DAfStb Heft 617: Attachment 5-1 to Part 5:

Notation and Formulary for the ACI-DAfStb Shear Databases vsw-PC-DS and vsw-PC-DK for p.c. beams with vertical stirrups subjected to point loads

Database vsw-PC-DS

<u>notation of test</u>

No.	running number
Author	Reference: author, year
Test Specimen	specimen as named by author
Units	dual input in Imperial units or SI-units in vuct-PC-DS; Imp. units are converted into SI-units; all calculations in SI-units

<u>section properties</u>

b	b	[in $\rightarrow$ mm]	width of flange
bw	b_w	[in $\rightarrow$ mm]	width of web
h	h	[in $\rightarrow$ mm]	height of beam
hf	h_f	[in $\rightarrow$ mm]	height of flange
hh,top	$h_{h,top}$	[in $\rightarrow$ mm]	height of top haunch
hw	h_w	[in $\rightarrow$ mm]	height of web
hft	h_{ft}	[in $\rightarrow$ mm]	height of tension flange
hhbot	$h_{h,bot}$	[in $\rightarrow$ mm]	height of bottom haunch
bft	b_{ft}	[in $\rightarrow$ mm]	width of tension flange
Ac	A_c	[mm^2]	gross area of concrete section
z_c2	z_{c2}	[mm]	distance of CGS from top fibre

loading and geometry

aa	a_A	[in → mm]	dimension of support plate in direction of beam axis
af	a_F	[in → mm]	dimension of loading plate in direction of beam axis
ba	b_A	[in → mm]	distance between support axis and beam end
L	L	[in → mm]	span
c_	c	[in → mm]	distance between point loads
a	a	[in → mm]	distance of point load F from support axis
kap	$\kappa = \frac{a}{d}$	[-]	moment-shear-force ratio
cc	c_c	[in → mm]	minimum concrete cover

longitudinal tension reinforcement

ds	d_s	[in → mm]	effective depth of reinforcement
bars_t	nr. + type of bars	[-]	number and type of bars (text description)
ns	n_s	[-]	number of bars
dst	$\varnothing_{st}$	[in → mm]	average diameter
fr	f_r	[-]	r = ribbed bars; 0 = plain bars; blank = not reported
As	A_s	[in² → mm²]	area of reinforcing steel for long. reinf.
alphaas	α_{as}	[-]	coefficient for anchorage (hook 0.7; straight 1.0; anchorage plate 0.01)
rhos	$\rho_s = \frac{A_s}{b \cdot d} \cdot 100$	[%]	geometrical percentage of long. reinforcement
rhosw	$\rho_{sw} = \frac{A_s}{b_w \cdot d} \cdot 100$	[%]	geom. perc. of long. reinforcement related to b_w
fsy	f_{sy}	[ksi → MPa]	yield strength of steel

esy	$e_{sy} = \frac{f_{sy}}{E_s}$	[‰]	steel strain at yield (E_s = 200.000 MPa)
ft	f_t	[ksi → MPa]	tensile strength (measured or nominal)
beta_fs	$\beta_{fs}=f_t / f_{sy}$	[-]	ratio
euk	ε_{uk}	[%]	steel strain at maximum steel stress

longitudinal compression reinforcement

bars_c	nr. + type of bars	[-]	number and type of bars (text description)
d_s2	d_{s2}	[in → mm]	distance of compress. reinforc. from compress. edge
n_s2	n_{s2}	[-]	number of bars
d_st2	$\varnothing_{st2}$	[in → mm]	average diameter of compr. bars
A_s2	A_{s2}	[in² → mm²]	area of compr. bars
f_sy2	f_{sy2}	[ksi → MPa]	yield strength of compression bars

prestressing steel

dpbot	d_{pbot}	[in → mm]	effective depth of prestressing steel at bottom
dpweb	d_{pweb}	[in → mm]	effective depth of prestressing steel in web
dptop	d_{ptop}	[in → mm]	effective depth of prestressing steel at top
type	type	[-]	number and type of prestressing
btype	bond type	[-]	bond type for anchorage check, 1 = strand
p_method	pre / post	[-]	pre- or posttensioning
diaps	$\varnothing_{ps}$	[in → mm]	nominal diameter
frp	f_{rp}	[-]	r = ribbed, 0 = plain
Apbot	A_{pbot}	[in² → mm²]	area of bottom prestressing steel
Apweb	A_{pweb}	[in² → mm²]	area of web prestressing steel

Aptop	A_{ptop}	[in² → mm^2]	area of top prestressing steel
Ap	$A_p = A_{pbot} + A_{pweb} + A_{ptop}$	[mm^2]	area of prestressing steel
alphaap	α_{ap}	[-]	coefficient for anchorage (straight 1.0; anchorage plate 0.01)
rhop	$\rho_p = \frac{A_{pbot}}{b \cdot d} \cdot 100$	[%]	geom. reinf. ratio of prestr. steel
rhopw	$\rho_{pw} = \frac{A_{pbot}}{b_w \cdot d} \cdot 100$	[%]	geom. reinf. ratio of prestr. steel related to b_w
rhol	$\rho_l = \rho_s + \rho_p$	[%]	geom. reinf. ratio
rholw	$\rho_{lw} = \rho_{sw} + \rho_{pw}$	[%]	geom. reinf. ratio
Ep	E_p	[MPa]	young’s modulus of prestressed steel (if not given E_p= 200.000 MPa)
fpy	f_{py}	[ksi → MPa]	yield strength = $f_{p0,1k}$
epy	$\varepsilon_{py} = f_{py}/E_p \cdot 1000$	[‰]	steel strain at yield
fp	f_p	[ksi → MPa]	tensile strength (measured or nominal)
beta_fp	$\beta_{fp} = f_p / f_{py}$	[-]	ratio
epuk	ε_{puk}	[%]	steel strain at maximum steel stress
lambda	$\lambda = \frac{A_{pbot} \cdot f_{py}}{(A_{pbot} \cdot f_{py}) + (A_s \cdot f_{sy})}$	[-]	prestressing ratio
d	$d = \frac{(A_{pbot} \cdot f_{py} \cdot d_{pbot}) + (A_s \cdot f_{sy} \cdot d_s)}{(A_{pbot} \cdot f_{py}) + (A_s \cdot f_{sy})}$	[mm]	average effective depth of tension chord

