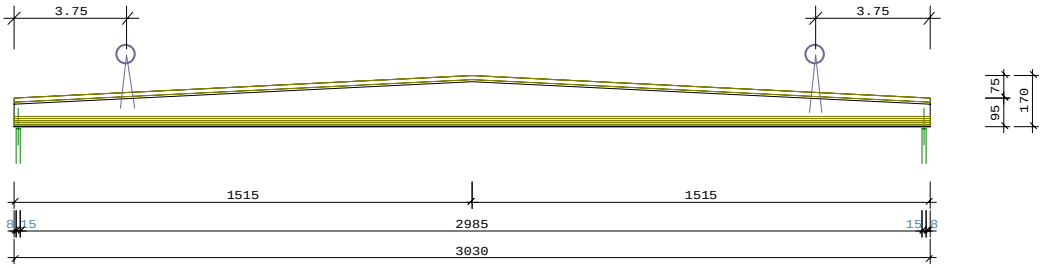
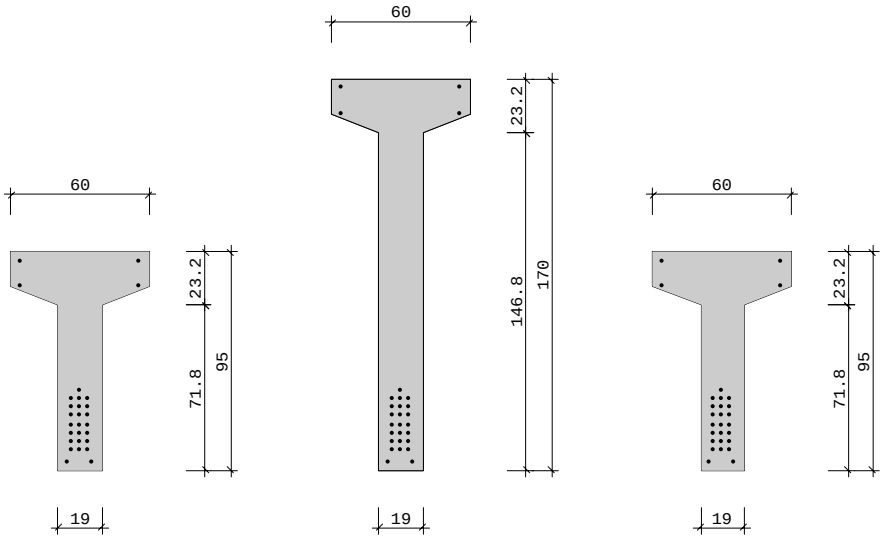
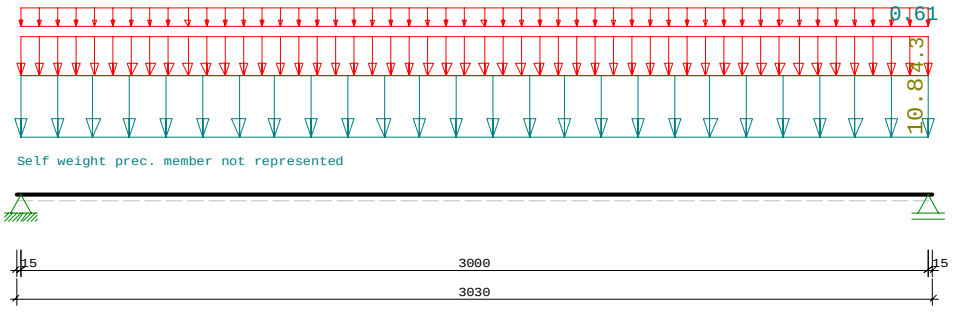
B8_001_FDB-Reference_eng Calculation example

Prestressed Concrete Girder B8 02/2022 (FRILO alpha)







System:

Double-pitch roof

Basics:

Load combinatorics: NA to BS EN 1990/A1:2009-06 + EN 1990:2002/AC:2010
ULS: Structural safety checks(STR)
permanent/variable design situation with equation 6.10 a,b

Design code: NA to BS EN 1992-1-1/A2:2015-07 + EN 1992-1-1:2004 /AC:2010
Prestressing for pretensioning with heat treatment in stressing mould

System Geometry:

Total	L	=	30.30	m	Effective	L1	=	30.00 m
Outstand left	L0	=	0.15	m	right	L2	=	0.15 m
Distance Ridge	L3	=	15.15	m				
Height beam :								
left	H1	=	95.0	cm	Ridge	H2	=	170.0 cm
right	H3	=	95.0	cm				

Relation eff.span to height of beam:
L1/H2 = 17.65

Erection attachment, distance from the beginning resp. end of beam:

Hook	L8	=	3.75	m	right	L9	=	3.75 m

Cross-section Precast :

Layer of cross-section from top to bottom			
Nr	Width [cm]	Distance [cm]	Remarks
1	60.0	0.0	
2	60.0	15.0	
3	19.0	23.2	Web begin
4	19.0	170.0	Web end
Top flange height over beam length constant			

Material:

Prestressing steel

Y1770S7 Strand 7 wires

d_d	=	4.1	mm	d_p	=	12.3	mm
E_p	=	195000	N/mm²	A_p	=	0.930	cm²
$f_{p0.1k}$	=	1520	N/mm²	f_{pk}	=	1770	N/mm²
ε_{uk}	=	35.0	‰	ε_{ud}	=	31.5	‰

Partial safety factor :
γ_s = 1.15

Coeff. prestress:

charact. value	r_{sup}	=	1.00	r_{inf}	=	1.00
Design value	$\gamma_{p,max}$	=	1.10	$\gamma_{p,min}$	=	0.90

Proof of crack width
Equ. diameter d_{pV} = 7.20 mm ξ = 0.60 (Tab. 6.2)

Relaxation class 2 (strands, wires, low relaxation)				
σ_{p0}/f_{pk}	10 h	200 h	1000 h	500000h
0.60	0.1	0.2	0.4	2.5
0.70	0.3	0.7	1.0	3.9
0.80	1.2	1.9	2.4	6.1
- Losses in % by 3.3.2 (6), example process				

Permitted stresses:

in formwork	σ_p	≤	1368.0	N/mm²	(0.90* $f_{p0.1k}$)
after anchor. release	σ_p	≤	1292.0	N/mm²	(0.85* $f_{p0.1k}$)
char. Lc	σ_p	≤	1327.5	N/mm²	(0.75* $f_{p0.1k}$)

Transmission length

	η_{p1}	=	3.20		η_1	=	1.00
	α_1	=	1.25		α_2	=	0.19
	σ_{pm0}	=	882	N/mm²			
PT:	f_{ctdt}	=	0.81	N/mm²	f_{bpt}	=	2.58 N/mm²
	l_{pt}	=	1.00	m			

Dispersion_length:

d = 0.91 m l_{disp} = 1.35 m

Reinforcing steel:

	Longitudinal B 500B		Stirrup B 500B	
E_s =	200000	N/mm²	200000	N/mm²
f_{yk} =	500	N/mm²	500	N/mm²
f_{tk} =	540	N/mm²	540	N/mm²
ε_{uk} =	50.0	‰	50.0	‰
ε_{ud} =	45.0	‰	45.0	‰

Partial safety factor :

γ_s = 1.15 γ_s = 1.15

permitted stresses in SLS :

$\sigma_s \leq$ 400 N/mm² $\sigma_s \leq$ 400 N/mm² (0.80 * f_{yk})

Requirements durability:

	top				bottom			
attack on concrete	X0				X0			
attack on reinforc.	XC1				XC1			
min. concrete class	C 20/25				C 20/25			
stirrup	φ,l =	8	mm					
long. reinforcement	φ,m =	20	mm		φ,m =	16	mm	
prestressed steel	d_p =	12.3	mm	strand				
allowance in design	Δc_{dev} =	5	mm	*2	Δc_{dev} =	5	mm	*2
stirrup	$c_{min,l}$ =	15	mm		$c_{min,l}$ =	15	mm	
concrete coverage	$c_{nom,l}$ =	20	mm		$c_{nom,l}$ =	20	mm	
longitudinal bars	$c_{min,m}$ =	20	mm	*5	$c_{min,m}$ =	16	mm	*5
concrete coverage	$c_{nom,m}$ =	28	mm	*1	$c_{nom,m}$ =	28	mm	*1
prestressing steel :	$c_{min,p}$ =	19	mm	*5	$c_{min,p}$ =	19	mm	*5
concrete coverage	$c_{nom,p}$ =	28	mm	*1	$c_{nom,p}$ =	28	mm	*1
laying dist. link	$c_{,l}$ =	20	mm		$c_{,l}$ =	20	mm	
all. crack width	w_{max} =	0.20	mm		w_{max} =	0.20	mm	
decompression	not req.				not req.			

*1:with cmin,l
*2: Quality Control
*5: bond decisive

Concrete:

Precast

	C 50/60		
f_{ck} =	50.00	N/mm²	
α_{cc} =	0.85		
$f_{ctk0.05}$ =	2.85	N/mm²	
α_{ct} =	1.00		
γ =	25.00	kN/m³	Unit
E_{cm} =	37000	N/mm²	
α_E =	1.00		Coeff. E-module
G_{cm} =	14800	N/mm²	

Partial safety factor :

γ_c = 1.50

permitted stresses in SLS :
char. Lc $\sigma_c \geq -30.00$ N/mm²
q.perm.Lc $\sigma_c \geq -22.50$ N/mm²
Removal the anchor t= t0T(sto)= 5.1 d
$f_{cm(t)} = 44.43$ N/mm²
$f_{ck(t)} = 36.43$ N/mm²
linear creep $\sigma_c \geq -16.39$ N/mm² (k2=0.45)
maximum $\sigma_c \geq -25.50$ N/mm² (k6=0.70)

Creep modulus & shrinkage strain

with heat treatment in stressing mould
Tt0= 60°C (until releasing the anchor)
teq= 4533 h (equivalent time difference for relaxation)
t0T= 5.1 d (according to temperature adjusted concrete age)
CementStrenght class 42,5R;52,5
ρ= 0.5 (Aging coefficient)
Reference point for t0 is the start of the concreting of the precast

Creep	t0 Days	RH %
Storage	1	70
Utilization precast	21	50

L.	Segment	Part-cross-section	t0	t	α	$t_{0,eff}$ B.9	β_{t0} B.5	β_H B.8	$\beta_{c(t,t0)}$ B.7	φ_{RH} B.3	β_{fcm} B.4	φ(t,t0) B.1
1	Storage	PcC	1.0	21.0	1	10.2	0.59	475.4	0.38	1.24	2.21	0.62
2	Utilization precast	PcC	21.0	26000.0	1	10.2	0.59	463.7	0.61	1.47	2.21	1.17

L.	A [cm²]	U [cm]	h0 [cm]	β_{ds}(t0,ts)	β_{ds}(t,ts) 3.10	β_{RH} B.12	$\varepsilon_{cd,0}$ B.11	β_{as} 3.13	ε_{ca}/10e6 3.12	ε_{cs}(t,t0) [‰]
1	4013.10	446.8	179.7	0.000	0.172	1.02	402.5	0.60	100.00	0.121
2	4013.10	446.8	179.7	0.172	0.996	1.36	536.0	1.00	100.00	0.430

Loads:

Self weight

Beam beginning g11 = 6.47 kN/m
Ridge g12 = 10.03 kN/m
Beam end g13 = 6.47 kN/m

Total G = 250.1 kN
Volume V = 10.00 m³
Surf. A = 95.00 m²

Units: Single load[kN] Single moment[kNm] line load[kN/m]

span	type	gle	qle	Dist. a [m]	gri	qri	Length [m]	Fact	Act.	Sim.	Alt.	Pos.
1	1	10.80	4.30					1.00	10	0	0	
1	1	0.00	0.61					1.00	9	0	0	

Load types: 1 = uniformly distr., 2 = single load at a, 3 = single moment at a
4 = trapezoidal load from a, 5 = triangle load over L

Actions:

Act.	γ_Q	ψ_0	ψ_1	ψ_2	Dep.	Cat.	Description
9	1.50	0.50	0.20	0.00	0	W	Wind loads
10	1.50	0.50	0.20	0.00	0	S	Snow loads <1000m

Tendons:

Dist(LE) > 3.5 cm axis horizontal > 3.7 cm vertical > 3.7 cm

lay. No.	num-ber	area Ap [cm²]	Dist.LE Yp [cm]	Prestressing $\sigma_p^{(0)}$ [N/mm²]	<--- Isolations ---> Count	to x1 [m]	from x2 [m]	Type ||
1	3	2.79	8.5	1000	0			LE
2	3	2.79	12.3	1000	0			LE
3	3	2.79	16.1	1000	0			LE
4	3	2.79	19.9	1000	0			LE
5	3	2.79	23.7	1000	0			LE
6	3	2.79	27.5	1000	0			LE
7	3	2.79	31.3	1000	0			LE
8	1	0.93	35.1	1000	0			LE

x1 and x2 with respect to the left beginning from joint
LE= parallel lower edge, UE= parallel upper edge
The calculation of the losses due to creep, shrinkage and relaxation following the method from Abelein

