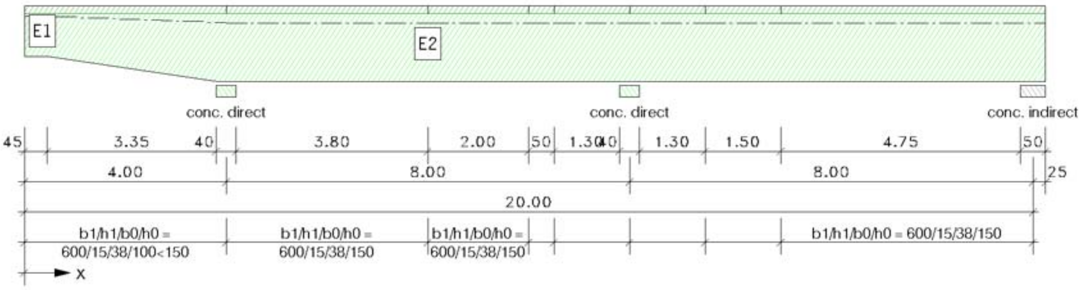
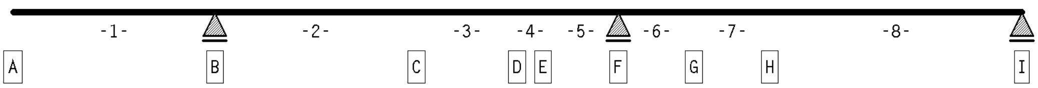
DBV 1045-1, BEISPIEL 6

System and loading

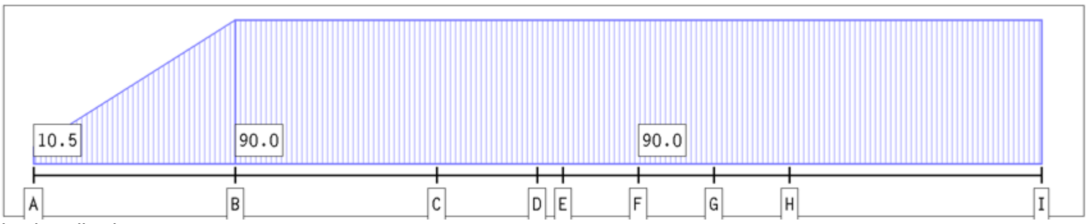
The detailpoints E1, E2 are separated described (see 'special verifications').

scale 1 : 150, length in m,cm

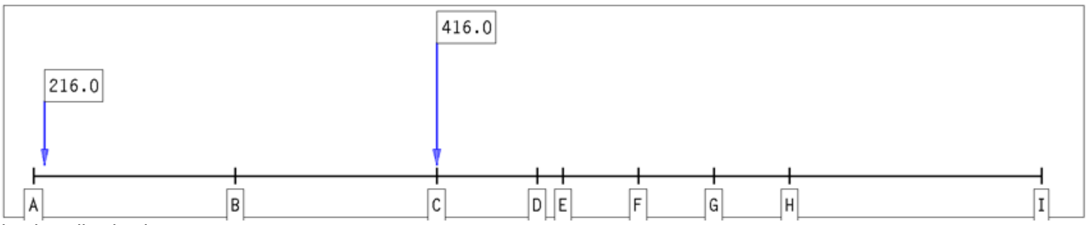




ACTION 1: permanent loads (permanent, 3 partial action effects)

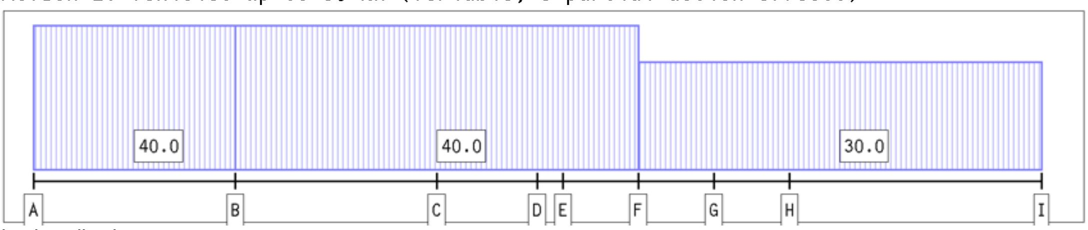


load application top



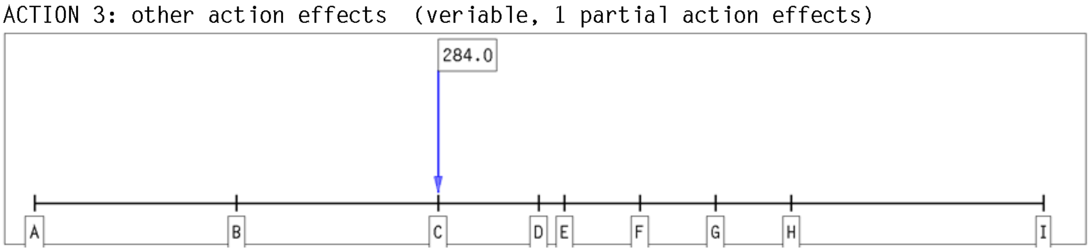
load application bottom

ACTION 2: vehicles up to 30 kN (veriable, 3 partial action effects)



load application top

ACTION 3: other action effects (veriable, 1 partial action effects)

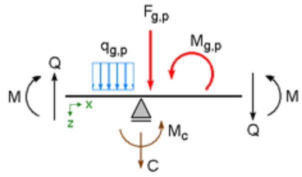


load application bottom

System

int. forces and moments	**yes**	regulation	**EC 2 / NA: Germany**
reinf. concrete design	**yes**	concrete quality	**C40/50**
reinforcem. proposal	**yes**	steel qu. flexure	**BSt 500 (B)**
		steel qu. shear	**BSt 500 (A)**

definition of internal forces and moments:

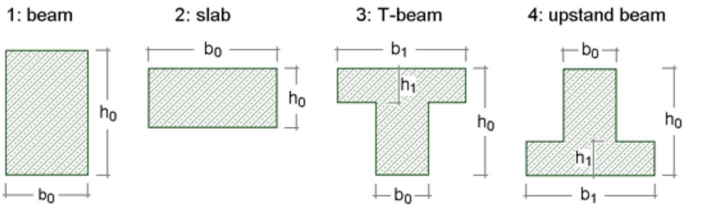


material properties (for the design calculation):

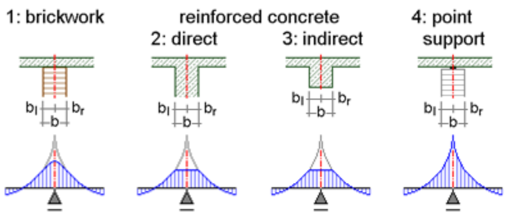
concrete	f_{ck} MN/m2	α -	ε_{c2} ‰	ε_{c2u} ‰	n_c -	E_{cm} MN/m2	f_{ctm} MN/m2
C40/50	40.0	0.850	-2.00	-3.50	2.00	35220.5	3.509

reinforcem.	f_{yk} MN/m2	f_{tk} MN/m2	ε_{su} ‰	E_s MN/m2
BSt 500 (B)	500.0	525.0	25.00	200000.0
BSt 500 (A)	500.0	525.0	25.00	200000.0

cross-section types:



support types:



section	dimensions x_a m	x_e m	L m	type*)	Δz cm	cross-sections b_{0a} cm	h_{0a} cm	b_{1a} cm	h_{1a} cm	b_{0e} cm	h_{0e} cm	b_{1e} cm	h_{1e} cm	haunch
-1-	0.00	4.00	4.00	3	0.0	38.0	100.0	600.0	15.0	38.0	150.0	600.0	$=d_{1a}$	bottom edge
-2-	4.00	8.00	4.00	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-3-	8.00	10.00	2.00	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-4-	10.00	10.50	0.50	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-5-	10.50	12.00	1.50	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-6-	12.00	13.50	1.50	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-7-	13.50	15.00	1.50	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	
-8-	15.00	20.00	5.00	3	0.0	38.0	150.0	600.0	15.0	----	----	----	----	

*) cross-section type

support	x m	c_F kN/m	c_M kNm/-	type*)	b cm	b_l cm	b_r cm	redis.o) %	check-)
A	0.00	----	----	0	45.0	0.0	45.0	0	yes
B	4.00	fix	----	2	40.0	20.0	20.0	20(opt)	yes
C	8.00	----	----	0	0.0	0.0	0.0	0	yes
D	10.00	----	----	0	0.0	0.0	0.0	0	yes
E	10.50	----	----	0	0.0	0.0	0.0	0	yes
F	12.00	fix	----	2	40.0	20.0	20.0	15	yes
G	13.50	----	----	0	0.0	0.0	0.0	0	yes
H	15.00	----	----	0	0.0	0.0	0.0	0	yes
I	20.00	fix	----	3	50.0	25.0	25.0	0	yes

*) support type
o) redistribution of the moments: reduction of the min. support moment considering the equilibrium
information: analysis of the redistribution factors approximately at an equivalent system.
optimized: redistr. of the moments without increase of max. moment in the span
-) redistribution acc. to 5.5(4) to be checked

Action effects

1. permanent: permanent loads

1. additive load case: gk,1
   - ⇒ trapez.load (top): q_a = 10.50 kN/m at x_a = 0.00 m, q_e = 90.00 kN/m at x_e = 4.00 m (section -1-)
   - ⇒ unif.distr.load (top): q = 90.00 kN/m from x_a = 4.00 m to x_e = 20.00 m (sections -2- to -8-)
2. additive load case: Gk,2
   - ⇒ point load (bottom): F = 216.00 kN at x = 0.23 m (support 'A' + 0.23 m)
3. additive load case: Gk,3
   - ⇒ point load (bottom): F = 416.00 kN at x = 8.00 m (support 'B' + 4.00 m)

2. veriable: vehicles up to 30 kN (traffic loads: vehicles up to 30 kN ⇒ Ψ_0=0.7 Ψ_1=0.7 Ψ_2=0.6)

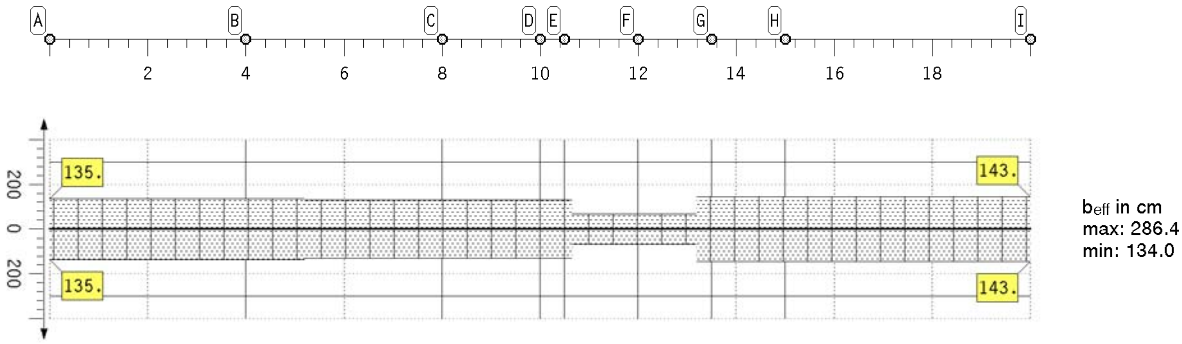
4. additive load case: qk,11
   - ⇒ unif.distr.load (top): q = 40.00 kN/m from x_a = 0.00 m to x_e = 4.00 m (section -1-)
5. additive load case: qk,12
   - ⇒ unif.distr.load (top): q = 40.00 kN/m from x_a = 4.00 m to x_e = 12.00 m (sections -2- to -5-)
6. additive load case: qk,13
   - ⇒ unif.distr.load (top): q = 30.00 kN/m from x_a = 12.00 m to x_e = 20.00 m (sections -6- to -8-)

3. veriable: other action effects (other action effects ⇒ Ψ_0=0.8 Ψ_1=0.7 Ψ_2=0.5)

7. additive load case: Qk,2
   - ⇒ point load (bottom): F = 284.00 kN at x = 8.00 m (support 'B' + 4.00 m)