<u>prestress</u>

Pbot_rep	$P_{bot,rep}$	[kip → kN]	reported prestressing force of bottom tendons
Pweb_rep	$P_{web,rep}$	[kip → kN]	reported prestressing force of web tendons
Ptop_rep	$P_{top,rep}$	[kip → kN]	reported prestressing force of top tendons

P_rep		P_{rep}	[kN]	prestressed force as reported
P_eff		P_{eff}	[kN]	effective prestress force at test including all losses
P_check	$P_{rep} = P_{eff}$:	$P_{check} = 1$	[-]	check if reported prestressing force is = P_{eff}
delta_sigp	$P_{check} = 1$:	$\Delta\sigma_P = 0$	[MPa]	assumption of loss of prestress
	$P_{check} = 0$:	$\Delta\sigma_P = 200$	[MPa]	
Pbot		P_{bot}	[kN]	prestressing force of bottom tendons
Pweb		P_{web}	[kN]	prestressing force of web tendons
Ptop		P_{top}	[kN]	prestressing force of top tendons
zpbot		z_{pbot}	[mm]	distance of bottom tendons from CGS
zpweb		z_{pweb}	[mm]	distance of web tendons from CGS
zptop		z_{ptop}	[mm]	distance of top tendons from CGS
P		$P = P_{bot} + P_{web} + P_{top}$	[kN]	total prestressing force
sigcp		$\sigma_{cp} = P/A_c$	[MPa]	axial concrete stress at CGS
nu_cp		$\nu_{cp} = \sigma_{cp}/f_{1c}$	[-]	non-dimensional prestressing force
Mp		$M_P = z_{pbot} \cdot P_{bot} + z_{pweb} \cdot P_{web} + z_{ptop} \cdot P_{top}$	[kNm]	moment due to prestress
sigpp		$\sigma_{pp} = P/A_p$	[MPa]	steel stress due to prestress
Vp		V_p	[kip $\rightarrow$ kN]	vertical component of effective prestressing force (only relevant in –dt and –cb databases)

<u>axial force</u>

N	N	[kN]	axial force
sigcN	$\sigma_{cN} = N/A_c$	[MPa]	axial concrete stress at CGS
nu_cN	$\nu_{cN} = \sigma_{cN}/f_{1c}$	[-]	non-dimensional axial force

nu_c	$\nu_c = \sigma_c / f_{1c}$	[-]	ratio for total axial force stress with $\sigma_c = \sigma_{cp} + \sigma_{cN}$

<u>stirrup reinforcement</u>

diaw	$\varnothing_w$	[in → mm]	diameter of one stirrup leg
nsw	n_{sw}	[-]	number of stirrup legs
Asw	A_{sw}	[in² → mm²]	area of one stirrup with n_{sw} legs
frw	f_{rw}	[-]	r = ribbed, 0 = plain; blank = not reported
sw	s_w	[in → mm]	stirrup spacing
sw_h	s_w / h	[-]	ratio of stirrup spacing and beam height
sw_d	s_w / d	[-]	ratio of stirrup spacing and effective depth
z_w1	z_{w1}	[mm]	inner lever arm, defined through beam height
z_w2	z_{w2}	[mm]	inner lever arm, defined through concrete cover
rhow	$\rho_w = \frac{A_{sw}}{s_w \cdot b_w} \cdot 100$	[%]	geom. reinf. ratio of stirrups related to b_w
fyw	f_{yw}	[ksi → MPa]	yield strength of stirrups
rhoswy	$\rho_{swy} = \frac{f_{yw} \cdot \rho_w}{100}$	[MPa]	smeared tension force of stirrups (virtual tension)
fwt	f_{wt}	[ksi → MPa]	tensile strength of stirrups (measured or nominal)
beta_fw	$\beta_{fw} = f_{wt} / f_{yw}$	[-]	ratio of stirrup tensile and yield strength
ewuk	ε_{wuk}	[%]	strain of stirrup steel at maximum tension