Untensioned reinforcement:

Layer No.	num-ber	diam. Φs,l [mm]	area As [cm²]	Dist.LE Ys [cm]	effective range from xA [m]	to xE [m]	Type ||
1	2	16	4.02	3.6	0.00	30.30	LE
2	2	20	6.28	166.2	0.00	30.30	UE
3	2	20	6.28	155.0	0.00	30.30	UE

xA and xE with respect to the left beginning from joint
LE= parallel lower edge, UE= parallel upper edge

Surface reinforcement acc.to Tab. NA.J.41 (B0 < D0) :

Web (Z1/S3) AsS = 1.24 cm²/m (UwkS <= XC4) (per side)
Top flange (Z3/S1) AsO = 0.00 cm²/m (UwkS <= XC4)

Settings for shear resistance check

Bearing width, distance bearing edge, effective height of the bearing line
left bAl = 0.15 m al = 0.07 m dAl = 0.92 m
right bAr = 0.15 m ar = 0.07 m dAR = 0.92 m
For shear reinforcement not decisive ranges over support A and B:
xaRe=0.99 m direct bearing (width of bearing/2 + eff. depth)
xbLi=0.99 m direct bearing (width of bearing/2 + eff. depth)

Check the limit deformation:

Total sagging	f ≤ L/ 250	Increase deflection	|df| ≤ L/ 500
Cantilever left	f ≤ 0.1 cm		|df| ≤ 0.1 cm
Span	f ≤ 12.0 cm		|df| ≤ 6.0 cm
Cantilever right	f ≤ 0.1 cm		|df| ≤ 0.1 cm

quasi- permanent combination and eff. char. prestress
Deflection due to shrinkage considered
Tension stiffening: Member rigidity, Characteristic combination

RESULTS (summary)

Reaction forces (t = infinitely):

Units: all [kN] G:perm., Q:variable. ,V: Sum

Support point	G	<------char. value-----> min Q	max Q	<--ULS(PT)----> min V	max V
A (left)	287.01	0.00	73.65	287.01	462.02
B (right)	287.01	0.00	73.65	287.01	462.02

max. bending moment in erection state(char. value):

MF = = 2763.72 kNm at x = = 15.15 m

Checks are not complied with:

Checkvalue		Extrem		Utilisation	x [m]
Resisting tens force bot	η=	0.86		1.16	30.15
Crack MinAs+AsDuc bottom A	AsMin =	6.7	cm²	1.66	15.15
Prc.:Compr.stress t0(sto)	σc =	-27.31	N/mm²	1.07	3.75
Buckling installed state (Stiglat)	η=	1.69		1.19	

Warning

Prc.:lin. creep t0(Sto)σc =-23.09 N/mm2 x= 0.80 m
σc <0.45*fck(t)=-16.39 N/mm2
_disproportional creeping by increased creep modulus considered(fk= 1.32)

Required shear reinforcement:

Column A: asw = 5.00 cm²/m
Column B: asw = 5.00 cm²/m

Bursting reinforcement

left Laying length = 1.02 m
from x = 0.00 m As = 5.3 cm²
right Laying length = 1.02 m
from x = 30.30 m As = 5.3 cm²

Check of anchorage

left: Tensile force resistance in anchoring area Util = 1.16
additional reinforcement necessary
right: Tensile force resistance in anchoring area Util = 1.16
additional reinforcement necessary

Overview crit. sections

Selected basic grid: 10 Sections

Checkvalue		Extrem		Utilisation	x [m]	
Flexural capacity bottom	η=	1.17		0.86	19.53	
Flexural capacity top	η=	6.64		0.15	3.75	
Resisting tens force bot	η=	0.86		1.16	30.15	!
Resisting tens force top	η=	6.64		0.15	3.75	
Prc.:Compr.stress t0(sto)	σc =	-27.31	N/mm²	1.07	3.75	!
Prc.:Compr.stress Cc	σc =	-22.83	N/mm²	0.76	3.75	
Stress in prestress.steel	σp,Cc =	1068.4	N/mm²	0.80	19.19	
Stress in rebars	σs =	142.7	N/mm²	0.36	10.81	
Crack MinAs+AsDuc bottom A	AsMin =	6.7	cm²	1.66	15.15	!
Crack MinAs+AsDuc top A	AsMin =	----	cm²	----	----	
Crack width bottom	wk =	0	mm	0.40	11.15	
Crack width top	wk =	0	mm	0.76	3.75	
Sagging top	fo =	-2.5	cm	0.20	13.47	
Sagging bottom	fu =	7.3	cm	0.61	16.83	
Incr.-deflection(Util)	|df|=	6.0	cm	1.00	16.83	
Prc.:Shear reinf (web)	asw =	5.00	cm²/m	1.00	29.16	
Concrete strut capacity	η=	1.58		0.63	30.08	

---- Check not required
**** Check not fulfilled
Prc.:Precast member Add.: in-situ supplement
IS : Installed state SC : State of construction
AsDuk:Ductility reinforcement

Linear creep limit, informative:		Extrem		Utilisation	x [m]
Prc.:lin. creep t0(Sto)	σc =	-23.09	N/mm²	1.41	0.80
Prc.:Compression quasi-permanent Lc	σc =	-19.11	N/mm²	0.85	1.00

Tensile stress state I, informative:		Extrem		Utilisation	x [m]
Prc.:Tens.stress (IS)	σt =	9.52	N/mm²	2.34	10.14
Prc.:Tens.stress (SC)	σt =	3.01	N/mm²	1.19	0.80

Internal forces ULS [kN,kNm]

	Design sit. permanent/transient				from prestressing (formwork state)				
x [m]	Min My	Max My	Min Qz	Max Qz	Sto.tA Nv	Sto.tA Mv	Use.tE Nv	Use.tE Mv	PRE Deg
0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00
0.15	-0.10	-0.07	-1.3	-1.0	-300.0	-113.15	75.2	-16.91	2.41
0.15	-0.10	0.43	-1.3	460.8	-305.6	-115.28	72.7	-17.94	2.26
0.80	-2.83	293.41	-7.1	442.2	-1951.4	-771.31	-787.4	-359.95	1.66
1.00	-4.43	381.28	-8.9	436.5	-1956.7	-784.23	-1001.6	-467.11	2.00
1.35	-8.10	532.27	-12.1	426.4	-1956.7	-803.11	-1225.3	-591.58	2.30
1.36	-8.22	536.53	-12.2	426.1	-1956.7	-803.65	-1225.8	-592.43	2.28
3.37	-51.67	1334.23	-31.3	367.5	-1956.7	-911.27	-1317.2	-752.12	1.15
3.75	-64.26	1471.73	98.4	356.2	-1956.7	-931.47	-1327.8	-779.14	1.08
6.73	197.38	2400.70	75.4	266.8	-1956.7	-1088.60	-1386.4	-974.98	0.82
10.10	406.74	3125.02	46.9	162.5	-1956.7	-1263.95	-1416.4	-1164.27	0.75
11.15	451.87	3278.28	37.5	129.3	-1956.7	-1318.17	-1420.4	-1216.76	0.74
13.47	515.66	3492.30	15.8	54.9	-1956.7	-1437.39	-1423.1	-1322.50	0.76
15.15	529.63	3538.52	-0.7	0.7	-1956.7	-1523.27	-1420.7	-1390.67	0.79
16.83	515.66	3492.30	-54.9	-15.8	-1956.7	-1437.39	-1423.1	-1322.50	0.76
20.20	406.76	3125.02	-162.5	-46.9	-1956.7	-1263.95	-1416.4	-1164.27	0.75
23.57	197.39	2400.70	-266.8	-75.4	-1956.7	-1088.60	-1386.4	-974.98	0.82
26.55	-64.22	1471.73	-356.2	35.0	-1956.7	-931.47	-1327.8	-779.14	1.08
26.93	-51.64	1334.23	-367.5	31.2	-1956.7	-911.27	-1317.2	-752.12	1.15
28.94	-8.21	536.53	-426.1	12.2	-1956.7	-803.65	-1225.8	-592.43	2.28
28.95	-8.09	532.27	-426.4	12.1	-1956.7	-803.11	-1225.3	-591.58	2.30
29.16	-5.76	442.10	-432.4	10.2	-1956.7	-791.79	-1149.6	-543.73	2.35
30.08	-0.21	32.11	-458.8	1.9	-481.2	-182.49	-12.7	-52.60	1.61
30.15	-0.10	0.43	-460.8	1.3	-305.6	-115.28	72.7	-17.94	2.26
30.15	-0.10	-0.07	1.0	1.3	-300.0	-113.15	75.2	-16.91	2.41
30.30	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00

Internal forces SLS

	<- char. Lc->		<- freq. Lc->		<q.- perm. Lc>	
x [m]	Min My	Max My	Min My	Max My	Min My	Max My
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
0.15	-0.07	0.32	-0.07	0.26	-0.07	0.24
0.80	-2.10	226.11	-2.10	190.39	-2.10	182.18
1.00	-3.28	293.83	-3.28	247.44	-3.28	236.78
1.35	-6.00	410.22	-6.00	345.50	-6.00	330.64
1.36	-6.09	413.50	-6.09	348.27	-6.09	333.29
3.37	-38.27	1028.49	-38.27	867.02	-38.27	829.94
3.75	-47.60	1134.52	-47.60	956.56	-47.60	915.69
6.73	214.02	1851.08	214.02	1562.52	214.02	1496.25
10.10	423.39	2410.09	423.39	2036.53	423.39	1950.74
11.15	468.52	2528.41	468.52	2137.06	468.52	2047.19
13.47	532.31	2693.69	532.31	2277.66	532.31	2182.13
15.15	546.28	2729.40	546.28	2308.09	546.28	2211.34
16.83	532.31	2693.69	532.31	2277.66	532.31	2182.13
20.20	423.40	2410.09	423.40	2036.53	423.40	1950.74
23.57	214.04	1851.08	214.04	1562.52	214.04	1496.25
26.55	-47.57	1134.52	-47.57	956.56	-47.57	915.69
26.93	-38.25	1028.49	-38.25	867.02	-38.25	829.94
28.94	-6.08	413.50	-6.08	348.27	-6.08	333.29
28.95	-5.99	410.22	-5.99	345.50	-5.99	330.64
29.16	-4.26	340.71	-4.26	286.93	-4.26	274.59
30.08	-0.16	24.73	-0.16	20.81	-0.16	19.91
30.15	-0.07	0.32	-0.07	0.26	-0.07	0.24
30.15	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
30.30	0.00	0.00	0.00	0.00	0.00	0.00

