
Bending strength	$f_{m,k}$	16 N/mm²
Tensile strength	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.2 N/mm²
Shear strength	$f_{v,k}$	2.2 N/mm²
Rolling shear strength	$f_{R,k}$	1.1 N/mm²
2. In-plane of cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	8000 N/mm²
Shear modulus	G_{mean}	500 N/mm²
Bending strength	$f_{m,k}$	16 N/mm²
Tensile strength	$f_{t,0,k}$	8.5 N/mm²
Compression strength	$f_{c,0,k}$	17 N/mm²
Shear strength	$f_{v,k}$	3.2 N/mm²
Other mechanical actions		
Creep and duration of load		to EN 1995-1-1
Bond integrity		Passed

Table – Possible specification of CLT made from UK Larch (C20 grade)

CLT - UK Larch

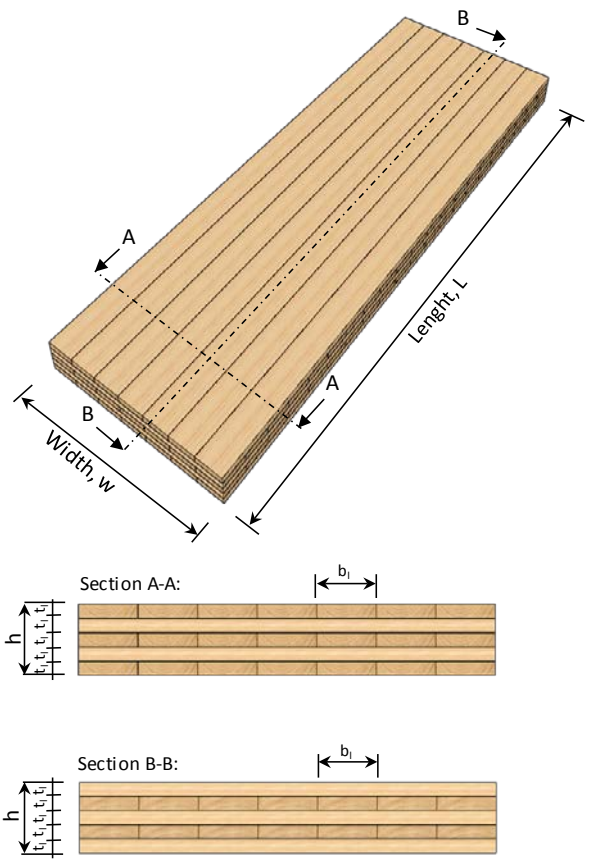


Utilisation of Sitka spruce graded to C16 = 100%

Cross laminated timber element		
Wood species:		UK Larch
Number of layers:		3 to 9
Lay-up configuration		100% C22
Max width, w		≤ 3.5 m
Max length, L		≤ 13 m
Type of adhesive		Type 1
Formaldyde emission		E1
Reaction to fire:		D-s2, d0
Durability against biological attack:		2
Service classes:		1 and 2
Boards		
Thickness, t_l		6 to 45 mm
Width, b_l		40 to 300 mm
Ratio width to thickness		≥ 4:1
Moisture content to EN 13183-2:		6 to 15%
Mechanical resistance		
1. Perpendicular to cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	9500 N/mm²
Shear modulus	G_{mean}	590 N/mm²
Rolling shear modulus	$G_{R,mean}$	50 N/mm²
Bending strength	$f_{m,k}$	20 N/mm²
Tensile strength	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.4 N/mm²
Shear strength	$f_{v,k}$	2.4 N/mm²
Rolling shear strength	$f_{R,k}$	1.1 N/mm²
2. In-plane of cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	9500 N/mm²
Shear modulus	G_{mean}	590 N/mm²
Bending strength	$f_{m,k}$	20 N/mm²
Tensile strength	$f_{t,0,k}$	11.5 N/mm²
Compression strength	$f_{c,0,k}$	19 N/mm²
Shear strength	$f_{v,k}$	3.6 N/mm²
Other mechanical actions		
Creep and duration of load		to EN 1995-1-1
Bond integrity		Passed

Table - Possible specification of CLT made from UK Sitka Spruce (C16/C27 grade combination)

