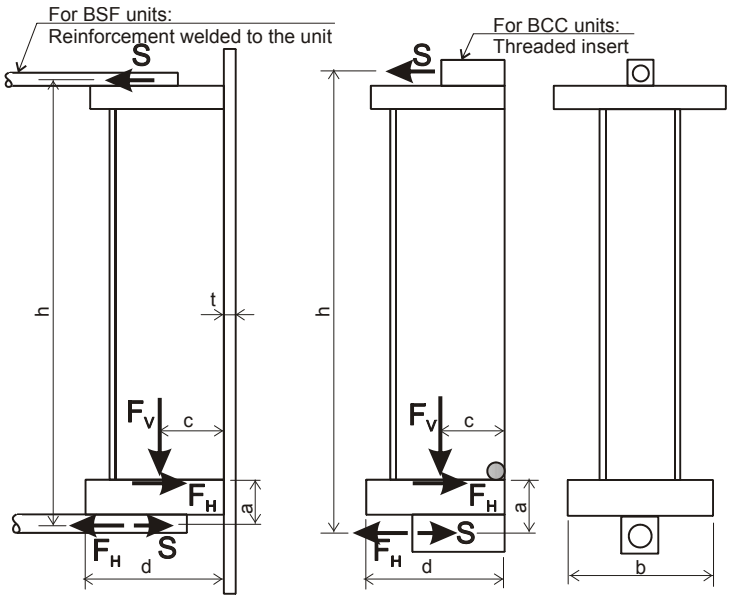
Reinforcement design for column unit BSF, BCC

The calculations shown in this memo are based on the Norwegian concrete design code. Experience with the design of the units according to norwegian rules and EC2 has documented that the results are practically the same whether the Norwegian code or EC2 is used.



Equlibrium:

$M = F_H \times a + F_V \times [(d/2) - c]$
$M = 0{,}3 \times F_V \times a + F_V \times [(d/2) - c]$
$M = F_V \times (0{,}3 \times a + 0{,}5 \times d - c)$

$S = M/h$

Tension in the topp = S
Tension in the bottom = $F_H - S$

Splitting stress under the column unit according to Leonhardt ≈ $0{,}2 \times F_V$

The weld connecting the reinforcing bars to the column unit should have at least the same ultimate capacity as the reinforcing bars in order to have a ductile connection

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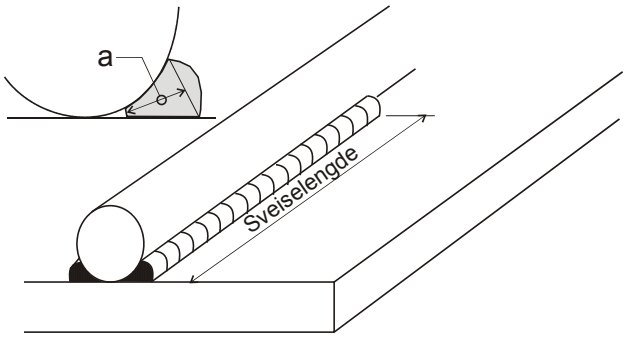
Required length of weld:

$$= \frac{a_s \times f_{sd} \times \gamma_m \times \sqrt{3}}{2 \times a \times 355} + 2 \times a$$



Welding

a_s is the area of the reinforcement bar
γ_m is the material factor for the weld.

Simplified:
When it is welded on both sides of the reinforcing bar, and the welds a-height is 0,3 times the diameter of the reinforcing bar. Will the welding length be 4 times the diameter for the reinforcing bar. If the chosen a-height is 0,2, the necessary welding length will be 5,2 times the diameter of the reinforcing bar.

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Anchoring of the bolt`s:

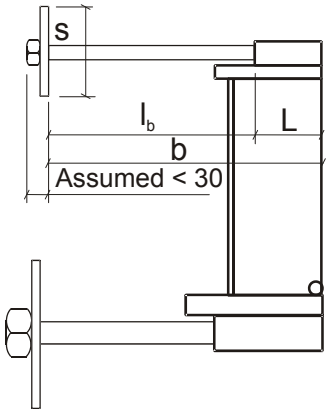
Maximum tension in the bolt = f_{sd} = 640/1,1 = 582 MPa (provided 8.8 steel quality)
Maximum force in the bolt = P = A_s×582 N (A_s is the bolt`s tension area)

Nominal diameter $Ø_{nom}$ (mm)	M10	M12	M16	M20	M24	M30	M33	M36
Equivalent diameter $Ø_{eq}$ (mm)	8,6	10,4	14,1	17,7	21,2	26,7	29,7	32,6
Stress area A_s (mm^2)	58	84	157	245	353	561	694	835

