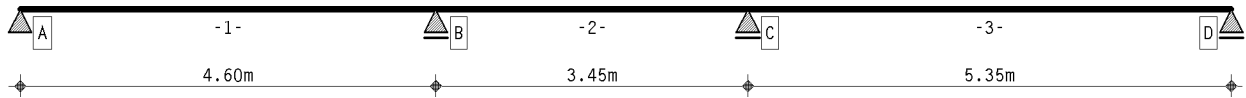


1. Options for Calculations

calculation DIN EN 1995:2010, Germany

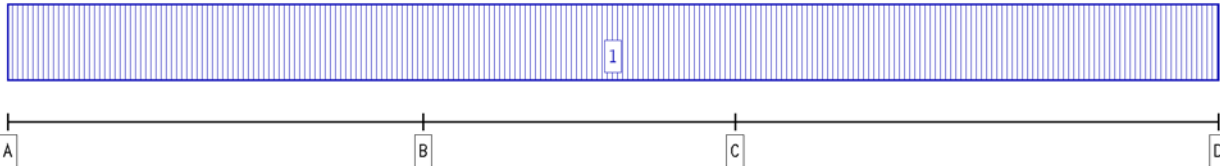
service class 1

2. Structural system



main beam

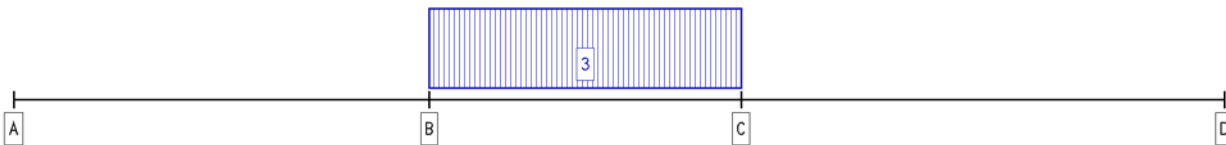
3. Loading



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



action effect 2: live loads (transient, 3 load cases)



D

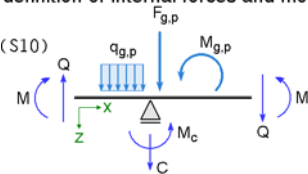


D

4. material parameters

beam Cross	Laminated Timber	userdefined, BSP-GRAZ
structure		34.0-22.0-34.0-22.0-34.0 solid coniferous timber, C24 (S10)
direction of fibre		x-axis (strong axis)
service class		1
beam width/-höhe		b/h = 1000 mm / 146 mm
coeff. thermal expan. timber		0.500 *10 ⁻⁵ /°K
shear coefficient κ		0.243560

definition of internal forces and moments:



5. Beam sections

beam sections

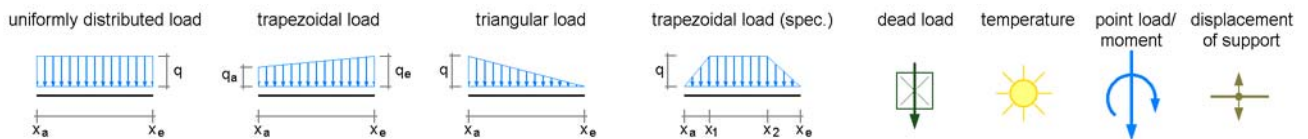
section	x_A m	x_E m	l m	l_v m	cant.11.	EI_{eff} Nmm ²	GA_{eff} N	EA_{eff} N	$EI_{eff,fire}$ Nmm ²	$GA_{eff,fire}$ N	$EA_{eff,fire}$ N	$z_{s,fire}$ mm
1	0.00	4.60	4.60	4.60	-	2453.814	17881190.00	1122000000.	1709.327	15799731.00	968000000.0	66.0
2	0.00	8.05	3.45	3.45	-	2453.814	17881190.00	1122000000.	1709.327	15799731.00	968000000.0	66.0
3	0.00	13.40	5.35	5.35	-	2453.814	17881190.00	1122000000.	1709.327	15799731.00	968000000.0	66.0

6. Supports

coordinates of supports

supp.name	x m	width mm	depth mm	cF kN/m	cm kNm/-	restraint (F) (M)
A	0.00	100	1000	fix	----	X -
B	4.60	111	1000	fix	----	X -
C	8.05	111	1000	fix	----	X -
D	13.40	100	1000	fix	----	X -

7. Action effects



Permanent action effect: permanent loads

1. additive load case: EG

⇒ unif.distr.load: $q = 2.50$ kN/m from $x_a = 0.00$ m to $x_e = 13.40$ m

2. **Transient action effect: live loads**

2. additive load case: live loads (F1)

⇒ unif.distr.load: $q = 2.00$ kN/m from $x_a = 0.00$ m to $x_e = 4.60$ m

3. additive load case: live loads (F2)

⇒ unif.distr.load: $q = 2.00$ kN/m from $x_a = 4.60$ m to $x_e = 8.05$ m

4. additive load case: live loads (F3)

⇒ unif.distr.load: $q = 2.00$ kN/m from $x_a = 8.05$ m to $x_e = 13.40$ m

8. verifications

1: EC 5 load-carrying capacity

buckling analysis of compression flange acc. to DIN EN 1995, 6.3.2 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

3: EC 5 fire protection

fire resistance duration $t_f = 80$ min

side	protected	t_{ch}	$t_f = t_{ch}$	t_f	k_2	d_{ef}
bottom	-	-	-	-	-	7.00
top	-	-	-	-	-	7.00

