

1. Options for Calculations

calculation DIN EN 1995:2010, Germany

service class 1

coefficients of thermal expansion: timber $\alpha_t = 0.500 \cdot 10^{-5}/^{\circ}\text{K}$, steel $\alpha_t = 1.200 \cdot 10^{-5}/^{\circ}\text{K}$

2. Structural system



reinforcement left side

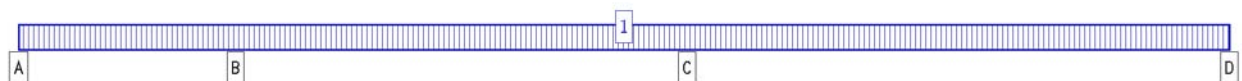


main beam



reinforcement right side

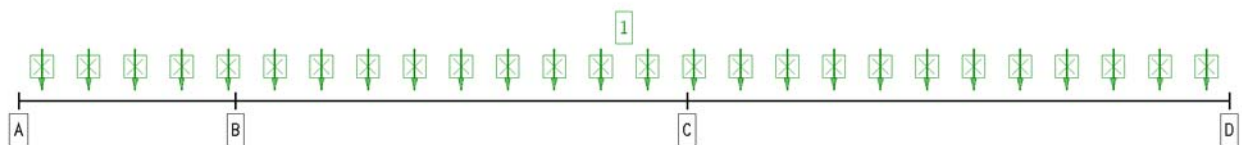
3. Loading



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



D



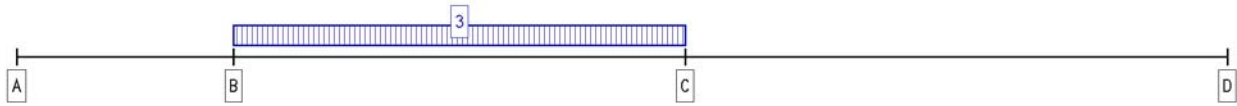
D



D



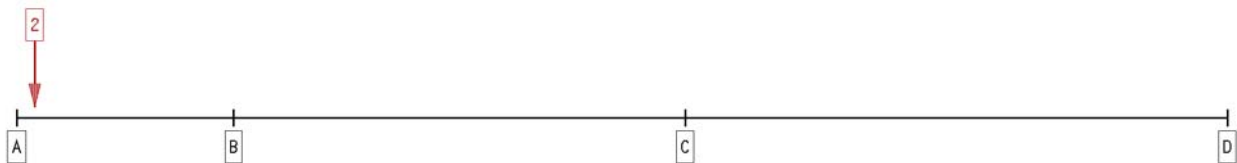
action effect 2: live loads (transient, 3 load cases)



D



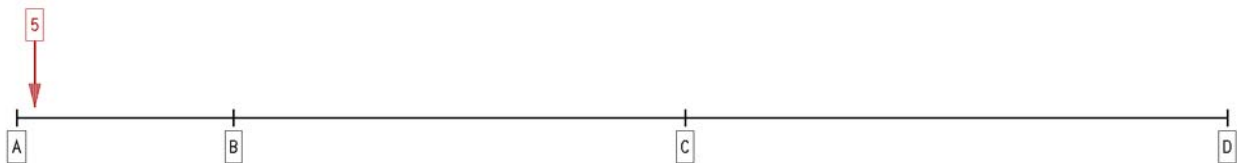
D



D



action effect 3: snow (transient, 1 load cases)



D

4. material parameters

timber grade main beam	solid coniferous timber, C24 (S10)
service class	1
beam width	$b = 120 \text{ mm}$
coeff. therm.expan. timber:	$0.500 \cdot 10^{-5} / ^\circ\text{K}$
coeff. thermal expan. steel:	$1.200 \cdot 10^{-5} / ^\circ\text{K}$
char. bend. strength $f_{m,k}$	24.0 N/mm^2
char. shear strength $f_{v,k}$	4.0 N/mm^2
modulus of elast. $E_{0,mean}$	11000 N/mm^2
k_{cr}	$0.50 \text{ mm}^2/\text{N}$

definition of internal forces and moments:



5. Beam sections

main beam sections

section	x_A m	x_E m	l m	l_{ef} m	k_m -	l_v m	cantil.	$h_{main\ beam}$ mm
1	0.00	1.20	1.20	2.00	1.0000	1.20	x	200
2	1.20	3.70	2.50	2.00	1.0000	2.50	x	200
3	3.70	6.70	3.00	4.00	1.0000	3.00	-	200

sections with reinforcements

section	reinforcement left side	reinforcement right side
1	steel plate S235 U120	steel plate S235 U120
2	steel plate S235 U120	steel plate S235 U120
3	-	-

6. Fastener data

section 1 from $x_A = 0.00$ m to $x_E = 1.20$

bolt 10 mm, FK 4.6

1 - row, simplified verification acc. to NA.8.2.5

$f_{uk} = 400$ N/mm², $M_{yk} = 47773$ Nmm

$K_{ser} = 7485$ N/mm, $\gamma_M = 1.10$, $R_k = 4728.3$ N, all values per shear plane

coordinates of connectors section 1

Nr.	x_{Abs} m	x_D m
1	0.200	0.200
2	0.600	0.600
3	1.000	1.000

section 2 from $x_A = 1.20$ m to $x_E = 3.70$

bolt 10 mm, FK 4.6

1 - row, simplified verification acc. to NA.8.2.5

$f_{uk} = 400$ N/mm², $M_{yk} = 47773$ Nmm

$K_{ser} = 7485$ N/mm, $\gamma_M = 1.10$, $R_k = 4728.3$ N, all values per shear plane

coordinates of connectors section 2

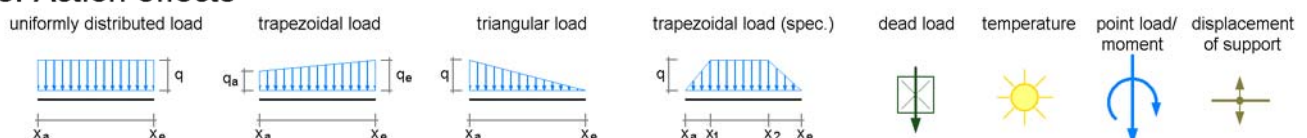
Nr.	x_{Abs} m	x_D m	Nr.	x_{Abs} m	x_D m
1	0.200	1.400	4	1.400	2.600
2	0.600	1.800	5	1.800	3.000
3	1.000	2.200	6	2.200	3.400

7. Supports

coordinates of supports

supp.name	x m	CF kN/m	CM kNm/-	left reinf. (F) (M)	main beam (F) (M)	right reinf. (F) (M)
B	1.20	fix	----	- -	X -	- -
C	3.70	fix	----	- -	X -	- -
D	6.70	fix	----	- -	X -	- -

8. Action effects



Permanent action effect: permanent loads

1. additive load case: dead load (1)

- unif.distr.load (main beam): $q = 2.00$ kN/m from $x_A = 0.00$ m to $x_E = 6.70$ m
- point load (main beam): $F = 3.00$ kN at $x = 0.10$ m
- unif.distr.load (main beam): $q = 1.50$ kN/m from $x_A = 3.20$ m to $x_E = 4.20$ m
- dead load (main beam): $\gamma = 6.00$ kN/m³ from $x_A = 0.00$ m to $x_E = 6.70$ m

2. Transient action effect: live loads

2. additive load case: span 1

- unif.distr.load (main beam): $q = 1.20$ kN/m from $x_A = 0.00$ m to $x_E = 1.20$ m
- point load (main beam): $F = 2.00$ kN at $x = 0.10$ m

3. additive load case: span 2

- unif.distr.load (main beam): $q = 1.20$ kN/m from $x_A = 1.20$ m to $x_E = 3.70$ m

4. additive load case: span 3

- unif.distr.load (main beam): $q = 1.20$ kN/m from $x_A = 3.70$ m to $x_E = 6.70$ m

3. Transient action effect: snow

5. additive load case: snow

- unif.distr.load (main beam): $q = 1.00 \text{ kN/m}$ from $x_a = 3.20 \text{ m}$ to $x_e = 4.20 \text{ m}$
- point load (main beam): $F = 2.00 \text{ kN}$ at $x = 0.10 \text{ m}$

