COCIS Research into Mass Timber Systems – Glued Laminated Timber

---

AUTHOR: ***Wojciech Plowas***
REPORT CONTACT: w.plowas@napier.ac.uk
DATE: ***04/12/2019***

INSTITUTE FOR SUSTAINABLE CONSTRUCTION

EDINBURGH NAPIER UNIVERSITY
www.napier.ac.uk

CONTENTS

1 GLT - Compliance criteria

- GLT initial type testing – Summary

Outlined in Table below is the complete list of essential requirements, test methods and compliance criteria for GLT contained in BS EN 14080, which should carried out prior to obtaining European Technical Approval. (NOTE: all mechanical properties of GLT can also be derived from calculations).

Table - Initial type testing for glued laminated products

Characteristic	Symbol	Assessment method	Test Standard	No. of tests	Notes/Compliance Criteria
1. Mechanical properties of glued laminated timber					
1.1 Bending Strength	$f_{m,g,k}$	Bending test	BS EN 408:2010	30	Bending tests in accordance with EN 408 cl. 9, 10 and 19
1.2 Modulus of Elasticity	$E_{0,g,05}$			30	
	$E_{90,g,05}$			30	
1.3 Compressive Strength	$f_{c,90,g,k}$	Compression test	BS EN 408:2010	30	Testing according to EN 408 cl. 15,16
	$f_{c,0,g,k}$			30	
1.4 Tensile Strength	$f_{t,90,g,k}$	Tension test		30	Testing according to EN 408 cl. 13
	$f_{t,0,g,k}$			30	
1.5 Shear strength	$f_{v,g,k}$	Shear test	BS EN 408:2010	30	Testing according to EN 408 cl. 19
1.6 Shear stiffness	$G_{g,mean}$				
1.7 Rolling shear strength	$f_{r,g,k}$	Shear test	BS EN 14080:2013 &/or EN 789:2004	30	
1.8 Rolling shear modulus	$G_{r,g,mean}$				
2. Bonding strength					
2.1 Bonding Strength of glue lines between laminations	*Delam* (%)	Delamination test	BS EN 14080:2013	10	Declared as Pass Delam or Pass Shear
	f_v	or Shear test	BS EN 14080:2013	10	
3. Durability of bonding strength					
3.1 Species	-	Check	BS EN 14080:2013	-	Untreated boards shall be between 6% and 15 % and preservative treated boards between 11% and 18%
3.2 Moisture of timber to be bonded	-	Test	BS EN 14080:2014	-	
3.3 Adhesive characteristic	-	Check or test	BS EN 14080:2013	-	Usually provided by adhesive/preservative manufacturer
3.4 Preservative treatment	-	Check or test	BS EN 14080:2013	-	
4. Durability of other characteristics against biological attack					
4.1 Without preservative treatment	-	Check	BS EN 14080:2013	-	The natural durability of GLT shall be taken as the natural durability of the timber from which they are made.
4.2 With preservative treatment	-	Check	BS EN 14080:2013	-	
5. Reaction to fire of nail 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. Resistance to fire of nail laminated timber					
4.1 Geometrical data	L, w, d	Measurement	BS EN 14080:2013 and/or EN 13823	-	Charring rate, declared based on species and strength class / tested if GLT does not meet the requirements or a higher classification is sought
4.2 Density of timber	ρ	Assess, check or test		-	
4.3 Species	-	Check		-	
7. Release / content of dangerous substances					
7.1 Formaldehyde emission	E1, E2	Check or test	BS EN 14080:2013	-	Declared as formaldehyde release class (E1 or E2)

- Mechanical resistance

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

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

Mechanical resistance of Glulam 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 glulam in accordance with BS EN 14080:2013.

