CORK INSTITUTE OF TECHNOLOGY
INSTITIÚID TEICNEOLAÍOCHTA CHORCAÍ

Semester 2 Examinations 2009/10

Module Title: Structural Design

Module Code: **CIVL7018**

School: Building and Civil

Programme Title: Bachelor of Engineering in Civil Engineering - Award

Programme Code: **CCIVL_7_Y3**

External Examiner(s): Ms. M. Kyne, Mr. J. Murphy
Internal Examiner(s): Dr. N. Power, Ms. S. Corcoran

Instructions: **Answer <u>all</u> questions**
Use seperate answer books for each section

Duration: 2 Hours

Sitting: Summer 2010

Requirements for this examination:
Candidates may refer to
1. *PP1990:2007 – 'Structural Eurocodes'*
Extract from Structural Eurocodes for students of structural design
2. *'Approved Design Aids' – (CIT Booklet)*
3. *PP7312:2002 - 'Structural Design'*
Extracts from British Standards for students of structural design

Note to Candidates: Please check the Programme Title and the Module Title to ensure that you have received the correct examination paper.
If in doubt please contact an Invigilator.

Section A – Reinforced Concrete & Masonry
(Attempt **both** QA1 **and** QA2)

QA1 Masonry (Total 20 Marks)

The figure below gives details of an internal wall which is supporting a precast concrete floor. The wall is constructed from group 1 units (440mm x 215mm x 100mm solid concrete blocks) with a mean compressive strength of 15N/mm^2, laid on flat with M2 mortar. Using the design data given below check the suitability of the proposed block/ mortar combination specified.

Characteristic permanent action – precast floor = 3.3kN/m^2
Characteristic variable action – precast floor = 4.1kN/m^2.
$W_{blockwork}$ (Characteristic) = 20 kN/m^3.
Manufacturing/execution control = category II/special

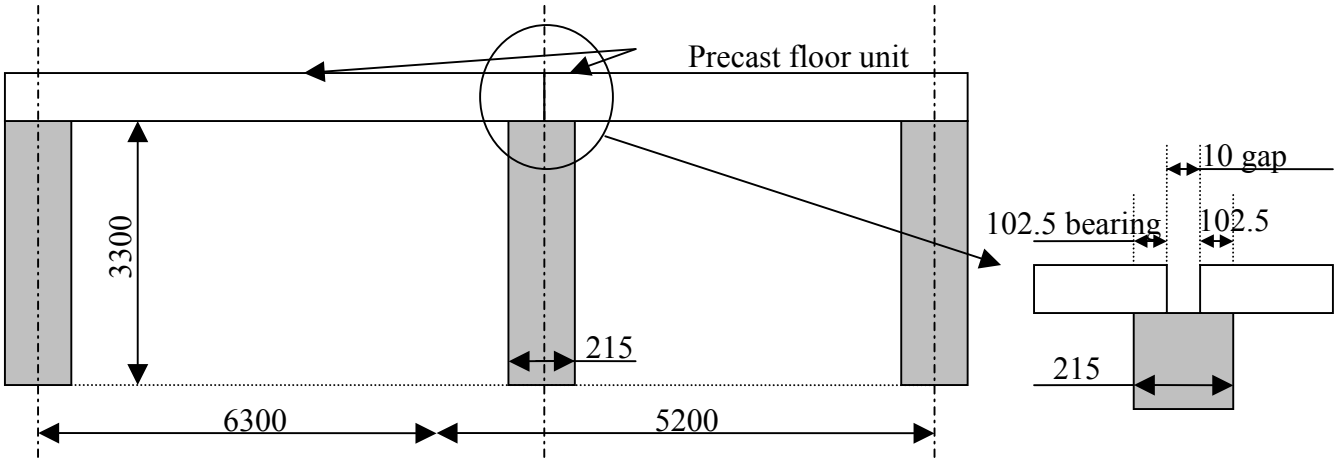


FIG. QA1

QA1 to BS5628 & IS325 For Students *Repeating Exams Only*
(Total 20 Marks)

Fig. QA1 gives details of an internal wall which is supporting a precast concrete floor. The wall is constructed from 440mm x 215mm x 100mm solid concrete blocks laid on flat. The wall has a clear height of 3.3m. Determine a suitable strength of unit and mortar combination for the wall.

