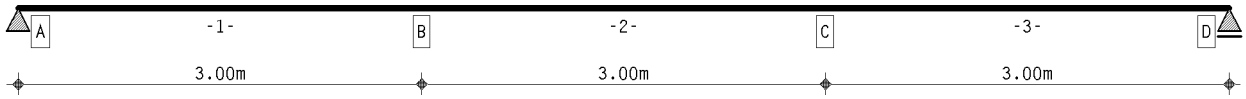
1. Options for Calculations

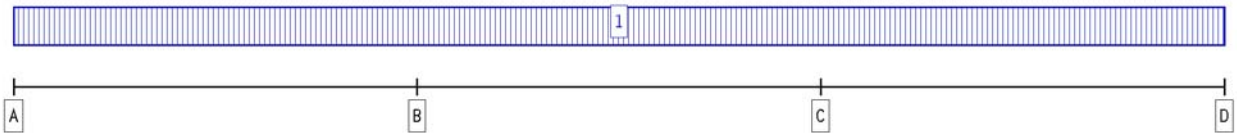
calculation DIN EN 1995:2010, Germany
service class 1
coefficient of thermal expansion for timber α_t = 0.500 *10^{-5}/°K
ψ_2 = 0.60 (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

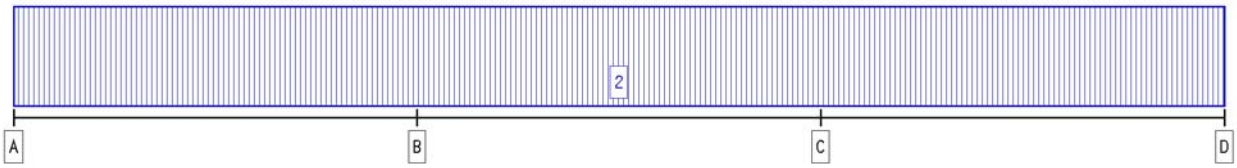


main beam

3. Loading



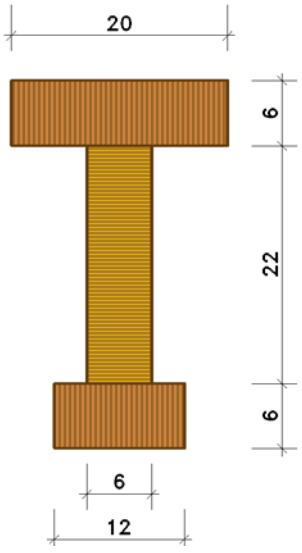
action effect 1: permanent loads (permanent, 1 load cases)



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

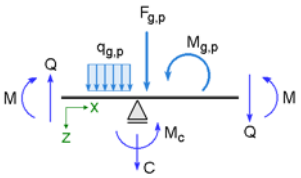
4. main beam

section scale 1: 7



timber grade top flange			**solid coniferous timber, C30 (S13)**
char. bend. strength	$f_{m,k}$	:	30.0 N/mm²
char. shear strength	$f_{v,k}$	:	4.0 N/mm²
char. ten. strength	$f_{t,k}$	:	19.0 N/mm²
char. compr. strength	$f_{c,0,k}$	:	24.0 N/mm²
char. compr. strength	$f_{c,90,k}$	:	2.7 N/mm²
modulus of elasticity	$E_{0,mean}$	:	12000 N/mm²
Dichte ρ_k / ρ_m		:	380 / 456 kg/m³
deformation factor	k_{def}	:	0.60 -
area	A_{flange}	:	120.000 cm²
moment of inertia	I_{flange}	:	360.000 cm⁴
timber grade web			**solid coniferous timber, C30 (S13)**
char. bend. strength	$f_{m,k}$	:	30.0 N/mm²
char. shear strength	$f_{v,k}$	:	4.0 N/mm²
char. ten. strength	$f_{t,k}$	:	19.0 N/mm²
char. compr. strength	$f_{c,0,k}$	:	24.0 N/mm²
char. compr. strength	$f_{c,90,k}$	:	2.7 N/mm²
	k_{cr}	:	0.50 mm²/N
modulus of elasticity	$E_{0,mean}$	:	12000 N/mm²
Dichte ρ_k / ρ_m		:	380 / 456 kg/m³
deformation factor	k_{def}	:	0.60 -
area	A_{flange}	:	132.000 cm²
moment of inertia	I_{flange}	:	5324.000 cm⁴
timber grade bottom flange			**solid coniferous timber, C30 (S13)**
char. bend. strength	$f_{m,k}$	:	30.0 N/mm²
char. shear strength	$f_{v,k}$	:	4.0 N/mm²
char. ten. strength	$f_{t,k}$	:	19.0 N/mm²
char. compr. strength	$f_{c,0,k}$	:	24.0 N/mm²
char. compr. strength	$f_{c,90,k}$	:	2.7 N/mm²
modulus of elasticity	$E_{0,mean}$	:	12000 N/mm²
Dichte ρ_k / ρ_m		:	380 / 456 kg/m³
deformation factor	k_{def}	:	0.60 -
area	A_{flange}	:	72.000 cm²
moment of inertia	I_{flange}	:	216.000 cm⁴