<u>concrete compressive strength</u>

diaa	$\varnothing_a$	[in → mm]	max. diameter of aggregates
SCC	SCC	[-]	self-compacting concrete (= 1) regular concrete (-)
fccyl	$f_{c,cyl}$	[ksi → MPa]	cylinder strength of concrete

dimcyl		[in → mm]	dimension of cylinders
f1ccyl	$f_{1c,cyl}$	[MPa]	uniaxial compr. strength derived from $f_{c,cyl}$
fccu	$f_{c,cube}$	[ksi → MPa]	cube strength of concrete
dimcu		[in → mm]	dimension of cubes
f1ccu	$f_{1c,cu}$	[MPa]	uniaxial compr. strength derived from $f_{c,cube}$
fcpr	$f_{c,prism}$	[ksi → MPa]	prism strength of concrete
dimpr		[in → mm]	dimension of prisms
f1cpr	$f_{1c,pr}$	[MPa]	uniaxial compr. strength derived from $f_{c,prism}$
f1c	f_{1c}	[MPa]	uniaxial compr. strength of concrete
cs_method	CS test method	[-]	testing method (cyl; cu; pr)
fcwu	$f_{cwu} = 0,8 \cdot f_{1c}$	[MPa]	web concrete compressive strength

<u>concrete tensile strength</u>

fctfl	$f_{ct,fl}$	[ksi → MPa]	modulus of rupture
dimfl		[in → mm]	dimension of control specimen
f1ctfl	$f_{1ct,fl}$	[MPa]	axial tensile strength derived from $f_{ct,fl}$
fctsp	$f_{ct,sp}$	[ksi → MPa]	splitting tensile strength
dimsp		[in → mm]	dimension of control specimen
f1ctsp	$f_{1ct,sp}$	[MPa]	axial tensile strength derived from $f_{ct,sp}$
f1cttest	$f_{1ct,test}$	[MPa]	test value for axial tensile strength
ts_method	TS test method	[-]	testing method (fl; sp)
betacttest	$\beta_{ct,test} = f_{1ct,test}/f_{1c}$	[-]	ratio
f1ctmcal	$f_{1ctm,cal}$	[MPa]	calculated value of axial tensile strength
betactcal	$\beta_{ct,cal} = f_{1ctm,cal} / f_{1c}$	[-]	ratio

mechanical reinforcement ratios

oms	$\omega_s = \frac{A_s \cdot f_{sy}}{b \cdot d \cdot f_{1c}}$	[-]	mech. reinf. ratio of reinf. steel in tension chord
omp	$\omega_p = \frac{A_{pbot} \cdot f_{py}}{b \cdot d \cdot f_{1c}}$	[-]	mech. reinf. ratio of prestr. steel in tension chord
oml	$\omega_l = \omega_s + \omega_p$	[-]	mech. reinf. ratio of tension chord
omwy	$\omega_{wy} = \frac{A_{sw} \cdot f_{yw}}{s_w \cdot b_w \cdot f_{cwu}}$	[-]	mech. reinf. ratio of stirrups related to b_w

test

g	$g = A_c \cdot 24$	[kip/in→kip/ft →kN/m]	self-weight
Vg	$V_g = g \cdot (0{,}5 \cdot c + (a - x_r))$	[kip → kN]	shear force due to self-weight
F	F	[kip → kN]	failure load
Vu_Fg_Rep	$V_{u,F+g,Rep}$	[kip → kN]	shear force at failure without self-weight
Vu_Rep	$V_{u,Rep}$	[kip → kN]	shear force at failure with self-weight (from report)
Vu_gF	$V_{u,g+F}$	[kip → kN]	shear force at failure with self-weight
betar_meas	β_r	[°]	measured crack angle
xr_meas	$x_{r,meas}$	[in → mm]	measured distance of failure crack from support axis
xr	x_r	[in → mm]	calculated dist. of failure crack from support axis
sigswmeas	$\sigma_{sw,meas}$	[ksi → MPa]	measured stirrup stress at failure
sigswass	$\sigma_{sw,ass}$	[ksi → MPa]	assumed stirrup stress at failure
sigsw	σ_{sw}	[ksi → MPa]	stirrup stress at failure

omwu	$\omega_{wu} = \frac{\omega_{wy} \cdot \sigma_{sw}}{f_{yw}}$	[-]	mech. reinf. ratio of stirrups based on stirrup stress σ_{sw} at failure
tof		[-]	type of failure as reported
oft		[-]	other failure type
com		[-]	comment

check

contr	[-]	=0 if data is not controllable based on report

konx	=IF(OR(f1c=0;fpy=0;fyw=0;sw=0;Vu_Rep=0;Pbot_rep=0;kap=0;contr=0);0;1)
kon_61	=IF(d>0;IF(kap>=2,4;1;0);0)
kons1	=konx·kon_61
kon_62	=IF(d>0;IF(kap<2,4;1;0);0)
kon_24	=kon_62·konx
b___bw	=IF(b=bw;1;0)

conversion factors

1 inch	= 25,4 mm
1 pound	= 4,448 N
1 kip	= 4,448 kN
1 klbf ft	= 1,36 kNm
1 psi	= 1/145 MPa
1 ksi	= 1000/145 MPa
1 kp	= 9,81 N
1 kp/cm2	= 9,81/100 MPa = 9,81/100 N/mm²

type of prestressing

SWS/270	Seven- Wire Strand (f_{pk} = 270 ksi)
SWS/250	Seven- Wire Strand (f_{pk} = 250 ksi)
TFWS	Three- and Four- Wire Strand (f_{pk} = 250 ksi)
PW	Prestressing Wire
SPB/145	Smooth Prestressing Bars (f_{pk} = 145 ksi)
SPB/160	Smooth Prestressing Bars (f_{pk} = 160 ksi)
DPB	Deformed Prestressing Bars

