CIV-E 4120 Timber Structures

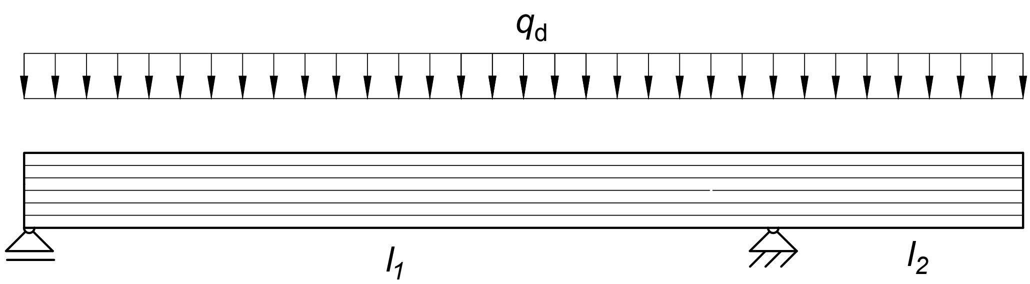
Examination date 29.10.2021

General

- **Each student has specific input values (see mycourses)**
- Answer the question on an empty of squared paper
- ONLY handwritten answers are accepted!
- 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.
- Upload a scan or picture from your answer during the examination time (the submission is closed at 12.00)

Question 1

A glulam beam (strength GL24h, length: $l_1 = 5$ m & l_2 (take the value from Table), height: $h = 500$ mm, width: $b = 100$ mm) is loaded with a uniformly distributed design load q_d (take the value from Table). Load-duration class Medium-term and Service class 2 apply.



a.) Calculate the reaction forces and illustrate the internal forces [M], [V], [N]. (3 points)

b.) Check the bending stresses in the most critical section of the beam.(1 points)

Near the left support a round hole (take the diameter d from Table) will be made.

c.) Select the closest position of the hole near the support and check it's required dimensions (not reinforced). (2 points)

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

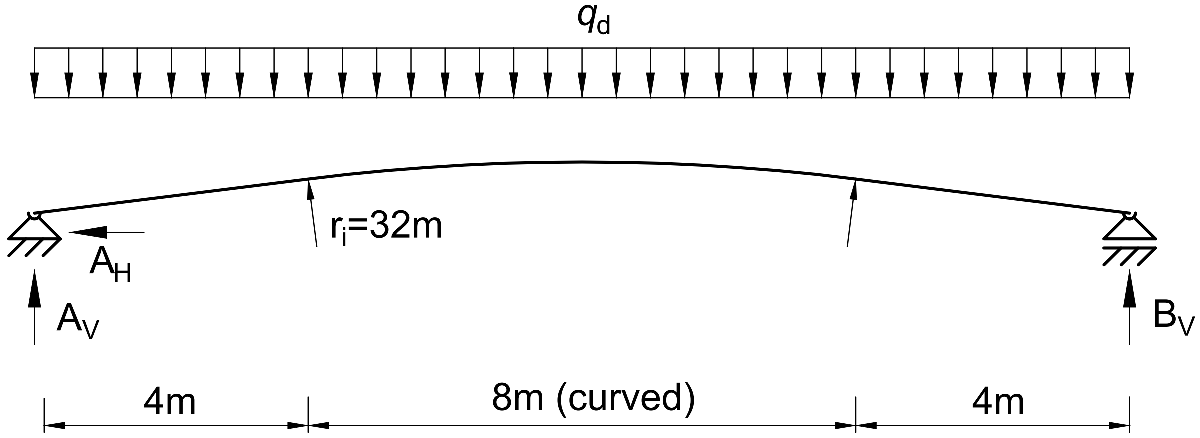
Reinforce the hole by using glued in rods (f_y = 235 MPa). If all ULS requirements of Questions d) are fulfilled assume an higher load.

e.) Schematically illustrate the reinforcements (incl. position, lenght, orientation) using glued in rods and mark all relevant parameter needed for the design (2 points)

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

Question 2

A curved glulam beam (strength GL32h, constant height: h = 800 mm, lamella thickness t = 30 mm, width: b (take the value from the table)) is loaded with a uniformly distributed design load q_d (take the value from the table). Load-duration class Medium-term and Service class 2 apply.



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

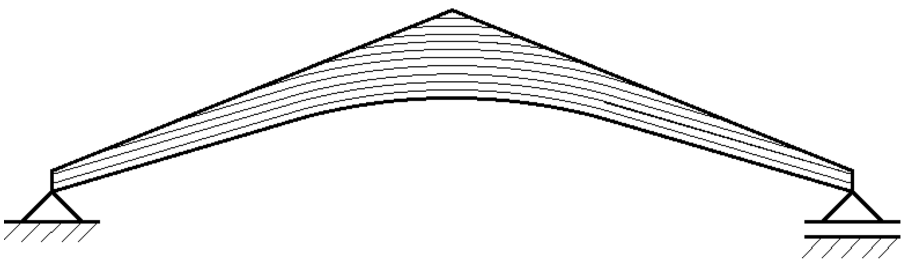
h.) Check all ULS requirements of the beam (instability is prevented). (8 points)

Question 3

i.) Name two advantages and two disadvantages of prefabricated modular systems compared to prefabricated panel systems. (1 point)

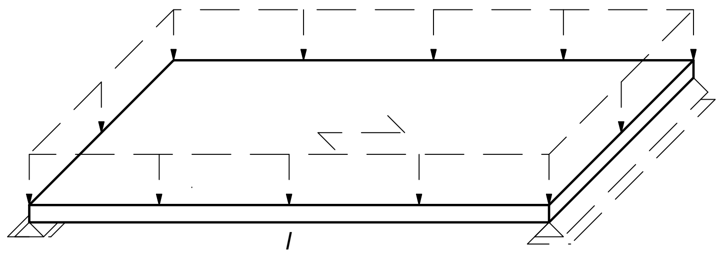
j.) Schematically illustrate the stresses perpendicular to grain in the piched cambered beam illustrated below. (2 points)

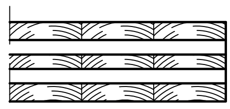
k.) Schematically illustrate the reinforcements of the stresses perpendicular to grain using glued in rods in the pitched cambered beam illustrated below. (1 points)



Question 4

A CLT slab ($l = 5$ m) is loaded with a uniformly distributed design load q_d (take the value from table). All 5 layer of the CLT plate have the same thickness t (take the value from table).





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

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

n.) 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)

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

p.) 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!

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	