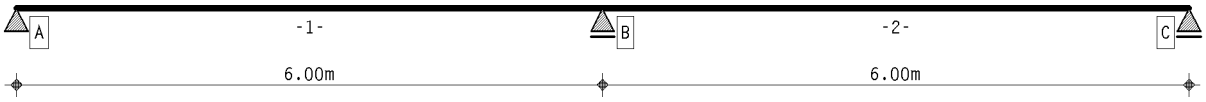
1. Options for Calculations

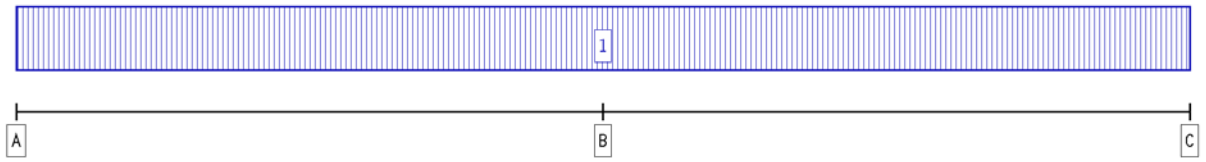
calculation DIN EN 1995:2010, Germany
service class 1
coefficient of thermal expansion for timber α_t = 0.500 *10^{-5}/°K
ψ_2 = 0.60 (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

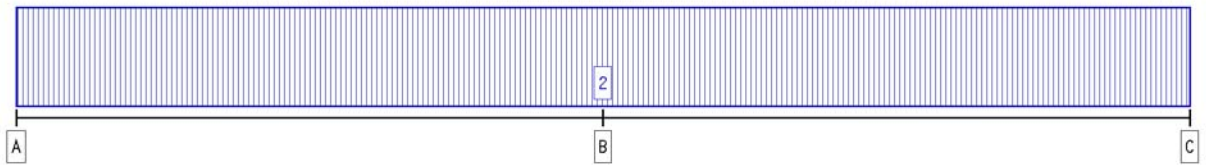


main beam

3. Loading



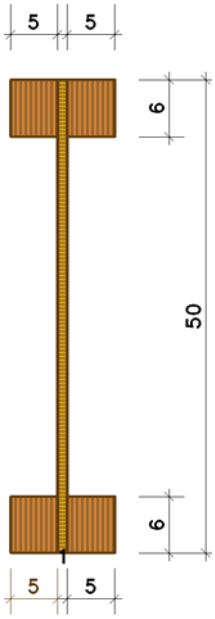
action effect 1: permanent loads (permanent, 1 load cases)