Extreme rule 1: standardkombination

4: EC 5 Verification of vibration

verification of vibration acc. to DIN EN 1995-1-1, 7.3

value acc. to DIN EN 1995-1-1, 7.3.3, figure 7.2: $a = 1.00$ mm/kN ⇒ $b = 120.00$

modal damping ratio $\xi = 0.04$

numeric calculation with Fourier series

Attention! Gelenke bleiben unberücksichtigt

Federn werden nur in den Zwischenlagern berücksichtigt

in consideration of shear deformation

Poisson's ratio $\nu = 0.00$, torsionstiffness = 50.0 %

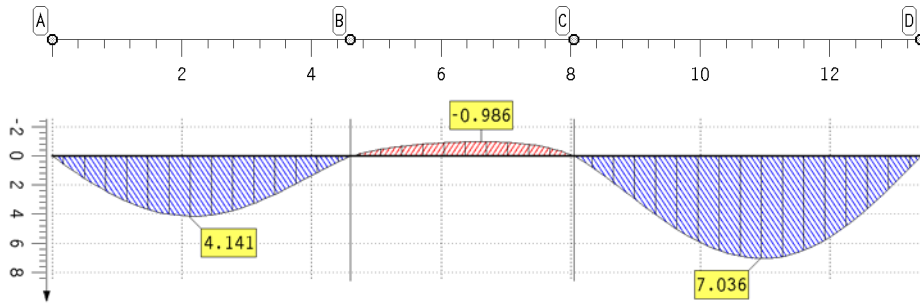
80 mm, $E = 25000$ N/mm², $g = 0.220$ kN/mm², $I_{screed} = 43$ mm⁴

in consideration of 2-dimensional effects

9. Results of load cases

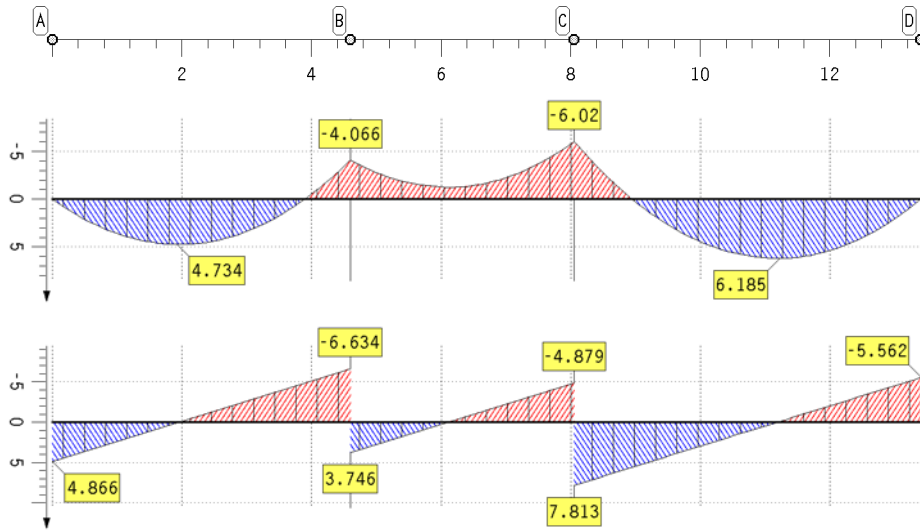
9.1. Action effect 1: load case 1: EG

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.99
Max: 7.04

internal forces and moments



flexural moment
main beam
M in kNm
Min: -6.02
Max: 6.19

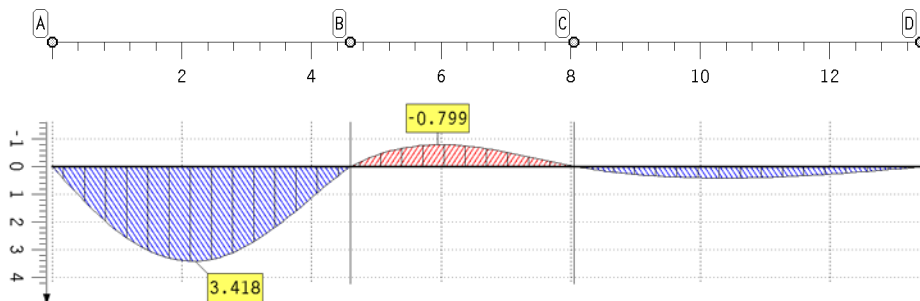
shear force
main beam
V in kN
Min: -6.63
Max: 7.81

support forces

point	x m	AP kN
A	0.000	-4.87
B	4.600	-10.38
C	8.050	-12.69
D	13.400	-5.56

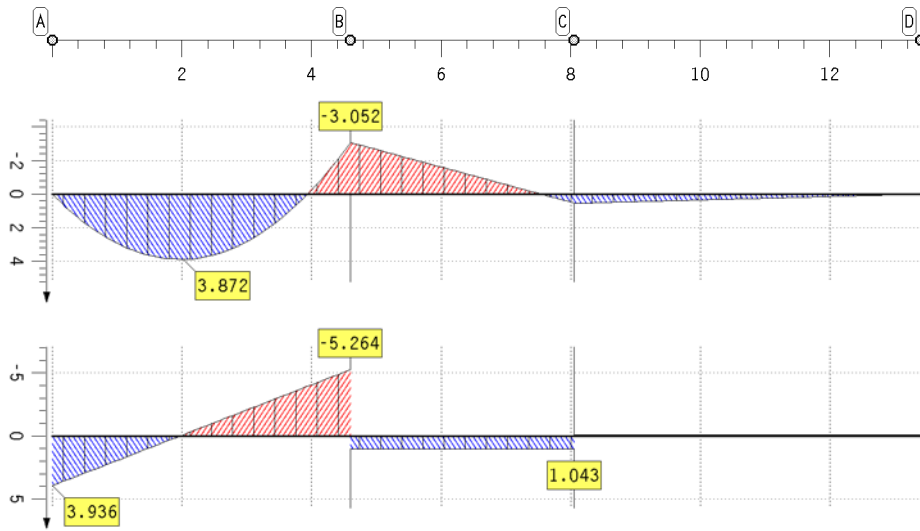
9.2. Action effect 2: load case 2: live loads (F1)

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.80
Max: 3.42

internal forces and moments



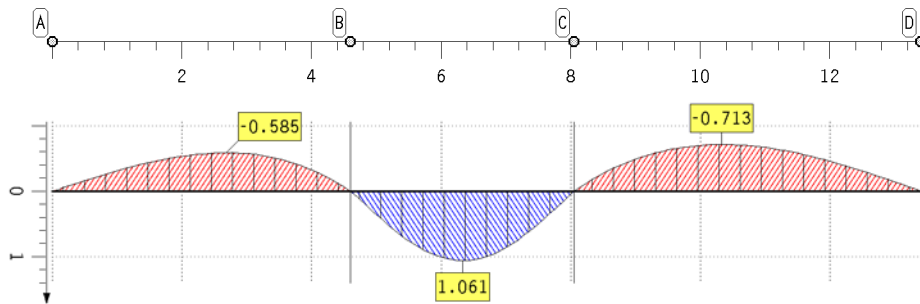
flexural moment
main beam
M in kNm
Min: -3.05
Max: 3.87