Characteristic dead load – precast floor = 3.3kN/m^2
Characteristic imposed load – precast floor = 4.1kN/m^2.
$W_{blockwork}$ (Characteristic) = 20 kN/m^3.
Manufacturing/construction control = normal/special

QA2 Column (Total 30 Marks)

The attached drawing, Fig QA2, details the structural framing arrangement of a three storey building of in-situ reinforced concrete construction. The ground floor will comprise ground bearing concrete slab construction and no loading from this level will be carried by the structural framing. Lateral stability of the building will be provided independently of the main beam and column framing shown.

Column B3

Design column B3 from foundation to 1st floor.
(Assume a pinned connection between column and its footing).

Design Information:
Exposure: XC3

Loading:
Specific weight of concrete = 25kN/m^3
Roof: Characteristic permanent action* (incl. self wt. of slab and beams) = 9.8kN/m^2 of floor
Characteristic variable action = 2.0kN/m^2 of floor
Floor: Characteristic permanent action*(incl. self wt. of slab and beams) = 9.8kN/m^2 of floor
Characteristic variable action = 3.0kN/m^2 of floor

Materials: Concrete: C28/35
Reinforcement: f_{yk} = 500MPa

QA2 to BS8110 For Students *Repeating Exams Only* (Total 30 Marks)

The attached drawing, Fig QA2, details the structural framing arrangement of a three storey building of in-situ reinforced concrete construction. The ground floor will comprise ground bearing concrete slab construction and no loading from this level will be carried by the structural framing. Lateral stability of the building will be provided independently of the main beam and column framing shown.

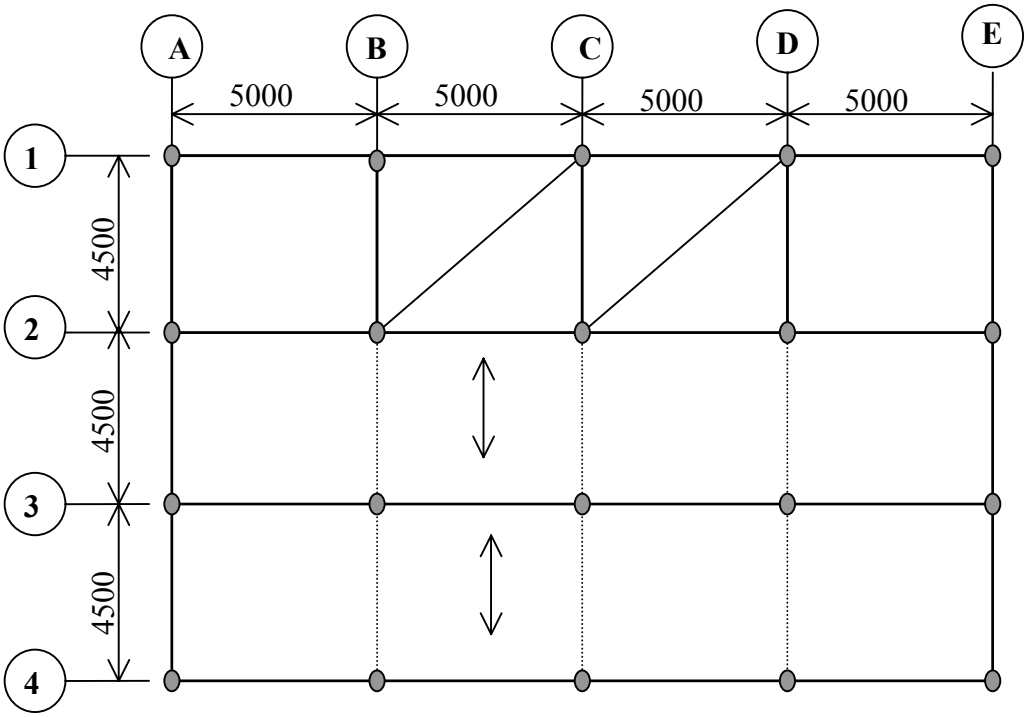
Column B3

Design column B3 from foundation to 1st floor.
(Assume a pinned connection between column and its footing).