Verification of Mechanical Resistance of Glulam:

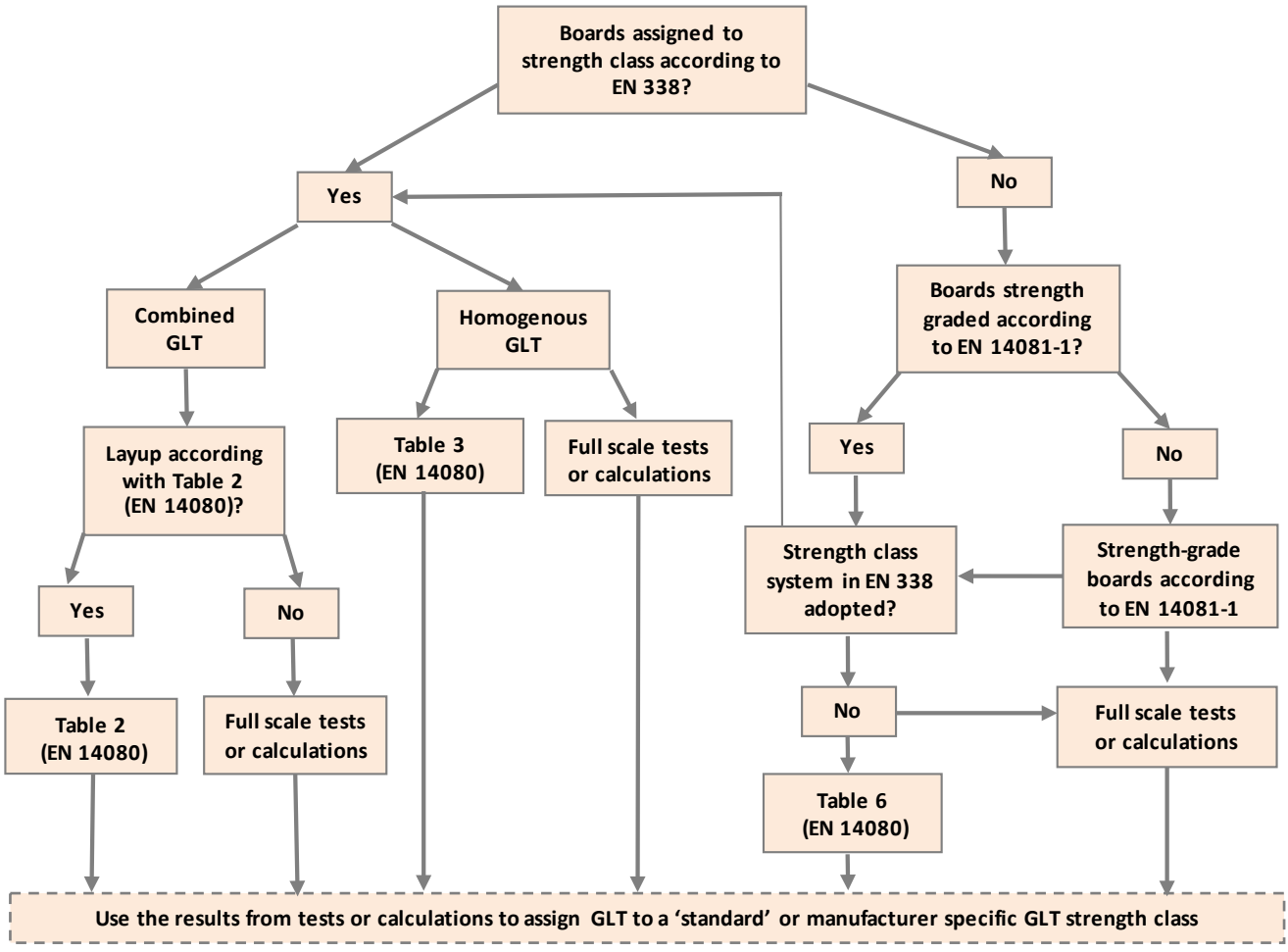
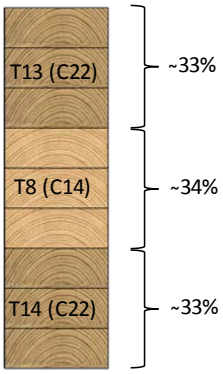
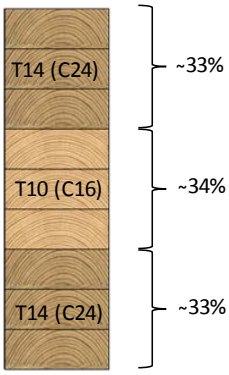