	<Flex. capacity->		<-----resisting tensile force-------->					
x[m]	ηbo $=M_{Rd}/M_{Ed}$	ηto $=M_{Rd}/M_{Ed}$	ηbo $=T_{Rd}/T_{Ed}$	σI/σR [N/mm²]	al [cm]	ηto $=T_{Rd}/T_{Ed}$	σI/σR [N/mm²]	al [cm]
0.00	---	---	---	0.00#	---	---	0.00#	---
0.08	---	---	---	0.00#	---	438.69	0.00#	43.0
0.15	---	---	---	0.00#	---	344.37	0.00#	43.2
0.15	---	---	0.86	0.00#	103.7	342.39	0.00#	43.2
0.20	88.35	---	1.01	0.00#	103.9	291.79	0.00#	43.3
0.40	18.09	699.13	1.53	0.00#	105.1	136.69	0.00#	43.8
0.60	10.31	283.22	1.94	0.00#	106.2	74.87	3.09*!	44.3
0.80	7.27	118.53	2.25	0.00#	107.3	48.00	4.18*!	44.8
1.00	5.67	76.13	2.54	0.00#	108.4	36.30	4.22*!	45.3
1.20	4.71	53.14	2.54	1.59#	109.5	28.21	4.26*!	45.8
1.35	4.20	42.15	2.41	1.50#	110.3	23.76	4.29*!	46.1
1.36	4.17	41.54	2.40	1.49#	110.4	23.50	4.29*!	46.2
1.40	4.05	40.52	2.37	1.47#	110.6	23.00	4.30*!	46.3
1.60	3.58	32.15	2.23	1.11#	111.7	18.93	4.34*!	46.8
1.80	3.22	25.55	2.10	1.03#	112.8	15.47	4.38*!	47.3
2.00	2.90	20.81	1.99	0.97#	114.0	13.08	4.43*!	47.8
3.37	1.92	8.15	1.63	5.93*!	121.6	7.67	4.83*!	51.1
3.75	1.79	6.64	1.56	7.51*!	123.7	6.64	4.97*!	96.0
6.73	1.30	---	1.26	15.14*!	88.6	---	0.02#	---
10.10	1.17	---	1.17	17.18*!	70.7	---	0.00#	---
11.15	1.17	---	1.17	16.94*!	73.3	---	0.00#	---
13.47	1.22	---	1.20	15.42*!	79.0	---	0.00#	---
16.83	1.22	---	1.21	15.42*!	79.0	---	0.00#	---
20.20	1.17	---	1.17	17.18*!	70.7	---	0.00#	---
23.57	1.30	---	1.26	15.14*!	88.6	---	0.02#	---
26.55	1.79	6.65	1.56	7.51*!	123.7	6.65	4.97*!	52.1
26.93	1.92	8.16	1.63	5.93*!	121.6	7.58	4.83*!	51.1
28.30	2.90	20.83	1.99	0.97#	114.0	13.09	4.43*!	47.8
28.50	3.22	25.58	2.10	1.03#	112.8	15.48	4.38*!	47.3
28.70	3.58	32.19	2.23	1.11#	111.7	18.95	4.34*!	46.8
28.90	4.05	40.58	2.37	1.47#	110.6	23.02	4.30*!	46.3
28.94	4.17	41.60	2.40	1.49#	110.4	23.53	4.29*!	46.2
28.95	4.20	42.21	2.41	1.50#	110.3	23.78	4.29*!	46.1
29.10	4.71	53.23	2.54	1.59#	109.5	28.25	4.26*!	45.8
29.30	5.67	76.28	2.54	0.00#	108.4	36.35	4.22*!	45.3
29.50	7.27	118.81	2.25	0.00#	107.3	48.07	4.18*!	44.8
29.70	10.31	284.02	1.94	0.00#	106.2	75.01	3.09*!	44.3
29.90	18.09	701.62	1.53	0.00#	105.1	136.99	0.00#	43.8
30.10	88.35	---	1.01	0.00#	103.9	292.58	0.00#	43.3
30.15	---	---	0.86	0.00#	103.7	343.36	0.00#	43.2
30.15	---	---	---	0.00#	---	345.35	0.00#	43.2
30.22	---	---	---	0.00#	---	440.04	0.00#	43.0
30.30	---	---	---	0.00#	---	---	0.00#	---

---- Check not required
**** Check not fulfilled
#:Main tens.stressσI #!:σI > fctk0.05
*:Edge tens. str.σR *!:σR > fctk0.05

Concrete stresses precast

x [m]	σc,1 [N/mm²]	σc,2 [N/mm²]	σc,Cc [N/mm²]	σc,Qc [N/mm²]	σt,Cc [N/mm²]	σt,SC [N/mm²]
0.08	-1.56	-1.56	-0.82	-0.82	1.52	0.34
0.15	-3.76	-3.76	-2.87	-2.87	0.92	0.67
0.15	-3.83	-3.83	-2.94	-2.93	0.92	0.68
0.68	-18.93	-22.44	-16.91	-16.91	1.14	2.56
0.80	-23.09	-26.50	-15.49	-15.49	1.21	3.01
0.83	-23.02	-26.57	-15.35	-15.35	1.11	2.97
1.00	-21.70	-26.55	-19.11	-19.11	0.50	2.71
1.14	-21.28	-26.55	-19.80	-18.63	0.01	2.50

x [m]	σc,1 [N/mm²]	σc,2 [N/mm²]	σc,Cc [N/mm²]	σc,Qc [N/mm²]	σt,Cc [N/mm²]	σt,SC [N/mm²]
1.35	-20.67	-26.55	-21.05	-18.08	---	2.21
1.36	-20.64	-26.55	-21.06	-18.05	---	2.19
3.37	-16.00	-27.10	-22.61	-14.17	0.56	4.68
3.75	-15.31	-27.31	-22.83	-13.56	1.77	4.78
6.73	-11.52	-17.59	-16.23	-10.16	7.72	2.28
10.10	-9.48	-14.30	-15.81	-10.67	9.52	1.03
13.47	-8.85	-12.78	-14.49	-9.69	8.44	0.81
15.15	-8.88	-12.46	-13.01	-8.71	7.25	0.96
16.83	-8.85	-12.78	-14.49	-9.69	8.44	0.81
20.20	-9.48	-14.30	-15.81	-10.67	9.52	1.03
23.57	-11.52	-17.59	-16.23	-10.16	7.72	2.28
26.55	-15.31	-27.31	-22.83	-13.56	1.77	4.78
26.93	-16.00	-27.10	-22.61	-14.17	0.56	4.68
28.94	-20.64	-26.55	-21.06	-18.05	---	2.19
28.95	-20.67	-26.55	-21.05	-18.08	---	2.21
29.16	-21.28	-26.55	-19.80	-18.63	0.01	2.50
29.30	-21.70	-26.55	-19.11	-19.11	0.50	2.71
29.47	-23.02	-26.57	-15.35	-15.35	1.11	2.97
29.50	-23.09	-26.50	-15.49	-15.49	1.21	3.01
29.62	-18.93	-22.44	-16.91	-16.91	1.14	2.56
30.15	-3.83	-3.83	-2.94	-2.93	0.92	0.68
30.15	-3.76	-3.76	-2.87	-2.87	0.92	0.67
30.22	-1.56	-1.56	-0.82	-0.82	1.52	0.34

---- Check not required
**** Check not fulfilled
σc,1 : Compression and disproportional creeping check with early strength (storage)
σc,2 : Compressive stress check with early strength (erection)
σc,Cc : Compression check Characteristic load combination
σc,Qc : Disproportional creep check quasi-perm. load combination
σt,Cc : Tensile stresses ,Installed state, Characteristic load combination (informative)
σt,SC : Tensile stresses,State of construction (informative)

Check the limit deformation:

Total sagging	f ≤ L/ 250		Increase deflection	|df| ≤ L/ 500	
Cantilever left	f ≤ 0.1	cm		|df| ≤ 0.1	cm
Span	f ≤ 12.0	cm		|df| ≤ 6.0	cm
Cantilever right	f ≤ 0.1	cm		|df| ≤ 0.1	cm

quasi- permanent combination and eff. char. prestress
Deflection due to shrinkage considered
Tension stiffening: Member rigidity, Characteristic combination

	Storage		Utilization		
x [m]	ftA [cm]	ftE [cm]	ftA [cm]	ftE [cm]	|df| [cm]
0.00	0.0	0.1	-0.0	-0.1	-0.1
3.37	-0.9	-1.2	0.3	2.4	2.1
6.73	-1.4	-1.9	0.8	4.8	4.0
10.10	-1.7	-2.3	1.2	6.6	5.4
13.47	-1.8	-2.5	1.4	7.3	6.0
16.83	-1.8	-2.5	1.4	7.3	6.0
20.20	-1.7	-2.3	1.2	6.6	5.4
23.57	-1.4	-1.9	0.8	4.8	4.0
26.93	-0.9	-1.2	0.3	2.4	2.1
30.30	0.0	0.1	-0.0	-0.1	-0.1

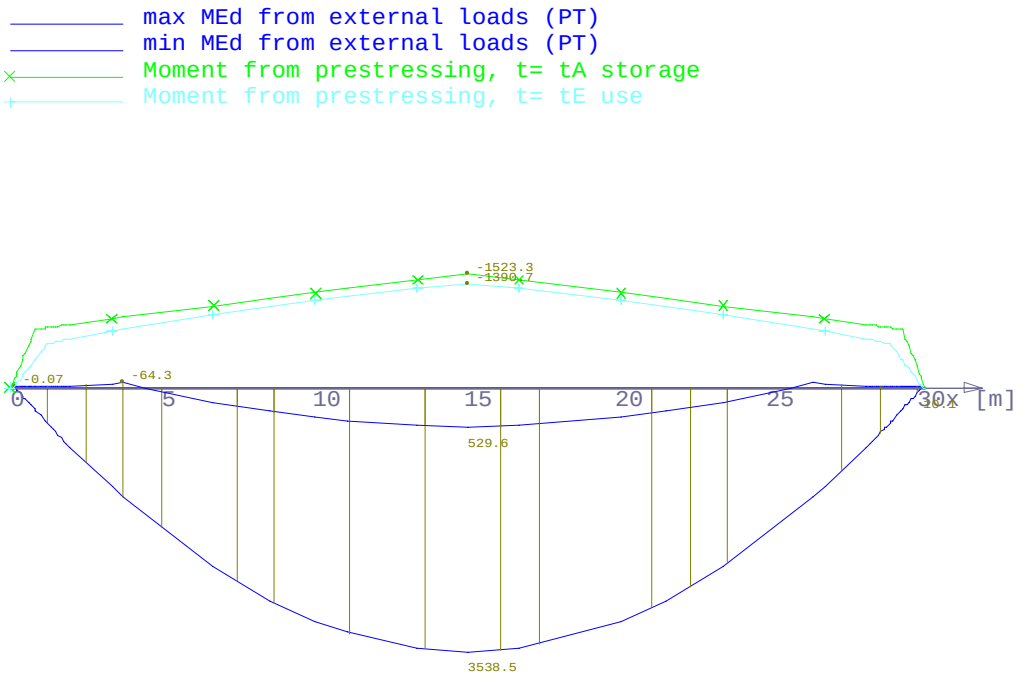
|df|= ftE(service)- ftA(service)

Shear resistance

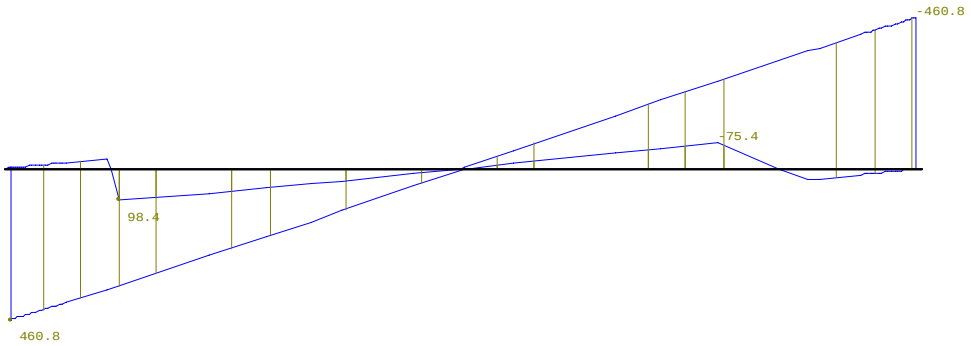
x [m]	V_{Ed} [kN]	$V_{Ed,red}$ [kN]	cotΘ	z [cm]	asw,Web [cm²/m]	η =$V_{Rd,max}/V_{Ed}$
0.08	0.7	----	1.00	58.4	2.15	---
0.22	456.5	----	2.50*	68.9	5.00	1.58
0.23	455.9	----	2.50*	69.1	5.00	1.59
1.14	402.9	402.9	2.50	74.2	5.00	2.15
1.35	391.4	391.4	2.50	75.3	4.78	2.26
1.36	390.8	390.8	2.50	75.3	4.77	2.27
3.37	289.9	289.9	2.50	85.2	3.13	2.65
3.75	272.4	272.4	2.50	86.9	2.88	3.09
6.73	149.8	149.8	1.58	101.6	2.15	10.40
10.10	41.0	41.0	1.00	118.5	2.15	41.18
13.47	73.4	73.4	1.00	134.8	2.15	30.71
15.15	122.4	122.4	1.00	143.1	2.15	19.47
16.83	73.4	73.4	1.00	134.8	2.15	30.71
20.20	41.0	41.0	1.00	118.5	2.15	41.18
23.57	149.8	149.8	1.58	101.6	2.15	10.40
26.55	272.4	272.4	2.50	86.9	2.88	3.09
26.93	289.9	289.9	2.50	85.2	3.13	2.65
28.94	390.8	390.8	2.50	75.3	4.77	2.27
28.95	391.4	391.4	2.50	75.3	4.78	2.26
29.16	402.9	402.9	2.50	74.2	5.00	2.15
30.08	456.5	----	2.50*	68.9	5.00	1.58
30.22	0.7	----	1.00	58.4	2.15	---

---- Check not required
**** Check not fulfilled
*: Take over from last construction phase

