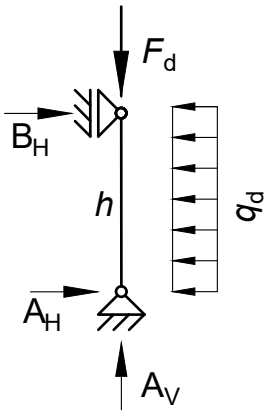
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.

Question



A column (GL28h, $h = 9$ m) is loaded with a point design load $F_d = 140$ kN and a uniformly distributed design load $q_d = 5$ kN/m. Load-duration class Medium-term and Service class 1 apply. The dimensions of the column are $t \times w = 160 \times 400$ mm^2 (the stronger axis is in plane direction).

a.) Calculate the reaction forces and the internal forces. (0.5 points)

b.) Check the stability of the column. (6 points)

A single supported beam (GL28h, $l = 20$ m) is loaded with a uniformly distributed design load $q_d = 11$ kN/m. The load applies at the compression edge of the beam. In the middle the beam is supported against lateral buckling. Load-duration class Medium-term and Service class 2 apply. The dimensions of the beam are $b \times h = 200 \times 1200$ mm^2.

c.) Calculate the effective length of the beam. (1 points)

d.) Check the stability of the beam. (3.5 points)

Appendix

Characteristic values – GLT

For softwood GLT – homogeneous lay-up			Strength classes GL20h	GL24h	GL28h	GL32h
Strength properties MPa	Bending	$f_{m,g,k}$	20	24	28	32
	Tension parallel	$f_{t,0,g,k}$	16	19.2	22.3	25.6
	Tension perpendicular	$f_{t,90,g,k}$	0.5	0.5	0.5	0.5
	Compression parallel	$f_{c,0,g,k}$	20	24	28	32
	Compression perpendicular	$f_{c,90,g,k}$	2.5	2.5	2.5	2.5
	Shear	$f_{v,g,k}$	3.5	3.5	3.5	3.5
	Rolling shear	$f_{r,g,k}$	1.2	1.2	1.2	1.2
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{0,g,mean}$	8.4	11.5	12.6	14.2
	5 % modulus of elasticity parallel	$E_{0,g,05}$	7.0	9.6	10.5	11.8
	Mean modulus of elasticity perpendicular	$E_{90,g,mean}$	0.30	0.30	0.30	0.30
	5 % modulus of elasticity perpendicular	$E_{90,g,05}$	0.25	0.25	0.25	0.25
	Mean shear modulus	$G_{g,mean}$	0.65	0.65	0.65	0.65
	5 % shear modulus	$G_{g,05}$	0.54	0.54	0.54	0.54
	Mean rolling shear modulus	$G_{r,g,mean}$	0.065	0.065	0.065	0.065
	5 % rolling shear modulus	$G_{r,g,05}$	0.054	0.054	0.054	0.054
Density [kg/m^3]	Density	ρ_k	340	385	425	440
	Mean Density	ρ_{mean}	370	420	460	490

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90

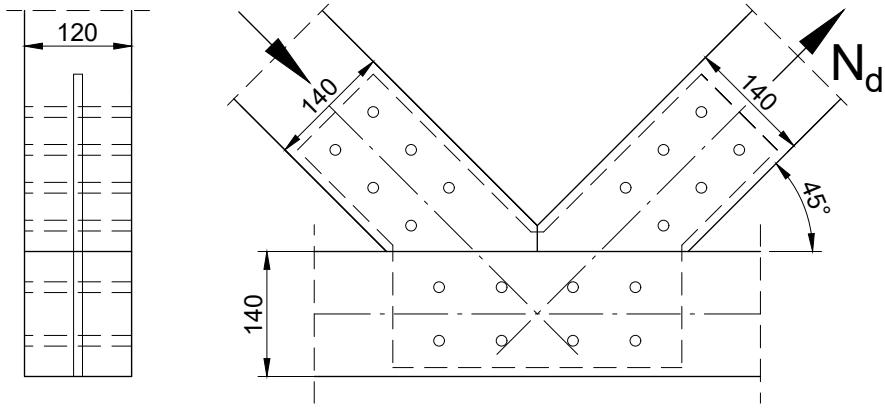
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.
- Use the equations given in the appendix for the design of the connection.