Net compressive area for the square washer = $A_{c,net} = s^2 - \pi \times Ø_{nom}^2/4$
Capacity in the pressure area = $P_t = f_{cd} \times A_{c,net}$
The bolt is anchjoring a force P-P_t by bond:
$P - P_t = 582 \times A_s - f_{cd} \times A_{c,net} = \pi \times Ø_{nom} \times l_b \times f_{bd}$

$A_{c,net} = (582 \times A_s - \pi \times Ø_{nom} \times l_b \times f_{bd})/f_{cd}$

NS 3473, pkt 12.8.5:
$f_{bd} = f_{bc} + f_{bs} \leq 2k_1 \times f_{td}$
$f_{bs} = 0$
it can be shown that f_{bc} only will be governing when $Ø_{nom}$ > 60 mm



Anchoring of the column unit

Consequently: $f_{bd} = 2k_1 \times f_{td} = 2{,}4\ f_{td}$
$A_{c,netto} = (582 \times A_s - \pi \times Ø_{nom} \times l_b \times 2{,}4 \times f_{td})/ f_{cd}$
$S^2 - \pi \times Ø^2_{nom} / 4 = (582 \times A_s - 7{,}54 \times Ø_{nom} \times l_b \times f_{td})/ f_{cd}$

$$s = \sqrt{\frac{582 \times A_s - 7{,}54 \times Ø_{nom} \times l_b \times f_{td}}{f_{cd}} + \frac{\pi \times Ø_{nom}^2}{4}}$$

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b = 150 mm			Concrete grade C30/37				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	100	17,0	1,28	39	40x40x4
12	84	50	100	17,0	1,28	48	50x50x4
16	157	60	90	17,0	1,28	69	70x70x4
20	245	70	80	17,0	1,28	88	90x90x5
24	353	80	70	17,0	1,28	108	110x110x5

b = 150 mm			Concrete grade C35/45				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	100	19,5	1,43	35	35x35x4
12	84	50	100	19,5	1,43	44	45x45x4
16	157	60	90	19,5	1,43	64	65x65x4
20	245	70	80	19,5	1,43	82	80x80x5
24	353	80	70	19,5	1,43	100	100x100x5

b = 150 mm			Concrete grade C45/55				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	100	24,5	1,64	31	Standard washer
12	84	50	100	24,5	1,64	39	Standard washer
16	157	60	90	24,5	1,64	57	60x60x4
20	245	70	80	24,5	1,64	73	75x75x5
24	353	80	70	24,5	1,64	89	90x90x5

b = 150 mm			Concrete grade C55/67				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	100	28,4	1,82	28	Standard washer
12	84	50	100	28,4	1,82	35	Standard washer
16	157	60	90	28,4	1,82	52	Standard washer
20	245	70	80	28,4	1,82	68	70x70x5
24	353	80	70	28,4	1,82	83	85x85x5

$Ø_{nom}$	Standard square washer
10	30×30×3
12	40×40×3
16	50×50×4
20	60×60×4
24	80×80×5

Reinforcement design for column unit BSF, BCC

b = 250 mm			Concrete grade C30/37				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	200	17,0	1,28	39	Standard washer
12	84	50	200	17,0	1,28	40	Standard washer
16	157	60	190	17,0	1,28	62	60x60x4
20	245	70	180	17,0	1,28	82	80x80x5
24	353	80	170	17,0	1,28	101	100x100x5

b = 250 mm			Concrete grade C35/45				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	200	19,5	1,43	27	Standard washer
12	84	50	200	19,5	1,43	36	Standard washer
16	157	60	190	19,5	1,43	57	60x60x4
20	245	70	180	19,5	1,43	75	75x75x5
24	353	80	170	19,5	1,43	93	95x95x5

b = 250 mm			Concrete grade C45/55				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	200	24,5	1,64	21	Standard washer
12	84	50	200	24,5	1,64	30	Standard washer
16	157	60	190	24,5	1,64	49	Standard washer
20	245	70	180	24,5	1,64	65	65x65x5
24	353	80	170	24,5	1,64	82	Standard washer

Reinforcement design for column unit BSF, BCC

b = 350 mm			Concrete grade C30/37				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	300	17,0	1,28	19	Standard washer
12	84	50	300	17,0	1,28	30	Standard washer
16	157	60	290	17,0	1,28	54	55x55x4
20	245	70	280	17,0	1,28	74	75x75x5
24	353	80	270	17,0	1,28	94	95x95x5

b = 350 mm			Concrete grade C35/45				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	300	19,5	1,43	12	Standard washer
12	84	50	300	19,5	1,43	25	Standard washer
16	157	60	290	19,5	1,43	48	Standard washer
20	245	70	280	19,5	1,43	67	65x65x5
24	353	80	270	19,5	1,43	86	85x85x5

b = 350 mm			Concrete grade C4555				
$Ø_{nom}$	A_s	L	l_b	f_{cd}	f_{td}	s	Recommend square washer
10	58	50	300	24,5	1,64	0	Standard washer
12	84	50	300	24,5	1,64	17	Standard washer
16	157	60	290	24,5	1,64	40	Standard washer
20	245	70	280	24,5	1,64	58	Standard washer
24	353	80	270	24,5	1,64	75	Standard washer