Database vsw-PC-DK

Internal forces at failure

Mu	$M_u = \frac{V_{u,Re\,p} \cdot a}{1000}$	[kNm]	max. moment at failure
muu	$\mu_u = \frac{M_u \cdot 10^6}{b \cdot d^2 \cdot f_{1c}}$	[-]	non-dimensional value of ultimate moment
vutest	$\upsilon_{u,test} = \frac{\tau_{u,test}}{f_{cwu}} = \frac{V_{u,Rep}}{b_w \cdot z_{test} \cdot f_{cwu}}$	[-]	non-dimensional value of ultimate shear force with respect to compressive strength
vutestct	$\upsilon_{u,test,ct} = \frac{\tau_{u,test}}{f_{1ctm,cal}} = \frac{V_{u,Re\,p}}{b_w \cdot z_{test} \cdot f_{1ctm,cal}}$	[-]	non-dimensional value of ultimate shear force with respect to tensile strength

Check of flexural failure

kapc		$\kappa_c = 1 - \frac{f_{1c}}{250}$	[-]	coefficient for maximum stress of stress block
epp		$\varepsilon_{pp} = \frac{\sigma_{pp} \cdot 10^3}{E_p}$	[‰]	stress in prestr. steel due to prestress
omgr	$A_s = 0$	$\omega_{gr} = \kappa_c \cdot \frac{0{,}4 \cdot d_{pbot}}{d}$	[-]	limiting reinforcement ratio
	$A_s > 0$	$\omega_{gr} = \kappa_c \cdot \frac{0{,}4 \cdot d_s}{d}$	[-]	
xsi11		$\xi_{11} = \frac{\omega_l}{\kappa_c}$	[-]	factor for depth of compression zone
zeta11	$\omega_{gr} > \omega_l$	$\zeta_{11} = 1 - \frac{1}{2} \cdot \frac{\omega_l}{\kappa_c}$	[-]	factor for inner lever arm z_1
acal1	$A_s = 0$	$a_{cal1} = 1{,}0$	[-]	auxiliary factor
	$A_s > 0$	$a_{cal1} = \frac{\omega_p}{\varepsilon_{py}} + \frac{\omega_s \cdot d_s}{d_{pbot} \cdot \varepsilon_{sy}}$	[-]	
bcal1	$A_s = 0$	$b_{cal1} = \varepsilon_{pp} + 3{,}5$	[-]	auxiliary factor
	$A_s > 0$	$b_{cal1} = \omega_p \cdot \frac{\varepsilon_{pp} + 3{,}5}{\varepsilon_{py}} + \omega_s \cdot \frac{3{,}5}{\varepsilon_{sy}} \cdot \left(2 \cdot \frac{d_s}{d_{pbot}} - 1\right)$	[-]	
ccal1	$A_s = 0$	$c_{cal1} = \varepsilon_{pp} \cdot 3{,}5 - \frac{\kappa_c \cdot \varepsilon_{py} \cdot 3{,}5}{\omega_p}$	[-]	auxiliary factor
	$A_s > 0$	$c_{cal1} = \omega_p \cdot \frac{\varepsilon_{pp} \cdot 3{,}5}{\varepsilon_{py}} + \omega_s \cdot \frac{3{,}5^2}{\varepsilon_{sy}} \cdot \left(\frac{d_s}{d_{pbot}} - 1\right) - \kappa_c \cdot 3{,}5 \cdot \frac{d_{pbot}}{d}$	[-]	

deltaep		$\Delta\varepsilon_p = \frac{-b_{call} + \sqrt{b_{call}^2 - 4 \cdot a_{call} \cdot c_{call}}}{2 \cdot a_{call}}$	[‰]	strain of prestr. steel
xsi12	$A_s = 0$	$\xi_{12} = \frac{3{,}5}{3{,}5 + \Delta\varepsilon_p}$	[-]	factor for depth of compression zone
	$A_s > 0$	$\xi_{12} = \frac{d_{pbot}}{d}\frac{3{,}5}{3{,}5 + \Delta\varepsilon_p}$	[-]	
zeta12	$\omega_{gr} < \omega_l$	$\zeta_{12} = 1 - \frac{1}{2} \cdot \xi_{12}$	[-]	factor for inner lever arm z_2
muflex11		$\mu_{u,flex11} = \omega_l \cdot \zeta_{11}$	[-]	non-dimensional moment
muflex12	$A_s = 0$	$\mu_{u,flex12} = \omega_l \cdot \frac{\Delta\varepsilon_p + \varepsilon_{pp}}{\varepsilon_{py}} \cdot \zeta_{12}$	[-]	non-dimensional moment
	$A_s > 0$	$\mu_{u,flex12} = \omega_p \cdot \frac{\Delta\varepsilon_p + \varepsilon_{pp}}{\varepsilon_{py}} \cdot \left(\frac{d_{pbot}}{d} - \frac{1}{2} \cdot \xi_{12}\right) + \frac{\omega_s}{\varepsilon_{sy}} \cdot \left(\frac{d_s}{d_{pbot}} \cdot (\Delta\varepsilon_p + 3{,}5) - 3{,}5\right) \cdot \left(\frac{d_s}{d} - \frac{1}{2} \cdot \xi_{12}\right)$	[-]	
muflex1		$\mu_{u,flex1}$	[-]	non-dimensional moment at flexural failure
xsi_1	$\zeta_{11} = 0$	$\xi_1 = \xi_{12}$	[-]	factor for depth of compression zone
	$\zeta_{11} \neq 0$	$\xi_1 = \xi_{11}$	[-]	
x_1		$x_1 = \xi_1 \cdot d$	[mm]	depth of compression zone
Mu_flex1		$M_{u,flex1} = \frac{\mu_{u,flex1} \cdot b \cdot d^2 \cdot f_{1c}}{1000^2}$	[kNm]	moment at flexural failure
beta_flex1		$\beta_{flex,1} = \frac{\mu_u}{\mu_{u,flex1}}$	[-]	ratio of attained to calc. moment
betax1		$\beta_{x1} = \frac{x_1}{h_f}$	[-]	ratio of depth of compression zone to height of flange of beams without haunch

