

1. Options for Calculations

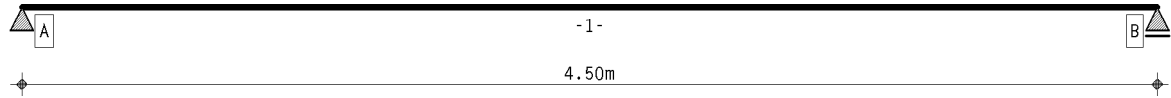
calculation DIN EN 1995:2010, Germany

service class 2

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

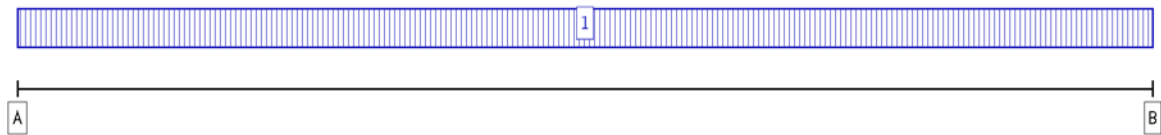
$\psi_2 = 0.60$ (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

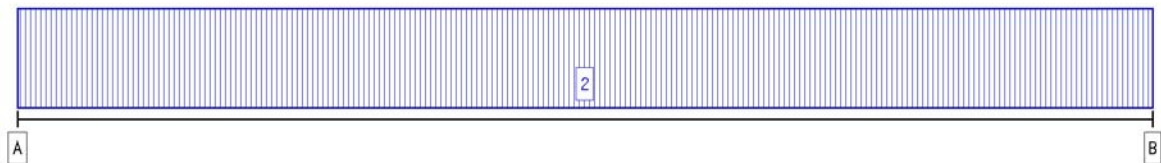


main beam

3. Loading



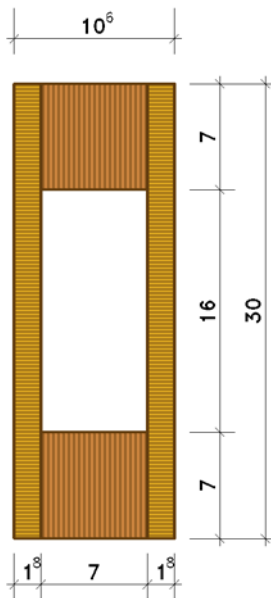
action effect 1: permanent loads (permanent, 1 load cases)



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

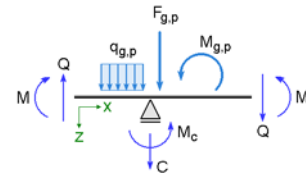
4. main beam

section scale 1: 5



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}	: 49.000 cm ²
moment of inertia I_{flange}	: 200.083 cm ⁴
timber grade web (fibre II)	plywood F40/30
d = 18.0 mm (hochkant)	
char. bend. strength $f_{m,k}$	: 29.0 N/mm ²
char. shear strength $f_{v,k}$	: 9.5 N/mm ²
char. ten. strength $f_{t,k}$	: 29.0 N/mm ²
char. compr. strength $f_{c,0,k}$	: 21.0 N/mm ²
char. compr. strength $f_{c,90,k}$	: 9.0 N/mm ²
k_{cr}	: 1.00 mm ² /N
e-modulus $E_{0,mean}$ (diaphragm)	: 4400 N/mm ²
e-modulus $E_{0,mean}$ (plate)	: 6000 N/mm ²
Dichte ρ_k/ρ_m	: 600 / 720 kg/m ³
deformation factor k_{def}	: 0.80 -
area A_{flange}	: 108.000 cm ²
moment of inertia I_{flange}	: 8100.000 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/m ³
deformation factor k_{def}	: 0.60 -
area A_{flange}	: 49.000 cm ²
moment of inertia I_{flange}	: 200.083 cm ⁴

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	-	30.0

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	$EI_{ef,inst}$ Nmm ²	ϕ k_{def} -
1	1.0000	0.0	808	0.5061	-115.0	808	0.5061	115.0	1.1220E12	0.5640