shear force
main beam
V in kN
Min: -5.26
Max: 3.94

support forces

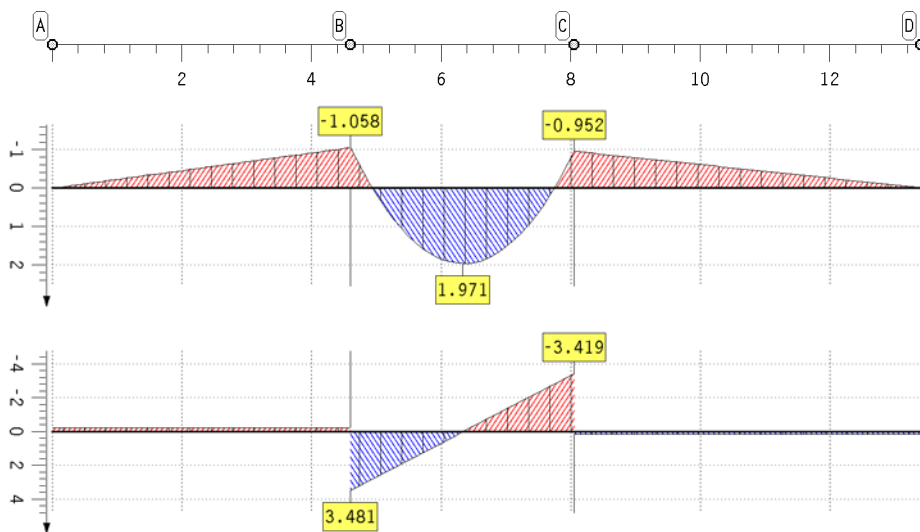
point	x m	AP kN
A	0.000	-3.94
B	4.600	-6.31
C	8.050	1.14
D	13.400	-0.10

9.3. Action effect 2: load case 3: live loads (F2)
deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.71
Max: 1.06

internal forces and moments



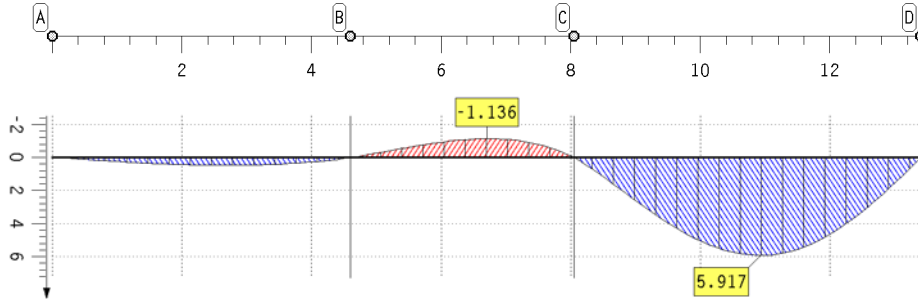
flexural moment
main beam
M in kNm
Min: -1.06
Max: 1.97

shear force
main beam
V in kN
Min: -3.42
Max: 3.48

support forces

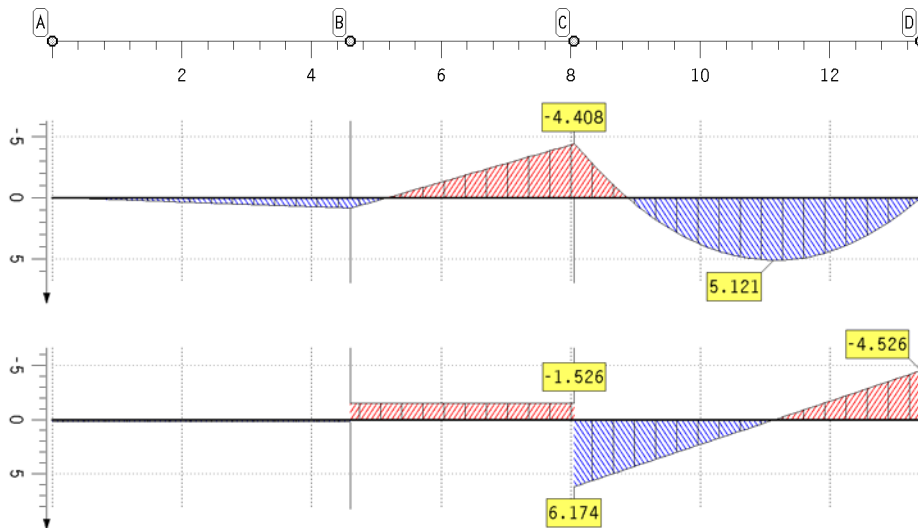
point	x m	AP kN
A	0.000	0.23
B	4.600	-3.71
C	8.050	-3.60
D	13.400	0.18

9.4. Action effect 2: load case 4: live loads (F3)
deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -1.14
Max: 5.92

internal forces and moments



flexural moment
main beam
M in kNm
Min: -4.41
Max: 5.12

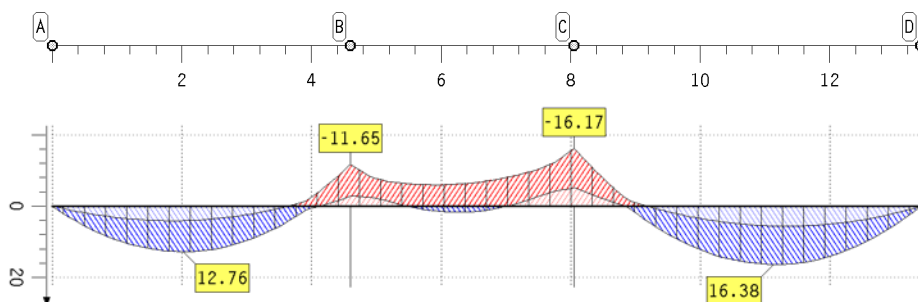
shear force
main beam
V in kN
Min: -4.53
Max: 6.17

support forces

point	x m	AP kN
A	0.000	-0.19
B	4.600	1.71
C	8.050	-7.70
D	13.400	-4.53

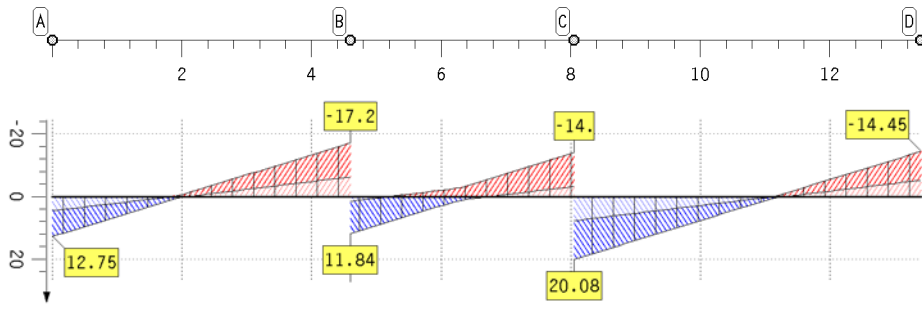
10. Results of verification of ultimate limit state

