Table B.2 *(continued)*

AA 5059 Alustar	Sheet, strip, plate $3 < t < 50$	Al,Mg 5-6	0/H111	330	300	160	160	0,7	112	65
AA 5059 Alustar	Sheet, strip, plate $3 < t < 50$	Al,Mg 5-6	H32	370	300	270	160	0,7	112	65
EN AW-5383	Sheet, strip, plate $3 < t < 50$	Al,Mg 4,5 Mn 0,9	0/H111	290	290	145	145	0,7	102	59
EN AW-5383	Sheet, strip, plate $3 < t < 50$	Al,Mg 4,5 Mn 0,9	H32	305	290	220	145	0,7	102	59
Aluminium alloys (heat treatable) $\sigma_d = 0{,}7\ \sigma_{yw}$ and $\tau_d = 0{,}58\ \sigma_d$										
EN AW-6060	Profiles, bars, Tubes $3 < t < 25$	Al,Mg Si	T5,T6	190	95	150	65	0,7	46	26
EN AW-6061	Profiles, bars, Tubes $3 < t < 25$	Al,Mg1, Si Cu	T5,T6	260	165	240	115	0,7	81	47
EN AW-6061	Closed profiles	Al,Mg1, Si Cu	T5,T6	245	165	205	115	0,7	81	47
EN AW-6063	Profiles, bars, Tubes $3 < t < 25$	Al,Mg 0,7 Si	T5	150	100	110	65	0,7	46	26
EN AW-6063	Profiles, bars, Tubes $3 < t < 52$	Al,Mg 0,7 Si	T6	205	100	170	65	0,7	46	26
EN AW-6005A	Profiles, bars, Tubes $3 < t < 51$	Al,Si,Mg (A)	T5,T6	260	165	215	115	0,7	81	47
EN AW-6005A	Closed profiles $3 < t < 50$	Al,Si,Mg (A)	T5,T6	250	165	215	115	0,7	81	47
EN AW-6082	Profiles, bars, Tubes $3 < t < 25$	Al,Si 1,Mg,Mn	T5,T6	310	170	260	115	0,7	81	47
EN AW-6082	Closed profiles	Al,Si 1,Mg,Mn	T5,T6	290	170	240	115	0,7	81	47
EN AW-6106	Profiles, bars, Tubes $3 < t < 25$	Al,Mg,Si,Mn	T6	240	240	195	195	0,7	81	47

[a] The ultimate values are given for information only as the design stress is based on yield strength in welded conditions.

[b] The value of design stress is for welded aluminium. For unwelded aluminium (riveted or glued), σ_d = min ($0{,}6\sigma_{uw}$ or $0{,}9\sigma_{yw}$) unwelded a.

NOTE σ_u and σ_y are tensile stresses.

The value of E modulus of metal is required in some formulas (e.g. Table A.9, A.11 & A.12, etc.) and, unless specifically documented, the default following values may be used:

Mild steel E = 210 000 N/mm^2 Aluminium alloys E = 70 000 N/mm^2.

Annex C
(normative)

FRP laminates properties and calculations

C.1 Status of this Annex

This Annex shall be used for the analysis methods 1 to 3 of Table 2. For the analysis method 5 (FEM), other documented values may be used but it should be checked that their values do not differ from the ones in this Annex by a large margin.

C.2 Determination of the mechanical properties

C.2.1 Tests and test standards

Mechanical properties to be used as input in determining the bending moment, stiffness and shear capabilities of FRP laminates and stiffeners may be derived either by testing of representative samples using the appropriate ISO or ASTM test standards or by calculation or by a combination of the two.

Table C.1 — Examples of test standard references and specific tests

1-Examples of test standards
Tensile properties: ISO 527-4, ISO 527-5
Flexural properties: ISO 178
Compressive properties: ISO 14126
Inplane shear properties: ISO 14129
Interlaminar shear stress: ISO 14130
Through-thickness « flatwise » tensile properties: ASTM D7291
2-General application of the above standards
Where an International Standard does not exist, a national standard may be used instead. The number of samples to be tested shall be as laid down in international or national standards but shall not be less than five samples for any given property.
When determining the flexural strength, the gel coat side of the specimen shall be stressed in tension.
Unless specifically stated in the test standard, the mechanical properties used in the calculations shall be corrected from test values as follows: — for strength 90 % of the mean ultimate strength or the mean value minus two standard deviations whichever is the lesser; — for elastic modulus, the mean value.

Table C.1 *(continued)*

3-Alternative method for testing compression strength of UDs
It is often difficult to apply ISO 14126, particularly for carbon-based UD
An alternative method based on four-point bending tests can be used to measure compressive stress of unidirectional composites (glass, carbon fibres).
Comparing to « pure » compressive tests (ISO 14126), the advantages of four-point bending tests are the followings: — sample geometry (no end tabs, tolerances); — common tooling's; — adapted for thick laminates; — possibility to measure ultimate compressive stress of unidirectional layers inside real scantlings.
In order to prevent early damages under load points, bi-axial layers (0/90 or +−45) on sample facings and load tabs can be used.
Sample failures are validated when the failure occur at the upper face between the 2 load points.
From ply thickness measurements, an ultimate compressive strength in the UD is then calculated using the recorded force at failure.
These tests may be conducted using the specifications of ASTM D6272 standard.

