Technical Assessment

for MKT highload anchor SZ
(gvz and A4)
in fiber reinforced concrete

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IEA 18-011 - Independent Technical Assessment for:
Name of the product: MKT highload anchor SZ (gvz and A4)
Type of product: Torque-controlled expansion anchor
Product owner: MKT, Metall-Kunststoff-Technik GmbH & Co. KG
Validity: 5 year
Production plant: see ETA-02/0030
Intended use: acc. Static and quasi-static loading in fiber reinforced concrete
Technical Assessment bases on: ETA-02/0030 and EAD 330232-01-0601 and tests in concrete with fibers, Report FAST 18-011.

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Prof. Dr.-Ing. Jan Hofmann

IEA GmbH & Co. KG Independent Technical Assessment

1 Introduction and scope

The use in fiber reinforced concrete is excluded according to the provisions given in the ETA 02/0030 or the ESR-3173. To show that the anchoring system SZ can be used in concrete with fibers, tests were performed and evaluated. The tests were performed in accordance with EAD 330232-00-0601 but with fiber reinforced concrete instead of normal concrete without fibers.

The indented use of the anchors therefore change and the anchors can be used for a base material made of

- Cracked and uncracked concrete
- Compacted, reinforced or compacted unreinforced normal weight concrete
- Concrete with steel fibers that fulfill the following conditions
  - Length of the steel fiber ≤ 35 mm.
  - The diameter of the fiber ≤ 0.55 mm.
  - Characteristic steel strength of the fiber ≥ 1200 N/mm².
  - Fiber content of the concrete mix ≤ 80 kg/m³.
- Strength classes C20/25 to C50/60 according to EN 206:2013

Both material versions (gvz and A4) of the SZ anchors are geometrically identical. Also, the characteristic resistances for the different sizes (except of size M8) are equal. For this reason, it can be assumed that the principal behavior of the anchors is comparable regarding the existing fibers. The environmental conditions that are allowed depend on the material type:

- For structures subject to dry internal conditions zinc plated steel or stainless steel can be used.
- For structures subject to external atmospheric exposure (including industrial and marine environment) and permanently damp internal conditions (if no particular aggressive conditions exist stainless steel can be used.

For the design of the product the conditions given in EN 1992-4 must be fulfilled and the anchorages are designed under the responsibility of an engineer. The anchorages can be designed for static or quasi-static actions accordance with EN 1992-4 and TR 055.

Highload Anchor SZ, steel zinc plated	**10/M6**	**12/M8**	**15/M10**	**18/M12**	**24/M16**	**24/ M16L**	**28/M20**	**32/M24**
Static or quasi-static action	✓							
Seismic action (SZ-B and SZ-S)	Not covered							
Seismic action (SZ-SK)								
Fire exposure								
Highload Anchor SZ, stainless steel A4		**12/M8**	**15/M10**	**18/M12**	**24/M16**			
Static or quasi-static action		✓						
Seismic action (SZ-B and SZ-S)		Not covered						
Seismic action (SZ-SK)								
Fire exposure								

Table 1-1: Intended use for the highload anchor SZ in plain concrete **with *steel fibers.***

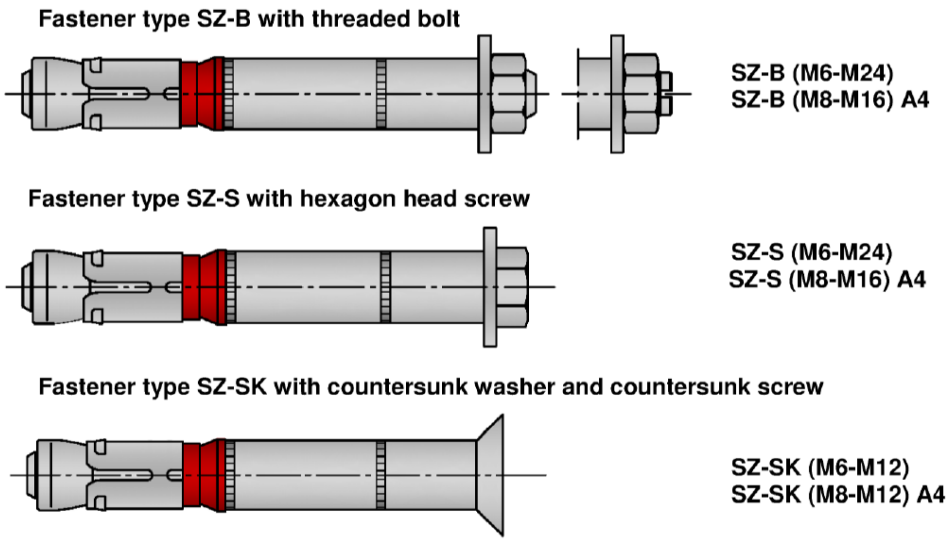


Figure 1-1: Schematic drawing of the anchors SZ for steel fiber reinforced concrete as different types SZ-B, SZ-S and SZ-SK.

