Rakennusteollisuus RT

SBKL fastening plates
Manual

Design according to Eurocodes

18.5.2017

This manual is written in cooperation between the companies listed below and Betoniteollisuus Ry.

The companies listed are entitled to manufacture the SBKL-fastening plates presented in this manual.

By harmonizing SBKL-fastening plates, the work of designers, manufacturers, concrete element manufacturers, contractors and officials is made easier owing to the interchangeability of the fastening plates.

The guidelines given are intended to be used by qualified persons with the ability to understand the restrictions of the guidelines and to take responsibility for applying the guidelines in practical construction projects. Although the preparation of this manual has been done by the leading technical experts in the nation, neither Betoniteollisuus Ry or the persons involved in the preparation do not assume liability for guidelines given in this manual.

Manufacturers:

Anstar Oy

Peikko Finland Oy

R-Group Oy

Semko Oy

Publisher: Rakennusteollisuus ry

Betoniteollisuus ry

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1 PRINCIPLE OF OPERATION OF THE FASTENING PLATES

SBKL fastening plates are steel plates equipped with resistance welded stud head anchors. The fastening plates are cast into concrete. SBKL fastening plates are intended to be used as base plates to which steel profiles are welded. The fastening plates transfer loads from structures welded on it to concrete structures. The loads are transferred through rebar anchors.

SBKL fastening plates consist of a steel on which stud head anchors are welded. Multiple sizes of plates are manufactured with different material options.

The resistances of SBKL fastening plates are calculated for static loads.

Minimum reinforcement according to SFS-EN 1992-1-1 is always to be used in the location of the fastening plates to guarantee ductility of the structure in ultimate limit state. If in this manual the resistance is given without additional reinforcement, the minimum reinforcement is not contributing to the resistance given. When in this manual the resistance is presented with additional reinforcement, in addition to the minimum reinforcement, the structure has additional reinforcement according to section 4.9.

2 DIMENSIONS AND MATERIALS OF THE FASTENING PLATES

2.1 Materials of the fastening plates and corresponding standards

Type	Component	Material	Standard
SBKL	Steel plate	S355J2+N	SFS-EN 10025
	Anchor	S235JR+AR	SFS-EN 10025
SBKLR	Steel plate	1.4301	SFS-EN 10088
	Anchor	S235JR+AR	SFS-EN 10025
SBKLH	Steel plate	1.4401	SFS-EN 10088
	Anchor	S235JR+AR	SFS-EN 10025
SBKLRr	Steel plate	1.4301	SFS-EN 10088
	Anchor	1.4301	SFS-EN 10088

2.2 Dimensions of the fastening plates

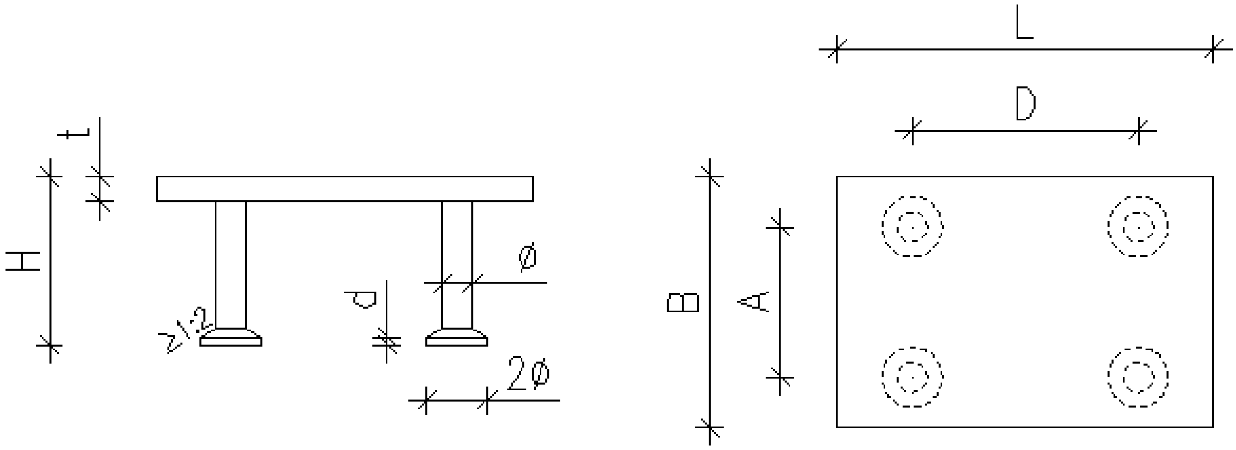

Figure 1. Dimension markings of SBKL fastening plates

Table 1. Dimensions of SBKL fastening plates

SBKL fastening plate				H	A	D	t	Ø	d
SBKL	B	x	L	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
SBKL	50	x	100	68	-	60	8	12	3
SBKL	100	x	100	68	60	60	8	12	3
SBKL	100	x	150	70	60	90	10	12	3
SBKL	150	x	150	162	90	90	12	12	3
SBKL	100	x	200	162	60	120	12	12	3
SBKL	200	x	200	162	120	120	12	16	4
SBKL	250	x	250	165	170	170	15	16	4
SBKL	100	x	300	165	60	180	15	16	4
SBKL	200	x	300	165	120	180	15	16	4
SBKL	300	x	300	165	180	180	15	16	4

Stud head dimensions according to table 1 and figure 1 unless the stud head anchor has a separate approval.

3 MANUFACTURING AND TOLERANCES OF THE FASTENING PLATES

3.1 Manufacturing method and execution class

Steel plates:	Thermal or mechanical cutting
Steel bars:	Mechanical cutting, heading (cold/hot)
Welding:	MAG welding, manual or robotic, resistance welding or arc stud welding
Welding class:	C (SFS-EN ISO 5817), EXC2 (SFS-EN 1090-2 section 7.6)
Execution class:	EXC2 (SFS-EN 1090-2) [more demanding classes according to a separate guideline]

3.2 Manufacturing tolerances

Plate side lengths:	± 3 mm L ≤ 120 mm ± 4 mm 120 mm < L ≤ 315 mm
Plate straightness:	L/150
Plate cut edge surface roughness:	SFS-EN 1090-2
Squareness of cut edges:	SFS-EN 1090-2
Steel part height:	± 3 mm
Anchor location:	± 5 mm
Anchor spacing:	± 5 mm
Anchor inclination:	± 5°

3.3 Surface treatment

Protective painting shall be applied to the visible surfaces of the fastening plates. The fastening plates are delivered with an approximately 40 µm shop priming. Upon request the fastening plates are delivered with a 60 µm epoxy painting or hot dip galvanized according to galvanizing standard. Stainless and acid-proof fastening plates are delivered without protective painting.

3.4 Quality control

Demands of product standards are to be applied in quality control. The manufacturer of the fastening plates has a valid quality control agreement for the quality control of steel part manufacturing.

4 RESISTANCES

4.1 Basis of structural design

The resistances of SBKL fastening plates have been calculated according to the following norms, rules and regulations:

SFS-EN 1992 Eurocode 2 Design of concrete structures
SFS-EN 1993 Eurocode 3 Design of steel structures
CEN/TS 1992-4 Design of fastenings for use in concrete

The resistances have been calculated with respect to static loads. For dynamic and fatigue loads the resistances need to be separately checked on a case-by-case basis.