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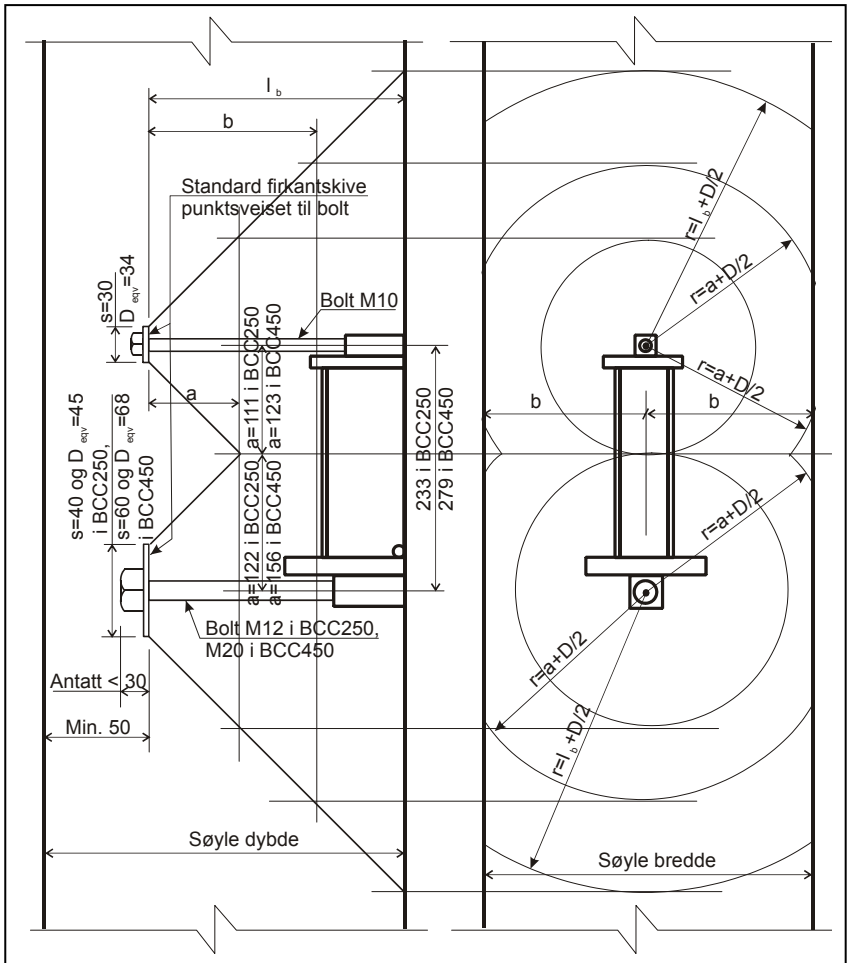
Cone fracture:

The capacity limited by cone fracture is calculated according to the method in Betongelementboken (The Concrete Element Book), volume B, clause 19.3.2.
The calculation of the surface areas of the cones is modified according to the figures on this page.
Detailed development of the formulas and numerical calculations can be found in " Beregning av forankringene som brukes I BCC enhetene" (Design of anchorage of BCC units) (in Norwegian only)

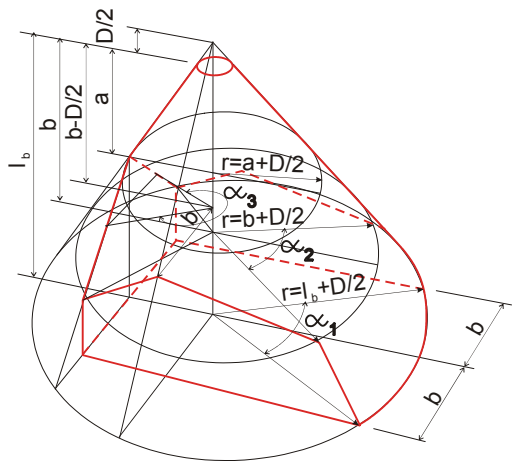
The result of the design for a column of 300x300 and 220 mm anchoring depth (l_b on the figure) and a 20 mm in diameter reinforcing bar is shown in the table below.



Pull out cone.

Bolt $Ø_{nom}$	Bolt	Capacities (kN) Cone C35/45	Cone C45/55
10	34	260	298
12	49	262	300
16	91	269	309
20	143	284	325
24	205	334	384

The capacity of the cone are consistently higher then the capacity of the bolt. Cone fracture is not governing.



Shape of pull out cone.