1. Options for Calculations

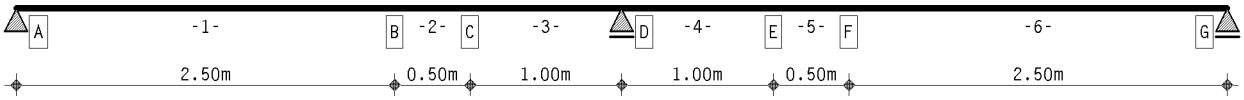
calculation DIN EN 1995:2010, Germany

service class 1

coefficients of thermal expansion: timber α_t = 0.500 *10^{-5}/°K, steel α_t = 1.200 *10^{-5}/°K

2. Structural system

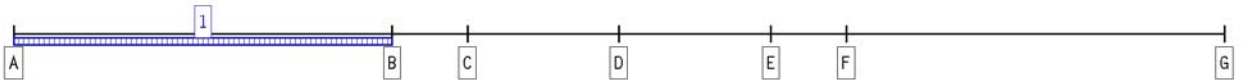
reinforcement left side



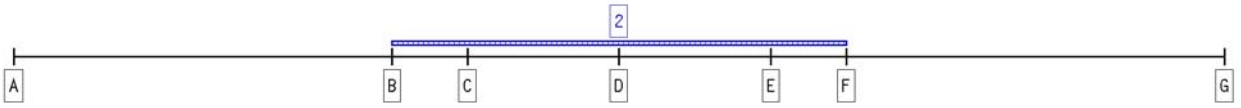
main beam

reinforcement right side

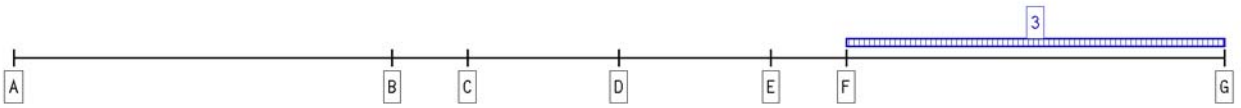
3. Loading



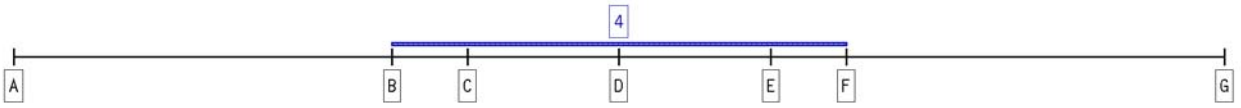
action effect 1: dead load (permanent, 5 load cases)



G



G



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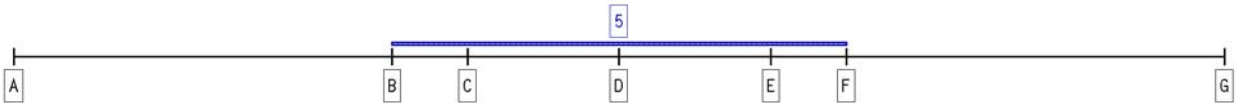

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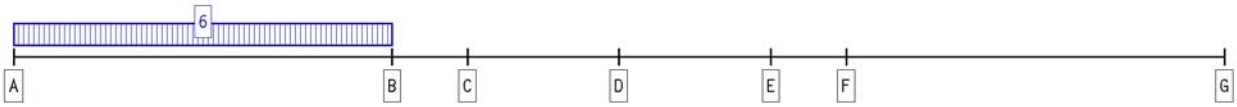
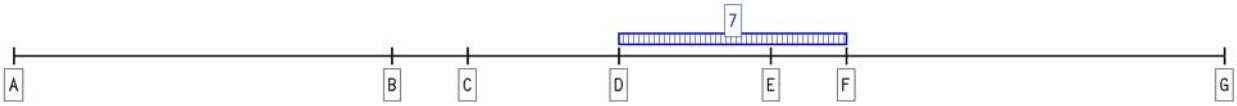


action effect 2: traffic (transient, 8 load cases)



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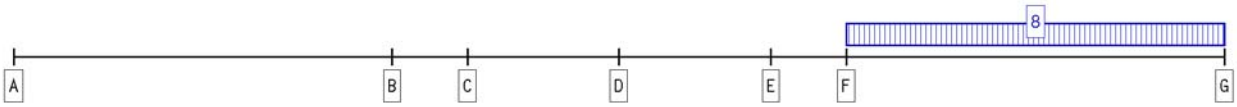

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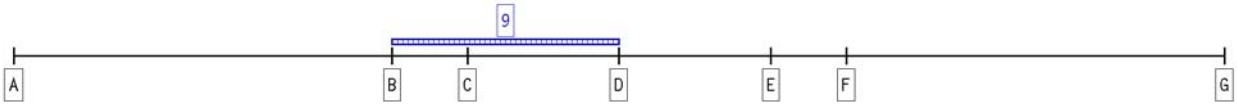

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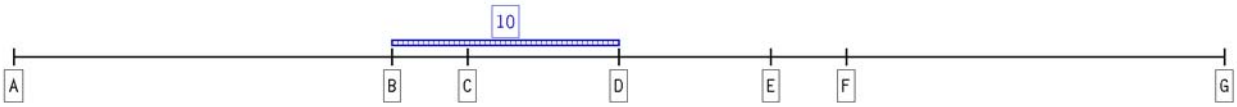