As a minimum, the fibre mass fraction (ψ) shall be measured by weighing a resin-consolidated panel of known fibre mass, see Example 1. Resin ignition tests may also be used. The panels used for this purpose shall be representative of the as built quality. Where it is not practical to take suitably sized panels from the actual or previous craft, special care must be taken to ensure that laboratory made samples are representative.

Table C.2 gives the relations between the mass fraction ψ, the volume fraction ϕ, the ratio t/w and laminate density ρ.

NOTE 1 The above requirements aim at taking the appropriate steps to ensure that the mechanical capability (not simply mechanical properties, but also taking geometry into account) and properties of the as-built laminate are equal or superior to those at the design stage.

C.2.2 Topics on tests and calculation

Many CLT software consider a linear behaviour $\sigma = E \times \varepsilon$, which is not true in reality: when testing a laminate, one can see that, after an initial linear behaviour, the stress/strain plot gets curved. This is due to micro cracks or damages occurring after the failure of some, non-critical, plies.

It is practically difficult to measure ε_u real, and when the initial elastic modulus, E initial, and $\sigma_{u\ test}$ are measured, one shall take E calculation = E initial and $\varepsilon_{calc} = \frac{\sigma_{test}}{E_{initial}}$, see Figure C.1.

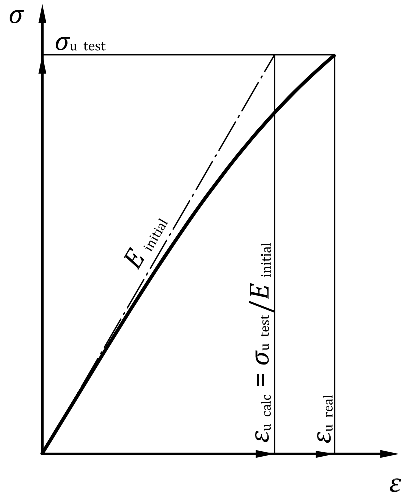

Figure C.1 — Determination of ε_u

Table C.2 — Values of t/w, composite density ρ_c according to fibre content by volume ϕ or mass ψ

$\psi = \dfrac{\phi \times \rho_f}{\phi \times \rho_f + (1-\phi) \times \rho_m}$	$\phi = \dfrac{\psi}{\psi + (1-\psi) \times \dfrac{\rho_f}{\rho_m}}$	$\dfrac{t}{w} = \dfrac{1}{\phi \times \rho_f}$
$\rho_c = \rho_f \times \phi + \rho_m \times (1-\phi)$ or $\rho_c = \dfrac{\rho_f \times \rho_m}{\rho_f + \psi(\rho_m - \rho_f)}$		$t = \dfrac{w}{\rho_f \times \rho_m}\left(\dfrac{\rho_f}{\psi} + \rho_m - \rho_f\right)$

t	Thickness of the laminate	mm
w	Dry mass of fibre	kg/m^2
ϕ	Fibre content by volume in the laminate (dry fibre volume/laminate volume)[a]	1
ψ	Fibre content by mass in the laminate (dry fibre mass/laminate mass).	1
ρ_f, ρ_m	Density, respectively of fibre and matrix, may be taken from Table C.2 or from manufacturer's information	kg/m^3

[a] For guidance purposes see also Table C.7.

C.2.3 Use of flexural strain and strength

The values of flexural stresses as tested with ISO 178 or equivalent give significantly high stresses compared with tensile/compression. Reference [25] quotes $\sigma_{uf} = k_G \times \sigma_{ut} /(1 + \sigma_{ut}/\sigma_{uc})$ for GRP with k_G ranging from 2,5 to 3 according to the type of laminates, similar values for Carbon and Aramid. This high values of σ_{uf} induced that ISO 12215-5:2008 required single skin laminates using σ_f that were always thinner than the ones required by the ply by ply analysis of Annex H, using σ_t.or σ_c. However as the -thinner- laminates designed with σ_f did not prove to be underbuilt in practice, this revision document allows the use of $\pm\sigma_f$ instead of σ_t/ σ_c for the ply by ply analysis of single skin laminates in Annex H. The reason is that these laminates are likely to operate in the large deflection regime, particularly under high slam pressures. As the scantling formulas are based on the more conservative small deflection theory, the use of in plane ultimate strains may be a case of "double penalty". Sandwich panels, being stiffer are more likely to be operating within the small deflection regime and hence the use of inplane strains is appropriate. CLT theory method usually only apply σ_t/σ_c. Tables C.6 and C.9/C.10 detail the values of ε_{uf}.

C.2.4 Mechanical properties for the simplified method

The "simplified" method described in 11.2 and Table A.5 only considers Glass Reinforced Plastics (not Carbon composites). Unless derived from tests, according to C.2, the mechanical properties shall be derived from Tables C.6 to C.10. These tables do not give the values for one "thick" layer of a mixing of the plies given in Table C.6, like, for example, Mat/Roving. Clause C.4 and Table C.11 give some examples on such calculations.