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	$EI_{ef,inst}$ Nmm ²	$I_{ef,inst}$ mm ²	$h_{q,inst}$ mm	$A_{q,inst}$ mm
1	1.0000	-0.0	538	0.4059	-115.0	538	0.4059	115.0	9.7911E11	89009616.00	15.00	82.01

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	$EI_{ef,inf}$ Nmm ²	$I_{ef,inf}$ mm ²	$h_{q,inf}$ mm	$A_{q,inf}$ mm
1	1.0000	0.0	294	0.3366	-115.0	294	0.3366	115.0	6.2603E11	77399552.00	15.00	82.31

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	108.00	540.00	8100.00	49.00	57.17	200.08	49.00	57.17	200.08

6. Fasteners

section 1 from $x_A = 0.00$ m to $x_E = 4.50$

nail, 2.2 x 45.0 mm, $d_k = 5.5$ mm, not predrilled

2-row with $a_1 = 30.0$ mm

2 - row with $a_2 = 15.4$ mm, simplified verification acc. to NA.8.2.4

nail ends in timber member 2, penetration depth $t = 27$ mm $> 4 d = 9$ mm, 1 shear plane

$f_{uk} = 600$ N/mm², $M_{yk} = 1398$ Nmm

$K_{ser} = 808$ N/mm, $\gamma_M = 1.10$, $R_k = 452.9$ N, all values per shear plane

7. Supports

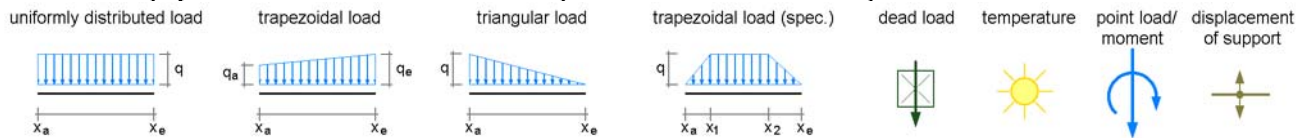
coordinates of supports

supp.name	x m	width mm	depth mm	cf kN/m	cm kNm/-	restraint (F) (M)	
A	0.00	150	36	fix	----	X	-
B	4.50	150	36	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: $q = 1.00$ 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

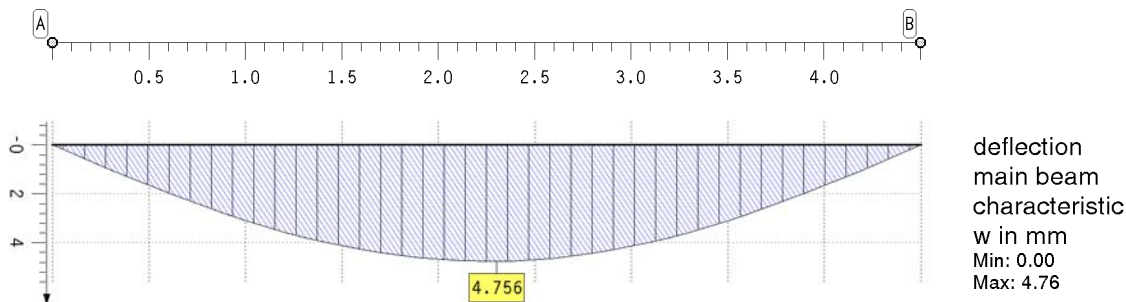
verification of bearing stress DIN EN 1995, 6.1.5 will be executed