betax2		$\beta_{x2} = \frac{x_1}{h_f + h_{h,top}}$	[-]	ratio of depth of compression zone to height of flange of beams with haunch
kon_hfu			[-]	=1 if $b > b_w$ and $\beta_{x1} > 1$
hhtop2	$\beta_{x1} > 1$ and $\beta_{x2} < 1$	$h_{h,top2} = x_1 - h_f$	[mm]	height of top haunch in compression
	$\beta_{x1} > 1$ and $\beta_{x2} > 1$	$h_{h,top2} = h_{h,top}$	[mm]	
alpha_fl		α_{fl}	[°]	inclination of top haunch
A_cc		A_{cc}	[mm²]	area of compression zone in T- and I-beams
z_cc		z_{cc}	[mm]	inner lever arm z in T- and I-beams
My_hf		$M_{y,hf}$	[kNm]	moment at failure of longitud. tension reinforcement in T- and I beams
Mc_fl		$M_{c,fl}$	[kNm]	moment at failure of compression zone in T- and I-beams
Mfl_min		$M_{fl,min}$	[kNm]	moment at flexural failure (min. of $M_{y,hf}$, $M_{c,fl}$)
Mu_flex		$M_{u,flex}$	[kNm]	moment at flexural failure (min. of $M_{u,flex1}$, $M_{fl,min}$)
betaflex		$\beta_{flex} = \frac{M_u}{M_{u,flex}}$	[-]	ratio of attained to calc. moment
FlexF		comment	[-]	remark (FF = flexural failure)
Vu_flex		$\upsilon_{u,flex} = \frac{M_{u,flex}}{a} \cdot 1000$	[kN]	shear force at flexural failure
xsi	for kon_hfu = 0	$\xi = \xi_1$	[-]	factor for depth of compression zone
	for kon_hfu = 1	$\xi = \frac{(h_f + h_{h,top2})}{d}$	[-]	

x		$x = \xi \cdot d$	[mm]	depth of compression zone
zeta		$\zeta = 1 - \frac{1}{2} \cdot \xi$	[-]	factor for z
z_		$z = \zeta \cdot d$	[mm]	inner lever arm
muflex		$\mu_{u,flex} = \frac{M_{u,flex}}{b \cdot d^2 \cdot f_{1c}}$	[-]	non-dimensional moment at flexural failure

Calculation of z_{test}

acal	$A_s = 0$	$a_{cal} = 0$	[-]	auxiliary value
	$A_s > 0$	$a_{cal} = \frac{\omega_s^2}{\varepsilon_{sy}^2} + 1{,}968 \cdot 0{,}9578 \cdot \omega_s \cdot \omega_p \cdot \frac{1}{\varepsilon_{sy} \cdot \varepsilon_{py}} + 0{,}968 \cdot 0{,}9578^2 \frac{\omega_p^2}{\varepsilon_{py}^2}$	[-]	
bcal	$A_s = 0$	$b_{cal} = 0$	[-]	auxiliary value
	$A_s > 0$	$b_{cal} = -2 \cdot \kappa_c \cdot \frac{d_s}{d} \cdot \left(\frac{\omega_s}{\varepsilon_{sy}} + \omega_p \cdot 0{,}9578 \cdot 0{,}968 \cdot \frac{1}{\varepsilon_{py}} \right) + 1{,}968 \cdot \left(\omega_s \cdot \omega_p \cdot \frac{\varepsilon_{pp}}{\varepsilon_{sy}} \cdot \varepsilon_{py} \right) + 2 \cdot 0{,}9578 \cdot 0{,}968 \cdot \omega_p{}^2 \cdot \frac{\varepsilon_{pp}}{\varepsilon_{py}{}^2}$	[-]	
ccal	$A_s = 0$	$c_{cal} = 0$	[-]	auxiliary value
	$A_s > 0$:	$c_{cal} = 0{,}968 \cdot \frac{\omega_p^2}{\varepsilon_{py}^2} \cdot \varepsilon_{pp}^2 - 2 \cdot 0{,}968 \cdot \kappa_c \cdot \frac{d_s}{d} \cdot \frac{\omega_p}{\varepsilon_{py}} \cdot \varepsilon_{pp} + 2 \cdot \kappa_c \cdot \mu_u$	[-]	
estest		$\varepsilon_{stest} = \frac{-b_{cal} - \sqrt{b_{cal}{}^2 - 4 \cdot a_{cal} \cdot c_{cal}}}{2 \cdot a_{cal}}$	[‰]	strain in reinf. steel
deltaeptest		$\Delta\varepsilon_{ptest} = \varepsilon_{stest} \cdot \frac{d_{pbot} - \xi_{test} \cdot d}{d_s - \xi_{test} \cdot d}$	[‰]	strain in prestr. steel

