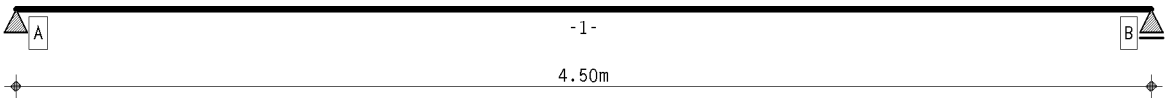
1. Options for Calculations

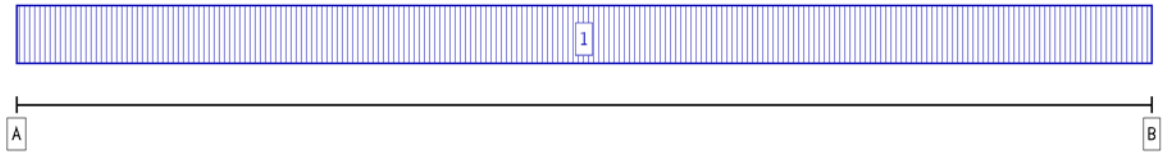
calculation DIN EN 1995:2010, Germany
service class 1
coefficient of thermal expansion for timber α_t = 0.500 *10^{-5}/°K
ψ_2 = 0.60 (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

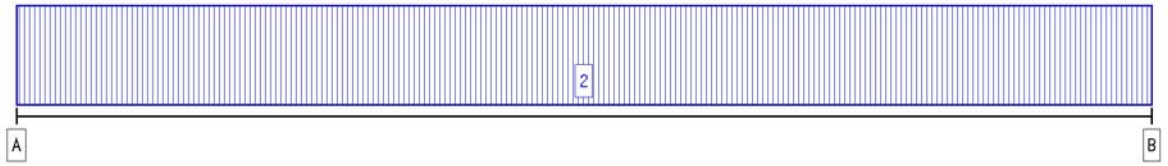


main beam

3. Loading



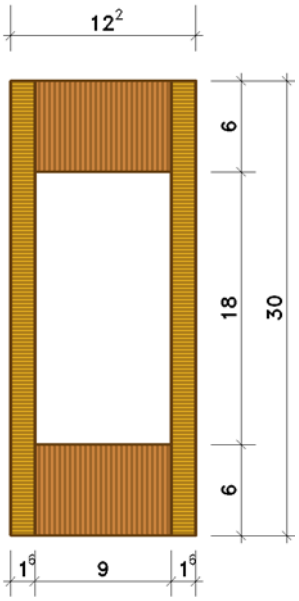
action effect 1: permanent loads (permanent, 1 load cases)



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

4. main beam

section scale 1: 5



timber grade top flange — **solid coniferous timber, C24 (S10)**

char. bend. strength	$f_{m,k}$	: 24.0 N/mm²
char. shear strength	$f_{v,k}$	: 4.0 N/mm²
char. ten. strength	$f_{t,k}$	: 14.5 N/mm²
char. compr. strength	$f_{c,0,k}$	: 21.0 N/mm²
char. compr. strength	$f_{c,90,k}$	: 2.5 N/mm²
modulus of elasticity	$E_{0,mean}$	:11000 N/mm²
Dichte	ρ_k / ρ_m	: 350 / 420 kg/m³
deformation factor	k_{def}	: 0.60 -
area	A_{flange}	: 54.000 cm²
moment of inertia	I_{flange}	: 162.000 cm⁴

timber grade web — **particleboard type P6**

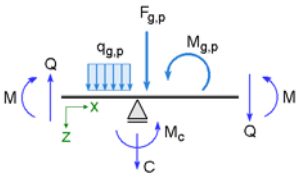
d = 16.0 mm (hochkant)

