COCIS Research into Mass Timber Systems – Nail Laminated Timber

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1 NLT - Compliance criteria

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

Table - Initial type testing for nail laminated timber

Characteristic	Symbol	Assessment method	Test Standard	No. of tests	Notes/Compliance Criteria
1. Mechanical properties perpendicular to the plane of nail laminated timber					
1.1 Modulus of Elasticity	$E_{0,mean}$	Bending test	BS EN 408:2010	30	Bending tests in accordance with EN 408 cl. 9, 10 and 19
1.2 Bending Strength	$f_{m,k}$				
1.3 Compressive Strength	$f_{c,90,k}$	Compression test	BS EN 408:2010	30	Testing according to EN 408 cl. 15,16
1.4 Tensile Strength	$f_{t,90,k}$	Tension test		30	Testing according to EN 408 cl. 13
2. Mechanical properties in plane of nail laminated timber					
2.1 Modulus of Elasticity	$E_{0,mean}$	Bending test	BS EN 408:2010	30	Bending tests in accordance with EN 408 cl. 9, 10 and 19
2.2 Bending Strength	$f_{m,k}$				
2.3 Shear stiffness	$G_{090,mean}$	Shear test		30	Testing according to EN 408 cl. 19
2.4 Shear strength	$F_{v,090,k}$				
2.5 Compressive Strength	$f_{c,0,k}$	Compression test		30	Testing according to EN 408 cl. 15,16
2.6 Tensile Strength	$f_{t,0,k}$	Tension test		30	Testing according to EN 408 cl. 13
1.3 (Racking) Shear stiffness	R	Racking test	BS EN 594:2011	30	Shear tests may be performed following the principles of EN 594
1.4 (Racking) Shear strength	F_{max}				
3. Dimensional stability of nail laminated timber					
3.1 Tolerances of dimensions	L, w, d	Check/Measurement	EN 1309-1	-	Manufacturing tolerances and dimensional changes due to varying MC shall not have inadmissible effects on the performance and stability of NLT
3.2 Stability of dimensions	MC (%)	Check/Measurement		-	
4. Durability / In-service environment					
4.1 Species	-	Check	EN 350-2	-	Service class to EC5 shall be given
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	EN 14081–1 and/or EN 13501-2	-	Charring rate (of layers), declared based on species used and strength class
4.2 Density of timber	ρ	Assess, check or test		-	
4.3 Species	-	Check		-	
7. Other requirements					
7.1 Water vapour permeability	μ	Test	EN ISO 10456	-	-
7.2 Airborne sound insulation	R	Test	EN ISO 10140-2	-	-
7.3 Impact sound insulation	$L_{n,w}$ (C_I)	Test	EN ISO 10140-3	-	-
7.4 Thermal conductivity	λ	Check	EN ISO 10456	-	-
7.5 Air permeability	Class A-C	Test	EN 12114	-	-
7.6 Thermal inertia	c_p	Check	EN ISO 10456	-	-
7.3 Impact sound insulation	$L_{n,w}$ (C_I)	Test	EN ISO 10140-3	-	-
7.4 Thermal conductivity	λ	Check	EN ISO 10456	-	-
7.5 Air permeability	Class A-C	Test	EN 12114	-	-
7.6 Thermal inertia	c_p	Check	EN ISO 10456	-	-

- Mechanical resistance

According to EAD 130011-00-0304 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 NLT 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 NLT in accordance with European Assessment Document - EAD 130011-00-0304.

Verification of Mechanical Resistance of NLT:

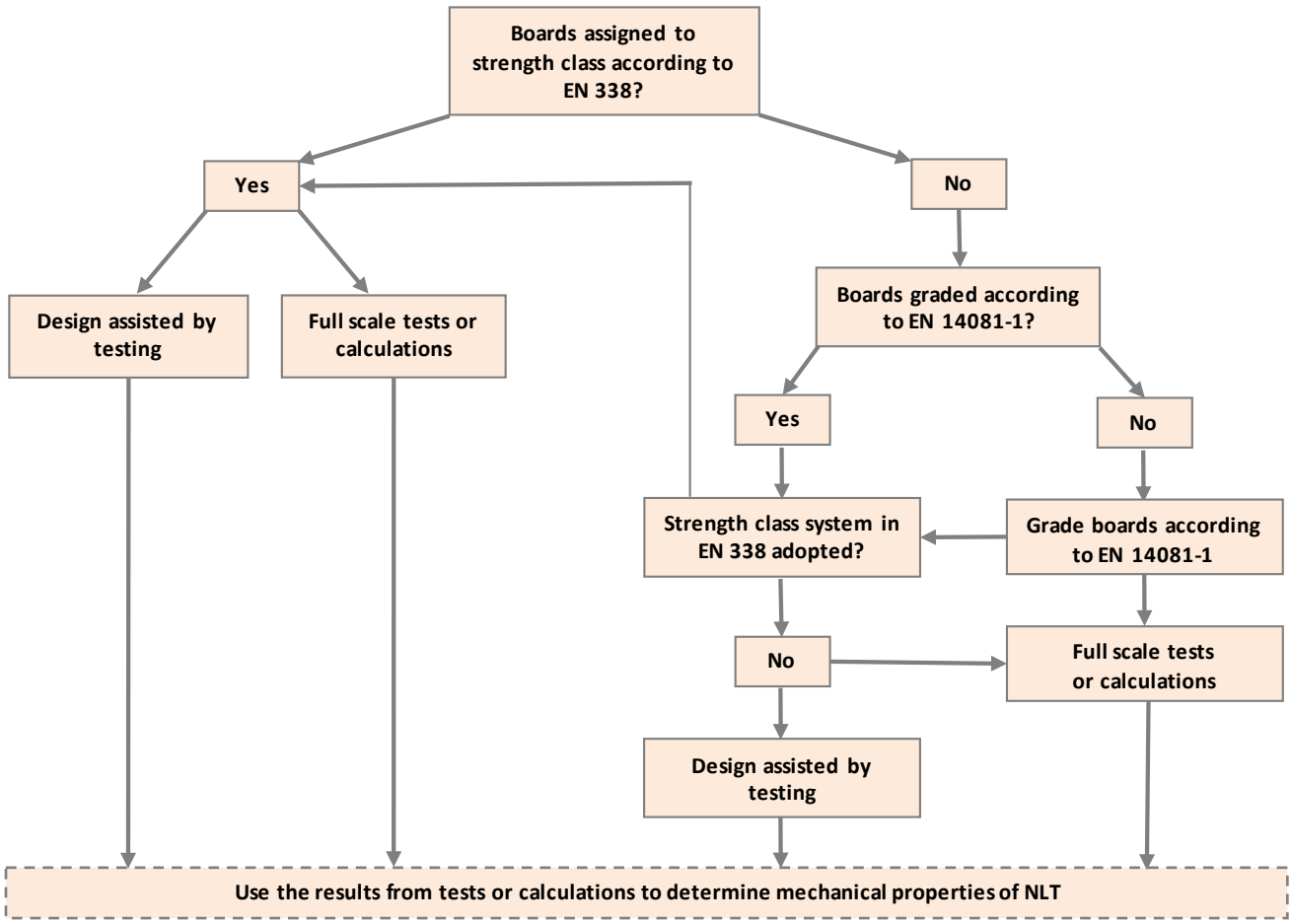


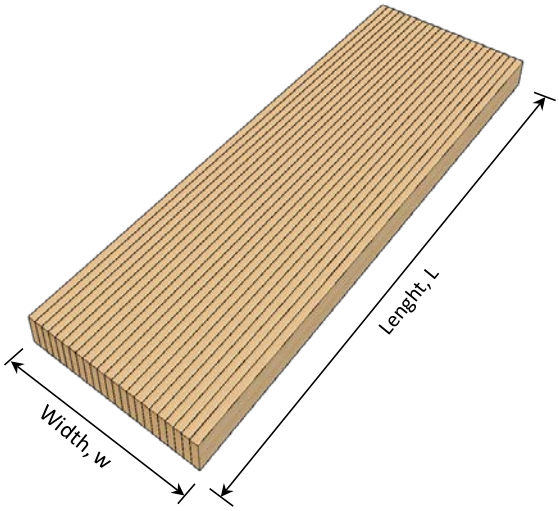
Figure 1 – Procedures for determination mechanical resistance of NLT to EAD 130011-00-0304