10.1. Verification of ultimate limit state
extremal internal forces



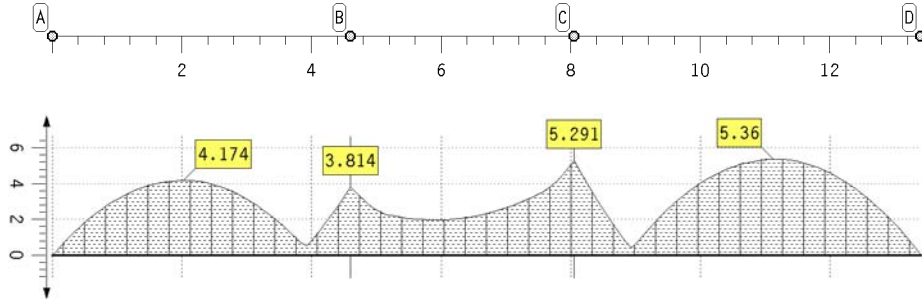
flexural moment
main beam
M in kNm
Min: -16.17
Max: 16.38

extremal internal forces

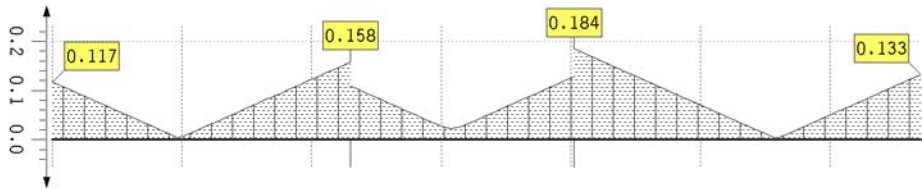


shear force
main beam
V in kN
Min: -17.20
Max: 20.08

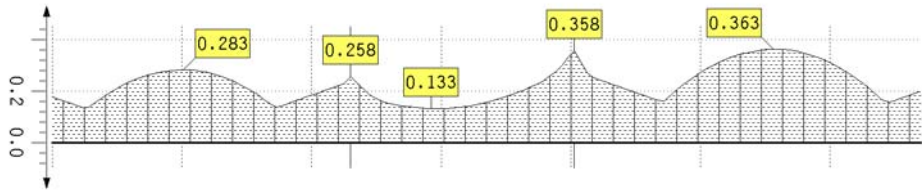
results of verification of ultimate limit state



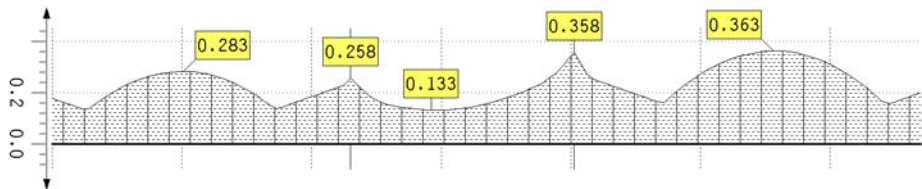
bending stress
main beam
 σ_h in MN/m²
Max: 5.36



shear stress
main beam
 τ_h in MN/m²
Max: 0.18



utilization
main beam
Max: 0.36



maximal
utilization
Max: 0.36

verification of ultimate limit state of main beam

point	x m	$k_{mod,h}$	σ_h MN/m ²	τ_h MN/m ²	U_h	point	x m	$k_{mod,h}$	σ_h MN/m ²	τ_h MN/m ²	U_h
A	0.000	0.000	0.00	0.12	0.177	C	7.475	0.000	3.36	0.09	0.228
	0.479	0.000	1.76	0.09	0.135		8.050	0.000	5.29	0.13	0.358
	1.246	0.000	3.58	0.04	0.242		8.050	0.000	5.29	0.18	0.358
	1.917	0.000	4.17	0.00	0.282		8.347	0.000	3.43	0.17	0.252
	2.013	0.000	4.17	0.01	0.283		8.942	0.000	0.41	0.13	0.200
	2.683	0.000	3.69	0.05	0.250		9.437	0.000	2.36	0.10	0.160
	3.450	0.000	1.98	0.09	0.137		10.230	0.000	4.51	0.06	0.305
	3.929	0.000	0.52	0.12	0.179		11.121	0.000	5.36	0.00	0.363
	4.504	0.000	3.28	0.15	0.230		11.914	0.000	4.72	0.05	0.320
	4.600	0.000	3.81	0.16	0.258		12.905	0.000	2.09	0.10	0.157
B	4.600	0.000	3.81	0.11	0.258	D	13.400	0.000	0.00	0.13	0.200
	5.079	0.000	2.38	0.08	0.161		minimum	0.000	0.00	0.00	0.133
	5.846	0.000	1.96	0.04	0.133	maximum	0.000	5.36	0.18	0.363	
	6.133	0.000	2.00	0.02	0.135						



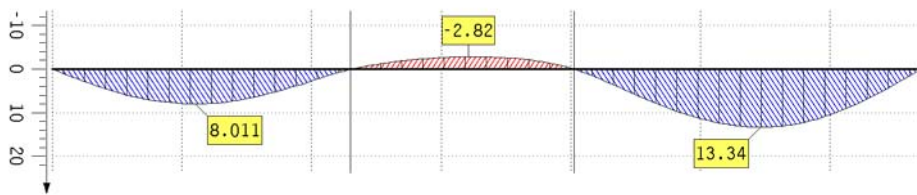
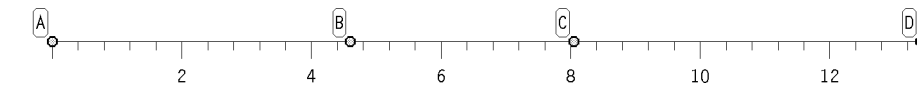
maximal utilization

point	x	U	point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-	-	m	-
A	0.000	0.177		4.504	0.230		7.762	0.275		11.121	0.363
	0.479	0.135	B	4.600	0.258	C	8.050	0.358		11.914	0.320
	1.342	0.252	B	4.600	0.258	C	8.050	0.358		12.905	0.157
	2.013	0.283		5.079	0.161		8.347	0.252	D	13.400	0.200
	2.683	0.250		5.846	0.133		9.437	0.160	minimum		0.133
	3.450	0.137		7.283	0.206		10.230	0.305	maximum		0.363