Extreme rule 1

10. Results of action effects

10.1. Action effect 1: permanent loads

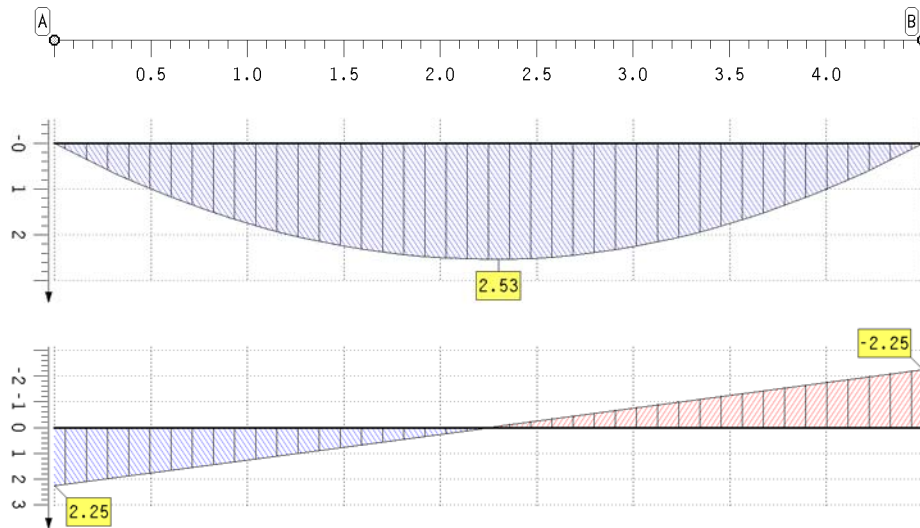
extremal deflections of main beam (characteristic)



extremal deflections of main beam (characteristic)

point	x m	min w mm	max w mm	point	x m	min w mm	max w mm
A	0.000	0.00	0.00	B	4.500	0.00	0.00
	1.200	3.56	3.56	minimum		0.00	0.00
	2.200	4.76	4.76	maximum		4.76	4.76
	3.200	3.77	3.77				

extremal internal forces



extremal internal forces

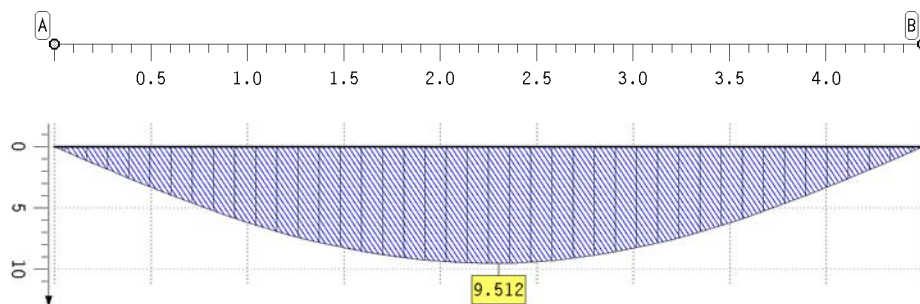
point	x	min M	max M	min V	max V	point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN	-	m	kNm	kNm	kN	kN
A	0.000	-0.00	-0.00	2.25	2.25	B	4.500	0.00	0.00	-2.25	-2.25
	1.100	1.87	1.87	1.15	1.15	minimum		-0.00	-0.00	-2.25	-2.25
	2.200	2.53	2.53	0.05	0.05	maximum		2.53	2.53	2.25	2.25
	3.400	1.87	1.87	-1.15	-1.15						

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-2.25	-2.25
B	4.500	-2.25	-2.25

10.2. Action effect 2: live loads (1)

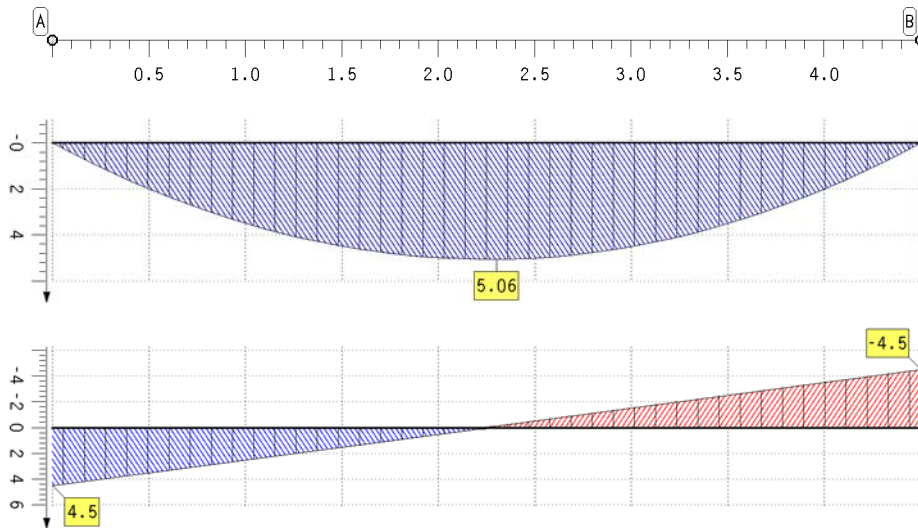
extremal deflections of main beam (characteristic)