2 UK NLT – Possible configurations

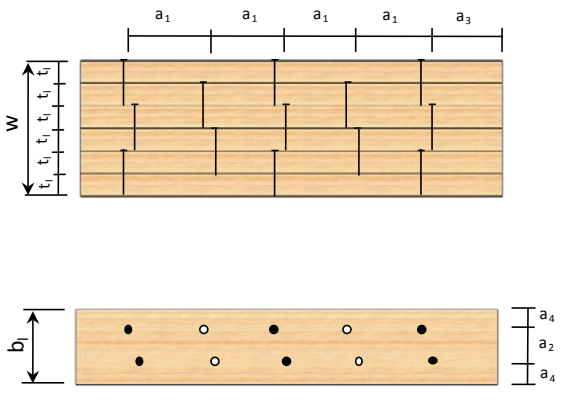
Using grading setting for UK timber in conjunction with the requirements contained in EAD 130011-00-0304 is possible to assign key mechanical and non-mechanical properties of NLT made from UK grown timber by declaring appropriate lamella properties (strength classes). Shown below are some examples of possible NLT lay-ups with all corresponding properties listed in EAD 130011-00-0304. Presented in tables below 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). In order to confirm the properties of NLT, structural testing or a calculation exercise, using numerical methods adopted in EN 1995-1-1, Annex B (for elements with up to three members) or EOTA Technical Report EOTA TR019, section C.1 (for more than three members) is recommended. This will also lead to further optimisation of lamella lay-up creating an opportunity for UK NLT that could compete with the products currently available in Europe.

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

NLT - UK Sitka Spruce



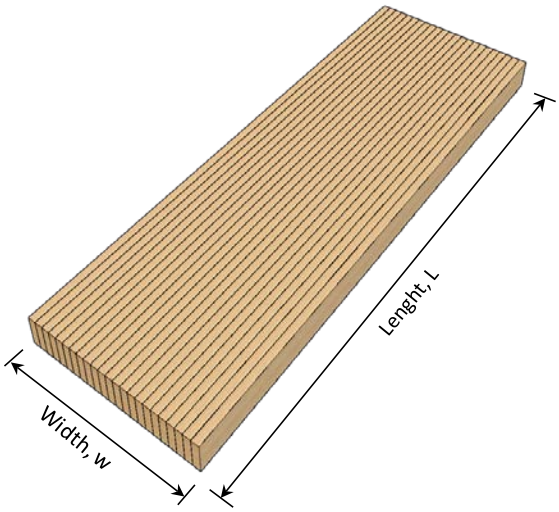
Nail spacing and plank lay-up:



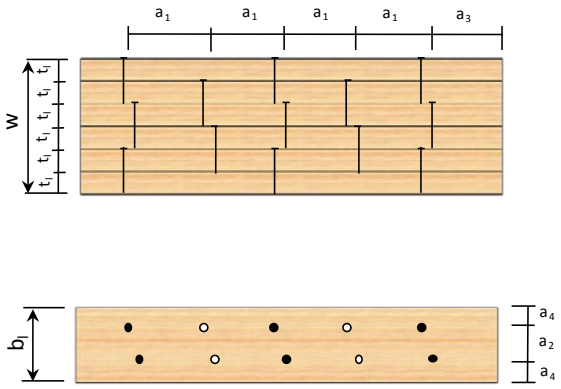
Nail laminated timber element		
Wood species:		UK Sitka Spruce
Max width, w		≤ 3.45 m
Max length, L		≤ 20 m
Reaction to fire:		D-s2, d0
Service classes:		1 and 2
Boards		
Strength class		C16
Thickness, t_l		≥ 21 mm
Width, b_l		60 to 300 mm
Moisture content to EN 13183-2:		15% ± 3%
Fixings		
Fastener type:		3.1x90mm ring shanks
Spacing parallel to the grain, a1		200 mm
Spacing perpendicular to the grain, a2		28 mm
End distance, a3		200 mm
Edge distance, a4		22 mm
Mechanical resistance		
1. Perpendicular to nail 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	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.2 N/mm²
Shear strength	$f_{v,k}$	2.2 N/mm²
2. In-plane of nail 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