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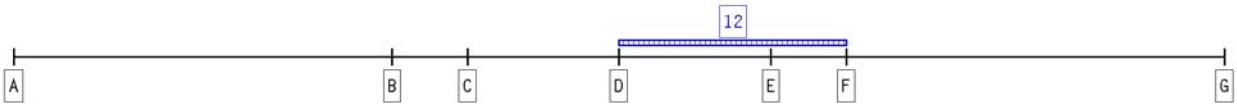

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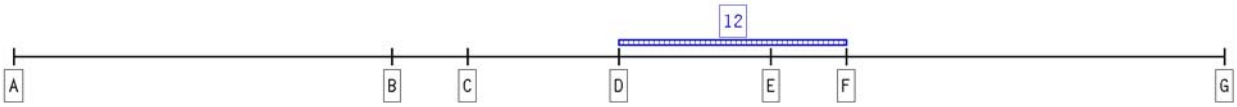

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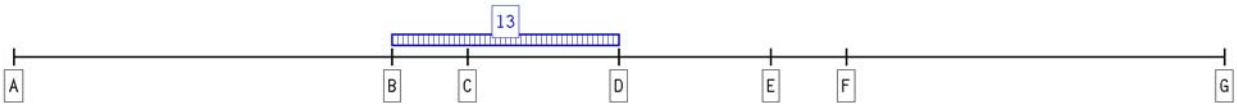
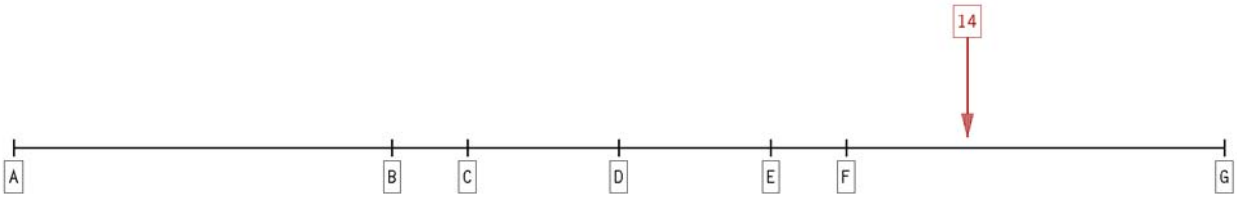
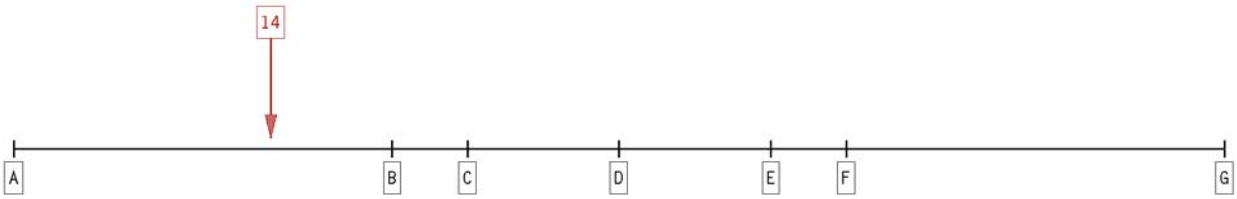


G



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

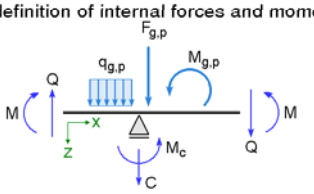


G

4. material parameters

timber grade main beam		solid coniferous timber, C24 (S10)
service class		1
beam width		b = 100 mm
coeff. therm.expan. timber:		0.500 *10-5 /°K
coeff. thermal expan. steel:		1.200 *10-5 /°K
char. bend. strength $f_{m,k}$:		24.0 N/mm²
char. shear strength $f_{v,k}$:		4.0 N/mm²
modulus of elast. $E_{0,mean}$	:	11000 N/mm²
k_{cr}	:	0.50 mm²/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	2.50	2.50	4.00	1.0000	4.00	-	240
2	2.50	3.00	0.50	4.00	1.0000	4.00	-	240
3	3.00	4.00	1.00	4.00	1.0000	4.00	-	240
4	4.00	5.00	1.00	4.00	1.0000	4.00	-	240
5	5.00	5.50	0.50	4.00	1.0000	4.00	-	240
6	5.50	8.00	2.50	4.00	1.0000	4.00	-	240

sections with reinforcements

section	reinforcement left side	reinforcement right side
1	-	-
2	steel plate S235 6/160 mm	steel plate S235 6/160 mm
3	steel plate S235 6/160 mm	steel plate S235 6/160 mm
4	steel plate S235 6/160 mm	steel plate S235 6/160 mm
5	steel plate S235 6/160 mm	steel plate S235 6/160 mm
6	-	-

