

1. Options for Calculations

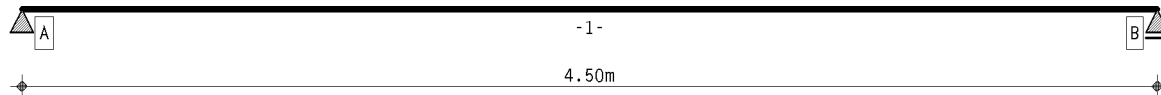
calculation DIN EN 1995:2010, Germany

service class 1

coefficient of thermal expansion for timber $\alpha_t = 0.500 \cdot 10^{-5}/^{\circ}\text{K}$

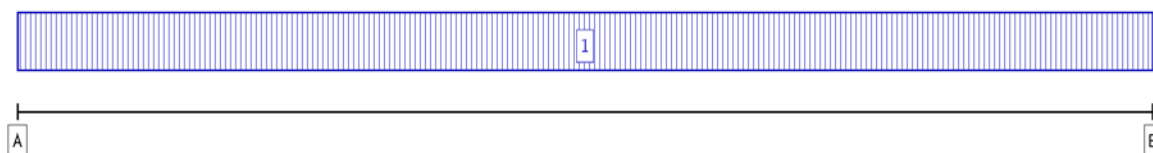
$\psi_2 = 0.60$ (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

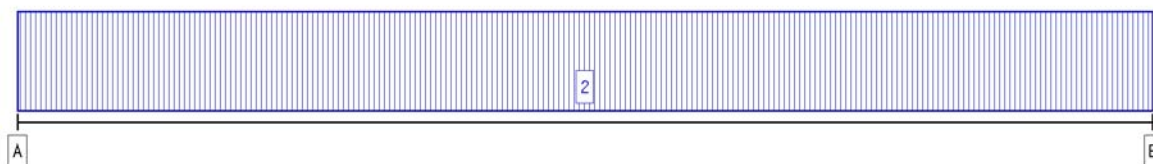


main beam

3. Loading



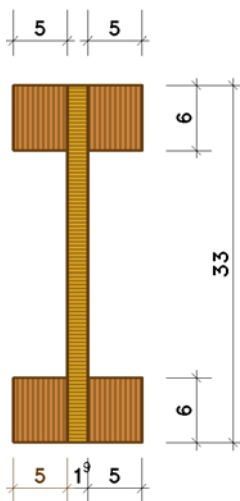
action effect 1: permanent loads (permanent, 1 load cases)



action effect 2: live loads (1) (transient, 1 load cases)

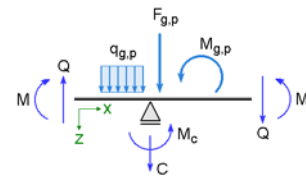
4. main beam

section scale 1: 7



timber grade top flange	solid coniferous timber, C24 (S10)
char. bend. strength $f_{m,k}$	: 24.0 N/mm ²
char. shear strength $f_{v,k}$	: 4.0 N/mm ²
char. ten. strength $f_{t,k}$	: 14.5 N/mm ²
char. compr. strength $f_{c,0,k}$	: 21.0 N/mm ²
char. compr. strength $f_{c,90,k}$	: 2.5 N/mm ²
modulus of elasticity $E_{0,mean}$	: 11000 N/mm ²
Dichte ρ_k/ρ_m	: 350 / 420 kg/m ³
deformation factor k_{def}	: 0.60 -
area A_{flange}	: 60.000 cm ²
moment of inertia I_{flange}	: 180.000 cm ⁴
timber grade web	particleboard type P6
d = 19.0 mm (hochkant)	
char. bend. strength $f_{m,k}$	: 9.5 N/mm ²
char. shear strength $f_{v,k}$	: 7.3 N/mm ²
char. ten. strength $f_{t,k}$	: 9.5 N/mm ²
char. compr. strength $f_{c,0,k}$	: 13.3 N/mm ²
char. compr. strength $f_{c,90,k}$	: 13.3 N/mm ²
k_{cr}	: 1.00 mm ² /N
e-modulus $E_{0,mean}$ (diaphragm)	: 2400 N/mm ²
e-modulus $E_{0,mean}$ (plate)	: 4100 N/mm ²
Dichte ρ_k/ρ_m	: 500 / 600 kg/m ³
deformation factor k_{def}	: 1.50 -
area A_{flange}	: 62.700 cm ²
moment of inertia I_{flange}	: 5690.025 cm ⁴
timber grade bottom flange	solid coniferous timber, C24 (S10)
char. bend. strength $f_{m,k}$	: 24.0 N/mm ²
char. shear strength $f_{v,k}$	: 4.0 N/mm ²
char. ten. strength $f_{t,k}$	: 14.5 N/mm ²
char. compr. strength $f_{c,0,k}$	: 21.0 N/mm ²
char. compr. strength $f_{c,90,k}$	: 2.5 N/mm ²
modulus of elasticity $E_{0,mean}$	: 11000 N/mm ²