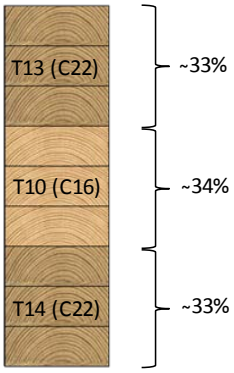
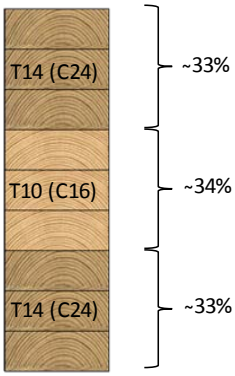
Figure - Glulam mechanical resistance procedures to BS EN 14080-2013

2 UK GLT – Possible configurations

- Combined Glulam

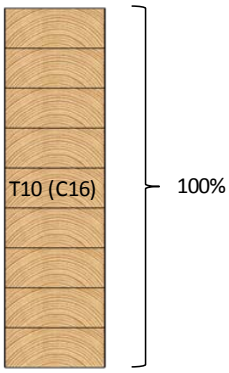
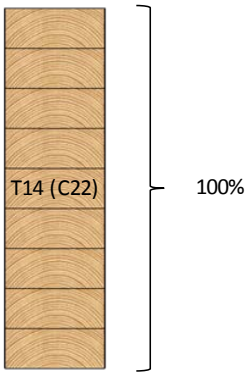
Using Table 1 in BS EN 14080 and Figure 7 in BS EN 14080 it is possible to assign GLT made from UK grown timber to appropriate strength class. This can be achieved if UK grown Sitka spruce and Larches were to be graded to C22/C14 and C24/C16 combination and beam layup would fulfil the requirements set out in BS EN 14080. Some examples of combined GLT which could be manufactured from home-grown resource and assigned to recognised strength class are shown below.

GL22c - UK Sitka spruce			**GL24c - UK Sitka spruce**		
					
Estimated utilisation of Sitka spruce graded to C22/C14 ≈ 89% (remaining 11% of timber is C14 or C16)			Estimated utilisation of Sitka spruce graded to C24/C16 ≈ 60% (remaining 40% of timber is C16)		
Wood species:		Sitka spruce	Wood species:		Sitka spruce
Type of adhesive		Type 1	Type of adhesive		Type 1
Formaldyde emission		E1	Formaldyde emission		E1
Reaction to fire:		D-s2, d0	Reaction to fire:		D-s2, d0
Durability against biological attack:		2	Durability against biological attack:		2
Service classes:		1 and 2	Service classes:		1 and 2
Maximum cross-section:		200x400mm	Maximum cross-section:		200x400mm
Maximum production length:		13m	Maximum production length:		13m
Bending strength	$f_{m,g,k}$	22 N/mm²	Bending strength	$f_{m,g,k}$	24 N/mm²
Tensile strength	$f_{t,0,g,k}$	16 N/mm2	Tensile strength	$f_{t,0,g,k}$	17 N/mm2
	$f_{t,90,g,k}$	0.5 N/mm²		$f_{t,90,g,k}$	0.5 N/mm²
Compression strength	$f_{c,0,g,k}$	20 N/mm²	Compression strength	$f_{c,0,g,k}$	21.5 N/mm²
	$f_{c,90,g,k}$	2.5 N/mm²		$f_{c,90,g,k}$	2.5 N/mm²
Shear strength	$f_{v,g,k}$	3.5 N/mm²	Shear strength	$f_{v,g,k}$	3.5 N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2 N/mm²	Rolling shear strength	$f_{r,g,k}$	1.2 N/mm²
Modulus of elasticity	$E_{0,g,mean}$	10400 N/mm²	Modulus of elasticity	$E_{0,g,mean}$	11000 N/mm²
	$E_{0,g,05}$	8600 N/mm²		$E_{0,g,05}$	9100 N/mm²
	$E_{90,g,mean}$	300 N/mm²		$E_{90,g,mean}$	300 N/mm²
	$E_{90,g,05}$	250 N/mm²		$E_{90,g,05}$	250 N/mm²
Shear -modulus	$G_{g,mean}$	650 N/mm²	Shear -modulus	$G_{g,mean}$	650 N/mm²
	$G_{g,05}$	540 N/mm²		$G_{g,05}$	540 N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65 N/mm²	Rolling shear modulus	$G_{r,g,mean}$	65 N/mm²
	$G_{r,g,05}$	54 N/mm²		$G_{r,g,05}$	54 N/mm²
Density	$\rho_{g,k}$	355 kg/m³	Density	$\rho_{g,k}$	365 kg/m³
Mean density	$\rho_{g,mean}$	390 kg/m³	Mean density	$\rho_{g,mean}$	400 kg/m³