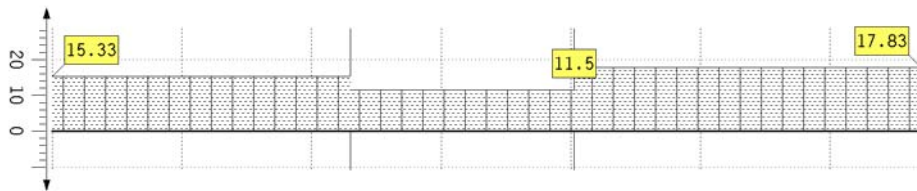
11. Results of verification of deflections

11.1. Verification of deflections

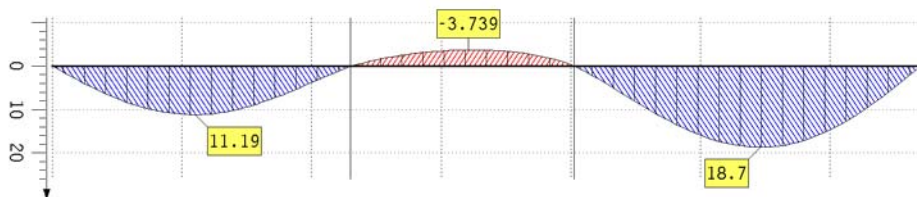
results of verification of deflections



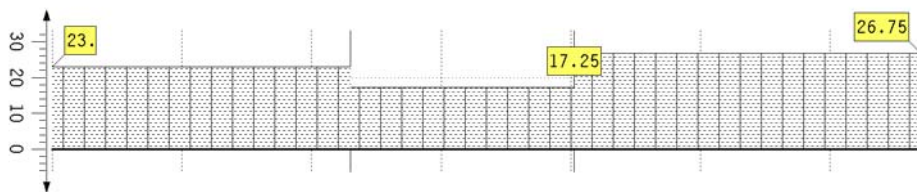
extremal deflections
Winst
in mm
Min: -2.82
Max: 13.34



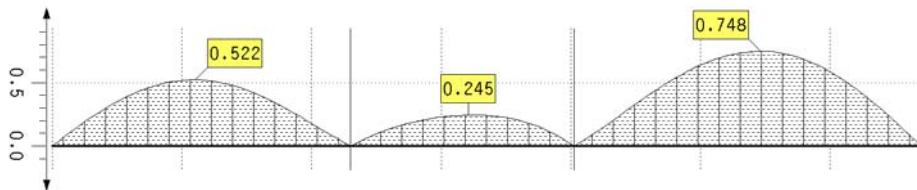
decisive deflection
Winst, req
in mm
Min: 11.50
Max: 17.83



extremal deflections
Wfin
in mm
Min: -3.74
Max: 18.70



decisive deflection
Wfin, req
in mm
Min: 17.25
Max: 26.75



maximal utilization
Max: 0.75

verification of deflections

point	x	min/max/req w _{inst}			min/max/req w _{fin}			min/max/req w _{net, fin}			U
		mm	mm	mm	mm	mm	mm	mm	mm	mm	
A	0.000	0.00	0.00	15.33	0.00	0.00	23.00	----	----	----	0.000
	1.246	0.00	6.36	15.33	0.00	8.89	23.00	----	----	----	0.415
	2.204	0.00	8.01	15.33	0.00	11.19	23.00	----	----	----	0.522
	3.162	0.00	6.24	15.33	0.00	8.69	23.00	----	----	----	0.407
B	4.600	0.00	0.00	15.33	0.00	0.00	23.00	----	----	----	0.000
B	4.600	0.00	0.00	11.50	0.00	0.00	17.25	----	----	----	0.000
	5.367	-1.88	0.00	11.50	-2.50	0.00	17.25	----	----	----	0.164
	5.846	-2.52	0.08	11.50	-3.34	0.00	17.25	----	----	----	0.219
	6.133	-2.74	0.10	11.50	-3.63	0.00	17.25	----	----	----	0.238



verification of deflections

point	x m	min/max/req w_{inst}			min/max/req w_{fin}			min/max/req $w_{net,fin}$			U
		mm	mm	mm	mm	mm	mm	mm	mm	mm	
	6.421	-2.82	0.08	11.50	-3.74	0.00	17.25	----	----	----	0.245
	6.804	-2.71	0.00	11.50	-3.61	0.00	17.25	----	----	----	0.236
	7.475	-1.79	0.00	11.50	-2.41	0.00	17.25	----	----	----	0.155
C	8.050	0.00	0.00	11.50	0.00	0.00	17.25	----	----	----	0.000
C	8.050	0.00	0.00	17.83	0.00	0.00	26.75	----	----	----	0.000
	9.833	0.00	10.69	17.83	0.00	14.94	26.75	----	----	----	0.599
	10.923	0.00	13.34	17.83	0.00	18.70	26.75	----	----	----	0.748
	12.013	0.00	10.37	17.83	0.00	14.56	26.75	----	----	----	0.582
D	13.400	0.00	0.00	17.83	0.00	0.00	26.75	----	----	----	0.000
minimum		-2.82	0.00	11.50	-3.74	0.00	17.25	0.00	0.00	0.00	0.000
maximum		0.00	13.34	17.83	0.00	18.70	26.75	0.00	0.00	0.00	0.748

12. Verification of vibrationergebnisse

12.1. Eigenfrequenz

$EI_{längs} = 3.520481 \text{ MNm}^2/\text{m}$, $EI_{quer} = 1.465644 \text{ MNm}^2/\text{m}$

$f_e = 8.124 \text{ Hz} \geq f_e = 8 \text{ Hz} \Rightarrow$ **Kriterium successful!**