Question



GLT beams (GL24h) are connected with a dowel connection. The dowel diameter $d = 14$ mm. The design load $N_d = 100$ kN (axial load). Load-duration class Medium-term and Service class 2 apply. The thickness of the steel plate is 10 mm (no proof required).

a.) Calculate the design load-carrying capacity per shear plane per fastener. (4.5 points)

Answer the following questions ONLY for the diagonal tensile member:

b.) Calculated the minimum spacings and edge and end distances for the dowels and illustrate it. (2 points)

c.) Find the required number of dowels (for 2 dowel rows) and check the resistance of the connection. (2.5 points)

d.) Check the resistance of the beam. (2 points)

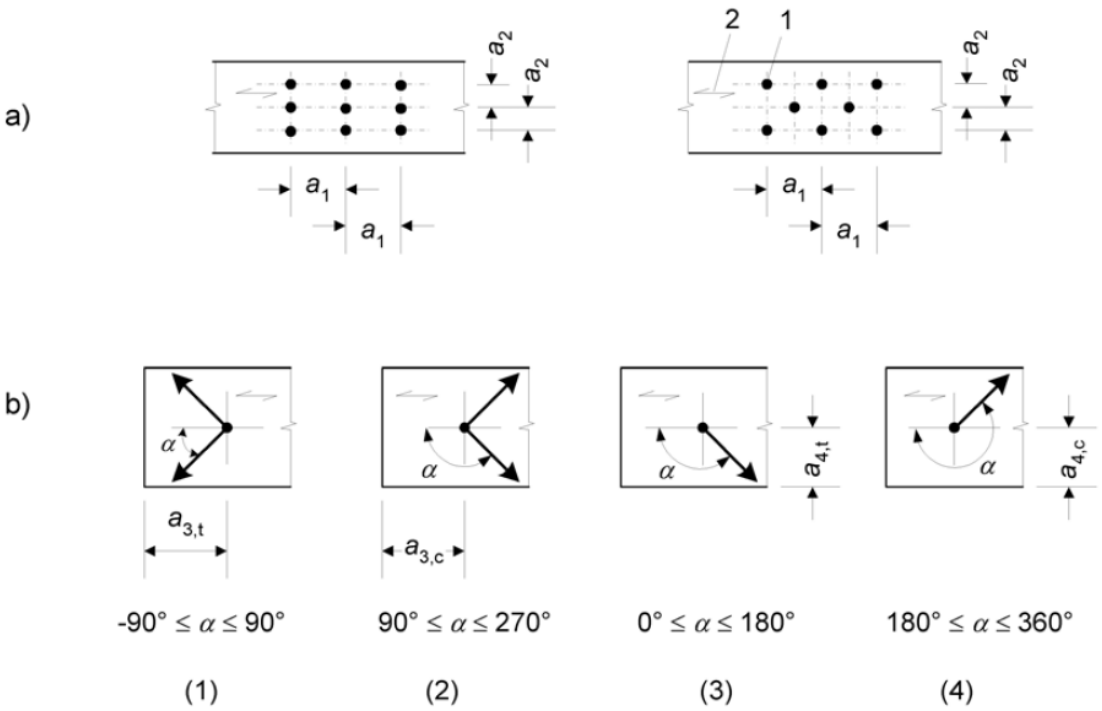
Appendix

Characteristic values – GLT

For softwood GLT – homogeneous lay-up			Strength classes GL20h	GL24h	GL28h	GL32h
Strength properties MPa	Bending	$f_{\mathrm{m,g,k}}$	20	24	28	32
	Tension parallel	$f_{\mathrm{t,0,g,k}}$	16	19.2	22.3	25.6
	Tension perpendicular	$f_{\mathrm{t,90,g,k}}$	0.5	0.5	0.5	0.5
	Compression parallel	$f_{\mathrm{c,0,g,k}}$	20	24	28	32
	Compression perpendicular	$f_{\mathrm{c,90,g,k}}$	2.5	2.5	2.5	2.5
	Shear	$f_{\mathrm{v,g,k}}$	3.5	3.5	3.5	3.5
	Rolling shear	$f_{\mathrm{r,g,k}}$	1.2	1.2	1.2	1.2
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{\mathrm{0,g,mean}}$	8.4	11.5	12.6	14.2
	5 % modulus of elasticity parallel	$E_{\mathrm{0,g,05}}$	7.0	9.6	10.5	11.8
	Mean modulus of elasticity perpendicular	$E_{\mathrm{90,g,mean}}$	0.30	0.30	0.30	0.30
	5 % modulus of elasticity perpendicular	$E_{\mathrm{90,g,05}}$	0.25	0.25	0.25	0.25
	Mean shear modulus	$G_{\mathrm{g,mean}}$	0.65	0.65	0.65	0.65
	5 % shear modulus	$G_{\mathrm{g,05}}$	0.54	0.54	0.54	0.54
	Mean rolling shear modulus	$G_{\mathrm{r,g,mean}}$	0.065	0.065	0.065	0.065
	5 % rolling shear modulus	$G_{\mathrm{r,g,05}}$	0.054	0.054	0.054	0.054
Density [kg/m^3]	Density	ρ_{k}	340	385	425	440
	Mean Density	ρ_{mean}	370	420	460	490