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

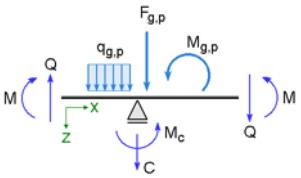
4. main beam

section scale 1: 8



timber grade top flange			**glue lam. timber DIN, GL28h (BS14)**
char. bend. strength	$f_{m,k}$	:	28.0 N/mm²
char. shear strength	$f_{v,k}$	:	3.5 N/mm²
char. ten. strength	$f_{t,k}$	:	19.5 N/mm²
char. compr. strength	$f_{c,0,k}$	:	26.5 N/mm²
char. compr. strength	$f_{c,90,k}$	:	3.0 N/mm²
modulus of elasticity	$E_{0,mean}$	:	12600 N/mm²
Dichte	ρ_k / ρ_m	:	410 / 492 kg/m³
deformation factor	k_{def}	:	0.60 -
area	A_{flange}	:	60.000 cm²
moment of inertia	I_{flange}	:	180.000 cm⁴
timber grade web			**fibreboard medium**
d = 10.0 mm (hochkant)			
char. bend. strength	$f_{m,k}$	:	9.0 N/mm²
char. shear strength	$f_{v,k}$	:	5.5 N/mm²
char. ten. strength	$f_{t,k}$	:	9.0 N/mm²
char. compr. strength	$f_{c,0,k}$	:	9.0 N/mm²
char. compr. strength	$f_{c,90,k}$	:	8.0 N/mm²
	k_{cr}	:	1.00 mm²/N
e-modulus	$E_{0,mean}$ (diaphragm)	:	3100 N/mm²
e-modulus	$E_{0,mean}$ (plate)	:	3100 N/mm²
Dichte	ρ_k / ρ_m	:	600 / 720 kg/m³
deformation factor	k_{def}	:	3.00 -
area	A_{flange}	:	50.000 cm²
moment of inertia	I_{flange}	:	10416.667 cm⁴
timber grade bottom flange			**glue lam. timber DIN, GL28h (BS14)**
char. bend. strength	$f_{m,k}$	:	28.0 N/mm²
char. shear strength	$f_{v,k}$	:	3.5 N/mm²
char. ten. strength	$f_{t,k}$	:	19.5 N/mm²
char. compr. strength	$f_{c,0,k}$	:	26.5 N/mm²
char. compr. strength	$f_{c,90,k}$	:	3.0 N/mm²
modulus of elasticity	$E_{0,mean}$	:	12600 N/mm²
Dichte	ρ_k / ρ_m	:	410 / 492 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_{ef} m	i_z mm	k -	λ -	$\lambda_{rel,c}$ -	k_c -	l_v m	cantil.	s_{ef} mm
1	0.00	6.00	6.00	2.00	28.9000	1.1527	69.2042	1.1067	0.6779	0.00	-	n.e.
2	6.00	12.00	6.00	0.10	28.9000	0.4893	3.4602	0.0553	1.0000	6.00	-	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	$EI_{ef,inst}$ Nmm2	ø k_{def} -
1	1.0000	-0.0	1	1.0000	-220.0	1	1.0000	220.0	7.6864E12	0.3900
2	1.0000	-0.0	1	1.0000	-220.0	1	1.0000	220.0	7.6864E12	0.3900

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	-0.0	1	1.0000	-220.0	1	1.0000	220.0	7.6864E12	610028288.0	25.00	33.33
2	1.0000	-0.0	1	1.0000	-220.0	1	1.0000	220.0	7.6864E12	610028288.0	25.00	33.33

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	0.0	1	1.0000	-220.0	1	1.0000	220.0	5.5296E12	596848064.0	25.00	33.33
2	1.0000	0.0	1	1.0000	-220.0	1	1.0000	220.0	5.5296E12	596848064.0	25.00	33.33

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	50.00	416.67	10416.67	60.00	60.00	180.00	60.00	60.00	180.00
2	50.00	416.67	10416.67	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 = 6.00, glued joint
section 2 from x_A = 6.00 m to x_E = 12.00, glued joint

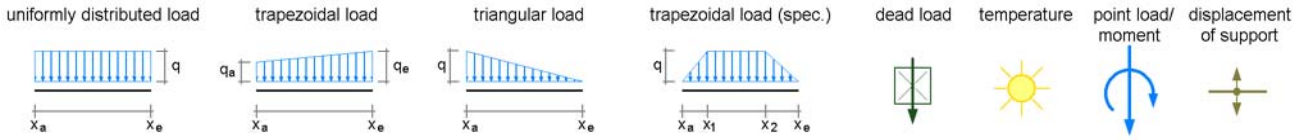
7. Supports

coordinates of supports

supp.name	x m	width mm	depth mm	c_F kN/m	c_M kNm/-	restraint (F)	restraint (M)
A	0.00	150	10	fix	----	X	-
B	6.00	150	10	fix	----	X	-
C	12.00	150	10	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 = 0.50 kN/m from x_a = 0.00 m to x_e = 12.00 m

2. Transient action effect: live loads (1)
2. additive load case: live loads (1/1)
⇒ unif.distr.load: q = 0.60 kN/m from x_a = 0.00 m to x_e = 12.00 m