9. verifications

1: EC 5 load-carrying capacity

safety against overturning 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 $t_f = 30 \text{ min}$

combustion depth $d_f = 2.40 \text{ cm}$

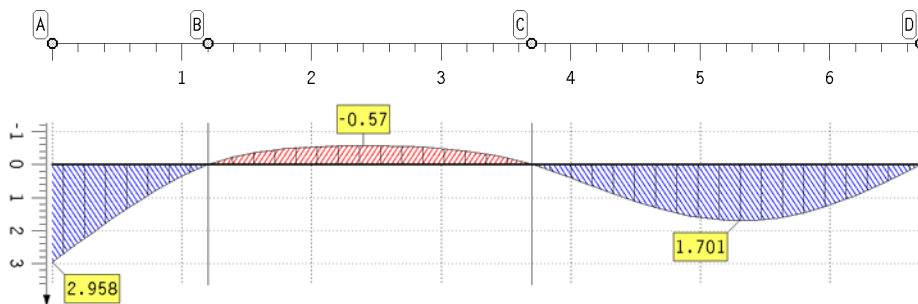
Abbrand 4-seitig

Extreme rule 1

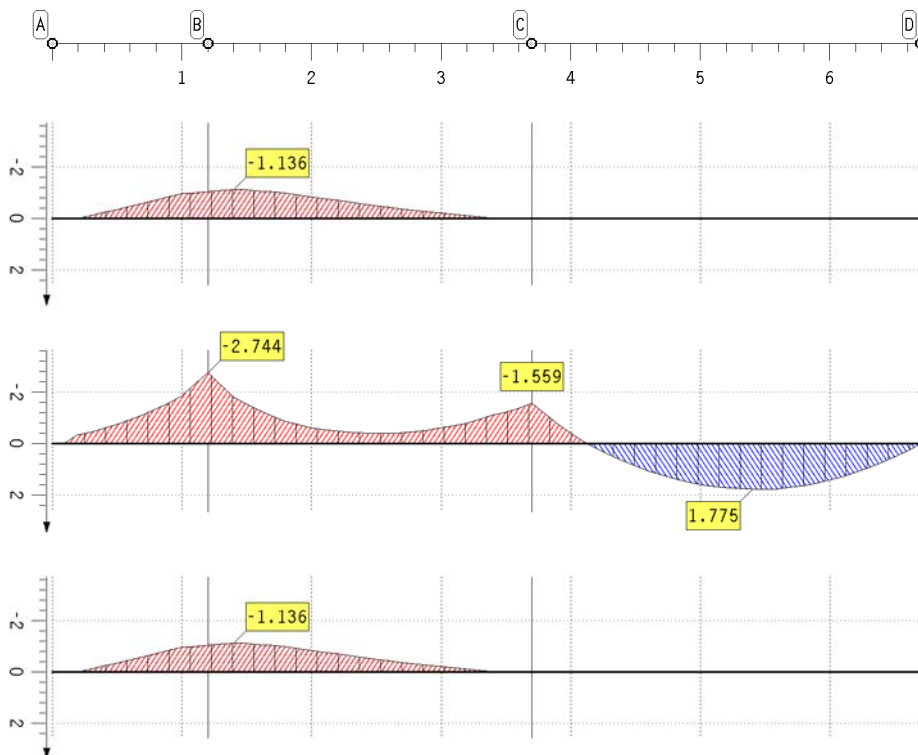
10. Results of load cases

10.1. Action effect 1: load case 1: dead load (1)

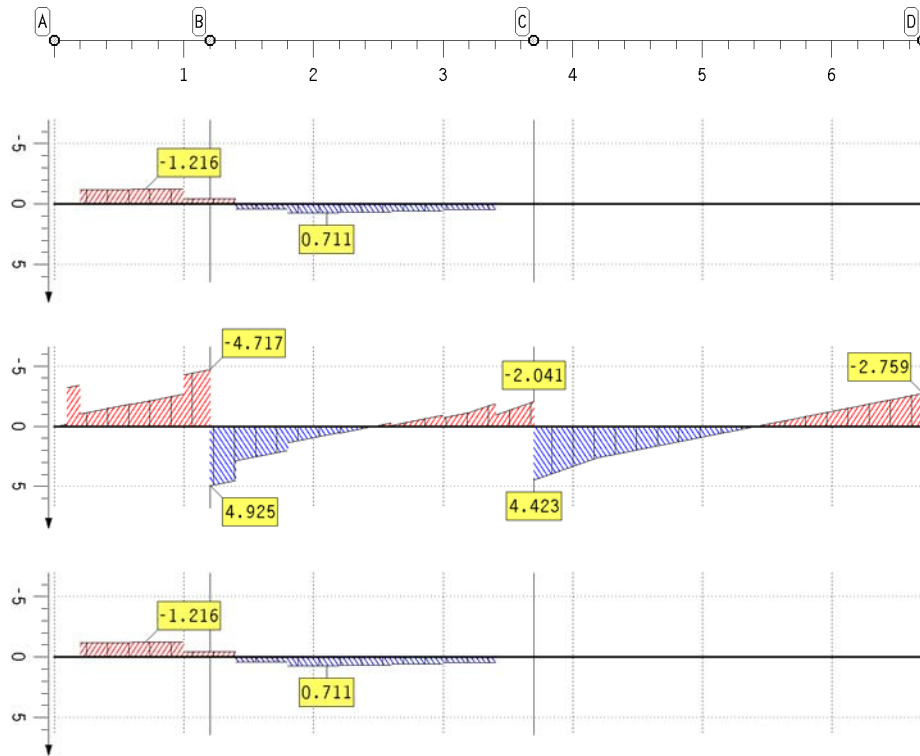
deflections of main beam (characteristic)



internal forces and moments



internal forces and moments



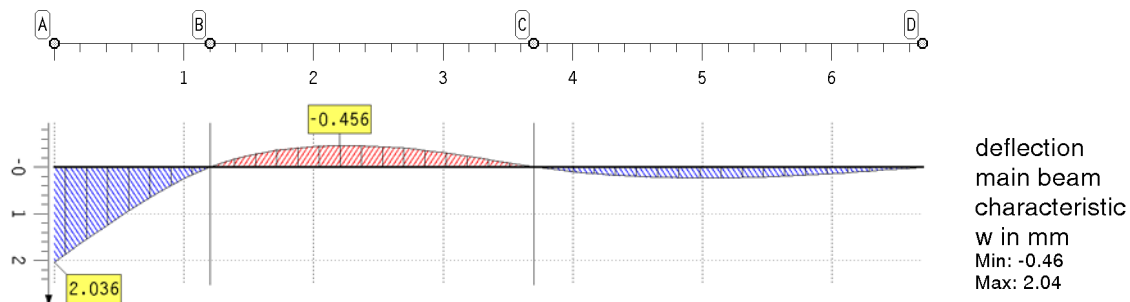
support forces

point	x m	AP kN	AP _l kN	AP _r kN	ΣAP kN
B	1.200	-9.64	-0.00	-0.00	-9.64
C	3.700	-6.46	0.00	0.00	-6.46
D	6.700	-2.76	-----	-----	-2.76