Design calculation and reinforcement proposal acc. to DIN EN 1992-1-1 (EC 2, 1.11)

effective width of flange of flanges in T-beams/upstand beams



existing width of flange b_p and effective width of flange b_{eff}:

x m	b_p cm	b_{eff} cm
0.00	600.0	270.4
0.45	600.0	270.4
1.37	600.0	270.4
2.37	600.0	270.4
4.00	600.0	270.4

x m	b_p cm	b_{eff} cm
4.00	600.0	270.4
5.20	600.0	270.4
5.20	600.0	262.0
8.00	600.0	262.0
8.00	600.0	262.0

x m	b_p cm	b_{eff} cm
10.00	600.0	262.0
10.00	600.0	262.0
10.50	600.0	262.0
10.50	600.0	262.0
10.65	600.0	262.0

x m	b_p cm	b_{eff} cm
10.65	600.0	134.0
12.00	600.0	134.0
12.00	600.0	134.0
13.20	600.0	134.0
13.20	600.0	286.4

x m	b_p cm	b_{eff} cm
13.50	600.0	286.4
13.50	600.0	286.4
15.00	600.0	286.4
15.00	600.0	286.4
20.00	600.0	286.4

initial reinforcement, reinforcement edge distances, additional information for the type of reinforcement

section	A_{s0o} cm²	A_{s0u} cm²	$a_{s0b\hat{u}}$ cm²/m	h_{s0o} cm	h_{s0u} cm	c_{vo} mm	c_{vu} mm	c_{vr} mm	d_{sb} mm	n_s	d_{so} mm	d_{su} mm	min n_o	min n_u	max n_o	max n_u	welded mesh top	 bottom
-1-	34.36	0.00	0.00	7.0	9.0	35	35	45	8	2	25	16	0	0	5	8	--	--
-2-	34.36	34.36	0.00	7.0	9.0	35	35	45	8	2	25	25	0	0	5	5	--	--
-3-	0.00	34.36	0.00	7.0	9.0	35	35	45	8	2	25	25	0	0	5	5	--	--
-4-	24.54	34.36	0.00	7.0	9.0	35	35	45	8	2	25	25	0	0	5	5	--	--
-5-	24.54	0.00	0.00	7.0	9.0	35	35	45	8	2	25	25	0	0	5	5	--	--
-6-	24.54	0.00	0.00	7.0	6.0	35	35	45	8	2	25	20	0	0	5	7	--	--
-7-	24.54	15.70	0.00	7.0	6.0	35	35	45	8	2	25	20	0	0	5	7	--	--
-8-	0.00	15.70	0.00	7.0	6.0	35	35	45	8	2	25	20	0	0	5	7	--	--

Verification 1: EC 2 design calculation

bending design calculation (6.1)

column **(1)**: consideration of minimum reinforcement (9.2.1.1)
column **(2)**: inimum moments at face of support (5.3.2.2(3))
column **(3)**: minimum moments at simply supported end support (9.2.1.2(1))
column **(4)**: compliance of max. compression area ratio (5.6.3(2))
column **(5)**: determination of the cross-section utilization

section	(1)	(2)	(3)	(4)	(5)
-1-	x	x	-	-	-
-2-	x	x	-	-	-
-3-	x	x	-	-	-
-4-	x	x	-	-	-

section	(1)	(2)	(3)	(4)	(5)
-5-	x	x	-	-	-
-6-	x	x	-	-	-
-7-	x	x	-	-	-
-8-	x	x	-	-	-

shear analysis (6.2)

column **(1)**: stepped distr. of shear reinforcement
column **(2)**: point loads near to support 9.2.2(5)
column **(3)**: strut inclination as flat as possible
column **(4)**: inner lever arm z^{II} either from ' bend'ing design calculation or acc. to ' 6.2.3'(1)
column **(5)**: V_{Rdct} limitation (6.2.2(1))
column **(6)**: verification of a horizontal interface (6.2.5)

section		min ρ_w ‰	(1)	(2)	(3)	θ °	(4)	(5)	(6)	surface	b_j cm	h_j cm	outs.w.A_s %
-1-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-2-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-3-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-4-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-5-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-6-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-7-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60
-8-(*)	beam	1.12	x	-	x	0	6.2.3	x	-		0.0	0.0	60

(*): T-beam/upstand beam: connection between flange and web is **not** being checked !

extreme rule: standard combination

act.	Ψ_{dom}	Ψ_{sub}	γ_{sup}	γ_{inf}
1	1.00	1.00	1.35	1.00
2	1.00	0.70	1.50	0.00
3	1.00	0.80	1.50	0.00

material safety factors: concrete γ_C = 1.50, reinf. γ_S = 1.15
design strengths: concrete f_{cd} = 22.7 MN/m², reinf. f_{yd} = 434.8 MN/m² f_{td} = 456.5 MN/m² (E_{cm} = 35220.5 MN/m²)

Verification 2: EC 2 crack limitation

crack control in the limit state of serviceability (7.3.2, 7.3.3)

column **(1)** : first crack formation due to flexural restraint, centr. restr. (intrinsically resp. extr. imposed) or without restr.
column **(2)** : good or bad bond
column **(3)** : slowly hardening concrete (reduction of the minimum reinforcement)
column **(4)** : min. tensile strength required: $f_{ct,eff} \geq f_{ct0}$ for $k_{zt} \geq 1$, f_{ct0} = 3.0 MN/m²

section	d_{sgro} mm	d_{sgru} mm	(1)	(2)	w_{cal} mm	(3)	$k_{z,t}$	(4)	$f_{ct,eff}$ MN/m²
-1-	25	16	flex.+	good	0.30	-	1.00	-	3.509
-2-	25	25	flex.+	good	0.30	-	1.00	-	3.509
-3-	25	25	flex.+	good	0.30	-	1.00	-	3.509
-4-	25	25	flex.+	good	0.30	-	1.00	-	3.509
-5-	25	25	flex.+	good	0.30	-	1.00	-	3.509
-6-	25	20	flex.+	good	0.30	-	1.00	-	3.509
-7-	25	20	flex.+	good	0.30	-	1.00	-	3.509
-8-	25	20	flex.+	good	0.30	-	1.00	-	3.509

+) intrinsically imposed restraint

extreme rule: standard combination

act.	Ψ_{dom}	Ψ_{sub}	γ_{sup}	γ_{inf}
1	1.00	1.00	1.00	1.00
2	0.60	0.60	1.00	0.00
3	0.50	0.50	1.00	0.00

material safety factors: concrete γ_C = 1.00, reinf. γ_S = 1.00
stress-strain-relationship: concrete acc. to 3.1.5 with $f_c = f_{cm}$ = 48.0 MN/m², ε_{c1} = -8.13 ‰, ε_{c1u} = -12.25 ‰
reinforcement acc. to 3.2 with $f_{yd} = f_{yk}$
creep and shrinkage: creep coefficient φeff = 2.500, shrinkage strain εcs = 0.400‰ (E_{cm} = 10063.0 MN/m²)

Verification 3: EC 2 stress verification

limitation of stresses in the serviceability limit state (7.2)

section	σ_c MN/m²	σ_s MN/m²	section	σ_c MN/m²	σ_s MN/m²
-1-	-24.0	400.0	-5-	-15.0	400.0
-2-	-15.0	400.0	-6-	---	400.0
-3-	-15.0	400.0	-7-	---	400.0
-4-	-15.0	400.0	-8-	---	400.0

extreme rule: standard combination

act.	Ψ_{dom}	Ψ_{sub}	γ_{sup}	γ_{inf}
1	1.00	1.00	1.00	1.00
2	1.00	0.70	1.00	0.00
3	1.00	0.80	1.00	0.00

material safety factors: concrete γ_c = 1.00, reinf. γ_s = 1.00
stress-strain-relationship: concrete acc. to 3.1.5 with $f_c = f_{cm}$ = 48.0 MN/m², ε_{c1} = -8.13 ‰, ε_{c1u} = -12.25 ‰
reinforcement acc. to 3.2 with $f_{yd} = f_{yk}$
creep and shrinkage: creep coefficient φeff = 2.500, shrinkage strain εcs = 0.400‰ (E_{cm} = 2875.1 MN/m²)

Verification 4: EC 2 verif. of deformation

limitation of deformations in the serviceability limit state (issue 240, DAfStb)

deformations based on existing reinforcement

section	p^I %	p^{II} %	p^k %	section	p^I %	p^{II} %	p^k %
-1-	0	100	100	-5-	0	100	100
-2-	0	100	100	-6-	0	100	100
-3-	0	100	100	-7-	0	100	100
-4-	0	100	100	-8-	0	100	100

extreme rule: standard combination

act.	Ψ_{dom}	Ψ_{sub}	γ_{sup}	γ_{inf}
1	1.00	1.00	1.00	1.00
2	0.60	0.60	1.00	0.00
3	0.50	0.50	1.00	0.00

material safety factors: concrete γ_c = 1.00, reinf. γ_s = 1.00
stress-strain-relationship: concrete acc. to 3.1.5 with $f_c = f_{cm}$ = 48.0 MN/m², ε_{c1} = -2.32 ‰, ε_{c1u} = -3.50 ‰
reinforcement acc. to 3.2 with $f_{yd} = f_{yk}$
creep and shrinkage: creep coefficient φeff = 2.500, shrinkage strain εcs = 0.400‰ (E_{cm} = 2875.1 MN/m²)

Results

support reaction of characteristic values (Ψ=1, γ=1/0)

extremal support reactions C, M_c:

support	max C kN	min C kN	max M_c kNm	min M_c kNm
B	-1022.84	-1504.12	0.00	0.00
F	-905.47	-1500.47	0.00	0.00
I	-228.94	-388.16	0.00	0.00

extremal support reactions C, M_c (extremized by action effects):

support	max C kN	min C kN	max M_c kNm	min M_c kNm
act. 1: permanent loads				
B	-1036.48	-1036.48	0.00	0.00
F	-963.97	-963.97	0.00	0.00
I	-272.55	-272.55	0.00	0.00
act. 2: vehicles up to 30 kN				
B	13.64	-350.44	0.00	0.00
F	58.50	-344.89	0.00	0.00
I	18.80	-115.61	0.00	0.00
act. 3: other action effects				
B	0.00	-117.19	0.00	0.00
F	0.00	-191.62	0.00	0.00
I	24.81	0.00	0.00	0.00

support reactions C, M_c (by load case):

support	C kN	M_c kNm
E1/L1: gk,1		
B	-523.33	0.00
F	-832.35	0.00
I	-285.33	0.00
E1/L2: Gk,2		
B	-341.49	0.00
F	149.06	0.00

support	C kN	M_c kNm
I	-23.57	0.00
E1/L3: Gk,3		
B	-171.66	0.00
F	-280.68	0.00
I	36.34	0.00
E2/L4: qk,11		
B	-209.25	0.00

support	C kN	M_c kNm
F	58.50	0.00
I	-9.25	0.00
E2/L5: qk,12		
B	-141.20	0.00
F	-197.61	0.00
I	18.80	0.00
E2/L6: qk,13		

support	C kN	M_c kNm
B	13.64	0.00
F	-147.28	0.00
I	-106.36	0.00
E3/L7: Qk,2		
B	-117.19	0.00
F	-191.62	0.00
I	24.81	0.00