9. verifications

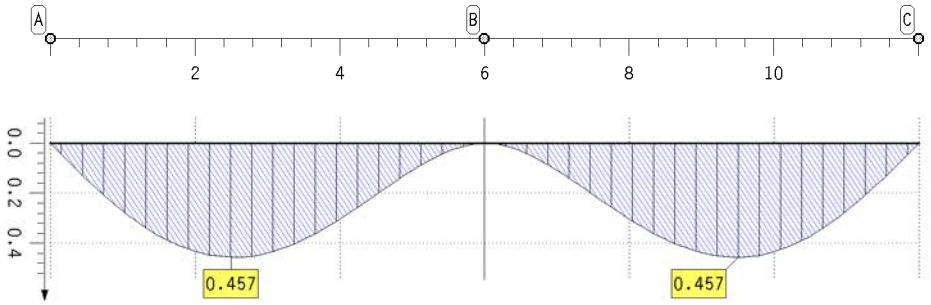
1: EC 5 load-carrying capacity
verification of buckling resistance acc. to DIN EN 1995, 9.1.1(7) will be executed
buckling analysis of compression flange acc. to DIN EN 1995, 6.3.2 will be executed
verification of bearing stress DIN EN 1995, 6.1.5 will be executed
Extreme rule 1

2: EC 5 deformations
Grenzwerte für deformations acc. to DIN EN 1995-1-1, Tab. 7.2!
Extreme rule 1

10. Results of action effects

10.1. Action effect 1: permanent loads

extremal deflections of main beam (characteristic)

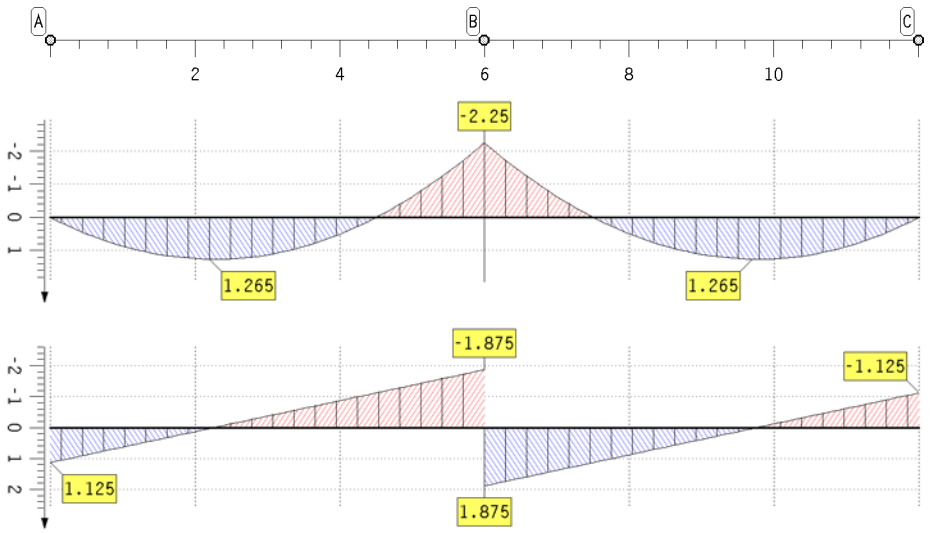


deflection
main beam
characteristic
w in mm
Min: -0.00
Max: 0.46

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	B	6.000	-0.00	-0.00		10.600	0.35	0.35
	1.400	0.35	0.35	B	6.000	0.00	0.00	C	12.000	0.00	0.00
	2.500	0.46	0.46		6.700	0.06	0.06	**minimum**		**-0.00**	**-0.00**
	3.400	0.40	0.40		8.600	0.40	0.40	**maximum**		**0.46**	**0.46**
	5.300	0.06	0.06		9.500	0.46	0.46				