2 Description of the product

2.1 Installed anchors

The anchor is installed properly if the embedment depth is at least the required one and the installation torque could be fully applied to the anchor. The anchor length must comply with the necessary embedment depth h_{ef} and the defined thickness of fixture t_{fix}.

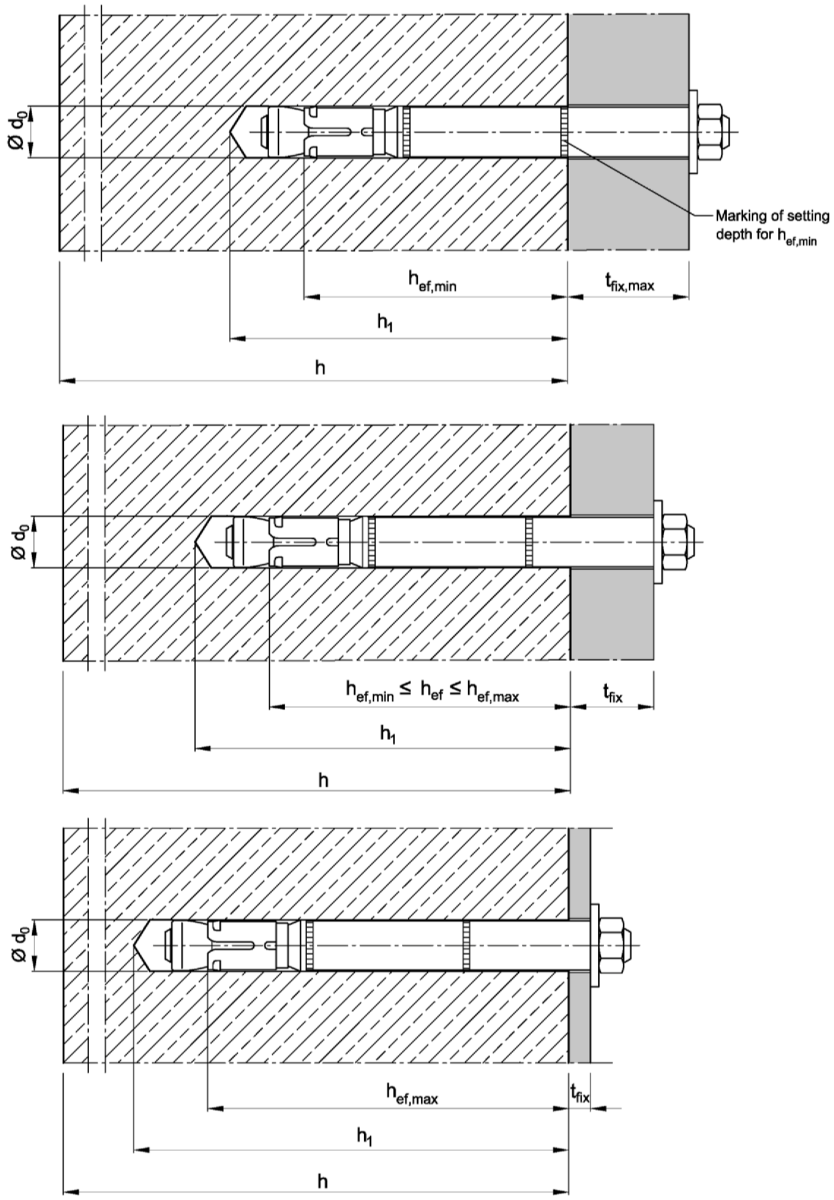


Figure 2-1: Example of an installation situation and nomenclature of the dimension after installation ***in steel fiber reinforced concrete****.*

2.2 Parts and materials

The product consists of several parts. These parts are given in figure 2-2 and the nomenclature is summarized in Table 2-1.