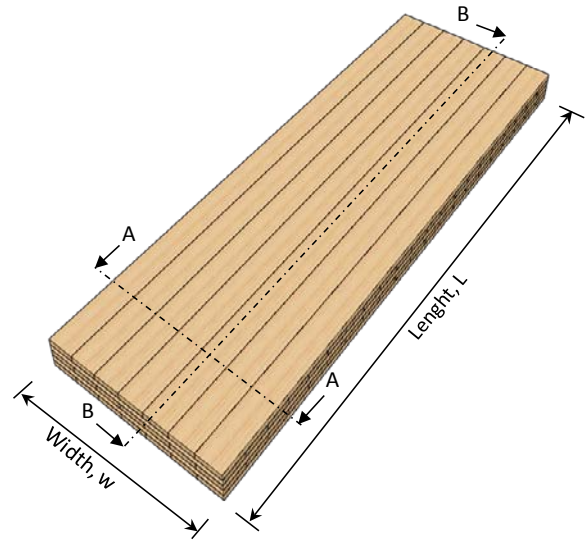
CLT - UK Sitka Spruce (Pontential)		
Cross laminated timber element		
Wood species:		UK Sitka Spruce
Number of layers:		3 to 9
Lay-up configuration (for 5-layer CLT)		C24-C16-C16-C16-C24
Max width, w		≤ 3.5 m
Max length, L		≤ 13 m
Type of adhesive		Type 1
Formaldyde emission		E1
Reaction to fire:		D-s2, d0
Durability against biological attack:		2
Service classes:		1 and 2
Boards		
Thickness, t_l		6 to 45 mm
Width, b_l		40 to 300 mm
Ratio width to thickness		≥ 4:1
Moisture content to EN 13183-2:		6 to 15%
Mechanical resistance		
1. Perpendicular to cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	11000 N/mm²
Shear modulus	G_{mean}	690 N/mm²
Rolling shear modulus	$G_{R,mean}$	50 N/mm²
Bending strength	$f_{m,k}$	24 N/mm²
Tensile strength	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.5 N/mm²
Shear strength	$f_{v,k}$	2.5 N/mm²
Rolling shear strength	$f_{R,k}$	1.1 N/mm²
2. In-plane of cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	11000 N/mm²
Shear modulus	G_{mean}	690 N/mm²
Bending strength	$f_{m,k}$	24 N/mm²
Tensile strength	$f_{t,0,k}$	14 N/mm²
Compression strength	$f_{c,0,k}$	21 N/mm²
Shear strength	$f_{v,k}$	4.0 N/mm²
Other mechanical actions		
Creep and duration of load		to EN 1995-1-1
Bond integrity		Passed



Estimated utilisation of Sitka spruce graded to C24/C16 ≈ 86%
(remaining 14% of timber is C16)

Table - Possible specification of CLT made from UK Larch (C16/C27 grade combination)

CLT - UK Larch (Potential)



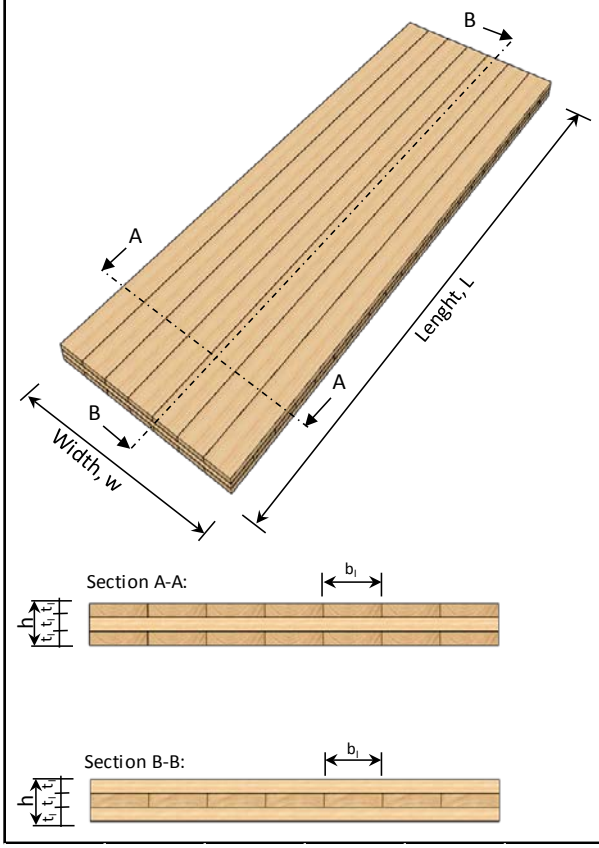
Estimated utilisation of UK Larch graded to C27/C16 ≈ 95% (remaining 1% of timber is C16)