sigp	$A_s = 0$	$\sigma_p = \frac{\kappa_c \cdot f_{py}}{\omega_p} \cdot \left(1 - \sqrt{1 - 2 \cdot \frac{\mu_u}{\kappa_c}}\right)$	[MPa]	stress in prestr. steel
	$A_s > 0$	$\sigma_p = E_p \cdot (\varepsilon_{pp} + \Delta\varepsilon_{ptest})$	[MPa]	stress in reinf. steel
xsi_1test	$A_s = 0$	$\xi_{1,test} = \frac{\omega_p \cdot \sigma_p}{\kappa_c \cdot f_{py}}$	[-]	factor for depth of compression zone
	$A_s > 0$	$\xi_{1,test} = \frac{\varepsilon_{stest}}{\kappa_c} \cdot \left(\frac{\omega_s}{\varepsilon_{sy}} + \frac{\omega_p}{\varepsilon_{py}} \cdot 0{,}9578\right) + \frac{\varepsilon_{pp} \cdot \omega_p}{\kappa_c \cdot \varepsilon_{py}}$	[-]	
x_1test		$x_{1,test} = \xi_{1,test} \cdot d$	[mm]	depth of compression zone $x_{1,test}$
zeta1test		$\zeta_{1,test} = 1 - \frac{1}{2} \cdot \xi_{1,test}$	[-]	factor for inner lever arm $z_{1,test}$
z_1test		$z_{1,test} = \zeta_{1,test} \cdot d$	[mm]	inner lever arm $z_{1,test}$
betax1test		$\beta_{x1,test} = \frac{x_{1,test}}{h_f}$	[-]	ratio of depth of compression zone x_{test} to height of flange of beams without haunch
betax2test		$\beta_{x2,test} = \frac{x_{1,test}}{h_f + h_{h,top}}$	[-]	ratio of depth of compression zone x_{test} to height of flange of beams with haunch
kon_hfutest			[-]	=1 if $b > b_w$ and $\beta_{x1,test} > 1$
hhtop2test	$\beta_{x1,test} > 1$ and $\beta_{x2,test} < 1$	$h_{h,top2,test} = x_{1,test} - h_f$	[mm]	height of top haunch in compression
	$\beta_{x1,test} > 1$ and $\beta_{x2,test} > 1$	$h_{h,top2,test} = h_{h,top}$	[mm]	
A_cctest		$A_{cc,test}$	[mm²]	area of compression zone in T- and I-beams
z_cctest		$z_{cc,test}$	[mm]	inner lever arm z in T- and I-beams
z_test	for FlexF = FF	$z_{test} = z$	[mm]	inner lever arm z_{test}

	for $\beta_{x1,test} > 1{,}0$	$z_{test} = z_{cc,test}$	[mm]	
	no FF and $\beta_{x1,test} \leq 1{,}0$	$z_{test} = z_{1,test}$	[mm]	
xsitest		$\xi_{test} = 2 \cdot (1 - \zeta_{test})$	[-]	factor for depth of compression zone
xtest		$x_{test} = \xi_{test} \cdot d$	[mm]	depth of compression zone $x_{1,test}$
zetatest		$\zeta_{test} = z_{test} / d$	[-]	factor for inner lever arm $z_{1,test}$

<u>Shear force PT (for ν=0,8)</u>

sin2thp	$\sin^2 \theta_p = \omega_{wy}$	[-]	
thp	$\theta_p = \arcsin \sqrt{\sin^2 \theta_p} \cdot \frac{180}{\pi}$	[°]	strut inclination according to PT
cotthp	$\cot\ \theta_p = \frac{1}{\tan\left(\theta_p \cdot \frac{\pi}{180}\right)}$	[-]	
vup	$\upsilon_{up} = \omega_{wy} \cdot \cot\ \theta_p$	[-]	failure shear force according to PT

<u>Failure shear force in test</u>

gamwp	$\gamma_{wp} = \frac{\upsilon_{u,test}}{\upsilon_{up}}$	[-]	ratio
cotthu	$\cot\ \theta_u = \frac{\upsilon_{u,test}}{\omega_{wu}}$	[-]	cotθ strut inclination at failure
thu	$\theta_u = \arctan\left(\frac{1}{\cot\ \theta_u}\right) \cdot \frac{180}{\pi}$	[°]	strut inclination at failure
nueu	$\nu_u = \frac{0{,}8 \cdot \omega_{wu}}{\sin^2\left(\theta_u \cdot \frac{\pi}{180}\right)}$	[-]	coefficient for strut strength ($\nu_u = f_{cwu}/f_{1c}$)