Dichte ρ_k/ρ_m : 350 / 420 kg/m³
 deformation factor k_{def} : 0.60 -
 area A_{flange} : 60.000 cm²
 moment of inertia I_{flange} : 180.000 cm⁴
 definition of internal forces and moments:



5. Beam sections

beam sections

section	x_A m	x_E m	l m	l_v m	cantil.	s_{ef} mm
1	0.00	4.50	4.50	4.50	-	n.e.

stiffness values serviceability initial state

section	γ_2 -	a_2 mm	K_1 N/mm	γ_{1r} -	a_1 mm	K_3 N/mm	γ_{3r} -	a_3 mm	$E I_{ef,inst}$ Nmm ²	ϕ k_{def} -
1	1.0000	-0.0	1	1.0000	-135.0	1	1.0000	135.0	2.5819E12	0.3808

stiffness values load-carrying capacity initial state

section	γ_2 -	a_2 mm	K_1 N/mm	γ_1 -	a_1 mm	K_3 N/mm	γ_3 -	a_3 mm	$E I_{ef,inst}$ Nmm ²	$I_{ef,inst}$ mm ²	$h_{q,inst}$ mm	$A_{q,inst}$ mm
1	1.0000	-0.0	1	1.0000	-135.0	1	1.0000	135.0	2.5819E12	234714592.0	16.50	41.80

stiffness values load-carrying capacity final state

section	γ_2 -	a_2 mm	K_1 N/mm	γ_1 -	a_1 mm	K_3 N/mm	γ_3 -	a_3 mm	$E I_{ef,inf}$ Nmm ²	$I_{ef,inf}$ mm ²	$h_{q,inf}$ mm	$A_{q,inf}$ mm
1	1.0000	0.0	1	1.0000	-135.0	1	1.0000	135.0	1.8699E12	231186240.0	16.50	41.80

net section properties

section	$A_{n,2}$ cm ²	$W_{n,2}$ cm ³	$I_{n,2}$ cm ⁴	$A_{n,1}$ cm ²	$W_{n,1}$ cm ³	$I_{n,1}$ cm ⁴	$A_{n,3}$ cm ²	$W_{n,3}$ cm ³	$I_{n,3}$ cm ⁴
1	62.70	344.85	5690.02	60.00	60.00	180.00	60.00	60.00	180.00

6. Fasteners

section 1 from $x_A = 0.00$ m to $x_E = 4.50$, glued joint

7. Supports

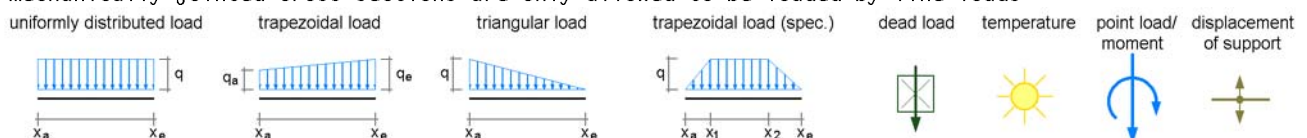
coordinates of supports

supp.name	x m	width mm	depth mm	c_F kN/m	c_M kNm/-	restraint (F) (M)
A	0.00	150	19	fix	----	X -
B	4.50	150	19	fix	----	X -