definition of internal forces and moments:



5. Beam sections

beam sections

section	x_A m	x_E m	l m	l_{ef} m	i_z mm	k -	λ -	$\lambda_{rel,c}$ -	k_c -	l_v m	cantil.	s_{ef} mm
1	0.00	3.00	3.00	4.50	57.8000	1.5270	77.8547	1.3574	0.4492	9.00	-	45.0
2	3.00	6.00	3.00	4.50	57.8000	1.5270	77.8547	1.3574	0.4492	9.00	-	74.0
3	6.00	9.00	3.00	4.50	57.8000	1.5270	77.8547	1.3574	0.4492	9.00	-	45.0

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	$EI_{ef,inst}$ Nmm2	ø k_{def} -
1	1.0000	-10.4	1023	0.5644	-129.6	1023	0.6835	150.4	3.4261E12	0.4861
2	1.0000	-7.4	1023	0.4407	-132.6	1023	0.5677	147.4	2.8982E12	0.5059
3	1.0000	-10.4	1023	0.5644	-129.6	1023	0.6835	150.4	3.4261E12	0.4861

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	$EI_{ef,inst}$ Nmm2	$I_{ef,inst}$ mm2	$h_{q,inst}$ mm	$A_{q,inst}$ mm
1	1.0000	-8.0	682	0.4635	-132.0	682	0.5901	148.0	2.9978E12	249820784.0	11.80	143.24
2	1.0000	-5.2	682	0.3444	-134.8	682	0.4668	145.2	2.4638E12	205316464.0	11.52	138.98
3	1.0000	-8.0	682	0.4635	-132.0	682	0.5901	148.0	2.9978E12	249820784.0	11.80	143.24

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	$EI_{ef,inf}$ Nmm2	$I_{ef,inf}$ mm2	$h_{q,inf}$ mm	$A_{q,inf}$ mm
1	1.0000	-6.6	397	0.4058	-133.4	397	0.5324	146.6	2.0172E12	228619040.0	11.66	141.40
2	1.0000	-4.1	397	0.2935	-135.9	397	0.4091	144.1	1.6361E12	185423248.0	11.41	136.51
3	1.0000	-6.6	397	0.4058	-133.4	397	0.5324	146.6	2.0172E12	228619040.0	11.66	141.40

net section properties

section	$A_{n,2}$ cm2	$W_{n,2}$ cm3	$I_{n,2}$ cm4	$A_{n,1}$ cm2	$W_{n,1}$ cm3	$I_{n,1}$ cm4	$A_{n,3}$ cm2	$W_{n,3}$ cm3	$I_{n,3}$ cm4
1	132.00	484.00	5324.00	120.00	120.00	360.00	72.00	72.00	216.00
2	132.00	484.00	5324.00	120.00	120.00	360.00	72.00	72.00	216.00
3	132.00	484.00	5324.00	120.00	120.00	360.00	72.00	72.00	216.00