Internal forces

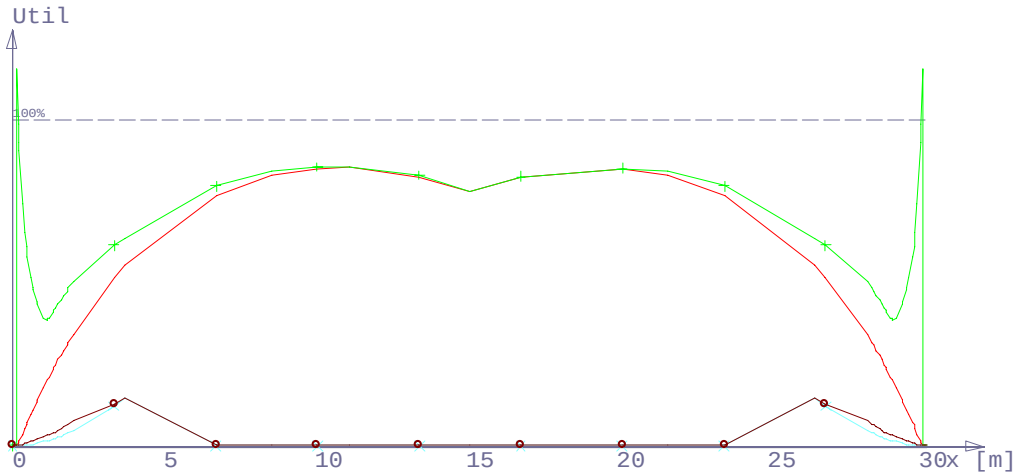


max VEd from external loads (PT)
min VEd from external loads (PT)



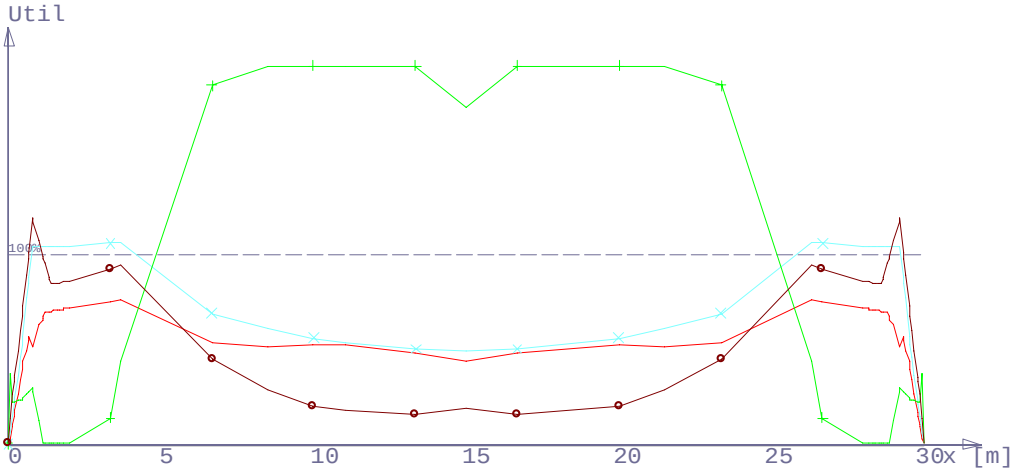
Bending resitance (failure safety)

Flexural capacity bottom	η =	1.17	x=19.53 m
Flexural capacity top	η =	6.64	x= 3.75 m
Resisting tens force bot	η =	0.86	x=30.15 m
Resisting tens force top	η =	6.64	x= 3.75 m



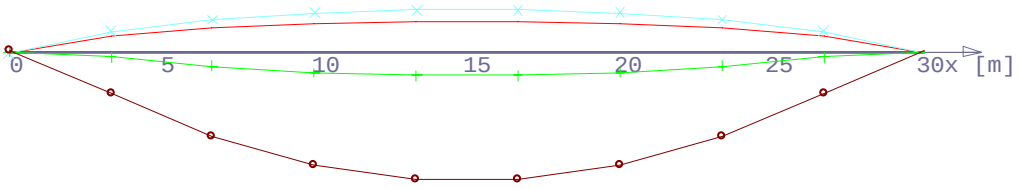
Ultimate stress precast component

Prc.:Compr.stress Cc σc =-22.83 N/mm2 x= 3.75 m
Prc.:Compr.stress t0(sto) σc =-27.31 N/mm2 x= 3.75 m
Prc.:Tens.stress (IS) > 100% condition II, informative only
Prc.:Tens.stress (SC) > 100% condition II, informative only



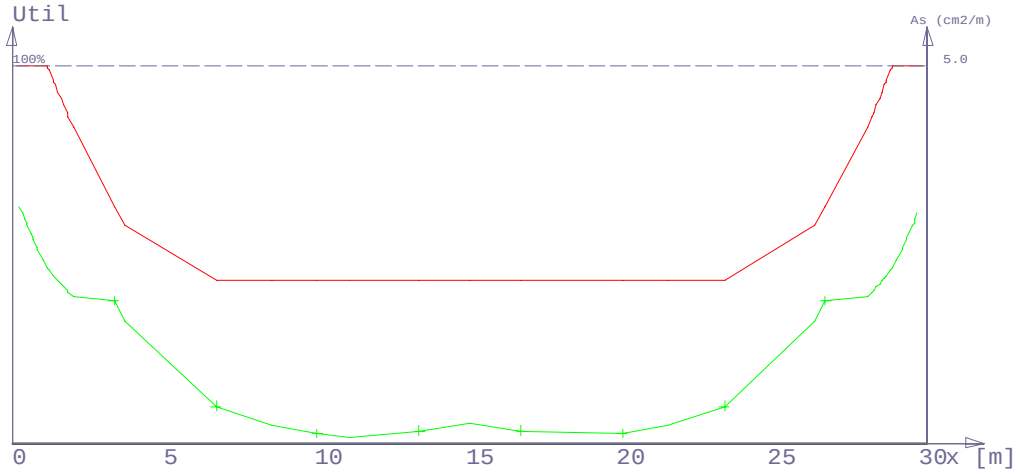
Deformation

Sagging t=tA storage -1.83 cm
Sagging t=tE storage -2.45 cm
Sagging t=tA utilisatio 1.36 cm
Sagging t=tE utilisa 7.34 cm



Shear force resistance (shear covering)

Prc.:Shear reinf (web) asw = 5.00 cm2/m x=29.16 m
Concrete strut capacity η = 1.58 x=30.08 m



Selected section x = 11.00 m from left support

Internal force combinations from external loading
LAc: dominant variable action (leading action)
ULS-PT : permanent + transient design situation (fundam. combination)
SLS-Cc : characteristic combination
SLS-Fc : frequent combination
SLS-Qc : quasi-permanent combination

maximum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	1240.12	918.59	918.59	918.59
Storage/Erection	649.16	468.52	468.52	468.52
Utilization	3278.28	2528.41	2137.06	2047.19
LAc	10	10	10	-

Minimum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	918.56	918.59	918.59	918.59
Storage/Erection	451.87	468.52	468.52	468.52
Utilization	2047.16	2047.19	2047.19	2047.19
LAc	-	-	-	-

maximum shear force:[kN]

	ULS-PT
Storage	51.6
Storage/Erection	52.4
Utilization	129.3
LAc	10

Effective Tendons (prestressed formwork state for t = t0 (sto))

	No.	Area	Distance	Prestress		tens.force		Shorttime
Layer No.		Ap [cm²]	f.bottom [cm]	max [N/mm²]	min [N/mm²]	max [kN]	min [kN]	Relaxation [N/mm²]
1	3	2.8	8.5	956.37	956.37	266.8	266.8	-4.63
2	3	2.8	12.3	956.37	956.37	266.8	266.8	-4.63
3	3	2.8	16.1	956.37	956.37	266.8	266.8	-4.63
4	3	2.8	19.9	956.37	956.37	266.8	266.8	-4.63
5	3	2.8	23.7	956.37	956.37	266.8	266.8	-4.63
6	3	2.8	27.5	956.37	956.37	266.8	266.8	-4.63
7	3	2.8	31.3	956.37	956.37	266.8	266.8	-4.63
8	1	0.9	35.1	956.37	956.37	88.9	88.9	-4.63
Δσ(Tt0)= -39 N/mm2 due to heat treatment								

Untensioned reinforcement

Layer	Number	Diameter [mm]	Area [cm²]	LE [cm]
1	2	16	4.0	3.6
2	2	20	6.3	135.2
3	2	20	6.3	146.4

Cross-section Precast :

Layer of cross-section from top to bottom			
Nr	Width [cm]	Distance [cm]	Remarks
1	60.0	0.0	
2	60.0	15.0	
3	19.0	23.2	Web begin
4	19.0	150.2	Web end

Cross-section Values

	brutto			ideal		
	A_c [cm²]	z_u [cm]	I_c [cm⁴]	A_i [cm²]	z_i [cm]	I_i [cm⁴]
Precast cross-section	3636.9	89.2	8019344	3797.3	88.0	8768771

Internal forces from prestress (mean values, prestressed formwork state)

	$N_{pm}^{(0)}$		$M_{pm}^{(0)}$	
Creep period	tB [kN]	tE [kN]	tB [kNm]	tE [kNm]
Storage	-1956.7	-1793.6	-1318.17	-1254.74
Utilization	-1793.6	-1420.4	-1254.74	-1216.76
tA=Begin, tE=End creep period				

Prestress steel relaxation		
Lay. No.	Storage $\Delta\sigma_{p,r1}$ [N/mm²]	Utilization $\Delta\sigma_{p,r2}$ [N/mm²]
1	-0.10	-13.00
2	-0.10	-12.94
3	-0.11	-12.89
4	-0.11	-12.84
5	-0.11	-12.79
6	-0.11	-12.73
7	-0.11	-12.68
8	-0.11	-12.63

Prestr. steel, losses due to creeping, shrinking and relaxation:		
Lay. No.	Storage $\Delta\sigma_{p,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{p,csr2}^{(0)}$ [N/mm²]
1	-50.61	-75.05
2	-50.09	-77.17
3	-49.57	-79.29
4	-49.05	-81.41
5	-48.54	-83.53
6	-48.02	-85.65
7	-47.50	-87.77
8	-46.98	-89.89

Stress in rebars due to creeping,shringing and relaxation:		
Lay. No.	Storage $\Delta\sigma_{s,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{s,csr2}^{(0)}$ [N/mm²]
1	-52.51	-63.45
2	-34.06	-140.25
3	-32.50	-146.79

Bending with Normal Force ULS

L.	Creep period	Cross-section	Tens-zone	z [cm]	M_{Rd} [kNm]	M_{Ed} [kNm]	η (>1.0)	
1	tB Storage	P	top	119.4	634.58	MEd < 0	n/a	#1
2	tE Storage	P	bottom	123.7	3829.99	1240.12	3.09	
3	tB Storage/Erection	P	top	119.4	634.58	MEd < 0	n/a	#1
4	tE Storage/Erection	P	bottom	123.7	3829.99	649.16	5.90	
5	tE Utilization	P	top	125.0	781.51	MEd < 0	n/a	
6	tE Utilization	P	bottom	123.4	3843.82	3278.28	1.17	

#1: fck(t)= 0.73 * fck

Interim results : Ultimate elongation and internal forces										
L.	ε_c [‰]	ε_s [‰]	x [cm]	Ap [cm²]	As [cm²]	Zp [kN]	Zs [kN]	Dc [kN]	Dp [kN]	Ds [kN]
1	3.500	5.500	56.9	0.0	12.6	0.0	549.1	1807.6	-1441.6	166.9
2	3.500	21.900	20.2	20.5	4.0	2962.2	180.5	2730.3	0.0	380.1
3	3.500	5.500	56.9	0.0	12.6	0.0	549.1	1807.6	-1441.6	166.9
4	3.500	21.900	20.2	20.5	4.0	2962.2	180.5	2730.3	0.0	380.1
5	3.500	9.500	39.4	0.0	12.6	0.0	551.9	1717.7	-1308.2	163.9
6	3.500	22.700	19.6	20.5	4.0	2967.4	180.7	2660.2	0.0	468.0

Shear Resistance

Design value shear force						
L.	Creep period	Combination	$V_{Ed,0}$ [kN]	M_{Ed} [kNm]	dV [kN]	due to
1	tB Storage	QMax	51.6	1240.10	-49.6	Vccd
2	tE Storage	QMax	51.6	1240.10	-49.6	Vccd
3	tB Storage/Erection	QMax	52.4	637.91	-25.5	Vccd
4	tE Storage/Erection	QMax	52.4	637.91	-25.5	Vccd
5	tB Utilization	MMax	129.3	3278.28	-131.5	Vccd
6	tE Utilization	MMax	129.3	3278.28	-131.5	Vccd

Effective cross-section									
L.	Cross-section	Tens-zone	b_w [cm]	d [cm]	z [cm]	A_c [cm²]	A_{sl} [cm²]	σ_{cp} [N/mm²]	V_{Rdc} [kN]
1	P	bottom	19.0	146.6	123.7	3636.9	24.5	4.84	347.6
2	P	bottom	19.0	146.6	123.7	3636.9	24.5	4.44	347.0
3	P	bottom	19.0	146.6	123.7	3636.9	24.5	4.84	347.6
4	P	bottom	19.0	146.6	123.7	3636.9	24.5	4.44	347.0
5	P	bottom	19.0	146.6	123.4	3636.9	24.5	4.44	347.0
6	P	bottom	19.0	146.6	123.4	3636.9	24.5	3.52	308.4