Cross laminated timber element		
Wood species:		UK Larch
Number of layers:		3 to 9
Lay-up configuration (for 5-layer CLT)		C27-C16-C16-C16-C27
Max width, w		≤ 3.5 m
Max length, L		≤ 13 m
Type of adhesive		Type 1
Formaldyde emission		E1
Reaction to fire:		D-s2, d0
Durability against biological attack:		2
Service classes:		1 and 2
Boards		
Thickness, t_l		6 to 45 mm
Width, b_l		40 to 300 mm
Ratio width to thickness		≥ 4:1
Moisture content to EN 13183-2:		6 to 15%
Mechanical resistance		
1. Perpendicular to cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	11500 N/mm²
Shear modulus	G_{mean}	720 N/mm²
Rolling shear modulus	$G_{R,mean}$	50 N/mm²
Bending strength	$f_{m,k}$	27 N/mm²
Tensile strength	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.5 N/mm²
Shear strength	$f_{v,k}$	2.5 N/mm²
Rolling shear strength	$f_{R,k}$	1.1 N/mm²
2. In-plane of cross laminated timber		
Modulus of elasticity	$E_{0,mean}$	11500 N/mm²
Shear modulus	G_{mean}	720 N/mm²
Bending strength	$f_{m,k}$	27 N/mm²
Tensile strength	$f_{t,0,k}$	16.5 N/mm²
Compression strength	$f_{c,0,k}$	22 N/mm²
Shear strength	$f_{v,k}$	4.0 N/mm²
Other mechanical actions		
Creep and duration of load		to EN 1995-1-1
Bond integrity		Passed

3 UK CLT - Pilot manufacture

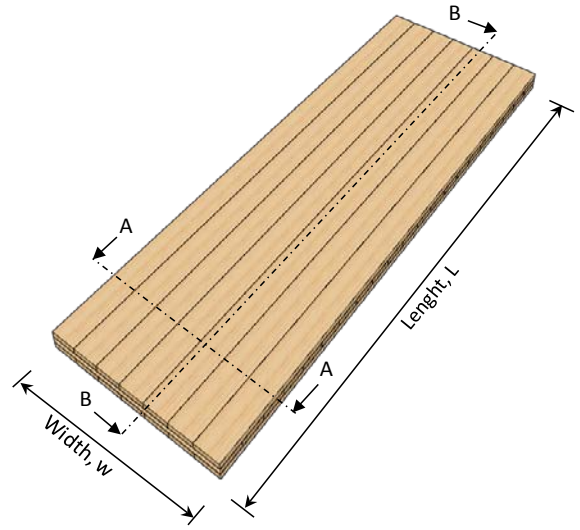
Over the last 7 years COCIS has been involved in pilot manufacture of a number of CLT panels utilising home-grown resource to demonstrate the feasibility the various material for CLT production. Presented in this section is an outline and specifications of all the CLT panels manufactured.

CLT - UK Sitka Spruce (Derix)



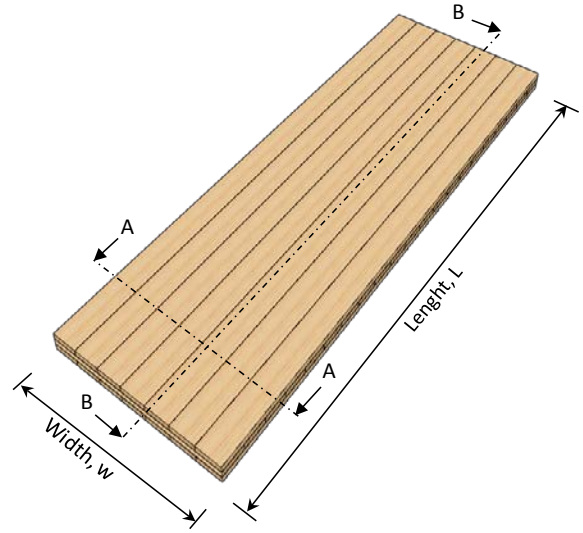
Cross laminated timber element	
Wood species:	UK Sitka Spruce
Number of layers:	3 ≤ n ≤ 5
Layer thickness and orientation (3ply):	30l-40c-30l
Layer thickness and orientation (5ply):	40l-30c-30l-30c-40l
Strength class of layers:	100% C16
Panel width, w:	2.9 to 3.0 m
Panel length, L:	10.5 to 13.5 m
Panel depth, h:	100 to 170 mm
Type of adhesive:	(MUF) 1255/7555
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	W.u.J. Derix GmbH
Controlled environment:	Yes
Year of manufacture:	2014
Press type:	Hydraulic press
Number of panels manufactured:	2
Boards	
Strength graded to EN 14081:	Yes
Strength class:	C16
Surface:	Planed
Thickness, t_l	30 to 40 mm
Width, b_l	100 to 170 mm
Ratio width to thickness	≥ 4:1
Finger joints	Yes
Moisture content to EN 13183-2:	11 - 15%
Mean Densiy	415 kg/m^3