extremal internal forces



flexural moment
main beam
M in kNm
Min: -2.25
Max: 1.26

shear force
main beam
V in kN
Min: -1.88
Max: 1.88

extremal internal forces

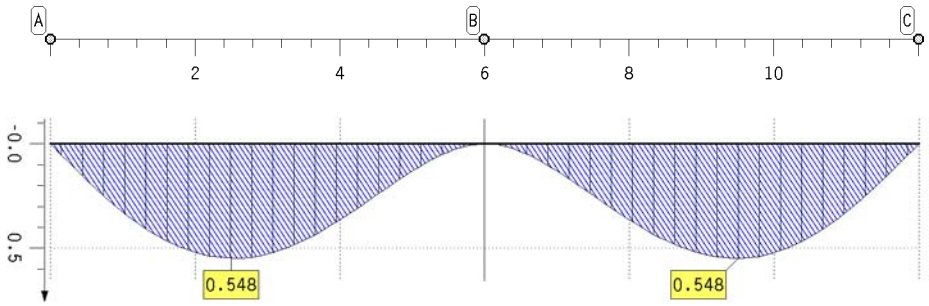
point	x	min M	max M	min V	max V	point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN	-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	1.12	1.12		7.900	0.41	0.41	0.93	0.93
	2.200	1.26	1.26	0.03	0.03		9.700	1.26	1.26	0.03	0.03
	4.100	0.41	0.41	-0.93	-0.93	C	12.000	0.00	0.00	-1.12	-1.12
B	6.000	-2.25	-2.25	-1.88	-1.88	**minimum**		**-2.25**	**-2.25**	**-1.88**	**-1.88**
B	6.000	-2.25	-2.25	1.88	1.88	**maximum**		**1.26**	**1.26**	**1.88**	**1.88**

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-1.12	-1.12
B	6.000	-3.75	-3.75
C	12.000	-1.12	-1.12

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: 0.55

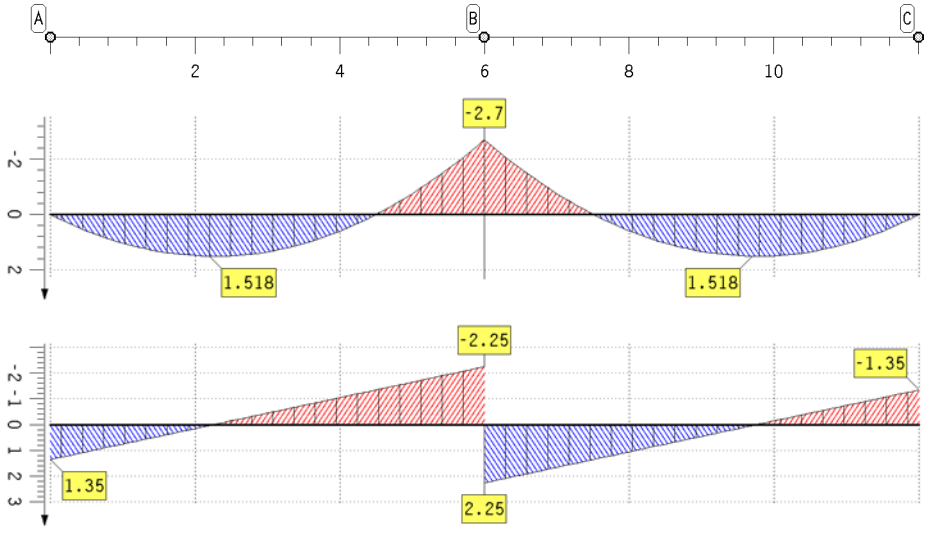
extremal deflections of main beam (characteristic)

point	x	min w	max w
-	m	mm	mm
A	0.000	0.00	0.00
	1.400	0.00	0.42
	2.500	0.00	0.55
	3.400	0.00	0.48
	5.300	0.00	0.07

point	x	min w	max w
-	m	mm	mm
B	6.000	0.00	0.00
B	6.000	0.00	0.00
	6.700	0.00	0.07
	8.600	0.00	0.48
	9.500	0.00	0.55