6. Fastener data

section 2 from x_A = 2.50 m to x_E = 3.00

bolt 20 mm, FK 5.8
1 - row, simplified verification acc. to NA.8.2.5
f_{uk} = 500 N/mm², M_{yk} = 362051 Nmm
reduction of R_k with f = 0.843 for $vorh t < t_{req}$
K_{ser} = 14969 N/mm, γ_M = 1.10, **R_k = 11970.0 N, all values per shear plane**

coordinates of connectors section 2

Nr.	x_{Abs} m	x_D m
1	0.100	2.600

section 3 from x_A = 3.00 m to x_E = 4.00

bolt 20 mm, FK 5.8
1 - row, simplified verification acc. to NA.8.2.5
f_{uk} = 500 N/mm², M_{yk} = 362051 Nmm
reduction of R_k with f = 0.843 for $vorh t < t_{req}$
K_{ser} = 14969 N/mm, γ_M = 1.10, **R_k = 11970.0 N, all values per shear plane**

coordinates of connectors section 3

Nr.	x_{Abs} m	x_D m
1	0.150	3.150
2	0.700	3.700

section 4 from x_A = 4.00 m to x_E = 5.00

bolt 20 mm, FK 5.8
1 - row, simplified verification acc. to NA.8.2.5
f_{uk} = 500 N/mm², M_{yk} = 362051 Nmm
reduction of R_k with f = 0.843 for $vorh t < t_{req}$
K_{ser} = 14969 N/mm, γ_M = 1.10, **R_k = 11970.0 N, all values per shear plane**

coordinates of connectors section 4

Nr.	x_{Abs} m	x_D m
1	0.300	4.300
2	0.850	4.850

section 5 from x_A = 5.00 m to x_E = 5.50

bolt 20 mm, FK 5.8
1 - row, simplified verification acc. to NA.8.2.5
f_{uk} = 500 N/mm², M_{yk} = 362051 Nmm
reduction of R_k with f = 0.843 for $vorh t < t_{req}$
K_{ser} = 14969 N/mm, γ_M = 1.10, **R_k = 11970.0 N, all values per shear plane**

coordinates of connectors section 5

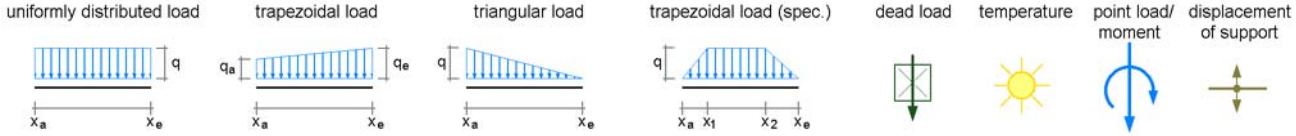
Nr.	x_{Abs} m	x_D m
1	0.400	5.400

7. Supports

coordinates of supports

supp.name	x m	c_F kN/m	c_M kNm/-	left reinf. (F)	left reinf. (M)	main beam (F)	main beam (M)	right reinf. (F)	right reinf. (M)
A	0.00	fix	----	-	-	X	-	-	-
D	4.00	fix	----	X	-	X	-	X	-
G	8.00	fix	----	-	-	X	-	-	-

8. Action effects



Permanent action effect: dead load

1. additive load case: permanent main beam 1
   ⇒ unif.distr.load (main beam): q = 1.60 kN/m from x_a = 0.00 m to x_e = 2.50 m
2. additive load case: permanent main beam 2
   ⇒ unif.distr.load (main beam): q = 0.80 kN/m from x_a = 2.50 m to x_e = 5.50 m
3. additive load case: permanent main beam 3
   ⇒ unif.distr.load (main beam): q = 1.60 kN/m from x_a = 5.50 m to x_e = 8.00 m
4. additive load case: permanent U140 left side
   ⇒ unif.distr.load (reinforcement left side): q = 0.50 kN/m from x_a = 2.50 m to x_e = 5.50 m
5. additive load case: permanent U140 right side
   ⇒ unif.distr.load (reinforcement right side): q = 0.50 kN/m from x_a = 2.50 m to x_e = 5.50 m

2. Transient action effect: traffic

6. additive load case: traffic main beam 1
   ⇒ unif.distr.load (main beam): q = 3.50 kN/m from x_a = 0.00 m to x_e = 2.50 m
7. additive load case: traffic main beam 2 a
   ⇒ unif.distr.load (main beam): q = 1.75 kN/m from x_a = 4.00 m to x_e = 5.50 m
8. additive load case: traffic main beam 3
   ⇒ unif.distr.load (main beam): q = 3.50 kN/m from x_a = 5.50 m to x_e = 8.00 m
9. additive load case: traffic U140 left side
   ⇒ unif.distr.load (reinforcement left side): q = 0.88 kN/m from x_a = 2.50 m to x_e = 4.00 m
10. additive load case: traffic U140 right side
    ⇒ unif.distr.load (reinforcement right side): q = 0.88 kN/m from x_a = 2.50 m to x_e = 4.00 m
12. additive load case: traffic U140 right side 2
    ⇒ unif.distr.load (reinforcement right side): q = 0.88 kN/m from x_a = 4.00 m to x_e = 5.50 m
    ⇒ unif.distr.load (reinforcement left side): q = 0.88 kN/m from x_a = 4.00 m to x_e = 5.50 m
13. additive load case: traffic main beam 2 b
    ⇒ unif.distr.load (main beam): q = 1.75 kN/m from x_a = 2.50 m to x_e = 4.00 m