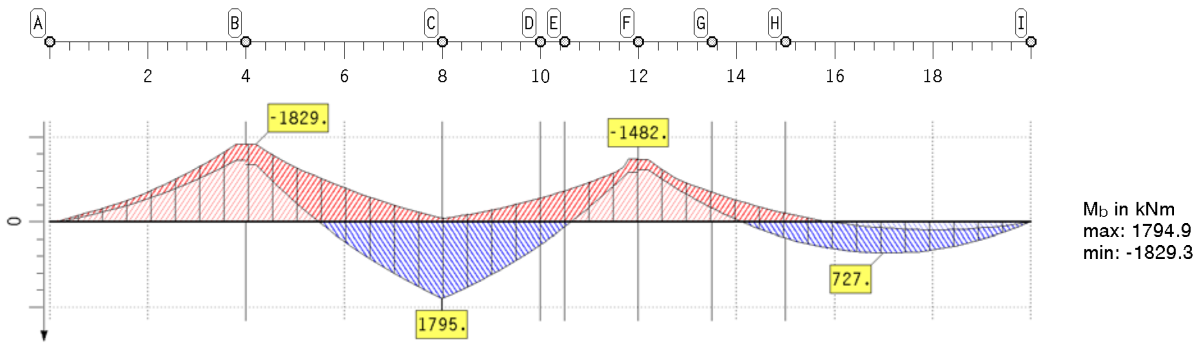
Verification 1: EC 2 design calculation

support reaction (Ψ-,γ-fach, see rules of extremizations)

extremal support reactions C, M_c, support reactions from permanent loads C_g, M_{cg}, maximal bearing stress p_c (face of support left, right), surface of pressure A_p

support	max C kN	min C kN	max M_c kNm	min M_c kNm	max C_g kN	max M_{cg} kNm	min C_g kN	min M_{cg} kNm	max p_{cl} MN/m2	max p_{cr} MN/m2	A_p cm2
B	-1016.02	-2065.55	0.00	0.00	-1036.48	0.00	-1399.25	0.00	13.589	13.589	1520.0
F	-824.05	-2100.79	0.00	0.00	-911.79	0.00	-1353.52	0.00	13.821	13.821	1520.0
I	-201.86	-554.08	0.00	0.00	-259.84	0.00	-380.67	0.00	2.916	2.916	1900.0

extremal flexural moment (design moment)



extremal flexural moment M_b

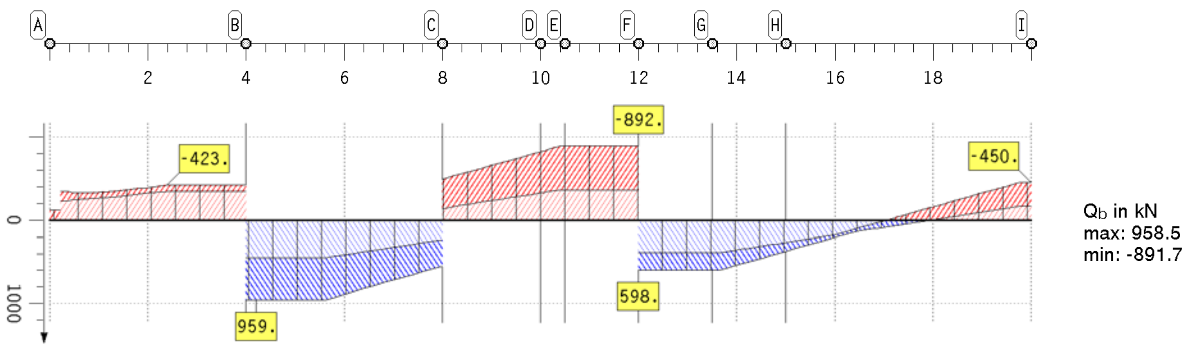
x m	max M_b kNm	min M_b kNm
0.00	0.00	0.00
0.45	-56.04	-103.17
1.37	-322.00	-427.66
2.37	-700.35	-893.33
4.00	1454.81	-1823.39

x m	max M_b kNm	min M_b kNm
4.00	1348.10	-1829.32
8.00	1794.95	-82.49
8.00	1794.95	-82.49
10.00	539.17	-557.34
10.00	539.17	-557.34

x m	max M_b kNm	min M_b kNm
10.50	120.38	-732.30
10.50	120.38	-732.30
12.00	1167.95	-1482.23
12.00	1227.52	-1467.06
13.50	-319.47	-692.41

x m	max M_b kNm	min M_b kNm
13.50	-319.47	-692.41
15.00	378.63	-195.12
15.00	378.63	-195.12
17.00	726.68	152.93
20.00	0.00	0.00

extremal shear force (design shear force)



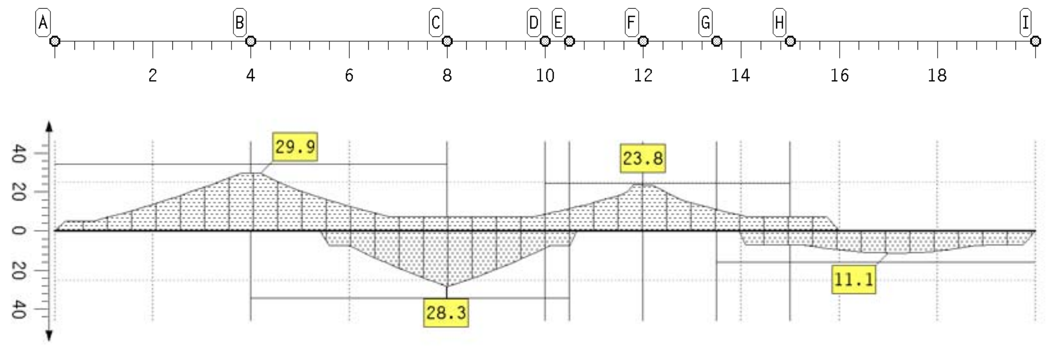
extremal shear force Q_b with associated flexural moment M_b

x m	max Q_b kN	M_b kNm	min Q_b kN	M_b kNm
0.00	0.05	0.00	-117.88	0.00
0.45	-240.83	-56.04	-332.11	-88.07
1.37	-285.18	-322.95	-353.92	-414.99
2.37	-341.74	-817.11	-420.97	-893.33
4.00	-342.27	-1584.31	-422.56	-1980.39
4.00	958.51	-1980.39	447.11	-1584.31
8.00	549.32	1332.91	232.01	795.75

x m	max Q_b kN	M_b kNm	min Q_b kN	M_b kNm
8.00	-134.48	117.71	-493.34	1700.74
10.00	-327.43	-557.34	-820.90	366.92
10.00	-327.43	-557.34	-820.90	366.92
10.50	-362.53	-732.30	-891.68	-66.22
10.50	-362.53	-732.30	-891.68	-66.22
12.00	-362.53	-1392.19	-891.68	-1637.87
12.00	597.67	-1637.87	386.42	-1392.19

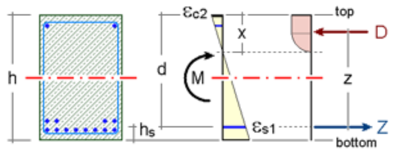
x m	max Q_b kN	M_b kNm	min Q_b kN	M_b kNm
13.50	597.67	-519.09	386.42	-692.41
13.50	597.67	-519.09	386.42	-692.41
15.00	371.23	225.08	264.02	-195.12
15.00	371.23	225.08	264.02	-195.12
20.00	-163.48	0.00	-450.35	0.00

minimum longitudinal reinforcement from bending design calculation



A_s in cm2
max A_{so}: 29.87
max A_{su}: 28.25

min. longitudinal reinforcement A_s, min. reinf. A_{scr} acc. to 13.1.1 (T-/upstand beam only web), reinf. edge distances h_s
values associated to extremal flexural moment:
static height d, depth of the neutral axis k_x=x/d, relative inner lever arm k_z=z/d, strains ε_c,ε_s



$\varepsilon_{c2} = \min(\varepsilon_{co}, \varepsilon_{cu})$
$\varepsilon_{s1} = \max(\varepsilon_{so}, \varepsilon_{su})$
$x = k_x d$
$z = k_z d$
$d = h - h_s$

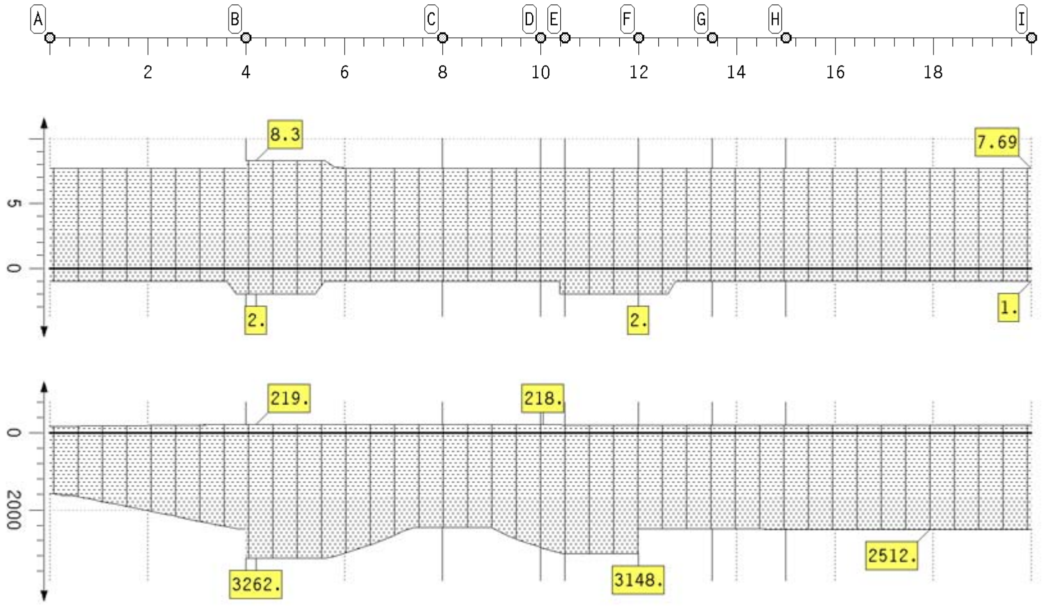
x m	max M_b kNm	min M_b kNm	A_{so} cm2	A_{su} cm2	A_{scro} cm2	A_{scru} cm2	h_{so} cm	h_{su} cm	d cm	k_x -	k_z -	ε_{co} ‰	ε_{so} ‰	ε_{su} ‰	ε_{cu} ‰
0.00	0.00	0.00	0.00	0.00	4.88	4.99	7.0	9.0	91.0	0.000	1.000	0.00	0.00	0.00	0.00
0.45	-56.04	-103.17	4.88	0.00	4.88	4.99	7.0	9.0	93.0	0.036	0.988	26.95	25.00	1.58	-0.93
1.37	-322.00	-427.66	9.01	0.00	5.49	5.60	7.0	9.0	106.7	0.070	0.974	26.76	25.00	0.40	-1.87
2.37	-700.35	-893.33	16.73	0.00	6.17	6.27	7.0	9.0	121.7	0.097	0.962	26.59	25.00	-0.64	-2.68
4.00	-1454.81	-1823.39	29.77	0.00	7.13	7.24	7.0	9.0	143.0	0.136	0.944	23.59	22.33	-1.87	-3.50
4.00	-1348.10	-1829.32	29.87	0.00	7.13	7.24	7.0	9.0	143.0	0.136	0.943	23.50	22.24	-1.88	-3.50
4.20	-1348.10	-1829.32	29.87	0.00	7.13	7.24	7.0	9.0	143.0	0.136	0.943	23.50	22.24	-1.88	-3.50
8.00	1794.95	-82.49	7.13	28.25	7.13	7.24	7.0	9.0	141.0	0.038	0.987	-0.98	0.31	25.00	26.66
8.00	1794.95	-82.49	7.13	28.25	7.13	7.24	7.0	9.0	141.0	0.038	0.987	-0.98	0.31	25.00	26.66
10.00	539.17	-557.34	8.72	8.43	7.13	7.24	7.0	9.0	143.0	0.057	0.979	26.30	25.00	0.15	-1.51
10.00	539.17	-557.34	8.72	8.43	7.13	7.24	7.0	9.0	143.0	0.057	0.979	26.30	25.00	0.15	-1.51
10.50	120.38	-732.30	11.50	7.24	7.13	7.24	7.0	9.0	143.0	0.067	0.975	26.31	25.00	-0.12	-1.81
10.50	120.38	-732.30	11.50	7.24	7.13	7.24	7.0	9.0	143.0	0.067	0.975	26.31	25.00	-0.12	-1.81
12.00	-1167.95	-1482.23	23.79	0.00	7.13	7.24	7.0	9.0	143.0	0.112	0.954	26.38	25.00	-1.38	-3.15
12.00	-1227.52	-1467.06	23.54	0.00	7.13	7.08	7.0	6.0	143.0	0.111	0.955	26.38	25.00	-1.94	-3.12
12.20	-1227.52	-1467.06	23.54	0.00	7.13	7.08	7.0	6.0	143.0	0.111	0.955	26.38	25.00	-1.94	-3.12
13.50	-319.47	-692.41	10.87	0.00	7.13	7.08	7.0	6.0	143.0	0.065	0.976	26.31	25.00	-0.62	-1.74
13.50	-319.47	-692.41	10.87	0.00	7.13	7.08	7.0	6.0	143.0	0.065	0.976	26.31	25.00	-0.62	-1.74
15.00	378.63	-195.12	7.13	7.08	7.13	7.08	7.0	6.0	144.0	0.015	0.995	-0.39	0.84	25.00	26.06
15.00	378.63	-195.12	7.13	7.08	7.13	7.08	7.0	6.0	144.0	0.015	0.995	-0.39	0.84	25.00	26.06
17.00	726.68	152.93	0.00	11.13	7.13	7.08	7.0	6.0	144.0	0.022	0.993	-0.55	0.69	25.00	26.06
20.00	0.00	0.00	0.00	0.00	7.13	7.08	7.0	6.0	144.0	0.000	1.000	0.00	0.00	0.00	0.00