point	x	min w	max w
-	m	mm	mm
	10.600	0.00	0.42
C	12.000	0.00	0.00
minimum		**0.00**	**0.00**
maximum		**0.00**	**0.55**

extremal internal forces



flexural moment
main beam
M in kNm
Min: -2.70
Max: 1.52

shear force
main beam
V in kN
Min: -2.25
Max: 2.25

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	1.35
	1.100	0.00	1.12	0.00	0.69
	2.200	0.00	1.52	0.00	0.03
	3.400	0.00	1.12	-0.69	-0.00
	4.500	-0.00	-0.00	-1.35	-0.00
B	6.000	-2.70	-0.00	-2.25	-0.00
B	6.000	-2.70	-0.00	0.00	2.25

point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
	7.500	0.00	0.00	0.00	1.35
	8.600	0.00	1.12	0.00	0.69
	9.700	0.00	1.52	0.00	0.03
	10.800	0.00	1.19	-0.63	-0.00
C	12.000	0.00	0.00	-1.35	-0.00
minimum		**-2.70**	**-0.00**	**-2.25**	**-0.00**
maximum		**0.00**	**1.52**	**0.00**	**2.25**

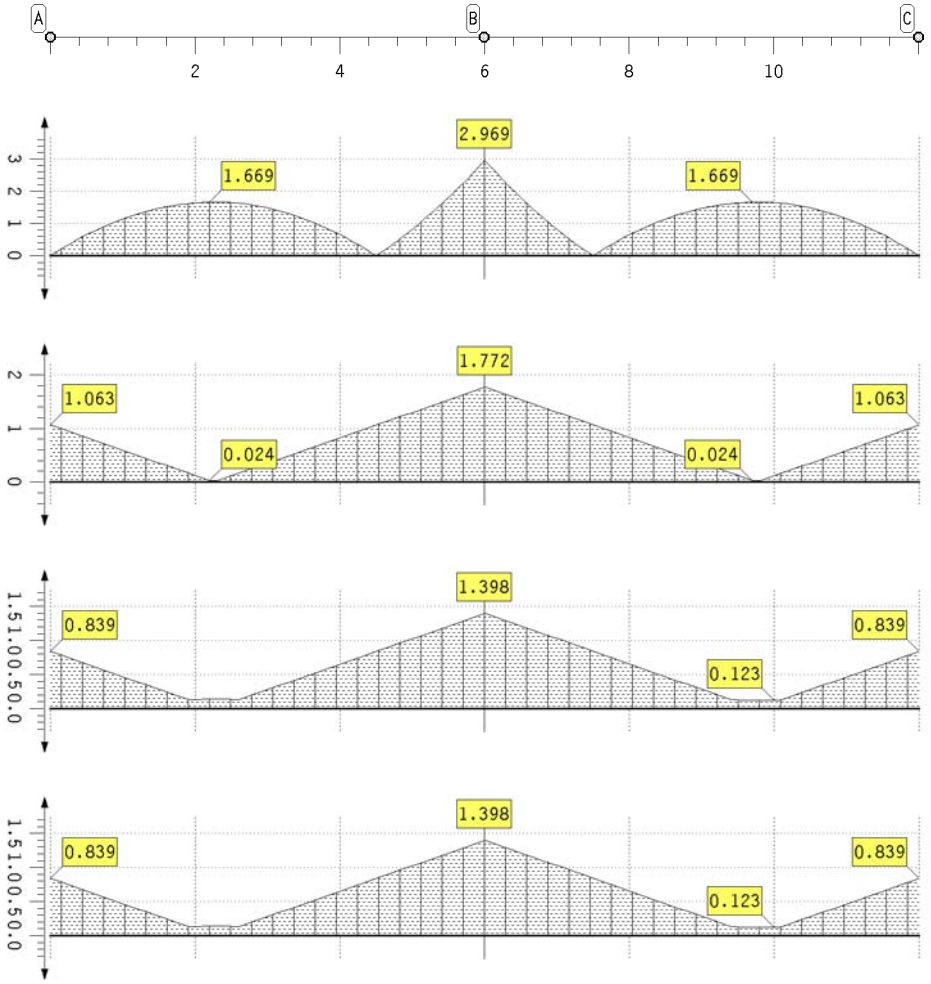
extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-1.35	-0.00
B	6.000	-4.50	-0.00
C	12.000	-1.35	-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: 2.97