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

NLT - UK Larch



Nail spacing and plank lay-up:

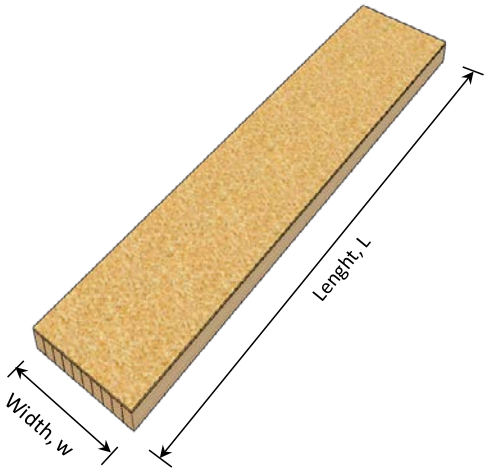


Nail laminated timber element		
Wood species:		UK Larch
Max width, w		≤ 3.45 m
Max length, L		≤ 20 m
Reaction to fire:		D-s2, d0
Service classes:		1 and 2
Boards		
Strength class		C22
Thickness, t_l		≥ 21 mm
Width, b_l		60 to 300 mm
Moisture content to EN 13183-2:		15% ± 3%
Fixings		
Fastener type:		3.1x90mm ring shanks
Spacing parallel to the grain, a1		200 mm
Spacing perpendicular to the grain, a2		28 mm
End distance, a3		200 mm
Edge distance, a4		22 mm
Mechanical resistance		
1. Perpendicular to nail 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	$f_{t,90,k}$	0.4 N/mm²
Compression strength	$f_{c,90,k}$	2.4 N/mm²
Shear strength	$f_{v,k}$	2.4 N/mm²
2. In-plane of nail 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

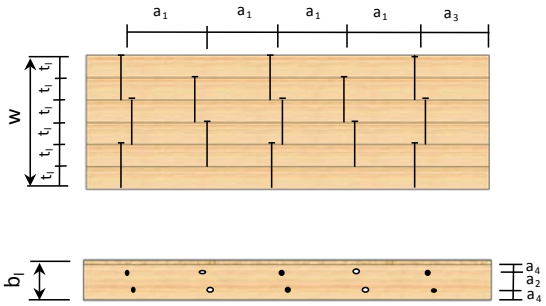
3 UK NLT - Pilot manufacture

In 2012 COCIS has been involved in pilot manufacture of a number of NLT panels utilising home-grown resource. Presented in this section is an outline and specifications of all the NLT panels manufactured. Overall a 30no. panels were manufactured using 45x70 C16 planks at moisture content 16% , using 2 type of nails.

NLT - UK Sitka Spruce



Nail spacing and plank lay-up:



Nail laminated timber element	
Wood species:	UK Sitka Spruce
Width, w	0.45 to 2.34 m
Length, L	2.40 m
No. of planks:	10 to 52
Manufactured by:	MAKAR
Year of manufacture:	2012
Number of panels manufactured:	38
Boards	
Strength class	C16
Thickness, t_l	45 mm
Width, b_l	70 mm
Moisture content to EN 13183-2:	16%
Fixings	
Fastener type:	Ring shank nail
Diameter:	3.1 mm and 32.7 mm
Length:	90 mm and 89 mm
Material	Steel and Aluminium
Supplier:	ITW
Spacing parallel to the grain, a1	200 mm
Spacing perpendicular to the grain, a2	28 mm
End distance, a3	200 mm
Edge distance, a4	22 mm
Sheating	
Sheathing type:	OSB3
Sheathing thickness:	9 and 11 mm
Fastener type:	Ring shank nail
Diameter:	2.8 mm
Length:	50 mm
Material	Steel
Intermediate spacing:	300 mm
Perimeter spacing:	150 mm

NOTES:

- The supply of the specified C16 grade timber at 16% proved difficult and only one supplier supplied timber (for the racking tests) that met the required grade as checked against acoustic sorting with the Hitman HM200 and subsequently confirmed through testing.
- Manufacturing of the test panels was straightforward with the steel nails. However, although preferable from a post machining perspective, it appears that aluminium nailing, while possible, would lead to greater costs due to about 10% wastage on the nails plus additional time to correct for incomplete or problematic driving.
- More automation would be possible for basic panels but would be difficult where larger panels with openings are considered.