depth of the neutral axis k_x, permitted redistribution ratio δ_{zul},
extremal redistribution ratio δ_{max} for maximum, δ_{min} for minimum internal forces and moments

support	k_x=x/d -	δ_{zul} %	δ_{max} %	δ_{min} %
B	0.136	74.8	---	---
F	0.112	72.9	---	---
I	---	---	---	---

minimum shear reinforcement

T-beam/upstand beam: connection between flange and web is not being checked!
assumption: strut inclination as flat as possible



top: $a_{sbü}$ in cm^2/m
bottom: range of utilization
max $a_{sbü}$: 8.30
max AB: 2

top: V_{Rdct} in kN
bottom: V_{Rdmax} in kN
max V_{Rdct}: 219.16
max V_{Rdmax}: 3261.68

design value of the maximal shear force: max Q_b without reduction (verification of V_{Rdmax}), V_{Ed} with reduction, angle of compression strut θ, ratio of longitudinal reinforcement ρ_l, inner lever arm z^{II}, value of design resistance without shear reinforcement V_{Rdct}, value of design resistance V_{Rdsy}, value of maximum design resistance V_{Rdmax}, range of the shear force utilization AB, minimum stirrup reinforcement $a_{sbü}$, maximal permitted spacing of the stirrups lim s,

x m	max Q_b kN	V_{Ed} kN	θ °	ρ_l %	z^{II} cm	V_{Rdct} kN	V_{Rdsy} kN	V_{Rdmax} kN	AB -	$a_{sbü}$ cm2/m	lim s cm
0.00	0.00	117.88	18.43	0.99	81.9	173.33	821.56	1587.22	1	7.69+	30.0
0.45	327.70	332.11	18.43	0.97	83.7	175.26	839.62	1622.11	1	7.69+	30.0
1.37	418.40	353.92	18.43	0.85	96.1	188.06	963.59	1861.61	1	7.69+	30.0
2.37	542.75	420.97	18.43	0.74	109.5	201.28	1098.34	2121.94	1	7.69+	30.0
4.00	802.95	422.56	18.43	0.63	128.7	219.16	1291.03	2494.21	2	7.69+	30.0
4.00	1262.60	958.51	25.84	0.63	128.7	219.16	958.51	3261.68	2	8.30	30.0
8.00	590.98	549.32	18.43	0.64	126.9	217.53	1272.97	2459.32	1	7.69+	30.0
8.00	539.50	493.34	18.43	0.64	126.9	217.53	1272.97	2459.32	1	7.69+	30.0
10.00	867.06	820.90	23.34	0.64	126.9	217.53	1291.03	2982.25	1	7.69+	30.0
10.00	867.06	820.90	23.34	0.64	126.9	217.53	1291.03	2982.25	1	7.69+	30.0
10.50	957.81	891.68	24.62	0.45	128.7	195.90	1291.03	3148.40	2	7.69+	30.0
10.50	957.81	891.68	24.62	0.45	128.7	195.90	1291.03	3148.40	2	7.69+	30.0
12.00	1230.06	891.68	24.62	0.45	128.7	195.90	1291.03	3148.40	2	7.69+	30.0
12.00	870.73	597.67	18.43	0.45	128.7	195.90	1291.03	2494.21	2	7.69+	30.0
13.50	620.98	597.67	18.43	0.45	128.7	195.90	1291.03	2494.21	1	7.69+	30.0
13.50	620.98	597.67	18.43	0.45	128.7	195.90	1291.03	2494.21	1	7.69+	30.0
15.00	371.23	371.23	18.43	0.29	129.6	194.80	1300.06	2511.65	1	7.69+	30.0
15.00	371.23	371.23	18.43	0.29	129.6	194.80	1300.06	2511.65	1	7.69+	30.0
20.00	554.08	450.35	18.43	0.29	128.7	193.73	1291.03	2494.21	1	7.69+	30.0

(+): minimum shear reinforcement decisive

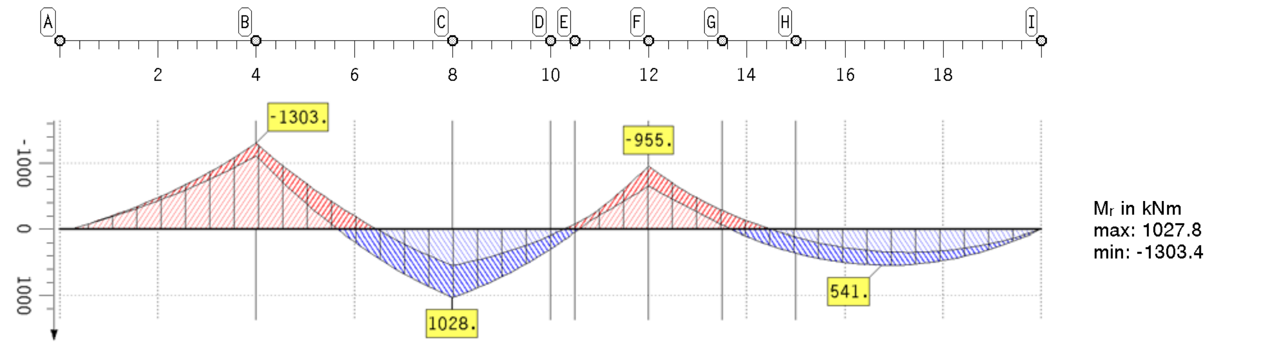
Verification 2: EC 2 crack limitation

support reaction (Ψ-,γ-fach, see rules of extremizations)

extremal support reactions C, M_c, maximal bearing stress p_c (face of support left, right), surface of pressure A_p

support	max C kN	min C kN	max M_c kNm	min M_c kNm	max p_{cl} MN/m2	max p_{cr} MN/m2	A_p cm2
B	-1028.30	-1305.34	0.00	0.00	8.588	8.588	1520.0
F	-928.87	-1266.71	0.00	0.00	8.334	8.334	1520.0
I	-248.87	-341.92	0.00	0.00	1.800	1.800	1900.0

extremal flexural moment (cracking moment)

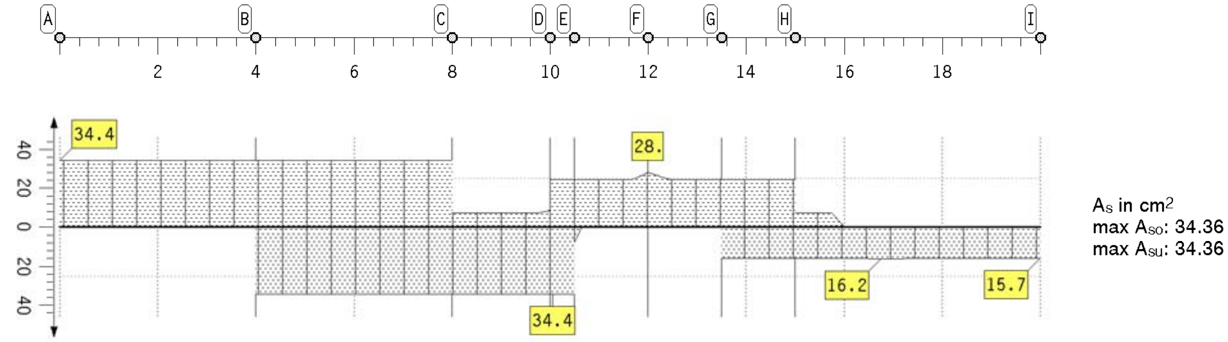


extremal flexural moment M_r

x	max M_r	min M_r
m	kNm	kNm
0.00	0.00	0.00
0.45	-49.96	-52.39
1.37	-265.69	-288.21
2.37	-536.90	-604.31
4.00	-1111.40	-1303.40
4.00	-1111.40	-1303.40
8.00	1027.77	539.98
8.00	1027.77	539.98
10.00	297.36	89.67
10.00	297.36	89.67
10.50	43.58	-79.23
10.50	43.58	-79.23
12.00	-655.17	-954.52
12.00	-655.17	-954.52
13.50	-59.02	-283.60
13.50	-59.02	-283.60
15.00	359.60	119.34
15.00	359.60	119.34
16.75	540.87	333.51
20.00	0.00	0.00

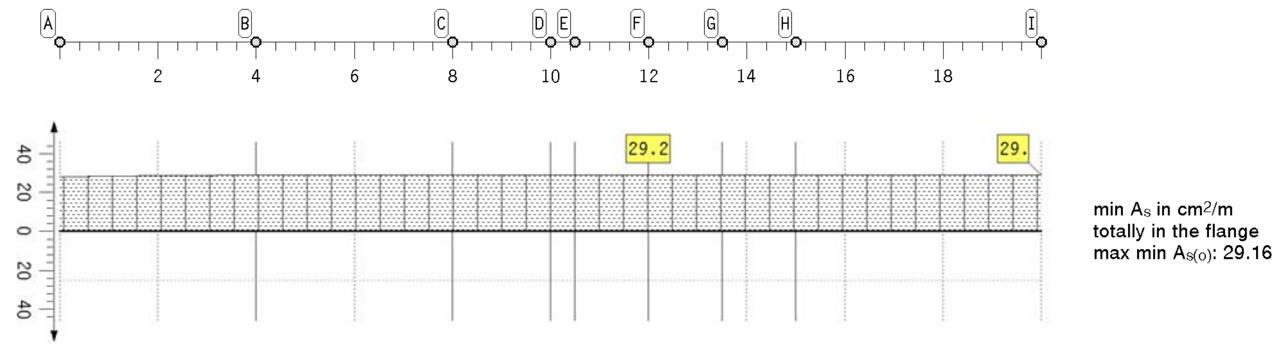
minimum longitudinal reinforcement (incl. main longitudinal reinforcement)

the minimum reinforcement (in cm2/m) is not extremized with the longitudinal reinforcement, see below.
the radius of influence of the flange is limited to b_{web} + b_{flange} + 3 * reinforcement edge distance.



minimum reinforcement of crack control

T-beam/upstand beam: minimum reinforcement (in cm2/m) is only calculated for the flange.



minimum longitudinal reinforcement A_s = initial reinforcement A_{sb} + additional reinforcement ΔA_{sr} (from load), reinforcement stresses σ_{sr}, maximum bar diameter d_{sgr}, minimum reinforcement min A_s