C.2.5 Elastic constants using 'CLT' method (classical laminate theory)

In the 'CLT' method, the elastic constants are derived from manufacturers' fibre and resin properties for a known fibre volume content using well-established and empirically modified rule of mixtures formulas. It is not necessary to provide these formulas within the document since they are documented in the "Law of mixtures" and Classical Lamination theory (CLT). As for single skin, the flexural stress is used, it is recommended to replace the design strains ε_{ut} or ε_{uc} by $\pm\varepsilon_{uf}$ otherwise the scantlings could be conservative compared to the simplified or enhanced method.

NOTE For guidance, the Bureau Veritas or DNV-GL publications listed in the bibliography were among the source references used in developing Tables C.5 and C.6. Elastic constants of woven roving, double-bias (+45/−45), etc. may be obtained separately from the [A] submatrix by combining unidirectional plies at the appropriate orientation (a symmetrical layup being recommended to eliminate in-plane/out of plane coupling).

C.2.6 Elastic constants using 'SRM' method (simplified regression method)

For the builders or designers not wishing to use the CLT method, the simpler Simplified Regression Method (SRM) is proposed, both methods work similarly for cross plies, but treat angle plies differently, see details in C.2.5. Table C.4 shows physical and mechanical properties used in the CLT method, and Table C.5 gives the main mechanical properties of UD and of several "typical" plies/multiplies.

Table C.3 sums up the "flow chart" of the procedure to follow in either SRM/Ply stack analysis or CLT.

Table C.3 — Procedure to obtain mechanical properties and allowable bending moment and shear forces for single skin or sandwich plating

<table>
<tr><th colspan="2">STAGE 1-PLY ELASTIC CONSTANTS AND BREAKING STRAINS</th></tr>
<tr><td colspan="2">Obtained from;
Test data or Simplified regression formulas (Tables C.4 to C.8 tabulated in Tables C.9 & C.10) or Other verified formulae (Tables C.2 & C.5)</td></tr>
<tr><th colspan="2">STAGE 2-MODIFY PROPERTIES TO REFLECT BOAT BUILDING CHARACTERISTICS k_{BB} (Table 16)</th></tr>
<tr><td colspan="2">Obtained from;
Same formulas as above but modified following tests and details and by k_{BB} in Table 16</td></tr>
<tr><th colspan="2">STAGE 3-OBTAIN LAST PLY FAILURE BENDING MOMENT AND SHEAR FORCES</th></tr>
<tr><td colspan="2">For single skin laminates use $\sigma_d = 0{,}5 \pm \sigma_{uf} \times k_{BB}$
For sandwich laminates, depending on stress sense use $\sigma_d = \sigma_{ut}$ or σ_{uc} or wrinkling $\times k_{BB}$
Obtain flexural stiffness for deflection checks</td></tr>
<tr><th>OPTION 1
Annex H: Simplified laminate stack method</th><th>OPTION 2
CLT (Classical Lamination Theory)[a]</th></tr>
<tr><td>Multiply the previous design stress by $k_{AM} = 0{,}95$ for FRP according to Table 16 (Enhanced method)
Caution: the strains and stresses are along fibre</td><td>Multiply the previous design stress by $k_{AM} = 1$ for FRP according to Table 16 (developed method)
Caution; CLT software may not always check wrinkling, then a manual check is needed
For DBx and Qx input as angled WR combination and transformed into 1-2 system for assessment
Failures are based on any of the generally recognized failure envelope formulas.</td></tr>
</table>

Table C.3 *(continued)*

STAGE 4-OBTAIN ACTUAL vs REQUIRED LAST PLY FAILURE BENDING MOMENT AND SHEAR FORCES
Use Annex H or CLT software to find last ply failure stress (see NOTE), calculate design stress per Table 17 and find the compliance factor CF=σ design/ σ actual that shall be ≥1
[a] For sandwich check whether CLT software can obtain shear force internally (need to have transverse shear stiffness with 4 × 4 matrix) otherwise use method in Annex H for sandwich.
NOTE The last ply failure is usually the first ply failure, but this is not always the case, particularly when one mix stiff (carbon) and non stiff plies (GRP), or when using UD plies at 90° from mains stress direction. For example in a ply with 90 % UD in the sense of maximal stress and 10 % UD perpendicular to it, the transverse ply fails first but 90 % of the strength remains.

C.2.7 Final mechanical properties

This Annex proposes several methods to define the mechanical properties of the laminate, but their final values depend significantly on the “as built” quality of the material achieved by the boatbuilder. Therefore, the final "design" mechanical properties used for calculation of composites in Table 17 needs to be adjusted by the factors k_{BB} and k_{AM} defined in Table 16.

Tables C.4 to C.10 may be implemented for other fibres or matrices.

