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Timber structures — Glued laminated timber — Assignment of glued laminated timber characteristic values from laminate properties

Structures en bois — Bois lamellé-collé — Valeurs caractéristiques du bois lamellé-collé sur la base des propriétés des lamelles

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Foreword

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This document was prepared by Technical Committee ISO/TC 165, *Timber structures*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was prepared in response to the growing interest in development of the strength and stiffness of structural glued laminated timber (glulam) from the characteristic values of lumber laminations.

Since its first introduction in 1890s, glulam has been used in timber construction for over 125 years with excellent track record of performance. Many countries around the world, which have experience in glulam construction, have various glulam production capabilities that are supported by methodologies or analytical models for development of glulam strength and stiffness from the characteristic values of lumber laminations. This document reviews methodologies from Europe, the USA, Australia/New Zealand, and Canada that have successfully demonstrated their acceptance through years of practice and end uses.

This document does not cover all methodologies around the world and is not intended to exclude other methodologies that can demonstrate their capabilities of correlating the analytical results with the actual product performance. This document will be updated with those additional methodologies when their documentation becomes available in the future.

This document promotes the understanding of the differences between methodologies as a first step toward an international harmonization in the process of assigning glulam characteristic values from laminate properties.

Timber structures — Glued laminated timber — Assignment of glued laminated timber characteristic values from laminate properties

1 Scope

This document reviews the methodologies or analytical models that have been used to develop the strength and stiffness of structural glued laminated timber (glulam) from the characteristic properties of lumber laminations. The review is limited to the methodologies used in Europe, the USA, Australia/New Zealand, and Canada as they represent different fundamental philosophies in these areas. As a result, the methodologies are not intended to be combined unless there is clear understanding of the fundamental assumptions adopted by the respective methodologies.

NOTE Detailed assumptions used by the respective methodologies are available from the standards listed in the Bibliography.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 European methodologies

EN 14080 provides three different routes for producer to classify the glulam and all of them are related to properties in structural sizes. The glulam standard covers only properties related to nominal 12 % moisture content (in lamination, joint, and structural specimen tests, moisture content may be 12 ± 3 % without mandatory adjustments).

4.1 General

Mechanical resistance of glulam is intended to be determined from and declared:

— on the basis of geometrical data (e.g. cross-sectional sizes of laminations and layups) and material properties (strength, stiffness and density properties of laminations and strength properties of finger joints); or

— from tests.

4.1.1 Timber

Timber is strength graded according to EN 14081-1.

4.1.2 Related material properties

The characteristic strength, stiffness and density properties of glulam are verified either:

a) from classifications from layups and lamination properties (this route is a direct result of the calculation procedure implemented in 4.3);

b) from calculations taking into account the cross-sectional layup and documented properties of boards and finger joints according to 4.3, or

c) from full scale tests according to 4.4.

The characteristic strength, stiffness and density properties may be declared by reference to a strength class according to Table 3 or 4 or to a manufacturer's specific strength class. For glulam having an asymmetrical layup, "ca" should be added to the class name, e.g. GL28 ca. The class name of resawn glulam is marked by "s", e.g. GL24 cs.

The characteristic bending strength should be valid for glulam with a depth h of 600 mm and a lamination thickness of $t = 40$ mm. If the lamination thickness is less than 40 mm, the bending strength may be multiplied by k as given in Formula (1). For lamination thicknesses 40 mm < $t \le 45$ mm, it is not necessary to take any strength modification into account.

$$k = \min \begin{cases} \left(\frac{40}{t}\right)^{0,1} \\ 1,05 \end{cases} \quad (1)$$

where t is the lamination thickness, in mm.

The characteristic tensile strength parallel to the grain should be valid for glulam with depth h of 600 mm or width b of 600 mm.

The characteristic tensile strength perpendicular to the grain should be valid for glulam with a stressed volume of 0,01 m^3.

The 5 %-fractile of a shear modulus or a modulus of elasticity should be estimated from the mean value by applying the ratio of $G_{g,k}/G_{g,mean} = 5/6$ and $E_{0,g,k}/E_{0,g,mean} = 5/6$, respectively.

For glulam members made of at least 10 laminations the product ($E_{0,g,k}$ $G_{g,k}$) may be increased by a factor $k = 1,40$.

For rectangular glued laminated timber with depths in bending or widths in tension less than 600 mm, the characteristic values for $f_{m,k}$ and $f_{t,0,k}$ may be increased by the factor k_h given by

$$k_h = \min \begin{cases} \left(\frac{600}{h}\right)^{0,1} \\ 1,1 \end{cases} \quad (2)$$

where h is the depth for bending members or width for tensile members, in mm.