CLT - UK Sitka Spruce (Norbuild)



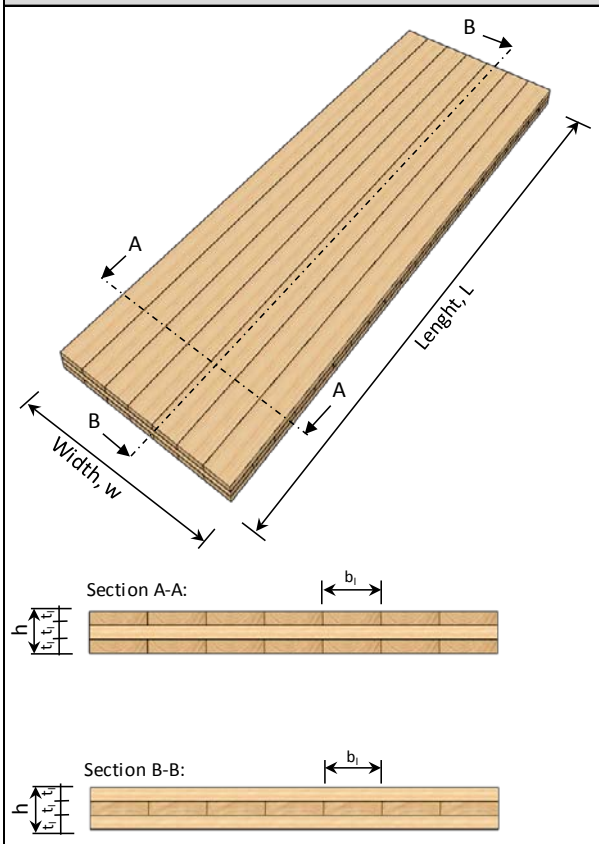
Cross laminated timber element	
Wood species:	UK Sitka Spruce
Number of layers:	3 ≤ n ≤ 5
Layer thickness and orientation (3ply):	40l-40c-40l
Layer thickness and orientation (5ply):	20l-20c-20l-20c-20l
Strength class of layers:	100% C16
Panel width, w:	1.2 to 1.3 m
Panel length, L:	2.6 to 3.2 m
Panel depth, h:	100 to 120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face and Edge
Large finger joints:	No
Manufactured by:	Norbuild
Controlled environment:	No
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	13
Boards	
Strength graded to EN 14081:	Yes
Strength class:	C16
Surface:	Planed
Thickness, t_l	20 to 40 mm
Width, b_l	95 to 140 mm
Ratio width to thickness	Varies
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	426 kg/m^3

CLT - UK Scots Pine



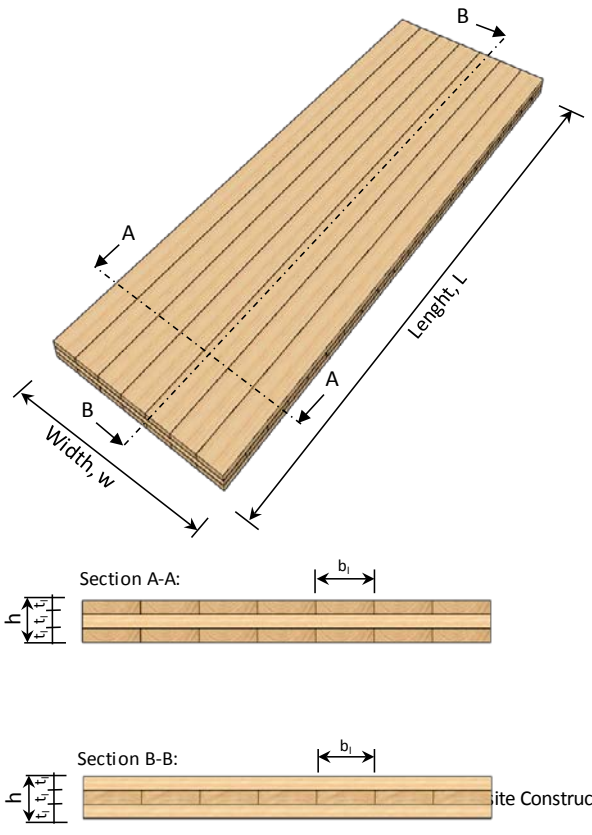
Cross laminated timber element	
Wood species:	UK Scots Pine
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Strength class of layers:	100% ≈C16
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Controlled environment:	No
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	3
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C16
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	523 kg/m^3

