Project: Prestressing
Structural member: Beam

Beam - Section

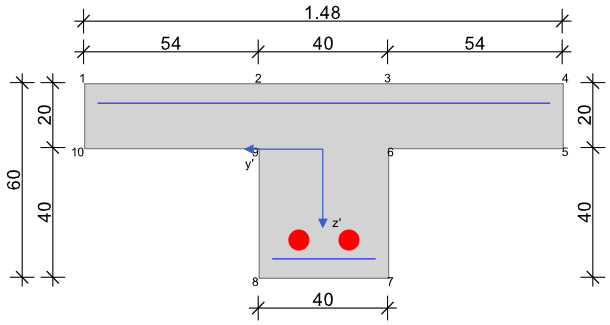
Structure class:	Structural engineering	Design standard:	DIN EN 1992-1-1
Type of action:	Beam cross-section uniaxia	Design situation:	permanent/transient
Requirement class:	S3	Type of action:	Load / Restraint action

Material data: [N/mm2]

C30/37	fcd 17.0	fctm 2.9	Ecm 32800	Cem 32,5 R	
B500S	fyd 434.8		Es 200000	highly ductile	
ST1570/1770	fp01k 1500.0	fpk 1770.0	Ep 195000		

Default reinforc. [cm,cm2]	d1-t	d1-l	d1-b	minAst	minAsl	minAsb	Minimum reinforcement
	6.0	4.0	6.0	0.00	0.00	0.00	compute

Prestressing [cm,N/mm2,kN,cm2]	z	tg r.sup	r.inf	sig.rsk	V	Ap	Prest. steel
Post-tensioned bond	48.2	-0.034	1.10	0.90	100.0	1733.6	16.80	ST1570/1770



Section properties	A	Iy	Iz	zs	Woy	Wuy
[m2,m4,cm,m3]	0.4560	0.012467	0.056163	20.53	0.06074	0.03158

Load cases [kN,kNm]	Art	NEk	MEk,y	VEk,z	MEk,z	VEk,y	MEk,x
1 dead load	G	0.0	236.8	-11.5	0.0	0.0	0.0
2 finishings load	G	0.0	160.4	-7.8	0.0	0.0	0.0
3 snow	S+	0.0	36.1	-0.7	0.0	0.0	0.0
4 Q,min	Q?	0.0	-21.8	-5.9	0.0	0.0	0.0
5 Q,max	Q?	0.0	126.6	0.9	0.0	0.0	0.0
6 prestress restr	V	0.0	185.6	-15.0	0.0	0.0	0.0
7 Prestressing	V0	-1732.6	-479.8	59.6	0.0	0.0	0.0

Combination factors		gam.sup	gam.inf	psi.0	psi.1	psi.2	psi.1'
Permanent load	G	1.35	1.00	1.00	1.00	1.00	1.00
Prestressing	V	1.00	1.00	1.00	1.00	1.00	1.00
Snow	S	1.50	0.00	0.50	0.20	0.00	0.50
Live load/UDL	Q	1.50	0.00	0.70	0.50	0.30	1.00

Combination [kN,kNm]		NEd	MEd,y	VEd,z	MEd,z	VEd,y	MEd,x	Lc
Basic combination 2 4 6 7	minMy	-1732.6	70.3	16.5	0.0	0.0	0.0	1
Basic combination 2 3 5 6 7	maxMy	-1732.6	459.1	19.4	0.0	0.0	0.0	1
Basic combination 2 3 4 6 7	minVz	-1732.6	236.5	9.3	0.0	0.0	0.0	1
Basic combination	maxVz	-1732.6	292.9	26.7	0.0	0.0	0.0	1

2 5 6 7							
Rare	minMy	-1732.6	81.3	19.5	0.0	0.0	0.0 1 2 4 6 7
Rare	maxMy	-1732.6	247.7	25.9	0.0	0.0	0.0 1 2 3 5 6 7
Frequent	minMy	-1732.6	92.2	22.4	0.0	0.0	0.0 1 2 4 6 7
Frequent	maxMy	-1732.6	166.4	25.8	0.0	0.0	0.0 1 2 5 6 7
Quasi-permanent	minMy	-1732.6	96.5	23.6	0.0	0.0	0.0 1 2 4 6 7
Quasi-permanent	maxMy	-1732.6	141.1	25.6	0.0	0.0	0.0 1 2 5 6 7

selected analysis: Bending(M+N) Shear Crack width Stresses Fire protection

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Project: Prestressing
Structural member: Beam