4.2 Verification from classification of standardised beam lay-ups and lamination properties of glued laminated timber

4.2.1 Properties of the boards

The requirements of the boards given in Table 1 should be fulfilled. The essential material properties needed for the EN 14080 model are tension strength, modulus of elasticity, and density of the unjointed laminations and further finger joint tension or bending strength (see Table 1). Laminations up to T-class T18 can be graded visually according to several European grading standards and then assigned to T-classes, provided the respective classification reports on the basis of EN 384 exist. (issue of flatwise and edgewise bending needs to be addressed).

In case no information exists, the effort to group laminations based on tension tests according to EN 408 into a certain T-class (similar as for C class) is

— 40 specimens from 5 growth areas: no reduction in evaluation, based on mean of the 5 % quantiles of all 5 samples or 1,2 times of the sample with the lowest 5 % quantile (the lesser value is relevant)

— 40 specimens from 3 growth areas; penalization by factor of 0,89

— 40 specimens from 1 growth area; penalization by 0,77

Table 1 — Characteristic strength and stiffness properties for T-classes in N/mm^2 and densities in kg/m^3 for boards or planks for glued laminated timber

T-class of boards[a]	$f_{t,0,l,k}$	$E_{t,0,l,mean}$	$\rho_{l,k}$
T8 (C14)	8	7 000	290
T9	9	7 500	300
T10 (C16)	10	8 000	310
T11 (C18)	11	9 000	320
T12 (C20)	12	9 500	330
T13 (C22)	13	10 000	340
T14 (C24)	14	11 000	350
T14,5	14,5	11 000	350
T15	15	11 500	360
T16 (C27)	16	11 500	370
T18 (C30)	18	12 000	380
T21 (C35)	21	13 000	390
T22	22	13 000	390
T24 (C40)	24	13 500	400
T26	26	14 000	410
T27 (C45)	27	15 000	410
T28	28	15 000	420
T30 (C50)	30	15 500	430
[a] The C-classes according to EN 338:2009 meet at least the required values of the respective T-classes.			

4.2.2 Strength of finger joints

The declared or necessary finger joint strength values depend on the different glulam classification approaches.

— For classification approach (A), fixed values need to be met.

— For classification/verification approach (B), i.e. the calculation method, values in a certain bandwidth can be declared.

The required characteristic values of the flatwise bending strength of finger joints $f_{m,j,k}$ in laminations for glulam classification approach (A) should be taken from Table 2 or 3. If the finger joints are tested in tension the required characteristic value of the tensile strength of finger joints should be taken as

$$f_{t,0,j,k} = f_{m,j,k} / 1,4 \tag{3}$$

4.2.3 Beam lay-up and strength class

Provided the beam lay-up is in accordance with Table 2 or 3, the glulam fulfils the requirements of a strength class given in Table 4 or 5.

The zones of the cross section are defined in Figure 1.

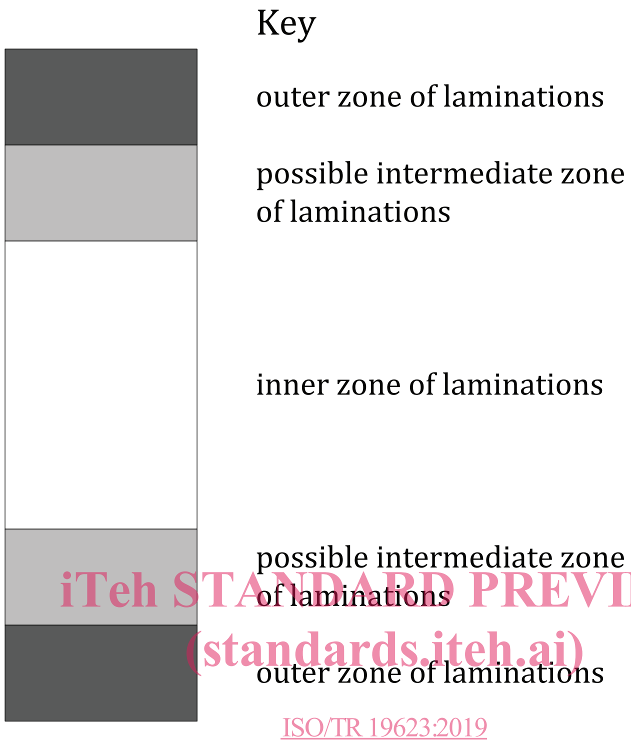

Figure 1 — Example of a beam lay-up of combined glulam

— For combined glulam, the outer zones of lamination grades (see Figure 1) should be at least the proportion given in Table 2, but at least two laminations for glulam with more than 10 laminations and at least one lamination for glulam with up to 10 laminations.