8. Action effects

Attention! Acc. to DIN EN 1995-1-1, annex B.1

mechanically jointed cross-sections are only allowed to be loaded by line loads



Permanent action effect: permanent loads

1. additive load case: dead load (1)

⇒ unif.distr.load: $q = 1.50$ kN/m from $x_a = 0.00$ m to $x_e = 4.50$ m

2. Transient action effect: live loads (1)

2. additive load case: live loads (1/1)

⇒ unif.distr.load: $q = 2.00$ kN/m from $x_a = 0.00$ m to $x_e = 4.50$ m

9. verifications

1: EC 5 load-carrying capacity

verification of buckling resistance acc. to DIN EN 1995, 9.1.1(7) will be executed

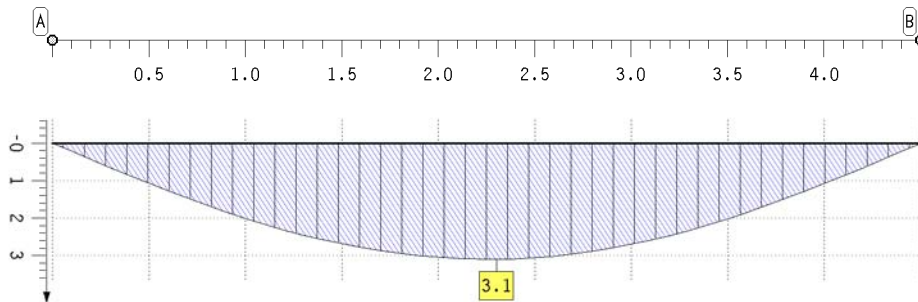
verification of bearing stress DIN EN 1995, 6.1.5 will be executed

Extreme rule 1

10. Results of action effects

10.1. Action effect 1: permanent loads

extremal deflections of main beam (characteristic)

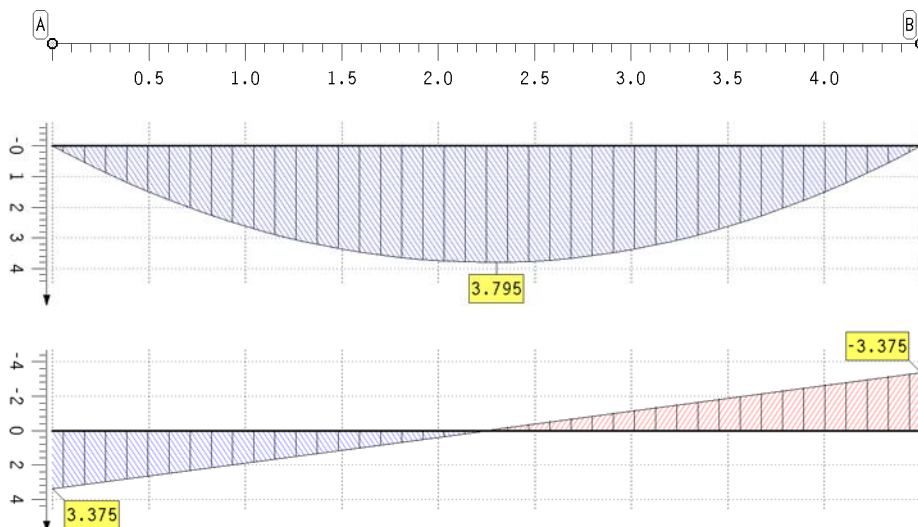


deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 3.10

extremal deflections of main beam (characteristic)

point	x	min w	max w	point	x	min w	max w
-	m	mm	mm	-	m	mm	mm
A	0.000	0.00	0.00	B	4.500	0.00	0.00
	1.200	2.32	2.32	minimum		0.00	0.00
	2.200	3.10	3.10	maximum		3.10	3.10
	3.200	2.46	2.46				