4.2 Resistances without the effect of edge distances and additional reinforcement

Table 2 presents the resistances of SBKL fastening plates when only one loading acts at a time. The resistance of SBKL fastening plates with respect to combinations of load effects shall be checked according to 4.6.

The resistances given in table 2 have been calculated using the following assumptions:

- Concrete strength C25/30
- Cracking can occur in the location of the fastening plate.
- No additional reinforcement at the location of the fastening plate. Structure only reinforced with minimum reinforcement. The resistances of fastening plate with additional reinforcement is presented in section 4.9.
- The fastening plate is located so far from the edge that the breakage of the edge of concrete structure is not a governing failure mechanism (the required edge distances are given in section 4.4). If the edge distance is smaller than what given in 4.4, the resistances need to be reduced according to section 4.7 or additional reinforcement according to section 4.9 needs to be used at the location of the fastening plate.
- The thickness of the member on which the fastening plate is mounted is according to section 4.5 table 5 column h_{min}. With smaller thicknesses, the resistances need to be reduced according to section 4.5.
- The tolerance for the location of a load is max. ± 15 mm (In addition the manufacturing tolerance ± 5 mm has been considered in the calculations).
- The fastening surface of the steel component to be mounted on the fastening plate shall have minimum area according to section 4.3.
- Shear force V_{Ed} can act in both directions of the plate but in one direction at a time. Shear force acting in both directions need to be considered according to section 4.6.
- Torsional moment T_{Ed} can act in both plate directions but only in one direction at a time. acting in both directions simultaneously shall be considered according to section 4.6.
- Bending moment M_{Ed} can act in both plate directions but only in one direction at a time. Bending moment acting in both directions simultaneously shall be considered according to section 4.6

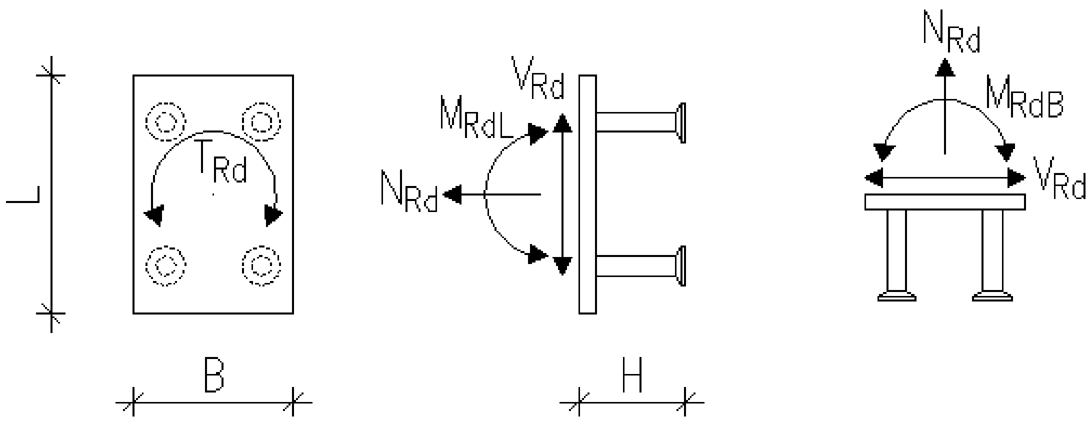

Figure 2. Notation for force directions in SBKL fastening plates

Table 2. Resistances of SBKL fastening plates for single load effects for cracked C25/30 concrete without additional reinforcement and without considering the effect of edge distances.

Fastening plate				H	N_{Rd}	V_{Rd}	M_{RdL}	M_{RdB}	T_{Rd}
SBKL	B	x	L	mm	[kN]	[kN]	[kNm]	[kNm]	[kNm]
SBKL	50	x	100	68	11,5	22,5	0,5	0,1	0,6
SBKL	100	x	100	68	14,5	28,5	0,6	0,6	1,1
SBKL	100	x	150	70	17,1	33,5	1,0	0,7	1,7
SBKL	150	x	150	162	72,4	82,2	3,6	3,6	4,9
SBKL	100	x	200	162	72,8	82,2	4,9	2,4	5,2
SBKL	200	x	200	162	80,2	147,4	7,5	7,5	12,0
SBKL	250	x	250	165	96,3	147,4	11,9	11,9	17,2
SBKL	100	x	300	165	81,4	147,4	10,5	4,0	13,5
SBKL	200	x	300	165	90,3	147,4	11,7	8,4	15,4
SBKL	300	x	300	165	99,2	147,4	12,8	12,8	18,3

The values in table 2 are maximum resistances of SBKL fastening plates for individual load effects. The maximum resistances given are values for concrete structures with minimum reinforcement and fastening plate locations according to tables 4 and 5 without additional reinforcement.

NOTE! In normal situations, the maximum resistances in table 2 are reduced according to section 4.7. Section 7 contains a design example.

4.3 Fastening area

When using resistances given in table 2, the fastening areas of the steel components to be attached on the SBKL fastening plates shall have minimum values according to table 3. If the steel component is welded all around, the welds can be taken as part of the fastening area. If needed, stiffeners can be used in the connection between the fastening plate and the steel component to achieve the required fastening area.

Table 3. Minimum fastening areas of SBKL fastening plates

Fastening plate				Minimum fastening area					
				SBKL			SBKLR, SBKLH, SBKLRr		
SBKL	B	x	L	[mm]	x	[mm]	[mm]	x	[mm]
SBKL	50	x	100	15	x	40	15	x	50
SBKL	100	x	100	40	x	40	45	x	45
SBKL	100	x	150	40	x	45	40	x	65
SBKL	150	x	150	60	x	60	75	x	75
SBKL	100	x	200	40	x	100	40	x	110
SBKL	200	x	200	95	x	95	105	x	105
SBKL	250	x	250	125	x	125	145	x	145
SBKL	100	x	300	40	x	160	40	x	170
SBKL	200	x	300	65	x	140	90	x	160
SBKL	300	x	300	125	x	125	150	x	150

If the fastening area of the component to be mounted on the fastening plate is smaller than value given in table 3, the resistances of SBKL fastening plate need to be reduced according to formula 1.
.

$$N_{Rd.red} = N_{Rd} \times \frac{(c - a_0)}{(c - a_1)} \qquad , a_0 > a_1 \qquad (1)$$

where

$N_{Rd.red}$ = reduced resistance to normal force
N_{Rd} = given normal force resistance for the minimum fastening area
c = distance between anchor centers
a_0 = side length of the minimum fastening surface (value according to table 3)
a_1 = side length of the fastening surface

The same formula for the reduction of capacity can be used for moment capacity also. For shear force and torsional moment, it is not necessary to reduce the resistances due to fastening area.

4.4 Minimum allowable edge and center distances for resistances according to 4.2

When using resistance values given in table 2, the center and edge distances of SBKL fastening plates need to equal to at least the values given in table 4. The values given in table 4 are such that the edge of the concrete will not break. With smaller edge or center distances the resistances of SBKL fastening plates shall be reduced according to section 4.7.