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	7.12	minimum		0.00	0.00
	2.200	0.00	9.51	maximum		0.00	9.51
	3.200	0.00	7.54				

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						

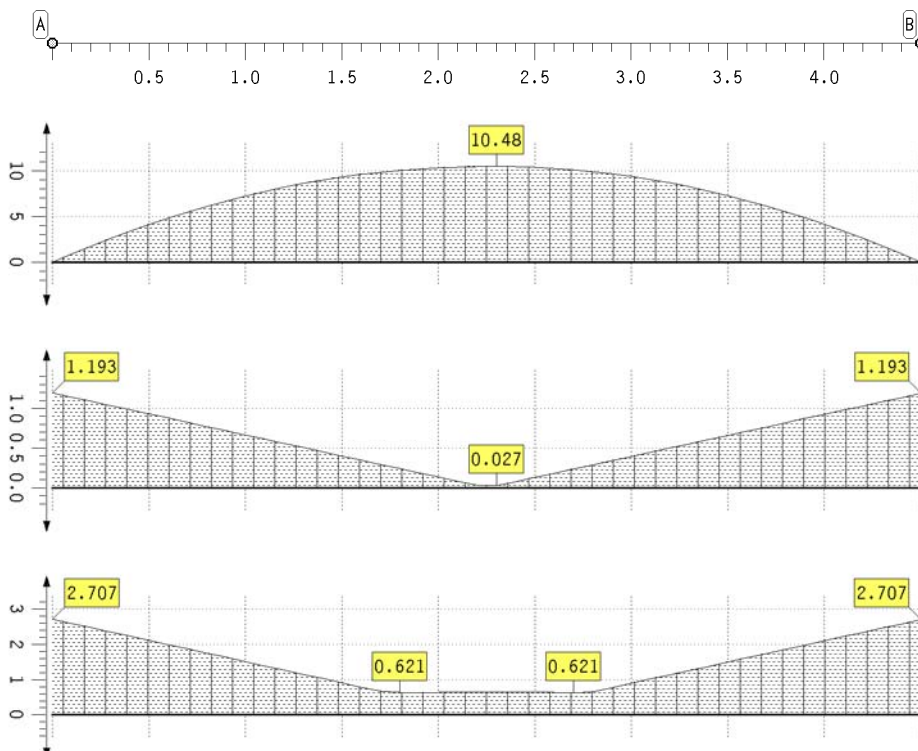
extremal support forces

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

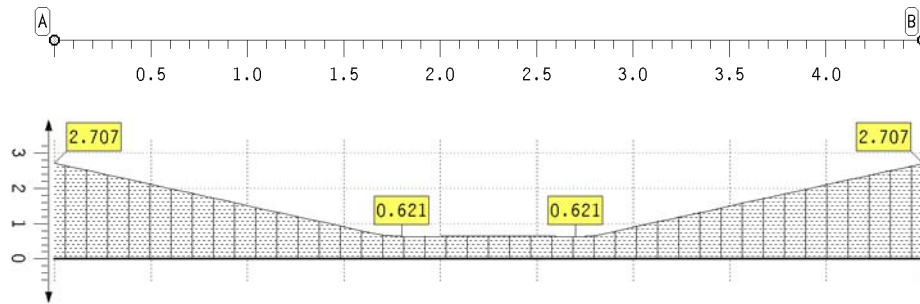


bending stress
main beam
 σ_h in MN/m²
Max: 10.48

shear stress
main beam
 τ_h in MN/m²
Max: 1.19

utilization
main beam
Max: 2.71

results of verification of ultimate limit state



maximal
utilization
Max: 2.71

maximal utilization

point	x	U	point	x	U
-	m	-	-	m	-
A	0.000	2.707	B	4.500	2.707
	1.800	0.621	minimum		0.621
	2.800	0.662	maximum		2.707