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90



Key:
(1) Loaded end
(2) Unloaded end
(3) Loaded edge
(4) Unloaded edge
1 Fastener
2 Grain direction

Spacing and edge/end distances (see Figure 8.7)	**Angle**	**Minimum spacing or edge/end distance**
a_1 (parallel to grain)	$0^\circ \le \alpha \le 360^\circ$	$(3 + 2\lvert\cos\alpha\rvert)\,d$
a_2 (perpendicular to grain)	$0^\circ \le \alpha \le 360^\circ$	$3\,d$
$a_{3,t}$ (loaded end)	$-90^\circ \le \alpha \le 90^\circ$	max (7 d; 80 mm)
$a_{3,c}$ (unloaded end)	$90^\circ \le \alpha < 150^\circ$ $150^\circ \le \alpha < 210^\circ$ $210^\circ \le \alpha \le 270^\circ$	$\max(a_{3,t}\lvert\sin\alpha\rvert)\,d;\ 3d)$ $3\,d$ $\max(a_{3,t}\lvert\sin\alpha\rvert)\,d;\ 3d)$
$a_{4,t}$ (loaded edge)	$0^\circ \le \alpha \le 180^\circ$	$\max([2 + 2\sin\alpha)\,d;\ 3d)$
$a_{4,c}$ (unloaded edge)	$180^\circ \le \alpha \le 360^\circ$	$3\,d$

$$M_{y,Rk} = 0{,}3\, f_{u,k}\, d^{2,6}$$

where:

$M_{y,Rk}$ is the characteristic value for the yield moment, in Nmm;

$f_{u,k}$ is the characteristic tensile strength, in N/mm²;

d is the bolt diameter, in mm.

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \sin^2\alpha + \cos^2\alpha}$$

$$f_{h,0,k} = 0{,}082\,(1 - 0{,}01\, d)\, \rho_k$$

where:

$$k_{90} = \begin{cases} 1{,}35 + 0{,}015\, d & \text{for softwoods} \\ 1{,}30 + 0{,}015\, d & \text{for LVL} \\ 0{,}90 + 0{,}015\, d & \text{for hardwoods} \end{cases}$$

and:

$f_{h,0,k}$ is the characteristc embedment strength parallel to grain, in N/mm^2;

ρ_k is the characteristic timber density, in kg/m³;

α is the angle of the load to the grain;

d is the bolt diameter, in mm.

$$n_{ef} = \min \begin{cases} n \\ n^{0,9} \sqrt[4]{\dfrac{a_1}{13d}} \end{cases}$$

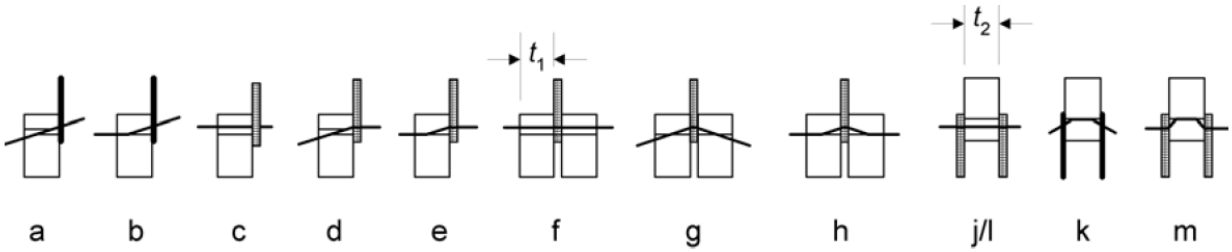
$$F_{v,Rk} = \min \begin{cases} 0{,}4\, f_{h,k}\, t_1\, d & \text{(a)} \\ 1{,}15\sqrt{2 M_{y,Rk}\, f_{h,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(b)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} f_{h,k}\, t_1\, d \left[\sqrt{2 + \dfrac{4 M_{y,Rk}}{f_{h,k}\, d\, t_1^2}} - 1 \right] + \dfrac{F_{ax,Rk}}{4} & \text{(c)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(d)} \\ f_{h,k}\, t_1\, d & \text{(e)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k}\, t_1\, d & \text{(f)} \\ f_{h,1,k}\, t_1\, d \left[\sqrt{2 + \dfrac{4 M_{y,Rk}}{f_{h,1,k}\, d\, t_1^2}} - 1 \right] + \dfrac{F_{ax,Rk}}{4} & \text{(g)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,1,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(h)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} 0{,}5\, f_{h,2,k}\, t_2\, d & \text{(j)} \\ 1{,}15\sqrt{2 M_{y,Rk}\, f_{h,2,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(k)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} 0{,}5\, f_{h,2,k}\, t_2\, d & \text{(l)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,2,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(m)} \end{cases}$$