3. Transient action effect: snow

14. additive load case: snow
    ⇒ point load (main beam): F = 8.00 kN at x = 6.30 m
    ⇒ point load (main beam): F = 8.00 kN at x = 1.70 m

9. verifications

1: EC 5 load-carrying capacity

safety against overturning 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

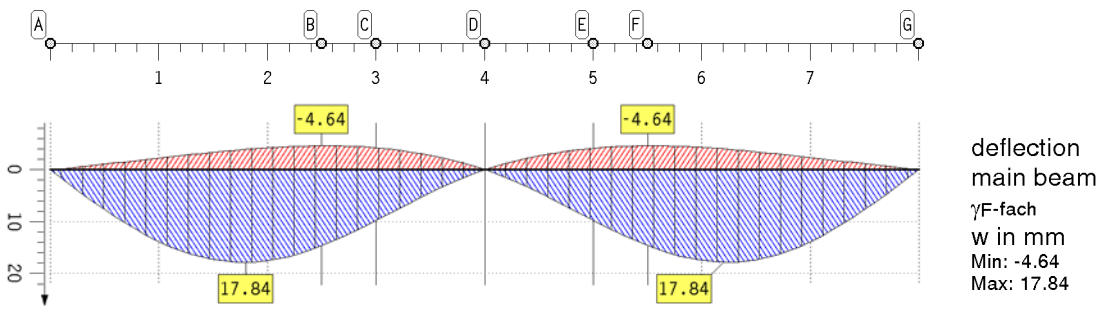
3: EC 5 fire protection

fire resistance duration t_f = 30 min
combustion depth d_f = 2.40 cm
Abbrand 4-seitig
Extreme rule 1

10. Results of verification of ultimate limit state

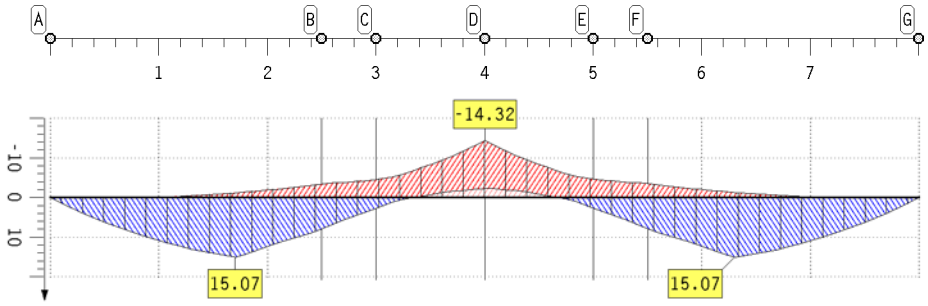
10.1. Verification of ultimate limit state

extremal deflections of main beam (incl. γ_F)

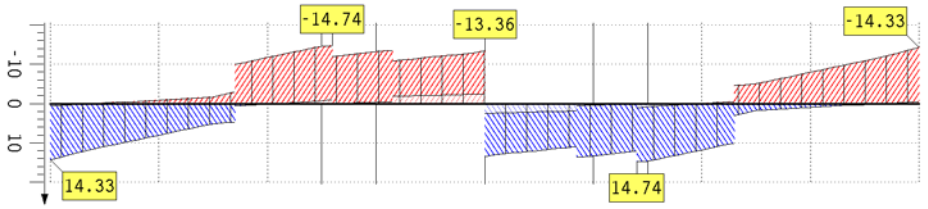


deflection
main beam
γ_F-fach
w in mm
Min: -4.64
Max: 17.84

extremal internal forces

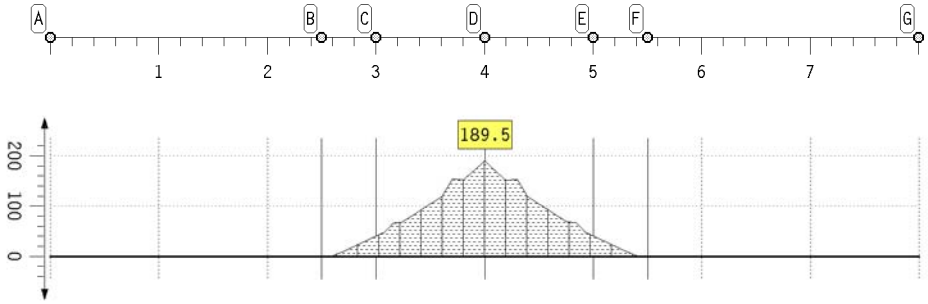


flexural moment
main beam
M in kNm
Min: -14.32
Max: 15.07

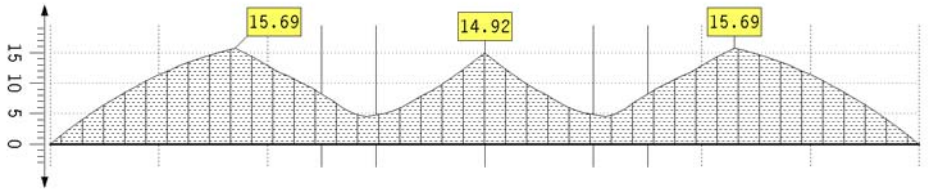


shear force
main beam
V in kN
Min: -14.74
Max: 14.74

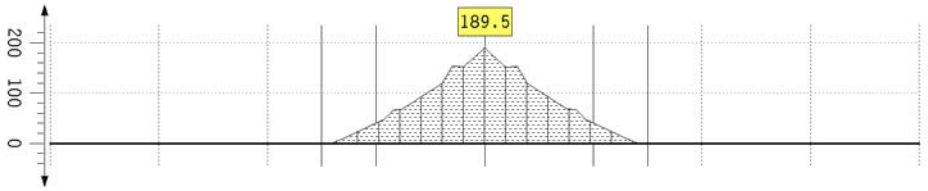
results of verification of ultimate limit state