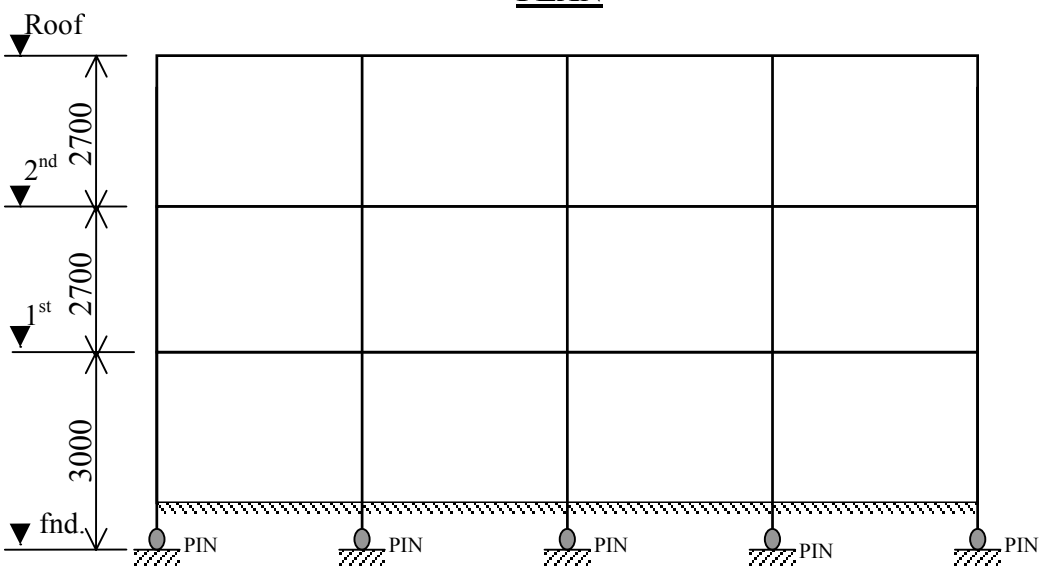
Design Information:
Exposure: moderate

Loading:
Specific weight of concrete = 24kN/m^3
Roof: Characteristic dead load*(incl. self wt. of slab and beams) = 9.8kN/m^2 of floor
Characteristic imposed load = 2.0kN/m^2 of floor
Floor: Characteristic dead load*(incl. self wt. of slab and beams) = 9.8kN/m^2 of floor
Characteristic imposed load = 3.0kN/m^2 of floor

Materials: Concrete: C35
Reinforcement: f_y = 460N/mm^2



PLAN



ELEVATION

All columns are 275 x 275

FIG. QA2

Masonry Unit		General Purpose Mortar	Thin Layer Mortar (Bed Joint ≥ 0,5 mm and ≤ 3 mm)	Lightweight Mortar of Density	
				$600 \leq \rho_d \leq 800$ kg/m^3	$800 < \rho_d \leq 1\,300$kg/m^3
Clay	Group 1	0,55	0,75	0,3	0,4
	Group 2	0,45	0,70	0,25	0,30
	Group 3	0,35	0,50	0,20	0,25
	Group 4	0,35	0,35	0,20	0,25
Calcium Silicate	Group 1	0,55	0,80	‡	‡
	Group 2	0,45	0,65	‡	‡
Aggregate Concrete	Group 1	0,55	0,80	0,45	0,45
	Group 2	0,45	0,65	0,45	0,45
	Group 3	0,40	0,50	‡	‡
	Group 4	0,35	‡	‡	‡
Autoclaved Aerated Concrete	Group 1	0,55	0,80	0,45	0,45
Manufactured Stone	Group 1	0,45	0,75	‡	‡
Dimensioned Natural Stone	Group 1	0,45	‡	‡	‡