Table 2 — Beam lay-up of combined glued laminated timber and minimum values for bending strength of finger joints in laminations in N/mm²

Glued laminated timber	Outer zones of laminations			Intermediate zones of laminations			Inner zone of laminations		
Strength class	Strength class	Proportion [%]	$f_{m,j,k}$ [N/mm²]	Strength class	Proportion [%]	$f_{m,j,k}$ [N/mm²]	Strength class[a]	Proportion [%]	$f_{m,j,k}$ [N/mm²]
GL 20c	T13	2 × 33	21	—	—	—	T8	34	18
GL 22c	T13	2 × 33	26	—	—	—	T8	34	18
GL 24c	T14	2 × 33	31	—	—	—	T9	34	19
GL 26c	T16	2 × 33	34	—	—	—	T11	34	22
GL 28c	T18	2 × 25	37	—	—	—	T14	50	28
GL 28c	T21	2 × 17	36	—	—	—	T14	66	26
GL 28c	T21	2 × 17	38	—	—	—	T13	66	25
GL 28c	T21	2 × 25	35	—	—	—	T11	50	22
GL 28c	T21	2 × 20	35	T14	2 × 20	28	T11	20	22
GL 28c	T22	2 × 20	35	—	—	—	T13	60	25

Table 2 *(continued)*

Glued laminated timber Strength class	Outer zones of laminations			Intermediate zones of laminations			Inner zone of laminations		
	Strength class	Proportion [%]	$f_{m,j,k}$ [N/mm^2]	Strength class	Proportion [%]	$f_{m,j,k}$ [N/mm^2]	Strength class[a]	Proportion [%]	$f_{m,j,k}$ [N/mm^2]
GL 30c	T22	2 × 17	40	—	—	—	T15	66	27
GL 30c	T22	2 × 17	41	—	—	—	T14	66	28
GL 30c	T22	2 × 20	40	T14	2 × 20	30	T11	20	22
GL 30c	T22	2 × 17	42	T14	2 × 23	31	T11	20	22
GL 32c	T24	2 × 17	44	—	—	—	T18	66	31
GL 32c	T26	2 × 17	45	—	—	—	T14	66	26
GL 32c	T26	2 × 10	48	T18	2 × 20	32	T11	40	22

Table 3 — Beam lay-up of homogeneous glued laminated timber and minimum values for bending strength of finger joints in laminations in N/mm^2

Strength class glued laminated timber	Strength class laminations	$f_{m,j,k}$
GL 20h	T10	25
GL 20h	T11	22
GL 22h	T13	25
GL 24h	T14	30
GL 26h	T16	33
GL 28h	T18	36
GL 30h	T21	38
GL 30h	T22	37
GL 32h	T24	41
GL 32h	T26	38

Table 4 — Characteristic strength and stiffness properties in N/mm^2 and densities in kg/m^3 for combined glulam

Property[a]	Symbol	Glulam strength class						
		GL 20c	GL 22c	GL 24c	GL 26c	GL 28c	GL 30c	GL 32c
Bending strength	$f_{m,g,k}$	20	22	24	26	28	30	32
Tensile strength	$f_{t,0,g,k}$	15	16	17	19	19,5	19,5	19,5
	$f_{t,90,g,k}$	0,5						
Compression strength	$f_{c,0,g,k}$	18,5	20	21,5	23,5	24	24,5	24,5
	$f_{c,90,g,k}$	2,5						
Shear strength (shear and torsion)	$f_{v,g,k}$	3,5						
Rolling shear strength	$f_{r,g,k}$	1,2						
Modulus of elasticity	$E_{0,g,mean}$	10 400	10 400	11 000	12 000	12 500	13 000	13 500
	$E_{0,g,05}$	8 600	8 600	9 100	10 000	10 400	10 800	11 200
	$E_{90,g,mean}$	300						
	$E_{90,g,05}$	250						

[a] Properties given in this table have been calculated on the basis of the layups given in Table 2. If different layups for a certain strength class lead to different characteristic values the lowest values are given here.

[b] Calculated as the weighted mean of the densities of the different lamination zones.

Table 4 *(continued)*

Property[a]	Symbol	Glulam strength class						
		GL 20c	GL 22c	GL 24c	GL 26c	GL 28c	GL 30c	GL 32c
Shear-modulus	$G_{g,mean}$	650						
	$G_{g,05}$	540						
Rolling shear modulus	$G_{r,g,mean}$	65						
	$G_{r,g,05}$	54						
Density[b]	$\rho_{g,k}$	355	355	365	385	390	390	400
	$\rho_{g,mean}$	390	390	400	420	420	430	440

[a] Properties given in this table have been calculated on the basis of the layups given in Table 2. If different layups for a certain strength class lead to different characteristic values the lowest values are given here.

[b] Calculated as the weighted mean of the densities of the different lamination zones.