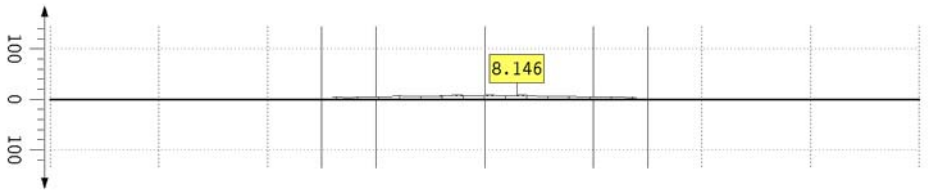
bending stress
reinf. left
σ_l in MN/m²
Max: 189.51



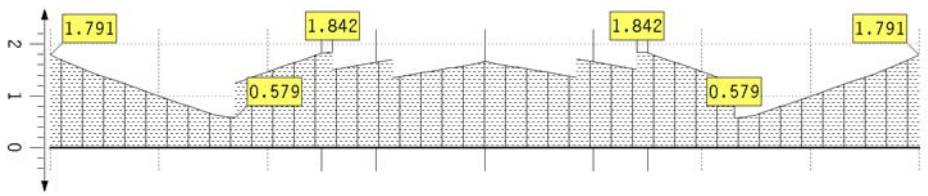
bending stress
main beam
σ_h in MN/m²
Max: 15.69