6. Fasteners

section 1 from x_A = 0.00 m to x_E = 3.00
nail, 4.2 x 100.0 mm, d_k = 20.0 mm, not predrilled
1-row with a_1 = **45.0 mm**
1 - row, simplified verification acc. to NA.8.2.4
nail ends in timber member 2, penetration depth t = 40 mm > 4 d = 17 mm, 1 shear plane
f_{uk} = 600 N/mm², M_{yk} = 7511 Nmm
K_{ser} = 1023 N/mm, γ_M = 1.10, **R_k = 1130.6 N, all values per shear plane**

section 2 from x_A = 3.00 m to x_E = 6.00
nail, 4.2 x 100.0 mm, d_k = 0.0 mm, not predrilled
1-row with a_1 = **74.0 mm**
1 - row, simplified verification acc. to NA.8.2.4
nail ends in timber member 2, penetration depth t = 40 mm > 4 d = 17 mm, 1 shear plane
f_{uk} = 600 N/mm², M_{yk} = 7511 Nmm
K_{ser} = 1023 N/mm, γ_M = 1.10, **R_k = 1130.6 N, all values per shear plane**

section 3 from x_A = 6.00 m to x_E = 9.00
nail, 4.2 x 100.0 mm, d_k = 0.0 mm, not predrilled
1-row with a_1 = **45.0 mm**
1 - row, simplified verification acc. to NA.8.2.4
nail ends in timber member 2, penetration depth t = 40 mm > 4 d = 17 mm, 1 shear plane
f_{uk} = 600 N/mm², M_{yk} = 7511 Nmm
K_{ser} = 1023 N/mm, γ_M = 1.10, **R_k = 1130.6 N, all values per shear plane**

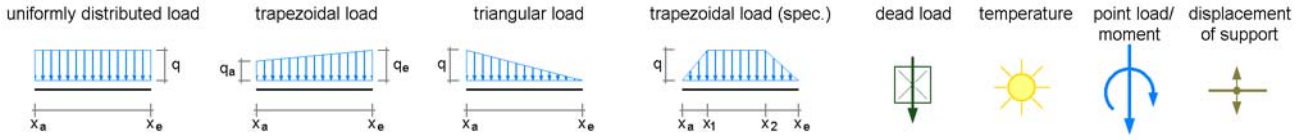
7. Supports

coordinates of supports

supp.name	x	width	depth	c_F	c_M	restraint	
	m	mm	mm	kN/m	kNm/-	(F)	(M)
A	0.00	150	120	fix	----	X	-
B	3.00	0	120	----	----	-	-
C	6.00	0	120	----	----	-	-
D	9.00	150	120	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 = 0.35 kN/m from x_a = 0.00 m to x_e = 9.00 m

2. Transient action effect: live loads (1)
2. additive load case: live loads (1/1)
⇒ unif.distr.load: q = 0.70 kN/m from x_a = 0.00 m to x_e = 9.00 m

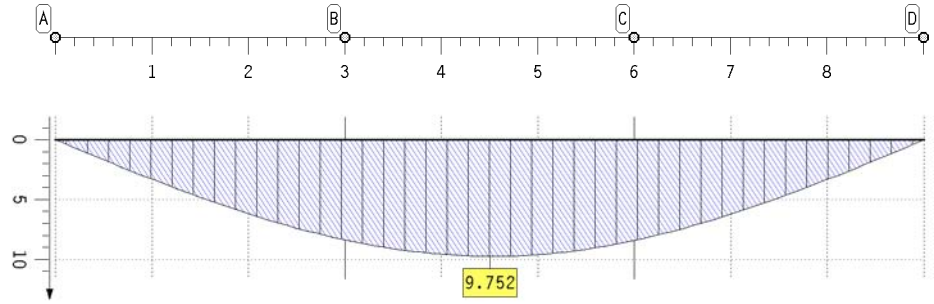
9. verifications

1: EC 5 load-carrying capacity
verification of buckling resistance acc. to DIN EN 1995, 9.1.1(7) will be executed
buckling analysis of compression flange acc. to DIN EN 1995, 6.3.2 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)