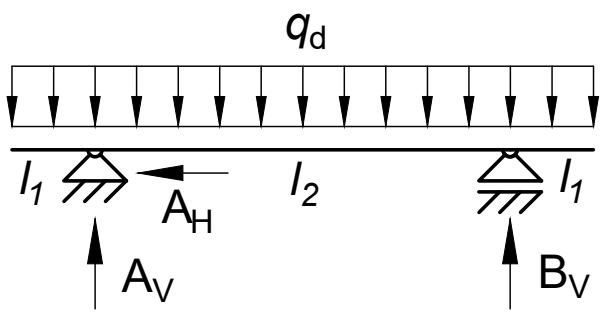
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.

Question



A LVL beam (Kerto-S, $l_1 = 2\text{m}, l_2 = 7\text{m}$) is loaded with a uniformly distributed design load $q_\text{d} = 9$ kN/m. Load-duration class Medium-term and Service class 2 apply. Beam and column are LVL (Kerto-S). The dimensions of the beam are $b \times h = 75 \times 400$ mm^2.

a.) Calculate the reaction forces and illustrate the internal forces [M], [V], [N]. (1 point)

b.) Check all ULS requirements of the beam (instability is prevented). (3 points)

c.) At A the beam is supported on a 100×100 mm^2 member. Check the compression strength perpendicular to grain at the support A. (2 points)

d.) Name two solutions for the case that the compression perpendicular to grain requirement is not fulfilled. (1 point)

e.) Calculate the effective cross section (using reduced cross-section method) for the beam after $t = 30$ min fire exposure. (1 point)

f.) The beam is loaded out of plane with an additional uniform load $q_{\text{d,z}} = 2$ kN/m. The beam can be assumed to be supported in point A and B. Check all ULS requirements of the beam (instability is prevented). (3 points)

Appendix

Characteristic values – LVL

For LVL			Type Kerto-S	Kerto-T	Kerto-Q
Strength properties MPa	Bending – Edgewise	$f_{\mathrm{m,0,edge,k}}$	44	27	32
	Size effective parameter	s	0.12	0.15	0.12
	Bending – flatwise	$f_{\mathrm{m,0,flat,k}}$	50	32	36
	Tension – parallel	$f_{\mathrm{t,0,k}}$	35	24	26
	Tension – perpendicular, edgewise	$f_{\mathrm{t,90,edge,k}}$	0.8	0.5	6.0
	Compression – parallel	$f_{\mathrm{c,0,k}}$	35	26	26
	Compression – perpendicular, edgewise	$f_{\mathrm{c,90,edge,k}}$	6	1	9
	Compression – perpendicular, flatwise	$f_{\mathrm{c,90,flat,k}}$	1.8	1.0	2.2
	Shear (edgewise)	$f_{\mathrm{v,k}}$	4.1	2.4	4.5
	Shear (flatwise, parallel)	$f_{\mathrm{v,0,flat,k}}$	2.3	1.3	1.3
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{0,\mathrm{mean}}$	13.8	10.0	10.5
	Mean shear modulus	$G_{\mathrm{edge,mean}}$	0.60	0.40	0.60
Density [kg/m^3]	Density	ρ_{k}	480	410	480
	Mean Density	ρ_{mean}	510	440	510

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90

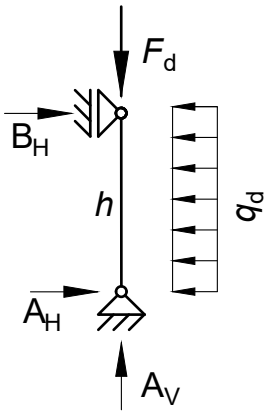
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.