extremal internal forces



flexural moment
main beam
M in kNm
Min: 0.00
Max: 3.80

shear force
main beam
V in kN
Min: -3.38
Max: 3.38

extremal internal forces

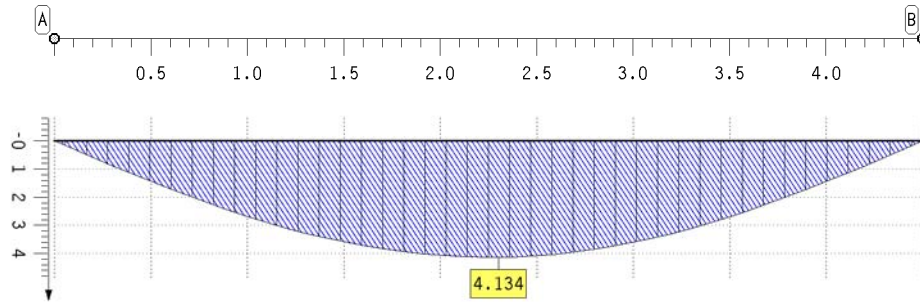
point	x	min M	max M	min V	max V	point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN	-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	3.38	3.38	B	4.500	0.00	0.00	-3.38	-3.38
	1.100	2.81	2.81	1.73	1.73	minimum		0.00	0.00	-3.38	-3.38
	2.200	3.80	3.80	0.08	0.08	maximum		3.80	3.80	3.38	3.38
	3.400	2.81	2.81	-1.73	-1.73						

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-3.38	-3.38
B	4.500	-3.38	-3.38

10.2. Action effect 2: live loads (1)

extremal deflections of main beam (characteristic)

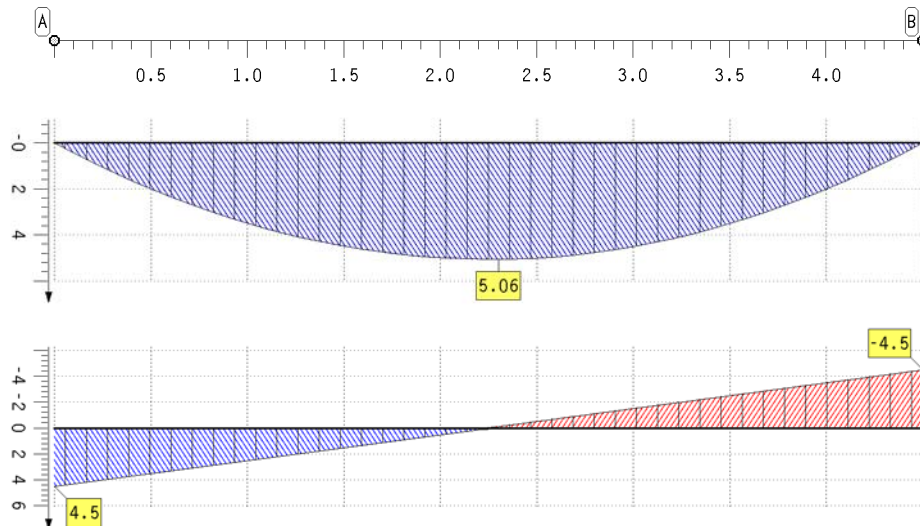


deflection
main beam
characteristic
w in mm
Min: -0.00
Max: 4.13

extremal deflections of main beam (characteristic)

point	x	min w	max w	point	x	min w	max w
-	m	mm	mm	-	m	mm	mm
A	0.000	0.00	0.00	B	4.500	-0.00	-0.00
	1.200	0.00	3.09	minimum		-0.00	0.00
	2.200	0.00	4.13	maximum		0.00	4.13
	3.200	0.00	3.28				

extremal internal forces



flexural moment
main beam
M in kNm
Min: 0.00
Max: 5.06

shear force
main beam
V in kN
Min: -4.50
Max: 4.50

extremal internal forces

point	x	min M	max M	min V	max V	point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN	-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	0.00	4.50	B	4.500	0.00	0.00	-4.50	-0.00
	1.100	0.00	3.74	0.00	2.30	minimum		0.00	0.00	-4.50	-0.00
	2.200	0.00	5.06	0.00	0.10	maximum		0.00	5.06	0.00	4.50
	3.400	0.00	3.74	-2.30	-0.00						