CLT - UK Douglas Fir



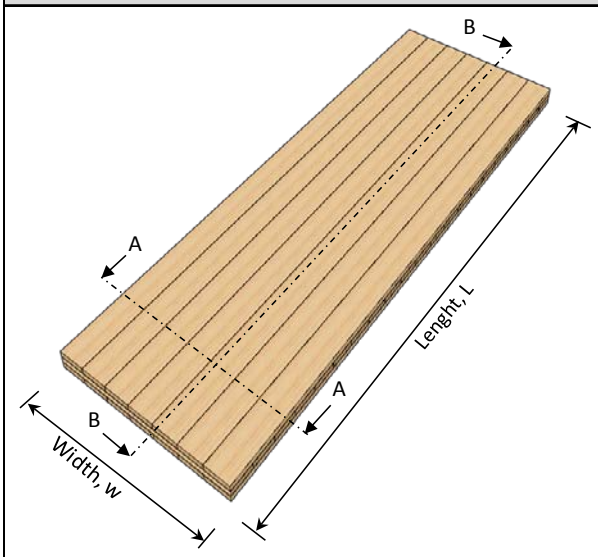
Cross laminated timber element	
Wood species:	UK Douglas Fir
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Strength class of layers:	100% ≈C22
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Harmonized standard:	BS EN 16351
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	3
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C22
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	481 kg/m^3

CLT - UK Western Hemlock



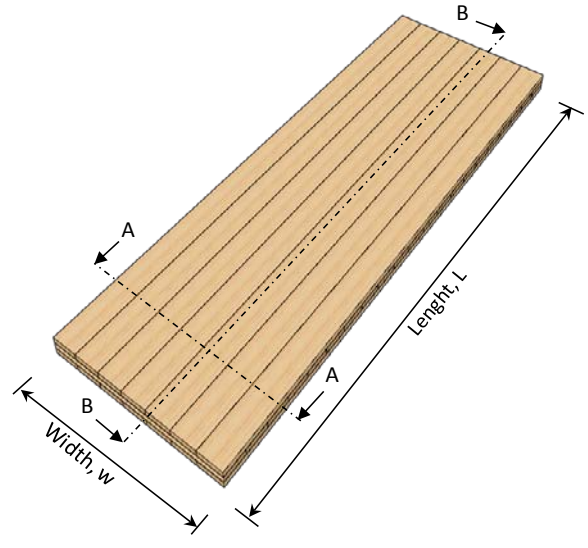
Cross laminated timber element	
Wood species:	UK Western Hemlock
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Strength class of layers:	100% ≈C18
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Controlled environment:	No
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	3
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C18
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	462 kg/m^3

CLT - UK Lawson Cypress



Cross laminated timber element	
Wood species:	UK Lawson Cypress
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Strength class of layers:	100% ≈C20
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Controlled environment:	No
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	3
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C20
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	464 kg/m^3

CLT - UK Larch



Cross laminated timber element	
Wood species:	UK Larch
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Strength class of layers:	100% ≈C14
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Controlled environment:	No
Year of manufacture:	2012
Press type:	Veneering press
Number of panels manufactured:	3
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C14
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	512 kg/m^3

4 UK CLT – Verified properties

- Tests on full scale panels

Outlined in the table below is summarised test programmes carried out on CLT manufactured from home grown material, including: Sitka spruce, Larch, Douglas Fir and Scots Pine, Western Hemlock and Lawson Cypress. In the past 7 years two large test programmes took place, which evaluated a number of CLT properties manufactured from hoe-grown species. The initial tests, carried out in 2012 by ENU, included bending and glue line shear tests on CLT manufactured by Norbuild utilising a number of home-grown species. The follow test programme on test programme included only CLT manufactured from Sitka Spruce in the controlled factory environment and tested by accredited testing facility (Graz University of Technology, Institute of Timber Engineering and Wood Technology, Lignum Test Centre).

Details on both test programmes are indicated in the table below.

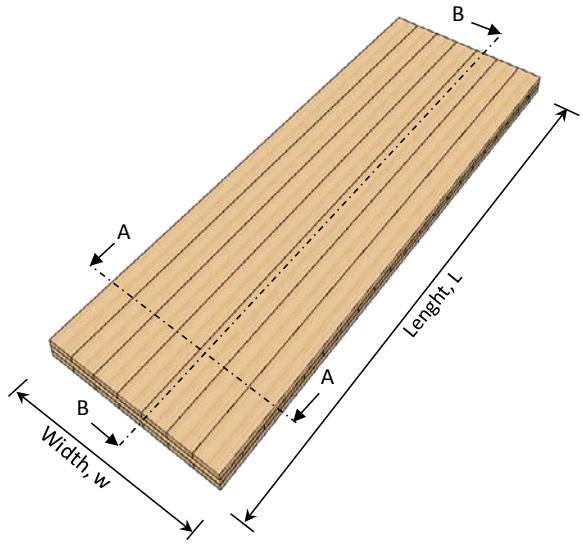
Table 1 - Test programmes of home-grown CLT carried out at ENU and Graz University