Class of Execution Control:	γ_M	
	4[A] *(Special)*	5[A] *(Normal)*
Material		
Masonry made with:		
Units of Category I, Designed Mortar[B,D]	2,2	2,5
Units of Category I, Prescribed Mortar[C,D]	2,5	2,7
Units of Category II, Any Mortar[B,C,D,H]	2,7	3,0
Anchorage of reinforcing steel	2,5[F]	2,7[E]
Reinforcing steel and prestressing steel	1,15[F]	1,15[E]
Ancillary Components[G,I]	2,5	2,7
Lintels in accordance with IS EN 845-2	See NA to IS EN 845-2	See NA to IS EN 845-2

Compressive Strength Class[A]	Equivalent Prescribed Mortars (Proportion of Materials by Volume) *(see Note)*			Mortar Designation
	Cement : Lime : Sand with or without Air Entrainment	Masonry Cement : Sand	Cement : Sand with or without Air Entrainment	
M12	1 : 0 to ¼ : 3	Not suitable	Not suitable	(i)
M6	1 : ½ : 4 to 4½	1 : 2½ to 3½	1 : 3 to 4	(ii)
M4	1 : 1 : 5 to 6	1 : 4 to 5	1 : 5 to 6	(iii)
M2	1 : 2 : 8 to 9	1 : 5½ to 6½	1 : 7 to 8	(iv)

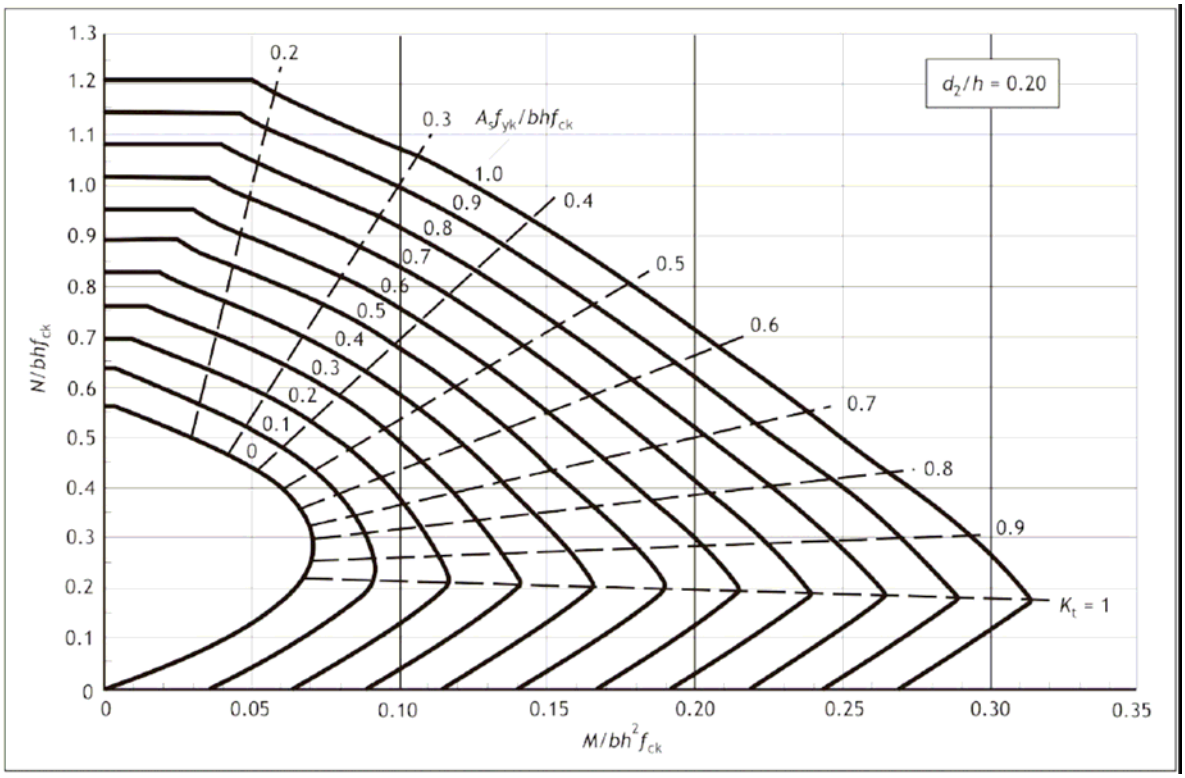
Determination of Normalised Strength from the Declared Mean Compressive Strength of a Masonry Unit