Table C.4 — Physical and mechanical properties of fibres and matrices

			Reinforcement fibres			Matrices
			E Glass	Aramid	Carbon HS	Polyester/epoxy
Specific gravity ρ (ρ_f or ρ_m)		t/m^3	2,56	1,44	1,78	1,2
Elastic modulus E (E_{f1} , E_{f2} or E$_m$)	E_{f1}// Fibres	N/mm^2	73 000	124 000	235 000	3 300
	E_{f2}⊥ Fibres	N/mm^2	73 000	6 900	20 000	3 300
Shear modulus G (G_f or G_m)		N/mm^2	30 000	2 800	50 000	1 222
Poisson's ratio ν (ν_f or ν_m)		1	0,22	0,36	0,27	0,32

NOTE The standard formulas in the CLT method are either exact linear (major modulus and Poisson’s ratio) or very nearly quadratic (minor modulus and shear modulus). The CLT method requires input data which may not be readily available from manufacturers, such as transverse modulus of fibre and resin Poisson’s ratio. Furthermore, there is no fixed relationship between for example modulus of polyester versus that of epoxy which holds for all commercially available resin. Consequently, the source references above together with predictions from formulas used either using Reference [24] or by the National Physical Laboratory (UK) (which include empirical correction factors) have been used for generic fibres and resin as defined in Table C.4.

Table C.5 — Formulas for UD and laminates of Tables C.6 and C.7

1-Theoretical formulas for UD			
$E_{\text{UD1}}=0{,}975\times\left[E_{\text{f1}}\times\phi+E_{\text{m}}\times(1-\phi)\right]$		$E_{\text{UD2}}=E_{\text{m}}\dfrac{1+\zeta\times\eta_{\text{E}}\times\phi}{1-\eta_{\text{E}}\times\phi}$ with $\zeta=1$ and $\eta_{\text{E}}=\dfrac{E_{\text{f2}}/E_{\text{m}}-1}{E_{\text{f2}}/E_{\text{m}}+\zeta}$	
$G_{\text{UD12}}=G_{\text{m}}\dfrac{1+\zeta\times\eta_{\text{G}}\times\phi}{1-\eta_{\text{G}}\times\phi}$ with $\zeta=1$ and $\eta_{\text{G}}=\dfrac{G_{\text{f}}/G_{\text{m}}-1}{G_{\text{f}}/G_{\text{m}}+\zeta}$		$\nu_{\text{UD}}=\nu_{\text{f}}\times\phi+\nu_{\text{m}}\times(1-\phi)$ Poisson's ratio	
$\tau_{\text{UIL}}=22{,}5-\dfrac{33\phi}{\phi+0{,}89}$ interlaminar shear stress		$\nu_{\text{UD 21}}=\nu_{\text{UD 12}}\dfrac{E_{\text{UD2}}}{E_{\text{UD1}}}$	
The above formulas are derived from Halpin-Tsai formulas, where ϕ is the fibre content in volume, and other variables defined in Table C.4			
2-Formulas for other laminates: CSM; biaxial 0/90 (BD+); double bias ±45 (DB×), and quadriaxial (Q×)			
Except for *E* glass chopped strand mat, the formulas apply to any "building" FRP fibre (Glass, carbon, Aramid, etc.)			
Material	Young's modulus	Shear modulus	Major Poisson's ratio
E Glass Chopped strand mat	$E_{\text{CSM}}=3/8\,E_{\text{UD1}}+5/8\,E_{\text{UD2}}$	$G_{\text{CSM}}=1/8\,E_{\text{UD1}}+1/4\,E_{\text{UD2}}$	$\nu_{\text{CSM}}=E_{\text{CSM}}/2\,G_{\text{CSM}}-1$
BD+ 0/90 Biaxial or woven roving	$E_{\text{BD+}}=0{,}5\,(E_{\text{UD1}}+E_{\text{UD2}})$	$G_{\text{BD+}}=G_{\text{UD12}}$	$\nu_{\text{BD+}}=\nu_{\text{UD12}}\dfrac{E_{\text{UD2}}}{E_{\text{BD+}}}$
DB× ±45° Double bias	$E_{\text{DBx}}=\dfrac{4E_{\text{BD+}}}{\dfrac{E_{\text{BD+}}}{G_{\text{BD+}}}+2(1-\nu_{\text{BD+}})}$	$G_{\text{DBx}}=\dfrac{E_{\text{BD+}}}{2(1+\nu_{\text{BD+}})}$	$\nu_{\text{DBx}}=\dfrac{E_{\text{DBx}}}{4E_{\text{BD+}}}\left[\dfrac{E_{\text{BD+}}}{G_{\text{BD+}}}-2(1-\nu_{\text{BD+}})\right]$
Q× Quadriaxial 0/45/90/−45°	$E_{\text{QX}}=0{,}5[A_{11}-A_{12}^2/A_{11}]$	$G_{\text{QX}}=0{,}5\,(G_{\text{BD+}}+G_{\text{DBx}})$	$\nu_{\text{QX}}=A_{12}/A_{11}$
with $A_{11}=\dfrac{E_{\text{BD+}}}{1-\nu_{\text{BD+}}^2}+\dfrac{E_{\text{DBx}}}{1-\nu_{\text{DBx}}^2}$ and $A_{12}=\dfrac{\nu_{\text{BD+}}\times E_{\text{BD+}}}{1-\nu_{\text{BD+}}^2}+\dfrac{\nu_{\text{DBx}}\times E_{\text{DBx}}}{1-\nu_{\text{DBx}}^2}$			

C.2.8 Breaking strains — Both methods CLT or SRM

The breaking strains, to be used in Table C.8 are given in Table C.6.