char. bend. strength	$f_{m,k}$	: 9.5 N/mm²
char. shear strength	$f_{v,k}$	: 7.3 N/mm²
char. ten. strength	$f_{t,k}$	: 9.5 N/mm²
char. compr. strength	$f_{c,0,k}$	: 13.3 N/mm²
char. compr. strength	$f_{c,90,k}$	: 13.3 N/mm²
	k_{cr}	: 1.00 mm²/N
e-modulus	$E_{0,mean}$ (diaphragm)	: 2400 N/mm²
e-modulus	$E_{0,mean}$ (plate)	: 4100 N/mm²
Dichte	ρ_k / ρ_m	: 550 / 660 kg/m³
deformation factor	k_{def}	: 1.50 -
area	A_{flange}	: 96.000 cm²
moment of inertia	I_{flange}	: 7200.000 cm⁴

timber grade bottom flange — **solid coniferous timber, C24 (S10)**

char. bend. strength	$f_{m,k}$	: 24.0 N/mm²
char. shear strength	$f_{v,k}$	: 4.0 N/mm²
char. ten. strength	$f_{t,k}$	: 14.5 N/mm²
char. compr. strength	$f_{c,0,k}$	: 21.0 N/mm²
char. compr. strength	$f_{c,90,k}$	: 2.5 N/mm²
modulus of elasticity	$E_{0,mean}$	:11000 N/mm²
Dichte	ρ_k / ρ_m	: 350 / 420 kg/m³
deformation factor	k_{def}	: 0.60 -
area	A_{flange}	: 54.000 cm²
moment of inertia	I_{flange}	: 162.000 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	0.00	-	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	-120.0	1	1.0000	120.0	1.9192E12	0.3957

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	-120.0	1	1.0000	120.0	1.9192E12	174469088.0	15.00	64.00

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	-120.0	1	1.0000	120.0	1.3750E12	170004400.0	15.00	64.00

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	96.00	480.00	7200.00	54.00	54.00	162.00	54.00	54.00	162.00

6. Fasteners

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

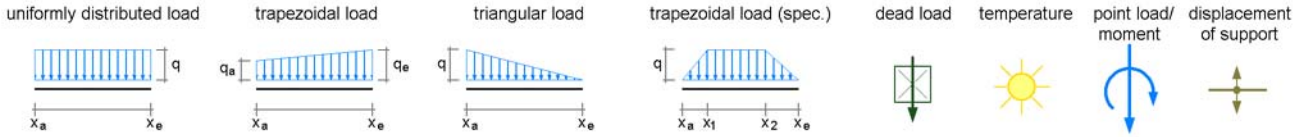
7. Supports

coordinates of supports

supp.name	x	width	depth	c_F	c_M	restraint	
	m	mm	mm	kN/m	kNm/-	(F)	(M)
A	0.00	150	90	fix	----	X	-
B	4.50	150	32	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

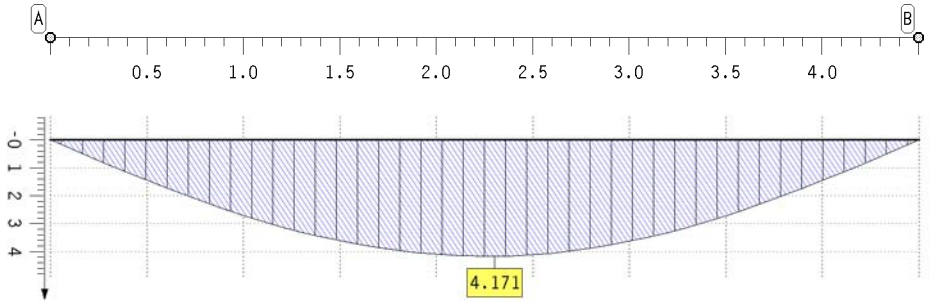
9. verifications

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)