12.2. Einheitsimpuls geschwindigkeit

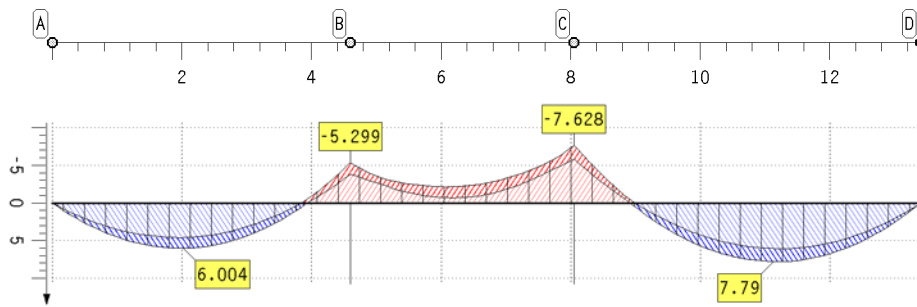
$n_{40} = 4$

$v = 33.6 \text{ mm}/(\text{Ns}^2) \leq v_{grenz} = 39.5 \text{ mm}/(\text{Ns}^2) \Rightarrow$ **Kriterium successful!**

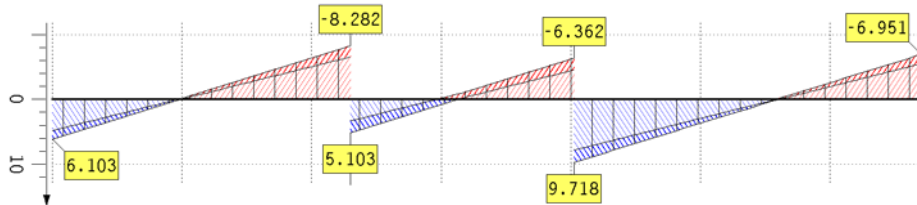
13. Results of verification of fire protection

13.1. Verification of fire protection

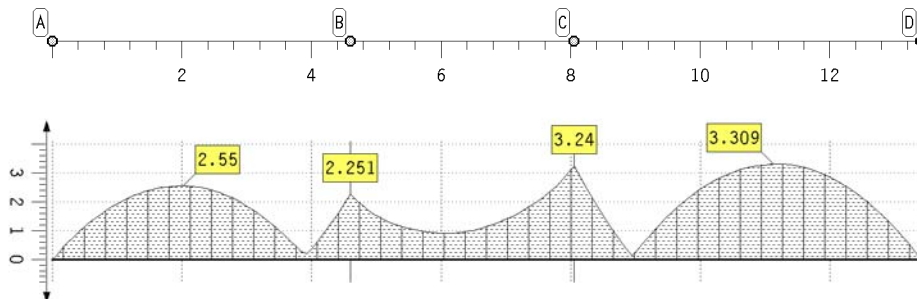
extremal internal forces



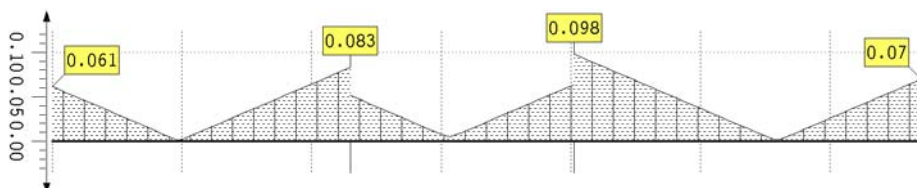
flexural moment
main beam
M in kNm
Min: -7.63
Max: 7.79



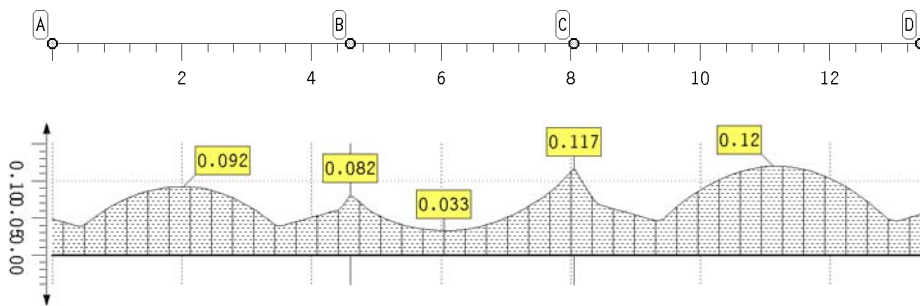
shear force
main beam
V in kN
Min: -8.28
Max: 9.72



bending stress
main beam
 σ_h in MN/m^2
Max: 3.31



shear stress
main beam
 τ_h in MN/m^2
Max: 0.10



utilization
main beam
Max: 0.12

verification of ultimate limit state of main beam

point	x m	k _{mod,h}	σ _h MN/m ²	τ _h MN/m ²	U _h	point	x m	k _{mod,h}	σ _h MN/m ²	τ _h MN/m ²	U _h
A	0.000	0.000	0.00	0.06	0.048						
	0.383	0.000	0.90	0.05	0.039						
	1.246	0.000	2.21	0.02	0.080						
	1.917	0.000	2.55	0.00	0.092						
	2.013	0.000	2.55	0.00	0.092						
	2.683	0.000	2.22	0.02	0.080						
	3.450	0.000	1.11	0.05	0.040						
	3.929	0.000	0.19	0.06	0.049						
	4.408	0.000	1.60	0.08	0.061						
B	4.600	0.000	2.25	0.08	0.082						
B	4.600	0.000	2.25	0.05	0.082						
	5.175	0.000	1.30	0.03	0.047						
	6.037	0.000	0.91	0.01	0.033						
	6.133	0.000	0.91	0.01	0.033						
							7.188	0.000	1.60	0.04	0.058
							8.050	0.000	3.24	0.06	0.117
							8.050	0.000	3.24	0.10	0.117
							8.446	0.000	1.71	0.09	0.067
							8.942	0.000	0.12	0.07	0.055
							9.338	0.000	1.13	0.06	0.045
							10.329	0.000	2.86	0.03	0.104
							11.121	0.000	3.31	0.00	0.120
							11.220	0.000	3.31	0.00	0.120
							12.013	0.000	2.83	0.03	0.102
							13.004	0.000	1.07	0.06	0.045
							D 13.400	0.000	0.00	0.07	0.055
							minimum	0.000	0.00	0.00	0.033
							maximum	0.000	3.31	0.10	0.120

13.2. Eigenfrequenz

$EI_{längs} = 3.520481 \text{ MNm}^2/\text{m}$, $EI_{quer} = 1.465644 \text{ MNm}^2/\text{m}$
 $f_e = 8.124 \text{ Hz} \geq f_e = 8 \text{ Hz} \Rightarrow \text{Kriterium successful!}$