GL22c - UK Larch				GL24c - UK Larch			
							
Estimated utilisation of UK Larch graded to C22/C16 ≈ 100% (remaining 11% of timber is C16)				Estimated utilisation of UK Larch graded to C24/C16 ≈ 99% (remaining 1% of timber is C16)			
Wood species:		Larch		Wood species:		Larch	
Type of adhesive		Type 1		Type of adhesive		Type 1	
Formaldyde emission		E1		Formaldyde emission		E1	
Reaction to fire:		D-s2, d0		Reaction to fire:		D-s2, d0	
Durability against biological attack:		2		Durability against biological attack:		2	
Service classes:		1 and 2		Service classes:		1 and 2	
Maximum cross-section:		200x400mm		Maximum cross-section:		200x400mm	
Maximum production length:		13m		Maximum production length:		13m	
Bending strength	$f_{m,g,k}$	22 N/mm²		Bending strength	$f_{m,g,k}$	24 N/mm²	
Tensile strength	$f_{t,0,g,k}$	16 N/mm2		Tensile strength	$f_{t,0,g,k}$	17 N/mm2	
	$f_{t,90,g,k}$	0.5 N/mm²			$f_{t,90,g,k}$	0.5 N/mm²	
Compression strength	$f_{c,0,g,k}$	20 N/mm²		Compression strength	$f_{c,0,g,k}$	21.5 N/mm²	
	$f_{c,90,g,k}$	2.5 N/mm²			$f_{c,90,g,k}$	2.5 N/mm²	
Shear strength	$f_{v,g,k}$	3.5 N/mm²		Shear strength	$f_{v,g,k}$	3.5 N/mm²	
Rolling shear strength	$f_{r,g,k}$	1.2 N/mm²		Rolling shear strength	$f_{r,g,k}$	1.2 N/mm²	
Modulus of elasticity	$E_{0,g,mean}$	10400 N/mm²		Modulus of elasticity	$E_{0,g,mean}$	11000 N/mm²	
	$E_{0,g,05}$	8600 N/mm²			$E_{0,g,05}$	9100 N/mm²	
	$E_{90,g,mean}$	300 N/mm²			$E_{90,g,mean}$	300 N/mm²	
	$E_{90,g,05}$	250 N/mm²			$E_{90,g,05}$	250 N/mm²	
Shear -modulus	$G_{g,mean}$	650 N/mm²		Shear -modulus	$G_{g,mean}$	650 N/mm²	
	$G_{g,05}$	540 N/mm²			$G_{g,05}$	540 N/mm²	
Rolling shear modulus	$G_{r,g,mean}$	65 N/mm²		Rolling shear modulus	$G_{r,g,mean}$	65 N/mm²	
	$G_{r,g,05}$	54 N/mm²			$G_{r,g,05}$	54 N/mm²	
Density	$\rho_{g,k}$	355 kg/m³		Density	$\rho_{g,k}$	365 kg/m³	
Mean density	$\rho_{g,mean}$	390 kg/m³		Mean density	$\rho_{g,mean}$	400 kg/m³	

- Homogeneous Glulam

Similarly as in case combined GLT, it is possible to assign homogenous glulam, consisting of UK grown timber, to one of the standard strength class using Tables 2 and 3 (in BS EN 14080) in conjunction with Table 13. This can be achieved if UK grown Sitka spruce and Larches were to be graded to C16 and C22 respectively. Some examples of combined GLT which could be manufactured from home-grown resource and assigned to recognised strength class are shown below.