Question



A column (GL28h, $h = 9$ m) is loaded with a point design load $F_d = 140$ kN and a uniformly distributed design load $q_d = 5$ kN/m. Load-duration class Medium-term and Service class 1 apply. The dimensions of the column are $t \times w = 160 \times 400$ mm^2 (the stronger axis is in plane direction).

a.) Calculate the reaction forces and the internal forces. (0.5 points)

b.) Check the stability of the column. (6 points)

A single supported beam (GL28h, $l = 20$ m) is loaded with a uniformly distributed design load $q_d = 11$ kN/m. The load applies at the compression edge of the beam. In the middle the beam is supported against lateral buckling. Load-duration class Medium-term and Service class 2 apply. The dimensions of the beam are $b \times h = 200 \times 1200$ mm^2.

c.) Calculate the effective length of the beam. (1 points)

d.) Check the stability of the beam. (3.5 points)

Appendix

Characteristic values – GLT

For softwood GLT – homogeneous lay-up			Strength classes GL20h	GL24h	GL28h	GL32h
Strength properties MPa	Bending	$f_{m,g,k}$	20	24	28	32
	Tension parallel	$f_{t,0,g,k}$	16	19.2	22.3	25.6
	Tension perpendicular	$f_{t,90,g,k}$	0.5	0.5	0.5	0.5
	Compression parallel	$f_{c,0,g,k}$	20	24	28	32
	Compression perpendicular	$f_{c,90,g,k}$	2.5	2.5	2.5	2.5
	Shear	$f_{v,g,k}$	3.5	3.5	3.5	3.5
	Rolling shear	$f_{r,g,k}$	1.2	1.2	1.2	1.2
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{0,g,mean}$	8.4	11.5	12.6	14.2
	5 % modulus of elasticity parallel	$E_{0,g,05}$	7.0	9.6	10.5	11.8
	Mean modulus of elasticity perpendicular	$E_{90,g,mean}$	0.30	0.30	0.30	0.30
	5 % modulus of elasticity perpendicular	$E_{90,g,05}$	0.25	0.25	0.25	0.25
	Mean shear modulus	$G_{g,mean}$	0.65	0.65	0.65	0.65
	5 % shear modulus	$G_{g,05}$	0.54	0.54	0.54	0.54
	Mean rolling shear modulus	$G_{r,g,mean}$	0.065	0.065	0.065	0.065
	5 % rolling shear modulus	$G_{r,g,05}$	0.054	0.054	0.054	0.054
Density [kg/m^3]	Density	ρ_k	340	385	425	440
	Mean Density	ρ_{mean}	370	420	460	490

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90

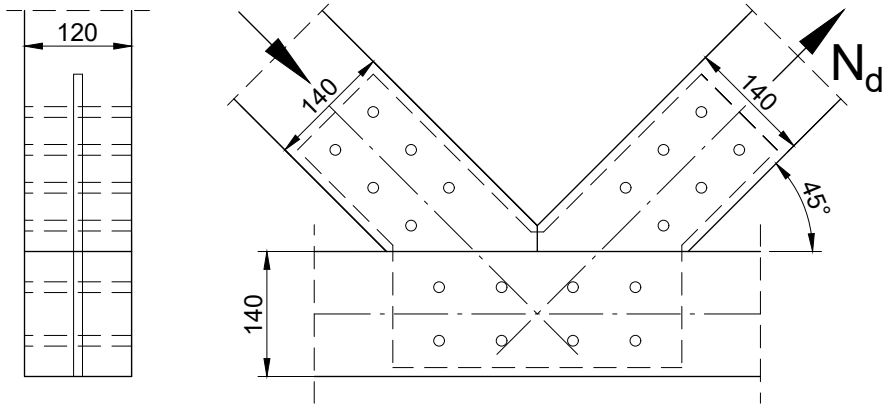
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.
- Use the equations given in the appendix for the design of the connection.

