1. Options for Calculations

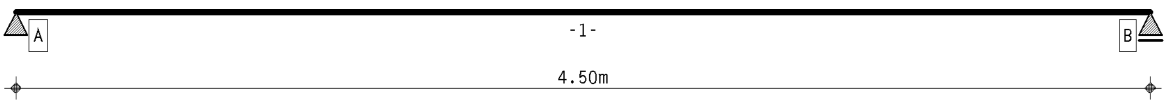
calculation DIN EN 1995:2010, Germany

service class 2

coefficient of thermal expansion for timber α_t = 0.500 *10^{-5}/°K

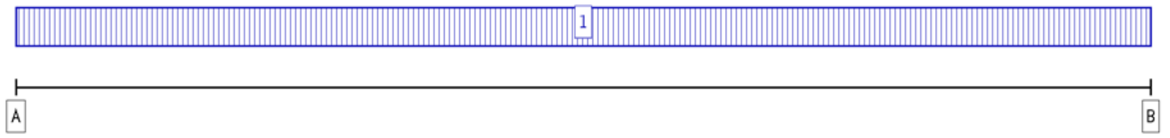
ψ_2 = 0.60 (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

2. Structural system

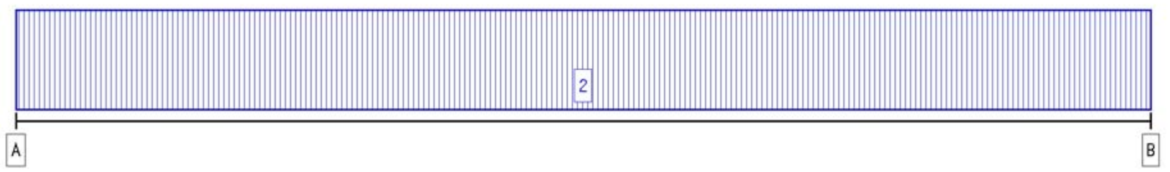


main beam

3. Loading



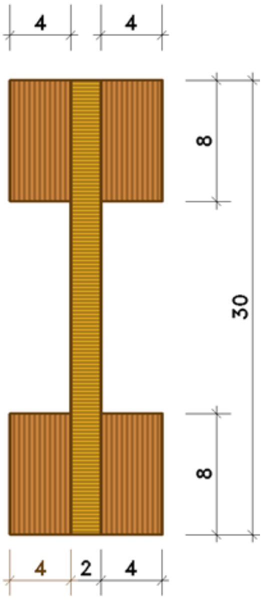
action effect 1: permanent loads (permanent, 1 load cases)



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/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} : 64.000 cm^2
moment of inertia I_{flange} : 341.333 cm^4

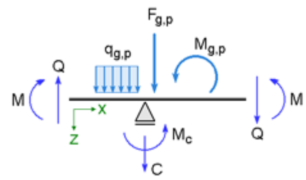
timber grade web (fibre ll) **plywood F40/30**

d = 20.0 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} : 60.000 cm^2
moment of inertia I_{flange} : 4500.000 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} : 64.000 cm^2
moment of inertia I_{flange} : 341.333 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	-	32.0

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	-0.0	1251	0.5325	-110.0	1251	0.5325	110.0	1.1803E12	0.5739

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	834	0.4316	-110.0	834	0.4316	110.0	1.0084E12	91675144.00	15.00	46.55

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	455	0.3606	-110.0	455	0.3606	110.0	6.4070E11	79213616.00	15.00	47.07

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	60.00	300.00	4500.00	64.00	85.33	341.33	64.00	85.33	341.33

6. Fasteners

section 1 from x_A = 0.00 m to x_E = 4.50
nail, 3.8 x 100.0 mm, d_k = 20.0 mm, not predrilled
2-row with a_1 = **64.0 mm**
2 - row with a_2 = 30.0 mm, simplified verification acc. to NA.8.2.4
nail ends in timber member 2, 2 shear plane(s), penetration depth t = 40 mm > 4 d = 15 mm
f_{uk} = 600 N/mm^2, M_{yk} = 5790 Nmm
K_{ser} = 1251 N/mm, γ_M = 1.10, **R_k = 1116.0 N, all values per shear plane**

