CIV-E 4120 Timber Structures

Examination date 11.12.2020

General

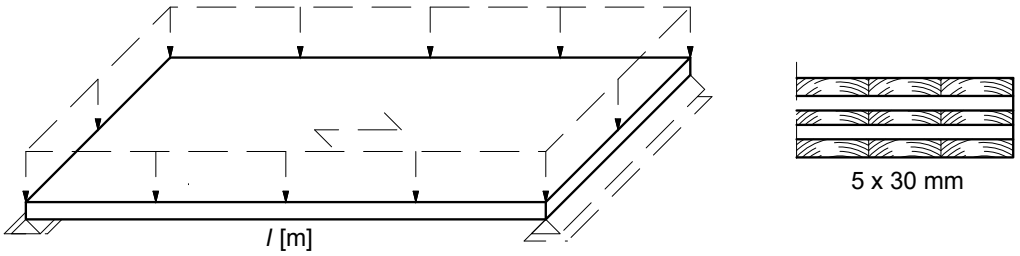
- Write clearly on every paper you hand in: the code and name of the course, the date of the exam, your full name, your student number and your signature.
- Write clear and show intermediate steps.
- If some intermediate results are missing, choose an assumption (make a clear mark!) and continue the 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]	$q_{\mathrm{v,d}}$ [kN/m]	$q_{\mathrm{h,d}}$ [kN/m]	b [mm]	q_{d} [kN/m]
800967	7	8	480	120	200	16
425999	6	9	450	110	180	15
527363	6.5	9	500	100	160	14

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 points)

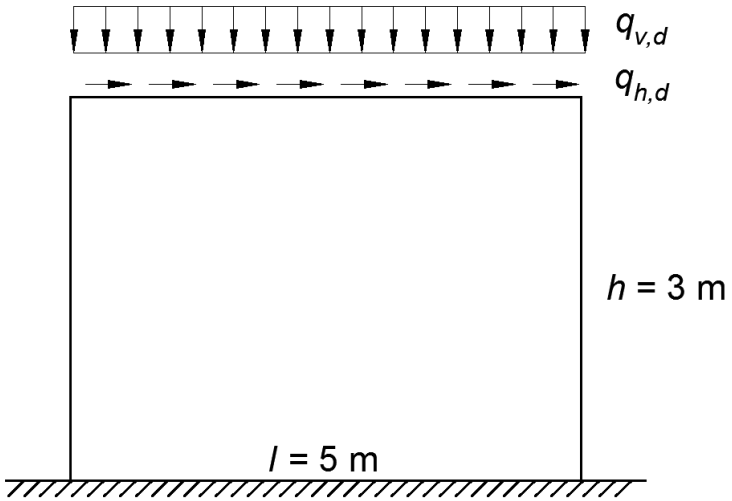
c.) Check the relevant ULS requirements. Use $f_{\mathrm{m,CLT,d}} = 16$ MPa, $f_{\mathrm{v,CLT,d}} = 1.9$ MPa, $f_{\mathrm{r,CLT,d}} = 0.8$ MPa. (5 points)

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

e.) Propose a more efficient layup for the specific load situation (the total slab thickness should not change), illustrate it's ULS stresses and compare them with d.). (2 points)

Question 2

A CLT wall (use the CLT setup from Question 1) is loaded with $q_{\mathrm{v,d}}$ and $q_{\mathrm{h,d}}$ (use the values from the Table). Use the material properties from the table in the appendix, assume that the timber boards are 100 mm wide.

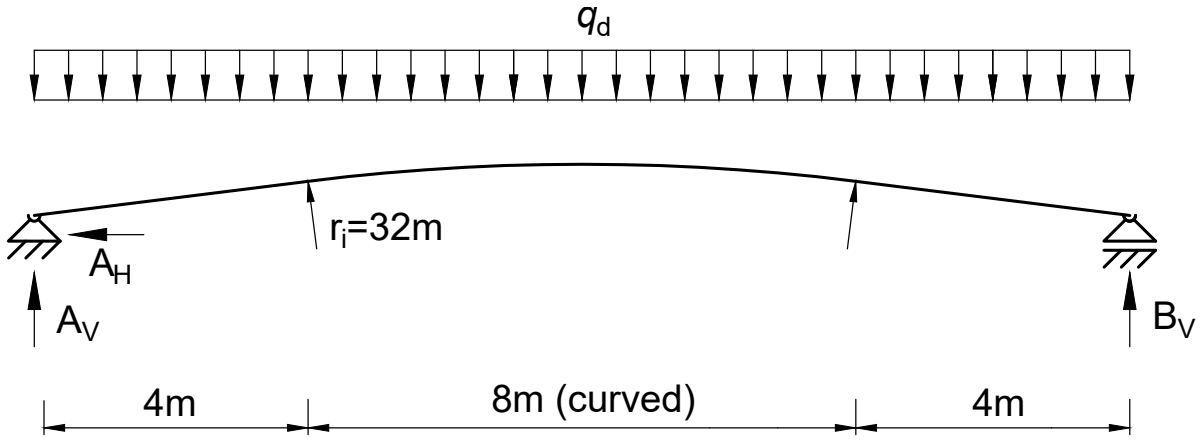


f.) Choose the more efficient orientation of the CLT plate. (0.5 point)

g.) Check the compressive strength and the shear strength. (4 point)

Question 3

A curved glulam beam (strength GL32h, constant height: $h = 1000$ mm, lamella thickness $t = 35$ mm, width: b (Table)) is loaded with a uniformly distributed design load $q_{\mathrm{d}} = 16$ kN/m. Load-duration class Medium-term and Service class 2 apply.



h.) Schematically illustrate the stresses perpendicular to grain. (1 points)

i.) Check the all ULS requirements of the beam (instability is prevented). (8 points)

Assume that the tensile stress perpendicular to grain are too large (assume $\sigma_{\mathrm{t,90,d}} = 0.3$ MPa) and reinforcement for the apex zone is required. Reinforce the beam by using glued in rods: Diameter of the rod $d = 10$ mm (assume the entire area for the calculation), yield strength of the rod $f_{\mathrm{y}} = 235$ MPa,

j.) Design the reinforcement for the apex zone of the beam.(4 points)

k.) Illustrate the reinforcements (incl. position, length, orientation). (1 points)

Appendix

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 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

Material properties for the CLT wall [MPa]

Property	Symbol	value
Compressive strength parallel to grain	$f_{c,0,d}$	19
Shear strength parallel to grain	$f_{v,CLT,d}$	3.5
Torsional shear strength	$f_{T,CLT,d}$	1.8

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	