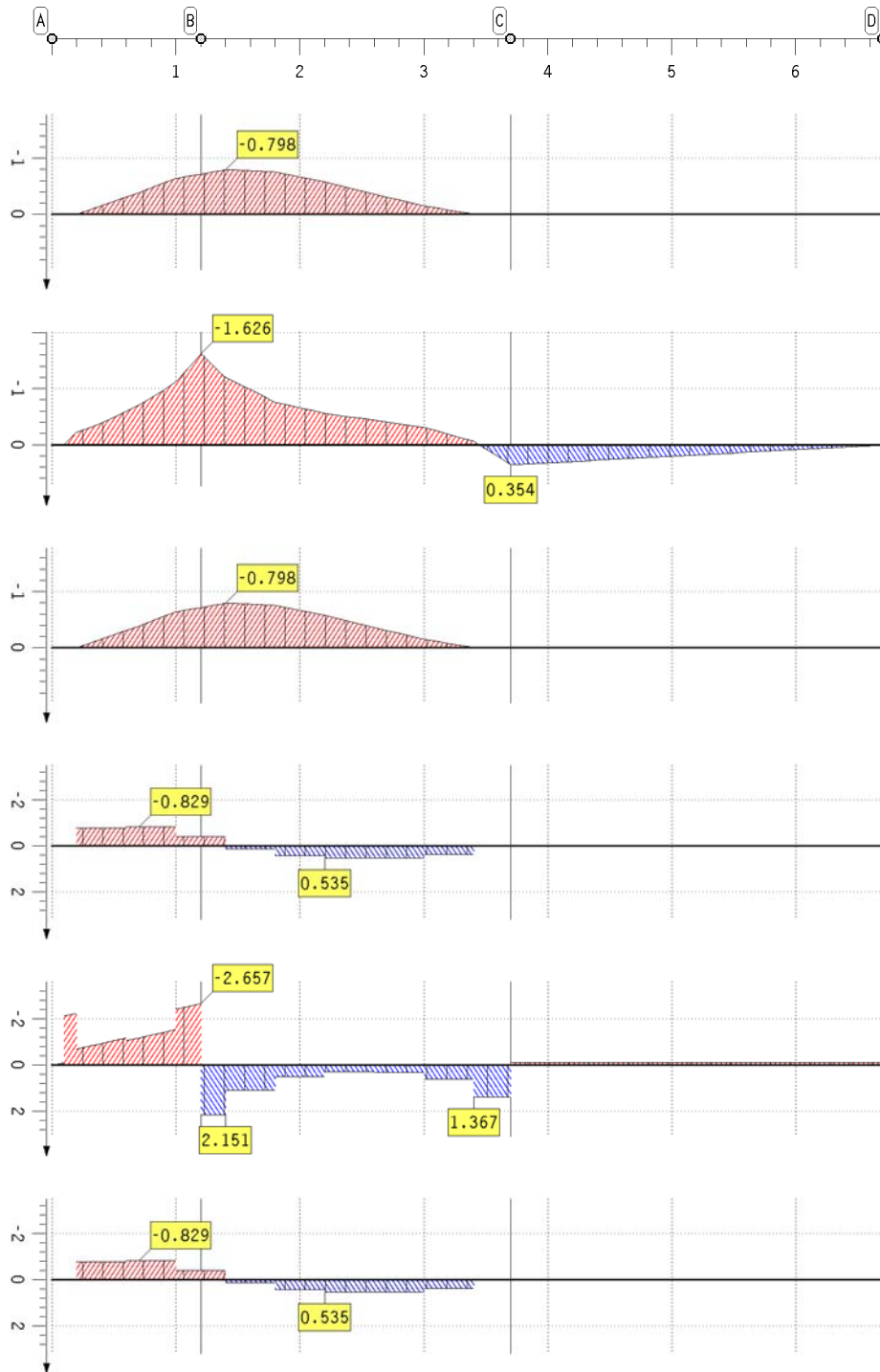
connector reactions

x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm	x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm
0.200	1.20	0.00	1.20	0.00	2.200	0.03	0.00	0.03	0.00
0.600	0.02	0.00	0.02	0.00	2.600	0.10	0.00	0.10	0.00
1.000	-0.79	0.00	-0.79	0.00	3.000	0.10	0.00	0.10	0.00
1.400	-0.83	0.00	-0.83	0.00	3.400	0.47	0.00	0.47	0.00
1.800	-0.31	0.00	-0.31	0.00					

10.2. Action effect 2: load case 2: span 1 deflections of main beam (characteristic)



internal forces and moments



support forces

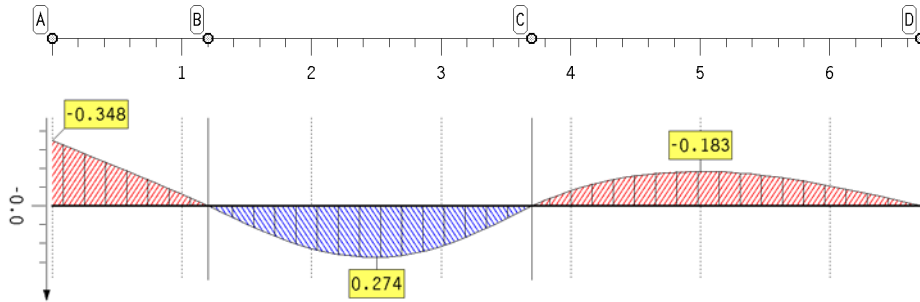
point	x m	AP kN	AP _l kN	AP _r kN	ΣAP kN
B	1.200	-4.81	-0.00	-0.00	-4.81
C	3.700	1.49	0.00	0.00	1.49
D	6.700	-0.12	-----	-----	-0.12

connector reactions

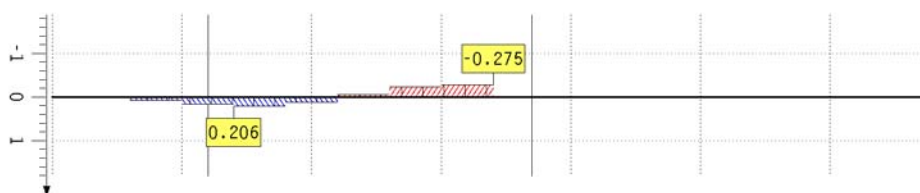
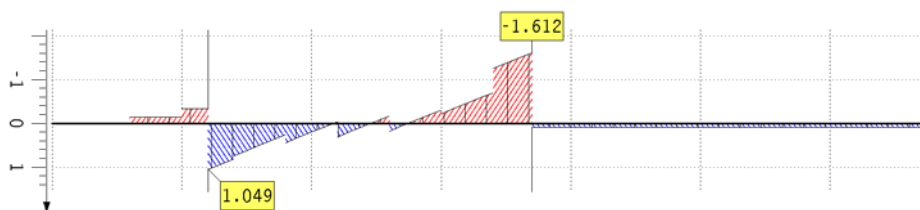
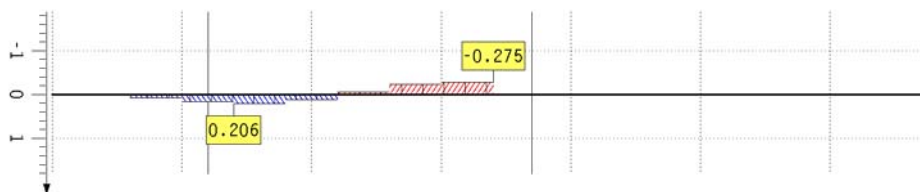
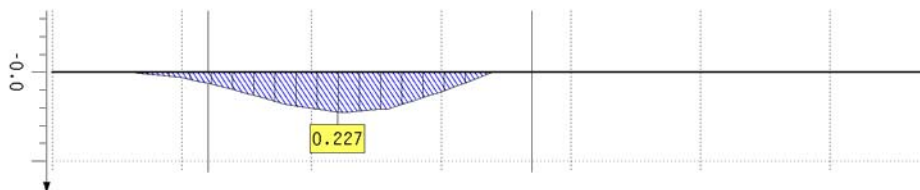
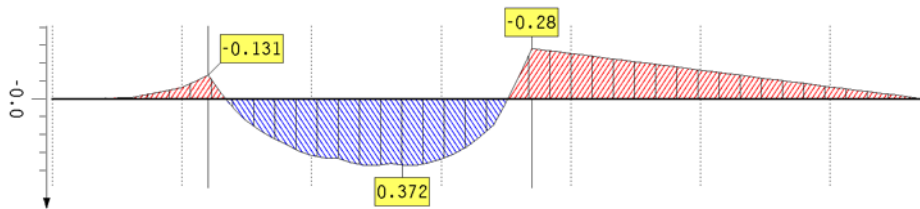
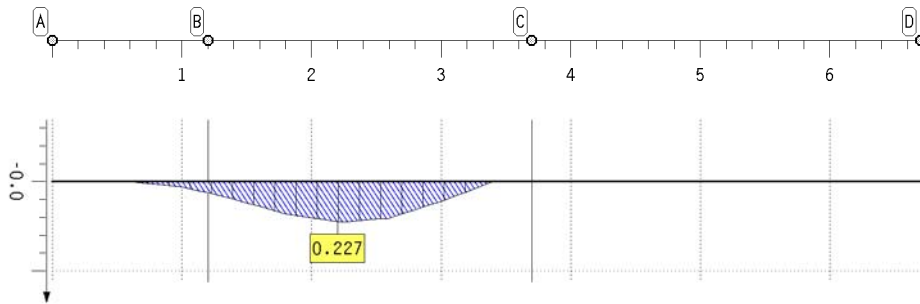
x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm	x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm
0.200	0.77	0.00	0.77	0.00	2.200	-0.10	0.00	-0.10	0.00
0.600	0.06	0.00	0.06	0.00	2.600	0.01	0.00	0.01	0.00
1.000	-0.44	0.00	-0.44	0.00	3.000	0.15	0.00	0.15	0.00
1.400	-0.53	0.00	-0.53	0.00	3.400	0.37	0.00	0.37	0.00
1.800	-0.30	0.00	-0.30	0.00					

10.3. Action effect 2: load case 3: span 2

deflections of main beam (characteristic)



internal forces and moments



support forces

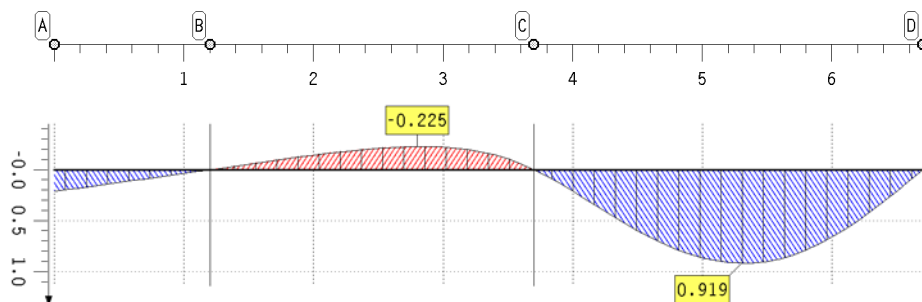
point	x m	AP kN	AP _l kN	AP _r kN	ΣAP kN
B	1.200	-1.39	0.00	0.00	-1.39
C	3.700	-1.70	-0.00	-0.00	-1.70
D	6.700	0.09	-----	-----	0.09

connector reactions

x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm	x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm
0.200	-0.01	0.00	-0.01	0.00	2.200	0.17	0.00	0.17	0.00
0.600	-0.06	0.00	-0.06	0.00	2.600	0.17	0.00	0.17	0.00
1.000	-0.10	0.00	-0.10	0.00	3.000	0.04	0.00	0.04	0.00
1.400	-0.04	0.00	-0.04	0.00	3.400	-0.27	0.00	-0.27	0.00
1.800	0.09	0.00	0.09	0.00					