shear stress
main beam
τ_h in MN/m²
Max: 1.77

utilization
main beam
Max: 1.40

maximal
utilization
Max: 1.40

maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.839	B	6.000	1.398	**minimum**		**0.123**
	1.900	0.134		9.500	0.123	**maximum**		**1.398**
	2.600	0.134		10.100	0.130			
B	6.000	1.398	C	12.000	0.839			

extremal support forces

point	x	min AP	max AP
-	m	kN	kN
A	0.000	-3.54	-1.12
B	6.000	-11.81	-3.75
C	12.000	-3.54	-1.12

verification of bearing stress

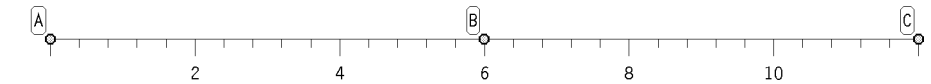
support	l_{ef} mm	A_{ef} mm²	A_P N	k_{c90}	k_{mod} -	f_{c90d} N/mm²	σ_{c90d} N/mm²	u -
A	180	1800	1519	1.00	0.20	1.23	0.84	0.69
B	210	2100	5063	1.00	0.20	1.23	2.41	1.96
C	180	1800	1519	1.00	0.20	1.23	0.84	0.69

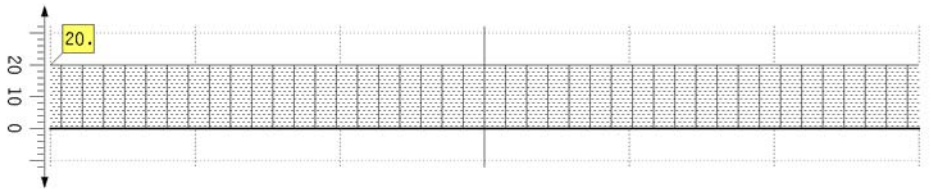
verification of bearing stresses für den main beam(u = 1.959) does not meet the requirements!

12. Results of verification of deflections

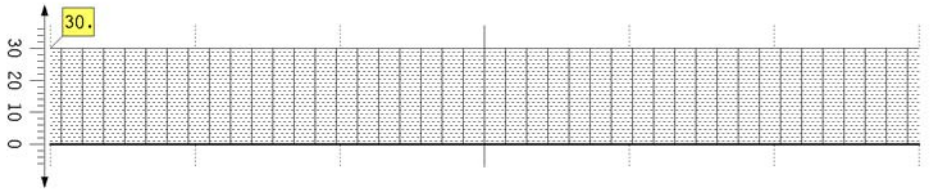
12.1. Verification of deflections

results of verification of deflections

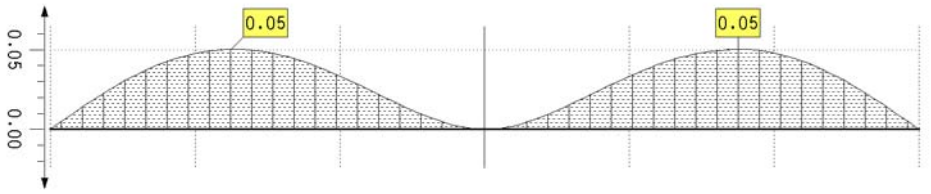




decisive deflection
Winst,req
in mm
Min: 20.00
Max: 20.00



decisive deflection
Wfin,req
in mm
Min: 30.00
Max: 30.00



maximal utilization
Max: 0.05

maximal utilization

point	x m	U -	point	x m	U -	point	x m	U -	point	x m	U -
A	0.000	0.000		5.300	0.006		8.600	0.044	**minimum**		**0.000**
	1.400	0.039	B	6.000	0.000		9.500	0.050	**maximum**		**0.050**
	2.500	0.050	B	6.000	0.000		10.600	0.039			
	3.400	0.044		6.700	0.006	C	12.000	0.000			