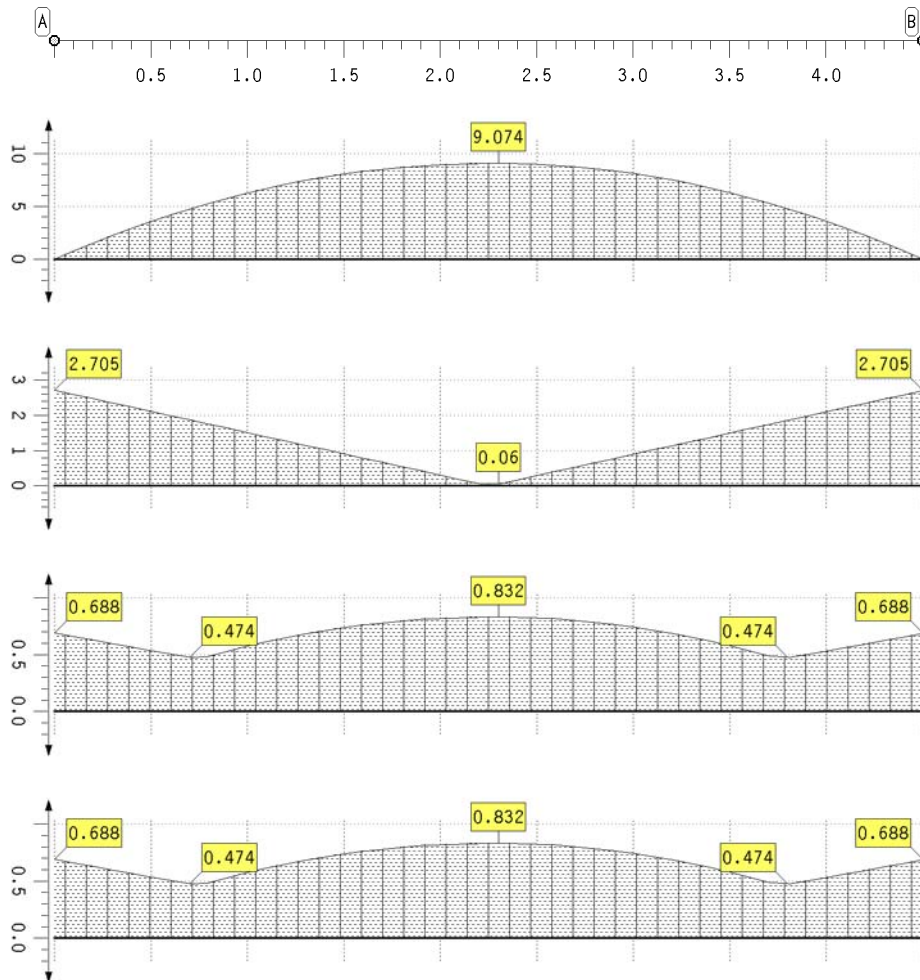
extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-4.50	-0.00
B	4.500	-4.50	-0.00

11. Results of verification of ultimate limit state

11.1. Verification of ultimate limit state

results of verification of ultimate limit state



bending stress
main beam
 σ_h in MN/m^2
Max: 9.07

shear stress
main beam
 τ_h in MN/m^2
Max: 2.70

utilization
main beam
Max: 0.83

maximal
utilization
Max: 0.83

maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.688		2.200	0.832	B	4.500	0.688
	0.700	0.474		2.900	0.763	minimum		0.474
	1.500	0.740		3.800	0.474	maximum		0.832