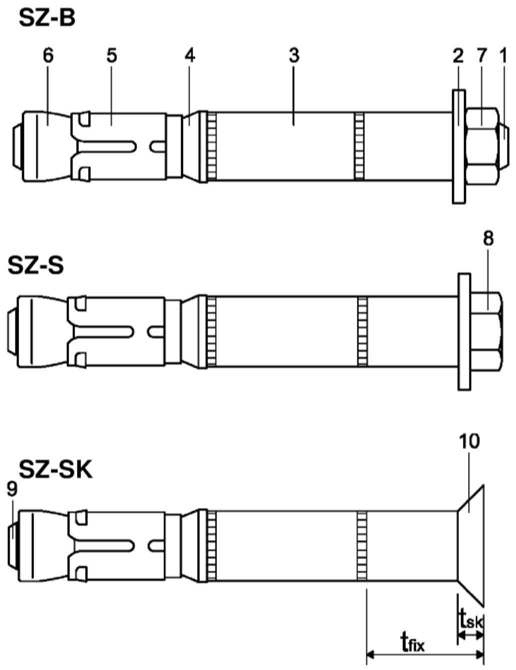


Figure 2-2: Drawing of the MKT anchor system SZ and single parts of an anchor.

Part	Designation	Materials galvanized ≥ 5 µm, acc. to EN ISO 4042:1999	Stainless steel A4
1	Threaded bolt	Steel, Strength class 8.8, EN ISO 898-1:2013	Stainless steel, 1.4401, 1.4404 or 1.4571, EN 10088:2014
2	Washer	Steel, EN 10139:2016	Stainless steel, EN 10088:2014
3	Distance sleeve	Steel tube EN 10305-2:2016, EN 10305-3:2016;	Steel tube stainless steel, 1.4401, 1.4404 or 1.4571; EN 10217-7:2014, EN 10216-5:2013
4	Ring	Polyethylene	Polyethylene
5	Expansion sleeve	Steel, EN 10139:2016	Stainless steel, 1.4401, 1.4404 or 1.4571, EN 10088:2014
6	Threaded cone	Steel EN 10083-2:2006	Stainless steel, 1.4401, 1.4404 or 1.4571, EN 10088:2014
7	Hexagon nut	Steel, Strength class 8, EN ISO 898-2:2012	Stainless steel, strength class 70, EN ISO 3506-2:2009
8	Hexagon head screw	Steel, Strength class 8.8, EN ISO 898-1:2013	Stainless steel, strength class 70, EN ISO 3506-1:2009
9	Countersunk screw	Steel, Strength class 8.8, EN ISO 898-1:2013	Stainless steel, strength class 70, EN ISO 3506-1:2009
10	Countersunk washer	Steel, EN 10083-2:2006	Stainless steel, 1.4401, 1.4404 or 1.4571, EN 10088:2014, zinc plated

*Table 2-1: Nomenclature of the different parts of the MKT anchor system SZ and materials definitions of the single parts of an anchor used for **steel fiber reinforced concrete**.*

3 Installation of the product

Before the anchor is installed in the drilled borehole, dust and debris must be removed from the hole using a hand pump, compressed air or a vacuum cleaner. The anchor must be driven into the predrilled hole using a hammer until the nominal embedment depth is achieved. The anchor is tightened until the specified installation torque moment (T_{inst}) is achieved.