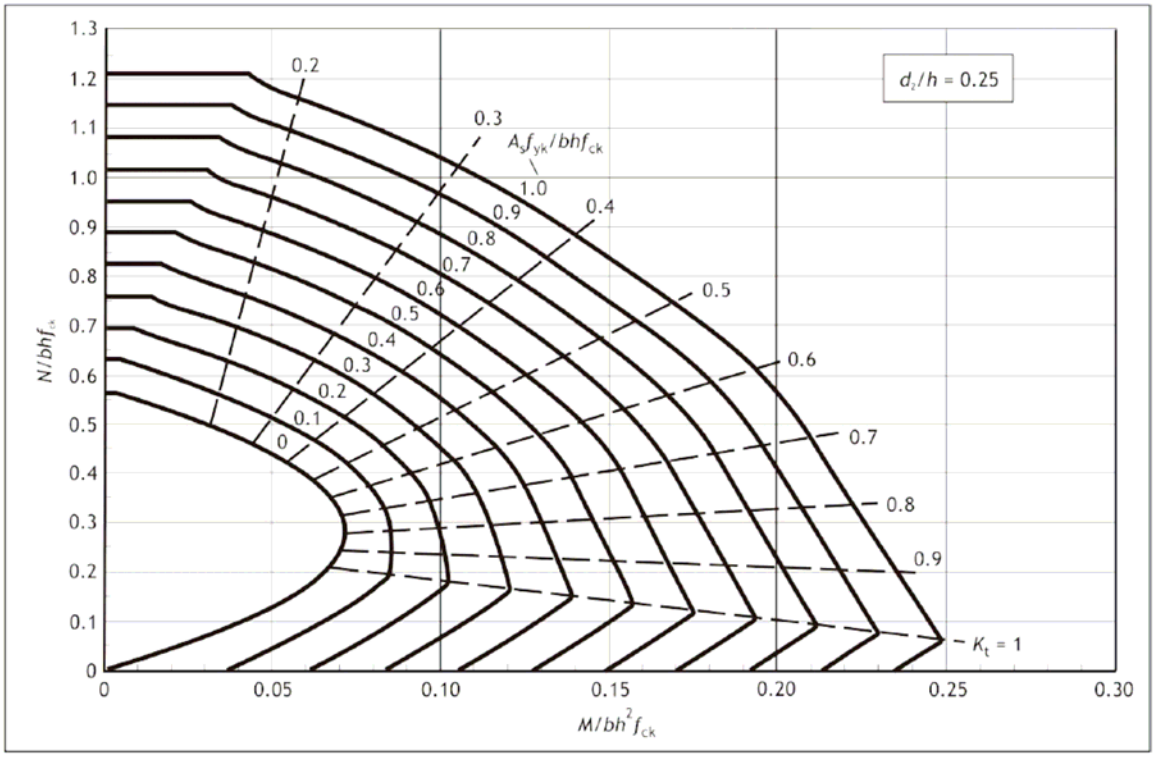
Conversion to an equivalent air dry conditioning regime