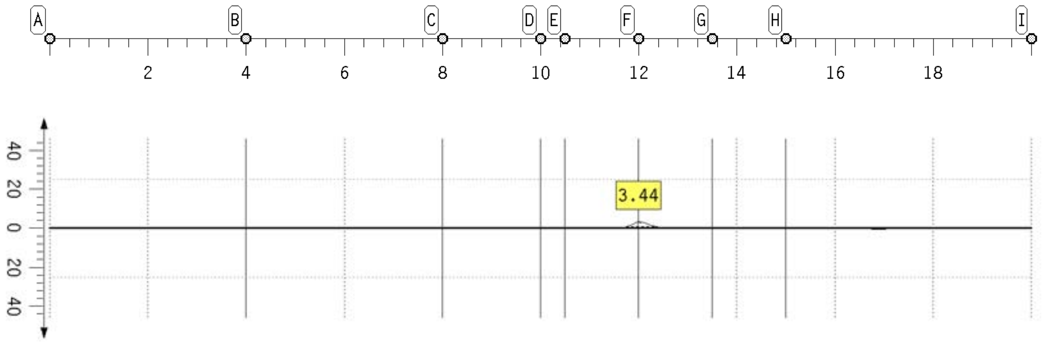
x	max M_r	min M_r	A_{so}	A_{su}	A_{sbo}	A_{sbu}	ΔA_{sro}	ΔA_{sru}	σ_{sro}	σ_{sru}	d_{sgro}	d_{sgru}	min A_{so}	min A_{su}
m	kNm	kNm	cm2	cm2	cm2	cm2	cm2	cm2	N/mm2	N/mm2	mm	mm	cm2/m	cm2/m
0.00	0.00	0.00	34.36	0.00	34.36	0.00	0.00	0.00	0.00	0.00	0.0	0.0	28.22	0.00
0.45	-49.96	-52.39	34.36	0.00	34.36	0.00	0.00	0.00	19.35	0.00	60.0	0.0	28.22	0.00
1.37	-265.69	-288.21	34.36	0.00	34.36	0.00	0.00	0.00	92.03	0.00	60.0	0.0	28.52	0.00
2.37	-536.90	-604.31	34.36	0.00	34.36	0.00	0.00	0.00	168.06	0.00	49.9	0.0	28.76	0.00
4.00	-1111.40	-1303.40	34.36	0.00	34.36	0.00	0.00	0.00	305.77	0.00	27.4	0.0	29.01	0.00
4.00	-1111.40	-1303.40	34.36	34.36	34.36	34.36	0.00	0.00	291.83	-96.47	28.7	0.0	29.01	0.00

minimum longitudinal reinforcement A_s = initial reinforcement A_{sb} + additional reinforcement ΔA_{sr} (from load), reinforcement stresses σ_{sr}, maximum bar diameter d_{sgr}, minimum reinforcement min A_s

x	max M_r	min M_r	A_{so}	A_{su}	A_{sbo}	A_{sbu}	ΔA_{sro}	ΔA_{sru}	σ_{sro}	σ_{sru}	d_{sgro}	d_{sgru}	min A_{so}	min A_{su}
m	kNm	kNm	cm²	cm²	cm²	cm²	cm²	cm²	N/mm²	N/mm²	mm	mm	cm²/m	cm²/m
8.00	1027.77	539.98	34.36	34.36	34.36	34.36	0.00	0.00	-42.35	229.09	0.0	33.4	29.02	0.00
8.00	1027.77	539.98	7.13	34.36	7.13	34.36	0.00	0.00	-55.40	234.71	0.0	32.6	29.02	0.00
10.00	297.36	89.67	8.72	34.36	8.72	34.36	0.00	0.00	-9.00	67.73	0.0	60.0	29.02	0.00
10.00	297.36	89.67	24.54	34.36	24.54	34.36	0.00	0.00	-7.67	66.71	0.0	60.0	29.02	0.00
10.50	43.58	-79.23	24.54	34.36	24.54	34.36	0.00	0.00	24.54	9.77	60.0	60.0	29.02	0.00
10.50	43.58	-79.23	24.54	7.24	24.54	7.24	0.00	0.00	25.19	44.81	60.0	60.0	29.02	0.00
12.00	-655.17	-954.52	27.98	0.00	24.54	0.00	3.44	0.00	271.72	0.00	25.1	0.0	29.16	0.00
12.00	-655.17	-954.52	27.98	0.00	24.54	0.00	3.44	0.00	271.72	0.00	25.1	0.0	29.16	0.00
13.50	-59.02	-283.60	24.54	0.00	24.54	0.00	0.00	0.00	91.31	0.00	60.0	0.0	29.00	0.00
13.50	-59.02	-283.60	24.54	15.70	24.54	15.70	0.00	0.00	88.58	-7.04	60.0	0.0	29.00	0.00
15.00	359.60	119.34	24.54	15.70	24.54	15.70	0.00	0.00	-11.37	168.93	0.0	44.3	29.00	0.00
15.00	359.60	119.34	7.13	15.70	7.13	15.70	0.00	0.00	-13.98	170.67	0.0	43.4	29.00	0.00
16.75	540.87	333.51	0.00	16.25	0.00	15.70	0.00	0.55	0.00	250.06	0.0	20.2	29.00	0.00
20.00	0.00	0.00	0.00	15.70	0.00	15.70	0.00	0.00	0.00	0.00	0.0	0.0	29.00	0.00

the minimum reinforcement (in cm²/m) is not extremized with the longitudinal reinforcement.
T-beam/upstand beam: minimum reinforcement is only calculated for the flange.
the radius of influence of the flange is limited to b_{web} + b_{flange} + 3 * reinforcement edge distance.

additional reinforcement from crack control (from load)



ΔA_{sr} in cm²
max ΔA_{sro}: 3.44
max ΔA_{sru}: 0.55

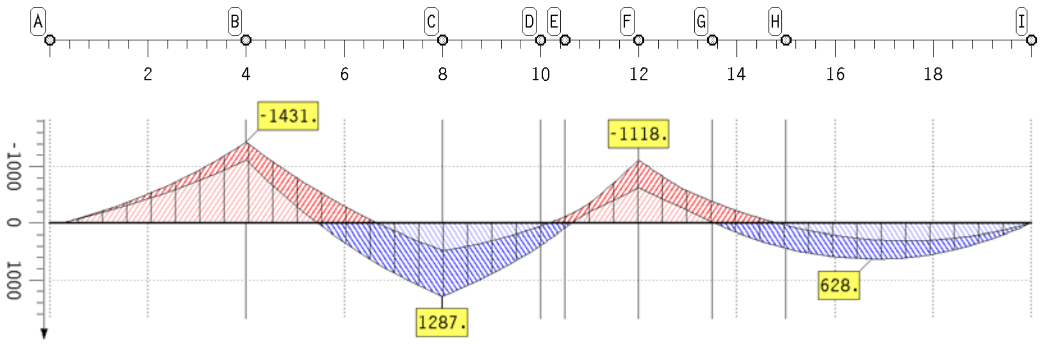
Verification 3: EC 2 stress verification

support reaction (Ψ-,γ-fach, see rules of extremizations)

extremal support reactions C, M_c, maximal bearing stress p_c (face of support left, right), surface of pressure A_p

support	max C	min C	max M_c	min M_c	max p_{cl}	max p_{cr}	A_p
	kN	kN	kNm	kNm	MN/m²	MN/m²	cm²
B	-1022.84	-1480.68	0.00	0.00	9.741	9.741	1520.0
F	-905.47	-1462.15	0.00	0.00	9.619	9.619	1520.0
I	-233.90	-388.16	0.00	0.00	2.043	2.043	1900.0

extremal flexural moment (for the stress verification)



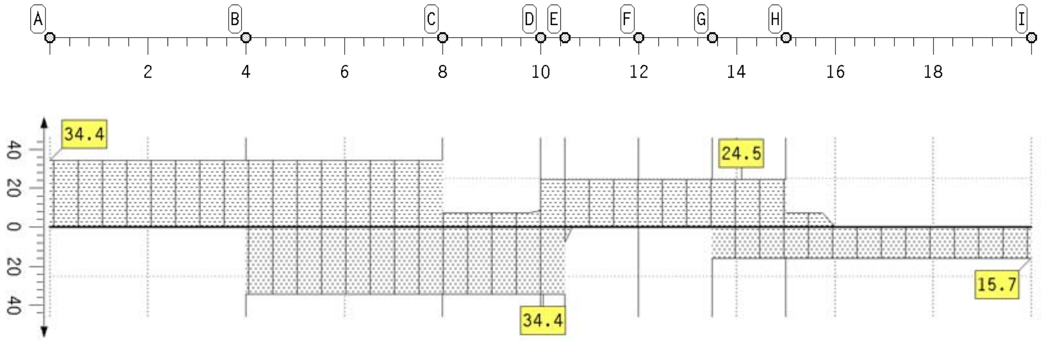
M_σ in kNm
max: 1286.6
min: -1431.4

extremal flexural moment M_σ

x	max M_σ	min M_σ	x	max M_σ	min M_σ	x	max M_σ	min M_σ	x	max M_σ	min M_σ
m	kNm	kNm	m	kNm	kNm	m	kNm	kNm	m	kNm	kNm
0.00	0.00	0.00	4.00	1111.40	-1431.40	10.50	88.26	-114.69	13.50	-11.94	-380.87
0.45	-49.96	-54.01	8.00	1286.64	468.95	10.50	88.26	-114.69	15.00	440.82	44.52
1.37	-265.69	-303.23	8.00	1286.64	468.95	12.00	-625.57	-1117.88	15.00	440.82	44.52
2.37	-536.90	-649.24	10.00	388.78	47.13	12.00	-625.57	-1117.88	16.75	627.78	284.88
4.00	-1111.40	-1431.40	10.00	388.78	47.13	13.50	-11.94	-380.87	20.00	0.00	0.00

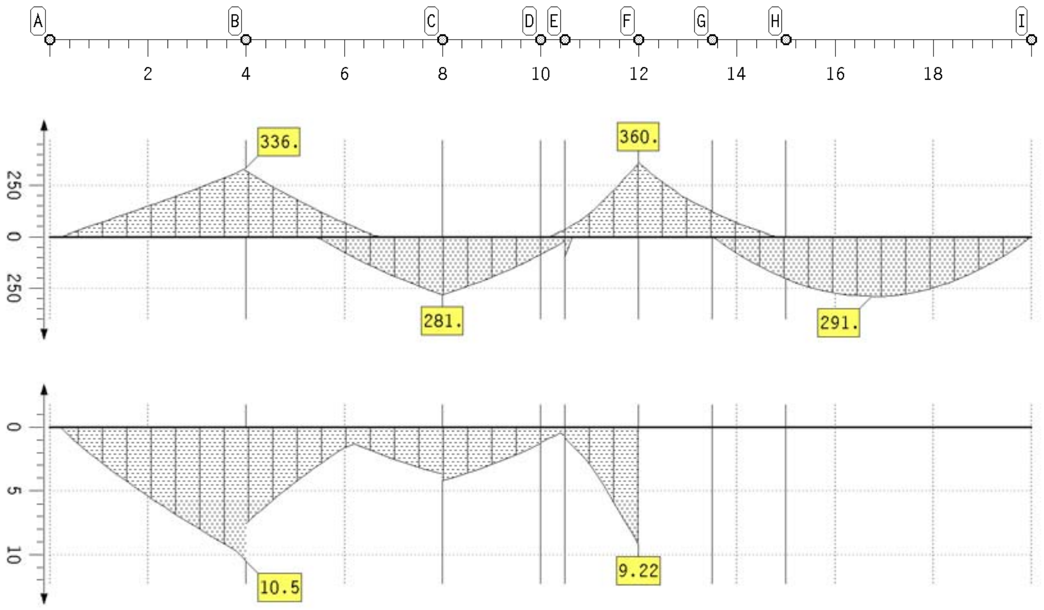
minimum longitudinal reinforcement (incl. main longitudinal reinforcement)

the radius of influence of the flange is limited to b_{web} + b_{flange} + 3 * reinforcement edge distance.