Table C.6 — Breaking strains in %

Breaking strains[a] (ultimate strength/initial *E* modulus) in %			
Type of fibre & resin		E Glass & polyester	HS Carbon & epoxy
$\varepsilon_{ufi} = k_G\, \varepsilon_{uti}/(1 + \varepsilon_{uti}/\varepsilon_{uci})$ with i = 1 or 2 and k_G[b]= 2,50 or 2,94, see columns 3 and 4.		k_G = 2,50	k_G = 2,94
Unidirectional quoted "UD"	ε_{ut1}	1,90	1,00
	ε_{ut2}	0,50	0,50
	ε_{uc1}	1,40	0,70
	ε_{uc2}	1,40	1,90
	ε_{uf1}[b]	2,02	1,21
	ε_{uf2}[c]	0,92	1,16
	γ_{u12}	1,70	1,50
CSM Chopped strand mat	ε_{ut}	1,35	Not applicable
	ε_{uc}	1,70	
	ε_{uf}[b]	1,88	
	γ_{u12}	2,00	
WR/bidirectional 0/90° quoted" BD+"	ε_{ut}	1,55	1,00
	ε_{uc}	1,40	0,70
	ε_{uf}[b]	1,84	1,21
	γ_{u}	1,70	1,40
Double bias ±45 quoted "DB×"°	ε_{ut}	1,06	0,77
	ε_{uc}	1,02	0,75
	ε_{uf}[b]	1,30	1,12
	γ_{u}	1,80	1,02
Quadriaxial 0/45/90/_45 quoted "Q×"°	ε_{ut}	1,30	0,92
	ε_{ut}	1,20	0,74
	ε_{uf}[b]	1,56	1,21
	γ_{u}	1,70	1,02

[a] Design strain (%) = 0,5 × breaking strain. Design stress= 0,5 × Associated modulus × breaking strain/100 Associated modulus means use E_{UD2} with ε_{UC2} to obtain compressive strength perpendicular to fibres for a unidirectional, G_{BX} with γ_U to obtain the shear strength for a biaxial, etc.

[b] The experimental factor k_G is proposed by Green in Reference [25] to correlate flexural strain with tensile and compressive strains in the fibre direction for UD and generally in composites.

[c] The value in b above has been applied to transverse strains on UD, but this is pending validation, σ_{uf2} being anyway << σ_{uf1}.

NOTE Table C.6 is based on published values in two classification rules, ISO 12215-5:2008 and data supplied by industry.

NOTE Tables C.6, C.7, C.9 and C.10 are only computed for *E* glass/polyester and *HS* Carbon/epoxy. Other building fibres (Other type of glass or carbon, Aramid, etc) or resins may be used provided documented values are used.

C.2.9 Practical use of CLT & SRM methods

C.2.9.1 Preliminary

When using the CLT method, panel coordinate system strains (ε_x, ε_y and γ_{xy}) are transformed into individual ply coordinate system strains (ε_1, ε_2 and γ_{12}) and hence a double-bias cloth is transformed into a WR/BD+ and the above strains may be used.

In SRM method, there is no transformation and it is necessary to determine E_{DBx} etc. for use in the laminate stack (see Annex H), it is also necessary to determine the breaking strain at 45 degrees to the fibres.

For built-in panels, the traditional approach is to use a single uniaxial stress or strain load case. Using the maximum stress or strain criterion, a double bias subjected to such a strain fails when; $\varepsilon_{DB} = 2\ \gamma_{U12}\ [G_{BX}/E_{DB}]$ (with γ_{U12} taken from Table C.7 for WR/BD+).

C.2.9.2 Use of CLT and SRM methods

The Classical Lamination Theory (CLT) method is intended for the ones using complex layups, often including UD plies at 0 and 90 degrees and/or triaxial or unbalanced biaxial cloths (different fibre mass in warp and weft) as well as asymmetrical layups up which generate D_{16}, D_{26} and $B_{ij} \neq 0$ in the stiffness matrix, therefore introducing complex coupling effects.

Users may apply SRM method properties as input into validated CLT software (commercial or in-house) with the load vector determined using the simple methods of the document.

However, when using UD-90 plies which generally have low tensile strain (ε_{ut2}) as indicated in Table C.6, CLT or Annex H are liable to give a low bending capability value as the method underpinning this document is first ply to fail. Analysing the stack as last ply to fail is normally outside the scope of this Annex.

The SRM method is intended for users who generally use combinations of biaxial, double bias and quadriaxial with or without mat, to achieve a reasonably balanced laminate.

The simple formulae for bending moments and shear forces using this standard generally do not consider more than one significant stress acting at any given point, i.e. the load vector generally consists of just Mx or My or Nxy). This permits a laminate to be analysed using the laminate stack method outlined in Annex H.