Question



GLT beams (GL24h) are connected with a dowel connection. The dowel diameter $d = 14$ mm. The design load $N_d = 100$ kN (axial load). Load-duration class Medium-term and Service class 2 apply. The thickness of the steel plate is 10 mm (no proof required).

a.) Calculate the design load-carrying capacity per shear plane per fastener. (4.5 points)

Answer the following questions ONLY for the diagonal tensile member:

b.) Calculated the minimum spacings and edge and end distances for the dowels and illustrate it. (2 points)

c.) Find the required number of dowels (for 2 dowel rows) and check the resistance of the connection. (2.5 points)

d.) Check the resistance of the beam. (2 points)

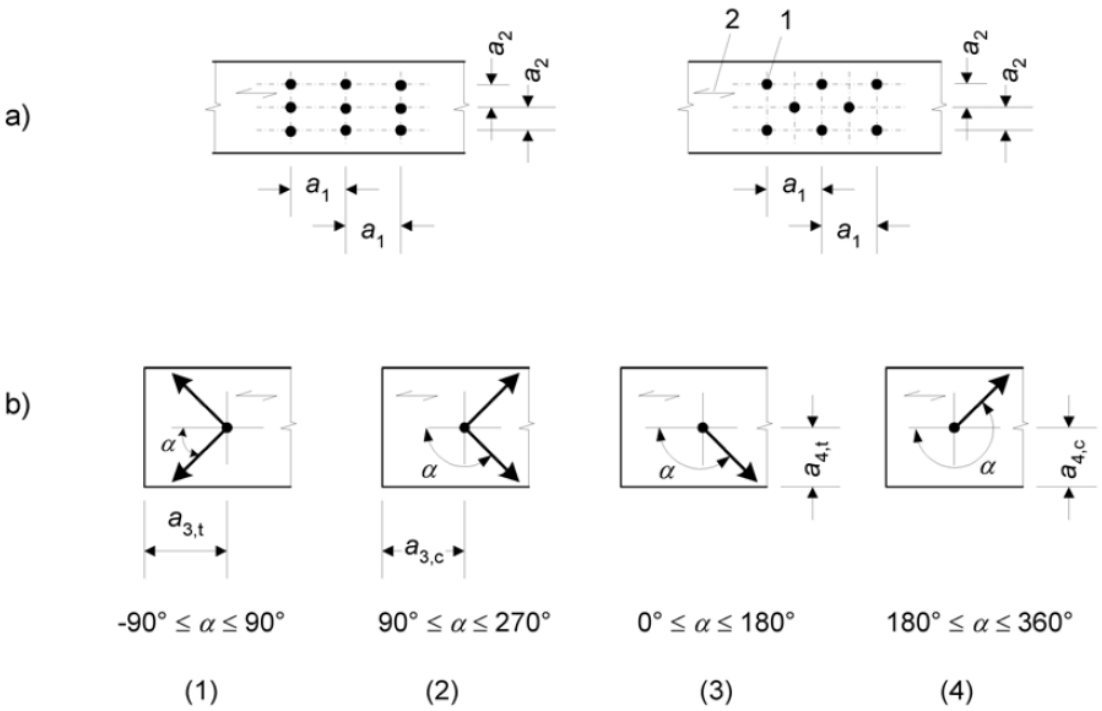
Appendix

Characteristic values – GLT

For softwood GLT – homogeneous lay-up			Strength classes GL20h	GL24h	GL28h	GL32h
Strength properties MPa	Bending	$f_{\mathrm{m,g,k}}$	20	24	28	32
	Tension parallel	$f_{\mathrm{t,0,g,k}}$	16	19.2	22.3	25.6
	Tension perpendicular	$f_{\mathrm{t,90,g,k}}$	0.5	0.5	0.5	0.5
	Compression parallel	$f_{\mathrm{c,0,g,k}}$	20	24	28	32
	Compression perpendicular	$f_{\mathrm{c,90,g,k}}$	2.5	2.5	2.5	2.5
	Shear	$f_{\mathrm{v,g,k}}$	3.5	3.5	3.5	3.5
	Rolling shear	$f_{\mathrm{r,g,k}}$	1.2	1.2	1.2	1.2
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{\mathrm{0,g,mean}}$	8.4	11.5	12.6	14.2
	5 % modulus of elasticity parallel	$E_{\mathrm{0,g,05}}$	7.0	9.6	10.5	11.8
	Mean modulus of elasticity perpendicular	$E_{\mathrm{90,g,mean}}$	0.30	0.30	0.30	0.30
	5 % modulus of elasticity perpendicular	$E_{\mathrm{90,g,05}}$	0.25	0.25	0.25	0.25
	Mean shear modulus	$G_{\mathrm{g,mean}}$	0.65	0.65	0.65	0.65
	5 % shear modulus	$G_{\mathrm{g,05}}$	0.54	0.54	0.54	0.54
	Mean rolling shear modulus	$G_{\mathrm{r,g,mean}}$	0.065	0.065	0.065	0.065
	5 % rolling shear modulus	$G_{\mathrm{r,g,05}}$	0.054	0.054	0.054	0.054
Density [kg/m^3]	Density	ρ_{k}	340	385	425	440
	Mean Density	ρ_{mean}	370	420	460	490