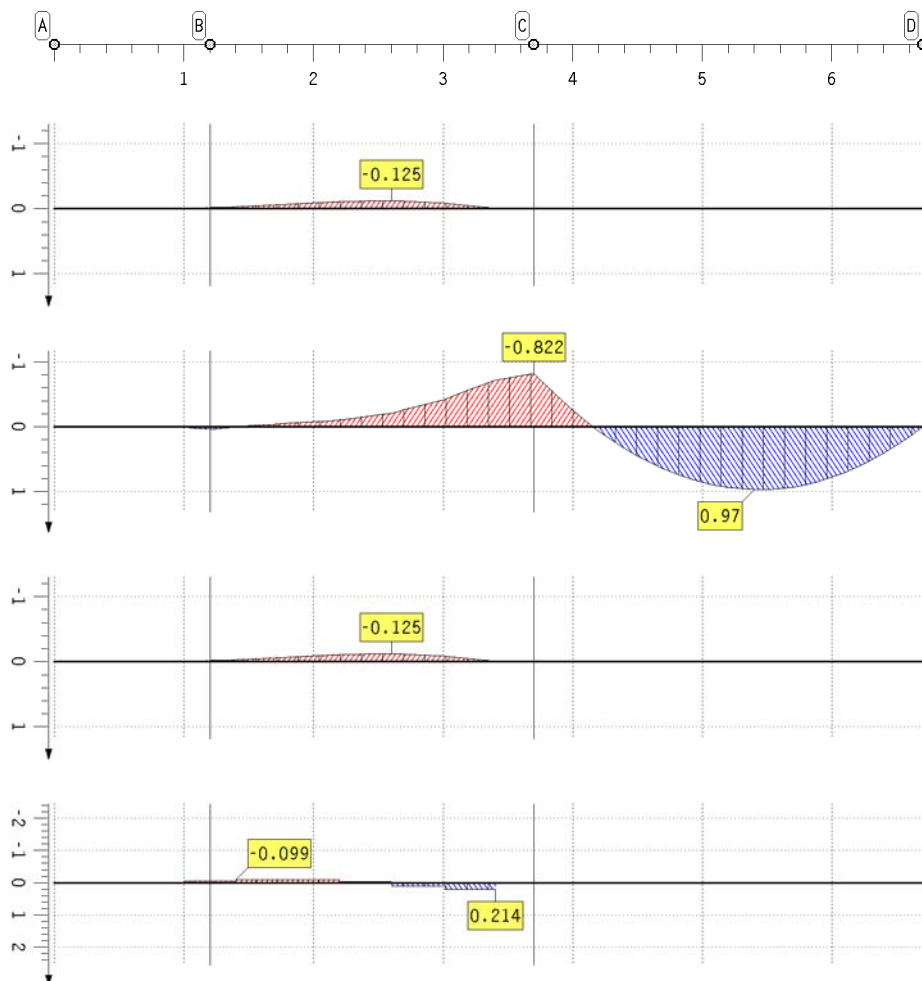
10.4. Action effect 2: load case 4: span3

deflections of main beam (characteristic)



deflection
main beam
characteristic
w in mm
Min: -0.22
Max: 0.92

internal forces and moments



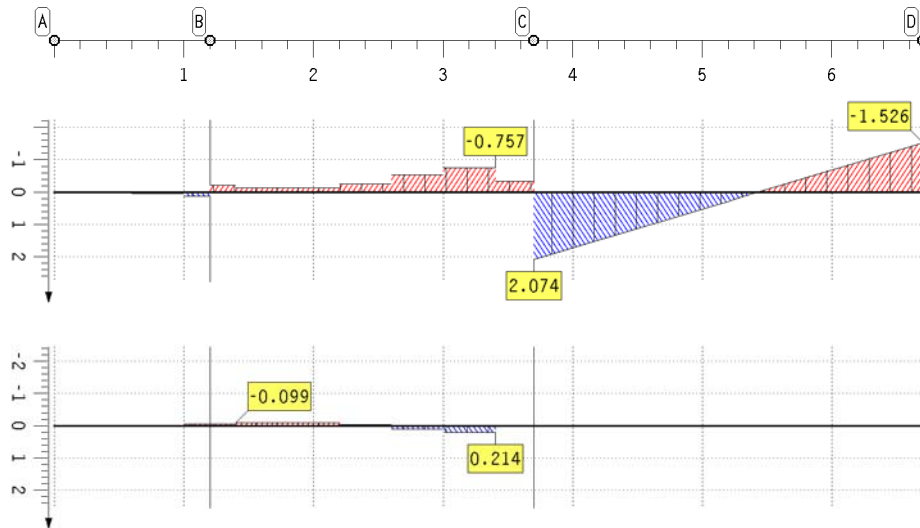
flexural moment
reinf. left
M_l in kNm
Min: -0.12
Max: 0.00

flexural moment
main beam
M in kNm
Min: -0.82
Max: 0.97

flexural moment
reinf. right
M_r in kNm
Min: -0.12
Max: 0.00

shear force
reinf. left
V_l in kN
Min: -0.10
Max: 0.21

internal forces and moments



shear force
main beam
V in kN
Min: -1.53
Max: 2.07

shear force
reinf. right
V_r in kN
Min: -0.10
Max: 0.21

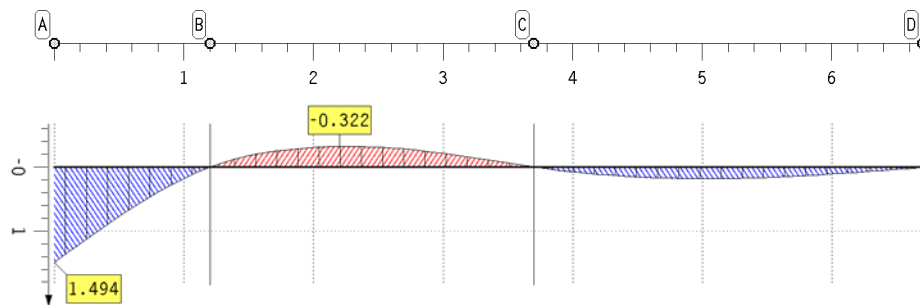
support forces

point	x m	AP kN	AP ₁ kN	AP _r kN	ΣAP kN
B	1.200	0.33	0.00	0.00	0.33
C	3.700	-2.40	-0.00	0.00	-2.40
D	6.700	-1.53	-----	-----	-1.53

connector reactions

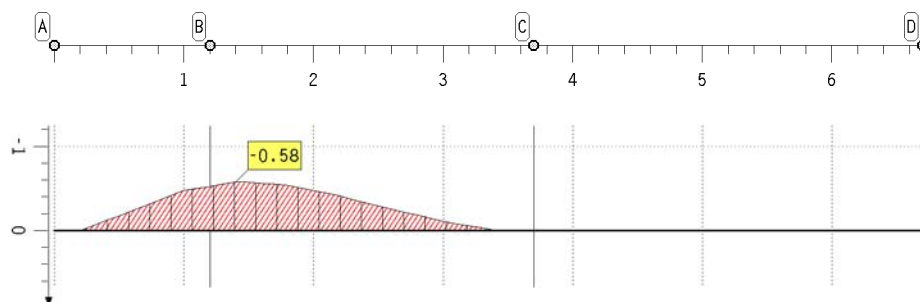
x m	CP ₁ kN	CM ₁ kNm	CP _r kN	CM _r kNm	x m	CP ₁ kN	CM ₁ kNm	CP _r kN	CM _r kNm
0.200	-0.00	0.00	-0.00	0.00	2.200	-0.06	0.00	-0.06	0.00
0.600	0.02	0.00	0.02	0.00	2.600	-0.13	0.00	-0.13	0.00
1.000	0.04	0.00	0.04	0.00	3.000	-0.12	0.00	-0.12	0.00
1.400	0.04	0.00	0.04	0.00	3.400	0.21	0.00	0.21	0.00
1.800	-0.00	0.00	-0.00	0.00					