Bending design [o/oo,cm,cm2] - Time of initial loading: 28 d

Basic combination:	eps.c	eps.s	zi	x/d	**req Ast**	**req Ass**	**req Asb**
	-3.5	12.1	43.6	0.22	**2.09**	**0.00**	**4.16**

Shear design [kN,%,cm2/m] - Time of initial loading: 28 d - alfa: 90 degrees

Basic combination:	VEd	VRdmin	VRdct	VRdmax	rho.l	theta	as.min	**req asw**
	26.7	172.6	172.6	939.5	0.19	45.0	5.94	**5.94**M

Crack width analysis [mm,cm,cm2] - Time of crack formation: 28 d - ds(top/bottom): 20/20 mm

Frequent combination:	Sigc/fctm	w.prov	w.all	xII	Asr.t	Asr.s	Asr.b
	1.15	0.09	0.30	29.0	2.09	0.00	4.16

Limitation of stresses [N/mm2] - Time of initial loading: 28 d

Rare combination:	Sigs/adm	Sigp/adm	Sigc/adm	Sigs.s	Sigp.q	Sigc.q	Sigc.s
	0.28	0.89	0.63	111.0	1029.0	-6.16	-11.36
allowable:	1.00	1.00	1.00	400.0	1150.5	-13.50	-18.00

Fire protection: Analysis of R90 established

Project: Prestressing
Structural member: Beam

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Design parameters

Structure class	:Building construction
Using as	:Civil engineering
Design standard	:DIN EN 1992-1-1:2015
Design situation	:permanent
Superstructure type	:Beam elements
Cross-section type	:T-beam
Action type	:Predominantly bending
Action	:uniaxial
Exposure class Tab.7.1(NDP)	:XC1
Building element	:prestressed with bond
System	:statically indeterminate
Surface reinforcement detailing/prestressed	:yes/yes
Ductility reinforcement	:yes
Structural fire protection	:R 90

Conc. C 30/ 37

fck	:	30.0	N/mm2
Ecm(28)	:	32800	N/mm2
gamc	:	1.50	
alfa.cc(28)	:	0.85	
fcd(28), n=2.00 (S-D Line)	:	17.0	N/mm2
fctd(28)	:	1.15	N/mm2
fcd,fat(N*=10^6)	:	15.0	N/mm2
fctm(28)	:	2.90	N/mm2
fctk,0.05(28)	:	2.03	N/mm2
fcto	:	2.90	N/mm2
w,cal	:	0.30	mm
fbd	:	3.04	N/mm2
CEM N,R	:	0.25	

ReinfSteel B500(B)

fyk	:	500	N/mm2
Es	:	200000	N/mm2
gams	:	1.15	
fyd	:	434.8	N/mm2
kmin = ftk / fyk (Ductility class B)	:	1.08	

Prestressing steel St 1570/1770 (within bond)

fp0.1,k	:	1500	N/mm2
Ep	:	195000	N/mm2
gamp	:	1.15	
kmin = fpk / fp0.1,k (S-D Line)	:	1.18	
r.inf / r.sup	:	0.90/1.10	

Durability

min concrete class - indicative	:	C25/30
Moisture class - Alcali silica reaction	:	W0
Requirement class reinforcement	:	S3
Concrete cover Cnom top / bottom	:	30/ 30 mm
Laying dim. Cvl bottom	:	30 mm

Reinforcement

max ds / web top	:	20.0	mm
max ds / web bottom	:	20.0	mm
max ds / top flange	:	10.0	mm
max ds / bottom flange	:	10.0	mm
d1x,t	:	6.00	cm
d1x,l	:	6.00	cm
cvL	:	4.00	cm
lb,rqd / Web,top (Basic value, anchorage length)	:	71.5	cm
lb,rqd / Web, bottom	:	71.5	cm

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Project: Prestressing
Structural member: Beam

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lb,rqd / Top chord	:	35.7	cm
lb,rqd / Bottom chord	:	35.7	cm

Concrete age

Time of individual crack formation / Min. reinforcement	:	28 d
Time of stabilised cracking / Crack width limitation	:	28 d
Time of 1st loading / Conrete compressive strength	:	28 d
Time of 1st fatigue loading / Fatigue strength	:	28 d