The edge distances in table 5 are distances between the center of an anchor in SBKL fastening plate to the edge of the concrete structure, according to Figure 3. Similarly, the center distances are distances between the centers of adjacent anchors in SBKL fastening plates

The center distance k_t has the minimum value of 2 x the edge distance, if the full resistances according to table 2 are used. With smaller center distances, the resistance of the fastening plates shall be reduced according to section 4.7 as with single fastening plates. The center distance reducing factor is calculated using half of the center distance as the value of edge distances.

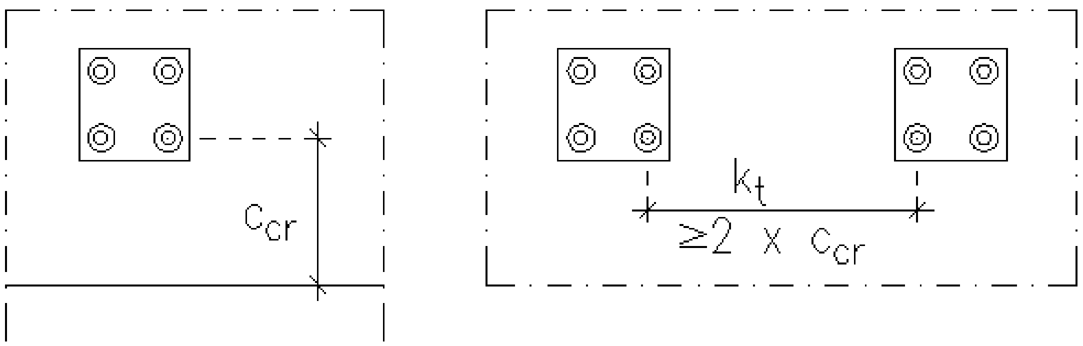

Figure 3. The edge distance c_{cr} of SBKL fastening plate from the center of the anchor to the edge of the concrete structure and the center distance between adjacent fastening plates.

Table 4. Minimum edge distances of SBKL fastening plates for resistances according to section 4.2.

Fastening plate				Minimum edge distance for resistances N_{Rd}, M_{RdL} and M_{RdB} in table 2	Minimum edge distance for resistances V_{Rd} and T_{Rd} in table 2
SBKL	B	x	L	$c_{cr.N}$ [mm]	$c_{cr.V}$ [mm]
SBKL	50	x	100	104	690
SBKL	100	x	100	104	690
SBKL	100	x	150	107	710
SBKL	150	x	150	241	720
SBKL	100	x	200	243	720
SBKL	200	x	200	243	960
SBKL	250	x	250	246	960
SBKL	100	x	300	246	960
SBKL	200	x	300	246	960
SBKL	300	x	300	246	960

4.5 Minimum thickness of the concrete base and the effect of base thickness to resistances

When using the resistances given in table 2 the thickness of the concrete base must have the minimum value given in table 5. With smaller thicknesses of the base, the resistances of SBKL fastening plates need to be reduced. The manufacturing tolerances of the SBKL fastening plates have been considered in the minimum concrete structure thickness values given in table 5.

Table 5. Minimum thicknesses for the concrete base structure for SBKL fastening plates

Fastening plate				Minimum thickness h_{min} of the base (concrete structure) for resistances according to table 2.	Minimum thickness $h_{min.cb}$ of the base (concrete structure) when concrete cover c_b = 20 mm
SBKL	B	x	L	[mm]	[mm]
SBKL	50	x	100	138	91
SBKL	100	x	100	138	91
SBKL	100	x	150	142	93
SBKL	150	x	150	322	185
SBKL	100	x	200	324	185
SBKL	200	x	200	322	185
SBKL	250	x	250	328	188
SBKL	100	x	300	328	188
SBKL	200	x	300	328	188
SBKL	300	x	300	328	188

The effect of base thickness h_c to SBKL fastening plate resistance can be taken into account by using reduction factor $k_{h.red}$. Given in the following formula. Base thicknesses smaller than minimum value $h_{min.cb}$ given in table 5 may not be used with the fastening plates.

$$k_{h.red} = \left(\frac{h_c}{h_{min}}\right)^{\frac{2}{3}} \leq 1.0 \qquad (2)$$

where

h_c = thickness of the concrete structure (minimum value of the concrete structure is $h_{min.cb}$ given in table 6).

h_{min} = Value of h_{min} according to table 5.

4.6 Resistances of fastening plates for combinations of load effects

If multiple load effects act simultaneously on SBKL fastening plate the resistance of the fastening plate shall be checked according to the following formula.

$$\left(\frac{N_{Ed}}{N_{Rd}} + 1.8\left(\frac{M_{EdB}}{M_{RdB}} + \frac{M_{EdL}}{M_{RdL}}\right)\right)^{\frac{2}{3}} + \left(\frac{V_{EdB}}{V_{Rd}} + \frac{V_{EdL}}{V_{Rd}} + \frac{T_{Ed}}{T_{Rd}}\right)^{\frac{2}{3}} \leq 1.0 \qquad (3)$$

Where subscript Ed means the ultimate limit state value for the dimensioning value of the load effect and Rd the corresponding resistance of the fastening plate.

4.7 Effects of edge and center distances to resistances

If the center or edge distances of SBKL fastening plates are smaller than the values given in table 4, the resistance values of the fastening plates according to section 4.2 need to be reduced. In table 6 reduction factors are given for cases where the fastening plate edge or center distances in one, two or three sides are the minimum values given in table 7. Linear interpolation can be used for the intermediate values between resistances given in table 2 and the ones calculated with the reduction factors in table 6.

Table 6. Fastening plate resistance reduction factor when edge distance c = $c_{cr.X.min}$

Load effect	Reduction factor when edge distance is $c_{cr.X.min}$		
	on single side (fastening plate in the edge of the structure)	on two sides (fastening plate in corner or in a narrow structure)	on three sides (fastening plate in the edge of a narrow structure)
N_{Rd}	0,49	0,23	0,20
M_{RdB} ja M_{RdL}	0,49	0,23	0,20
V_{Rd} ja T_{Rd}	0,18	0,13	0,11

In addition to the reduction factor given in table 6, the effect of the base thickness on the resistance of the fastening plates needs to be taken into account according to section 4.5.

Minimum values of edge distances are given in table 7. The edge distances cannot be smaller than these values. With edge distances smaller than ones given in table 7 additional reinforcement needs to be used according to sections 4.8 and 4.9.

Table 7. Minimum edge distances of SBKL fastening plates for reduction factors according to table 6.

Fastening plate				Minimum edge distances for reduction factors N_{Rd}, M_{RdL} and M_{RdB} according to table 6	Minimum edge distances for reduction factors V_{Rd} and T_{Rd} according to table 6
SBKL	B	x	L	$c_{cr.N.min}$ [mm]	$c_{cr.V.min}$ [mm]
SBKL	50	x	100	50	150
SBKL	100	x	100	50	150
SBKL	100	x	150	50	150
SBKL	150	x	150	50	150
SBKL	100	x	200	50	150
SBKL	200	x	200	50	150
SBKL	250	x	250	50	150
SBKL	100	x	300	60	150
SBKL	200	x	300	60	150
SBKL	300	x	300	60	150

4.8 Effect of additional reinforcement on edge distances

Positioning a SBKL fastening plate with additional reinforcement shall be made according to the minimum values of the edge distances given in column $c_{cr.N.min}$ of table 7.