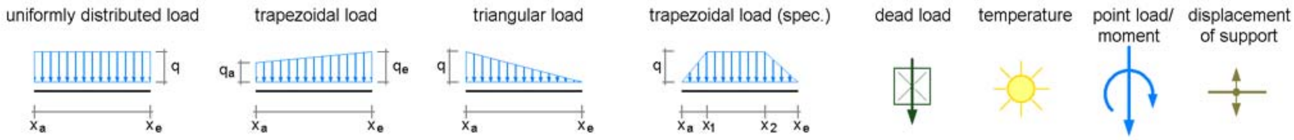
7. Supports

coordinates of supports

supp.name	x	width	depth	cF	cM	restraint	
	m	mm	mm	kN/m	kNm/-	(F)	(M)
A	0.00	150	20	fix	----	X	-
B	4.50	150	20	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

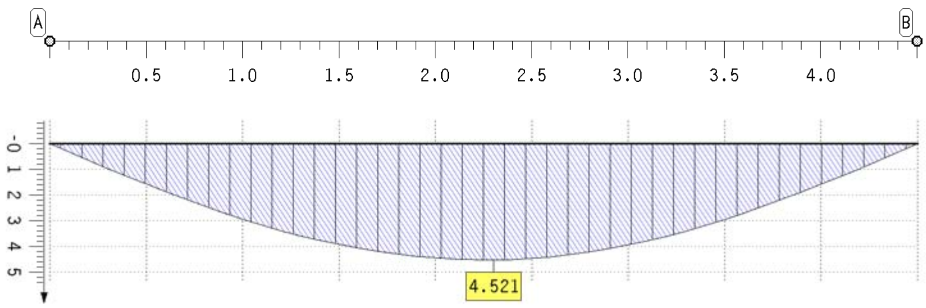
1: EC 5 load-carrying capacity

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)



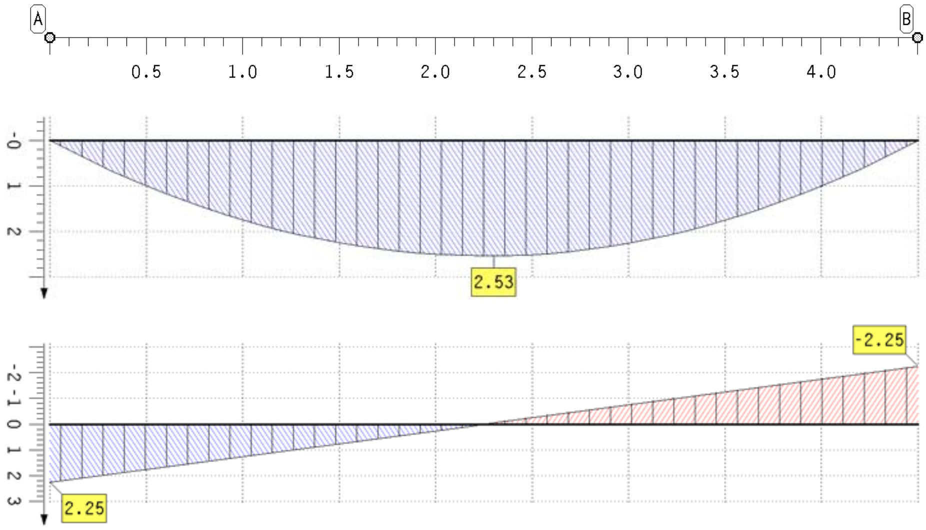
deflection
main beam
characteristic
w in mm
Min: -0.00
Max: 4.52

extremal deflections of main beam (characteristic)

point	x	min w	max w
-	m	mm	mm
A	0.000	0.00	0.00
	1.200	3.38	3.38
	2.200	4.52	4.52
	3.200	3.58	3.58

point	x	min w	max w
-	m	mm	mm
B	4.500	-0.00	-0.00
minimum		**-0.00**	**-0.00**
maximum		**4.52**	**4.52**