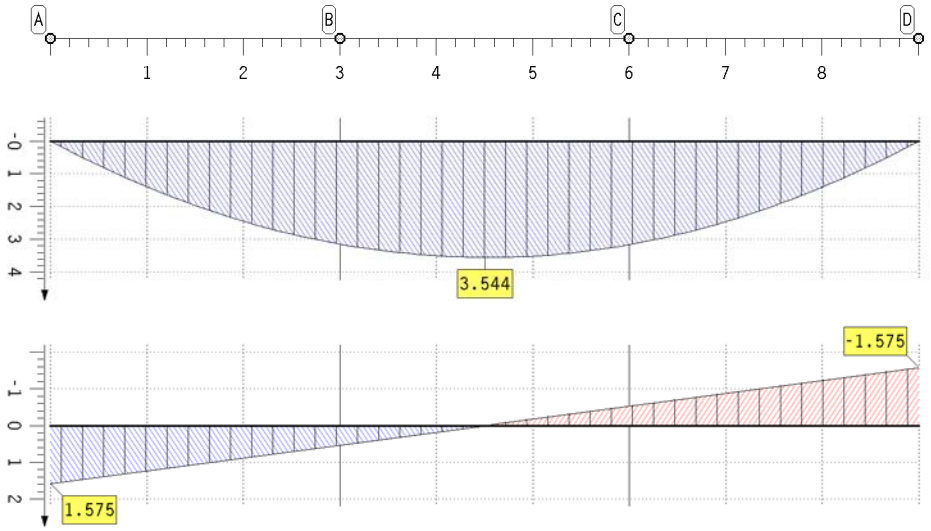


deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 9.75

extremal deflections of main beam (characteristic)

point	x	min w	max w	point	x	min w	max w	point	x	min w	max w
-	m	mm	mm	-	m	mm	mm	-	m	mm	mm
A	0.000	0.00	0.00		4.500	9.75	9.75	D	9.000	0.00	0.00
B	3.000	8.40	8.40		5.200	9.45	9.45	**minimum**		**0.00**	**0.00**
B	3.000	8.40	8.40	C	6.000	8.40	8.40	**maximum**		**9.75**	**9.75**
	3.800	9.45	9.45	C	6.000	8.40	8.40				

extremal internal forces



flexural moment
main beam
M in kNm
Min: -0.00
Max: 3.54

shear force
main beam
V in kN
Min: -1.58
Max: 1.58

extremal internal forces

point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
A	0.000	-0.00	-0.00	1.58	1.58
	1.500	1.97	1.97	1.05	1.05
B	3.000	3.15	3.15	0.52	0.52
B	3.000	3.15	3.15	0.52	0.52
	3.700	3.43	3.43	0.28	0.28
	4.500	3.54	3.54	0.00	0.00
	5.300	3.43	3.43	-0.28	-0.28

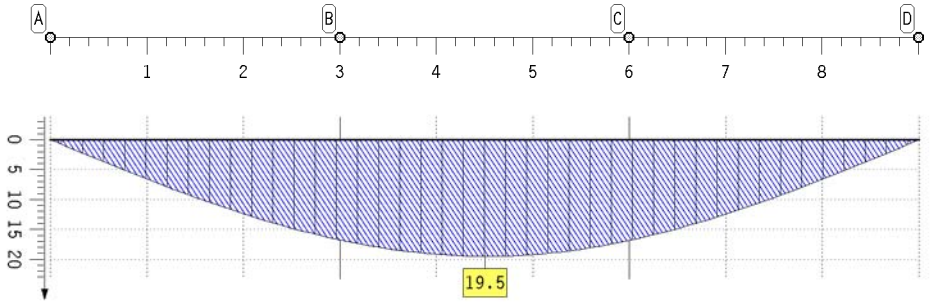
point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
C	6.000	3.15	3.15	-0.52	-0.52
C	6.000	3.15	3.15	-0.52	-0.52
	7.500	1.97	1.97	-1.05	-1.05
D	9.000	-0.00	-0.00	-1.58	-1.58
minimum		**-0.00**	**-0.00**	**-1.58**	**-1.58**
maximum		**3.54**	**3.54**	**1.58**	**1.58**

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-1.58	-1.58
D	9.000	-1.58	-1.58

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: 19.50

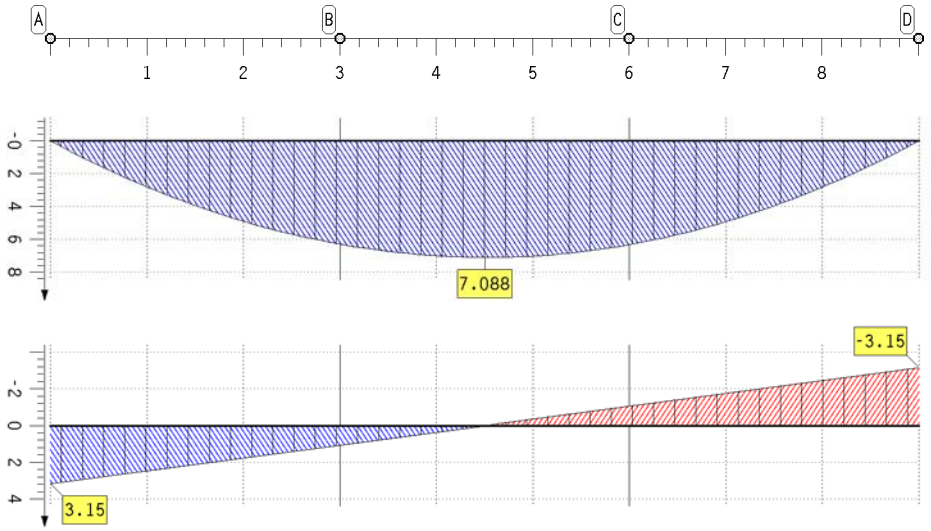
extremal deflections of main beam (characteristic)