Shear designv1= 0.480									
L.	V_{Ed} [kN]	$V_{Ed.red}$ [kN]	a_{cw}	cotΘ	asw [cm²/m]	Note	a_l [cm]	$V_{Rd.max}$ [kN]	
1	2.0	2.0	1.199	1.000	1.83	Min	73.3	1754.2	#1
2	2.0	2.0	1.133	1.000	2.15	Min	73.3	2130.3	
3	26.8	26.8	1.199	1.000	1.83	Min	73.3	1754.2	#1
4	26.8	26.8	1.133	1.000	2.15	Min	73.3	2130.3	
5	2.2	2.2	1.133	1.000	2.15	Min	73.3	2125.8	
6	2.2	2.2	1.105	1.000	2.15	Min	73.3	2073.9	
#1: fck(t)= 0.73 * fck									

Check of crack width limit in SLS

perm. crack width: wk < 0 mm, Frequent load combination

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	max.σ_s [N/mm²]	$s_{r.max}$ [mm]	ε_{sm}-ε_{cm} [‰]	w_k [mm]
1	tB Storage	P	top	1.00	CS completely compressed			
2	tE Storage	P	bottom	1.00	CS completely compressed			
3	tB Storage/Erection	P	top	1.00	no cracks			
4	tE Storage/Erection	P	bottom	1.00	CS completely compressed			
5	tE Utilization	P	top	1.00	CS completely compressed			
6	tE Utilization	P	bottom	1.00	128.75	206	0.386	0

Internal forces and elongation								
			State I		State II			
L.	N_{qes} [kN]	M_{qes} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]	
1	-1956.7	-399.59	-2.32	201.0				
2	-1793.6	-336.16	-8.10	211.2				
3	-1956.7	-849.65	0.88	141.1				
4	-1793.6	-786.22	-12.61	140.6				
5	-1420.4	830.43	-9.64	101.7				
6	-1420.4	920.30	5.49	97.9	1.78	-0.775	80.1	
X0I: Pressure zone height in state I X0II: Pressure zone height in state II								

L.	$h_{c,ef}$ [cm]	A_{ceff} [cm²]	ξ_1	Ap [cm²]	As [cm²]	$\rho_{p,ef}$ [%]	ρ_{tot} [%]	k1	k2	k3	c [cm]	k4
6	23.4	444.1	1.15	11.2	4.0	4.257	3.418	1.38	0.50	3.40	2.8	0.425

Internal forces cracking and strains (state II)							
			State I		State II		
L.	N_{qes} [kN]	M_{qes} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
6	-1420.4	778.83	4.07	104.4			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

Minimum reinforcement for crack control:

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	σ_t [N/mm²]	req. As [cm²]	exist. As [cm²]
1	tB Storage	P	top	1.00	-1.89	< 4.07 not req.	
2	tE Storage	P	bottom	1.00	-8.10	< 4.07 not req.	
3	tB Storage/Erection	P	top	1.00	1.31	< 4.07 not req.	
4	tE Storage/Erection	P	bottom	1.00	-12.61	< 4.07 not req.	
5	tE Utilization	P	top	1.00	-9.37	< 4.07 not req.	
6	tE Utilization	P	bottom	1.00	9.42	<= 0 cm2	

					Web				Flange			
L.	D [mm]	x0IZ [cm]	A_p [cm²]	ξ_1	k	k_c	A_{ct} [cm²]	A_s [cm²]	k	k_c	A_{ct} [cm²]	A_s [cm²]
6	16	45.8	5.6	1.15	0.65	0.29	871.0	4.3	--no flange--			

x0IZ: tensile zone in state I due to cracking forces

Ductility reinforcement in precompressed tensile zone:

b [cm³]	f_{ctm} [N/mm²]	Zs [cm]	req. As [cm²]	exist. As [cm²]
19	4.07	146.6	5.9	4.0

Stress checks SLS

Concrete edge stresses in state I due to prestress, creep, shrinkage and relaxation

		σ_RPrecast	
L.	due to	top [N/mm²]	bottom [N/mm²]
1	Prestr. release anchorage	4.20	-18.38
2	csr storage	-0.02	1.07
3	csr utilisation	0.71	1.36

Tab. Compr stresses of concrete

			M_{Ed}	σ_cPrecast		
L.	Creep period	Cross-section	+ = Max - = Min	Cc,Pk [N/mm²]	Qc,Pk [N/mm²]	
1	tB Storage	P	--	-9.16	-9.16	
2	tE Storage	P	--	-8.10	-8.10	
3	tB Storage/Erection	P	--	-13.68		
4	tE Storage/Erection	P	--	-12.61		
5	tB Utilization	P	+-	-15.68	-10.57	
6	tE Utilization	P	+-	-14.19	-9.53	

Tab. Steel- and Concrete tension stress

L.	Creep period	Cross-section	M_{Ed} + = Max - = Min	σ_p Cc,Pm [N/mm²]	σ_s Cc,Pk [N/mm²]	σ_t Cc,Pk [N/mm²]
1	tB Storage	P	-+-	916.52	< 0	ZII
2	tE Storage	P	-+-	873.82	< 0	ZII
3	tB Storage/Erection	P	---	902.22	2.76	0.88
4	tE Storage/Erection	P	-+-	859.52	< 0	0.86
5	tB Utilization	P	++-	1067.66	124.02	ZII
6	tE Utilization	P	++-	1068.31	142.41	ZII

Pk= Prestres char. value, Pm= prestress mean value, StII: State II

Selected section x = 1.00 m from left support

Internal force combinations from external loading
LAc: dominant variable action (leading action)
ULS-PT : permanent + transient design situation (fundam. combination)
SLS-Cc : characteristic combination
SLS-Fc : frequent combination
SLS-Qc : quasi-permanent combination

maximum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	162.93	120.67	120.67	120.67
Storage/Erection	-4.35	-4.35	-4.35	-4.35
Utilization	446.42	344.04	289.74	277.27
LAc	10	10	10	-

Minimum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	120.65	120.67	120.67	120.67
Storage/Erection	-5.87	-4.35	-4.35	-4.35
Utilization	277.25	277.27	277.27	277.27
LAc	-	-	-	-

maximum shear force:[kN]

	ULS-PT
Storage	158.5
Storage/Erection	-10.3
Utilization	432.1
LAc	10

Effective Tendons (prestressed formwork state for t = t0 (sto))

	No.	Area	Distance	Prestress		tens.force		Shorttime
Layer No.		Ap [cm²]	f.bottom [cm]	max [N/mm²]	min [N/mm²]	max [kN]	min [kN]	Relaxation [N/mm²]
1	3	2.8	8.5	956.37	912.14	266.8	254.5	-4.63
2	3	2.8	12.3	956.37	912.14	266.8	254.5	-4.63
3	3	2.8	16.1	956.37	912.14	266.8	254.5	-4.63
4	3	2.8	19.9	956.37	912.14	266.8	254.5	-4.63
5	3	2.8	23.7	956.37	912.14	266.8	254.5	-4.63
6	3	2.8	27.5	956.37	912.14	266.8	254.5	-4.63
7	3	2.8	31.3	956.37	912.14	266.8	254.5	-4.63
8	1	0.9	35.1	956.37	912.14	88.9	84.8	-4.63
Δσ(Tt0)= -39 N/mm2 due to heat treatment								

Untensioned reinforcement

Layer	Number	Diameter [mm]	Area [cm²]	LE [cm]
1	2	16	4.0	3.6
2	2	20	6.3	85.7
3	2	20	6.3	96.9

Cross-section Precast :

Layer of cross-section from top to bottom			
Nr	Width [cm]	Distance [cm]	Remarks
1	60.0	0.0	
2	60.0	15.0	
3	19.0	23.2	Web begin
4	19.0	100.7	Web end

Cross-section Values

	brutto			ideal		
	A_c [cm²]	z_u [cm]	I_c [cm⁴]	A_i [cm²]	z_i [cm]	I_i [cm⁴]
Precast cross-section	2696.3	62.2	2560641	2856.7	61.1	2848818

Internal forces from prestress (mean values, prestressed formwork state)

	$N_{pm}^{(0)}$		$M_{pm}^{(0)}$		φFak
Creep period	tB [kN]	tE [kN]	tB [kNm]	tE [kNm]	Prc
Storage	-1956.7	-1637.6	-792.33	-674.94	1.22
Utilization	-1717.0	-1160.2	-707.67	-549.27	1.00

tA=Begin, tE=End creep period
φFak: Increase factor creep modulus (non-linear creep:> 1.0)

Prestress steel relaxation

Lay. No.	Storage $\Delta\sigma_{p,r1}$ [N/mm²]	Utilization $\Delta\sigma_{p,r2}$ [N/mm²]
1	-0.08	-8.50
2	-0.08	-8.68
3	-0.09	-8.87
4	-0.09	-9.06
5	-0.09	-9.25
6	-0.09	-9.45
7	-0.09	-9.65
8	-0.10	-9.85

Prestr. steel, losses due to creeping, shrinking and relaxation:

Lay. No.	Storage $\Delta\sigma_{p,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{p,csr2}^{(0)}$ [N/mm²]
1	-93.48	-163.58
2	-90.24	-160.74
3	-86.99	-157.90
4	-83.75	-155.07
5	-80.51	-152.23
6	-77.27	-149.40
7	-74.03	-146.57
8	-70.79	-143.74

Stress in rebars due to creeping,shringing and relaxation:

Lay. No.	Storage $\Delta\sigma_{s,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{s,csr2}^{(0)}$ [N/mm²]
1	-100.10	-164.76
2	-28.24	-98.51
3	-18.44	-89.47

Bending with Normal Force ULS

L.	Creep period	Cross-section	Tens-zone	z [cm]	M_{Rd} [kNm]	M_{Ed} [kNm]	η (>1.0)	
1	tB Storage	P	top	70.5	339.08	MEd < 0	n/a	#1
2	tE Storage	P	bottom	74.4	2207.63	162.93	13.55	
3	tB Storage/Erection	P	top	70.5	339.08	5.87	57.79	#1
4	tE Storage/Erection	P	bottom	74.4	2207.63	MEd < 0	n/a	
5	tB Utilization	P	top	75.1	496.04	MEd < 0	n/a	
6	tE Utilization	P	bottom	74.3	2193.79	446.42	4.91	

#1: fck(t)= 0.73 * fck

Interim results : Ultimate elongation and internal forces										
L.	ε_c [‰]	ε_s [‰]	x [cm]	Ap [cm²]	As [cm²]	Zp [kN]	Zs [kN]	Dc [kN]	Dp [kN]	Ds [kN]
1	3.500	2.500	56.5	0.0	12.6	0.0	500.3	1794.5	-1443.3	166.9
2	3.500	13.900	19.5	20.5	4.0	2828.8	178.1	2654.0	0.0	365.7
3	3.500	2.500	56.5	0.0	12.6	0.0	500.3	1794.5	-1443.3	166.9
4	3.500	13.900	19.5	20.5	4.0	2828.8	178.1	2654.0	0.0	365.7
5	3.500	4.900	40.4	0.0	12.6	0.0	548.3	1759.4	-1403.1	163.9
6	3.500	14.700	18.7	20.5	4.0	2828.0	178.2	2551.6	0.0	419.9

Shear Resistance

Design value shear force						
L.	Creep period	Combination	$V_{Ed,0}$ [kN]	M_{Ed} [kNm]	dV [kN]	due to
1	tB Storage	QMax	158.5	162.91	-10.8	Vccd
2	tE Storage	QMax	158.5	162.91	-10.8	Vccd
3	tB Storage/Erection	QMax	-10.3	-5.87	0.0	-------
4	tE Storage/Erection	QMax	-10.3	-5.87	0.0	-------
5	tB Utilization	QMax	432.1	446.40	-29.8	Vccd
6	tE Utilization	QMax	432.1	446.40	-29.8	Vccd

Effective cross-section									
L.	Cross-section	Tens-zone	b_w [cm]	d [cm]	z [cm]	A_c [cm²]	A_{sl} [cm²]	σ_{cp} [N/mm²]	V_{Rdc} [kN]
1	P	bottom	19.0	97.1	74.4	2696.3	24.5	4.86	251.6
2	P	bottom	19.0	97.1	74.4	2696.3	24.5	5.47	281.6
3	P	top	19.0	91.3	70.5	2696.3	12.6	4.86	217.3
4	P	top	19.0	91.3	70.5	2696.3	12.6	5.47	243.3
5	P	bottom	19.0	97.1	74.3	2696.3	24.5	5.73	288.9
6	P	bottom	19.0	97.1	74.3	2696.3	24.5	3.87	237.5