Type of unit	Conversion factor	
Clay	1.0	
Calcium Silicate	0.8	
Concrete	1.0	
Autoclaved Aerated Concrete	1.0	
Manufactured Stone (conditioned clause 7.3.2.)	1.0	For full information see BS EN 772-1
Manufactured Stone (conditioned clause 7.3.5.)	1.2	For full information see BS EN 772-1
Stone	0.8	

Shape Factors for Normalised Strength

	Width mm (Historically called Thickness for some UK masonry units)											
Height mm	**50**	**75**	**90**	**100**	**115**	**125**	**140**	**150**	**200**	**215**	**225**	**≥250**
40	0.80	0.75	0.72	0.70								
50	0.85	0.80	0.77	0.75	0.74	0.73	0.71	0.70				
65	0.95	0.90	0.87	0.85	0.82	0.80	0.77	0.75	0.70	0.69	0.68	0.65
100	1.15	1.08	1.03	1.00	0.97	0.95	0.92	0.90	0.80	0.79	0.78	0.75
140	1.27	1.22	1.18	1.16	1.13	1.11	1.08	1.06	0.96	0.95	0.94	0.91
150	1.30	1.25	1.22	1.20	1.17	1.15	1.12	1.10	1.00	0.99	0.98	0.95
190	1.42	1.37	1.34	1.32	1.29	1.27	1.24	1.22	1.12	1.11	1.10	1.07
200	1.45	1.40	1.37	1.35	1.32	1.30	1.27	1.25	1.15	1.14	1.13	1.10
215	1.48	1.43	1.40	1.38	1.35	1.33	1.30	1.28	1.18	1.16	1.15	1.12
≥250	1.55	1.50	1.47	1.45	1.42	1.40	1.37	1.35	1.25	1.22	1.20	1.15


d_2/h = 0.20
$A_s f_{yk}/bhf_{ck}$
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
K_t = 1
N/bhf_{ck}
$M/bh^2 f_{ck}$
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35


d_2/h = 0.25
$A_s f_{yk}/bhf_{ck}$
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
K_t = 1
N/bhf_{ck}
$M/bh^2 f_{ck}$
0
0.05
0.10
0.15
0.20
0.25
0.30

Question B1 (30 marks)

A lattice beam is indicated in Figure QB1. It is to be used in the roof of a warehouse.

The roof deck is fixed directly to the top boom. The compression boom (top boom) is laterally restrained by the roof deck. The lattice beams will be positioned at 4.5m c/c's. Wind loading may be ignored.

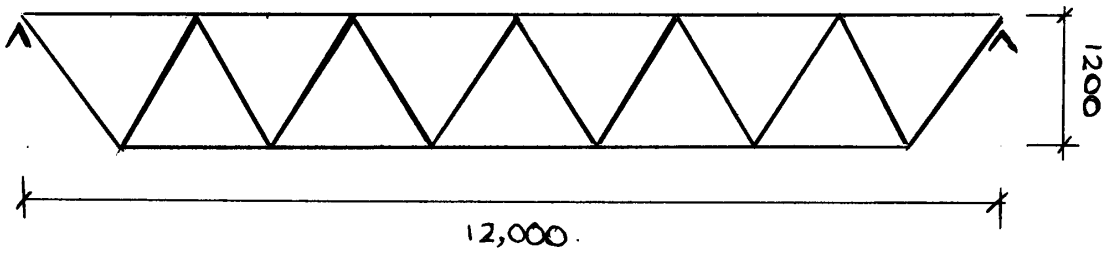


Figure QB1 Lattice Beam

Loading:	**kN/m^2**	**kN/m**
Roof decking	0.35	
Ceilings & Services	0.3	
Self Weight assumption		1
Live	1.5	

Design:

- The compression boom
- The internal tie – assume M16 bolts at c/c's $\geq 5d_o$

Available structural steel sections:

203 x 102 x 36T; 102 x 127 x 11T; 80 x 80 x 10EA; 80 x 80 x 8EA

Question B2 (20 marks)

Determine the size of joist capable of spanning 4.25m, supporting a floor consisting of 20mm T&G floorboards fixed to the joists. The joists are at 400mm c/c's and are simply supported at their ends on a wall plate on a 100mm masonry wall.
Refer to loading and design information in accordance to the appropriate code – EC5 and BS5268.