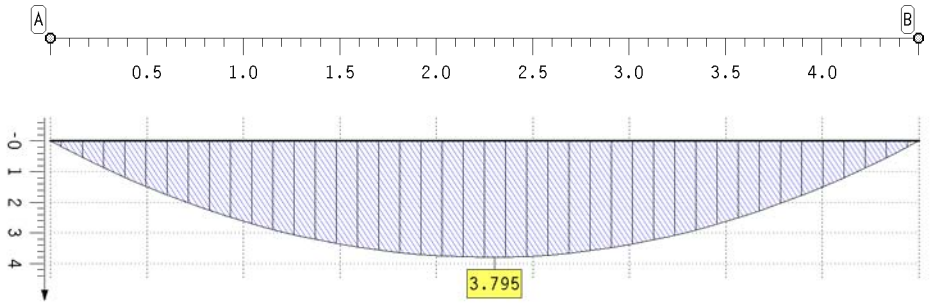


deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 4.17

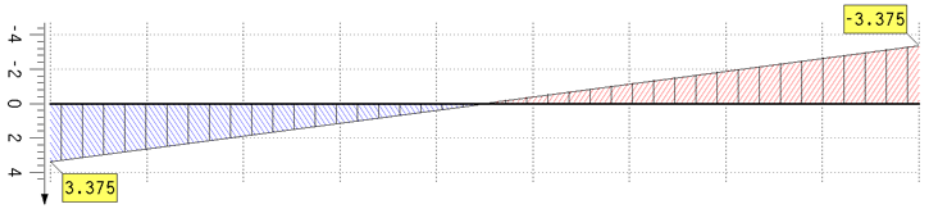
extremal deflections of main beam (characteristic)

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	3.12	3.12	**minimum**		**0.00**	**0.00**
	2.200	4.17	4.17	**maximum**		**4.17**	**4.17**
	3.200	3.31	3.31				

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

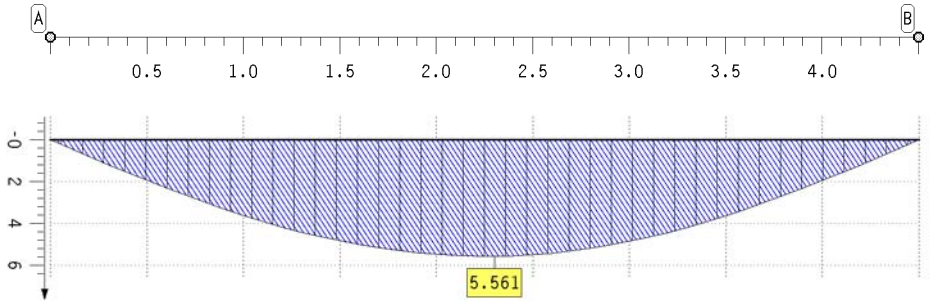
point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	3.38	3.38
	1.100	2.81	2.81	1.73	1.73
	2.200	3.80	3.80	0.08	0.08
	3.400	2.81	2.81	-1.73	-1.73
B	4.500	0.00	0.00	-3.38	-3.38
minimum		**0.00**	**0.00**	**-3.38**	**-3.38**
maximum		**3.80**	**3.80**	**3.38**	**3.38**

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)