The effect of additional reinforcement on the resistances of SBKL fastening plates are given in section 4.9. Principles of additional reinforcement placement are presented in figures 3 and 4.

4.9 Effect of additional reinforcement on resistances

Additional reinforcement can be used to increase the resistances of SBKL fastening plates when the edge distances are smaller than ones given in table 4. In tables 8 and 9 tensile and shear resistances of additional reinforcement placed as in figures 3 and 4 are given. Tables 8 and 9 give resistance of a single additional reinforcement link. The total resistance of a SBKL fastening plate with additional reinforcement can be calculated by multiplying the resistance of a single additional reinforcement with the number of additional reinforcement links.

The maximum resistances for SBKL fastening plate with additional reinforcement are presented in section 4.10.

Reinforcing steel B500B or equivalent reinforcing steel has been used for additional reinforcement in the calculations.

4.9.1 Additional reinforcement for tensile force and bending moment resistance

Additional reinforcement for tensile resistance and bending moments must be placed in the concrete structure in location of the SBKL fastening plate as presented in figure 4. The additional reinforcement is to be added as close as possible to the steel plate and anchors of the SBKL fastening plate. In lateral direction, the additional reinforcement can be located a maximum distance of 0,5H from center of an anchor in SBKL fastening plate as presented in figure 4. The additional reinforcement must be anchored to full tensile capacity outside of the failure cone of the SBKL fastening plate as presented in figure 4.

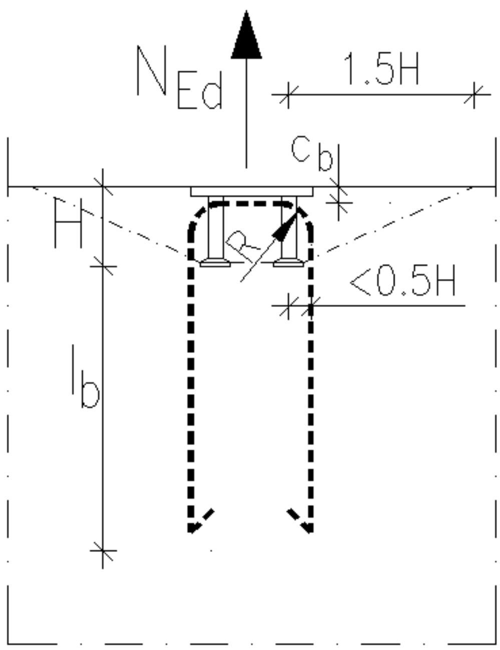

Figure 4. Additional reinforcement of SBKL fastening plate for tensile force and bending moment resistance.

c_b = concrete cover (Asm. 20mm) l_b = anchorage length according to SFS-EN 1992-1-1
R = interior bend radius of additional reinforcement according to SFS-EN 1992-1-1

Table 8 gives the anchorage capacities of additional reinforcement of SBKL fastening plates in the failure cone of a fastening plate with additional reinforcement positioned as in figure 4. Values in table 8 are calculated in bad bond conditions. Resistance of a SBKL fastening plate with additional reinforcement is calculated by multiplying the value for single additional reinforcement link given in table 8 with the number of additional reinforcement links at the location of the fastening plate.

Table 8. Tensile resistances of additional reinforcements of SBKL fastening plates (tensile resistance value for singe link placed according to figure 4)

Fastening plate				Tensile resistance of additional reinforcement $N_{Rd.s}$ [kN]			
				Bar diameter Φs [mm]			
SBKL	B	x	L	T6	T8	T10	T12
SBKL	50	x	100	3,2	-	-	-
SBKL	100	x	100	3,2	-	-	-
SBKL	100	x	150	3,4	4,5	-	-
SBKL	150	x	150	11,2	14,9	-	-
SBKL	100	x	200	11,2	14,9	18,7	22,4
SBKL	200	x	200	11,2	14,9	18,7	22,4
SBKL	250	x	250	11,5	15,3	19,1	22,9
SBKL	100	x	300	11,5	15,3	19,1	22,9
SBKL	200	x	300	11,5	15,3	19,1	22,9
SBKL	300	x	300	11,5	15,3	19,1	22,9

With fastening plates SBKL50x100 and 100x100 the size of the failure cone is only sufficient for anchorage of additional reinforcement with diameter 6mm. With fastening plates SBKL 100x150 and 150x150 the failure cone height is only sufficient for anchoring additional reinforcements with diameters 6mm and 8mm.

If concrete cover for additional reinforcement is larger than 20mm used in calculations, the anchorage capacity of additional reinforcement in failure cone needs to be separately calculated on a case-by-case basis.

Under good bond conditions the resistance values given in table 8 can be multiplied by factor 1,42.

4.9.2 Additional reinforcement for shear force and torsional moment

Additional reinforcement for shear force and torsional moment must be place into concrete in the location of the SBKL fastening plate according to figure 5. Additional reinforcement for shear force is placed perpendicular against the shear force and as close as possible to the steel plate of the SBKL fastening plate in the vertical direction. Additional reinforcement is bent in a such way that the additional reinforcement steels are contacting the anchors of the SBKL fastening plate. Additional reinforcement must be anchored in the concrete structure for full tensile capacity of the steel outside of the failure cone of the SBKL fastening plate according to section A-A in figure 5.

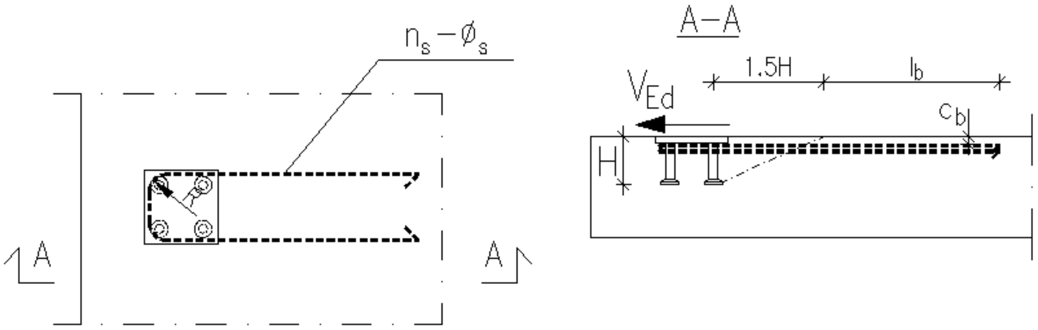

Figure 5. Additional reinforcement of SBKL fastening plate for shear force and torsional moment

c_b = concrete cover (Asm. 20mm) l_b = anchorage length according to SFS-EN 1992-1-1
R = interior bend radius of additional reinforcement according to SFS-EN 1992-1-1

Table 9. Shear resistances of SBKL fastening plates with additional reinforcement (Shear resistance of single additional reinforcement link positioned according to figure 5)

Fastening plate				Shear resistances of SBKL fastening plates with additional reinforcement $V_{Rd.s}$ [kN]			
				bar diameter Φs [mm]			
SBKL	B	x	L	T6	T8	T10	T12
SBKL	50	x	100	4,5	7,9	12,3	17,4
SBKL	100	x	100	4,5	7,9	12,3	17,4
SBKL	100	x	150	4,5	7,9	12,3	17,4
SBKL	150	x	150	4,8	8,4	13,0	18,6
SBKL	100	x	200	4,5	7,9	12,3	17,4
SBKL	200	x	200	5,0	8,8	13,6	19,4
SBKL	250	x	250	5,0	8,8	13,6	19,4
SBKL	100	x	300	4,5	7,9	12,3	17,4
SBKL	200	x	300	5,0	8,8	13,6	19,4
SBKL	300	x	300	5,3	9,2	14,4	20,5

Under good bond conditions the resistance values given in table 9 can be multiplied by factor 1,42.