LOADING

		kN/m^2
Permanent Load:	T&G floorboards	0.1
	Plasterboard	0.12
	Skim	0.1
Variable Load:	Domestic Dwelling	

Note: do not forget Self Weight

Available timber sections:

44 x 200 44 x 225

DESIGN INFORMATION for EC5

Durability:	Class 1
Loading Duration:	Medium and Long term
Material Data:	C16, $w_{timber} = 5kN/m^3$
Modification factors:	$k_{cr} = 0.67$
	$K_{c,90} = 1.0$ for UDL loading
Deflection Limits:	$\omega_{inst} = L/350$
	$\omega_{fin} = L/250$

FORMULAE for EC5

Deflection at mid-span for a simply supported beam with a uniformly distributed load of q (kN/m)

$$\omega_{inst} = 5/384\ qL^4/EI + 1.2qL^2/8AG$$
$$\omega_{fin,g} = \omega_{inst}(1+k_{def})$$
$$\omega_{fin,g} = \omega_{inst}(1+\psi_{21}k_{def}) \quad \text{where } \psi_{21} = 0.3$$

DESIGN INFORMATION for BS5268

Durability:	Dry Exposure
Loading Duration:	Long term

Material Data: C16, $w_{timber} = 5kN/m^3$

FORMULAE for BS5268

Deflection at mid-span for a simply supported beam with a uniformly distributed load of w (kN/m)

$$\delta_b = 5/384\ wL^4/EI$$

Deflection due to shear

$$\delta_s = 1.2M/GA \text{ where } G = E/16$$

Table 1 — Strength classes - Characteristic values

		Poplar and softwood species												Hardwood species					
		C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	D30	D35	D40	D50	D60	D70
Strength properties (in N/mm²)																			
Bending	$f_{m,k}$	14	16	18	20	22	24	27	30	35	40	45	50	30	35	40	50	60	70
Tension parallel	$f_{t,0,k}$	8	10	11	12	13	14	16	18	21	24	27	30	18	21	24	30	36	42
Tension perpendicular	$f_{t,90,k}$	0,4	0,5	0,5	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
Compression parallel	$f_{c,0,k}$	16	17	18	19	20	21	22	23	25	26	27	29	23	25	26	29	32	34
Compression perpendicular	$f_{c,90,k}$	2,0	2,2	2,2	2,3	2,4	2,5	2,6	2,7	2,8	2,9	3,1	3,2	8,0	8,4	8,8	9,7	10,5	13,5
Shear	$f_{v,k}$	1,7	1,8	2,0	2,2	2,4	2,5	2,6	3,0	3,4	3,8	3,8	3,8	3,0	3,4	3,8	4,6	5,3	6,0
Stiffness properties (in kN/mm²)																			
Mean modulus of elasticity parallel	$E_{0,mean}$	7	8	9	9,5	10	11	11,5	12	13	14	15	16	10	10	11	14	17	20
5% modulus of elasticity parallel	$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4	7,7	8,0	8,7	9,4	10,0	10,7	8,0	8,7	9,4	11,8	14,3	16,8
Mean modulus of elasticity perpendicular	$E_{90,mean}$	0,23	0,27	0,30	0,32	0,33	0,37	0,38	0,40	0,43	0,47	0,50	0,53	0,64	0,69	0,75	0,93	1,13	1,33
Mean shear modulus	G_{mean}	0,44	0,5	0,56	0,59	0,63	0,69	0,72	0,75	0,81	0,88	0,94	1,00	0,60	0,65	0,70	0,88	1,06	1,25