Table 5 — Characteristic strength and stiffness properties in N/mm² and densities in kg/m³ for homogeneous glulam

Property	Symbol	Glulam strength class						
		GL 20h	GL 22h	GL 24h	GL 26h	GL 28h	GL 30h	GL 32h
Bending strength	$f_{m,g,k}$	20	22	24	26	28	30	32
Tensile strength	$f_{t,0,g,k}$	16	17,6	19,2	20,8	22,3	24	25,6
	$f_{t,90,g,k}$	0,5						
Compression strength	$f_{c,0,g,k}$	20	22	24	26	28	30	32
	$f_{c,90,g,k}$	2,5						
Shear strength (shear and torsion)	$f_{v,g,k}$	3,5						
Rolling shear strength	$f_{r,g,k}$	1,2						
Modulus of elasticity	$E_{0,g,mean}$	8 400	10 500	11 500	12 100	12 600	13 600	14 200
	$E_{0,g,05}$	7 000	8 800	9 600	10 100	10 500	11 300	11 800
	$E_{90,g,mean}$	300						
	$E_{90,g,05}$	250						
Shear modulus	$G_{g,mean}$	650						
	$G_{g,05}$	540						
Rolling shear modulus	$G_{r,g,mean}$	65						
	$G_{r,g,05}$	54						
Density	$\rho_{g,k}$	340	370	385	405	425	430	440
	$\rho_{g,mean}$	370	410	420	445	460	480	490

4.3 Classification, verification according to method B from cross sectional layup and properties of boards and finger joints

4.3.1 Properties of the boards

If the boards comply with one of the relevant strength classes, the strength, stiffness and density properties may be taken from Table 1.

If the boards or planks do not comply with Table 1, the characteristic values of the tensile strength parallel to the grain $f_{t,0,l,k}$, the mean modulus of elasticity parallel to the grain $E_{t,0,l,mean}$ and the characteristic density $\rho_{l,k}$ should be derived from tests according to EN 408 and calculated in accordance with EN 384 as outlined in 4.2.1 (there also specimen numbers are given).

4.3.2 Strength of finger joints

The characteristic flat wise bending strength or tensile strength of the finger joints should be declared by the glulam manufacturer. The declared strength of finger joints should be verified by tests in accordance with Annex E of ISO 10983:2014 (30 specimens per species, grade, strength class) and evaluation according to EN 14358.

4.3.3 Determination of characteristic values for glued laminated timber

The strength and stiffness properties of homogeneous glulam should be determined from the strength and stiffness properties of the laminations using the formulae given in Table 6.

The characteristic bending strength, the characteristic tensile and compression strengths parallel to the grain, the mean modulus of elasticity and the characteristic density of a combined glulam should be determined from the respective values of the different lamination zones considered as homogeneous glulam by means of the elastic composite beam theory.

For combined glulam, the outer zones of lamination grades should be at least two laminations for glulam with more than 10 laminations and at least one lamination for glulam with up to 10 laminations.

The strength verification should be made at all relevant points of the cross section.

Table 6 — Characteristic strength and stiffness properties in N/mm² and densities in kg/m³ of homogeneous glued laminated timber

Property		Characteristic values
Bending strength (N/mm²)	$f_{m,g,k}$	The characteristic bending strength should be calculated using the following expression. $$f_{m,g,k} = -2{,}2 + 2{,}5 f_{t,0,l,k}^{0{,}75} + 1{,}5 \left(\frac{f_{m,j,k}}{1{,}4} - f_{t,0,l,k} + 6 \right)^{0{,}65}$$ The expression should only be used for a characteristic flat wise bending strength of the finger joint in the range: $1{,}4\, f_{t,0,l,k} \leq f_{m,j,k} \leq 1{,}4\, f_{t,0,l,k} + 12$ The formula is also applicable to glulam without finger joints provided $f_{m,j,k}$ is taken as: $f_{m,j,k} = 1{,}4\, f_{t,0,l,k} + 12$
Tensile strength (N/mm²)	$f_{t,0,g,k}$	The characteristic tensile strength should be taken as 80 % of the characteristic values of the bending strength $f_{m,g,k}$.
	$f_{t,90,g,k}$	0,5
Compression strength (N/mm²)	$f_{c,0,g,k}$	The characteristic compression strength should be taken as $f_{m,g,k}$ in N/mm² where $f_{m,g,k}$ is the characteristic bending strength of the glued laminated timber.
	$f_{c,90,g,k}$	2,5
Shear strength (N/mm²)	$f_{v,g,k}$	3,5
	$f_{r,g,k}$	1,2
Modulus of elasticity (N/mm²)	$E_{0,g,mean}$	The mean modulus of elasticity should be taken as $E_{0,g,mean} = 1{,}05\, E_{t,0,l,mean}$.
	$E_{90,g,mean}$	300
Shear modulus (N/mm²)	$G_{g,mean}$	650
	$G_{r,g,mean}$	65
Density (kg/m³)	$\rho_{g,k}$	$1{,}1\, \rho_{l,k}$
	$\rho_{g,mean}$	$\rho_{l,mean}$