Test type	Test standard	Property assessed		No. of samples tested	Tested by
Sitka Spruce CLT (Derix)					
Bending perpendicular to CLT	BS EN 16351:2015 BS EN 408:2010	Bending strength	$f_{m,k}$	10	Graz University of Technology, Institute of Timber Engineering and Wood Technology, Lignum Test Centre
		Bending stiffness	$E_{0,mean}$		
Bending in plane of CLT	BS EN 16351:2015 BS EN 408:2010	Bending strength	$f_{m,k}$	10	
		Bending stiffness	$E_{0,mean}$		
Rolling hear	BS EN 16351:2015	Rolling shear strength	$f_{R,k}$	24	
Shear	BS EN 14080:2013	Shear strength	$f_{v,k}$	10	
Delamination	BS EN 16351:2015	Delamination	$Delam_{tot}$	20	
Varying species CLT (Sitka Spruce, Scots Pine, Douglas Fir, Western Hemlock, Lawson Cypress, Larch)					
Bending perpendicular to CLT	BS EN 16351:2015 BS EN 408:2010	Bending strength	$f_{m,k}$	4	Edinburgh Napier University, Institute for Sustainable Construction
		Bending stiffness	$E_{0,mean}$		
Bending in plane of CLT	BS EN 16351:2015 BS EN 408:2010	Bending strength	$f_{m,k}$	4	
		Bending stiffness	$E_{0,mean}$		
Glue line shear	BS EN 16351:2015	Shear strength	f_v	5	

- Analysis and verification of the results

Presented in this section are the spec sheets of CLT manufactured from UK resource based on the structural test work carried out on various panel configurations and species as well as the properties of base material used for manufacture. The properties for each home grown CLT panels indicated in the tables below are based on results from lab based test work as well as on estimated CLT strength class that could be achieved for each panel type. The properties derived from tests for each of the home grown CLT beams are summarised in the table below.

CLT - UK Sitka Spruce (Derix)



Cross laminated timber element	
Wood species:	UK Sitka Spruce
Number of layers:	3 ≤ n ≤ 5
Layer thickness and orientation (3ply):	30l-40c-30l
Layer thickness and orientation (5ply):	40l-30c-30l-30c-40l
Panel width, w:	2.9 to 3.0 m
Panel length, L:	10.5 to 13.5 m
Panel depth, h:	100 to 170 mm
Type of adhesive:	(MUF) 1255/7555
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	W.u.J. Derix GmbH
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

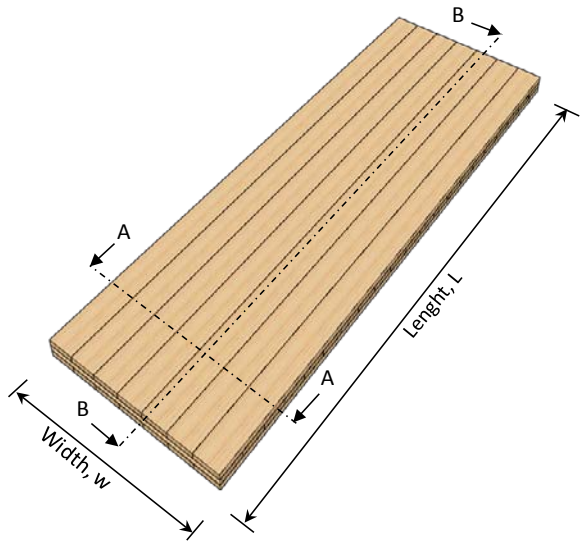
Boards	
Strength graded to EN 14081:	Yes
Strength class:	C16
Surface:	Planed
Thickness, t_l	30 to 40 mm
Width, b_l	100 to 170 mm
Ratio width to thickness	≥ 4:1
Finger joints	Yes
Moisture content to EN 13183-2:	11 - 15%
Mean Densiy	415 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	8332	N/mm²
Shear modulus	G_{mean}	532	N/mm²
Rolling shear modulus	$G_{R,mean}$	84.4	N/mm²
Bending strength	$f_{m,mean}$	25.8	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	1.94	N/mm²
Rolling shear strength	$f_{R,k}$	2.09	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9495	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength	$f_{m,k}$	21.75	N/mm²
Tensile strength	$f_{t,0,k}$	13.35	N/mm²
Compression strength	$f_{c,0,k}$	19	N/mm²
Shear strength	$f_{v,k}$	5	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338