10.5. Action effect 3: load case 5: snow deflections of main beam (characteristic)



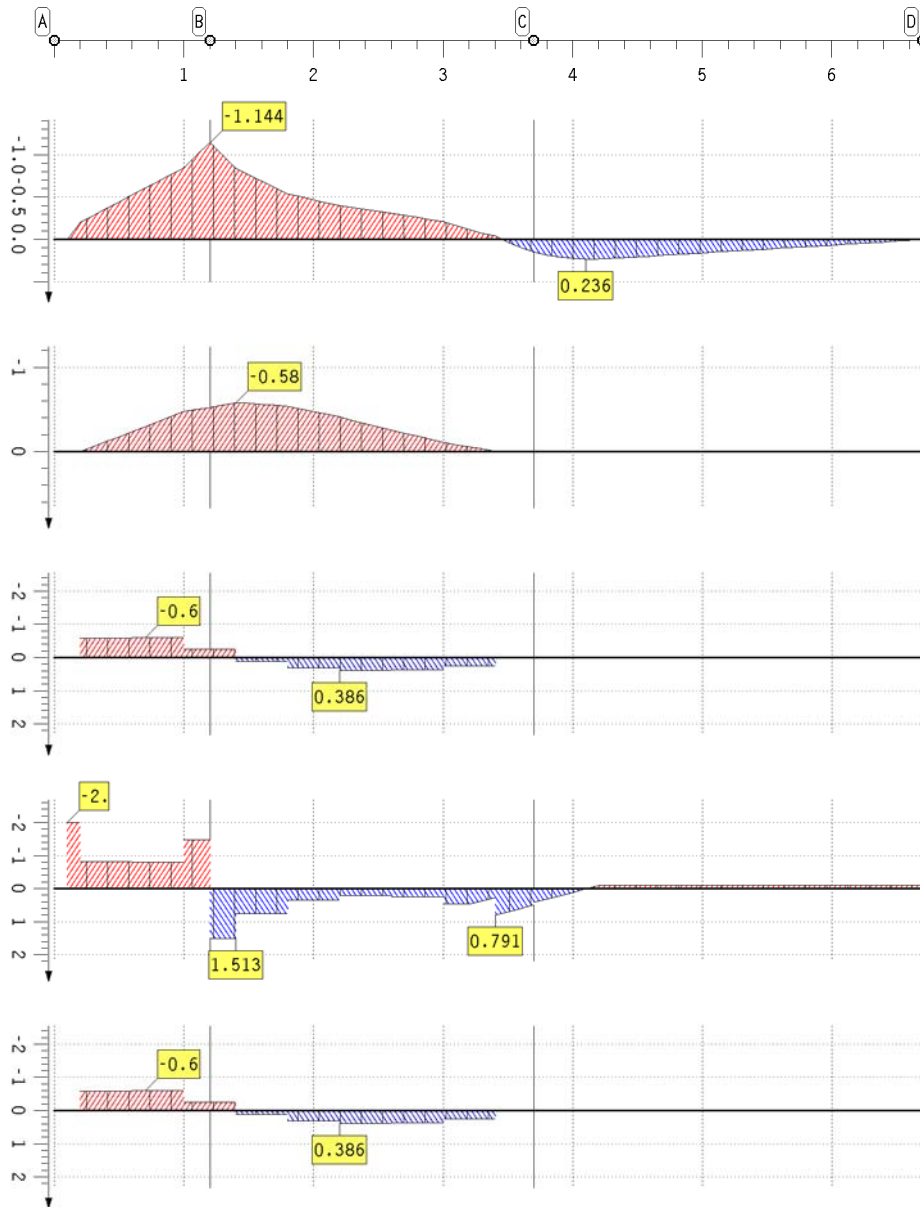
deflection
main beam
characteristic
w in mm
Min: -0.32
Max: 1.49

internal forces and moments



flexural moment
reinf. left
M_l in kNm
Min: -0.58
Max: 0.00

internal forces and moments



support forces

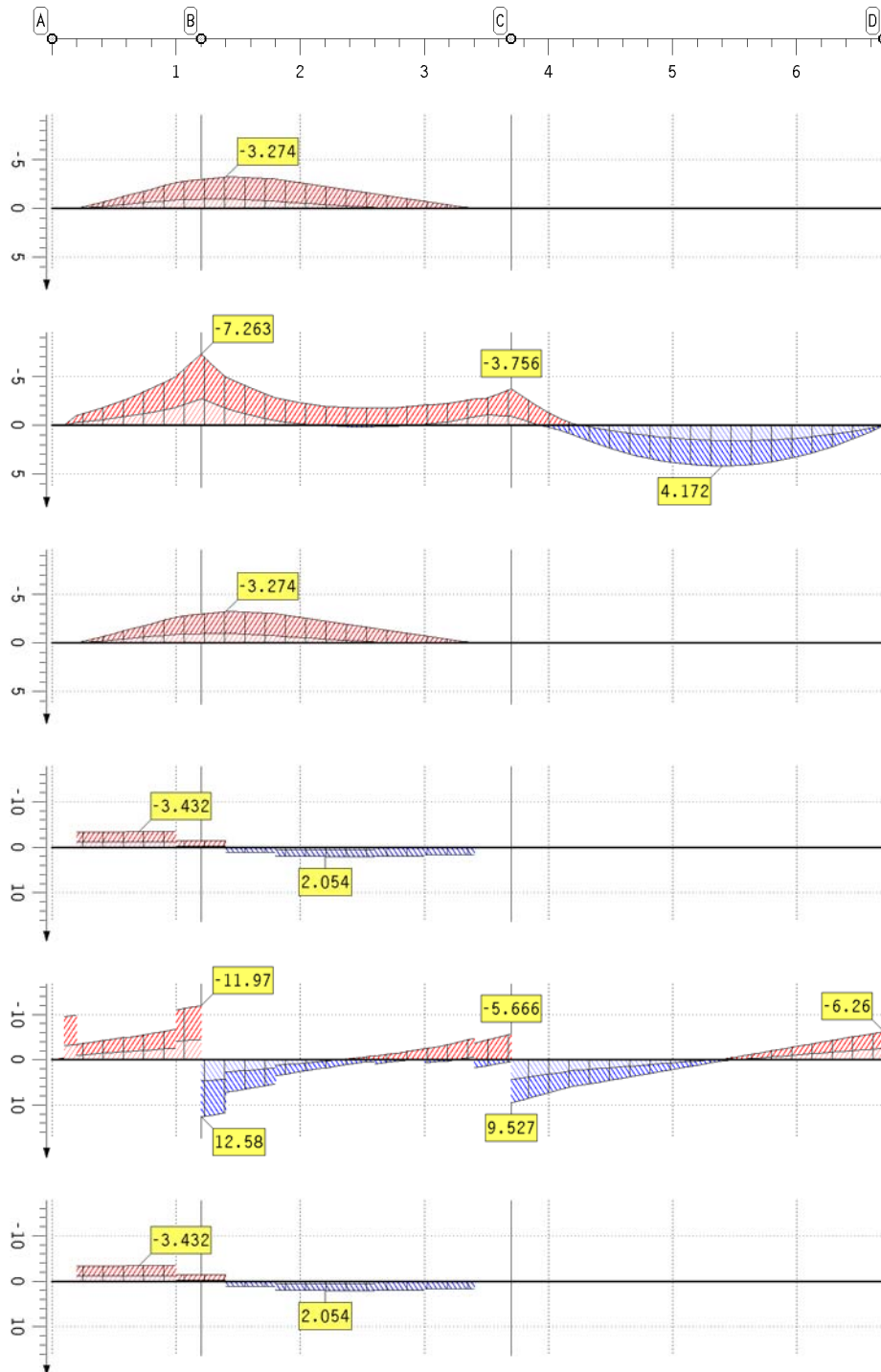
point	x m	AP kN	AP _l kN	AP _r kN	ΣAP kN
B	1.200	-2.99	-0.00	-0.00	-2.99
C	3.700	0.08	-0.00	-0.00	0.08
D	6.700	-0.09	-----	-----	-0.09

connector reactions

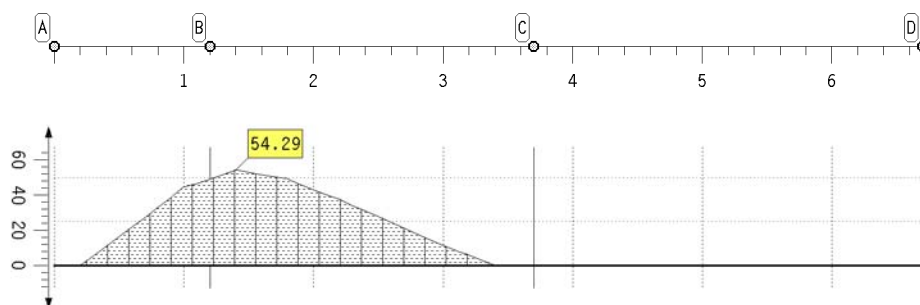
x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm	x m	CP _l kN	CM _l kNm	CP _r kN	CM _r kNm
0.200	0.59	0.00	0.59	0.00	2.200	-0.07	0.00	-0.07	0.00
0.600	0.01	0.00	0.01	0.00	2.600	0.02	0.00	0.02	0.00
1.000	-0.34	0.00	-0.34	0.00	3.000	0.11	0.00	0.11	0.00
1.400	-0.37	0.00	-0.37	0.00	3.400	0.26	0.00	0.26	0.00
1.800	-0.20	0.00	-0.20	0.00					