bending stress
reinf. right
σ_r in MN/m²
Max: 189.51

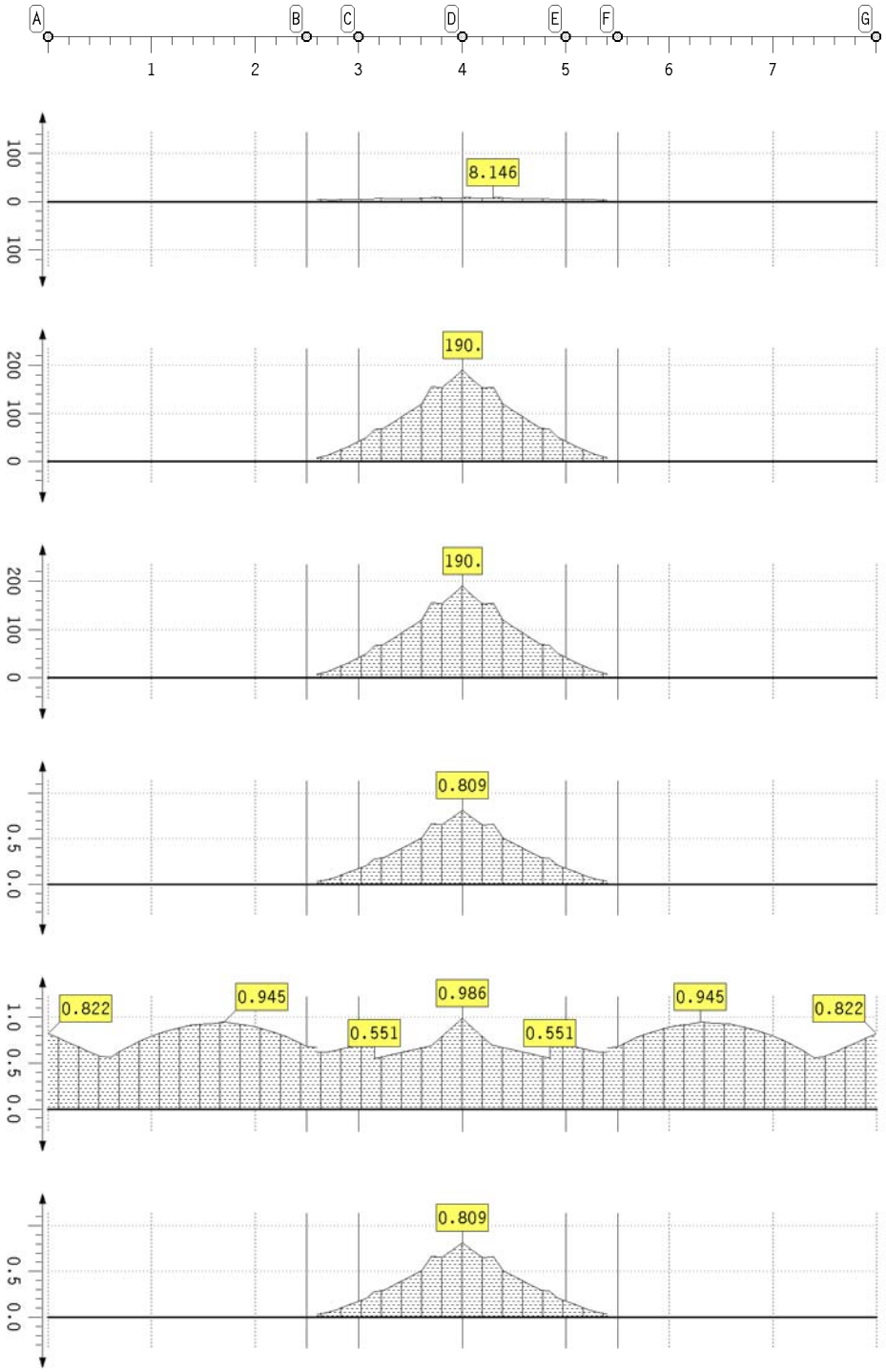


shear stress
reinf. left
τ_l in MN/m²
Max: 8.15



shear stress
main beam
τ_h in MN/m²
Max: 1.84

results of verification of ultimate limit state



shear stress
reinf. right
τ_r in MN/m²
Max: 8.15

equivalent stress
reinf. left
$\sigma_{v,l}$ in MN/m²
Max: 190.00

equivalent stress
$\sigma_{v,r}$ in MN/m²
Max: 190.00

utilization
reinf. left
Max: 0.81

utilization
main beam
Max: 0.99

utilization
reinf. right
Max: 0.81

verification of bearing stress

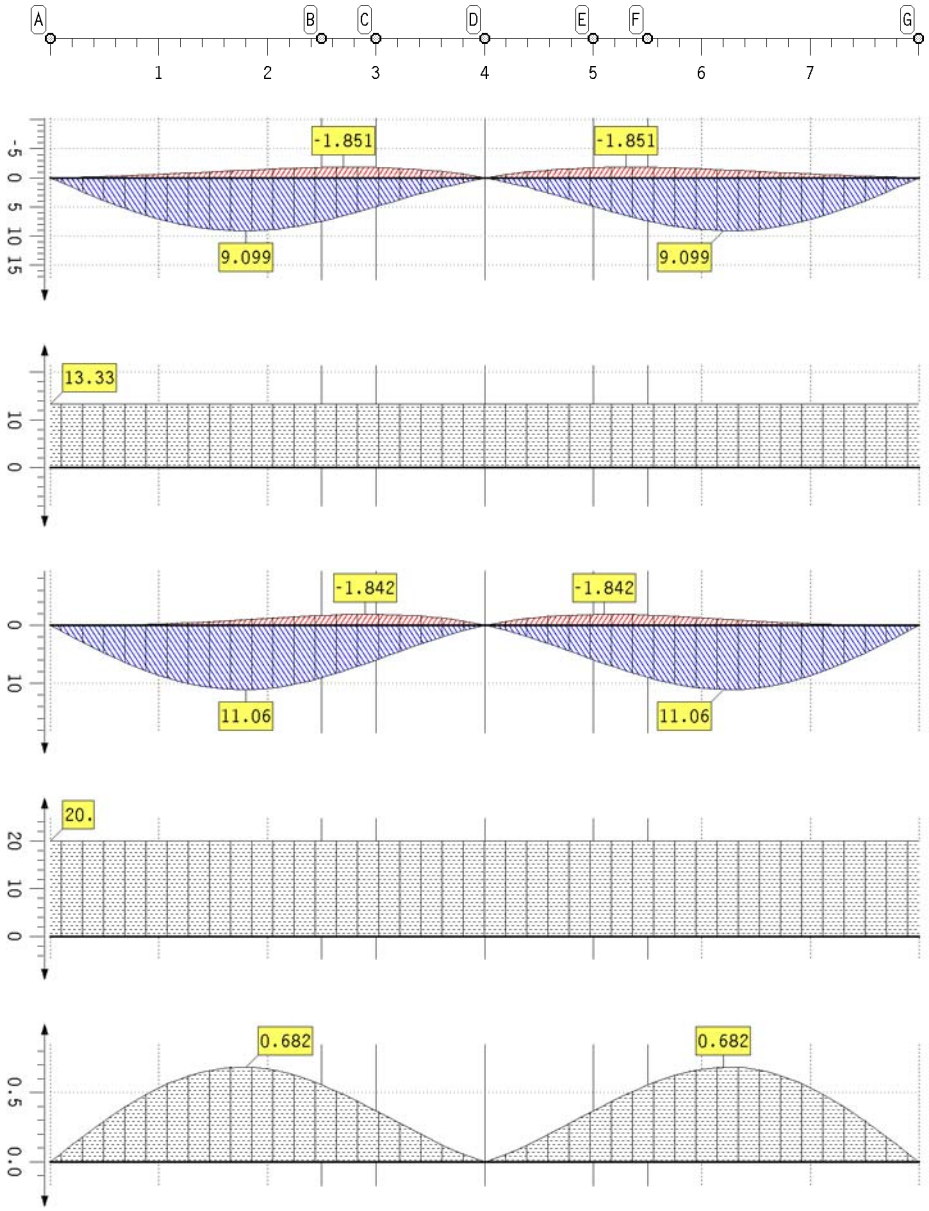
support	l_{ef}	A_{ef}	A_P	k_{c90}	k_{mod}	f_{c90d}	σ_{c90d}	u
	mm	mm²	N		-	N/mm²	N/mm²	-
A	8	800	12144	1.00	0.60	1.15	15.18	13.16
D	8	800	22369	1.00	0.60	1.15	27.96	24.23
G	8	800	12144	1.00	0.60	1.15	15.18	13.16

verification of bearing stresses für den main beam(u = 24.233) does not meet the requirements!