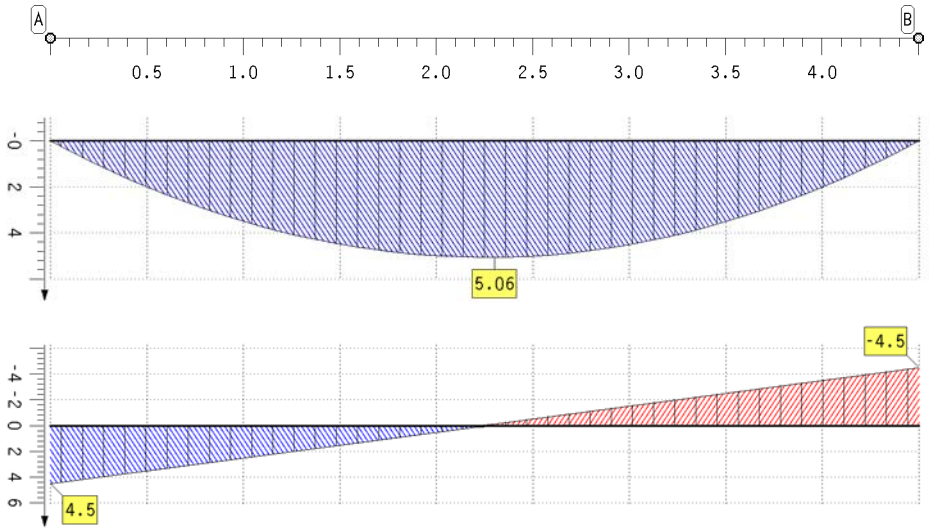


deflection
main beam
characteristic
w in mm
Min: 0.00
Max: 5.56

extremal deflections of main beam (characteristic)

point	x	min w	max w
-	m	mm	mm
A	0.000	0.00	0.00
	1.200	0.00	4.16
	2.200	0.00	5.56
	3.200	0.00	4.41
B	4.500	0.00	0.00
minimum		**0.00**	**0.00**
maximum		**0.00**	**5.56**

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
-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	0.00	4.50
	1.100	0.00	3.74	0.00	2.30
	2.200	0.00	5.06	0.00	0.10
	3.400	0.00	3.74	-2.30	-0.00
B	4.500	0.00	0.00	-4.50	-0.00
minimum		**0.00**	**0.00**	**-4.50**	**-0.00**
maximum		**0.00**	**5.06**	**0.00**	**4.50**

