CIV-E 4120 Timber Structures

Examination date 23.10.2020

General

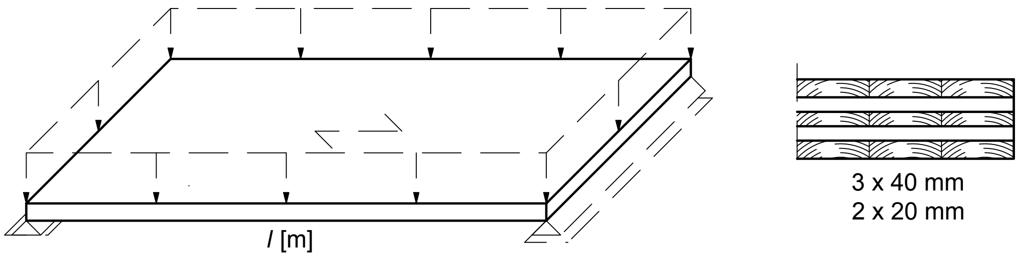
- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the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

Input variables – select according to your student no.

Student No.	Question 1		Question 2		Question 3	
	l [m]	q_d [kN/m^2]	l_1 [m]	h_1 [mm]	$\varnothing_{\mathrm{d}}$ [mm]	b [mm]
801063	7	9	6	500	200	140
681733	7	9	7	500	200	140
478629	7	9	6	400	200	140
473352	7	9	7	400	200	140
919942	7	9	6	500	200	120
804167	7	8	7	500	180	120
525640	7	8	6	400	180	120
79183M	7	8	7	400	180	120
801047	7	8	6	500	180	140
800967	7	8	7	500	180	140
425999	6	8	6	400	200	140
430188	6	8	7	400	200	140
800938	6	8	6	500	200	120
527363	6	8	7	500	200	120
84805K	6	8	6	400	200	120
41328D	6	9	7	400	180	120
801034	6	9	6	500	180	140
527813	6	9	7	500	180	140
800970	6	9	6	400	180	140
432393	6	9	7	400	180	140

Question 1

A CLT slab (use the length l from the Table) is loaded with a uniformly distributed design load q_d (Table).



a.) Choose the more efficient orientation of the slab. (0.5 point)

b.) Calculate the bending stiffness of the CLT slab. Use $E_0 = 11000$ MPa and $E_{90} \approx 0$ MPa. (3.5 points)

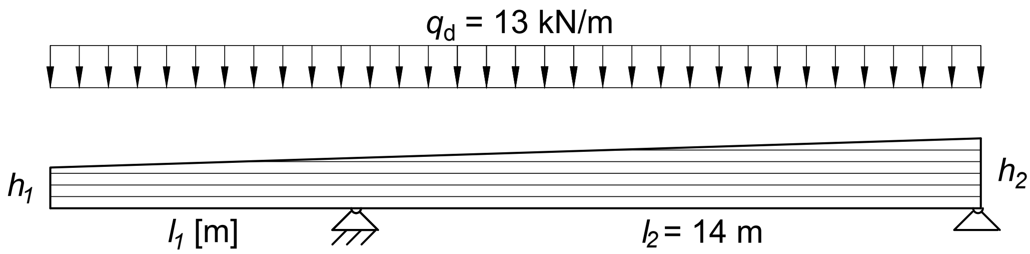
c.) Check the relevant ULS requirements. Use $f_{m,CLT,d} = 16$ MPa, $f_{v,CLT,d} = 1.9$ MPa, $f_{r,CLT,d} = 0.8$ MPa. (5 points)

d.) Illustrate the ULS stresses over the cross-section. Highlight the maximum stresses (bending, shear, rolling shear) in the illustration. (2 points)

e.) Schematically illustrate the stresses over the cross-section in the an fire event. Assume that only the lowest layer has become inactive. Highlight the maximum rolling shear stresses and the maximum shear stresses. (2 points) Note: No calculation required!

Question 2

A glulam beam (strength class GL24h, length: $l = l_1 + l_2$ m (use the length l_1 from the Table), height: h_1 (Table), $h_2 = 1400$ mm, width: $b = 180$ mm) is loaded with a uniformly distributed design load $q_d = 13$ kN/m. Load-duration class Medium-term and Service class 2 apply.



f.) Calculate the reaction forces and illustrate the internal forces [M], [V], [N]. (2 points)

g.) Calculate the bending stresses (in the relevant points). Illustrate the bending stresses over the entire beam (use a scale). (3 points)

h.) Check the bending stresses in the most critical section of the beam. The stress distribution over the cross-section can be assumed linear. (3 points)

i.) Check the all ULS requirements of the beam (instability is prevented). (2 points)

j.) Schematically illustrate a more efficient arrangements of the lamellas. (1 points)

Question 3

Use the statical system from Question 2.
The glulam beam (strength GL24h, constant height: $h = 800$ mm, width: b (Table)) is loaded with a uniformly distributed design load $q_\mathrm{d} = 13$ kN/m. Load-duration class Medium-term and Service class 2 apply. With 1 m distance (center of the hole) to the right support a round hole (use $\varnothing_\mathrm{d}$ from the Table) will be made.

k.) Check the geometrical required (not reinforced). Assume that the support is at the end of the beam. (2 points)

l.) Check the all ULS requirements of the beam and the hole (instability is prevented). (7 points)

Reinforce the hole by using glued in rods ($f_\mathrm{y} = 235$ MPa). If all ULS requirements of Questions l.) are fulfilled assume an higher load.

m.) Illustrate the reinforcements (incl. position, length, orientation) using glued in rods and mark all relevant parameter needed for the design. (2 points)

n.) Select an appropriate diameter for the rods and check the requirements. (4 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

Characteristic strength properties of the bond-line of reinforcements

Strength [MPa]	Effective bound length l_{ad} [mm] ≤ 250	$250 < l_{ad} \leq 500$	$500 < l_{ad} \leq 1000$
$f_{k1,d}$	4.0	$5.25 - 0.005 \cdot l_{ad}$	$3.5 - 0.0015 \cdot l_{ad}$
$f_{k2,d}$		0.75	
$f_{k3,d}$		1.50	