11. Results of verification of ultimate limit state

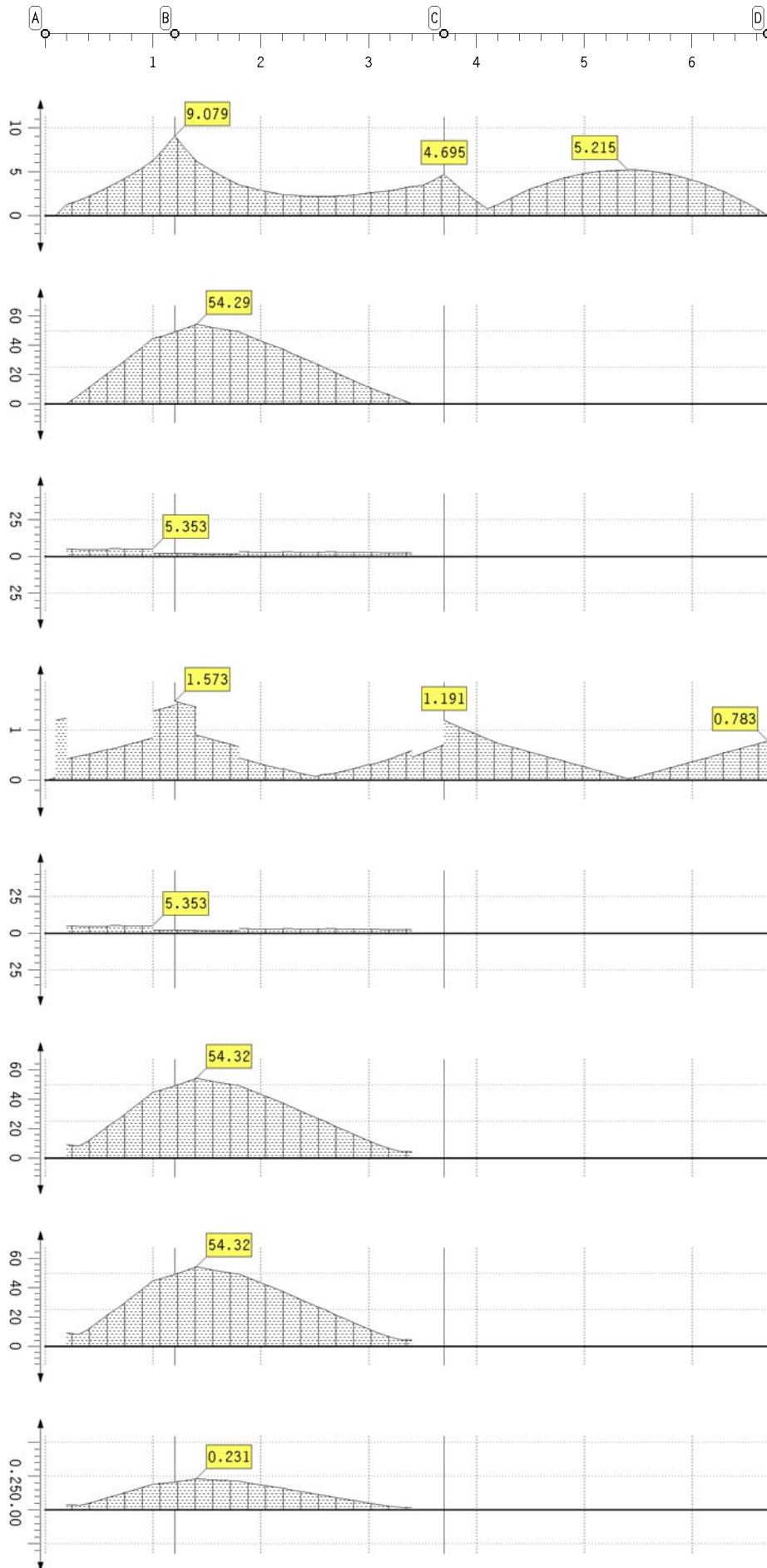
11.1. Verification of ultimate limit state extremal internal forces



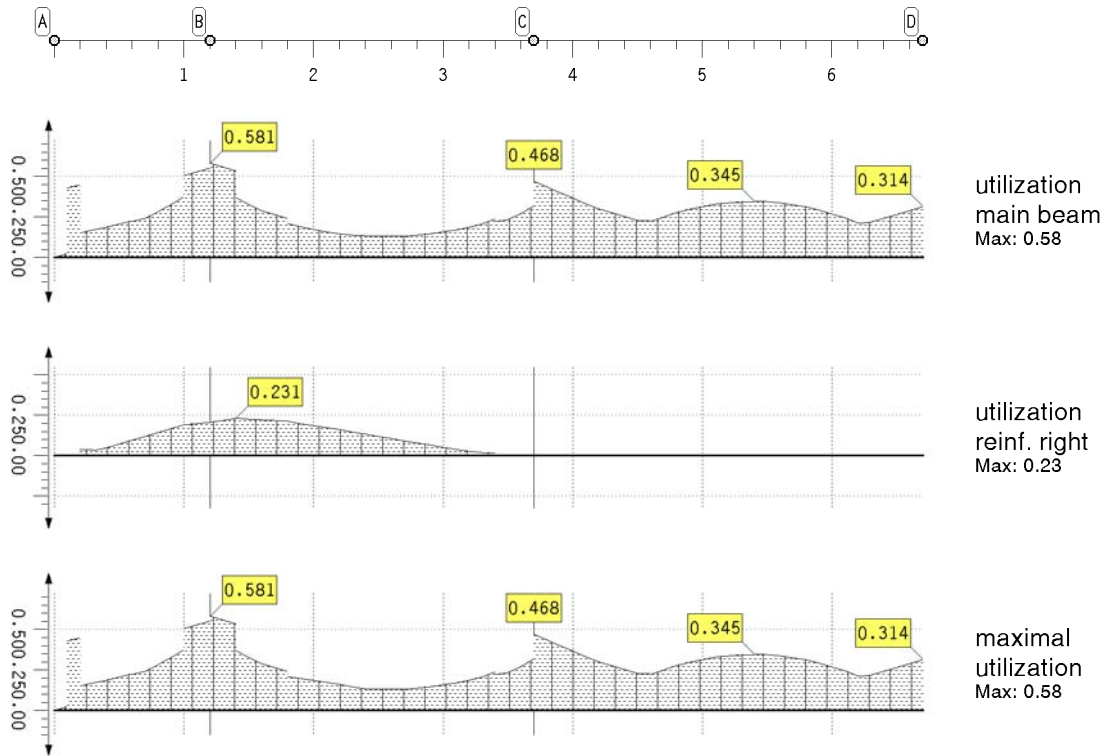
results of verification of ultimate limit state



results of verification of ultimate limit state



results of verification of ultimate limit state



verification of ultimate limit state of left-sided steel reinforcement

point	x	σ_1	τ_1	$\sigma_{v,1}$	U_1	point	x	σ_1	τ_1	$\sigma_{v,1}$	U_1
-	m	MN/m ²	MN/m ²	MN/m ²	-	-	m	MN/m ²	MN/m ²	MN/m ²	-
A	0.000	0.00	0.00	0.00	0.000		1.800	49.32	1.77	49.35	0.210
	0.200	0.00	0.00	0.00	0.000		1.800	49.32	3.15	49.40	0.210
	0.200	0.00	5.16	8.94	0.038		2.200	37.50	3.20	37.61	0.160
	0.500	16.37	4.73	16.97	0.072		3.000	11.39	3.10	11.71	0.050
	0.600	21.96	5.35	22.47	0.096		3.000	11.39	2.68	11.63	0.049
	1.000	44.71	5.35	44.96	0.191		3.100	8.49	2.45	8.80	0.037
B	1.000	44.71	2.27	44.75	0.190		3.400	0.00	2.68	4.64	0.020
	1.200	49.21	2.07	49.24	0.210		3.400	0.00	0.00	0.00	0.000
B	1.200	49.21	2.07	49.24	0.210	C	3.700	0.00	0.00	0.00	0.000
	1.400	54.29	2.27	54.32	0.231	minimum		0.00	0.00	0.00	0.000
	1.400	54.29	1.77	54.31	0.231	maximum		54.29	5.35	54.32	0.231
	1.700	50.26	1.62	50.29	0.214						