11. Results of verification of deflections

11.1. Verification of deflections

results of verification of deflections



extremal deflections
Winst
in mm
Min: -1.85
Max: 9.10

decisive deflection
Winst,req
in mm
Min: 13.33
Max: 13.33

extremal deflections
Wfin
in mm
Min: -1.84
Max: 11.06

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

maximal utilization
Max: 0.68

verification of deflections

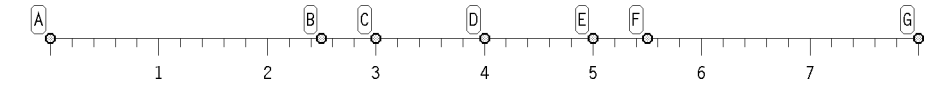
point	x	min/max/req w_{inst}			min/max/req w_{fin}			min/max/req $w_{net,fin}$			U
-	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	-
A	0.000	0.00	0.00	13.33	0.00	0.00	20.00	0.00	0.00	13.33	0.000
	1.000	-0.63	7.10	13.33	-0.23	8.66	20.00	0.00	4.48	13.33	0.533
	1.800	-1.34	9.10	13.33	-0.97	11.06	20.00	-0.38	5.72	13.33	0.682
B	2.500	-1.82	7.40	13.33	-1.69	8.98	20.00	-0.83	4.73	13.33	0.555
B	2.500	-1.82	7.40	13.33	-1.69	8.98	20.00	-0.83	4.73	13.33	0.555
	2.700	-1.85	6.48	13.33	-1.81	7.86	20.00	-0.91	4.17	13.33	0.486
	2.800	-1.84	5.98	13.33	-1.83	7.24	20.00	-0.94	3.85	13.33	0.448
	2.900	-1.81	5.45	13.33	-1.84	6.60	20.00	-0.95	3.52	13.33	0.409
C	3.000	-1.77	4.90	13.33	-1.83	5.93	20.00	-0.95	3.18	13.33	0.368
C	3.000	-1.77	4.90	13.33	-1.83	5.93	20.00	-0.95	3.18	13.33	0.368
	3.517	-1.19	2.09	13.33	-1.33	2.51	20.00	-0.72	1.37	13.33	0.157
D	4.000	-0.00	0.00	13.33	-0.00	0.00	20.00	-0.00	0.00	13.33	0.000
D	4.000	0.00	0.00	13.33	0.00	0.00	20.00	0.00	0.00	13.33	0.000
	4.483	-1.19	2.09	13.33	-1.33	2.51	20.00	-0.72	1.37	13.33	0.157
E	5.000	-1.77	4.90	13.33	-1.83	5.93	20.00	-0.95	3.18	13.33	0.368
E	5.000	-1.77	4.90	13.33	-1.83	5.93	20.00	-0.95	3.18	13.33	0.368
	5.100	-1.81	5.45	13.33	-1.84	6.60	20.00	-0.95	3.52	13.33	0.409
	5.200	-1.84	5.98	13.33	-1.83	7.24	20.00	-0.94	3.85	13.33	0.448
	5.300	-1.85	6.48	13.33	-1.81	7.86	20.00	-0.91	4.17	13.33	0.486
F	5.500	-1.82	7.40	13.33	-1.69	8.98	20.00	-0.83	4.73	13.33	0.555
F	5.500	-1.82	7.40	13.33	-1.69	8.98	20.00	-0.83	4.73	13.33	0.555
	6.200	-1.34	9.10	13.33	-0.97	11.06	20.00	-0.38	5.72	13.33	0.682
	7.000	-0.63	7.10	13.33	-0.23	8.66	20.00	0.00	4.48	13.33	0.533
G	8.000	-0.00	0.00	13.33	-0.00	0.00	20.00	-0.00	0.00	13.33	0.000

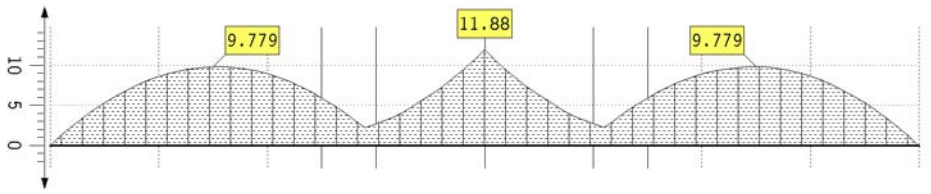
verification of deflections

point	x	min/max/req w_{inst}			min/max/req w_{fin}			min/max/req $w_{net,fin}$			U
-	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	-
minimum		-1.85	0.00	13.33	-1.84	0.00	20.00	-0.95	0.00	13.33	0.000
maximum		0.00	9.10	13.33	0.00	11.06	20.00	0.00	5.72	13.33	0.682