extremal internal forces



flexural moment
main beam
M in kNm
Min: 0.00
Max: 2.53

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

extremal internal forces

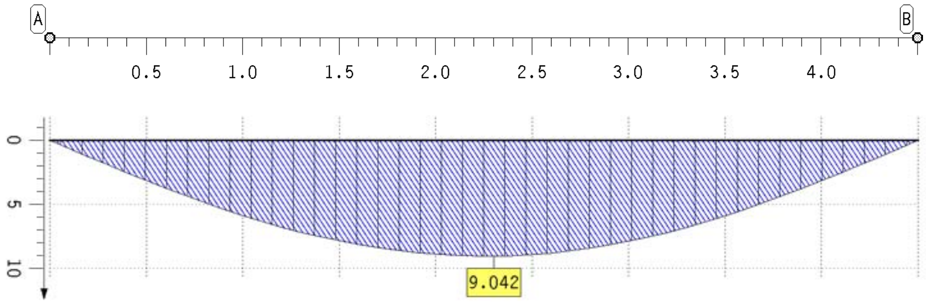
point	x	min M	max M	min V	max V
-	m	kNm	kNm	kN	kN
A	0.000	0.00	0.00	2.25	2.25
	1.100	1.87	1.87	1.15	1.15
	2.200	2.53	2.53	0.05	0.05
	3.400	1.87	1.87	-1.15	-1.15
B	4.500	0.00	0.00	-2.25	-2.25
minimum		**0.00**	**0.00**	**-2.25**	**-2.25**
maximum		**2.53**	**2.53**	**2.25**	**2.25**

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)

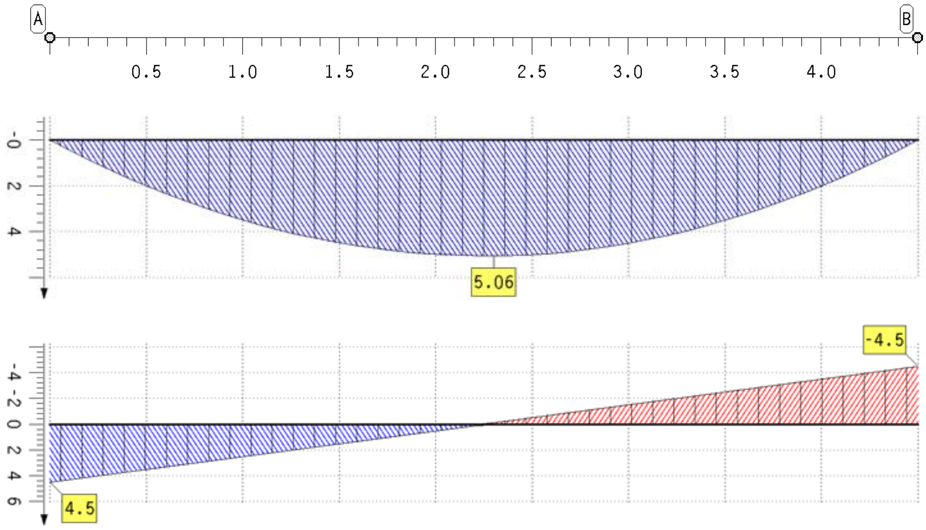


deflection
main beam
characteristic
w in mm
Min: -0.00
Max: 9.04

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	6.77
	2.200	0.00	9.04
	3.200	0.00	7.17
B	4.500	-0.00	-0.00
minimum		**-0.00**	**0.00**
maximum		**0.00**	**9.04**