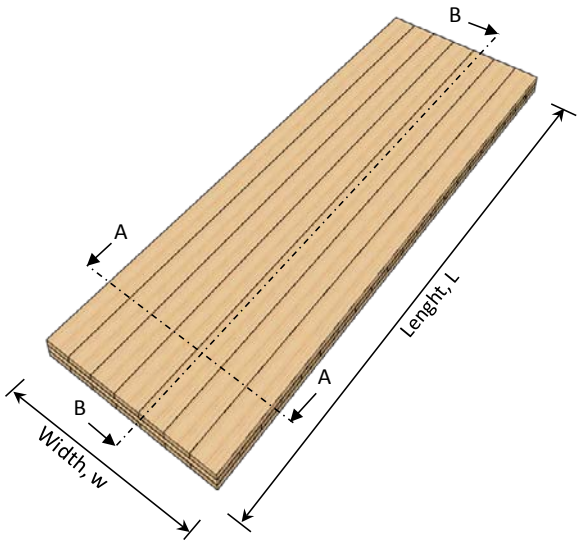
CLT - UK Sitka Spruce (Norbuild)



Cross laminated timber element			
Wood species:		UK Sitka Spruce	
Number of layers:		3 ≤ n ≤ 5	
Layer thickness and orientation (3ply):		40l-40c-40l	
Layer thickness and orientation (5ply):		20l-20c-20l-20c-20l	
Panel width, w:		1.2 to 1.3 m	
Panel length, L:		2.6 to 3.2 m	
Panel depth, h:		100 to 120 mm	
Type of adhesive:		PURBOND HB S709	
Bonded surface:		Face and Edge	
Large finger joints:		No	
Manufactured by:		Norbuild	
Reaction to fire:		D-s2, d0	
Durability against biological attack:		2	
Service classes:		1 and 2	
Boards			
Strength graded to EN 14081:		Yes	
Strength class:		C16	
Surface:		Planed	
Thickness, t_l		20 to 40 mm	
Width, b_l		95 to 140 mm	
Ratio width to thickness		Varies	
Finger joints		No	
Moisture content to EN 13183-2:		12 - 14%	
Mean Densiy		426 kg/m^3	
Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9933	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	27	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	2.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9651	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	40	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²
Other mechanical actions			
Creep and duration of load		to EN 1995-1-1	
Bond integrity		Passed	

Values obtained from tests
Values based on BS EN 338

CLT - UK Scots Pine



Cross laminated timber element	
Wood species:	UK Scots Pine
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

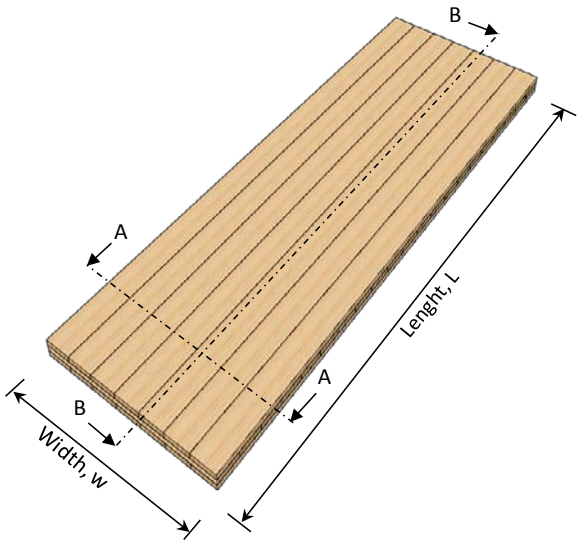
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C16
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	523 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9916	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	27	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	2.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	8164	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	38	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338

CLT - UK Douglas Fir



Cross laminated timber element	
Wood species:	UK Douglas Fir
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

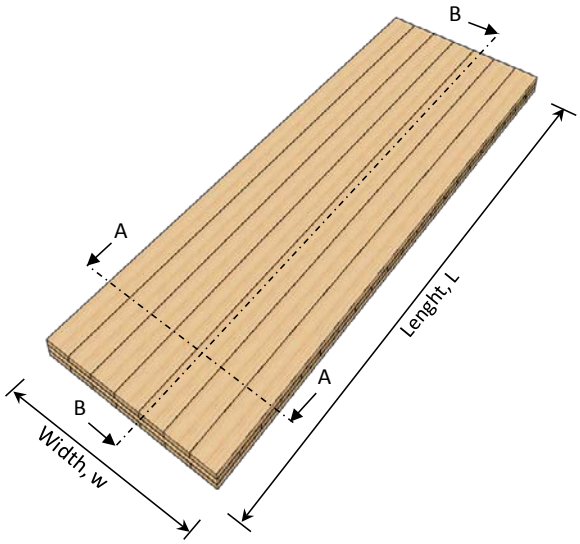
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C22
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	481 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	10613	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	24	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	10816	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	39	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338