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-11.31	-3.38
B	4.500	-11.31	-3.38

verification of bearing stress

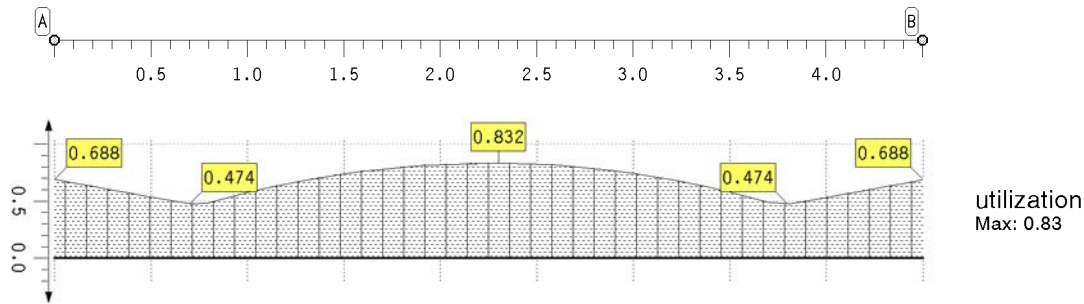
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm^2	N	-	-	N/mm^2	N/mm^2	-
A	180	3420	11306	1.00	0.70	7.16	3.31	0.46
B	180	3420	11306	1.00	0.70	7.16	3.31	0.46

verification of bearing stresses für den main beam(u = 0.462) successful!

12. Summary

12.1. Summary of all verifications

maximal utilization



maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.688	2.200	0.832	B	4.500	0.688	
	0.700	0.474	2.900	0.763	minimum		0.474	
	1.500	0.740	3.800	0.474	maximum		0.832	

verification of bearing stress

support	l_{ef}	A_{ef}	A_p	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm ²	N	-	-	N/mm ²	N/mm ²	-
A	180	3420	11306	1.00	0.70	7.16	3.31	0.46
B	180	3420	11306	1.00	0.70	7.16	3.31	0.46

verification of bearing stresses für den main beam(u = 0.462) successful!

13. Utilizations of all verifications

all verifications successful!

14. Detailed verification piont

14.1. Verification of load-carrying capacity at x = 0.00 m

internal forces and moments

state	M	V	M ₁	N ₁	M ₂	N ₂	M ₃	N ₃
	kNm	kN	Nmm	N	Nmm	N	Nmm	N
start,min	0.00	3.38	0	-0	0	0	0	0
start,max	0.00	11.31	0	-0	0	0	0	0
end,min	0.00	3.38	0	-0	0	0	0	0
end,max	0.00	11.31	0	-0	0	0	0	0

stresses and utilization web

state	$k_{mod,2}$	$\sigma_{m,2}$	$\sigma_{c,2}$	$u_{\sigma,2}$	τ_2	u_{τ}	u_2
	-	N/mm ²	N/mm ²	-	N/mm ²	-	-
start	0.7	0.00	0.00	0.00	2.70	0.69	0.69
end	0.7	0.00	0.00	0.00	2.70	0.69	0.69

stresses and utilization flanges

state	$k_{mod,1}$	$\sigma_{m,1}$	$\sigma_{c,1}$	u_1	$k_{mod,3}$	$\sigma_{m,3}$	$\sigma_{c,3}$	u_3
	-	N/mm ²	N/mm ²	-	-	N/mm ²	N/mm ²	-
start	0.8	0.00	-0.00	0.00	0.8	0.00	0.00	0.00
end	0.8	0.00	-0.00	0.00	0.8	0.00	0.00	0.00

adhering joint with $f_{v1,d} = 0.915$ N/mm²

state	$S_{1,d}$	$\tau_{1,d}$	$u_{1,d}$	$S_{2,d}$	$\tau_{2,d}$	$u_{2,d}$
	cm ²	N/mm ²	-	cm ²	N/mm ²	-
start	810	0.3301	0.36	810	0.3301	0.36
end	810	0.3301	0.36	810	0.3301	0.36

14.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with $b_w/h_w = 19/210$ mm

Eq. (9.8) $h_w = 21 \leq 70$ $b_w = 133$

Eq. (9.9) $V_d = 11.31 \text{ kN} \leq 201.65 \text{ kN}$

resulting utilization at verification point $u_{res} = 0.688$