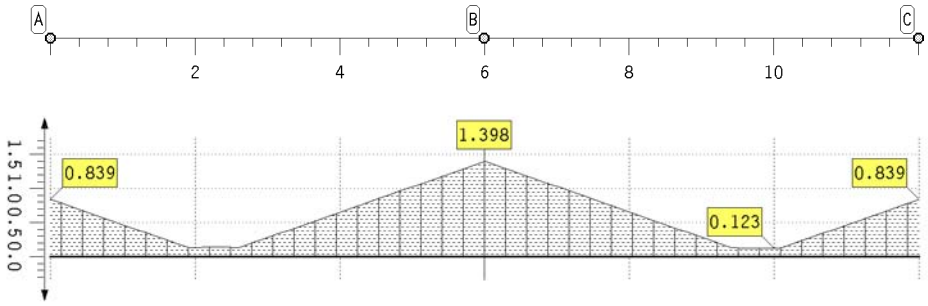
extremal support forces

point	x m	min AP kN	max AP kN
A	0.000	-3.07	-1.12
B	6.000	-10.24	-3.75
C	12.000	-3.07	-1.12

13. Summary

13.1. Summary of all verifications

maximal utilization



utilization
Max: 1.40

maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.839	B	6.000	1.398	**minimum**		**0.123**
	1.900	0.134		9.500	0.123	**maximum**		**1.398**
	2.600	0.134		10.100	0.130			
B	6.000	1.398	C	12.000	0.839			

verification of bearing stress

support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm²	N		-	N/mm²	N/mm²	-
A	180	1800	1519	1.00	0.20	1.23	0.84	0.69
B	210	2100	5063	1.00	0.20	1.23	2.41	1.96
C	180	1800	1519	1.00	0.20	1.23	0.84	0.69

verification of bearing stresses für den main beam(u = 1.959) does not meet the requirements!

14. Utilizations of all verifications

verification of load-carrying capacity (u = 1.959) does not meet the requirements!

15. Detailed verification piont

15.1. 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	1.13	0	-0	0	0	0	0
start,max	0.00	1.52	0	-0	0	0	0	0
end,min	0.00	1.13	0	-0	0	0	0	0
end,max	0.00	1.52	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/mm²	N/mm²	-	N/mm²	-	-
start	0.2	0.00	0.00	**0.00**	0.46	0.54	0.54
end	0.2	0.00	0.00	0.00	0.46	0.54	0.54

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/mm²	N/mm²	-	-	N/mm²	N/mm²	-
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**

adhering joint with fv1,d = 0.046 N/mm²

state	$S_{1,d}$	$\tau_{1,d}$	$u_{1,d}$	$S_{2,d}$	$\tau_{2,d}$	$u_{2,d}$
	cm²	N/mm²	-	cm²	N/mm²	-
start	1320	0.0280	**0.84**	1320	0.0280	**0.84**
end	1320	0.0280	0.84	1320	0.0280	0.84

15.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 10/380 mm

Eq. (9.8) $h_w = 38 \leq 70\ b_w = 70$

Eq. (9.9) $V_d = 1.52\ kN \leq 102.87\ kN$

resulting utilization at verification point u_{res} = 0.543

15.2. Verification of load-carrying capacity at x = 1.20 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	0.99	0.52	2921	-2142	41592	0	2921	2142
start,max	1.34	0.71	3944	-2892	56149	0	3944	2892
end,min	0.99	0.52	2986	-2190	20648	0	2986	2190
end,max	1.34	0.71	4031	-2956	27874	0	4031	2956