A_s in cm2
max A_{so}: 34.36
max A_{su}: 34.36

stresses



tensile stresses of reinf.
σ_s in N/mm2
max σ_{so}: 360.45
max σ_{su}: 290.50

compression stresses of conc.
σ_c in N/mm2
max σ_c: 10.51

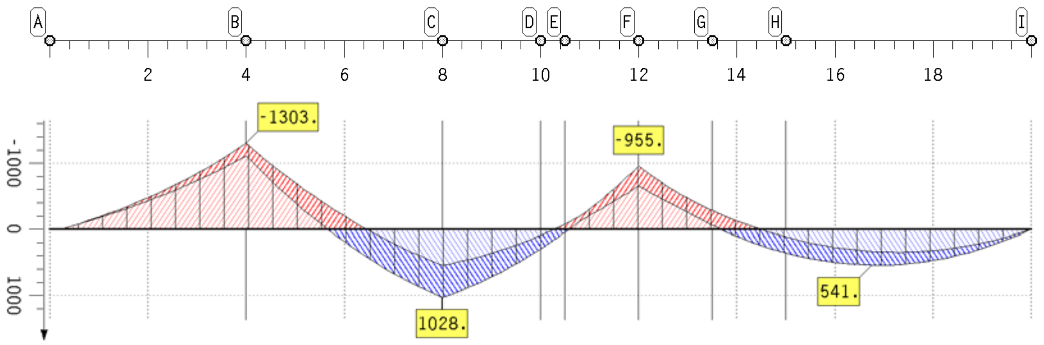
Verification 4: EC 2 verif. of deformation

support reaction (Ψ-,γ-fach, see rules of extremizations)

extremal support reactions C, M_c, maximal bearing stress p_c (face of support left, right), surface of pressure A_p

support	max C	min C	max M_c	min M_c	max p_{cl}	max p_{cr}	A_p
	kN	kN	kNm	kNm	MN/m2	MN/m2	cm2
B	-1028.30	-1305.34	0.00	0.00	8.588	8.588	1520.0
F	-928.87	-1266.71	0.00	0.00	8.334	8.334	1520.0
I	-248.87	-341.92	0.00	0.00	1.800	1.800	1900.0

extremal flexural moment (for the verification of deformation)



M_W in kNm
max: 1027.8
min: -1303.4

extremal flexural moment M_W

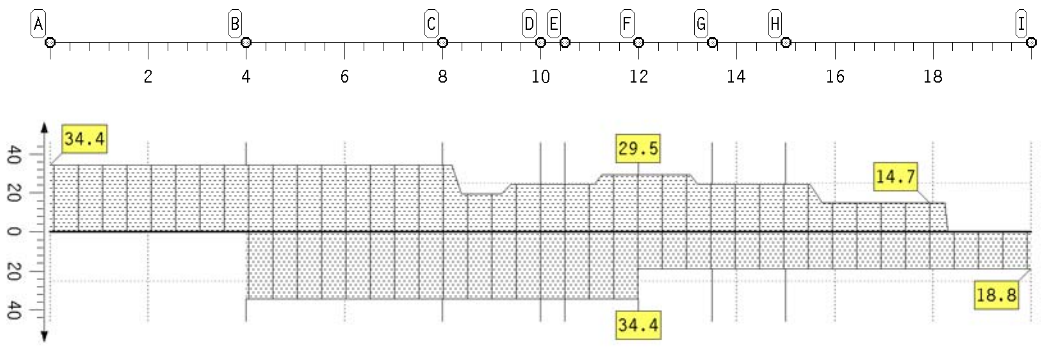
x m	max M_W kNm	min M_W kNm
0.00	0.00	0.00
0.45	-49.96	-52.39
1.37	-265.69	-288.21
2.37	-536.90	-604.31
4.00	-1111.40	-1303.40

x m	max M_W kNm	min M_W kNm
4.00	-1111.40	-1303.40
8.00	1027.77	539.98
8.00	1027.77	539.98
10.00	297.36	89.67
10.00	297.36	89.67

x m	max M_W kNm	min M_W kNm
10.50	43.58	-79.23
10.50	43.58	-79.23
12.00	-655.17	-954.52
12.00	-655.17	-954.52
13.50	-59.02	-283.60

x m	max M_W kNm	min M_W kNm
13.50	-59.02	-283.60
15.00	359.60	119.34
15.00	359.60	119.34
16.75	540.87	333.51
20.00	0.00	0.00

existing longitudinal reinforcement (from reinforcement proposal)



A_s in cm^2
max A_{so}: 34.36
max A_{su}: 34.36

longitudinal reinforcement A_s

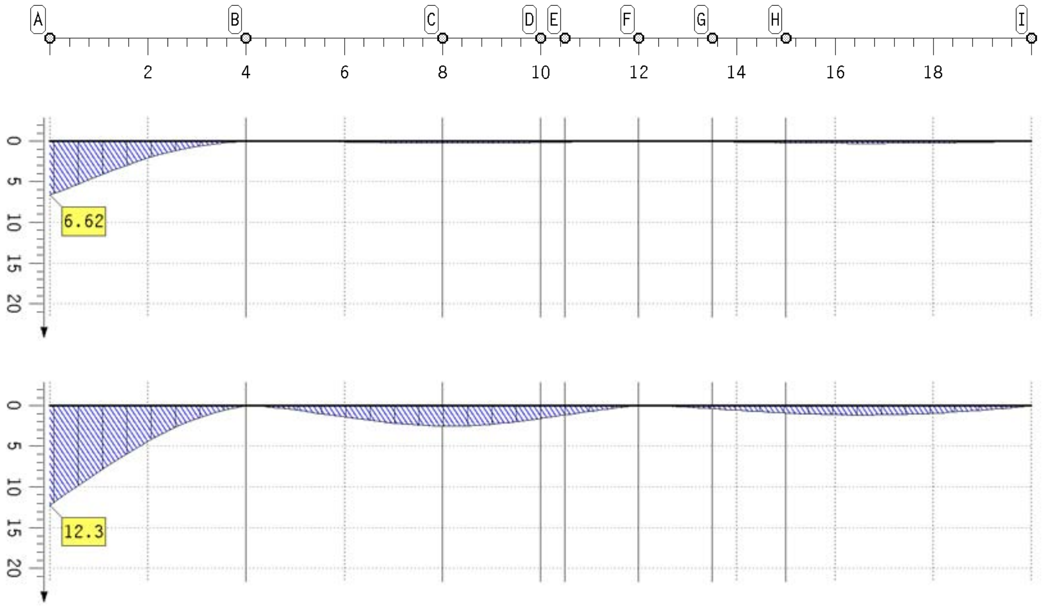
x m	max M_W kNm	min M_W kNm	A_{so} cm^2	A_{su} cm^2
0.00	0.00	0.00	34.36	0.00
0.45	-49.96	-52.39	34.36	0.00
1.37	-265.69	-288.21	34.36	0.00
2.37	-536.90	-604.31	34.36	0.00
4.00	-1111.40	-1303.40	34.36	0.00
4.00	-1111.40	-1303.40	34.36	34.36
8.00	1027.77	539.98	34.36	34.36

x m	max M_W kNm	min M_W kNm	A_{so} cm^2	A_{su} cm^2
8.00	1027.77	539.98	34.36	34.36
10.00	297.36	89.67	24.54	34.36
10.00	297.36	89.67	24.54	34.36
10.50	43.58	-79.23	24.54	34.36
10.50	43.58	-79.23	24.54	34.36
12.00	-655.17	-954.52	29.45	34.36
12.00	-655.17	-954.52	29.45	18.85

x m	max M_W kNm	min M_W kNm	A_{so} cm^2	A_{su} cm^2
13.50	-59.02	-283.60	24.54	18.85
13.50	-59.02	-283.60	24.54	18.85
15.00	359.60	119.34	24.54	18.85
15.00	359.60	119.34	24.54	18.85
16.75	540.87	333.51	14.73	18.85
20.00	0.00	0.00	0.00	18.85

verification of deflection acc. to Heft 240, DAfStb

simplified method for calculating the likely deflections



time T_{beg}

f_{beg} in mm
max: 6.62
min: -0.01

time T_{end}

f_{end} in mm
max: 12.26
min: -0.09

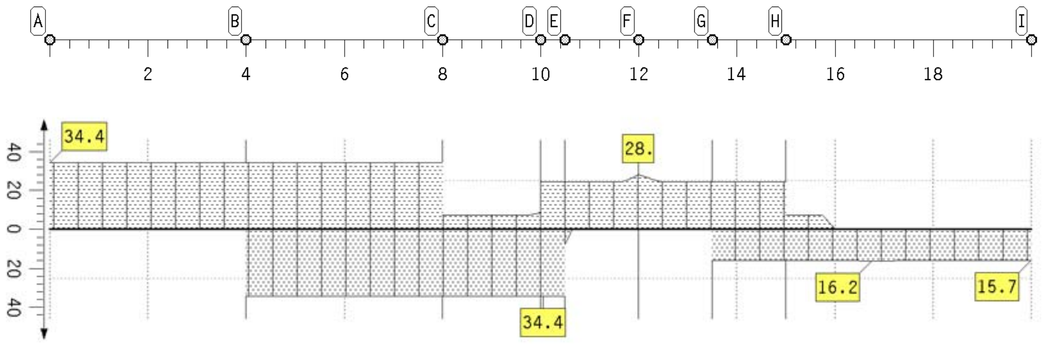
likely deflection: f_{beg} and f_{end}

x	w^I	w^{II}	w^k	M_{beg}	M_{end}	f^I_{beg}	f^{II}_{beg}	f_{beg}	f^I_{end}	f^{II}_{end}	f_{end}
m	mm	mm	mm	kNm	kNm	mm	mm	mm	mm	mm	mm
0.00	0.91	1.31	1.31	-1111.40	-1303.40	0.83	9.92	6.62	3.33	15.20	12.26
0.45	0.76	1.11	1.11	-1111.40	-1303.40	0.69	8.41	5.61	2.81	12.88	10.39
1.37	0.47	0.72	0.72	-1111.40	-1303.40	0.43	5.94	3.38	1.84	8.93	6.69
2.37	0.21	0.36	0.36	-1111.40	-1303.40	0.20	3.19	1.44	0.92	4.73	3.21
4.00	0.00	0.00	0.00	-1111.40	-1303.40	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	646.52	1027.77	0.00	0.00	0.00	0.00	0.00	0.00
4.20	-0.01	-0.02	-0.02	646.52	1027.77	-0.01	-0.16	-0.01	-0.05	-0.17	-0.09
4.40	-0.01	0.04	0.04	646.52	1027.77	-0.01	0.32	-0.01	0.08	0.34	0.16
8.00	0.27	0.56	0.56	646.52	1027.77	0.26	4.49	0.26	1.39	4.78	2.52
8.00	0.27	0.56	0.56	646.52	1027.77	0.26	4.49	0.26	1.39	4.78	2.52
8.20	0.27	0.56	0.56	646.52	1027.77	0.26	4.48	0.26	1.39	4.77	2.51
10.00	0.17	0.35	0.35	646.52	1027.77	0.16	2.79	0.16	0.86	2.96	1.56
10.00	0.17	0.35	0.35	646.52	1027.77	0.16	2.79	0.16	0.86	2.96	1.56
10.50	0.11	0.25	0.25	646.52	1027.77	0.11	2.00	0.11	0.61	2.13	1.12
10.50	0.11	0.25	0.25	646.52	1027.77	0.11	2.00	0.11	0.61	2.13	1.12
12.00	0.00	0.00	0.00	646.52	1027.77	0.00	0.00	0.00	0.00	0.00	0.00
12.00	0.00	0.00	0.00	410.49	540.87	0.00	0.00	0.00	0.00	0.00	0.00
12.15	0.00	-0.01	-0.01	410.49	540.87	0.00	-0.11	0.00	-0.03	-0.11	-0.03
12.45	0.00	-0.03	-0.03	410.49	540.87	0.00	-0.23	0.00	-0.05	-0.24	-0.05
13.50	0.08	0.14	0.14	410.49	540.87	0.07	1.25	0.07	0.39	1.30	0.39
13.50	0.08	0.14	0.14	410.49	540.87	0.07	1.25	0.07	0.39	1.30	0.39
15.00	0.21	0.32	0.32	410.49	540.87	0.20	2.81	0.20	0.91	2.91	0.91
15.00	0.21	0.32	0.32	410.49	540.87	0.20	2.81	0.20	0.91	2.91	0.91
16.50	0.27	0.39	0.39	410.49	540.87	0.27	3.46	0.27	1.14	3.58	1.14
20.00	0.00	0.00	0.00	410.49	540.87	0.00	0.00	0.00	0.00	0.00	0.00

w^I, w^{II}, w^k: basic value of deflection in condition I resp. II under permanent load causing creep
M_{beg}, M_{end}: extr. moment in span resp. cantilever moment for the real expected parts of traffic loads
f^I_{beg}, f^{II}_{beg}: lower resp. upper calculation values for the deflection at the time $t=t_{beg}$
f^I_{end}, f^{II}_{end}: lower resp. upper calculation values for the deflection at the time $t=t_{end}$

Construction

resulting longitudinal reinforcement (incl. main longitudinal reinforcement)