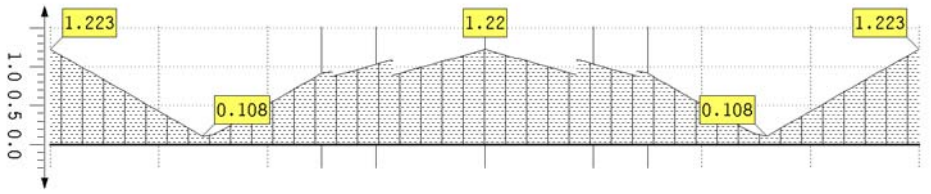
12. Results of verification of fire protection

12.1. Verification of fire protection

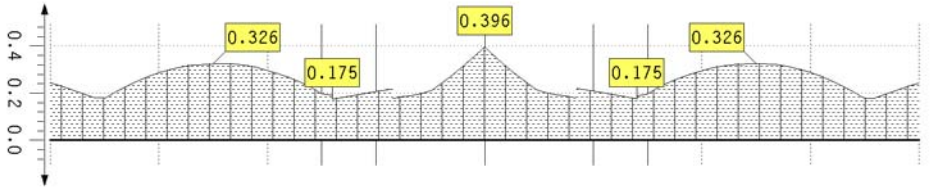




bending stress
main beam
σ_h in MN/m²
Max: 11.88



shear stress
main beam
τ_h in MN/m²
Max: 1.22



utilization
main beam
Max: 0.40

verification of ultimate limit state of main beam

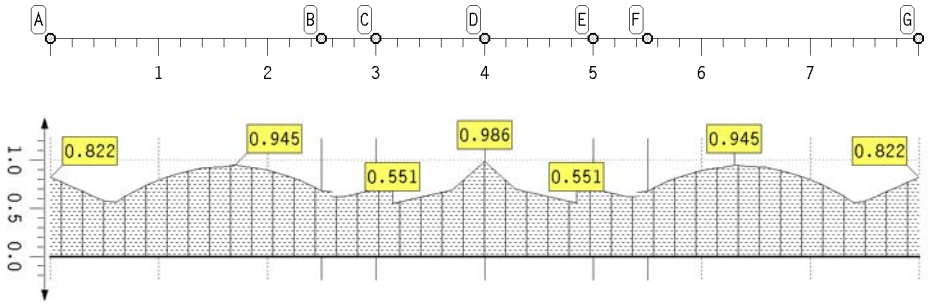
point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m²	MN/m²	-
A	0.000	1.000	0.00	1.22	0.245
	0.500	1.000	5.33	0.82	0.178
	1.000	1.000	8.59	0.43	0.286
	1.400	1.000	9.71	0.11	0.324
	1.500	1.000	9.78	0.13	0.326
	2.000	1.000	8.89	0.52	0.296
B	2.500	1.000	5.93	0.92	0.198
B	2.500	1.000	5.93	0.92	0.198
	2.600	1.000	5.11	0.94	0.188
	2.600	1.000	5.11	0.87	0.175
	2.900	1.000	2.23	0.99	0.199
C	3.000	1.000	2.73	1.03	0.207
C	3.000	1.000	2.73	1.03	0.207
	3.150	1.000	3.53	1.09	0.219
	3.150	1.000	3.53	0.89	0.178
	3.517	1.000	6.44	1.04	0.215
D	4.000	1.000	11.88	1.22	0.396
D	4.000	1.000	11.88	1.22	0.396

point	x	$k_{mod,h}$	σ_h	τ_h	U_h
-	m	-	MN/m²	MN/m²	-
	4.483	1.000	6.44	1.04	0.215
	4.850	1.000	3.53	0.89	0.178
	4.850	1.000	3.53	1.09	0.219
E	5.000	1.000	2.73	1.03	0.207
E	5.000	1.000	2.73	1.03	0.207
	5.100	1.000	2.23	0.99	0.199
	5.400	1.000	5.11	0.87	0.175
	5.400	1.000	5.11	0.94	0.188
F	5.500	1.000	5.93	0.92	0.198
F	5.500	1.000	5.93	0.92	0.198
	6.000	1.000	8.89	0.52	0.296
	6.500	1.000	9.78	0.13	0.326
	6.600	1.000	9.71	0.11	0.324
	7.000	1.000	8.59	0.43	0.286
	7.500	1.000	5.33	0.82	0.178
G	8.000	1.000	0.00	1.22	0.245
minimum		**1.000**	**0.00**	**0.11**	**0.175**
maximum		**1.000**	**11.88**	**1.22**	**0.396**

13. Summary

13.1. Summary of all verifications

maximal utilization



utilization
Max: 0.99

maximal connector utilization

x	U	x	U
m	-	m	-
2.600	0.31	4.300	0.11
3.150	0.35	4.850	0.31
3.700	0.12	5.400	0.31

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	8	800	12144	1.00	0.60	1.15	15.18	13.16
D	8	800	22369	1.00	0.60	1.15	27.96	24.23
G	8	800	12144	1.00	0.60	1.15	15.18	13.16

verification of bearing stresses für den main beam(u = 24.233) does not meet the requirements!

14. Utilizations of all verifications

verification of load-carrying capacity (u = 24.233) does not meet the requirements!