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**

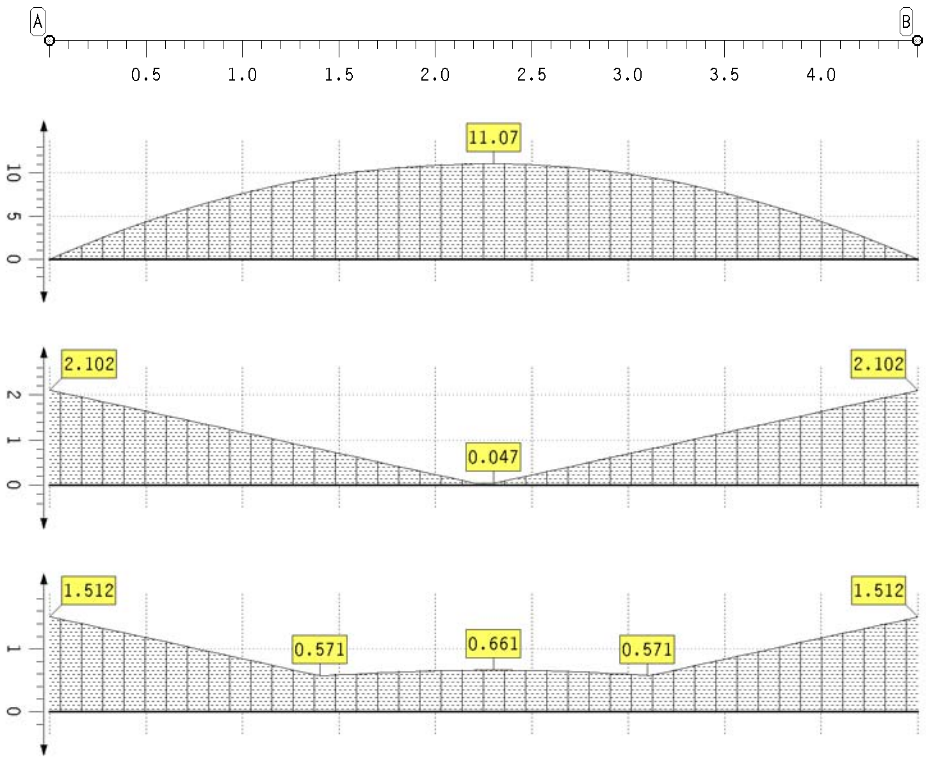
extremal support forces

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

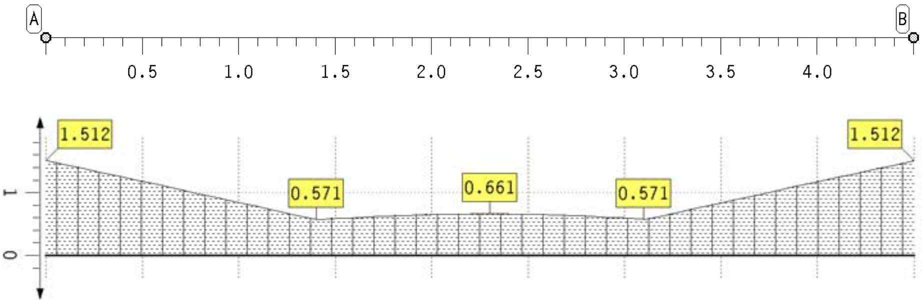


bending stress
main beam
σ_h in MN/m^2
Max: 11.07

shear stress
main beam
τ_h in MN/m^2
Max: 2.10

utilization
main beam
Max: 1.51

results of verification of ultimate limit state



maximal utilization
Max: 1.51

maximal utilization

point	x	U	point	x	U
-	m	-	-	m	-
A	0.000	1.512	B	4.500	1.512
	1.400	0.571	**minimum**		**0.571**
	3.100	0.571	**maximum**		**1.512**

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

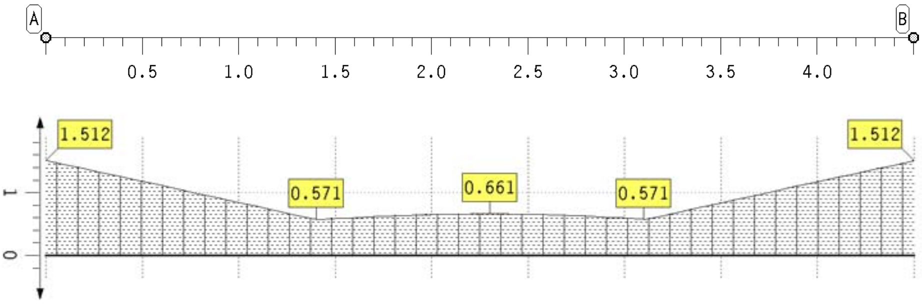
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm²	N		-	N/mm²	N/mm²	-
A	180	3600	9788	1.00	0.80	5.54	2.72	0.49
B	180	3600	9788	1.00	0.80	5.54	2.72	0.49

verification of bearing stresses für den main beam(u = 0.491) successful!

12. Summary

12.1. Summary of all verifications

maximal utilization



utilization
Max: 1.51

maximal utilization

point	x	U	point	x	U
-	m	-	-	m	-
A	0.000	1.512	B	4.500	1.512
	1.400	0.571	**minimum**		**0.571**
	3.100	0.571	**maximum**		**1.512**

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	3600	9788	1.00	0.80	5.54	2.72	0.49
B	180	3600	9788	1.00	0.80	5.54	2.72	0.49

verification of bearing stresses für den main beam(u = 0.491) successful!

13. Utilizations of all verifications

verification of load-carrying capacity (u = 1.512) 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	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	$k_{mod,2}$ -	$\sigma_{m,2}$ 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**	2.10	0.36	0.36
end	0.8	0.00	0.00	0.00	2.08	0.36	0.36

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	-1038	**1.51**	1038	**1.51**
end	-1004	1.46	1004	1.46

14.1.1. Verification of web buckling acc. to DIN EN 1995, 9.1.1(7) with bw/hw = 20/140 mm

Eq. (9.8) $h_w = 14 \leq 70\ b_w = 140$

Eq. (9.9) $V_d = 9.79$ kN ≤ 257.23 kN

resulting utilization at verification point u_{res} = 1.512