point	x	min w	max w
-	m	mm	mm
A	0.000	0.00	0.00
B	3.000	0.00	16.80
B	3.000	0.00	16.80
	3.800	0.00	18.91

point	x	min w	max w
-	m	mm	mm
	4.500	0.00	19.50
	5.200	0.00	18.91
C	6.000	0.00	16.80
C	6.000	0.00	16.80

point	x	min w	max w
-	m	mm	mm
D	9.000	0.00	0.00
minimum		**0.00**	**0.00**
maximum		**0.00**	**19.50**

extremal internal forces



flexural moment
main beam
M in kNm
Min: -0.00
Max: 7.09

shear force
main beam
V in kN
Min: -3.15
Max: 3.15

extremal internal forces

point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
A	0.000	-0.00	-0.00	0.00	3.15
	1.500	0.00	3.94	0.00	2.10
B	3.000	0.00	6.30	0.00	1.05
B	3.000	0.00	6.30	0.00	1.05
	3.700	0.00	6.86	0.00	0.56
	4.500	0.00	7.09	0.00	0.00
	5.300	0.00	6.86	-0.56	-0.00
C	6.000	0.00	6.30	-1.05	-0.00
C	6.000	0.00	6.30	-1.05	-0.00
	7.500	0.00	3.94	-2.10	-0.00
D	9.000	-0.00	-0.00	-3.15	-0.00
minimum		**-0.00**	**-0.00**	**-3.15**	**-0.00**
maximum		**0.00**	**7.09**	**0.00**	**3.15**

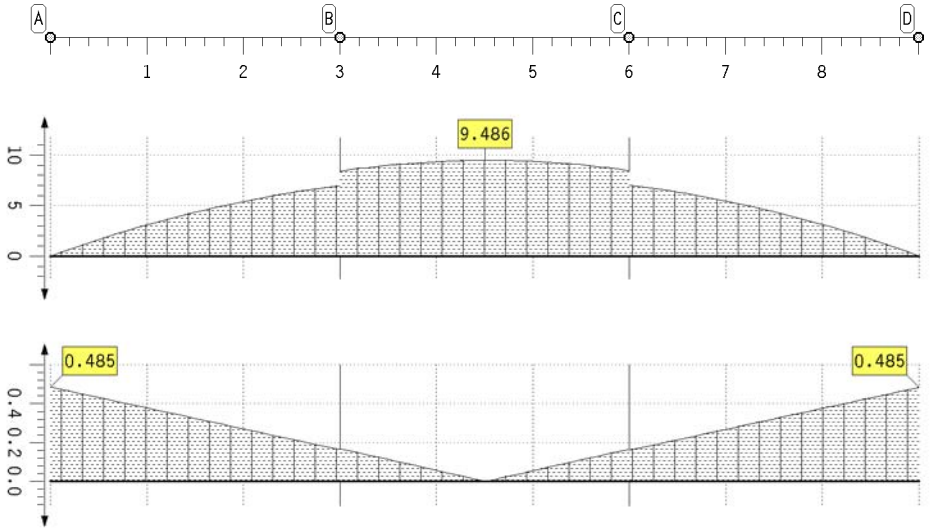
extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-3.15	-0.00
D	9.000	-3.15	-0.00