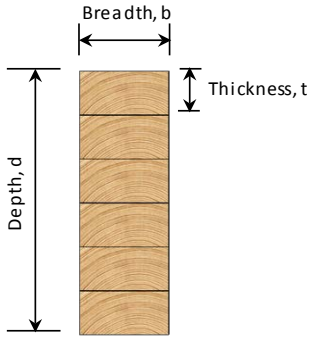
GL20h - UK Sitka spruce				**GL22h - UK Larch**			
							
Estimated utilisation of Sitka spruce graded to C16/reject ≈100%				Estimated utilisation of UK Larch graded to C22/reject ≈90%			
Wood species:		Sitka spruce		Wood species:		Larch	
Type of adhesive		Type 1		Type of adhesive		Type 1	
Formaldyde emission		E1		Formaldyde emission		E1	
Reaction to fire:		D-s2, d0		Reaction to fire:		D-s2, d0	
Durability against biological attack:		2		Durability against biological attack:		2	
Service classes:		1 and 2		Service classes:		1 and 2	
Maximum cross-section:		200x400mm		Maximum cross-section:		200x400mm	
Maximum production length:		13m		Maximum production length:		13m	
Bending strength	$f_{m,g,k}$	20	N/mm²	Bending strength	$f_{m,g,k}$	22	N/mm²
Tensile strength	$f_{t,0,g,k}$	16	N/mm2	Tensile strength	$f_{t,0,g,k}$	17.6	N/mm2
	$f_{t,90,g,k}$	0.5	N/mm²		$f_{t,90,g,k}$	0.5	N/mm²
Compression strength	$f_{c,0,g,k}$	20	N/mm²	Compression strength	$f_{c,0,g,k}$	22	N/mm²
	$f_{c,90,g,k}$	2.5	N/mm²		$f_{c,90,g,k}$	2.5	N/mm²
Shear strength	$f_{v,g,k}$	3.5	N/mm²	Shear strength	$f_{v,g,k}$	3.5	N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²	Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²
Modulus of elasticity	$E_{0,g,mean}$	8400	N/mm²	Modulus of elasticity	$E_{0,g,mean}$	10500	N/mm²
	$E_{0,g,05}$	7000	N/mm²		$E_{0,g,05}$	8800	N/mm²
	$E_{90,g,mean}$	300	N/mm²		$E_{90,g,mean}$	300	N/mm²
	$E_{90,g,05}$	250	N/mm²		$E_{90,g,05}$	250	N/mm²
Shear -modulus	$G_{g,mean}$	650	N/mm²	Shear -modulus	$G_{g,mean}$	650	N/mm²
	$G_{g,05}$	540	N/mm²		$G_{g,05}$	540	N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²	Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²
	$G_{r,g,05}$	54	N/mm²		$G_{r,g,05}$	54	N/mm²
Density	$\rho_{g,k}$	340	kg/m³	Density	$\rho_{g,k}$	370	kg/m³
Mean density	$\rho_{g,mean}$	370	kg/m³	Mean density	$\rho_{g,mean}$	410	kg/m³