Check of anchorage

lbprov	for $a_A \neq 0$; $b_A \neq 0$	$l_{b,prov} = a_A/2 + b_A - (h-d)$	[mm]	provided anchorage length
	for $a_A = 0$; $b_A \neq 0$:	$l_{b,prov} = b_A$	[mm]	
	for $a_A \neq 0$; $b_A = 0$:	$l_{b,prov} = a_A + 0{,}1\ d$	[mm]	
	for $a_A = b_A = 0$:	$l_{b,prov} = 0{,}25 \cdot d$	[mm]	
Fsa	for $a_A \neq 0$	$F_{sa} = V_{u,Rep} \cdot \left[0{,}5\frac{a_A}{z} + 2{,}20\frac{h-d}{z} + 1{,}1\right]$	[kN]	steel force to be anchored
	for $a_A = 0$	$F_{sa} = V_{u,Rep} \cdot \left[0{,}5\frac{0{,}2 \cdot d}{z} + 2{,}20\frac{h-d}{z} + 1{,}1\right]$	[kN]	
alpha		$\alpha = \frac{F_{sa}}{A_s \cdot f_{sy}}$	[-]	ratio of force to be anchored and steel force at yield
sslau		$\sigma_{slau} = \frac{F_{sa}}{A_s}$	[MPa]	steel stress near end suppport
lbreq1	for $\alpha \leq 1$	$l_{breq1} = \alpha_{as} \cdot d_{st} \cdot \sigma_{slau}/\left(9 \cdot f_{1ctm,cal}\right)$	[mm]	required anchorage length
lbreq2	for $\alpha > 1$	$l_{breq2} = \alpha_{as} \cdot d_{st} \cdot f_{sy}/\left(9 \cdot f_{1ctm,cal}\right)$	[mm]	required anchorage length
betalb1		$\beta_{lb1} = \frac{l_{breq1}}{l_{bprov}}$ or $\frac{l_{breq2}}{l_{bprov}}$	[-]	ratio of required to provided anchorage length
Fsaprov	for $\alpha \leq 1$ and $\beta_{lb1} > 1$	$F_{sa,prov} = \frac{F_{sa}}{\beta_{lb1}}$	[kN]	provided tension force at end support
	for $\alpha \leq 1$ and $\beta_{lb1} \leq 1$	$F_{sa,prov} = F_{sa}$	[kN]	

	for $\alpha > 1$ and $\beta_{lb1} > 1$	$F_{sa,prov} = \frac{A_s \cdot f_{sy}}{\beta_{lb1}}$	[kN]	
	for $\alpha > 1$ and $\beta_{lb1} \leq 1$	$F_{sa,prov} = A_s \cdot f_{sy}$	[kN]	
deltaFsa_p		$\Delta F_{sa,p} = F_{sa} - F_{sa,prov}$	[kN]	force difference
spau		$\sigma_{pau} = \frac{\Delta F_{sa,p}}{A_{pbot}}$	[MPa]	stress in prestr. steel due to $\Delta F_{sa,p}$
konfpy_anch		$kon_{fpy,anch}$	[-]	check if prestressing steel yields if $\Delta F_{sa,p}$ is applied
lbreq3	for SWS:	$l_{breq3} = \frac{\alpha_{ap} \cdot diaps}{4 \cdot 0{,}55 \cdot f_{1ctm,cal}} \cdot \left(0{,}5 \cdot \frac{P_{bot}}{A_{pbot}} + 0{,}8 \cdot \sigma_{pau}\right)$	[mm]	required anchorage length (pre-tensioned)
	for others:	$l_{breq3} = \frac{\alpha_{ap} \cdot diaps}{4 \cdot 0{,}641 \cdot f_{1ctm,cal}} \cdot \left(0{,}7 \cdot \frac{P_{bot}}{A_{pbot}} + 1{,}0 \cdot \sigma_{pau}\right)$	[mm]	required anchorage length (pre-tensioned)
lbreq4		$l_{breq4} = \alpha_{ap} \cdot diaps \cdot \left(\frac{P_{bot}}{A_{pbot}} + \sigma_{pau}\right) / \left(9 \cdot f_{1ctm,cal}\right)$	[mm]	required anchorage length (post-tensioned)
betalb		$\beta_{lb} = \frac{l_{breq3}}{l_{bprov}}$ or $\frac{l_{breq4}}{l_{bprov}}$	[-]	ratio of required to prov. anchorage length
AnchF		comment	[-]	AF = anchorage check not fulfilled

<u>criteria for data selection and sorting</u>

kon_1	=IF(f1c>12;1;0)
kon_2	=IF(f1c<100;1;0)
kon_3	=IF(bw>=40;1;0)
kon_31	=IF(bw<100;IF(bw>=40;1;0);0)

kon_4	=IF(h>=70;1;0)
kon_41	=IF(h<150;IF(h>=70;1;0);0)
kon_34	=IF(OR(kon_31=1;kon_41=1);0;1)
kon_5	=IF(kap>2,89;1;0)
kon_6	=IF(AND(kap>=2,4;kap<=2,89);1;0)
kon_x7	=IF(oml=0;0;1)
kon_7	=IF(kon_x7=0;0;IF(FlexF="FF";IF(xsi<=0,5;1;0);IF(xsitest<=0,5;1;0)))
kon_x8	=IF(betaflex=0;0;1)
kon_8	=IF(kon_x8=0;0;IF(betaflex<1;1;0))
kon_81	=IF(betaflex>=1;IF(betaflex<1,1;1;0);0)
kon_x9	=IF(nueu=0;0;1)
kon_9	=IF(kon_x9=0;0;IF(sigsw>0;(IF(nueu<=1;1;0));0))
kon_101	=IF(fr="r";1;0)
kon_102	=IF(frw="r";1;0)
kon_103	=IF(frp="r";1;0)
kon_10a	=IF(OR(kon_101=1;kon_103=1);1;0)
kon_10b	=IF(AND(kon_10a=0;p_method="Post");1;0)
kon_10c	=kon_102*kon_10a
kon_10	=IF(OR(kon_10a=1;kon_10b=1);1;0)
kon_x11	=IF(betalb=0;0;1)
kon_11	=IF(kon_x11=0;0;IF(betalb<1;1;0))
kon_12	=IF(sigsw>0;1;0)