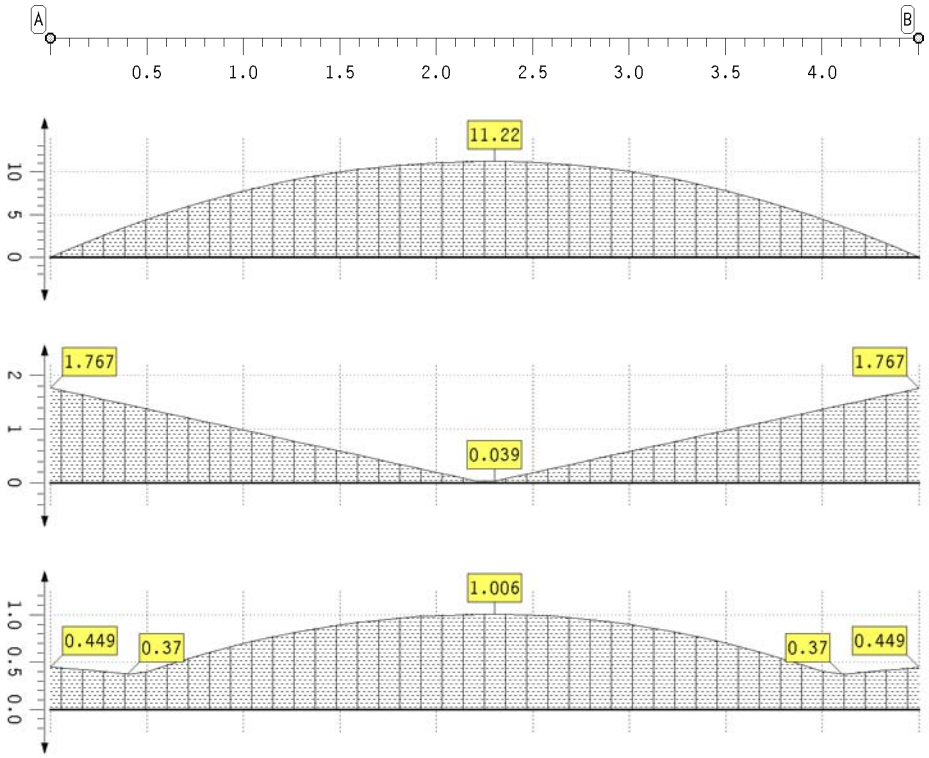
extremal support forces

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

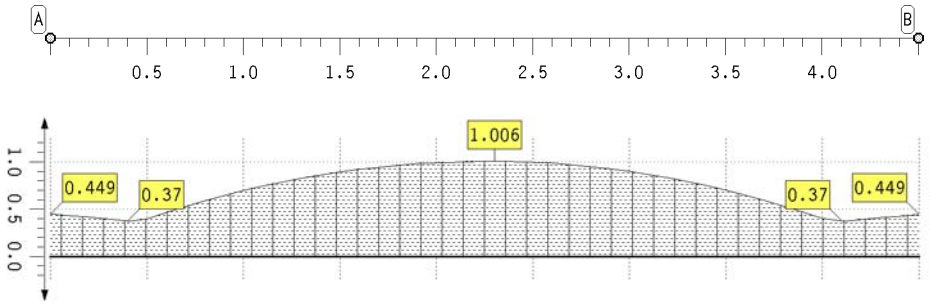


bending stress
main beam
σ_h in MN/m²
Max: 11.22

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

utilization
main beam
Max: 1.01

results of verification of ultimate limit state



maximal utilization
Max: 1.01

maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.449		2.200	1.006	B	4.500	0.449
	0.400	0.370		3.100	0.863	**minimum**		**0.370**
	1.400	0.863		4.100	0.370	**maximum**		**1.006**

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

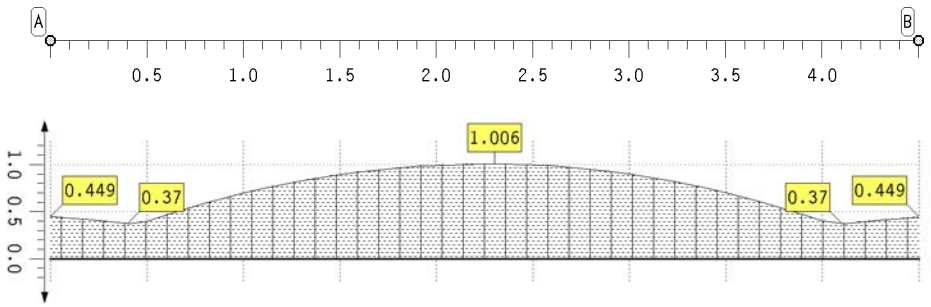
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm^2	N		-	N/mm^2	N/mm^2	-
A	180	16200	11306	1.00	0.80	1.54	0.70	0.45
B	180	5760	11306	1.00	0.70	7.16	1.96	0.27

verification of bearing stresses für den main beam(u = 0.454) successful!

12. Summary

12.1. Summary of all verifications

maximal utilization



utilization
Max: 1.01

maximal utilization

point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-
A	0.000	0.449		2.200	1.006	B	4.500	0.449
	0.400	0.370		3.100	0.863	**minimum**		**0.370**
	1.400	0.863		4.100	0.370	**maximum**		**1.006**

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	16200	11306	1.00	0.80	1.54	0.70	0.45
B	180	5760	11306	1.00	0.70	7.16	1.96	0.27

verification of bearing stresses für den main beam(u = 0.454) successful!

13. Utilizations of all verifications

verification of load-carrying capacity (u = 1.006) 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	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	$k_{mod,2}$ -	$\sigma_{m,2}$ N/mm²	$\sigma_{c,2}$ N/mm²	$u_{\sigma,2}$ -	τ_2 N/mm²	u_τ -	u_2 -
start	0.7	0.00	0.00	**0.00**	1.77	0.45	0.45
end	0.7	0.00	0.00	0.00	1.77	0.45	0.45

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

adhering joint with fv1,d = 0.915 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	648	0.3591	**0.39**	648	0.3591	**0.39**
end	648	0.3591	0.39	648	0.3591	0.39

14.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 16/180 mm

Eq. (9.8) $h_w = 18 \leq 70\ b_w = 112$

Eq. (9.9) $V_d = 11.31$ kN ≤ 301.88 kN

resulting utilization at verification point u_{res} = 0.449