CLT - UK Western Hemlock



Cross laminated timber element	
Wood species:	UK Western Hemlock
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

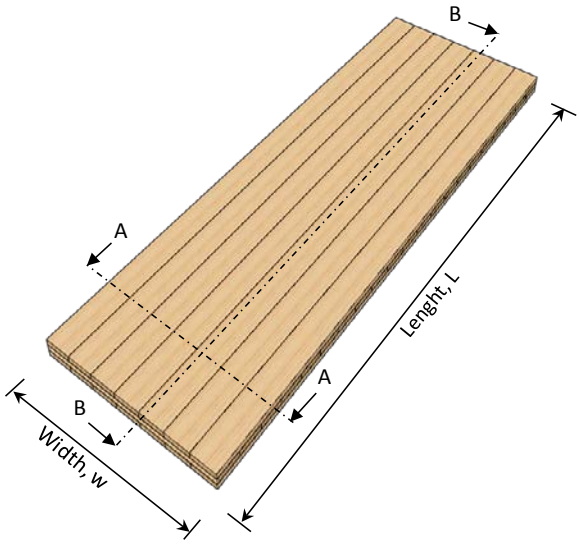
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C18
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	462 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	10261	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	26	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	2.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9329	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	36	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338

CLT - UK Lawson Cypress



Cross laminated timber element	
Wood species:	UK Lawson Cypress
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

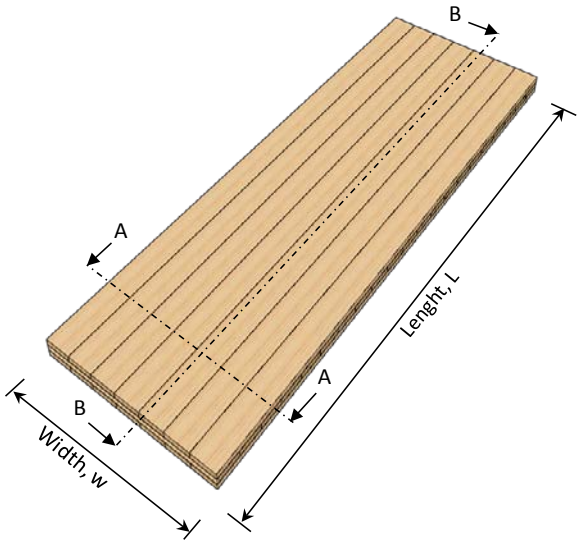
Boards	
Strength graded to EN 14081:	No
Strength class:	≈C20
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	464 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9069	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	24	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	2.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	9508	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	38	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338

CLT - UK Larch



Cross laminated timber element	
Wood species:	UK Larch
Number of layers:	3
Layer thickness and orientation:	40l-40c-40l
Panel width, w:	1260 mm
Panel length, L:	3200 mm
Panel depth, h:	120 mm
Type of adhesive:	PURBOND HB S709
Bonded surface:	Face
Large finger joints:	No
Manufactured by:	Norbuild
Reaction to fire:	D-s2, d0
Durability against biological attack:	2
Service classes:	1 and 2

Boards	
Strength graded to EN 14081:	No
Strength class:	≈C14
Surface:	Planed
Thickness, t_l	40 mm
Width, b_l	140 mm
Ratio width to thickness	≤ 4:1
Finger joints	No
Moisture content to EN 13183-2:	12 - 14%
Mean Densiy	512 kg/m^3

Mechanical resistance			
1. Perpendicular to cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	8308	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Rolling shear modulus	$G_{R,mean}$	50	N/mm²
Bending strength (mean)	$f_{m,k}$	18	N/mm²
Tensile strength	$f_{t,90,k}$	0.4	N/mm²
Compression strength	$f_{c,90,k}$	2.2	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²
Rolling shear strength	$f_{R,k}$	1.1	N/mm²
2. In-plane of cross laminated timber			
Modulus of elasticity	$E_{0,mean}$	7943	N/mm²
Shear modulus	G_{mean}	500	N/mm²
Bending strength (mean)	$f_{m,k}$	36	N/mm²
Tensile strength	$f_{t,0,k}$	8.5	N/mm²
Compression strength	$f_{c,0,k}$	17	N/mm²
Shear strength	$f_{v,k}$	3.2	N/mm²

Other mechanical actions	
Creep and duration of load	to EN 1995-1-1
Bond integrity	Passed

Values obtained from tests
Values based on BS EN 338