Action type
Combined effects of action by loading and restraint

Restraint type
internal restraint

Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

DIN EN 1992-1-1:2015

Section - My

Ultimate limit states for bending with longitudinal force

Conc.: C 30/ 37 gamma.c= 1.50 alfa.cc= 0.85 **Cross-sect.: Section**
ReinfSteel: B500(B) gamma.s= 1.15 uniaxial Bending
Pres.Steel fp0.1,d: 1304 gamma.s= 1.15 **permanent situation**

Design values of actions without P.dir within bond (Basic combination STR/GEO)

Decisive lc-combinations	Lc	MEdy(kNm)	MEdz(kNm)	NEdx(kN)	P.k
max MEdy;accord.MEdz, NEdx	1	938.8	0.0	0.0	1.0*Pm
min MEdy;accord.MEdz, NEdx	2	550.1	0.0	0.0	1.0*Pm

Req. longitudinal reinforcement:

Edge	min.As (cm2)	max.As (cm2)	required As (cm2)	cm2/m	Coordinates (m) y1	z1	y2	z2	Eps.pmo o/oo	Mat -
1- 2	0.8	539.5	0.8	1.41	-0.740	0.060	-0.200	0.060		
2- 3	0.6	399.6	0.6	1.41	-0.200	0.060	0.200	0.060		
3- 4	0.8	539.5	0.8	1.41	0.200	0.060	0.740	0.060		
7- 8	4.2	399.6	4.2	10.40	-0.200	0.540	0.200	0.540		
Spg 1	16.8	16.8	16.8		0.000	0.482			5.292	3
Total	23.1	1894.9	23.1		required.As/A.gross =				0.506 %	

Design values of resistance:

Lc	Resistance Rd NRdx(kN)	MRdy(kNm)	MRdz(kNm)	Strain (o/oo) Eps.1	Eps.2	Eps.s	Beta Degr	Gamma	Utilization
1	-0.	1103.	0.	-3.500	13.880	12.14	0.0	1.000	0.851
2	-0.	1103.	0.	-3.500	13.879	12.14	0.0	1.000	0.499

Lc	Compressive resultant (kN)	y(m)	z(m)	Acp(m2)	Tensile resultant (kN)	y(m)	z(m)	Act(m2)	Lever arm(m)
1	-2531.	0.000	0.051	0.1788	2531.	0.000	0.486	0.00210	0.4358
2	-2531.	0.000	0.051	0.1788	2531.	0.000	0.486	0.00210	0.4358

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Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

Section - My

Crack width limitation at concluded cracking

Conc.: C 30/37 fct.eff = 3.00 N/mm2 Cross-sect.: Section
ReinfSteel: B500(B) Es = 200000 N/mm2 uniaxial Bending
Pres.Steel fp0.1,d: 1304 Ksi = 0.5 **Exposure class:XC1**

Concrete stresses immediately before cracking:

		frequent combination				frequent combination	
Area	Point	Sig.cS	Sigr.cR	Sigr.cR	h.t	Sig.c	fctm
		---	(N/mm2)	---	(m)	---(N/mm2)---	
top	1	-3.45	-6.72	3.00	0.10	-4.94	
Botto	7	-3.45	3.00	-15.11	0.19	3.34 >	2.90

Design values of actions without P.dir within bond (frequent combination):

Decisive lc-combinations	Lc	MEdy(kNm)	MEdz(kNm)	NEdx(kN)	P.k
max MEdy;accord.MEdz, NEdx	3	646.1	0.0	0.0	0.90*Pm
min MEdy;accord.MEdz, NEdx	4	571.9	0.0	0.0	1.10*Pm

Stress strain plane in cracked cross-section (without tensile strength):

Lc	Resistance Rd			Strain (o/oo)			Beta	d.Sigz	XdII
	MRdy(kNm)	MRdz(kNm)	NRdx(kN)	Eps.1	Eps.2	Eps.s	Degr.	N/mm2	(m)
3	646.	0.	-0.	-0.248	0.264	0.21	0.0	116.2	0.29
4	572.	0.	0.	-0.151	-0.075	-0.08	0.0	66.9	0.60

Simplified limit diameter analysis with admi. crack width = .30 mm:

Outside Edge	min.As (cm2)	max.As (cm2)	required As (cm2)	LC cm2/m	Sigs.1 (N/mm2)	Sigs.2	ds* (mm)	lim.ds (mm)
Web								
Web								
Web								
Web								
Total As:	6.3	1878.1	6.3					

(Influence of reinforcement ratio on the limit diameter neglected)

Calculated crack width by specified limiting diameter and admissible crack width 0.30 mm:

Outside Edge	min.As (cm2)	max.As (cm2)	required As (cm2)	LC cm2/m	Sig.eff N/mm2	Act.eff (m2)	Rho.eff (-)	ds (mm)	w.k
Web									
Web									
Web									
Web									
Total As:	6.3	1878.1	6.3						

(D:Compression; Z:Tension; N:Tension and compression)
(+:steel stresses under different bond behaviour would be modified)

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Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

Section - My

Limitation of concrete compressive stresses and reinforcing steel stresses:

Conc.: C 30/ 37 Ecm = 32800.0 N/mm2 Cross-sect.: Section
ReinfSteel: B500(B) 0.80*fyk= 400.0 N/mm2 uniaxial Bending
Compressive strength: fck(28)= 30.0 ßcc=1.000 **Exposure class:XC1**

Concrete stresses in uncracked cross-section (rare combination)

Area	Point	Sig.c ---(N/mm2)---	fctm	adm. compr. stresses (N/mm2)
top	1	-4.76		0.60*fck(t) -18.0
Botto	7	5.91 >	2.90	0.60*fck(t) -18.0

Design values of actions without P.dir within bond (rare combi.):

Decisive lc-combinations	Lc	MEdy(kNm)	MEdz(kNm)	NEdx(kN)	P.k
max MEdy;accord.MEdz, NEdx	15	727.5	0.0	0.0	0.90*Pm
min MEdy;accord.MEdz, NEdx	16	561.0	0.0	0.0	1.10*Pm

Stress strain plane in cracked cross-section (without tensile strength):

Lc	Resistance Rd			Strain (o/oo)			Beta	H.ten
	MRdy(kNm)	MRdz(kNm)	NRdx(kN)	Eps.1	Eps.2	Eps.s	Degr	(m)
15	727.5	0.0	0.0	-0.346	0.652	0.55	0.0	0.39
16	561.0	0.0	0.1	-0.146	-0.084	-0.09	0.0	0.00

Design Values --- Reinforcement stresses--- Concrete compression

Locat	As	Lc	Eps.s	Sig.s	Lc	Eps.s	Sig.s	Utili	Lc	min Sig.c	Utili
	(cm2)		(o/oo)	N/mm2		(o/oo)	N/mm2	tion		N/mm2	tion
1- 2	0.8	15	-0.246	-49	16	-0.140	-28	0.000	15	-11.36	0.631
2- 3	0.6	15	-0.246	-49	16	-0.140	-28	0.000	15	-11.36	0.631
3- 4	0.8	15	-0.246	-49	16	-0.140	-28	0.000	15	-11.36	0.631
8- 7	4.2	16	-0.091	-18	15	0.553	111	0.278	16	-2.77	0.154

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Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

Section - My

Limitation of stresses wihin cracking cross-section

Conc.: C 30/ 37 Ecm = 32800.0 N/mm2 Cross-sect.: Section
Pres.Steel fpk: 1770 0.65*fpk= 1150.5 N/mm2 uniaxial Bending
Compressive strength: fck(28)= 30.0 ßcc=1.000 **Exposure class:XC1**

Concrete stresses in uncracked cross-section (rare combination)

Area	Point	Sig.c ---(N/mm2)---	fctm	adm. compr. stresses (N/mm2)
top	1	-4.76		0.45*fck(t) -13.5
Botto	7	5.91 >	2.90	0.45*fck(t) -13.5

Design values of actions without P.dir within bond (quasi-permanent combi.):

Decisive lc-combinations	Lc	MEdy(kNm)	MEdz(kNm)	NEdx(kN)	P.k
max MEdy;accord.MEdz, NEdx	11	620.8	0.0	0.0	1.00*pm
min MEdy;accord.MEdz, NEdx	12	576.3	0.0	0.0	1.00*pm

Stress strain plane in cracked cross-section (without tensile strength):