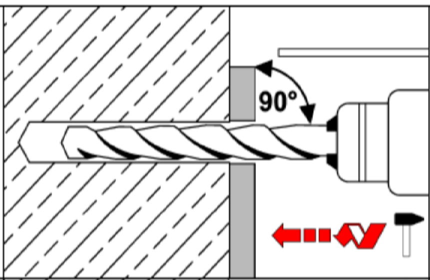
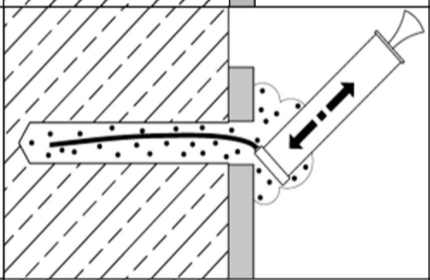
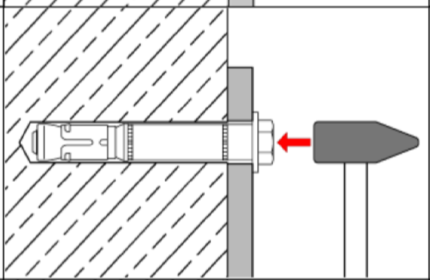
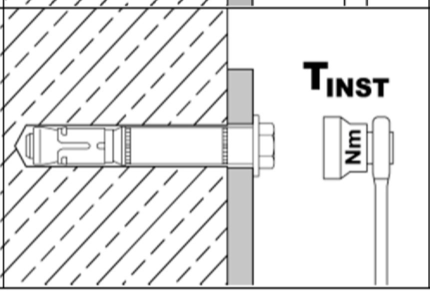
1		Drill hole perpendicular to concrete surface. If using a vacuum drill bit, proceed with step 3.
2		Blow out dust. Alternatively vacuum clean down to the bottom of the hole.
3		Drive in fastener.
4		Apply installation torque T_{inst} by using calibrated torque wrench.

Figure 3-1: Installation instruction by the manufacturer ***in steel fiber reinforced concrete****.*

Fastener size			10/M6	12/M8	15/M10	18/M12	24/M16	24/ M16L	28/M20	32/M24
Size of thread		[-]	M6	M8	M10	M12	M16	M16	M20	M24
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	50	60	71	80	100	115	125	150
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	76	100	110	130	114	150	185	210
Nominal diameter of drill bit	$d_0 =$	[mm]	10	12	15	18	24	24	28	32
Cutting diameter of drill bit	$d_{cut} \leq$	[mm]	10,45	12,5	15,5	18,5	24,55	24,55	28,55	32,7
Depth of drill hole	$h_1 \geq$	[mm]	h_{ef} + 15	h_{ef} + 20	h_{ef} + 25	h_{ef} + 25	h_{ef} + 30	h_{ef} + 30	h_{ef} + 35	h_{ef} + 30
Diameter of clearance hole in the fixture	$d_f \leq$	[mm]	12	14	17	20	26	26	31	35
Thickness of countersunk washer SZ-SK	t_{sk}	[mm]	4	5	6	7	-	-	-	-
Minimum thickness of fixture SZ-SK	$t_{fix\ min}$ 2)	[mm]	8	10	14	18	-	-	-	-
Installation torque	T_{inst} (SZ-B, SZ-S)	[Nm]	15	30	50	80	160	160	280	280
	T_{inst} (SZ-SK)	[Nm]	10	25	55	70	-	-	-	-
Minimum thickness of member	h_{min}	[mm]	h_{ef} + 50	h_{ef} + 60	h_{ef} +69	h_{ef} + 80	h_{ef} + 100	h_{ef} + 115	h_{ef} + 125	h_{ef} + 150
Minimum spacing 1) 3)	s_{min}	[mm]	50	50	60	70	100	100	125	150
cracked concrete	for $c \geq$	[mm]	50	80	120	140	180	180	300	300
Minimum edge distance 1) 3)	c_{min}	[mm]	50	55	60	70	100	100	180	150
cracked concrete	for $s \geq$	[mm]	50	100	120	160	220	220	540	300
Minimum spacing 1) 3)	s_{min}	[mm]	50	60	60	70	100	100	125	150
uncracked concrete	for $c \geq$	[mm]	80	100	120	140	180	180	300	300
Minimum edge distance 1) 3)	c_{min}	[mm]	50	60	60	70	100	100	180	150
uncracked concrete	for $s \geq$	[mm]	100	120	120	160	220	220	540	300

1) 2) 3) footnote see table 3-2

Table 3-1: Installation parameters for the different anchor sizes of the MKT anchor system SZ made of gvz-steel ***in steel fiber reinforced concrete****.*