Eccentricity between shear force and reinforcement causes additional tensile force into additional reinforcement. This additional force is accounted for in the following way:

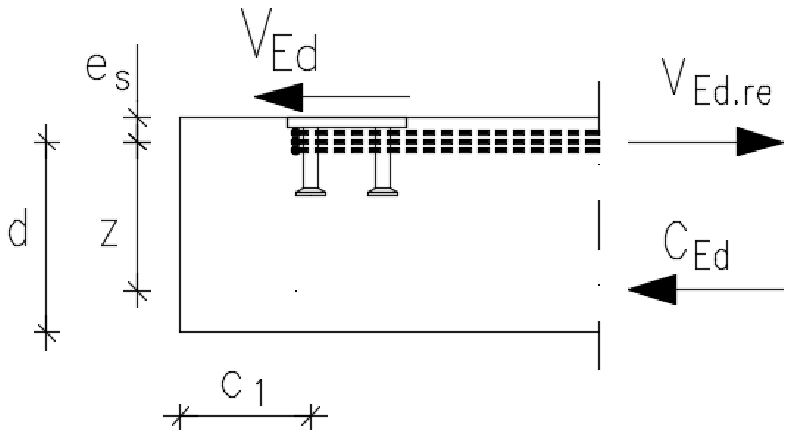

Figure 6. Additional tensile force in additional reinforcement

$$V_{Ed.re} = \left(\frac{e_s}{z} + 1\right) \cdot V_{Ed} \qquad (4)$$

where

e_s = distance between shear force (surface of steel plate) and center of the reinforcement

z = internal moment arm of the concrete structure ≈ 0,85d ($d \leq \min\begin{cases}2H\\2c_1\end{cases}$)

Example. SBKL150x150 fastening plate with additional reinforcement for shear force. V_{Ed} = 43 kN, e_s = 35 mm, z = 160 mm, additional reinforcement T12 links in bad bond conditions.

True tensile force in additional reinforcement when considering eccentricity $N_{Ed.re}$ = (35 mm / 160 mm + 1) x 55 kN = 52,4 kN.

52,4 kN / (2 x 18,6 kN) = 141 % -> 2 pieces T12 links is not enough.

52,4 kN / (3 x 18,6 kN) = 94 % -> 3 pieces T12 links is needed for additional reinforcement for shear force

4.10 Maximum resistances with additional reinforcement

Table 10 gives maximum resistances for SBKL fastening plates. True resistance of SBKL fastening plates depends on the amount of additional reinforcement used according to sections 4.9.1 and 4.9.2 (compare examples A, B and C below). Additional reinforcement is placed according to figures 4 and 5. In positioning SBKL fastening plate to a structure minimum edge distances given in table 7 column $c_{cr.N.min}$ must be complied with. Effect of the height of the concrete structure to the maximum resistances need to be taken into an account according to 4.5.

Table 10. Maximum resistances for SBKL fastening plates

Fastening plate				H	$N_{Rd.max}$ 1)	*$N_{Rd.max}$ 2)*	$V_{Rd.max}$	$M_{RdL.max}$	$M_{RdB.max}$	$T_{Rd.max}$
SBKL	B	x	L	mm	[kN]	*[kN]*	[kN]	[kNm]	[kNm]	[kNm]
SBKL	50	x	100	68	27,7	*42,8*	41,1	0,5	0,1	0,6
SBKL	100	x	100	68	35,9	*85,7*	82,2	0,6	0,6	1,1
SBKL	100	x	150	70	41,0	*85,7*	82,2	1,0	0,7	1,7
SBKL	150	x	150	162	46,8	*85,7*	82,2	3,6	3,6	2,3
SBKL	100	x	200	162	44,0	*85,7*	82,2	4,9	2,4	5,2
SBKL	200	x	200	162	96,6	*153,6*	147,4	7,5	7,5	12,0
SBKL	250	x	250	165	110,0	*153,6*	147,4	11,9	11,9	17,2
SBKL	100	x	300	165	84,8	*153,6*	147,4	10,5	4,0	13,5
SBKL	200	x	300	165	104,0	*153,6*	147,4	11,7	8,4	15,4
SBKL	300	x	300	165	111,9	*153,6*	147,4	12,8	12,8	18,3

1) Maximum resistance normally used in design of SBKL fastening plate that can be anchored into concrete structure.
2) Theoretical maximum resistance for failure of steel studs without eccentricity.

Example A:

In location of a SBKL 200x200 fastening plate with locations according to figure 4 additional reinforcements links 4 pieces T12 are installed in good bond conditions. The combined tensile resistance of the additional reinforcement is then F_{re} = 4 pcs x 1,42 x 22,4 kN/pc = 127,2 kN.

Maximum resistance for tensile force is $N_{Rd.max}$ = 96,6 kN and thus value $N_{Rd.max}$ should be used as the tensile resistance of a fastening plate with the described additional reinforcement.

Example B:

In location of SBKL 100x100 fastening plate with locations according to figure 4 2 pieces T6 additional reinforcement links are installed in good bond conditions. The combined tensile resistance of the additional reinforcement links is then F_{re} = 2 pcs x 1,42 x 3,2 kN/pc = 9,1 kN. Maximum resistance for tensile force is $N_{Rd.max}$ = 35,9 kN and thus this value $N_{Rd.max}$ cannot be used but F_{re} = 9,1 kN must be used for the tensile resistance.

Example C:

In location of a SBKL 150x150 fastening plate additional reinforcement of 2 pieces T10 is installed in good bond conditions with positioning according to figure 5. The combined shear force resistance of the additional reinforcement links is then V_{re} = 2 pcs x 1,42 x 11,0 kN/pc = 31,2 kN. The maximum resistance for tensile force is $V_{Rd.max}$ = 82,2 kN and thus value $V_{Rd.max}$ cannot be used as the shear force resistance but value V_{re} = 31,2 kN needs to be used. In calculating the resistance, the effect of shear force eccentricity for the tensile force in additional reinforcement must also be taken into account.

5 USE OF FASTENING PLATES

5.1 Service life and allowed exposure classes

Service life of SBKL fastening plates depends on the chosen fastening plate material. SBKL fastening plates may be used in all concrete structure exposure classes when the requirements of the exposure classes for the concrete cover of steel parts of the fastening plate are complied with. If necessary, stainless SBKLR, acid-proof SBKLH or completely stainless SBKLRr fastening plate types are to be used.

5.2 Limitations for use

Capacities for SBKL fastening plates are calculated for static loads. For dynamic or fatigue loads larger partial safety factors for loads must be used and the components of the connection must be checked on a case-by-case basis.

Resistances for SBKL fastening plates have been calculated for cracked concrete with strength C25/30.