13.3. Steifigkeitskriterium

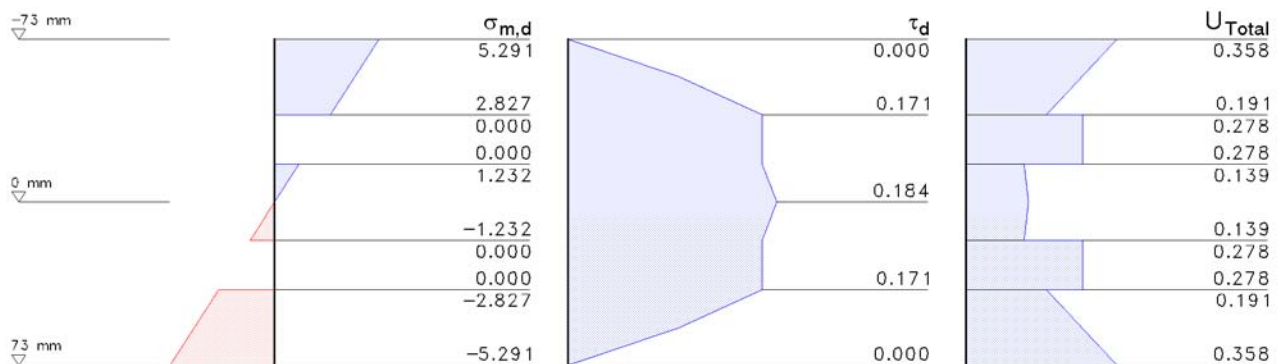
Raumbreite $b = 1.000 \text{ m}$, $b_{ef} = 1.000 \text{ m}$, $x_{max F} = 10.954 \text{ m}$, $x_{max w} = 10.954 \text{ m} \Rightarrow w_{max} = 0.593 \text{ mm}$
 $w(1\text{kN}) = 0.59 \text{ mm} \leq w_{grenz} = 1.0 \text{ mm} \Rightarrow \text{Kriterium successful!}$

13.4. Einheitsimpulsgeschwindigkeit

$n_{40} = 4$
 $v = 33.6 \text{ mm}/(\text{Ns}^2) \leq v_{grenz} = 39.5 \text{ mm}/(\text{Ns}^2) \Rightarrow \text{Kriterium successful!}$

14. Detailed verification piont

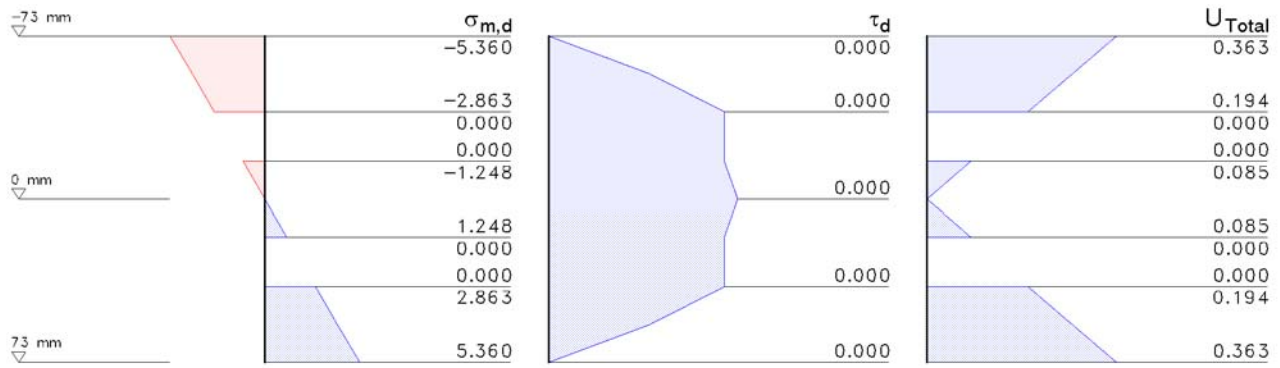
14.1. Verification of load-carrying capacity at $x = 8.05 \text{ m}$, $\max V_d = 20.08 \text{ kN}$, $\min M_d = -16.17 \text{ kNm}$, $\max M_d = -5.20 \text{ kNm}$



mechanical resistance and static terms: stiffness $B_x = 2453.814 \text{ Nmm}$

z mm	ES _x Nmm	σ _{m,d} N/mm ²	f _{m,d} N/mm ²	τ _{v,d} N/mm ²	f _{v,d} N/mm ²	z mm	ES _x Nmm	σ _{m,d} N/mm ²	f _{m,d} N/mm ²	τ _{v,d} N/mm ²	f _{v,d} N/mm ²
73.0	0.000	-5.291	14.77	0.000	1.23	-17.0	-20.944	0.000	14.77	0.171	0.62
56.0	-12.061	-4.059	14.77	0.099	1.23	-28.0	-20.944	0.000	14.77	0.171	0.62
39.0	-20.944	0.000	14.77	0.171	0.62	-39.0	-20.944	2.827	14.77	0.171	1.23
28.0	-20.944	0.000	14.77	0.171	0.62	-56.0	-12.061	4.059	14.77	0.099	1.23
17.0	-20.944	-1.232	14.77	0.171	1.23	-73.0	0.000	5.291	14.77	0.000	1.23
0.0	-22.534	-0.000	14.77	0.184	1.23						

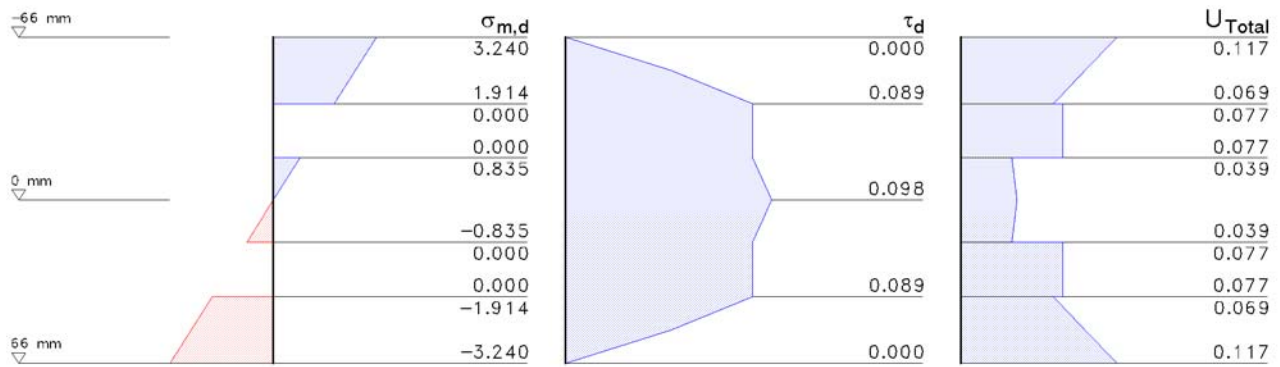
14.2. Verification of load-carrying capacity at $x = 11.12$ m, $\max V_d = 0.50$ kN, $\min M_d = 5.58$ kNm, $\max M_d = 16.38$ kNm