Fastener size			12/M8	15/M10	18/M12	24/M16
Size of thread		[-]	M8	M10	M12	M16
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	60	71	80	100
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	100	110	130	150
Nominal diameter of drill bit	$d_0 =$	[mm]	12	15	18	24
Cutting diameter of drill bit	$d_{cut} \leq$	[mm]	12,5	15,5	18,5	24,55
Depth of drill hole	$h_1 \geq$	[mm]	h_{ef} + 20	h_{ef} + 25	h_{ef} + 25	h_{ef} + 30
Diameter of clearance hole in the fixture	$d_f \leq$	[mm]	14	17	20	26
Thickness of countersunk washer SZ-SK	t_{sk}	[mm]	5	6	7	-
Minimum thickness of fixture SZ-SK	$t_{fix\,min}$ 2)	[mm]	10	14	18	-
Installation torque	T_{inst} (SZ-B)	[Nm]	35	55	90	170
	T_{inst} (SZ-S)	[Nm]	30	50	80	170
	T_{inst} (SZ-SK)	[Nm]	17,5	42,5	50	-
Minimum thickness of member	h_{min}	[mm]	h_{ef} + 60	h_{ef} + 69	h_{ef} + 80	h_{ef} + 100
Minimum spacing 1) 3)	s_{min}	[mm]	50	60	70	80
cracked concrete	for $c \geq$	[mm]	80	120	140	180
Minimum edge distance 1) 3)	c_{min}	[mm]	50	60	70	80
cracked concrete	for $s \geq$	[mm]	80	120	160	200
Minimum spacing 1) 3)	s_{min}	[mm]	50	60	70	80
uncracked concrete	for $c \geq$	[mm]	80	120	140	180
Minimum edge distance 1) 3)	c_{min}	[mm]	50	85	70	180
uncracked concrete	for $s \geq$	[mm]	80	185	160	80

1) intermediate values by linear interpolation
2) Depending on the existing shear load, the thickness of the fixture may be reduced to the thickness of the countersunk washer tfix. It must be verified that the present shear load can be transferred completely into the distance sleeve (bearing of hole).
3) For fire exposure from more than one side $c \geq 300$ mm or $c_{min} \geq 300$ mm applies.

Table 3-2: Installation parameters for the different anchor sizes of the MKT anchor system SZ made of A4-steel ***in steel fiber reinforced concrete****.*

4 Performance of the product in fiber reinforced concrete

4.1 Design resistance under tension loading

The design of the anchors is carried out under the responsibility of an engineer experienced in the field of fastening technology and concrete construction. Verifiable calculations and construction drawings shall be prepared. The design for static and quasi static tensile loads is carried out in accordance with EN 1992-4 in conjunction with TR 055.

Fastener size			**10/M6**	**12/M8**	**15/M10**	**18/M12**	**24/M16**	**24/ M16L**	**28/M20**	**32/M24**
Installation factor	γ_{inst}	[-]	1,0							
Steel failure										
Characteristic resistance	$N_{Rk,s}$	[kN]	16	29	46	67	126	126	196	282
Partial factor	γ_{Ms}	[-]	1,5							
Pull-out failure										
Characteristic resistance in cracked concrete C20/25	$N_{Rk,p}$	[kN]	5	12	16	25	36	44	50	65
Increasing factor for $N_{Rk,p}$	ψ_C	[-]	$\left(\frac{f_{ck}}{20}\right)^{0,5}$							
Concrete cone failure										
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	50	60	71	80	100	115	125	150
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	76	100	110	130	114	150	185	210
Factor for cracked concrete	$k_1 = k_{cr,N}$	[-]	7,7							

Table 4-1: Product performance for anchors made of gvz steel in ***fiber reinforced concrete (cracked).***

Fastener size			**12/M8**	**15/M10**	**18/M12**	**24/M16**
Installation factor	γ_{inst}	[-]	1,0			
Steel failure						
SZ-B						
Characteristic resistance	$N_{Rk,s}$	[kN]	26	41	60	110
Partial factor	γ_{Ms}	[-]	1,5			
SZ-S and SZ-SK						
Characteristic resistance	$N_{Rk,s}$	[kN]	26	41	60	110
Partial factor	γ_{Ms}	[-]	1,87			
Pull-out failure						
Characteristic resistance in cracked concrete C20/25	$N_{Rk,p}$	[kN]	9	16	25	36
Increasing factor for $N_{Rk,p}$	ψ_C	[-]	$\left(\frac{f_{ck}}{20}\right)^{0,5}$			
Concrete cone failure						
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	60	71	80	100
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	100	110	130	150
Factor for cracked concrete	$k_1 = k_{cr,N}$	[-]	7,7			

Table 4-2: Product performance for anchors made of stainless steel in ***fiber reinforced concrete (cracked)****.*