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	0.2	0.13	0.00	**0.10**	0.21	0.25	0.25
end	0.2	0.07	0.00	0.05	0.21	0.25	0.25

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	0.07	-0.48	0.06	0.6	0.07	0.48	0.05
end	0.6	0.07	-0.49	**0.06**	0.6	0.07	0.49	**0.05**

adhering joint with fv1,d = 0.046 N/mm²

state	$S_{1,d}$ cm²	$\tau_{1,d}$ N/mm²	$u_{1,d}$ -	$S_{2,d}$ cm²	$\tau_{2,d}$ N/mm²	$u_{2,d}$ -
start	1320	0.0131	**0.39**	1320	0.0131	**0.39**
end	1320	0.0131	0.39	1320	0.0131	0.39

15.2.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 10/380 mm

Eq. (9.8) $h_w = 38 \leq 70\ b_w = 70$

Eq. (9.9) $V_d = 0.71\ kN \leq 102.87\ kN$

resulting utilization at verification point u_{res} = 0.391

15.3. Verification of load-carrying capacity at x = 6.00 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	-3.04	1.88	-8963	6573	-127610	-0	-8963	-6573
start,max	-2.25	2.53	-6639	4869	-94526	-0	-6639	-4869
end,min	-3.04	1.88	-9161	6718	-63351	-0	-9161	-6718
end,max	-2.25	2.53	-6786	4976	-46927	-0	-6786	-4976

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	0.2	0.23	0.00	**0.16**	0.76	0.90	0.90
end	0.2	0.11	0.00	0.08	0.76	0.90	0.90

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	0.11	0.81	0.09	0.6	0.11	-0.81	0.07
end	0.6	0.11	0.83	**0.09**	0.6	0.11	-0.83	**0.07**

adhering joint with fv1,d = 0.046 N/mm²

state	$S_{1,d}$ cm²	$\tau_{1,d}$ N/mm²	$u_{1,d}$ -	$S_{2,d}$ cm²	$\tau_{2,d}$ N/mm²	$u_{2,d}$ -
start	1320	0.0467	**1.40**	1320	0.0467	**1.40**
end	1320	0.0467	1.40	1320	0.0467	1.40

15.3.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 10/380 mm

Eq. (9.8) $h_w = 38 \leq 70\ b_w = 70$

Eq. (9.9) $V_d = 2.53\ kN \leq 102.87\ kN$

resulting utilization at verification point $u_{res} = 1.398$

15.4. Verification of load-carrying capacity at x = 8.00 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	0.50	0.88	1475	-1082	21006	0	1475	1082
start,max	0.68	1.18	1992	-1461	28358	0	1992	1461
end,min	0.50	0.88	1508	-1106	10428	0	1508	1106
end,max	0.68	1.18	2036	-1493	14078	0	2036	1493

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	0.2	0.07	0.00	**0.05**	0.35	0.42	0.42
end	0.2	0.03	0.00	0.02	0.35	0.42	0.42

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	0.03	-0.24	0.02	0.6	0.03	0.24	0.03
end	0.6	0.03	-0.25	**0.02**	0.6	0.03	0.25	**0.03**

adhering joint with $f_{v1,d} = 0.046\ N/mm^2$

state	$S_{1,d}$ cm²	$\tau_{1,d}$ N/mm²	$u_{1,d}$ -	$S_{2,d}$ cm²	$\tau_{2,d}$ N/mm²	$u_{2,d}$ -
start	1320	0.0218	**0.65**	1320	0.0218	**0.65**
end	1320	0.0218	0.65	1320	0.0218	0.65

15.4.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 10/380 mm

Eq. (9.8) $h_w = 38 \leq 70\ b_w = 70$

Eq. (9.9) $V_d = 1.18\ kN \leq 102.87\ kN$

resulting utilization at verification point $u_{res} = 0.652$