C.2.10 Ply thickness

Ply theoretical thickness shall be calculated using the formulas of Table C.2 (top right cells), or according either to volume fraction ϕ, or mass fraction ψ or using the pre-computed values of Table C.7, C.9 or C.10

Table C.7 considers that fibre content in volume ϕ is mainly connected to the lamination process, and the fibre content in mass ψ is then calculated from the density of fibre and matrix (resin).

Table C.7 — "Guidance values" for fibre content

Lamination process	Material	Fibre content in volume	Fibre content in mass ψ , t/w and composite density ρ_c					
			Glass ρ_f =		2,56	Carbon HR ρ_f =		1,78
		ϕ	ψ	t/w	ρ_c	ψ	t/w	ρ_c
Hand layup simple surface	CSM	0,167	0,300	2,34	1,43	—	—	—
	Woven Roving	0,300	0,478	1,302	1,61	0,389	1,87	1,37
	Rovimat	0,246	0,410	1,588	1,53	—	—	
	Multidirectional	0,319	0,500	1,225	1,63	0,410	1,76	1,39
	Unidirectional	0,364	0,550	1,073	1,70	0,459	1,54	1,41
Hand layup Complex surface	CSM	0,134	0,248	2,924	1,38	—	—	—
	Woven Roving	0,240	0,403	1,628	1,53	0,319	2,34	1,34
	Rovimat	0,197	0,343	1,985	1,47	0,267	2,85	1,31
	Multidirectional	0,255	0,422	1,531	1,55	0,337	2,20	1,35
	Unidirectional	0,291	0,467	1,341	1,60	0,378	1,93	1,37
These values are given as a guide only and are considered achievable by the industry, but it is the responsibility of the builder to check the values that his building methods are currently achieving. For complex surfaces, the fibre content in volume is 80 % of the ones for simple surfaces.								

Table C.7 *(continued)*

Lamination process	Material	Fibre content in volume	Fibre content in mass ψ , t/w and composite density ρ_c					
			Glass ρ_f =		2,56	Carbon HR ρ_f =		1,78
		ϕ	ψ	t/w	ρ_c	ψ	t/w	ρ_c
RTM ECO	Any material	0,135	0,250	2,894	1,38	0,188	4,16	1,28
Infusion	CSM	0,21 - 0,30	0,36 - 0,48	1,86 - 1,30	1,49 - 1,61	0,28 - 0,39	2,68 - 1,87	1,32 - 1,37
	Woven Roving	0,42 - 0,50	0,61 - 0,68	0,93 - 0,78	1,77 - 1,88	0,52 - 0,60	1,34 - 1,12	1,44 - 1,49
	UD/Multidirectional	0,45 - 0,53	0,64 - 0,71	0,64 - 0,71	1,81 - 1,92	0,54 - 0,63	1,25 - 1,06	1,46 - 1,61
Prepreg void	UD/Multidirectional	0,530	0,706	0,737	1,92	0,626	1,06	1,51
Prepreg autoclave	UD/Multidirectional	0,530	0,706	0,737	1,92	0,626	1,06	1,51
These values are given as a guide only and are considered achievable by the industry, but it is the responsibility of the builder to check the values that his building methods are currently achieving. For complex surfaces, the fibre content in volume is 80 % of the ones for simple surfaces.								

C.3 Final calculation of E, G and ultimate stress

C.3.1 General calculation

Table C.8 — Final calculation of *E*, *G* , σ_u or τ_u*

$E = E_{TABLE\ C\ 5}$	$\sigma_U = E_{TABLE\ C\ 5} \times \varepsilon_{TABLE\ C\ 6}$
$G = G_{TABLE\ C\ 6}$	$\tau_U = G_{TABLE\ C\ 5} \times \gamma_{TABLE\ C\ 6}$

The calculations of Table C.8 are pre-computed in Table C.9 for Glass composites and in Table C.10 for High strength carbon composites.

CAUTION — The design stress defined in Table 17 shall then be determined using, the relevant value of k_{AM} and k_{BB} from Tables 15 & 16.

C.3.2 Builder's responsibility

The use of any property data given in this Annex does not imply that these are achievable in practice for any particular craft. It is entirely the responsibility of the builder or his representative to demonstrate this. The tables giving mechanical properties in this Annex shall be adjusted by the factor k_{BB} of Table 16 and used with care. It is subjective in nature and compliance with the table does not imply any guarantee that mechanical properties taken from this Annex are achieved for any particular craft in any particular location.