A reinforcement to guarantee ductile action of the structure in ultimate limit state must always be installed in location of the SBKL fastening plates.

6 STORAGE, TRANSPORTATION AND MARKING OF THE FASTENING PLATES

SBKL fastening plates are to be stored protected from the rain.

Marking is made into SBKL fastening plates that shows at least the manufacturer, type and identifier and manufacturing date of the fastening plate.

7 DESIGN EXAMPLE FOR SBKL FASTENING PLATE

7.1 Design example 1: SBKL fastening plate without additional reinforcement

Resistance of a SBKL fastening plate is checked for the situation presented in figure 7. No additional reinforcement for the SBKL fastening plate is installed and structure has only minimum reinforcement.

The exterior dimensions of component to be fixed to SBKL fastening plate are 140 x 140 mm. Distance of the fixed component to the edge of the concrete structure is 300 mm. In other directions the distance between the fixed component and the edge of the concrete structure is 1m. Thickness of the concrete structure is 250 mm.
The fixed component subjects following loads to the fastening plate in two different load cases.

Load case 1: V_{Ed} = 15 kN, N_{Ed} = 20 kN, M_{Ed} = 0 kNm

Load case 2: V_{Ed} = 2 kN, N_{Ed} = 15 kN, M_{Ed} = 2 kNm.

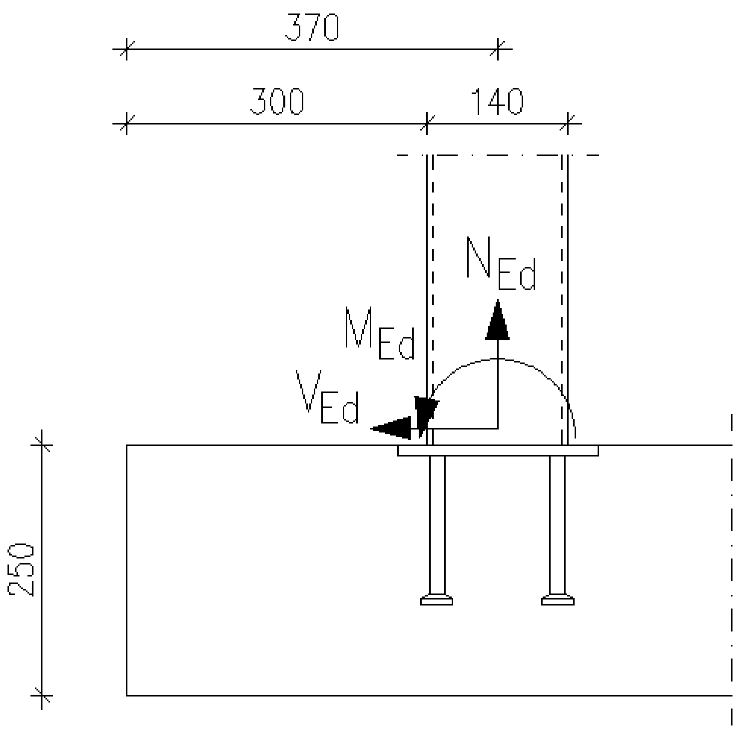

Figure 7. Design example for SBKL fastening plate without additional reinforcement, dimensions of fastening plate.

SBKL 200x200 fastening plate is chosen and its resistance against load effects is checked. Resistances without reductions of a SBKL 200x200 fastening plate according to table 2 are tensile resistance N_{Rd} = 80,2 kN, bending moment resistance M_{Rd} = 7,5 kNm ja shear force resistance V_{Rd} = 147,4 kN. Next the edge distances of the fastening plate, fastening area of the fixed component, thickness of the concrete structure are checked along with possible reductions given for the fastening plate resistances. The resistance of the fastening plate against combinations of load effects is checked.

Effect of edge distances to resistances

The distance c_{cr} of the fastening plate anchor to the edge of the concrete structure is given with dimensions in table 1.

$$c_{cr} = \frac{200mm\text{-}120mm}{2} + 370mm - \frac{200mm}{2} = 310mm$$

The minimum edge distances of SBKL200x200 fastening plate for resistances according to table 2 are given in table 4. The minimum edge distances for normal force and bending moment resistances is $c_{cr.N}$ = 243 mm and the minimum edge distance for shear force is $c_{cr.V}$ = 960 mm. With dimensions according to figure 6, the edge distance exceeds the minimum value for tensile force and bending moment so the resistance according to table 2 does not need to be reduced due to edge distances. For shear force the edge distance is smaller than required and the shear resistance needs to be reduced from the value given in table 2.

The reduction of shear resistance due to edge distance is done according to section 4.7. First the minimum value of the edge distance is fist checked from table 7. The minimum value for fastening plate without additional reinforcement in table 6 is 150mm for shear resistance. With positioning according to figure 6 the minimum value is exceeded and thus the reduced value for shear resistance can be calculated. In calculation the values from the first column of table 6 can be used because the edge distance is smaller than the minimum given in table 4 only on one edge. The reduction factor for shear force with edge distance of 150 mm according to table 7 is 0,18. The intermediate values of the reduction factor can be linearly interpolated according to edge distance and thus the reduction factor to be applied is

$$k_{red.V} = 0{,}18 + \frac{1\text{-}0{,}18}{960\text{mm-}150\text{mm}}(310\text{mm-}150\text{mm}) = 0{,}34$$

And the shear resistance reduced due to edge distance is:

$V_{Rd.red.c} = k_{red.V} \times V_{Rd}$ = 0,34 x 147,4 kN = 50,1 kN.

<u>Effect of dimensions of the steel part to be fastened to resistances</u>

In table 4 of section 4.3 the minimum fastening areas for which the full resistance of the SBKL fastening plate can be utilized are given. For SBKL 200x200 fastening plate the minimum fastening area is 89 mm x89 mm which is fulfilled by the fixed part with dimensions 140mmx140mm according to figure 6. Thus, the resistances do not need to be reduced or the fixed part size increased due to minimum fastening surface

<u>Effect of concrete structure thickness on the resistances</u>

Effect of concrete structure thickness on the resistances of SBKL fastening plate is checked according to 4.5. Table 5 gives minimum thickness of the concrete structure for which the resistances according to table 2 do not need to be reduced. For SBKL200x200 fastening plate this value is 322mm. The minimum required thickness of concrete structure is $h_{min.cb}$ = 185 mm according to table 5.
The concrete structure thickness h_c = 250 mm according to figure 6 fulfills the minimum thickness requirement $h_{min.cb}$ but is smaller than the required thickness h_{min} for use of resistances according to table 2 and the resistances need to be reduced. The resistances are reduced with factor

$$k_{h.red} = \left(\frac{250\text{mm}}{322\text{mm}}\right)^{\frac{2}{3}} = 0{,}84$$

$V_{Rd.red} = k_{h.red} \times V_{Rd.red.c}$ = 0,84 x 50,1 kN = 42,1 kN

$N_{Rd.red} = k_{h.red} \times N_{Rd}$ = 0,84 x 80,2 kN = 67,3 kN

$M_{Rd.red} = k_{h.red} \times M_{Rd}$ = 0,84 x 7,5 kNm = 6,3 kNm

Resistance for combinations of load effects

The resistance of SBKL fastening plate for combinations of load effect combinations are calculated according to section 4.6 with formula (2)

Load case 1: $\left(\frac{20kN}{67{,}3kN}\right)^{\frac{2}{3}} + \left(\frac{15kN}{42{,}1kN}\right)^{\frac{2}{3}} = 0{,}95$

Load case 2: $\left(\frac{15kN}{67{,}3kN} + 1{,}8\frac{2kNm}{6{,}3kNm}\right)^{\frac{2}{3}} + \left(\frac{2kN}{42{,}1kN}\right)^{\frac{2}{3}} = 0{,}97$

SBKL 200x200 fastening plate with dimensions according to figure 6 has enough resistance for the loadings given in both load cases.