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-9.79	-2.25
B	4.500	-9.79	-2.25

verification of bearing stress

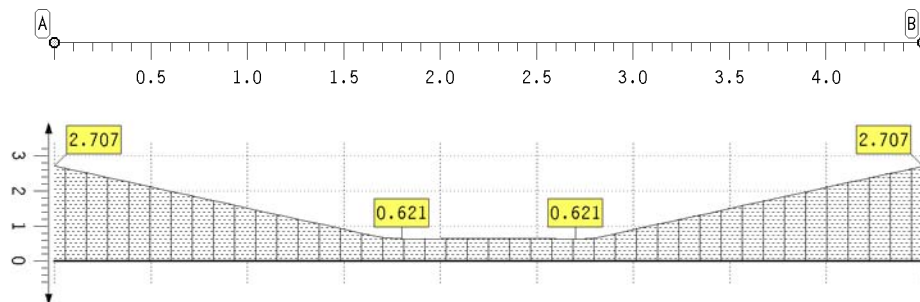
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm ²	N		-	N/mm ²	N/mm ²	-
A	180	6480	9788	1.00	0.80	5.54	1.51	0.27
B	180	6480	9788	1.00	0.80	5.54	1.51	0.27

verification of bearing stresses für den main beam(u = 0.273) successful!

12. Summary

12.1. Summary of all verifications

maximal utilization



utilization
Max: 2.71

maximal utilization

point	x	U	point	x	U
-	m	-	-	m	-
A	0.000	2.707	B	4.500	2.707
	1.800	0.621	minimum		0.621
	2.800	0.662	maximum		2.707

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	6480	9788	1.00	0.80	5.54	1.51	0.27
B	180	6480	9788	1.00	0.80	5.54	1.51	0.27

verification of bearing stresses für den main beam(u = 0.273) successful!

13. Utilizations of all verifications

verification of load-carrying capacity ($u = 2.707$) does not meet the requirements!

14. Detailed verification point

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

internal forces and moments

state	M kNm	V kN	M ₁ Nmm	N ₁ N	M ₂ Nmm	N ₂ N	M ₃ Nmm	N ₃ N
start,min	-0.00	2.25	-0	0	-0	-0	-0	-0
start,max	-0.00	9.79	-0	0	-0	-0	-0	-0
end,min	-0.00	2.25	-0	0	-0	-0	-0	-0
end,max	-0.00	9.79	-0	0	-0	-0	-0	-0

stresses and utilization web

state	k _{mod,2} -	σ _{m,2} N/mm ²	σ _{c,2} N/mm ²	u _{σ,2} -	τ ₂ N/mm ²	u _τ -	u ₂ -
start	0.8	0.00	0.00	0.00	1.19	0.20	0.20
end	0.8	0.00	0.00	0.00	1.19	0.20	0.20

stresses and utilization flanges

state	k _{mod,1} -	σ _{m,1} N/mm ²	σ _{c,1} N/mm ²	u ₁ -	k _{mod,3} -	σ _{m,3} N/mm ²	σ _{c,3} N/mm ²	u ₃ -
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

fastener

state	F _{1,d} N	u _{1,d} -	F _{2,d} N	u _{2,d} -
start	-755	2.71	755	2.71
end	-720	2.58	720	2.58

14.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with $b_w/h_w = 18/160$ mm

Eq. (9.8) $h_w = 16 \leq 70$ $b_w = 126$

Eq. (9.9) $V_d = 9.79$ kN ≤ 484.06 kN

resulting utilization at verification point $u_{res} = 2.707$