Shear designv1= 0.480									
L.	V_{Ed} [kN]	$V_{Ed,red}$ [kN]	a_{cw}	cotΘ	asw [cm²/m]	Note	a_l [cm]	$V_{Rd,max}$ [kN]	
1	147.7	147.7	1.250	2.487	1.83	Min	92.6	761.6	#1
2	147.7	147.7	1.164	2.123	2.15	Min	79.0	1015.3	
3	10.3	10.3	1.250	1.000	1.83	Min	45.6	1042.2	#1
4	10.3	10.3	1.164	1.000	2.15	Min	45.6	1247.5	
5	402.4	402.4	1.172	2.500	4.98	Var	92.8	912.3	
6	402.4	402.4	1.116	2.500	4.98	Var	92.8	868.9	
#1: fck(t)= 0.73 * fck									

Check of crack width limit in SLS

perm. crack width: wk < 0 mm, Frequent load combination

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	max.σ_s [N/mm²]	$s_{r,max}$ [mm]	ε_{sm}-ε_{cm} [‰]	w_k [mm]
1	tB Storage	P	top	1.00	no cracks			
2	tE Storage	P	bottom	1.00	CS completely compressed			
3	tB Storage/Erection	P	top	1.00	56.16	431	0.168	0
4	tE Storage/Erection	P	bottom	1.00	CS completely compressed			
5	tB Utilization	P	top	1.00	CS completely compressed			
6	tE Utilization	P	bottom	1.00	CS completely compressed			

Internal forces and elongation							
			State I		State II		
L.	N_{ges} [kN]	M_{ges} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
1	-1956.7	-671.66	2.49	90.1			
2	-1637.6	-554.27	-17.62	90.5			
3	-1956.7	-796.68	4.23	85.6	0.00	-0.718	69.6
4	-1637.6	-679.29	-20.30	85.1			
5	-1717.0	-430.40	-0.03	100.9			
6	-1160.2	-259.53	-9.63	105.7			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

L.	$h_{c,ef}$ [cm]	A_{ceff} [cm²]	ξ_1	Ap [cm²]	As [cm²]	$\rho_{p,ef}$ [%]	ρ_{tot} [%]	k1	k2	k3	c [cm]	k4
3	10.4	621.0	1.29	0.0	6.3	1.012	1.012	0.80	0.50	3.40	2.8	0.425

Internal forces cracking and strains (state II)							
			State I		State II		
L.	N_{ges} [kN]	M_{ges} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
3	-1956.7	-785.48	4.07	85.9			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

Minimum reinforcement for crack control:

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	σ_t [N/mm²]	req. As [cm²]	exist. As [cm²]
1	tB Storage	P	top	1.00	3.61	< 4.07	not req.
2	tE Storage	P	bottom	1.00	-17.62	< 4.07	not req.
3	tB Storage/Erection	P	top	1.00	5.34	<= 0 cm2	
4	tE Storage/Erection	P	bottom	1.00	-20.30	< 4.07	not req.
5	tB Utilization	P	top	1.00	1.92	< 4.07	not req.
6	tE Utilization	P	bottom	1.00	-8.46	< 4.07	not req.

					Web				Flange			
L.	D [mm]	x0IZ [cm]	A_p [cm²]	ξ_1	k	k_c	A_{ct} [cm²]	A_s [cm²]	k	k_c	A_{ct} [cm²]	A_s [cm²]
3	20	14.8	0.0	0.00	0.65	0.00	280.6	-nan(ind)	0.97	0.53	498.5	4.8
x0IZ: tensile zone in state I due to cracking forces												

Ductility reinforcement in precompressed tensile zone:

b [cm³]	f_{ctm} [N/mm²]	Zs [cm]	req. As [cm²]	exist. As [cm²]
19	4.07	97.1	3.9	4.0

Stress checks SLS

Concrete edge stresses in state I due to prestress, creep, shrinkage and relaxation			
		σ_RPrecast	
L.	due to	top [N/mm²]	bottom [N/mm²]
1	Prestr. release anchorage	4.17	-23.84
2	csr storage	-0.34	2.65
3	csr utilisation	-0.08	4.58

Tab. Compr stresses of concrete						
			M_{Ed}	σ_cPrecast		
L.	Creep period	Cross-section	+ = Max - = Min	Cc,Pk [N/mm²]	Qc,Pk [N/mm²]	
1	tB Storage	P	--	-21.25	-21.25	#1
2	tE Storage	P	--	-18.60	-18.60	
3	tB Storage/Erection	P	--	-26.55*		
4	tE Storage/Erection	P	--	-19.98		
5	tB Utilization	P	--	-15.24	-15.24	
6	tE Utilization	P	--	-10.66	-10.66	
#1: due toσc > 0.45* fck(t) increased ceep modulus						

Tab. Steel- and Concrete tension stress						
L.	Creep period	Cross-section	M_{Ed} + = Max - = Min	σ_D Cc,Pm [N/mm²]	σ_S Cc,Pk [N/mm²]	σ_t Cc,Pk [N/mm²]
1	tB Storage	P	---	887.99	8.61	2.49
2	tE Storage	P	-+-	781.46	< 0	2.15
3	tB Storage/Erection	P	---	900.14	56.16	ZII
4	tE Storage/Erection	P	---	764.91	48.15	ZII
5	tB Utilization	P	++-	836.43	< 0	ZII
6	tE Utilization	P	++-	664.02	< 0	ZII
Pk= Prestres char. value, Pm= prestress mean value, StII: State II						

Selected section x = 3.60 m from left support

Internal force combinations from external loading
LAc: dominant variable action (leading action)
ULS-PT : permanent + transient design situation (fundam. combination)
SLS-Cc : characteristic combination
SLS-Fc : frequent combination
SLS-Qc : quasi-permanent combination

maximum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	543.37	402.48	402.48	402.48
Storage/Erection	-47.60	-47.60	-47.60	-47.60
Utilization	1471.73	1134.52	956.56	915.69
LAc	10	10	10	-

Minimum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	402.45	402.48	402.48	402.48
Storage/Erection	-64.26	-47.60	-47.60	-47.60
Utilization	915.67	915.69	915.69	915.69
LAc	-	-	-	-

maximum shear force:[kN]

	ULS-PT
Storage	133.8
Storage/Erection	134.5
Utilization	356.2
LAc	10

Effective Tendons (prestressed formwork state for t = t0 (sto))

	No.	Area	Distance	Prestress		tens.force		Shorttime
Layer No.		Ap [cm²]	f.bottom [cm]	max [N/mm²]	min [N/mm²]	max [kN]	min [kN]	Relaxation [N/mm²]
1	3	2.8	8.5	956.37	956.37	266.8	266.8	-4.63
2	3	2.8	12.3	956.37	956.37	266.8	266.8	-4.63
3	3	2.8	16.1	956.37	956.37	266.8	266.8	-4.63
4	3	2.8	19.9	956.37	956.37	266.8	266.8	-4.63
5	3	2.8	23.7	956.37	956.37	266.8	266.8	-4.63
6	3	2.8	27.5	956.37	956.37	266.8	266.8	-4.63
7	3	2.8	31.3	956.37	956.37	266.8	266.8	-4.63
8	1	0.9	35.1	956.37	956.37	88.9	88.9	-4.63
Δσ(Tt0)= -39 N/mm2 due to heat treatment								

Untensioned reinforcement

Layer	Number	Diameter [mm]	Area [cm²]	LE [cm]
1	2	16	4.0	3.6
2	2	20	6.3	98.6
3	2	20	6.3	109.8

Cross-section Precast :

Layer of cross-section from top to bottom			
Nr	Width [cm]	Distance [cm]	Remarks
1	60.0	0.0	
2	60.0	15.0	
3	19.0	23.2	Web begin
4	19.0	113.6	Web end

Cross-section Values

	brutto			ideal		
	A_c [cm²]	z_u [cm]	I_c [cm⁴]	A_i [cm²]	z_i [cm]	I_i [cm⁴]
Precast cross-section	2940.8	69.3	3618822	3101.3	68.2	4006279

Internal forces from prestress (mean values, prestressed formwork state)

	$N_{pm}^{(0)}$		$M_{pm}^{(0)}$	
Creep period	tB [kN]	tE [kN]	tB [kNm]	tE [kNm]
Storage	-1956.7	-1763.7	-931.47	-864.86
Utilization	-1763.7	-1327.8	-864.86	-779.14
tA=Begin, tE=End creep period				

Prestress steel relaxation		
Lay. No.	Storage $\Delta\sigma_{p,r1}$ [N/mm²]	Utilization $\Delta\sigma_{p,r2}$ [N/mm²]
1	-0.09	-10.88
2	-0.09	-10.92
3	-0.09	-10.97
4	-0.10	-11.01
5	-0.10	-11.06
6	-0.10	-11.11
7	-0.10	-11.15
8	-0.10	-11.20

Prestr. steel, losses due to creeping, shrinking and relaxation:		
Lay. No.	Storage $\Delta\sigma_{p,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{p,csr2}^{(0)}$ [N/mm²]
1	-67.25	-114.61
2	-65.72	-115.19
3	-64.19	-115.77
4	-62.66	-116.36
5	-61.13	-116.94
6	-59.60	-117.52
7	-58.07	-118.11
8	-56.54	-118.69

Stress in rebars due to creeping,shringing and relaxation:		
Lay. No.	Storage $\Delta\sigma_{s,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{s,csr2}^{(0)}$ [N/mm²]
1	-70.93	-107.90
2	-31.67	-121.91
3	-27.04	-123.56

Bending with Normal Force ULS

L.	Creep period	Cross-section	Tens-zone	z [cm]	M_{Rd} [kNm]	M_{Ed} [kNm]	η (>1.0)	
1	tB Storage	P	top	82.3	426.83	MEd < 0	n/a	#1
2	tE Storage	P	bottom	87.4	2610.30	543.37	4.80	
3	tB Storage/Erection	P	top	82.3	426.83	64.26	6.64	#1
4	tE Storage/Erection	P	bottom	87.4	2610.30	MEd < 0	n/a	
5	tE Utilization	P	top	89.0	588.56	MEd < 0	n/a	
6	tE Utilization	P	bottom	86.9	2637.16	1471.73	1.79	

#1: fck(t)= 0.73 * fck

Interim results : Ultimate elongation and internal forces										
L.	ε_c [‰]	ε_s [‰]	x [cm]	Ap [cm²]	As [cm²]	Zp [kN]	Zs [kN]	Dc [kN]	Dp [kN]	Ds [kN]
1	3.500	3.100	58.2	0.0	12.6	0.0	546.9	1848.1	-1436.5	166.9
2	3.500	16.300	19.4	20.5	4.0	2871.2	178.9	2643.2	0.0	366.7
3	3.500	3.100	58.2	0.0	12.6	0.0	546.9	1848.1	-1436.5	166.9
4	3.500	16.300	19.4	20.5	4.0	2871.2	178.9	2643.2	0.0	366.7
5	3.500	6.700	37.7	0.0	12.6	0.0	549.4	1641.4	-1223.8	164.0
6	3.500	16.300	19.4	20.5	4.0	2862.7	178.7	2643.2	0.0	451.2

Shear Resistance

Design value shear force						
L.	Creep period	Combination	$V_{Ed,0}$ [kN]	M_{Ed} [kNm]	dV [kN]	due to
1	tB Storage	QMax	133.8	543.35	-30.8	Vccd
2	tE Storage	QMax	133.8	543.35	-30.8	Vccd
3	tB Storage/Erection	QMax	134.5	-64.26	0.0	-------
4	tE Storage/Erection	QMax	134.5	-64.26	0.0	-------
5	tB Utilization	QMax	356.2	1471.72	-83.8	Vccd
6	tE Utilization	QMax	356.2	1471.72	-83.8	Vccd

Effective cross-section									
L.	Cross-section	Tens-zone	b_w [cm]	d [cm]	z [cm]	A_c [cm²]	A_{sl} [cm²]	σ_{cp} [N/mm²]	V_{Rdc} [kN]
1	P	bottom	19.0	110.0	87.4	2940.8	24.5	4.86	277.2
2	P	bottom	19.0	110.0	87.4	2940.8	24.5	5.40	308.1
3	P	top	19.0	104.2	82.3	2940.8	12.6	4.86	241.5
4	P	top	19.0	104.2	82.3	2940.8	12.6	5.40	268.4
5	P	bottom	19.0	110.0	86.9	2940.8	24.5	5.40	308.1
6	P	bottom	19.0	110.0	86.9	2940.8	24.5	4.06	266.3

Shear designv1= 0.480									
L.	V_{Ed} [kN]	$V_{Ed.red}$ [kN]	a_{cw}	cotΘ	asw [cm²/m]	Note	a_l [cm]	$V_{Rd.max}$ [kN]	
1	103.0	103.0	1.247	1.477	1.83	Min	64.6	1196.6	#1
2	103.0	103.0	1.162	1.261	2.15	Min	55.1	1503.5	
3	134.5	134.5	1.247	2.048	1.83	Min	84.3	956.9	#1
4	134.5	134.5	1.162	1.748	2.15	Min	72.0	1253.3	
5	272.4	272.4	1.162	3.353	2.15	Min	145.7	840.8	
6	272.4	272.4	1.122	2.500	2.88	Var	108.6	1022.2	
#1: fck(t)= 0.73 * fck									