Fastener size			10/M6	12/M8	15/M10	18/M12	24/M16	24/ M16L	28/M20	32/M24
Installation factor	γ_{inst}	[-]	1,0							
Steel failure										
Characteristic resistance	$N_{Rk,s}$	[kN]	16	29	46	67	126	126	196	282
Partial factor	γ_{Ms}	[-]	1,5							
Pull-out failure										
Characteristic resistance in uncracked concrete C20/25	$N_{Rk,p}$	[kN]	17	20	30	36	50	1)	70	1)
Increasing factor for $N_{Rk,p}$	ψ_C	[-]	$\left(\frac{f_{ck}}{20}\right)^{0,5}$					-	$\left(\frac{f_{ck}}{20}\right)^{0,5}$	-
Splitting failure (The higher resistance of case 1 and case 2 may be applied)										
Case 1										
Characteristic resistance in uncracked concrete C20/25	$N^0_{Rk,sp}$	[kN]	12	16	25	30	40	70	50	70
Edge distance	$c_{cr,sp}$	[mm]	1,5 h_{ef}							
Increasing factor for $N^0_{Rk,sp}$	ψ_C	[-]	$\left(\frac{f_{ck}}{20}\right)^{0,5}$							
Case 2										
Characteristic resistance in uncracked concrete	$N^0_{Rk,sp}$	[kN]	min ($N_{Rk,p}$; $N^0_{Rk,c}$)							
Edge distance	$c_{cr,sp}$	[mm]	2,5 h_{ef}					1,5 h_{ef}	2,5 h_{ef}	2 h_{ef}
Concrete cone failure										
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	50	60	71	80	100	115	125	150
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	76	100	110	130	114	150	185	210
Edge distance	$c_{cr,N}$	[mm]	1,5 h_{ef}							
Factor for uncracked concrete	$k_1 = k_{ucr,N}$	[-]	11,0							

1) $N_{Rk,p} = N^0_{Rk,c}$ calculated with $h_{ef,min}$

*Table 4-3: Product performance for anchors made of gvz steel in **fiber reinforced concrete (uncracked)**.*

Fastener size			12/M8	15/M10	18/M12	24/M16
Installation factor	γ_{inst}	[-]	1,0			
Steel failure						
SZ-B						
Characteristic resistance	$N_{Rk,s}$	[kN]	26	41	60	110
Partial factor	γ_{Ms}	[-]	1,5			
SZ-S and SZ-SK						
Characteristic resistance	$N_{Rk,s}$	[kN]	26	41	60	110
Partial factor	γ_{Ms}	[-]	1,87			
Pull-out failure						
Characteristic resistance in uncracked concrete C20/25	$N_{Rk,p}$	[kN]	16	25	35	50
Increasing factor for $N_{Rk,p}$	ψ_C	[-]	$\left(\frac{f_{ck}}{20}\right)^{0,5}$			
Splitting failure						
Edge distance	$c_{cr,sp}$	[mm]	180	235	265	300
Concrete cone failure						
Minimum effective anchorage depth	$h_{ef,min}$	[mm]	60	71	80	100
Maximum effective anchorage depth	$h_{ef,max}$	[mm]	100	110	130	150
Edge distance	$c_{cr,N}$	[mm]	1,5 h_{ef}			
Factor for uncracked concrete	$k_1 = k_{ucr,N}$	[-]	11,0			

*Table 4-4: Product performance for anchors made of stainless steel in **fiber reinforced concrete (uncracked)**.*

4.2 Design resistance under shear loading

The design for static and quasi static shear loads is carried out in accordance with EN 1992-4 in conjunction with TR 055.

Fastener size			10/M6	12/M8	15/M10	18/M12	24/M16	24/ M16L	28/M20	32/M24
Steel failure without lever arm										
SZ-B										
Characteristic resistance	$V^0_{Rk,s}$	[kN]	16	25	36	63	91	91	122	200
Ductility factor	k_7	[-]	1,0							
SZ-S and SZ-SK										
Characteristic resistance	$V^0_{Rk,s}$	[kN]	18	30	48	73	126	126	150	200
Ductility factor	k_7	[-]	1,0							
Partial factor	γ_{Ms}	[-]	1,25							
Steel failure with lever arm										
Characteristic resistance	$M^0_{Rk,s}$	[Nm]	12	30	60	105	266	266	519	898
Partial factor	γ_{Ms}	[-]	1,25							
Concrete pry-out failure										
Pry-out factor	k_8	[-]	1,8 [1)]	2,0						
Concrete edge failure										
Effective length of fastener in shear loading	l_f	[mm]	h_{ef}							
Outside diameter of fastener	d_{nom}	[mm]	10	12	15	18	24	24	28	32