4 UK NLT – Verified properties

- Tests on full scale panels

Outlined in the table below is summarised test programmes carried out on NLT manufactured from home grown Sitka spruce. Tests conducted included:

- Racking (steel nails only)
- Bending as a panel using line and point loads

Eight no. timber stud wall panels were manufactured by MAKAR 2.40m high x 2.34m long panels sheathed with OSB3 as per the specification supplied and tested in accordance with BS EN 594:2011. Bending tests were conducted in accordance with BS EN 408 to investigate the behaviour of a basic panel in order to validate the acoustic sorting against the stated grade. Details on both test programmes are indicated in the table below.

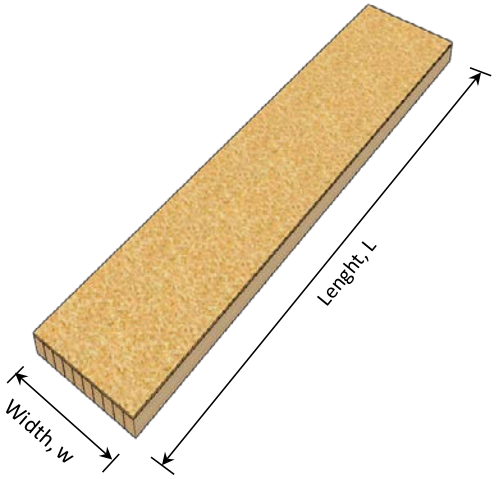
Table 1 - Test programmes of home-grown NLT carried out at ENU

Test type	Test standard	Property assessed		No. of samples tested	Tested by
Bending perpendicular to NLT	BS EN 408:2010	Bending strength	$f_{m,k}$	30	Edinburgh Napier University, Institute for Sustainable Construction
		Bending stiffness	$E_{0,mean}$		
Racking tests	BS EN 594:2011	Racking strength	F_{max}	8	
		Racking stiffness	R		

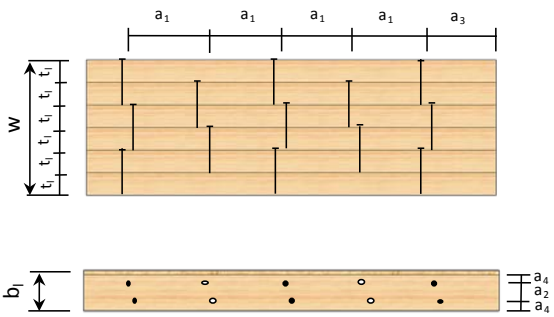
- Analysis and verification of the results

Presented in this section are the spec sheets of NLT manufactured from UK Sitka Spruce based on the structural test work carried out. The properties for each home grown NLT panels indicated in the tables below are based on results from lab based test work. The properties derived from tests for each of the home grown NLT panels are summarised in the table below.

NLT - UK Sitka Spruce



Nail spacing and plank lay-up:



Nail laminated timber element		
Wood species:		UK Sitka Spruce
Max width, w		≤ 3.45 m
Max length, L		≤ 20 m
Reaction to fire:		D-s2, d0
Service classes:		1 and 2
Boards		
Strength class		C16
Thickness, t_l		≥ 21 mm
Width, b_l		60 to 300 mm
Moisture content to EN 13183-2:		15% ± 3%
Fixings		
Fastener type:		3.1x90mm ring shanks
Spacing parallel to the grain, a1		200 mm
Spacing perpendicular to the grain, a2		28 mm
End distance, a3		200 mm
Edge distance, a4		22 mm
Mechanical resistance		
1. Perpendicular to nail laminated timber		
Modulus of elasticity	$E_{0,mean}$	6064 N/mm²
Shear modulus	G_{mean}	500 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
2. In-plane of nail 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		
Racking strength	F_{max}	14.7 kN
Racking stiffness	R	877.4 N/mm

Values obtained from tests

Values based on BS EN 338