kon_131	=IF(rhow>0,06228*(f1c/0,95-2,4)^0,5/fyw;1;0)
kon132	=IF(rhow>0,08*(f1c/0,95-4)^0,5/fyw;1;0)
kon_133a	=IF(rhow>(0,16*(f1ctmcal/fyw)*100);1;0)
kon_133b	=IF(rhow>(0,256*(f1ctmcal/fyw)*100);1;0)
kon_134a	=IF(rhow>(0,06228*(f1c/0,95-2,4)^0,5/fyw)*100;IF(rhow<(0,16*(f1ctmcal/fyw)*100);1;0);0)
kon_134b	=IF(rhow>(0,06228*(f1c/0,95-2,4)^0,5/fyw)*100;IF(rhow<(0,256*(f1ctmcal/fyw)*100);1;0);0)
kon_x14	=IF(sw=0;0;1)
kon_141	=IF(kon_x14=0;0;IF(sw<=IF(vutest<=0,12;0,7*h;IF(vutest>0,24;0,25*h;0,5*h));1;0))
kon_142	=IF(kon_x14=0;0;IF(f1c<=51,3;IF(sw<=300;1;0);IF(sw<=200;1;0)))
kon_14a	=kon_141*kon_142
kon_143	=IF(vutest<=0,12;IF(sw>0,75*h;0;1);IF(sw>0,375*h;0;1))
kon_144	=IF(vutest<=0,12;IF(sw<=610;1;0);IF(sw<=305;1;0))
kon_14b	=kon_143*kon_144
kon_15	=IF(oft="oft";0;1)
kon_161	=IF(fyw<=414;1;0)
kon_162	=IF(fyw<=552;1;0)

KON_A0a	=kon_1*kon_3*kon_4
KON_A0b	=KON_A0a*kon_7
KON_A0c	=KON_A0b*kon_15
KON_A0d	=KON_A0c*kon_10
KON_A0	=KON_A0d*kon_14a

KON_A21a	=KON_A0*kon_5*kon_8
KON_A22a	=KON_A0*kon_5*kon_81
KON_A2a	=IF(OR(KON_A21a=1;KON_A22a=1);1;0)
KON_A31a	=KON_A0*kon_6*kon_8
KON_A32a	=KON_A0*kon_6*kon_81
KON_A3a	=IF(OR(KON_A31a=1;KON_A32a=1);1;0)
A2a+A3a	=IF(OR(KON_A2a=1;KON_A3a=1);1;0)
KON_A21b	=KON_A21a*kon_131
KON_A22b	=KON_A22a*kon_131
KON_A2b	=IF(OR(KON_A21b=1;KON_A22b=1);1;0)
KON_A31b	=KON_A31a*kon_131
KON_A32b	=KON_A32a*kon_131
KON_A3b	=IF(OR(KON_A31b=1;KON_A32b=1);1;0)
A2b+A3b	=IF(OR(KON_A2b=1;KON_A3b=1);1;0)
KON_A21c	=KON_A21b*kon_12
KON_A22c	=KON_A22b*kon_12
KON_A2c	=IF(OR(KON_A21c=1;KON_A22c=1);1;0)
KON_A31c	=KON_A31b*kon_12
KON_A32c	=KON_A32b*kon_12
KON_A3c	=IF(OR(KON_A31c=1;KON_A32c=1);1;0)
A2c+A3c	=IF(OR(KON_A2c=1;KON_A3c=1);1;0)
KON_A21d	=KON_A21c*kon_9

KON_A22d	=KON_A22c*kon_9
KON_A2d	=IF(OR(KON_A21d=1;KON_A22d=1);1;0)
KON_A31d	=KON_A31c*kon_9
KON_A32d	=KON_A32c*kon_9
KON_A3d	=IF(OR(KON_A31d=1;KON_A32d=1);1;0)
A2d+A3d	=IF(OR(KON_A2d=1;KON_A3d=1);1;0)
KON_A21	=KON_A21d*kon_11
KON_A22	=KON_A22d*kon_11
KON_A2	=IF(OR(KON_A21=1;KON_A22=1);1;0)
KON_A31	=KON_A31d*kon_11
KON_A32	=KON_A32d*kon_11
KON_A3	=IF(OR(KON_A31=1;KON_A32=1);1;0)
A2+A3	=IF(OR(KON_A2=1;KON_A3=1);1;0)
KON_A4b	=KON_A2b*kon_34
KON_A5b	=KON_A3b*kon_34
A4b+A5b	=IF(OR(KON_A4b=1;KON_A5b=1);1;0)
Differenz	=IF(A2b_A3b=1;IF(A4b_A5b=1;0;1);0)
KON_A4	=KON_A2*kon_34
KON_A5	=KON_A3*kon_34
A4+A5	=IF(OR(KON_A4=1;KON_A5=1);1;0)
Differenz	=IF(A2_A3=1;IF(A4_A5=1;0;1);0)

Nominal values of concrete strength

f1ck	$f_{1ck} = f_{1c} - 3{,}8$	[MPa]	characteristic uniaxial concrete compressive strength
fcm_cyl	$f_{cm,cyl} = \frac{f_{1c}}{0{,}95}$	[MPa]	mean cylinder strength of concrete
fck	$f_{ck} = f_{cm,cyl} - 4$	[MPa]	characteristic cylinder strength
fc_prime	$f'_c = f_{ck} + 1{,}6$	[MPa]	specified compressive strength of concrete (ACI, CSA)