verification of ultimate limit state of main beam

point	x	$k_{mod,h}$	σ_h	τ_h	U_h	point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m ²	MN/m ²	-	-	m	-	MN/m ²	MN/m ²	-
A	0.000	0.900	0.00	0.00	0.000		2.500	0.900	2.18	0.07	0.131
	0.100	0.800	0.03	0.06	0.024		2.700	0.900	2.23	0.15	0.134
	0.100	0.900	0.03	1.20	0.432		2.800	0.800	2.31	0.20	0.140
	0.200	0.900	1.25	1.25	0.451	C	3.700	0.800	4.69	0.71	0.318
	0.200	0.900	1.25	0.42	0.153	C	3.700	0.800	4.69	1.19	0.468
	1.000	0.900	6.25	0.85	0.376		4.100	0.800	0.76	0.82	0.332
B	1.000	0.800	6.25	1.38	0.504		4.600	0.800	3.49	0.50	0.224
	1.200	0.800	9.08	1.50	0.552		5.000	0.800	4.82	0.26	0.317
B	1.200	0.800	9.08	1.57	0.581		5.400	0.800	5.21	0.03	0.345
	1.400	0.800	6.19	1.46	0.534		5.800	0.800	4.67	0.25	0.311
	1.400	0.900	6.19	0.89	0.373		6.200	0.800	3.18	0.49	0.212
	1.500	0.900	5.46	0.84	0.329	D	6.700	0.800	0.00	0.78	0.314
	1.600	0.800	4.76	0.78	0.287	minimum		0.800	0.00	0.00	0.000
	1.800	0.800	3.48	0.66	0.239	maximum		0.900	9.08	1.57	0.581
	1.800	0.900	3.48	0.44	0.210						

verification of ultimate limit state of right-sided steel reinforcement

point	x	σ_r	τ_r	$\sigma_{v,r}$	U_r	point	x	σ_r	τ_r	$\sigma_{v,r}$	U_r
-	m	MN/m ²	MN/m ²	MN/m ²	-	-	m	MN/m ²	MN/m ²	MN/m ²	-
A	0.000	0.00	0.00	0.00	0.000		1.800	49.32	1.77	49.35	0.210
	0.200	0.00	0.00	0.00	0.000		1.800	49.32	3.15	49.40	0.210
	0.200	0.00	5.16	8.94	0.038		2.200	37.50	3.20	37.61	0.160
	0.500	16.37	4.73	16.97	0.072		3.000	11.39	3.10	11.71	0.050
	0.600	21.96	5.35	22.47	0.096		3.000	11.39	2.68	11.63	0.049
	1.000	44.71	5.35	44.96	0.191		3.100	8.49	2.45	8.80	0.037
	1.000	44.71	2.27	44.75	0.190		3.400	0.00	2.68	4.64	0.020
B	1.200	49.21	2.07	49.24	0.210		3.400	0.00	0.00	0.00	0.000
B	1.200	49.21	2.07	49.24	0.210	C	3.700	0.00	0.00	0.00	0.000
	1.400	54.29	2.27	54.32	0.231	minimum		0.00	0.00	0.00	0.000
	1.400	54.29	1.77	54.31	0.231	maximum		54.29	5.35	54.32	0.231
	1.700	50.26	1.62	50.29	0.214						

maximal utilization

point	x	U	point	x	U	point	x	U	point	x	U
-	m	-	-	m	-	-	m	-	-	m	-
A	0.000	0.000		1.000	0.376		1.800	0.210		5.400	0.345
	0.100	0.024		1.000	0.504		2.500	0.131		5.800	0.311
	0.100	0.432	B	1.200	0.552		3.200	0.187		6.200	0.212
	0.200	0.451	B	1.200	0.581	C	3.700	0.318	D	6.700	0.314
	0.200	0.153		1.400	0.534	C	3.700	0.468	minimum		0.000
	0.800	0.283		1.400	0.373		4.500	0.226	maximum		0.581

extremal connector reactions

x	min CP ₁	max CP ₁	min CM ₁	max CM ₁	min CP _r	max CP _r	min CM _r	max CM _r
m	kN	kN	kNm	kNm	kN	kN	kNm	kNm
0.200	1.18	3.31	0.00	0.00	1.18	3.31	0.00	0.00
0.600	-0.07	0.15	0.00	0.00	-0.07	0.15	0.00	0.00
1.000	-2.14	-0.72	0.00	0.00	-2.14	-0.72	0.00	0.00
1.400	-2.27	-0.77	0.00	0.00	-2.27	-0.77	0.00	0.00
1.800	-1.04	-0.17	0.00	0.00	-1.04	-0.17	0.00	0.00
2.200	-0.27	0.31	0.00	0.00	-0.27	0.31	0.00	0.00
2.600	-0.10	0.43	0.00	0.00	-0.10	0.43	0.00	0.00
3.000	-0.07	0.50	0.00	0.00	-0.07	0.50	0.00	0.00
3.400	0.06	1.72	0.00	0.00	0.06	1.72	0.00	0.00

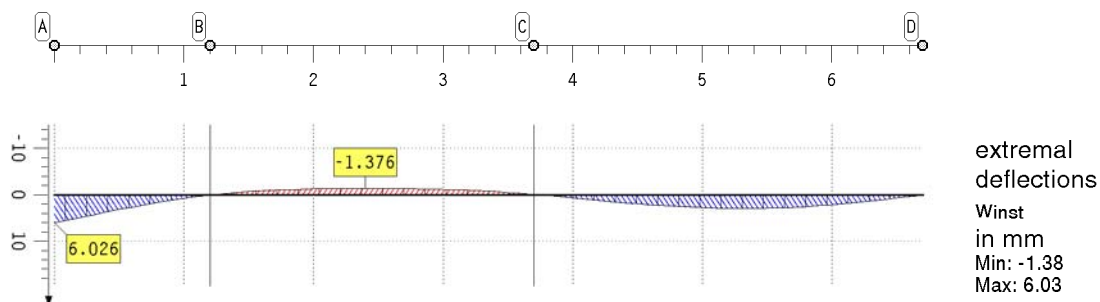
verification of ultimate limit state for connectors

x	k _{mod,1}	U ₁	k _{mod,r}	U _r	x	k _{mod,1}	U ₁	k _{mod,r}	U _r
m	-	-	-	-	m	-	-	-	-
0.200	0.900	1.011	0.900	1.011	2.200	0.800	0.106	0.800	0.106
0.600	0.800	0.049	0.800	0.049	2.600	0.800	0.143	0.800	0.143
1.000	0.900	0.653	0.900	0.653	3.000	0.900	0.154	0.900	0.154
1.400	0.900	0.694	0.900	0.694	3.400	0.900	0.524	0.900	0.524
1.800	0.900	0.317	0.900	0.317					

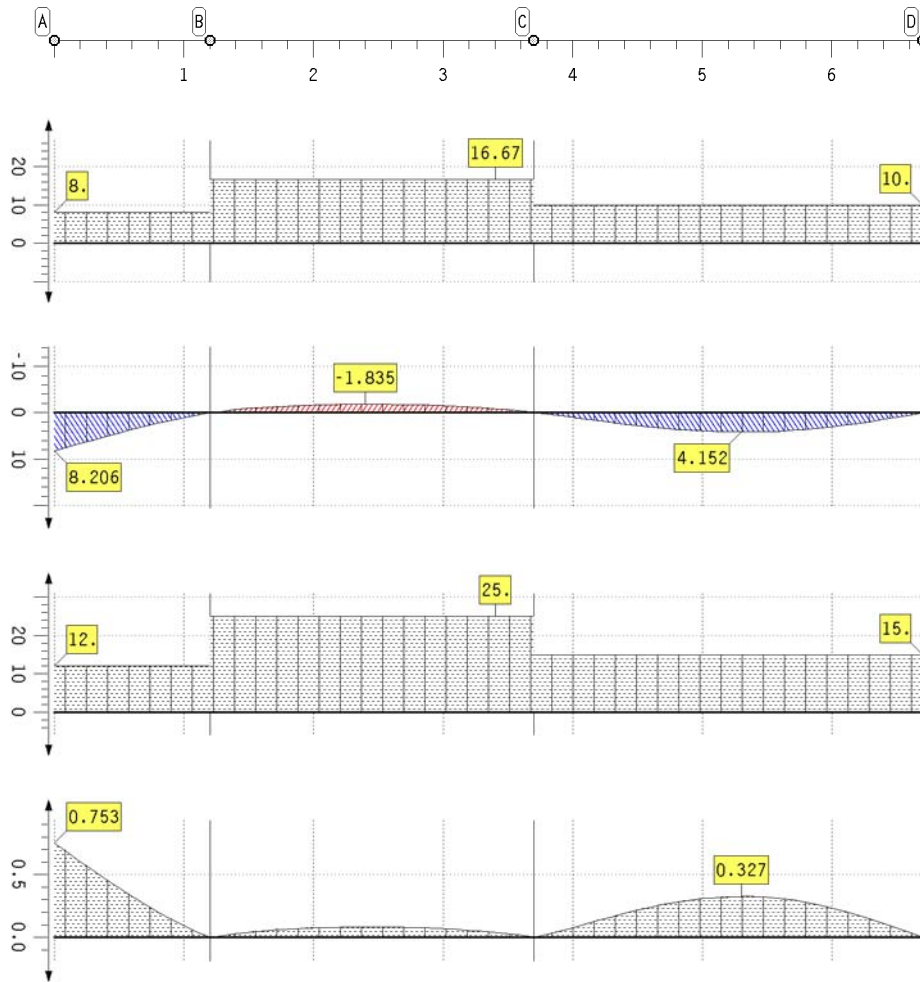
12. Results of verification of deflections