mechanical resistance and static terms: stiffness $B_x = 2453.814$ Nmm

z [mm]	$E S_x$ [Nmm]	$\sigma_{m,d}$ [N/mm ²]	$f_{m,d}$ [N/mm ²]	$\tau_{v,d}$ [N/mm ²]	$f_{v,d}$ [N/mm ²]	z [mm]	$E S_x$ [Nmm]	$\sigma_{m,d}$ [N/mm ²]	$f_{m,d}$ [N/mm ²]	$\tau_{v,d}$ [N/mm ²]	$f_{v,d}$ [N/mm ²]
73.0	0.000	5.360	14.77	0.000	1.23	-17.0	-20.944	0.000	14.77	0.000	0.62
56.0	-12.061	4.112	14.77	0.000	1.23	-28.0	-20.944	0.000	14.77	0.000	0.62
39.0	-20.944	0.000	14.77	0.000	0.62	-39.0	-20.944	-2.863	14.77	0.000	1.23
28.0	-20.944	0.000	14.77	0.000	0.62	-56.0	-12.061	-4.112	14.77	0.000	1.23
17.0	-20.944	1.248	14.77	0.000	1.23	-73.0	0.000	-5.360	14.77	0.000	1.23
0.0	-22.534	0.000	14.77	0.000	1.23						

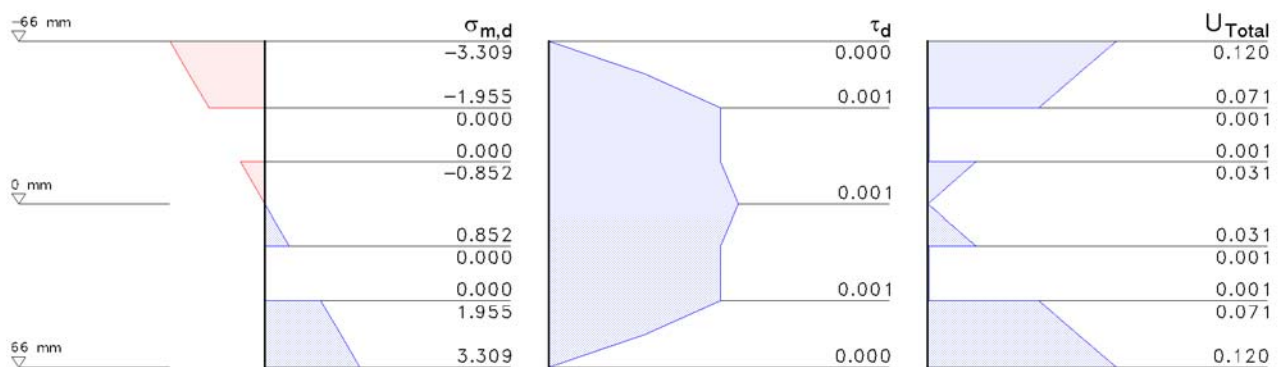
14.3. Resistance to fire at $x = 8.05$ m, $\max V_d = 9.72$ kN, $\min M_d = -7.63$ kNm, $\max M_d = -5.86$ kNm



mechanical resistance and static terms: stiffness $B_x = 1709.327$ Nmm

z [mm]	$E S_x$ [Nmm]	$\sigma_{m,d}$ [N/mm ²]	$f_{m,d}$ [N/mm ²]	$\tau_{v,d}$ [N/mm ²]	$f_{v,d}$ [N/mm ²]	z [mm]	$E S_x$ [Nmm]	$\sigma_{m,d}$ [N/mm ²]	$f_{m,d}$ [N/mm ²]	$\tau_{v,d}$ [N/mm ²]	$f_{v,d}$ [N/mm ²]
66.0	0.000	-3.240	27.60	0.000	2.30	-17.0	-15.592	0.000	27.60	0.089	1.15
52.5	-8.799	-2.577	27.60	0.050	2.30	-28.0	-15.592	0.000	27.60	0.089	1.15
39.0	-15.592	0.000	27.60	0.089	1.15	-39.0	-15.592	1.914	27.60	0.089	2.30
28.0	-15.592	0.000	27.60	0.089	1.15	-52.5	-8.799	2.577	27.60	0.050	2.30
17.0	-15.592	-0.835	27.60	0.089	2.30	-66.0	0.000	3.240	27.60	0.000	2.30
0.0	-17.182	-0.000	27.60	0.098	2.30						

14.4. Resistance to fire at $x = 11.12$ m, $\max V_d = 0.20$ kN, $\min M_d = 6.06$ kNm, $\max M_d = 7.79$ kNm



mechanical resistance and static terms: stiffness $B_x = 1709.327 \text{ Nmm}$

z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm ²	$f_{m,d}$ N/mm ²	$\tau_{v,d}$ N/mm ²	$f_{v,d}$ N/mm ²	z mm	ES_x Nmm	$\sigma_{m,d}$ N/mm ²	$f_{m,d}$ N/mm ²	$\tau_{v,d}$ N/mm ²	$f_{v,d}$ N/mm ²
66.0	0.000	3.309	27.60	0.000	2.30	-17.0	-15.592	0.000	27.60	0.001	1.15
52.5	-8.799	2.632	27.60	0.001	2.30	-28.0	-15.592	0.000	27.60	0.001	1.15
39.0	-15.592	0.000	27.60	0.001	1.15	-39.0	-15.592	-1.955	27.60	0.001	2.30
28.0	-15.592	0.000	27.60	0.001	1.15	-52.5	-8.799	-2.632	27.60	0.001	2.30
17.0	-15.592	0.852	27.60	0.001	2.30	-66.0	0.000	-3.309	27.60	0.000	2.30
0.0	-17.182	0.000	27.60	0.001	2.30						