Table C.9 — Computed values of Table C.5 to C.8 for glass laminates (with k_{BB} = 1)

E GLASS

ρ_f= 2,56			UD				CSM (Mat)			BD+ 0/90°			± 45° DBx Double bias			Quadraxial 0/45/90/-45		
ρ_m = 1,2			ν_f = 0,22				G_{CSM}=1/8 E_{UD1}+1/4 E_{UD2}											
Ef1= 73 000			ν_m = 0,32				υ_{CSM}=E_{CSM}/G_{CSM}-1											
Ef2= 73 000			ξ = 1															
Em= 3 300			ηE= 0,913															
Gf= 30 000			ηG= 0,922															
Gm= 1 222																		
ϕ Vol	ψ Mass	t/w 1/(ϕ*ρ_f)	E_{UD1}	E_{UD2}	G_{UD12}	ν_{UD12}	E_{CSM}	G_{CSM}	ν_{CSM}	E_{BD+}	G_{BD+}	ν_{BD+}	E_{DBx}	G_{DBx}	ν_{DBx}	E_{Quad}	G_{Quad}	ν_{Quad}
0,140	0,258	2,79	12 732	4 268	1 584	0,31	7 442	2 658	0,40	8 500	1 584	0,15	4 817	3 684	0,52	6 911	2 634	0,31
0,160	0,289	2,44	14 091	4 430	1 645	0,30	8 053	2 869	0,40	9 260	1 645	0,15	5 047	4 042	0,53	7 459	2 844	0,31
0,167	0,300	2,34	14 566	4 488	1 667	0,30	8 267	2 943	0,40	9 527	1 667	0,14	5 129	4 168	0,54	7 653	2 917	0,31
0,180	0,319	2,17	15 450	4 599	1 708	0,30	8 668	3 081	0,41	10 024	1 708	0,14	5 282	4 402	0,55	8 013	3 055	0,31
0,200	0,348	1,95	16 809	4 775	1 774	0,30	9 288	3 295	0,41	10 792	1 774	0,13	5 523	4 764	0,56	8 572	3 269	0,31
0,220	0,376	1,78	18 168	4 960	1 844	0,30	9 913	3 511	0,41	11 564	1 844	0,13	5 770	5 127	0,56	9 137	3 485	0,31
0,240	0,403	1,63	19 527	5 153	1 916	0,30	10 544	3 729	0,41	12 340	1 916	0,12	6 025	5 491	0,57	9 708	3 704	0,31
0,260	0,428	1,50	20 886	5 356	1 992	0,29	11 180	3 950	0,42	13 121	1 992	0,12	6 289	5 858	0,58	10 285	3 925	0,31
0,280	0,453	1,40	22 246	5 568	2 072	0,29	11 822	4 173	0,42	13 907	2 072	0,12	6 562	6 226	0,58	10 869	4 149	0,31
0,300	0,478	1,30	23 605	5 792	2 156	0,29	12 471	4 398	0,42	14 698	2 156	0,11	6 846	6 595	0,59	11 460	4 376	0,31
0,319	0,500	1,22	24 896	6 014	2 240	0,29	13 095	4 616	0,42	15 455	2 240	0,11	7 126	6 949	0,59	12 028	4 594	0,31
0,340	0,524	1,15	26 323	6 273	2 337	0,29	13 792	4 859	0,42	16 298	2 337	0,11	7 449	7 341	0,59	12 664	4 839	0,31
0,360	0,545	1,09	27 682	6 534	2 436	0,28	14 465	5 094	0,42	17 108	2 436	0,11	7 770	7 717	0,60	13 280	5 076	0,31
0,380	0,567	1,03	29 041	6 809	2 539	0,28	15 146	5 332	0,42	17 925	2 539	0,11	8 107	8 095	0,60	13 904	5 317	0,31
0,400	0,587	0,98	30 401	7 100	2 649	0,28	15 838	5 575	0,42	18 750	2 649	0,11	8 460	8 476	0,60	14 539	5 563	0,31
0,420	0,607	0,93	31 760	7 409	2 766	0,28	16 540	5 822	0,42	19 584	2 766	0,11	8 831	8 860	0,60	15 185	5 813	0,31
0,440	0,626	0,89	33 119	7 736	2 889	0,28	17 254	6 074	0,42	20 427	2 889	0,10	9 222	9 247	0,60	15 844	6 068	0,31
0,460	0,645	0,85	34 478	8 083	3 021	0,27	17 981	6 331	0,42	21 281	3 021	0,10	9 634	9 637	0,59	16 515	6 329	0,30
0,480	0,663	0,81	35 837	8 454	3 161	0,27	18 723	6 593	0,42	22 145	3 161	0,10	10 069	10 031	0,59	17 202	6 596	0,30
0,500	0,681	0,78	37 196	8 849	3 311	0,27	19 479	6 862	0,42	23 023	3 311	0,10	10 530	10 429	0,59	17 904	6 870	0,30
0,530	0,706	0,74	39 235	9 495	3 556	0,27	20 647	7 278	0,42	24 365	3 556	0,10	11 276	11 034	0,59	18 992	7 295	0,30