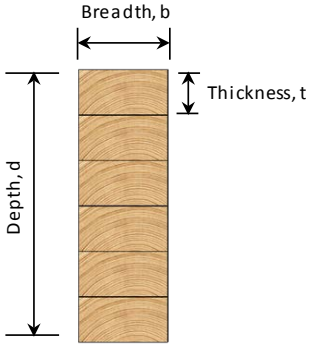
3 UK GLT - Pilot manufacture

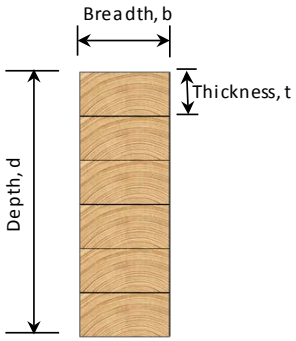
- Panel manufacture

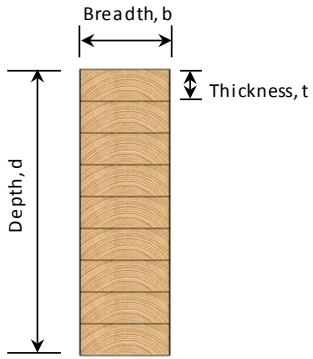
Fabrication of the Douglas Fir, Sitka Spruce and Scots Pine GluLam beams was carried out at Norbuild in controlled conditions and the adhesive used was Purbond HB S309. A total of five 250x86x4800mm beams for each species type were fabricated.

The manufacture of Larch GLT was undertaken by Buckland Timber (2 beams) and Wood Knowledge Wales (6 beams). Glulam beams manufactured by Buckland Timber were bonded with Melamine Urea Formaldehyde (MUF) adhesive (BASF KAURAMIN Glue 683 liquid and Hardener 688 liquid). The beams were manufactured as one single element from which smaller subsequent test samples were cut and prepared. The test specimens were representative of the beams manufactured commercially by Buckland. The nominal beam dimensions were 85mm wide x 270mm deep by 6m long comprising 9 of 30mm thick by 85mm wide lamellae. See tables below for specification of all GLT beams pilot manufactured from using home grown resource.

Sitka Spruce Pilot manufacture of GLT	
	
Glue Laminated Timber element	
Breadth, b	86 mm
Depth, d	252 mm
Length	4800 mm
Number of layers	6
GLT type	Combined
GLT strength class	N/A
Large finger joints	N/A
Adhesive	Purbond HB S309
Manufactured by	Norbuild
Manufactured to EN 14080	Yes
Boards	
Material	Sitka Spruce
Strength graded to EN 14081-2	No
Strength class	N/A
Thickness, t	42 mm
Finger joints	N/A
Moisture content to EN 13183-2	≈15% (avg.)
Mean Density to EN 384	397 kg/m^3

UK Scots Pine Pilot manufacture of GLT	
	
Glue Laminated Timber element	
Breadth, b	86 mm
Depth, d	252 mm
Length	4800 mm
Number of layers	6
GLT type	Combined
GLT strength class	N/A
Large finger joints	N/A
Adhesive	Purbond HB S309
Manufactured by	Norbuild
Manufactured to EN 14080	Yes
Boards	
Material	Scots Pine
Strength graded to EN 14081-2	No
Strength class	N/A
Thickness, t	42 mm
Finger joints	N/A
Moisture content to EN 13183-2	≈15% (avg.)
Mean Density to EN 384	500 kg/m^3

UK Douglas Fir Pilot manufacture of GLT	
	
Glue Laminated Timber element	
Breadth, b	86 mm
Depth, d	252 mm
Length	4800 mm
Number of layers	6
GLT type	Combined
GLT strength class	N/A
Large finger joints	N/A
Adhesive	Purbond HB S309
Manufactured by	Norbuild
Manufactured to EN 14080	Yes
Boards	
Material	Douglas Fir
Strength graded to EN 14081-2	No
Strength class	N/A
Thickness, t	42 mm
Finger joints	N/A
Moisture content to EN 13183-2	≈15% (avg.)
Mean Density to EN 384:	495 kg/m^3

UK Larch Pilot manufacture of GLT	
	
Glue Laminated Timber element	
Breadth, b	85 mm
Depth, d	270 mm
Length	6000 mm
Number of layers	9
GLT type	Homogenious
GLT strength class	N/A
Large finger joints	N/A
Adhesive	BASF KAURAMIN 683 (MUF)
Manufactured by	Buckland Timber
Manufactured to EN 14080	Yes
Boards	
Material	UK Larch
Strength graded to EN 14081-2	No
Strength class	N/A
Thickness, t	30 mm
Finger joints	According to EN 14080
Moisture content to EN 13183-2	≈15% (avg.)
Mean Density to EN 384	585 kg/m^3

4 UK GLT – Verified properties

- Tests on full scale panels

Outlined in the table below is summarised test programme carried out on glulam manufactured from home grown material, including: Larch, Sitka Spruce, Douglas Fir and Scots Pine.