Lc	Resistance Rd			Strain (o/oo)			Beta	H.ten
	MRdy(kNm)	MRdz(kNm)	NRdx(kN)	Eps.1	Eps.2	Eps.s	Degr	(m)
11	620.8	0.0	-0.0	-0.188	0.027	0.01	0.0	0.07
12	576.3	0.0	0.0	-0.165	-0.018	-0.03	0.0	0.00

Design Values --- Prestress steel stresses--- Concrete compr. stress

Locat.	Ap (cm2)	Eps.pmo (o/oo)	Lc	Eps.p (o/oo)	Sig.p N/mm2	Lc	Eps.p (o/oo)	Sig.p N/mm2	Utili zation	Lc	minSig.c N/mm2	Uti- liza.
1- 2										11	-6.16	
2- 3										11	-6.16	
3- 4										11	-6.16	
8- 7										12	-0.59	
Spg 1	16.8	5.292	12	5.245	1023	11	5.276	1029	0.894			

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Project: Prestressing
Structural member: Beam

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Section - My

Tabular fire resistance analysis

Analysis of the constructive resistance of fire according to DIN EN 1992-1-2
- mainly bending stressed beams listed in table 5.6
- statically indeterminate continuous beam
- trilateral fire load with ETK DIN EN 1992-1-2
- top reinforcement on intermediate supports: As.req(x)=As.req(0)(1-2.5x/leff)
- Further fire resistance design features must be complied with

Conc.: C 30/ 37 gamma.c= 1.50 alfa.cc= 0.85 **Cross-sect.: Section**
ReinfSteel: B500(B) gamma.s= 1.15 **flexion mem**
Pres.Steel fp0.1,d: 1304 gamma.s= 1.15 **accidental situation**

Fire resistance class R 90

existing reinforcement	As.tot(cm2) =	6.25	rho =	0.14%	
Accidental combination (kNm)			MEd,fi =	620.8	
Basic combination (kNm)			MEd =	938.8	
As.prov/As.req			=	1.3	
crit. temperature reinf. steel	crit.Ts =	549.9 °C	del.as =	-0.5	
crit. temperature prestr. steel	crit.Tp =	449.9 °C	del.ap =	0.5	

Web table 5.5 modified due to *crit T:*

web thickness - class: WC	exis.bw (cm) =	40.0	>=	req.bw =	10.0
Beam width S-S reinforcement	ex.bmin(cm) =	40.0	>=	req.bmin=	25.0
Center dist. tens. reinf.	exis.am (cm) =	6.0	>=	req.am =	2.0
Center distance of multilayer reinforcement				req.am/2=	3.0
Center distance single-ply reinforcement web sideward				req.asd =	2.0

=> Design conditions fulfilled

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Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

Longitudinal reinforcement

Conc.: C 30/ 37 - ReinfSteel: B500(B) Exposure class XC1

(M) Robustness and surface reinforcement
(B) Bending strength with longitudinal force
(R) Individual and final crack formation
(E) Analysis against fatigue - bending with longitudinal force
(P) internal prestressing bonded tendons

			--- Total reinforcement cm2 -----				cm2/mPE
Memb	Locat	Ap(P)	As(M)	As(B)	As(R)	As(E)	As(Q)	As(TL)
1	0.0	16.8	6.3	6.3	6.3			

Project: Prestressing
Structural member: Beam

RIB RTcDesign 18.0 Design concr struct t = 28 d

Utilization ratio

Conc.: C 30/ 37 - ReinfSteel: B500(B) Exposure class XC1

(B) Bending strength with longitudinal force
(R) w.cal terminated cracking
(E) dSig.equ Analysis against fatigue - reinforcing steel
(Ep) dSig.equ Analysis against fatigue - prestressing steel
(Q) Earthquake bearing capacity
(D) Shear bearing capacity of the strut
(F) dSig.sw Analysis against fatigue - shear force
(C) Sig.c in the cracked cross-section
(S) Sig.s within cracked cross-section
(P) Sig.p within cracked cross-section
(H) Sig.I Principal tensile stresses in the uncracked cross-section

Memb	Sect	A(B)	A(R)	A(E)	(Ep)	A(Q)	A(D)	A(F)	A(C)	A(S)	A(P)	A(H)	A(Z)	ULS	FLS	SLS
1	0.00	0.85	0.30						0.63	0.28	0.89			0.85		0.89
maxUtilization														**0.85**	**0.00**	**0.89**