Check of crack width limit in SLS

perm. crack width: wk < 0 mm, Frequent load combination

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	max.σ_s [N/mm²]	$s_{r.max}$ [mm]	ε_{sm}-ε_{cm} [‰]	w_k [mm]
1	tB Storage	P	top	1.00	CS completely compressed			
2	tE Storage	P	bottom	1.00	CS completely compressed			
3	tB Storage/Erection	P	top	1.00	87.39	578	0.262	0
4	tE Storage/Erection	P	bottom	1.00	CS completely compressed			
5	tE Utilization	P	top	1.00	CS completely compressed			
6	tE Utilization	P	bottom	1.00	CS completely compressed			

Internal forces and elongation							
			State I		State II		
L.	N_{qes} [kN]	M_{qes} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
1	-1956.7	-529.00	-0.32	116.0			
2	-1763.7	-462.38	-13.56	117.5			
3	-1956.7	-979.07	4.78	94.0	0.00	-0.738	68.9
4	-1763.7	-912.46	-21.22	93.2			
5	-1327.8	136.55	-5.83	171.0			
6	-1327.8	177.42	-1.26	142.0			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

L.	$h_{c,ef}$ [cm]	A_{ceff} [cm²]	ξ_1	Ap [cm²]	As [cm²]	$\rho_{p,ef}$ [%]	ρ_{tot} [%]	k1	k2	k3	c [cm]	k4
3	14.9	892.3	1.29	0.0	6.3	0.704	0.704	0.80	0.50	3.40	2.8	0.425

Internal forces cracking and strains (state II)							
			State I		State II		
L.	N_{qes} [kN]	M_{qes} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
3	-1763.7	-861.70	4.07	94.6			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

Minimum reinforcement for crack control:

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	σ_t [N/mm²]	req. As [cm²]	exist. As [cm²]
1	tB Storage	P	top	1.00	0.30	< 4.07 not req.	
2	tE Storage	P	bottom	1.00	-13.56	< 4.07 not req.	
3	tB Storage/Erection	P	top	1.00	4.65	<= 0 cm2	
4	tE Storage/Erection	P	bottom	1.00	-21.22	< 4.07 not req.	
5	tE Utilization	P	top	1.00	-4.86	< 4.07 not req.	
6	tE Utilization	P	bottom	1.00	1.77	< 4.07 not req.	

					Web				Flange			
L.	D [mm]	x0IZ [cm]	A_p [cm²]	ξ_1	k	k_c	A_{ct} [cm²]	A_s [cm²]	k	k_c	A_{ct} [cm²]	A_s [cm²]
3	20	18.9	0.0	0.00	0.65	0.00	359.7	-nan(ind)	0.97	0.63	639.0	9.0

x0IZ: tensile zone in state I due to cracking forces

Ductility reinforcement in precompressed tensile zone:

b [cm³]	f_{ctm} [N/mm²]	Zs [cm]	req. As [cm²]	exist. As [cm²]
19	4.07	110.0	4.4	4.0

Stress checks SLS

Concrete edge stresses in state I due to prestress, creep, shrinkage and relaxation

		σ_RPrecast	
L.	due to	top [N/mm²]	bottom [N/mm²]
1	Prestr. release anchorage	4.24	-22.16
2	csr storage	-0.13	1.76
3	csr utilisation	0.43	2.86

Tab. Compr stresses of concrete

			M_{Ed}	σ_cPrecast	
L.	Creep period	Cross-section	+ = Max - = Min	Cc,Pk [N/mm²]	Qc,Pk [N/mm²]
1	tB Storage	P	--	-15.31	-15.31
2	tE Storage	P	--	-13.56	-13.56
3	tB Storage/Erection	P	--	-27.31*	
4	tE Storage/Erection	P	--	-22.83	
5	tB Utilization	P	+-	-8.74	-6.26
6	tE Utilization	P	+-	-8.31	-5.83

Tab. Steel- and Concrete tension stress

L.	Creep period	Cross-section	M_{Ed} + = Max - = Min	σ_p Cc,Pm [N/mm²]	σ_s Cc,Pk [N/mm²]	σ_t Cc,Pk [N/mm²]
1	tB Storage	P	-+-	900.09	< 0	ZII
2	tE Storage	P	-+-	849.73	< 0	ZII
3	tB Storage/Erection	P	---	899.12	87.39	ZII
4	tE Storage/Erection	P	---	820.77	84.70	ZII
5	tB Utilization	P	++-	881.60	< 0	ZII
6	tE Utilization	P	+++	779.85	< 0	1.77

Pk= Prestres char. value, Pm= prestress mean value, StII: State II

Selected section x = 0.08 m from left support

Internal force combinations from external loading
LAc: dominant variable action (leading action)
ULS-PT : permanent + transient design situation (fundam. combination)
SLS-Cc : characteristic combination
SLS-Fc : frequent combination
SLS-Qc : quasi-permanent combination

maximum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	13.29	9.83	9.83	9.83
Storage/Erection	-0.17	-0.17	-0.17	-0.17
Utilization	36.70	28.27	23.78	22.75
LAc	10	10	10	-

Minimum moment : [kNm]

	ULS-PT	SLS-Cc	SLS-Fc	SLS-Qc
Storage	9.80	9.83	9.83	9.83
Storage/Erection	-0.23	-0.17	-0.17	-0.17
Utilization	22.73	22.75	22.75	22.75
LAc	-	-	-	-

maximum shear force:[kN]

	ULS-PT
Storage	166.7
Storage/Erection	-2.0
Utilization	458.5
LAc	10

Effective Tendons (prestressed formwork state for t = t0 (sto))

	No.	Area	Distance	Prestress		tens.force		Shorttime
Layer No.		Ap [cm²]	f.bottom [cm]	max [N/mm²]	min [N/mm²]	max [kN]	min [kN]	Relaxation [N/mm²]
1	3	2.8	8.5	247.68	152.10	69.1	42.4	-0.05
2	3	2.8	12.3	247.68	152.10	69.1	42.4	-0.05
3	3	2.8	16.1	247.68	152.10	69.1	42.4	-0.05
4	3	2.8	19.9	247.68	152.10	69.1	42.4	-0.05
5	3	2.8	23.7	247.68	152.10	69.1	42.4	-0.05
6	3	2.8	27.5	247.68	152.10	69.1	42.4	-0.05
7	3	2.8	31.3	247.68	152.10	69.1	42.4	-0.05
8	1	0.9	35.1	247.68	152.10	23.0	14.1	-0.05
Δσ(Tt0)= -39 N/mm2 due to heat treatment								

Untensioned reinforcement

Layer	Number	Diameter [mm]	Area [cm²]	LE [cm]
1	2	16	4.0	3.6
2	2	20	6.3	81.1
3	2	20	6.3	92.3

Cross-section Precast :

Layer of cross-section from top to bottom			
Nr	Width [cm]	Distance [cm]	Remarks
1	60.0	0.0	
2	60.0	15.0	
3	19.0	23.2	Web begin
4	19.0	96.1	Web end

Cross-section Values

	brutto			ideal		
	A_c [cm²]	z_u [cm]	I_c [cm⁴]	A_i [cm²]	z_i [cm]	I_i [cm⁴]
Precast cross-section	2609.7	59.6	2239971	2770.2	58.5	2496523

Internal forces from prestress (mean values, prestressed formwork state)

	$N_{pm}^{(0)}$		$M_{pm}^{(0)}$	
Creep period	tB [kN]	tE [kN]	tB [kNm]	tE [kNm]
Storage	-506.7	-240.7	-192.30	-101.51
Utilization	-391.9	-25.8	-165.30	-57.77
tA=Begin, tE=End creep period				

Prestress steel relaxation		
Lay. No.	Storage $\Delta\sigma_{p,r1}$ [N/mm²]	Utilization $\Delta\sigma_{p,r2}$ [N/mm²]
1	-0.00	-0.50
2	-0.00	-0.51
3	-0.00	-0.52
4	-0.00	-0.53
5	-0.00	-0.53
6	-0.00	-0.54
7	-0.00	-0.55
8	-0.00	-0.55

Prestr. steel, losses due to creeping, shrinking and relaxation:		
Lay. No.	Storage $\Delta\sigma_{p,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{p,csr2}^{(0)}$ [N/mm²]
1	-36.33	-102.24
2	-35.67	-101.24
3	-35.02	-100.25
4	-34.37	-99.25
5	-33.71	-98.26
6	-33.06	-97.26
7	-32.41	-96.27
8	-31.75	-95.27

Stress in rebars due to creeping,shringing and relaxation:		
Lay. No.	Storage $\Delta\sigma_{s,csr1}^{(0)}$ [N/mm²]	Utilization $\Delta\sigma_{s,csr2}^{(0)}$ [N/mm²]
1	-38.12	-105.77
2	-24.44	-84.82
3	-22.46	-81.80

Bending with Normal Force ULS

L.	Creep period	Cross-section	Tens-zone	z [cm]	M_{Rd} [kNm]	M_{Ed} [kNm]	η (>1.0)	
1	tB Storage	P	top	66.6	504.73	MEd < 0	n/a	#1
2	tE Storage	P	bottom	69.0	2032.94	13.29	152.91	
3	tB Storage/Erection	P	top	66.6	504.73	0.23	2170.79	#1
4	tE Storage/Erection	P	bottom	69.0	2032.94	MEd < 0	n/a	
5	tB Utilization	P	top	60.7	542.47	MEd < 0	n/a	
6	tE Utilization	P	bottom	69.1	2017.85	36.70	54.98	
#1: fck(t)= 0.73 * fck								

Interim results : Ultimate elongation and internal forces										
L.	ε_c [‰]	ε_s [‰]	x [cm]	Ap [cm²]	As [cm²]	Zp [kN]	Zs [kN]	Dc [kN]	Dp [kN]	Ds [kN]
1	3.500	10.300	23.4	9.3	12.6	338.5	553.0	743.6	-35.3	166.8
2	3.500	13.500	19.1	20.5	4.0	2769.6	178.1	2597.6	0.0	355.4
3	3.500	10.300	23.4	9.3	12.6	338.5	553.0	743.6	-35.3	166.8
4	3.500	13.500	19.1	20.5	4.0	2769.6	178.1	2597.6	0.0	355.4
5	3.500	12.500	20.2	9.3	12.6	433.0	554.8	880.3	-56.0	163.7
6	3.500	14.300	18.2	20.5	4.0	2772.7	178.2	2492.6	0.0	399.4

Shear Resistance

Design value shear force						
L.	Creep period	Combination	$V_{Ed.0}$ [kN]	M_{Ed} [kNm]	dV [kN]	due to
1	tB Storage	QMax	166.7	13.27	-1.0	Vccd
2	tE Storage	QMax	166.7	13.27	-1.0	Vccd
3	tB Storage/Erection	QMax	-2.0	-0.23	0.0	-------
4	tE Storage/Erection	QMax	-2.0	-0.23	0.0	-------
5	tB Utilization	QMax	458.5	36.68	-2.6	Vccd
6	tE Utilization	QMax	458.5	36.68	-2.6	Vccd

Effective cross-section									
L.	Cross-section	Tens-zone	b_w [cm]	d [cm]	z [cm]	A_c [cm²]	A_{sl} [cm²]	σ_{cp} [N/mm²]	V_{Rdc} [kN]
1	P	bottom	19.0	92.5	69.0	2609.7	24.5	1.75	160.5
2	P	bottom	19.0	92.5	69.0	2609.7	24.5	0.83	149.0
3	P	top	19.0	86.7	66.6	2609.7	12.6	1.75	131.9
4	P	top	19.0	86.7	66.6	2609.7	12.6	0.83	119.0
5	P	bottom	19.0	92.5	69.1	2609.7	24.5	1.35	162.8
6	P	bottom	19.0	92.5	69.1	2609.7	24.5	0.09	129.5

Shear designv1= 0.480									
Check VRd,s not requ.,asw und CotΘfrom the last contruction phase									
L.	V_{Ed} [kN]	$V_{Ed,red}$ [kN]	a_{cw}	cotΘ	asw [cm²/m]	Note	a_l [cm]	$V_{Rd,max}$ [kN]	
1	165.8	165.8	1.072	2.500	2.21	Var	86.2	603.2	#1
2	165.8	165.8	1.025	2.500	2.21	Var	86.2	741.3	
3	2.0	2.0	1.072	1.000	1.83	Min	43.4	844.4	#1
4	2.0	2.0	1.025	1.000	2.15	Min	43.4	1037.7	
5	455.9	455.9	1.041	2.500	6.07	Var	86.4	753.7	
6	455.9	455.9	1.003	2.500	6.07	Var	86.4	726.3	
#1: fck(t)= 0.73 * fck									