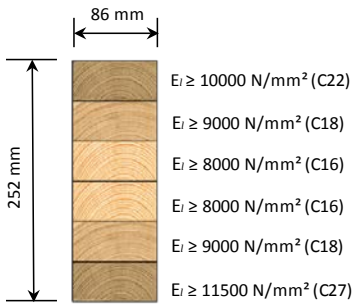
Table - GLT test programme carried out at ENU

Test type	Test standard	No. of samples tested
Larch GLT (homogenous)		
Glue line bond test	BS EN 14080:2013	61
Bending test of finger joints	BS EN 14080:2013 BS EN 408:2010	21
GLT Bending test	BS EN 14080:2013 BS EN 408:2010	8
GLT Tension test (perpendicular to grain)	BS EN 408:2010	9
GLT Compression test (perpendicular to the grain)	BS EN 408:2010	16
Sitka Spruce GLT (combined)		
Glue line bond test	Bespoke	6
GLT Bending test	BS EN 14080:2013 BS EN 408:2010	4
Douglas Fir GLT (combined)		
Glue line bond test	Bespoke	5
GLT Bending test	BS EN 14080:2013 BS EN 408:2010	4
Scots Pine GLT (combined)		
Glue line bond test	Bespoke	5
GLT Bending test	BS EN 14080:2013 BS EN 408:2010	4

- Analysis and verification of the results

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

GLT - UK Sitka spruce



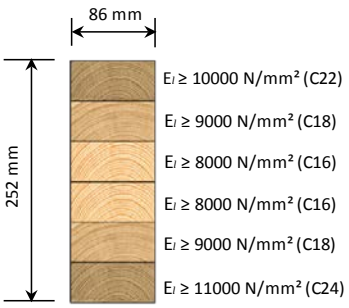
Estimated Glulam strength class - GL24c

Wood species:		Sitka spruce	
Type of adhesive		Type 1	
Formaldyde emission		E1	
Reaction to fire:		D-s2, d0	
Durability against biological attack:		2	
Service classes:		1 and 2	
Coss-section:		86x252 mm	
Length:		4800 mm	
Bending strength	$f_{m,g,k}$	33	N/mm²
Tensile strength	$f_{t,0,g,k}$	17	N/mm²
	$f_{t,90,g,k}$	0.5	N/mm²
Compression strength	$f_{c,0,g,k}$	21.5	N/mm²
	$f_{c,90,g,k}$	2.5	N/mm²
Shear strength	$f_{v,g,k}$	3.5	N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²
Modulus of elasticity	$E_{0,g,mean}$	11050	N/mm²
	$E_{0,g,05}$	9770	N/mm²
	$E_{90,g,mean}$	300	N/mm²
	$E_{90,g,05}$	250	N/mm²
Shear -modulus	$G_{g,mean}$	650	N/mm²
	$G_{g,05}$	540	N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²
	$G_{r,g,05}$	54	N/mm²
Density	$\rho_{g,k}$	405	kg/m³
Mean density	$\rho_{g,mean}$	475	kg/m³