7.2 Design example 2: SBKL fastening plate with additional reinforcement

Resistance of a SBKL fastening plate with dimensions, positioning and loadings as given in figure 8. Additional reinforcement will be installed if needed.

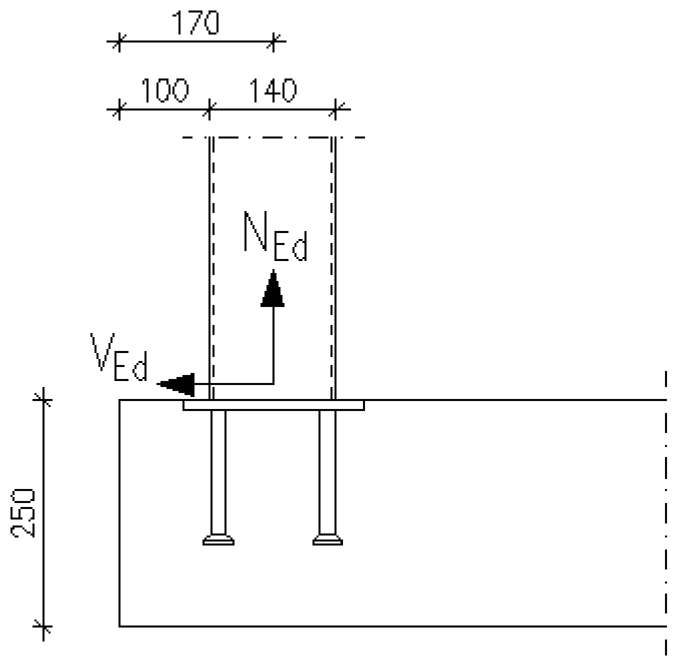

Figure 8. Design example for SBKL fastening plate with additional reinforcement. Fastening plate dimensions.

The exterior dimensions of the component fixed to the SBKL fastening plate are 140 mm x 140 mm. The distance from the edge of the fixed component to the edge of the concrete structure is 100 mm. In other directions the distance from the fixed component to the edge of the concrete structure is 3m. Thickness of the concrete structure is 250mm.
The fixed component subjects following loads to the fastening plate in three different load cases.

Load case 1: V_{Ed} = 22 kN, N_{Ed} = 20 kN, M_{Ed} = 0 kNm

Load case 2: V_{Ed} = 10 kN, N_{Ed} = 15 kN, M_{Ed} = 1 kNm

Load case 3: V_{Ed} = 10 kN, N_{Ed} = 40 kN, M_{Ed} = 0 kNm.

SBKL 200x200 fastening plate is chosen and its resistance against load effects is checked. Resistances without reductions of a SBKL 200x200 fastening plate according to table 2 are tensile resistance N_{Rd} = 80,2 kN, bending moment resistance M_{Rd} = 7,5 kNm ja shear force resistance V_{Rd} =

147,4 kN. Next the edge distances of the fastening plate, fastening area of the fixed component, thickness of the concrete structure are checked along with possible reductions given for the fastening plate resistances. The resistance of the fastening plate against combinations of load effects is checked.

Effect of edge distances to resistances

The distance c_{cr} of the fastening plate anchor to the edge of the concrete structure is given with dimensions in table 1.

$$c_{cr} = \frac{200mm\text{-}120mm}{2} + 170mm - \frac{200mm}{2} = 110mm$$

Distance c_{cr} is smaller than the minimum edge distance $c_{cr.V.min}$ for shear force required in table 7 for fastening plate without additional reinforcement so additional reinforcement in the location of the SBKL fastening plate is required at least for shear force.

The edge distance is smaller than the minimum value required by table 4 for tensile resistance so the resistance must be reduced from the value of table 2. Reduction of the tensile resistance is done according to section 4.6. The minimum edge distance according to table 7 is $c_{cr.N.min}$ = 50 mm and the reduction factor according to table 6 with the edge distance being $c_{cr.N.min}$ is 0,49. The reduction factors when edge distance is c_{cr} is calculated by linear interpolation

$$k_{red.N} = 0{,}49 + \frac{1\text{-}0{,}49}{243mm\text{-}50mm}(243mm\text{-}110mm) = 0{,}84$$

$$k_{red.M} = 0{,}49 + \frac{1\text{-}0{,}49}{243mm\text{-}50mm}(243mm\text{-}110mm) = 0{,}84$$

And the tensile and bending moment resistances reduced due to edge distances are

$N_{Rd.red.c}$ = 0,84 x 80,2 kN = 67,3 kN

$M_{Rd.red.c}$ = 0,84 x 7,5 kNm = 6,3 kNm.

Effect of dimensions of the steel part to be fastened to resistances

In table 4 of section 4.3 the minimum fastening areas for which the full resistance of the SBKL fastening plate can be utilized are given. For SBKL 200x200 fastening plate the minimum fastening area is 89 mm x89 mm which is fulfilled by the fixed part with dimensions 140mmx140mm according to figure 6. Thus, the resistances do not need to be reduced or the fixed part size increased due to minimum fastening surface

Effect of concrete structure thickness on the resistances

Effect of concrete structure thickness on the resistances of SBKL fastening plate is checked according to 4.5. Table 5 gives minimum thickness of the concrete structure for which the resistances according to table 2 do not need to be reduced. For SBKL200x200 fastening plate this value is 322mm. The minimum required thickness of concrete structure is $h_{min.cb}$ = 185 mm according to table 5.
The concrete structure thickness h_c = 250 mm according to figure 8 fulfills the minimum thickness requirement $h_{min.cb}$ but is smaller than the required thickness h_{min} for use of resistances according to table 2 and the resistances need to be reduced. The resistances are reduced with factor

$$k_{h.red} = \left(\frac{250mm}{322mm}\right)^{\frac{2}{3}} = 0{,}84$$

$N_{Rd.red} = k_{h.red}$ x $N_{Rd.red.c}$ = 0,84 x 67,3 kN = 56,5 kN

$M_{Rd.red} = k_{h.red}$ x $M_{Rd.red.c}$ = 0,84 x 6,3 kNm = 5,3 kNm.

Additional reinforcement of a SBKL fastening plate for shear force

The shear force resistance of additional reinforcement for SBKL fastening plate is calculated according to section 4.9.2. In table 9 shear force resistance of a single additional reinforcement link is given. 2 pcs T12 is chosen as additional reinforcement for SBKL 200x200 fastening plate. According to Eurocode SFS-EN 1992 section 8.4.2 additional reinforcement is casted under “good” bond conditions so for resistances according to table 9 factor of 1,42 can be used. The shear resistance anchored by the additional reinforcement is then

$V_{Rd.re}$ = 2 x 1,42 x 19,4 kN = 55,0 kN.