11. Results of verification of ultimate limit state

11.1. Verification of ultimate limit state

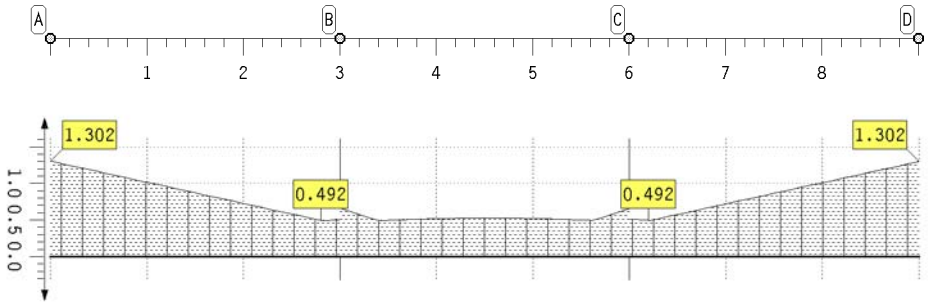
results of verification of ultimate limit state



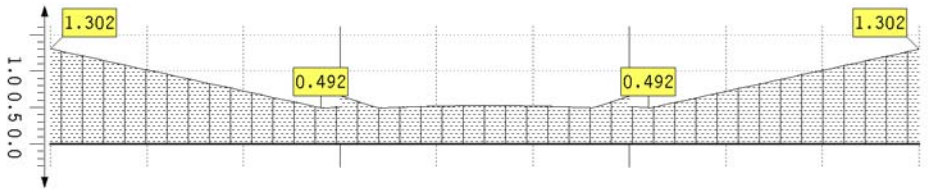
bending stress
main beam
σ_h in MN/m²
Max: 9.49

shear stress
main beam
τ_h in MN/m²
Max: 0.48

results of verification of ultimate limit state



utilization
main beam
Max: 1.30



maximal
utilization
Max: 1.30

maximal utilization

point	x	U	point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-	-	m	-
A	0.000	1.302		3.400	0.494	C	6.000	0.506	maximum		1.302
	2.800	0.492		4.500	0.525		6.200	0.492			
B	3.000	0.506		5.600	0.494	D	9.000	1.302			
B	3.000	0.659	C	6.000	0.659	minimum		0.492			

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-6.85	-1.58
D	9.000	-6.85	-1.58

verification of bearing stress

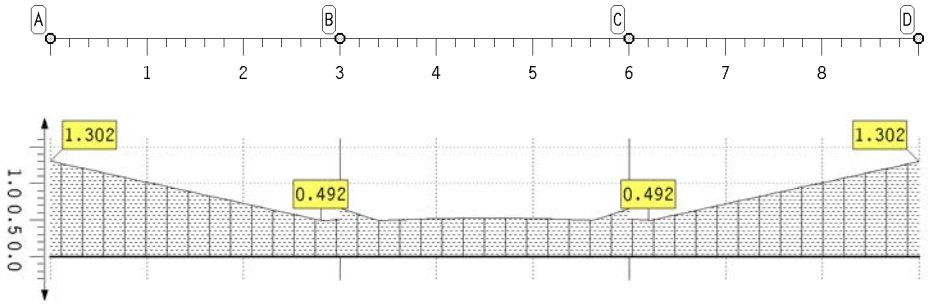
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm^2	N		-	N/mm^2	N/mm^2	-
A	180	21600	6851	1.00	0.80	1.66	0.32	0.19
D	180	21600	6851	1.00	0.80	1.66	0.32	0.19

verification of bearing stresses für den main beam(u = 0.191) successful!

12. Summary

12.1. Summary of all verifications

maximal utilization



utilization
Max: 1.30

maximal utilization

point	x	U	point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-	-	m	-
A	0.000	1.302		3.400	0.494	C	6.000	0.506	maximum		1.302
	2.800	0.492		4.500	0.525		6.200	0.492			
B	3.000	0.506		5.600	0.494	D	9.000	1.302			
B	3.000	0.659	C	6.000	0.659	minimum		0.492			

verification of bearing stress

support	l_{ef} mm	A_{ef} mm²	A_P N	k_{c90}	k_{mod} -	f_{c90d} N/mm²	σ_{c90d} N/mm²	u -
A	180	21600	6851	1.00	0.80	1.66	0.32	0.19
D	180	21600	6851	1.00	0.80	1.66	0.32	0.19

verification of bearing stresses für den main beam(u = 0.191) successful!

13. Utilizations of all verifications

verification of load-carrying capacity (u = 1.302) does not meet the requirements!