A_s in cm^2
max A_{so}: 34.36
max A_{su}: 34.36

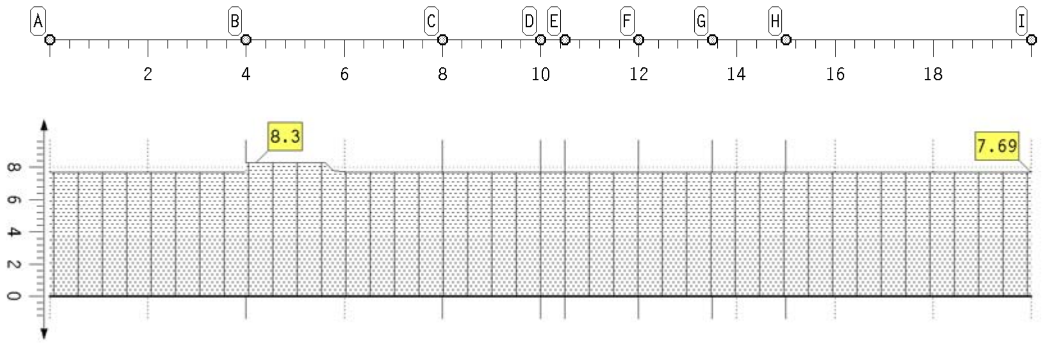
longitudinal reinforcement A_s, reinforcement ratio ρ

x m	A_{so} cm2	A_{su} cm2	ρ %
0.00	34.36	0.00	0.47
0.45	34.36	0.00	0.47
1.37	34.36	0.00	0.44
2.37	34.36	0.00	0.41
4.00	34.36	0.00	0.37
4.00	34.36	34.36	0.75
8.00	34.36	34.36	0.76

x m	A_{so} cm2	A_{su} cm2	ρ %
8.00	7.13	34.36	0.46
10.00	8.72	34.36	0.48
10.00	24.54	34.36	0.65
10.50	24.54	34.36	0.65
10.50	24.54	7.24	0.35
12.00	27.98	0.00	0.39
12.00	27.98	0.00	0.39

x m	A_{so} cm2	A_{su} cm2	ρ %
13.50	24.54	0.00	0.26
13.50	24.54	15.70	0.43
15.00	24.54	15.70	0.43
15.00	7.13	15.70	0.24
15.75	7.13	15.70	0.24
16.75	0.00	16.25	0.17
20.00	0.00	15.70	0.17

resulting stirrup reinforcement



$a_{sbü}$ in cm^2/m
max: 8.30

stirrup reinforcement $a_{sbü}$

x m	$a_{sbü}$ cm2/m
0.00	7.69
0.45	7.69
1.37	7.69
2.37	7.69

x m	$a_{sbü}$ cm2/m
4.00	7.69
4.00	8.30
8.00	7.69
8.00	7.69

x m	$a_{sbü}$ cm2/m
10.00	7.69
10.00	7.69
10.50	7.69
10.50	7.69

x m	$a_{sbü}$ cm2/m
12.00	7.69
12.00	7.69
13.50	7.69
13.50	7.69

x m	$a_{sbü}$ cm2/m
15.00	7.69
15.00	7.69
20.00	7.69

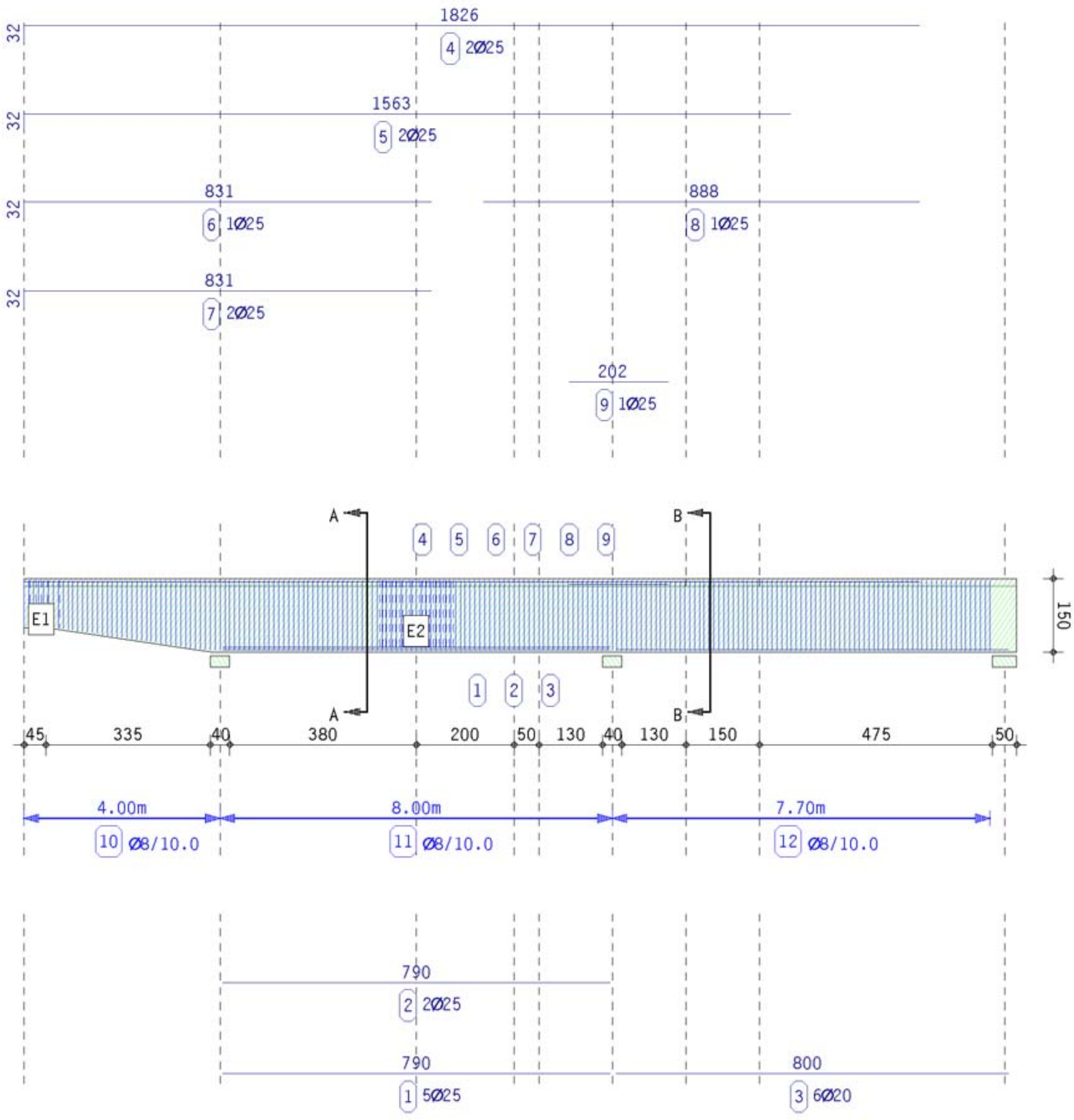
minimum reinforcement min A_s / min $a_{sbü}$, existing reinforcement exis A_s / exis $a_{sbü}$

x	min A_{so}	exis A_{so}	min A_{su}	exis A_{su}	min $a_{sbü}$	exis $a_{sbü}$
m	cm²	cm²	cm²	cm²	cm²/m	cm²/m
0.00	34.36	34.36	0.00	0.00	7.69	10.05
0.45	34.36	34.36	0.00	0.00	7.69	10.05
1.37	34.36	34.36	0.00	0.00	7.69	10.05
2.37	34.36	34.36	0.00	0.00	7.69	10.05
4.00	34.36	34.36	0.00	0.00	7.69	10.05
4.00	34.36	34.36	34.36	34.36	8.30	10.05
8.00	34.36	34.36	34.36	34.36	7.69	10.05
8.00	7.13	19.63	34.36	34.36	7.69	10.05
10.00	8.72	19.63	34.36	34.36	7.69	10.05
10.00	24.54	24.54	34.36	34.36	7.69	10.05
10.50	24.54	24.54	34.36	34.36	7.69	10.05
10.50	24.54	24.54	7.24	34.36	7.69	10.05
11.70	24.64	29.45	0.00	34.36	7.69	10.05
11.80	25.77	29.45	0.00	34.36	7.69	10.05
12.00	27.98	29.45	0.00	34.36	7.69	10.05
12.00	27.98	29.45	0.00	18.85	7.69	10.05
12.15	26.69	29.45	0.00	18.85	7.69	10.05
12.30	25.46	29.45	0.00	18.85	7.69	10.05
13.50	24.54	24.54	0.00	18.85	7.69	10.05
13.50	24.54	24.54	15.70	18.85	7.69	10.05
15.00	24.54	24.54	15.70	18.85	7.69	10.05
15.00	7.13	14.73	15.70	18.85	7.69	10.05
17.75	0.00	14.73	15.70	18.85	7.69	10.05
20.00	0.00	0.00	15.70	18.85	7.69	10.05

longitudinal section

reinforcement of the detailpoints E1, E2 is separated described (see 'special verifications').

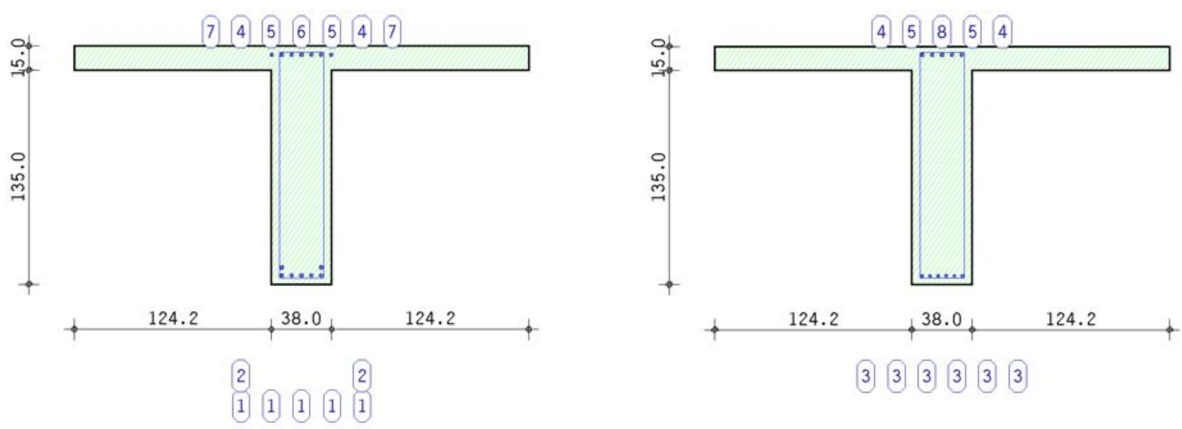
scale 1 : 150, length in m,cm



selected sections

section A-A (x=7.00m)

section B-B (x=14.00m)



information on the reinforcement proposal

for bending points without declaration of the diameter of the mandrel its minimum is effective 4 d_s (d_s < 20 mm) resp. 7 d_s ($d_s \geq$ 20 mm)!
anchorage lengths are calculated with the coeff. α_a = 1.0 (EC 2, tab.8.2)!
anchoring in restraining members is not considered!
lengths of delivery of steel bars (lapped splices) are not considered!
transverse spacing of the legs of shear links is not checked.