12.1. Verification of deflections

results of verification of deflections



results of verification of deflections



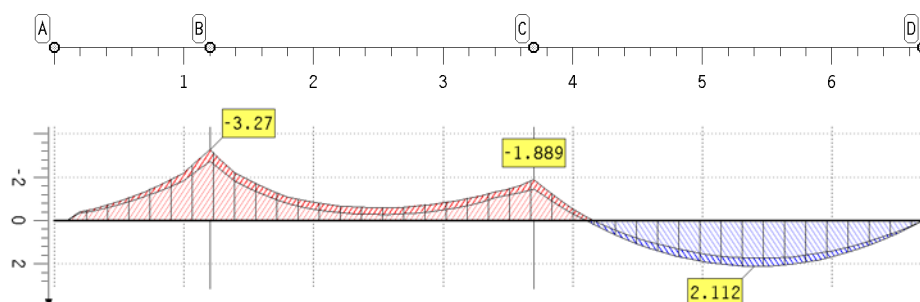
verification of deflections

point	x	min/max/req winst			min/max/req wfin			min/max/req wnet, fin			U
-	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	-
A	0.000	0.00	6.03	8.00	0.00	8.21	12.00	0.00	5.81	8.00	0.753
B	1.200	0.00	0.00	8.00	0.00	0.00	12.00	0.00	0.00	8.00	0.000
B	1.200	0.00	0.00	16.67	0.00	0.00	25.00	0.00	0.00	16.67	0.000
	1.700	-1.02	0.00	16.67	-1.36	0.00	25.00	-0.92	0.00	16.67	0.061
	2.400	-1.38	0.00	16.67	-1.83	0.00	25.00	-1.22	0.00	16.67	0.083
	3.100	-1.00	0.00	16.67	-1.34	0.00	25.00	-0.92	0.00	16.67	0.060
C	3.700	-0.00	0.00	16.67	-0.00	0.00	25.00	-0.00	0.00	16.67	0.000
C	3.700	0.00	0.00	10.00	0.00	0.00	15.00	0.00	0.00	10.00	0.000
	4.700	0.00	2.41	10.00	0.00	3.40	15.00	0.00	2.64	10.00	0.264
	5.300	0.00	2.93	10.00	0.00	4.15	15.00	0.00	3.27	10.00	0.327
	5.900	0.00	2.28	10.00	0.00	3.24	15.00	0.00	2.57	10.00	0.257
D	6.700	-0.00	0.00	10.00	-0.00	0.00	15.00	-0.00	0.00	10.00	0.000
minimum		-1.38	0.00	8.00	-1.83	0.00	12.00	-1.22	0.00	8.00	0.000
maximum		0.00	6.03	16.67	0.00	8.21	25.00	0.00	5.81	16.67	0.753

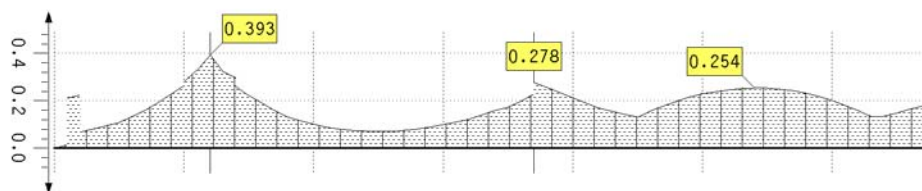
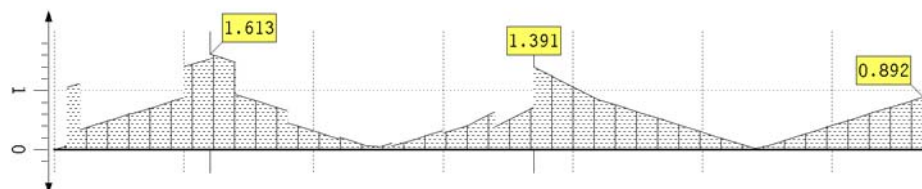
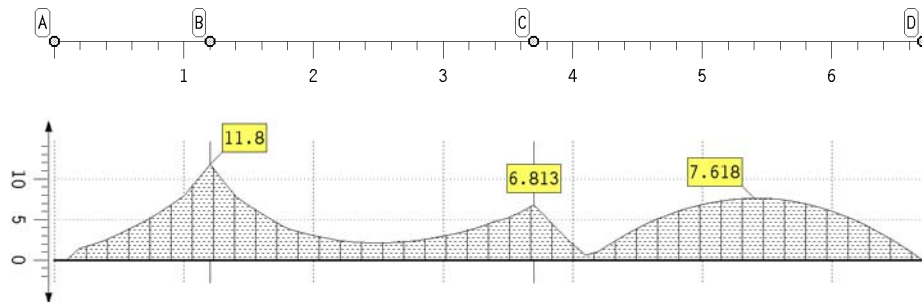
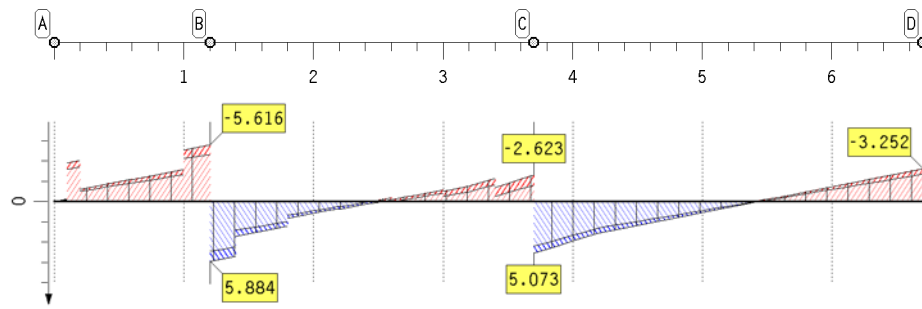
13. Results of verification of fire protection

13.1. Verification of fire protection

extremal internal forces



extremal internal forces



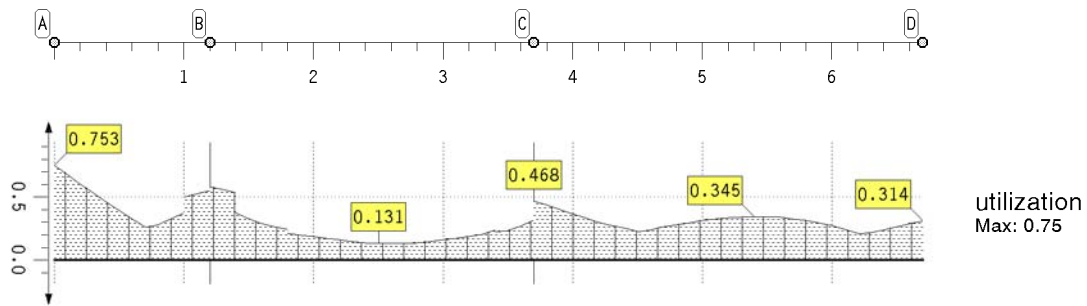
verification of ultimate limit state of main beam

point	x	$k_{mod,h}$	σ_h	τ_h	U_h	point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m ²	MN/m ²	-	-	m	-	MN/m ²	MN/m ²	-
A	0.000	1.000	0.00	0.00	0.000	C	2.500	1.000	2.11	0.05	0.070
	0.100	1.000	0.05	0.07	0.014		3.100	1.000	3.32	0.35	0.111
	0.100	1.000	0.05	1.06	0.211		3.700	1.000	6.81	0.72	0.227
	0.200	1.000	1.48	1.12	0.225		3.700	1.000	6.81	1.39	0.278
	0.200	1.000	1.48	0.34	0.069		4.100	1.000	0.65	0.95	0.190
	1.000	1.000	7.93	0.88	0.264		4.500	1.000	3.95	0.64	0.132
	1.000	1.000	7.93	1.40	0.280		5.000	1.000	6.89	0.29	0.230
B	1.200	1.000	11.80	1.54	0.393	D	5.400	1.000	7.62	0.02	0.254
B	1.200	1.000	11.80	1.61	0.393		5.800	1.000	6.90	0.27	0.230
	1.400	1.000	7.79	1.48	0.295		6.300	1.000	3.97	0.62	0.132
	1.400	1.000	7.79	0.93	0.260		6.700	1.000	0.00	0.89	0.178
	1.800	1.000	3.90	0.65	0.131		minimum	1.000	0.00	0.00	0.000
	1.800	1.000	3.90	0.45	0.130		maximum	1.000	11.80	1.61	0.393

14. Summary

14.1. Summary of all verifications

maximal utilization



maximal connector utilization

x m	U -	x m	U -	x m	U -
0.200	1.01	1.400	0.69	2.600	0.14
0.600	0.05	1.800	0.32	3.000	0.15
1.000	0.65	2.200	0.11	3.400	0.52

15. Utilizations of all verifications

load-carrying capacity of connectors ($u = 1.011$) does not meet the requirements!