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90



Key:
(1) Loaded end
(2) Unloaded end
(3) Loaded edge
(4) Unloaded edge
1 Fastener
2 Grain direction

Spacing and edge/end distances (see Figure 8.7)	**Angle**	**Minimum spacing or edge/end distance**
a_1 (parallel to grain)	$0^\circ \le \alpha \le 360^\circ$	$(3 + 2\lvert\cos\alpha\rvert)\,d$
a_2 (perpendicular to grain)	$0^\circ \le \alpha \le 360^\circ$	$3\,d$
$a_{3,t}$ (loaded end)	$-90^\circ \le \alpha \le 90^\circ$	max (7 d; 80 mm)
$a_{3,c}$ (unloaded end)	$90^\circ \le \alpha < 150^\circ$ $150^\circ \le \alpha < 210^\circ$ $210^\circ \le \alpha \le 270^\circ$	$\max(a_{3,t}\lvert\sin\alpha\rvert)\,d;\ 3d)$ $3\,d$ $\max(a_{3,t}\lvert\sin\alpha\rvert)\,d;\ 3d)$
$a_{4,t}$ (loaded edge)	$0^\circ \le \alpha \le 180^\circ$	$\max([2 + 2\sin\alpha)\,d;\ 3d)$
$a_{4,c}$ (unloaded edge)	$180^\circ \le \alpha \le 360^\circ$	$3\,d$

$$M_{y,Rk} = 0{,}3\, f_{u,k}\, d^{2,6}$$

where:

$M_{y,Rk}$ is the characteristic value for the yield moment, in Nmm;

$f_{u,k}$ is the characteristic tensile strength, in N/mm²;

d is the bolt diameter, in mm.

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \sin^2\alpha + \cos^2\alpha}$$

$$f_{h,0,k} = 0{,}082\,(1 - 0{,}01\, d)\, \rho_k$$

where:

$$k_{90} = \begin{cases} 1{,}35 + 0{,}015\, d & \text{for softwoods} \\ 1{,}30 + 0{,}015\, d & \text{for LVL} \\ 0{,}90 + 0{,}015\, d & \text{for hardwoods} \end{cases}$$

and:

$f_{h,0,k}$ is the characteristc embedment strength parallel to grain, in N/mm^2;

ρ_k is the characteristic timber density, in kg/m³;

α is the angle of the load to the grain;

d is the bolt diameter, in mm.

$$n_{ef} = \min \begin{cases} n \\ n^{0,9} \sqrt[4]{\dfrac{a_1}{13d}} \end{cases}$$

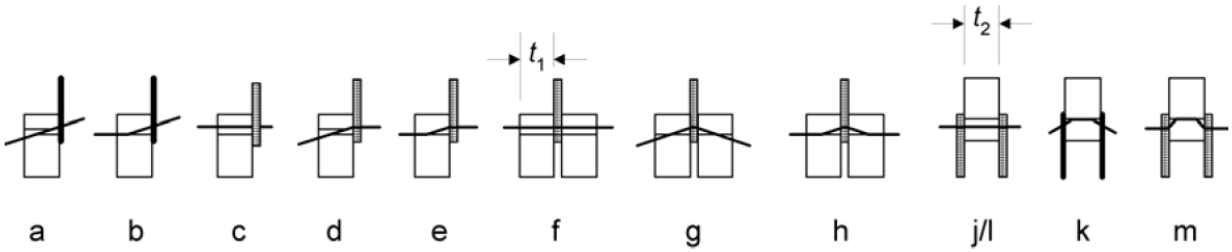
$$F_{v,Rk} = \min \begin{cases} 0{,}4\, f_{h,k}\, t_1\, d & \text{(a)} \\ 1{,}15\sqrt{2 M_{y,Rk}\, f_{h,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(b)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} f_{h,k}\, t_1\, d \left[\sqrt{2 + \dfrac{4 M_{y,Rk}}{f_{h,k}\, d\, t_1^2}} - 1 \right] + \dfrac{F_{ax,Rk}}{4} & \text{(c)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(d)} \\ f_{h,k}\, t_1\, d & \text{(e)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k}\, t_1\, d & \text{(f)} \\ f_{h,1,k}\, t_1\, d \left[\sqrt{2 + \dfrac{4 M_{y,Rk}}{f_{h,1,k}\, d\, t_1^2}} - 1 \right] + \dfrac{F_{ax,Rk}}{4} & \text{(g)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,1,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(h)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} 0{,}5\, f_{h,2,k}\, t_2\, d & \text{(j)} \\ 1{,}15\sqrt{2 M_{y,Rk}\, f_{h,2,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(k)} \end{cases}$$