Check of crack width limit in SLS

perm. crack width: wk < 0 mm, Frequent load combination

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	max.σ_s [N/mm²]	$s_{r,max}$ [mm]	ε_{sm}-ε_{cm} [‰]	w_k [mm]
1	tB Storage	P	top	1.00	no cracks			
2	tE Storage	P	bottom	1.00	CS completely compressed			
3	tB Storage/Erection	P	top	1.00	no cracks			
4	tE Storage/Erection	P	bottom	1.00	CS completely compressed			
5	tB Utilization	P	top	1.00	no cracks			
6	tE Utilization	P	bottom	1.00	CS completely compressed			

Internal forces and elongation							
			State I		State II		
L.	N_{ges} [kN]	M_{ges} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
1	-506.7	-182.47	0.92	83.6			
2	-240.7	-91.68	-3.02	82.2			
3	-506.7	-192.47	1.07	82.3			
4	-240.7	-101.68	-3.25	79.9			
5	-391.9	-142.54	0.73	83.3			
6	-25.8	-33.99	-0.89	65.4			
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

L.	$h_{c,ef}$ [cm]	A_{ceff} [cm²]	ξ_1	Ap [cm²]	As [cm²]	$\rho_{p,ef}$ [%]	ρ_{tot} [%]	k1	k2	k3	c [cm]	k4

Internal forces cracking and strains (state II)							
			State I		State II		
L.	N_{ges} [kN]	M_{ges} [kNm]	max.σ [N/mm²]	X0I [cm]	φ_{eff}	ε_c [‰]	X0II [cm]
X0I: Pressure zone height in state I X0II: Pressure zone height in state II							

Minimum reinforcement for crack control:

L.	Creep period	Cross-section	Tens-zone	r_{sup} r_{inf}	σ_t [N/mm²]	req. As [cm²]	exist. As [cm²]
1	tB Storage	P	top	1.00	1.88	< 4.07	not req.
2	tE Storage	P	bottom	1.00	-3.02	< 4.07	not req.
3	tB Storage/Erection	P	top	1.00	2.03	< 4.07	not req.
4	tE Storage/Erection	P	bottom	1.00	-3.25	< 4.07	not req.
5	tB Utilization	P	top	1.00	2.05	< 4.07	not req.
6	tE Utilization	P	bottom	1.00	-0.78	< 4.07	not req.

					Web				Flange			
L.	D [mm]	x0IZ [cm]	A_o [cm²]	ξ_1	k	k_c	A_{ct} [cm²]	A_s [cm²]	k	k_c	A_{ct} [cm²]	A_s [cm²]
x0IZ: tensile zone in state I due to cracking forces												

Ductility reinforcement in precompressed tensile zone:

b [cm³]	f_{ctm} [N/mm²]	Zs [cm]	req. As [cm²]	exist. As [cm²]
19	4.07	92.5	3.7	4.0

Stress checks SLS

Concrete edge stresses in state I due to prestress, creep, shrinkage and relaxation			
		σ_RPrecast	
L.	due to	top [N/mm²]	bottom [N/mm²]
1	Prestr. release anchorage	1.07	-6.34
2	csr storage	0.01	1.05
3	csr utilisation	0.19	2.93

Tab. Compr stresses of concrete						
			M_{Ed}	σ_cPrecast		
L.	Creep period	Cross-section	+ = Max - = Min	Cc,Pk [N/mm²]	Qc,Pk [N/mm²]	
1	tB Storage	P	--	-6.11	-6.11	
2	tE Storage	P	--	-5.06	-5.06	
3	tB Storage/Erection	P	--	-6.34		
4	tE Storage/Erection	P	--	-5.29		
5	tB Utilization	P	--	-4.76	-4.76	
6	tE Utilization	P	--	-1.82	-1.82	

Tab. Steel- and Concrete tension stress						
L.	Creep period	Cross-section	M_{Ed} + = Max - = Min	σ_p Cc,Pm [N/mm²]	σ_s Cc,Pk [N/mm²]	σ_t Cc,Pk [N/mm²]
1	tB Storage	P	---	229.01	3.47	0.92
2	tE Storage	P	-+-	105.20	< 0	0.93
3	tB Storage/Erection	P	---	228.51	4.20	1.07
4	tE Storage/Erection	P	-+-	104.70	< 0	1.08
5	tB Utilization	P	++-	201.69	< 0	0.73
6	tE Utilization	P	++-	21.02	< 0	0.92
Pk= Prestres char. value, Pm= prestress mean value, StII: State II						

Lateral buckling (Stiglat)

Safety in installed state η = 1.69 < 2.00
Design buckling moment: M_{kipp} = 4657.51 kNm
existing moment : M_{Ed} = 2763.72 kNm without prestress
Combination of characteristic values

Interim values acc. to 'Beton- und Stahlbetonbau' 1985, H. 9,10,11

E_{cm} =	37000	N/mm²	G_{cm} =	14800	N/mm²			It, Iy averaged
It =	208188	cm⁴	Iy =	394505	cm⁴			acc.to Rafla
Ix =	11379011	cm⁴	Ak =	4664.5	MN²cm⁴			(It 60% as C.II)
hc =	1.58	m	β_1 =	0.000		β_2 =	0.003	
k_1 =	3.540		k_2 =	1.000		k_3 =	0.920	
M_k =	7415.48	kNm	W_{xo} =	123859	cm³	x =	20.20	m
σ_B =	52.87	N/mm²	σ_T =	33.21	N/mm²	λ_V =	83.1	

(σT acc. eq.62calculated !)

a potentially nessecary reinforcement for torsion is not determined in the program

Lateral buckling check in erection state (acc. to Stiglat)

Height of left attachment point about LE beam
left Hmh = 114.0 cm right Hmh = 114.0 cm

Erection with lifting beam

Lateral buckling safety η = 4.29 > 2.50
Design buckling moment: M_{kipp} = 2343.70 kNm
existing moment : M_{Ed} = 546.28 kNm without prestress

Interim values acc. to 'Beton- und Stahlbetonbau' 1985, H. 9,10,11

β_4 =	0.000		δ =	0.000		γ =	1.000	
f =	0.331	m	Ak =	4664.5	MN²cm⁴	p =	0.752	
j(α) =	0.095		α =	1.478		q_{kl} =	47.76	kN/m
W_{xo} =	148769	cm³	M_k =	2700.05	kNm	x =	16.83	m
σ_B =	18.15	N/mm²	σ_T =	15.75	N/mm²	λ_V =	141.8	

Anchorage by bond (over the left bearing)

l_{pt2} = 1.20 m Distance first bending crack l_r = 3.37 m
η_{P2} = 1.20 f_{bpd} = 2.28 N/mm²

x [m]	Z_p [kN]	Z_s [kN]	T_{Ed} [kN]	η= $(Z_p+Z_s)/T_{Ed}$	Util
0.15	395.3	178.1	664.5	0.86	1.16
0.20	523.2	178.1	691.7	1.01	0.99
0.40	1046.5	178.0	799.3	1.53	0.65
0.60	1569.7	178.0	901.1	1.94	0.52
0.80	2093.0	178.0	1007.5	2.25	0.44
1.00	2616.2	178.1	1101.6	2.54	0.39
1.20	2831.2	178.2	1185.0	2.54	0.39
1.40	2832.3	178.2	1268.4	2.37	0.42
1.60	2833.2	178.2	1351.7	2.23	0.45
1.80	2834.1	178.2	1435.1	2.10	0.48
2.00	2845.5	178.4	1518.5	1.99	0.50

x [m]	Z_p [kN]	Z_s [kN]	T_{Ed} [kN]	η= $(Z_p+Z_s)/T_{Ed}$	Util

Z_p: resisting tensile force by the prestressed steel
Z_s: resisting tensile force by the rebars
T_{Ed}: tensile force to be anchored

No. Lay.	Dist.LE [cm]	XA [m]	σ_p [N/mm²]	Eq.	l_{bpd} [m]	xk [m]	ΣZ_p [kN]	ΣZ_s [kN]	T_{Ed} [kN]	add. As [cm²]	
1	8.5	0.00	619.00	8.21	2.15	Anchorage range uncracked					(PT)
2	12.3	0.00	629.03	8.21	2.14	Anchorage range uncracked					(PT)
3	16.1	0.00	639.06	8.21	2.13	Anchorage range uncracked					(PT)
4	19.9	0.00	649.09	8.21	2.12	Anchorage range uncracked					(PT)
5	23.7	0.00	659.11	8.21	2.11	Anchorage range uncracked					(PT)
6	27.5	0.00	669.13	8.21	2.10	Anchorage range uncracked					(PT)
7	31.3	0.00	679.15	8.21	2.34	Anchorage range uncracked					(PT)
8	35.1	0.00	689.17	8.21	2.33	Anchorage range uncracked					(PT)

XA: Beginning of the anchoring area of the steel layer (dist. from the corresp. binder side)
Eq. 8.21.1: Anchorage area uncracked,σp acc.to fig. 8.17DE (b)
Eq. 8.21.1: Anchorage area cracked,σp acc.to fig. 8.17DE (b)
xk: decisive section in the anchoring area of the layer (distance from the beginning of the binder)
add. As: Additional sagging reinforcement required for anchorage

Anchorage by bond (over the right bearing)

l_{bt2} = 1.20 m Distance first bending crack l_r = 3.37 m
η_{P2} = 1.20 f_{bpd} = 2.28 N/mm²

x [m]	Z_p [kN]	Z_s [kN]	T_{Ed} [kN]	η= $(Z_p+Z_s)/T_{Ed}$	Util
28.30	2845.5	178.4	1518.5	1.99	0.50
28.50	2834.1	178.2	1435.1	2.10	0.48
28.70	2833.2	178.2	1351.7	2.23	0.45
28.90	2832.3	178.2	1268.4	2.37	0.42
29.10	2831.2	178.2	1185.0	2.54	0.39
29.30	2616.2	178.1	1101.6	2.54	0.39
29.50	2093.0	178.0	1007.5	2.25	0.44
29.70	1569.7	178.0	901.1	1.94	0.52
29.90	1046.5	178.0	799.3	1.53	0.65
30.10	523.2	178.1	691.7	1.01	0.99
30.15	395.3	178.1	664.5	0.86	1.16

Z_p: resisting tensile force by the prestressed steel
Z_s: resisting tensile force by the rebars
T_{Ed}: tensile force to be anchored

No. Lay.	Dist.LE [cm]	XA [m]	σ_p [N/mm²]	Eq.	l_{bpd} [m]	xk [m]	ΣZ_p [kN]	ΣZ_s [kN]	T_{Ed} [kN]	add. As [cm²]	
1	8.5	0.00	619.00	8.21	2.15	Anchorage range uncracked					(PT)
2	12.3	0.00	629.03	8.21	2.14	Anchorage range uncracked					(PT)
3	16.1	0.00	639.06	8.21	2.13	Anchorage range uncracked					(PT)
4	19.9	0.00	649.09	8.21	2.12	Anchorage range uncracked					(PT)
5	23.7	0.00	659.11	8.21	2.11	Anchorage range uncracked					(PT)
6	27.5	0.00	669.13	8.21	2.10	Anchorage range uncracked					(PT)
7	31.3	0.00	679.15	8.21	2.34	Anchorage range uncracked					(PT)
8	35.1	0.00	689.17	8.21	2.33	Anchorage range uncracked					(PT)

XA: Beginning of the anchoring area of the steel layer (dist. from the corresp. binder side)
Eq. 8.21.1: Anchorage area uncracked,σp acc.to fig. 8.17DE (b)
Eq. 8.21.1: Anchorage area cracked,σp acc.to fig. 8.17DE (b)
xk: decisive section in the anchoring area of the layer (distance from the beginning of the binder)
add. As: Additional sagging reinforcement required for anchorage

Bursting Reinforcement at beginning of beam

$\gamma_{p,unfav}$ = 1.20 l_{disp} = 1.35 m

Initiation zone			Section over the last effective position of tension. member					
No.	from [m]	to [m]	Dist.LE [cm]	N_c [kN]	N_p [kN]	T_p [kN]	Factor Interpolation	req. As [cm²]
1	0.00	1.35	36.1	-1286.3	1762.0	475.8	0.406	5.3

The bursting reinforcement must be arranged in zone of reduced dispersion length.
red. dispersion length indented wire w.o. strand 3/4*l_{disp}=1.02 m

Burstring Reinforcement at end of beam

$\gamma_{p,unfav}$ = 1.20 l_{disp} = 1.35 m

Initiation zone			Section over the last effective position of tension. member					
No.	from [m]	to [m]	Dist.LE [cm]	N_c [kN]	N_p [kN]	T_p [kN]	Factor Interpolation	req. As [cm²]
1	30.30	28.95	36.1	-1286.3	1762.0	475.8	0.406	5.3

The bursting reinforcement must be arranged in zone of reduced dispersion length.
red. dispersion length indented wire w.o. strand 3/4*l_{disp}=1.02 m