Reinforcement schedule

longitudinal reinforcement

measurement from bar beginning, bar (anchorage) lengths, steel weights bottom:

(1) 5 Ø 25, x_a = 4.05 m, x_e = 11.95 m, L = 7.90 m (l_v=15/15cm), G = 155.2 kg
(2) 2 Ø 25, x_a = 4.05 m, x_e = 11.95 m, L = 7.90 m (l_v=15/15cm), G = 62.1 kg
(3) 6 Ø 20, x_a = 12.08 m, x_e = 20.08 m, L = 8.00 m (l_v=12/33cm), G = 120.7 kg

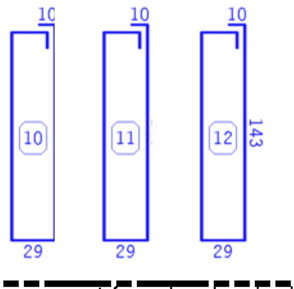
measurement from bar beginning, bar (anchorage) lengths, steel weights top:

(4) 2 Ø 25, x_a = 0.05 m, x_e = 18.26 m, L = 18.58 m (l_v=32/51cm), G = 146.0 kg
(5) 2 Ø 25, x_a = 0.05 m, x_e = 15.64 m, L = 15.95 m (l_v=32/64cm), G = 125.3 kg
(6) 1 Ø 25, x_a = 0.05 m, x_e = 8.31 m, L = 8.63 m (l_v=32/32cm), G = 33.9 kg
(7) 2 Ø 25, x_a = 0.05 m, x_e = 8.31 m, L = 8.63 m (l_v=32/32cm), G = 67.8 kg
(8) 1 Ø 25, x_a = 9.38 m, x_e = 18.26 m, L = 8.88 m (l_v=63/51cm), G = 34.9 kg
(9) 1 Ø 25, x_a = 11.13 m, x_e = 13.15 m, L = 2.02 m (l_v=57/85cm), G = 7.9 kg

steel weight longitudinal reinforcement: G_l = 753.7 kg

stirrup reinforcement

bending shapes (links to be closed in the neutral axis):



measurement from bar beginning, bar lengths, steel weights:

(10) x_a = 0.00 m, x_e = 4.00 m, 41 Ø 8/10.0cm, L = 2.64-3.64 m, G = 51.8 kg
(11) x_a = 4.00 m, x_e = 12.00 m, 81 Ø 8/10.0cm, L = 3.64 m, G = 118.6 kg
(12) x_a = 12.00 m, x_e = 19.70 m, 79 Ø 8/10.0cm, L = 3.64 m, G = 115.7 kg

(10)	x_a	a	L
	m	cm	m
1	0.05	93	2.68
2	0.15	93	2.68
3	0.24	93	2.68
4	0.34	93	2.68
5	0.44	93	2.68
6	0.54	94	2.70
7	0.63	96	2.74
8	0.73	97	2.76
9	0.83	99	2.80
10	0.93	100	2.82
11	1.02	102	2.86
12	1.12	103	2.88
13	1.22	105	2.92
14	1.32	106	2.94
15	1.41	107	2.96
16	1.51	109	3.00
17	1.61	110	3.02
18	1.71	112	3.06
19	1.80	113	3.08
20	1.90	115	3.12
21	2.00	116	3.14
22	2.10	118	3.18
23	2.20	119	3.20
24	2.29	121	3.24
25	2.39	122	3.26
26	2.49	123	3.28
27	2.59	125	3.32
28	2.68	126	3.34
29	2.78	128	3.38
30	2.88	129	3.40
31	2.98	131	3.44
32	3.07	132	3.46
33	3.17	134	3.50
34	3.27	135	3.52
35	3.37	137	3.56
36	3.46	138	3.58
37	3.56	139	3.60
38	3.66	141	3.64
39	3.76	142	3.66
40	3.85	143	3.68
41	3.95	143	3.68

steel weight stirrup reinforcement: G_b = 286.0 kg

steel weight in total

$G = G_l + G_b = 1039.7$ kg

Special verifications

hanger-reinforcement for point loads
a point load application at the bottom of the beam is lead through vertical links to the upper section edge.

detail E1 at x = 0.23 m:
$Z_v = \Sigma|F| = 291.6$ kN ⇒ min $A_{sbü}$ = 6.71 cm²
selected: 7 Ø 8 (2-shear), distributed along L = 0.72 m
⇒ exis $A_{sbü}$ = 7.04 cm² ≥ min $A_{sbü}$

detail E2 at x = 8.00 m:
$Z_v = \Sigma|F| = 987.6$ kN ⇒ min $A_{sbü}$ = 22.71 cm²
selected: 23 Ø 8 (2-shear), distributed along L = 1.50 m
⇒ exis $A_{sbü}$ = 23.12 cm² ≥ min $A_{sbü}$

NATIONAL APPENDIX OF EUROCODES

Load factors of the national appendix
Germany

DIN EN 1990 (EC 0)

Partial safety factors for actions
of permanent and transient design situation

Type of action effect	γ_{Fsup}	γ_{Finf}
permanent loads	1.35	1.00
transient loads	1.50	0.00
fluid pressure/engine loads	1.35	0.00
restraint	1.00	0.00
prestressing	1.00	1.00

Partial safety factors for actions
of accidental design situation

Type of action effect	γ_{Fsup}	γ_{Finf}
permanent loads	1.00	1.00
transient loads	1.00	0.00
fluid pressure/engine loads	1.00	0.00
restraint	1.00	0.00
prestressing	1.00	1.00
accidental action effects	1.00	1.00

Partial safety factors for actions
of earthquake situation

Type of action effect	γ_{Fsup}	γ_{Finf}
permanent loads	1.00	1.00
transient loads	1.00	0.00
fluid pressure/engine loads	1.00	0.00
restraint	1.00	0.00
prestressing	1.00	1.00
earthquake	1.00	1.00

Partial safety factors for actions
of design of serviceability and fatigue

Type of action effect	γ_{Fsup}	γ_{Finf}
permanent loads	1.00	1.00
transient loads	1.00	0.00
fluid pressure/engine loads	1.00	0.00
restraint	1.00	0.00
prestressing	1.00	1.00

Combination coefficients

Action effect	Category	Ψ_0	Ψ_1	Ψ_2
housing, office rooms	A, B	0.70	0.50	0.30
Assembly, salesrooms	C, D	0.70	0.70	0.60
storage rooms	E	1.00	0.90	0.80
vehicles to 30 kN	F	0.70	0.70	0.60
vehicles to 160 kN	G	0.70	0.50	0.30
roofs	H	0.00	0.00	0.00
snow/ice up to 1000 m alt.		0.50	0.20	0.00
snow/ice above 1000 m alt.		0.70	0.50	0.20
wind		0.60	0.20	0.00
temperature		0.60	0.50	0.00
soil settlements		1.00	1.00	1.00
other action effects		0.80	0.70	0.50

Note: fluid pressure/engine loads, restraint or soil settlements, other action effects take no part to EN 1990 (Eurocode).

Applied design parameters of the national appendix
Germany

DIN EN 1992-1-1 (EC 2)

Chapter	Value	Meaning
2.4.2.4(1)		Partial safety factors for concrete and reinforcement
	γ_c = 1.50 γ_s = 1.15	Permanent and transient design situation
	γ_c = 1.50 γ_s = 1.15	Fatigue design situation
	γ_c = 1.50 γ_s = 1.15	Earthquake design situation
	γ_c = 1.30 γ_s = 1.00	Accidental design situation
3.1.6(1)P	α_{cc} = 0.85	Coeff. to consider the long-term influence of compression strength of concrete and the unfavourable effect due to the kind of action effect
3.1.6(2)P	α_{ct} = 1.00	Coeff. of tensile strength of concrete to calculate the bond strength
4.4.1.2(5)	Exp.Kl. $c_{min,dur}$ $\Delta c_{dur,\gamma}$	minimum concrete cover taking account to the
	--- 0.00 0.00	exposure classes $c_{min,dur}$ [cm]
4.4.1.2(6)	X0 0.00 0.00	minimum concrete cover: additive safety element $\Delta c_{dur,\gamma}$ [cm]
	XC1 1.00 0.00	
	XC2 2.00 0.00	
	XC3 2.00 0.00	
	XC4 2.50 0.00	
	XD1 3.00 1.00	
	XD2 3.50 0.50	
	XD3 4.00 0.00	
	XS1 3.00 1.00	
	XS2 3.50 0.50	
	XS3 4.00 0.00	
4.4.1.2(7)	$\Delta c_{dur,st}$ = 0.00	minimum concrete cover: use of stainless steel [cm]
4.4.1.2(8)	$\Delta c_{dur,add}$ = 0.00	minimum concrete cover: concrete with additional protection [cm]
4.4.1.3(1)P	Δc_{dev} = 1.50	concrete cover: allowance in design for deviation [cm]
5.5(4)	k_1 = 0.64	redistribution: coeff. for the calculation of the allowed redistribution
	k_2 = 0.80	
	k_3 = 0.72	
	k_4 = 0.80	
	k_5 = 0.70	
	k_6 = 0.85	
6.2.2(1)	$C_{Rd,c}$ = 0.15 / γ_c	Coeff. to calculate the resistance of shear force
	$v_{min} = 0.0525/\gamma_c\ k^{3/2}\ f_{ck}^{1/2}$	
	k_1 = 0.12	
6.2.2(6)	ν_V = 0.675	Reduction factor of strength of shear force
6.3.2(4)	ν_T = 0.525	Reduction factor of strength of torsion
6.2.3(2)	min cot Θ = 1.00	lower limit of strut gradient
	max cot Θ = 3.00	upper limit of strut gradient
6.2.3(3)	α_{cw} = 1.00	Coeff. to consider the state of stress in the compress. boom
	ν_1 = 0.750	Coeff. to calculate the max. design resistance of shear force

Chapter	Value	Meaning
6.2.4(4)	cot Θ_{fz} = 1.00	Connections: strut gradient of tension booms
	cot Θ_{fd} = 1.20	Connections: strut gradient of compression booms
6.2.4(6)	k = 0.00	Connections: Coeff. of resisting tensile stress without through-reinforcement
6.2.5(1)	intended : ν = 0.700	Joints: Reduction factor of strength depending on subsurface condition
	rough : ν = 0.500	
	smooth : ν = 0.200	
	very smooth: ν = 0.000	
6.8.4(1)	$\gamma_{F,fat}$ = 1.00	Fatigue: Safety factor of action effects
6.8.7(1)	k_1 = 1.00	Fatigue: Coeff. to calculate the design strength of concrete
7.3.4(3)	k_3 = 0.00	Cracks: Coeff. to calculate the maximum crack distance if fracture pattern is completed
	k_4 = 0.278	Cracks: Coeff. to calculate the maximum crack distance if fracture pattern is completed
7.4.2(2)	$K_{one\ w.\ sp}$ = 1.00	Deflection control calc. omitted (span/depth ratio):
	$K_{end\ span}$ = 1.30	Coeff. for consideration of the structural system
	$K_{inter.\ sp.}$ = 1.50	
	$K_{flat\ slab}$ = 1.20	
	$K_{cantilever}$ = 0.40	
8.2(2)	k_1 = 1.00	Spacing of bars: Coeff. for the clear distance between parallel bars or horizontal layers
9.2.1.1(1)	$A_{s,min}$ s. NA-DE	minimum reinforcement of beams [cm²]
9.2.1.2(1)	β_1 = 0.25	Min. support moment at simply supp. end support: rate of the max. span moment to supp. mom.
9.2.1.4(1)	β_2 = 0.25	Anchorage of bottom reinforcement at end supports: minimum proportion of the area of steel provided in the span
9.2.2(5)	$\rho_{w,min}$ s. NA-DE	minimum ratio of shear reinforcement
11.3.5(1)	α_{lcc} = 0.75	Lightw.conc.: Reduction factor of compression strength of concrete
11.3.5(2)	α_{lct} = 1.00	Lightw.conc.: Reduction factor of tensile strength of concrete
11.6.1(1)	$C_{lRd,c}$ = 0.15 / γ_c	Lightw.conc.: Coeff. to calculate the resistance of shear force
	$\nu_{l,min}$ = 0.0525 $k^{3/2}$ $f_{lck}^{1/2}$	
	k_{l1} = 0.12	
11.6.1(2)	ν_l = 0.675 η_1	Lightw.conc.: Reduction factor of strength of shear force
	ν_l = 0.525 η_1	Lightw.conc.: Reduction factor of strength of torsion
11.6.2(1)	ν_{l1} = 0.750 η_1	Lightw.conc.: Coeff. to calculate the maximum design resistance of shear force

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Chapter	Value	Meaning
3.2.3(5)	Class N (table 3.2a)	reinforcement-class to describe stress-strain-relation at increased temperatures
3.3.3(1)	$\lambda_c = \lambda_{co}$ oder λ_{cu}	thermal conductivity of concrete
	see design calc. options	λ_{co} upper limit, λ_{cu} lower limit acc. to 3.3.3(2)
6.1(5)	Class 1 (table 6.1N)	high strength concrete: concrete-class to describe the reduction of strength
6.4.2.2(2)	k_m = 1.000	high strength concrete: Coeff. for moment load capacity under fire load in the tension zone

Regulations

DIN EN 1990, Eurocode 0: Basis of structural design;
German Version EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Edition December 2010
DIN EN 1990/NA, National Annex DIN EN 1990, Edition December 2010

DIN EN 1992-1-1, Eurocode 2: Design of concrete structures -
Part 1-1: General rules and rules for buildings
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DIN EN 1992-1-1/NA, National Annex DIN EN 1992-1-1, Edition January 2011

DIN EN 1992-1-2, Eurocode 2: Design of concrete structures
Part 1-2: General rules - Structural fire design;
German Version EN 1992-1-2:2004 + AC:2008, Edition December 2010
DIN EN 1992-1-2/NA, National Annex DIN EN 1992-1-2, Edition December 2010