E GLASS

ρ_m = 1,2			UD							CSM				BD+ 0/90°				± 45° DBx Double bias				Quadrax 0/45/90/-45				all plies inter laminar stress
ρ_f= 2,56			k_G = 2,50																							
Ef1= 73 000			ε_{ufi}=k_G ε_{uti}/(1+ε_{uti}/ε_{uci}) with i=1 or 2							ε_{uf}=k_G ε_{ut}/(1+ε_{ut}/ε_{uc})				ε_{uf}=k_G ε_{ut}/(1+ε_{ut}/ε_{uc})				ε_{uf}=k_G ε_{ut}/(1+ε_{ut}/ε_{uc})				ε_{uf}=k_G ε_{ut}/(1+ε_{ut}/ε_{uc})				
Ef2= 73 000																										
Em= 3 300			Values of strains (%)																							
Gf= 30 000			ε_{Ut1}	ε_{Ut2}	ε_{Uc1}	ε_{Uc2}	ε_{Uf1}	ε_{Uf2}	γ_{U12}	ε_{Ut}	ε_{Uc}	ε_{Uf}	γ_U	ε_{Ut}	ε_{Uc}	ε_{Uf}	γ_U	ε_{Ut}	ε_{Uc}	ε_{Uf}	γ_U	ε_{Ut}	ε_{Uc}	ε_{Uf}	γ_U	
Gm= 1 222			1,90	0,50	1,40	1,40	2,02	0,92	1,70	1,35	1,70	1,88	2,00	1,55	1,40	1,84	1,70	1,06	1,02	1,30	1,80	1,30	1,20	1,56	1,70	
ϕ	ψ	t/w	Values of stresses (N/mm²)																							τ_{il}
Vol	Mass	1/(ϕ*ρ_f)	σ_{Ut1}	σ_{Ut2}	σ_{Uc1}	σ_{Uc2}	σ_{Uf1}	σ_{Uf2}	τ_U	σ_{Ut}	σ_{Uc}	σ_{Uf}	τ_{UST}	σ_{Ut}	σ_{Uc}	σ_{Uf}	τ_{UST}	σ_{Ut}	σ_{Uc}	σ_{Uf}	τ_{UST}	σ_{Ut}	σ_{Uc}	σ_{Uf}	τ_{UST}	τ_{il}
0,140	0,258	2,79	242	21	178	60	257	39	27	100	127	140	53	132	119	156	27	51	49	63	66	90	83	108	45	18,0
0,160	0,289	2,44	268	22	197	62	284	41	28	109	137	151	57	144	130	170	28	53	51	66	73	97	90	116	48	17,5
0,167	0,300	2,34	277	22	204	63	294	41	28	112	141	156	59	148	133	175	28	54	52	67	75	99	92	119	50	17,3
0,180	0,319	2,17	294	23	216	64	311	42	29	117	147	163	62	155	140	184	29	56	54	69	79	104	96	125	52	16,9
0,200	0,348	1,95	319	24	235	67	339	44	30	125	158	175	66	167	151	198	30	59	56	72	86	111	103	134	56	16,4
0,220	0,376	1,78	345	25	254	69	366	46	31	134	169	186	70	179	162	213	31	61	59	75	92	119	110	143	59	16,0
0,240	0,403	1,63	371	26	273	72	394	47	33	142	179	198	75	191	173	227	33	64	61	78	99	126	116	151	63	15,5
0,260	0,428	1,50	397	27	292	75	421	49	34	151	190	210	79	203	184	241	34	67	64	82	105	134	123	160	67	15,0
0,280	0,453	1,40	423	28	311	78	448	51	35	160	201	222	83	216	195	256	35	70	67	85	112	141	130	170	71	14,6
0,300	0,478	1,30	448	29	330	81	476	53	37	168	212	235	88	228	206	270	37	73	70	89	119	149	138	179	74	14,2
0,319	0,500	1,22	473	30	349	84	502	55	38	177	223	246	92	240	216	284	38	76	73	93	125	156	144	188	78	13,8
0,340	0,524	1,15	500	31	369	88	530	58	40	186	234	259	97	253	228	300	40	79	76	97	132	165	152	198	82	13,4
0,360	0,545	1,09	526	33	388	91	558	60	41	195	246	272	102	265	240	315	41	82	79	101	139	173	159	207	86	13,0
0,380	0,567	1,03	552	34	407	95	585	63	43	204	257	285	107	278	251	330	43	86	83	105	146	181	167	217	90	12,6
0,400	0,587	0,98	578	36	426	99	613	65	45	214	269	298	112	291	263	345	45	90	86	110	153	189	174	227	95	12,3
0,420	0,607	0,93	603	37	445	104	640	68	47	223	281	311	116	304	274	360	47	94	90	115	159	197	182	237	99	11,9
0,440	0,626	0,89	629	39	464	108	667	71	49	233	293	325	121	317	286	376	49	98	94	120	166	206	190	247	103	11,6
0,460	0,645	0,85	655	40	483	113	695	74	51	243	306	338	127	330	298	391	51	102	98	125	173	215	198	258	108	11,3
0,480	0,663	0,81	681	42	502	118	722	78	54	253	318	352	132	343	310	407	54	107	103	131	181	224	206	268	112	10,9
0,500	0,681	0,78	707	44	521	124	750	82	56	263	331	366	137	357	322	423	56	112	107	137	188	233	215	279	117	10,6
0,530	0,706	0,74	745	47	549	133	791	87	60	279	351	388	146	378	341	448	60	120	115	147	199	247	228	296	124	10,2