$$F_{v,Rk} = \min \begin{cases} 0{,}5\, f_{h,2,k}\, t_2\, d & \text{(l)} \\ 2{,}3\sqrt{M_{y,Rk}\, f_{h,2,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(m)} \end{cases}$$



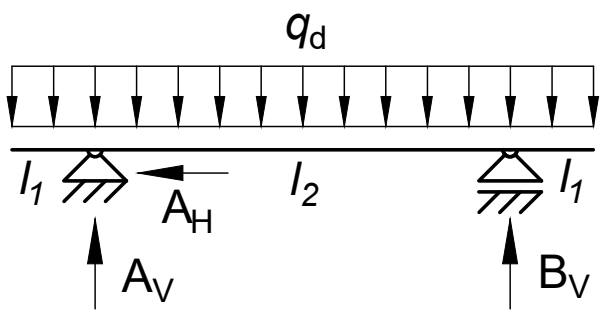
CIV-E 4110 Timber Engineering

Examination date 27.5.2020

General

- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the calculation.
- Use the material properties given in the appendix.

Question



A LVL beam (Kerto-S, $l_1 = 2\text{m}, l_2 = 7\text{m}$) is loaded with a uniformly distributed design load $q_\text{d} = 9$ kN/m. Load-duration class Medium-term and Service class 2 apply. Beam and column are LVL (Kerto-S). The dimensions of the beam are $b \times h = 75 \times 400$ mm^2.

a.) Calculate the reaction forces and illustrate the internal forces [M], [V], [N]. (1 point)

b.) Check all ULS requirements of the beam (instability is prevented). (3 points)

c.) At A the beam is supported on a 100×100 mm^2 member. Check the compression strength perpendicular to grain at the support A. (2 points)

d.) Name two solutions for the case that the compression perpendicular to grain requirement is not fulfilled. (1 point)

e.) Calculate the effective cross section (using reduced cross-section method) for the beam after $t = 30$ min fire exposure. (1 point)

f.) The beam is loaded out of plane with an additional uniform load $q_{\text{d,z}} = 2$ kN/m. The beam can be assumed to be supported in point A and B. Check all ULS requirements of the beam (instability is prevented). (3 points)

Appendix

Characteristic values – LVL

For LVL			Type Kerto-S	Kerto-T	Kerto-Q
Strength properties MPa	Bending – Edgewise	$f_{\mathrm{m,0,edge,k}}$	44	27	32
	Size effective parameter	s	0.12	0.15	0.12
	Bending – flatwise	$f_{\mathrm{m,0,flat,k}}$	50	32	36
	Tension – parallel	$f_{\mathrm{t,0,k}}$	35	24	26
	Tension – perpendicular, edgewise	$f_{\mathrm{t,90,edge,k}}$	0.8	0.5	6.0
	Compression – parallel	$f_{\mathrm{c,0,k}}$	35	26	26
	Compression – perpendicular, edgewise	$f_{\mathrm{c,90,edge,k}}$	6	1	9
	Compression – perpendicular, flatwise	$f_{\mathrm{c,90,flat,k}}$	1.8	1.0	2.2
	Shear (edgewise)	$f_{\mathrm{v,k}}$	4.1	2.4	4.5
	Shear (flatwise, parallel)	$f_{\mathrm{v,0,flat,k}}$	2.3	1.3	1.3
Stiffness properties [GPa]	Mean modulus of elasticity parallel	$E_{0,\mathrm{mean}}$	13.8	10.0	10.5
	Mean shear modulus	$G_{\mathrm{edge,mean}}$	0.60	0.40	0.60
Density [kg/m^3]	Density	ρ_{k}	480	410	480
	Mean Density	ρ_{mean}	510	440	510

k_{mod} for Solid timber, GLT, LVL, Plywood

Load-duration class	Service class 1	2	3
Permanent	0.60	0.60	0.50
Long-term	0.70	0.70	0.55
Medium-term	0.80	0.80	0.65
Short-term	0.90	0.90	0.70
Instantaneous	1.10	1.10	0.90