14. Detailed verification piont

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	1.58	-0	0	-0	-0	-0	-0
start,max	-0.00	2.13	-0	0	-0	-0	-0	-0
end,min	-0.00	1.58	-0	0	-0	-0	-0	-0
end,max	-0.00	2.13	-0	0	-0	-0	-0	-0

stresses and utilization web

state	$k_{mod,2}$ -	$\sigma_{m,2}$ N/mm²	$\sigma_{c,2}$ N/mm²	$u_{\sigma,2}$ -	τ_2 N/mm²	u_τ -	u_2 -
start	0.6	0.00	0.00	0.00	0.15	0.08	0.08
end	0.6	0.00	0.00	**0.00**	0.15	0.08	0.08

stresses and utilization flanges

state	$k_{mod,1}$ -	$\sigma_{m,1}$ N/mm²	$\sigma_{c,1}$ N/mm²	u_1 -	$k_{mod,3}$ -	$\sigma_{m,3}$ N/mm²	$\sigma_{c,3}$ N/mm²	u_3 -
start	0.6	0.00	0.00	**0.00**	0.6	0.00	-0.00	**0.00**
end	0.6	0.00	0.00	0.00	0.6	0.00	-0.00	0.00

fastener

state	$F_{1,d}$ N	$u_{1,d}$ -	$F_{2,d}$ N	$u_{2,d}$ -
start	-281	**0.54**	241	**0.46**
end	-272	0.52	235	0.45

14.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 60/220 mm

Eq. (9.8) $h_w = 22 \leq 70\ b_w = 420$

Eq. (9.9) $V_d = 2.13\ kN \leq 413.54\ kN$

resulting utilization at verification point u_{res} = 0.067

14.2. Verification of load-carrying capacity at x = 4.50 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	3.54	0.00	62136	-9614	918919	1189	37281	8425
start,max	15.42	0.00	270291	-41821	3997299	5174	162174	36647
end,min	3.54	0.00	68802	-9147	1017506	1035	41281	8112
end,max	15.42	0.00	299289	-39788	4426151	4502	179573	35286

stresses and utilization web

state	$k_{mod,2}$ -	$\sigma_{m,2}$ N/mm²	$\sigma_{c,2}$ N/mm²	$u_{\sigma,2}$ -	τ_2 N/mm²	u_τ -	u_2 -
start	0.8	8.26	0.39	0.47	0.00	0.00	0.47
end	0.8	9.14	0.34	**0.51**	0.00	0.00	0.51

stresses and utilization flanges

state	$k_{mod,1}$ -	$\sigma_{m,1}$ N/mm²	$\sigma_{c,1}$ N/mm²	u_1 -	$k_{mod,3}$ -	$\sigma_{m,3}$ N/mm²	$\sigma_{c,3}$ N/mm²	u_3 -
start	0.8	2.25	-3.49	**0.53**	0.8	2.25	5.09	**0.44**
end	0.8	2.49	-3.32	0.50	0.8	2.49	4.90	0.42

14.2.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 60/220 mm

Eq. (9.8) h_w = 22 ≤ 70 b_w = 420
Eq. (9.9) V_d = 0.00 kN ≤ 413.54 kN
resulting utilization at verification point u_{res} = 0.525

14.3. Verification of load-carrying capacity at x = 9.00 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	-6.85	-0	0	-0	-0	-0	-0
start,max	-0.00	-1.58	-0	0	-0	-0	-0	-0
end,min	-0.00	-6.85	-0	0	-0	-0	-0	-0
end,max	-0.00	-1.58	-0	0	-0	-0	-0	-0

stresses and utilization web

state	$k_{mod,2}$ -	$\sigma_{m,2}$ N/mm²	$\sigma_{c,2}$ N/mm²	$u_{\sigma,2}$ -	τ_2 N/mm²	u_τ -	u_2 -
start	0.8	0.00	0.00	0.00	0.48	0.19	0.19
end	0.8	0.00	0.00	**0.00**	0.48	0.20	0.20

stresses and utilization flanges

state	$k_{mod,1}$ -	$\sigma_{m,1}$ N/mm²	$\sigma_{c,1}$ N/mm²	u_1 -	$k_{mod,3}$ -	$\sigma_{m,3}$ N/mm²	$\sigma_{c,3}$ N/mm²	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	-906	**1.30**	776	**1.12**
end	-876	1.26	758	1.09

14.3.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 60/220 mm

Eq. (9.8) h_w = 22 ≤ 70 b_w = 420
Eq. (9.9) V_d = 6.85 kN ≤ 413.54 kN
resulting utilization at verification point u_{res} = 1.302