In the shear force resistance of additional reinforcement, the eccentricity between shear force and additional reinforcement is also taken into account. Values used in calculation: es = 30 mm, z = 0,85 x min(2 x 68 mm; 2 x 110 mm) = 115 mm.

$k_{red.ek}$ = (30 mm / 115 mm +1) =1,26

The shear force anchored by the additional reinforcement when eccentricity is taken into account is

$V_{Rd.re.ek}$ = $V_{Rd.re}$ / $k_{red.ek}$ = 55 kN / 1,26 = 43,7 kN.

Resistance of SBKL fastening plate for combinations of load effects

The resistance of fastening plate for combinations of load effect combinations are calculated according to section 4.6 according to formula (2)

Load case 1 1: $\left(\frac{20\text{kN}}{56{,}5\text{kN}}\right)^{\frac{2}{3}} + \left(\frac{22\text{kN}}{43{,}7\text{kN}}\right)^{\frac{2}{3}} = 1{,}13$

Load case 2: $\left(\frac{15\text{kN}}{56{,}5\text{kN}} + 1{,}8\frac{1\text{kNm}}{5{,}3\text{kNm}}\right)^{\frac{2}{3}} + \left(\frac{10\text{kN}}{43{,}7\text{kN}}\right)^{\frac{2}{3}} = 1{,}09$

Load case 3: $\left(\frac{40\text{kN}}{56{,}5\text{kN}}\right)^{\frac{2}{3}} + \left(\frac{10\text{kN}}{43{,}7\text{kN}}\right)^{\frac{2}{3}} = 1{,}17$

SBKL 200x 200 does not have enough resistance for the loads given. Additional reinforcement for tensile force is also installed and the resistances in different load cases are calculated again.

Additional reinforcement of SBKL fastening plate for tensile force

The resistance of SBKL fastening plate additional reinforcement for tensile force is defined according to section 4.9.1. Table 8 gives the resistance of a single additional reinforcement link for tensile force. 3 pcs T12 additional reinforcement links are chosen for tensile force additional reinforcement of SBK 200x200 fastening plate. According to Eurocode SFS-EN 1992 section 8.4.2 additional reinforcement is casted under “good” bond conditions so for resistances according to table 9 factor of 1,42 can be used. The tensile resistance of the additional reinforcement is then
$N_{Rd.re}$ = 4 x 1,42 x 22,4 kN = 127,2 kN.

In addition, maximum resistance of fastening plate with additional reinforcement according to table 10 is checked. Normally used maximum resistance of SBKL 200x200 fastening plate with additional reinforcement is $N_{Rd.max}$ = 96,6 kN.

Smaller of values $N_{Rd.re}$ ja $N_{Rd.max}$ is used for the resistance of the fastening plate.

<u>Resistance of SBKL fastening plate for combinations of load effects</u>

The resistance of fastening plate for combinations of load effect combinations are calculated according to section 4.6 according to formula (2)

Load case 1: $\left(\frac{20kN}{96,6kN}\right)^{\frac{2}{3}}+\left(\frac{22kN}{43,7kN}\right)^{\frac{2}{3}}= 0,98$

Load case 2: $\left(\frac{15kN}{96,6kN}+1,8\frac{1kNm}{5,3kNm}\right)^{\frac{2}{3}}+\left(\frac{10kN}{43,7kN}\right)^{\frac{2}{3}}=0,99$

Load case 3: $\left(\frac{40kN}{96,6kN}\right)^{\frac{2}{3}}+\left(\frac{10kN}{43,7kN}\right)^{\frac{2}{3}}=0,93$

SBKL 200x200 fastening plate with dimensions according to figure 7 has enough resistance for the loadings given in all load cases.

2-T12 was chosen for shear force additional reinforcement and 4-T12 for tensile force. Additional reinforcement must be positioned according to sections 4.9.1 and 4.9.2 into the structure. In low structures the additional reinforcement for tensile force must be bent into the structure and long enough anchorage length must be guaranteed outside of the failure cone of SBKL fastening plate.

8 LITERATURE RELATED TO THE MANUAL

CEN/TS 1992-4-1:2009. Design of fastenings for use in concrete. Part 1 General

CEN/TS 1992-4-2:2009. Design of fastenings for use in concrete. Part 2 Headed fasteners

fib bulletin 58:2011 Design of anchorages in concrete

SFS-EN 1992-1-1 Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings

SFS-EN 1993-1-1 Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings

SFS-EN 1993-1-8 Eurocode 3: Design of steel structures. Part 1-8: Design of joints

SFS-EN 1993-1-10 Eurocode 3: Design of steel structures. Part 1-10: Material toughness and through-thickness properties

SFS-EN 1090-2 Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures

SFS-EN 10080 Steel for the reinforcement of concrete. Weldable reinforcing steel. General

SFS 1216 Betoniteräkset. Hitsattava kuumavalssattu harjatanko A700HW

SFS 1257 Betoniteräkset. Kylmämuokattu harjatanko B500K

SFS 1259 Betoniteräkset. Kylmämuokattu ruostumaton harjatanko B600KX

SFS 1268 Betoniteräkset. Hitsattava kuumavalssattu harjatanko B500B

SFS 1269 Betoniteräkset. Hitsattava kuumavalssattu harjatanko B500C1

SFS 1300 Betoniteräkset. Hitsattavien betoniterästen ja betoniteräsverkkojen vähimmäisvaatimukset

SFS-EN 10025 Hot rolled products of structural steels.

SFS-EN 10088 Stainless steels

SFS-EN ISO 17660-1 Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints

SFS-EN ISO 5817 Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levers for imperfections.

SFS-EN ISO 3834-3 Quality requirements for fusion welding of metallic materials. Part 3: Standard quality requirements

SFS-EN ISO 14554-2 Quality requirements for welding. Resistance welding of metallic materials. Part 2: Elementary quality requirements.

SFS-EN 15609-1 Specification and qualification of welding procedures for metallic materials. Welding procedure specification. Part 1: Arc welding.

SFS-EN 15609-2 Specification and qualification of welding procedures for metallic materials. Welding procedure specification. Part 2: Gas welding

SFS-EN 15609-5 Specification and qualification of welding procedure for metallic materials. Welding procedure specification. Part 5: Resistance welding

SFS-EN 287-1 Qualification test of welders. Fusion welding Part 1: Steels

SFS-EN ISO 9606-1 Qualification testing of welders. Fusion welding. Part 1: Steels

SFS-EN ISO 14731 Welding coordination. Tasks and responsibilities

SFS-EN ISO 14732 Welding personnel. Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials

SFS-EN ISO 9018 Destructive tests on welds in metallic materials. Tensile test on cruciform and lapped joints.

SFS-EN 10204 Metallic products. Types of inspection documents

NA SFS-EN 1992-1-1 Finnish national annex

NA SFS-EN 1993-1-1 Finnish national annex

NA SFS-EN 1993-1-8 Finnish national annex

NA SFS-EN 1993-10 Finnish national annex

ETAG 001 Guideline for European technical approval of metal anchors for use in concrete.
Annex A: Details of tests.
Annex B: Tests for admissible service conditions, detailed information.