Values obtained from tests

Values based on estimated GLT strength class

GLT - UK Douglas Fir



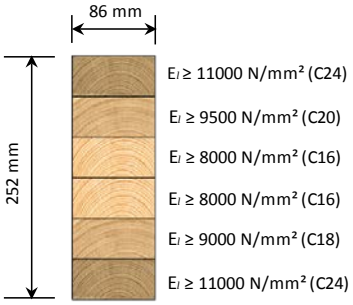
Estimated Glulam strength class - GL24c

Wood species:		Douglas Fir	
Type of adhesive		Type 1	
Formaldyde emission		E1	
Reaction to fire:		D-s2, d0	
Durability against biological attack:		2	
Service classes:		1 and 2	
Coss-section:		86x252 mm	
Length:		4800 mm	
Bending strength	$f_{m,g,k}$	25	N/mm²
Tensile strength	$f_{t,0,g,k}$	17	N/mm²
	$f_{t,90,g,k}$	0.5	N/mm²
Compression strength	$f_{c,0,g,k}$	21.5	N/mm²
	$f_{c,90,g,k}$	2.5	N/mm²
Shear strength	$f_{v,g,k}$	3.5	N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²
Modulus of elasticity	$E_{0,g,mean}$	10920	N/mm²
	$E_{0,g,05}$	9390	N/mm²
	$E_{90,g,mean}$	300	N/mm²
	$E_{90,g,05}$	250	N/mm²
Shear -modulus	$G_{g,mean}$	650	N/mm²
	$G_{g,05}$	540	N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²
	$G_{r,g,05}$	54	N/mm²
Density	$\rho_{g,k}$	420	kg/m³
Mean density	$\rho_{g,mean}$	495	kg/m³

Values obtained from tests

Values based on estimated GLT strength class

GLT - UK Scots Pine



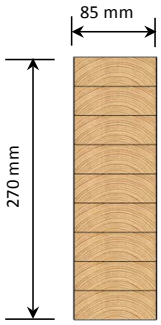
Estimated Glulam strength class - GL20c

Wood species:		Sitka spruce	
Type of adhesive		Type 1	
Formaldyde emission		E1	
Reaction to fire:		D-s2, d0	
Durability against biological attack:		2	
Service classes:		1 and 2	
Coss-section:		86x252 mm	
Length:		4800 mm	
Bending strength	$f_{m,g,k}$	22	N/mm²
Tensile strength	$f_{t,0,g,k}$	16	N/mm²
	$f_{t,90,g,k}$	0.5	N/mm²
Compression strength	$f_{c,0,g,k}$	20	N/mm²
	$f_{c,90,g,k}$	2.5	N/mm²
Shear strength	$f_{v,g,k}$	3.5	N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²
Modulus of elasticity	$E_{0,g,mean}$	9780	N/mm²
	$E_{0,g,05}$	8030	N/mm²
	$E_{90,g,mean}$	300	N/mm²
	$E_{90,g,05}$	250	N/mm²
Shear -modulus	$G_{g,mean}$	650	N/mm²
	$G_{g,05}$	540	N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²
	$G_{r,g,05}$	54	N/mm²
Density	$\rho_{g,k}$	475	kg/m³
Mean density	$\rho_{g,mean}$	555	kg/m³

Values obtained from tests

Values based on estimated GLT strength class

GLT - UK Larch



Estimated Glulam strength class - 20h

Wood species:		Larch	
Type of adhesive		Type 1	
Formaldyde emission		E1	
Reaction to fire:		D-s2, d0	
Durability against biological attack:		2	
Service classes:		1 and 2	
Coss-section:		85x270 mm	
Length:		6000 mm	
Bending strength	$f_{m,g,k}$	20	N/mm²
Tensile strength	$f_{t,0,g,k}$	16	N/mm²
	$f_{t,90,g,k}$	0.6	N/mm²
Compression strength	$f_{c,0,g,k}$	20	N/mm²
	$f_{c,90,g,k}$	2.5	N/mm²
Shear strength	$f_{v,g,k}$	3.5	N/mm²
Rolling shear strength	$f_{r,g,k}$	1.2	N/mm²
Modulus of elasticity	$E_{0,g,mean}$	9420	N/mm²
	$E_{0,g,05}$	7000	N/mm²
	$E_{90,g,mean}$	300	N/mm²
	$E_{90,g,05}$	250	N/mm²
Shear -modulus	$G_{g,mean}$	650	N/mm²
	$G_{g,05}$	540	N/mm²
Rolling shear modulus	$G_{r,g,mean}$	65	N/mm²
	$G_{r,g,05}$	54	N/mm²
Density	$\rho_{g,k}$	455	kg/m³
Mean density	$\rho_{g,mean}$	585	kg/m³

Values obtained from tests

Values based on estimated GLT strength class