[1)] $k_8 = 2{,}0$ for $h_{ef} \geq 60$ mm

Table 4-5: Product performance for anchors made of gvz steel in ***fiber reinforced concrete (cracked and uncracked)****.*

Fastener size			12/M8	15/M10	18/M12	24/M16
Steel failure without lever arm						
Characteristic resistance	$V^0_{Rk,s}$	[kN]	24	37	62	92
SZ-B						
Ductility factor	k_7	[-]	1,0			
Partial factor	γ_{Ms}	[-]	1,25			
SZ-S						
Ductility factor	k_7	[-]	1,0			
Partial factor	γ_{Ms}	[-]	1,36			
SZ-SK						
Ductility factor	k_7	[-]	0,8			-
Partial factor	γ_{Ms}	[-]	1,36			-
Steel failure with lever arm						
Characteristic bending resistance	$M^0_{Rk,s}$	[Nm]	26	52	92	232
SZ-B						
Partial factor	γ_{Ms}	[-]	1,25			
SZ-S and SZ-SK						
Partial factor	γ_{Ms}	[-]	1,56			
Concrete pry-out failure						
Pry-out factor	k_8	[-]	2,0			
Concrete edge failure						
Effective length of fastener in shear loading	l_f	[mm]	h_{ef}			
Outside diameter of fastener	d_{nom}	[mm]	12	15	18	24

Table 4-6: Product performance for anchors made of stainless steel in ***fiber reinforced concrete (cracked and uncracked)****.*

4.3 Displacements

Table 4-7 and table 4-8 summarizes the displacements that shall be taken into account in the design. The displacements are valid for gvz- and A4- anchors in concrete with and without steel fibers. The displacements must be accounted for in case of static and quasi static loads under tensile loading and shear loading.

Fastener size			10/ M6	12/ M8	15/ M10	18/ M12	24/ M16	24 /M16L	28/ M20	32/ M24
Tension load										
Tension load in cracked concrete	N	[kN]	2,4	5,7	7,6	12,3	17,1	21,1	24	26,2
Displacement	δ_{N0}	[mm]	0,5	0,5	0,5	0,7	0,8	0,7	0,9	1,4
	$\delta_{N\infty}$	[mm]	2,0	2,0	1,3	1,3	1,3	1,3	1,4	1,9
Tension load in uncracked concrete	N	[kN]	8,5	9,5	14,3	17,2	24	29,6	34	43
Displacement	δ_{N0}	[mm]	0,8	1,0	1,1			1,3	0,3	0,7
	$\delta_{N\infty}$	[mm]	3,4		1,7			2,3	1,4	0,7
Shear load										
SZ-B										
Shear load in cracked and uncracked concrete	V	[kN]	9,1	14	20,7	35,1	52,1	52,1	77	86,6
Displacement	δ_{V0}	[mm]	2,5	2,1	2,7	3,0	5,1	5,1	4,3	10,5
	$\delta_{V\infty}$	[mm]	3,8	3,1	4,1	4,5	7,6	7,6	6,5	15,8
SZ-S										
Shear load in cracked and uncracked concrete	V	[kN]	10,1	17,1	27,5	41,5	72	72	77	86,6
Displacement	δ_{V0}	[mm]	2,9	2,5	3,6	3,5	7,0	7,0	4,3	10,5
	$\delta_{V\infty}$	[mm]	4,4	3,8	5,4	5,3	10,5	10,5	6,5	15,8
SZ-SK										
Shear load in cracked and uncracked concrete	V	[kN]	10,1	17,1	27,5	41,5	-	-	-	-
Displacement	δ_{V0}	[mm]	2,9	2,5	3,6	3,5	-	-	-	-
	$\delta_{V\infty}$	[mm]	4,4	3,8	5,4	5,3	-	-	-	-

*Table 4-7: Displacements for the MKT anchor SZ made of gvz- and A4-Stahl in **steel fibre reinforcement (tension loading)**.*

Fastener size			12/M8	15/M10	18/M12	24/M16
Tension load						
Tension load in cracked concrete	N	[kN]	4,3	7,6	12,1	17,0
Displacement	δ_{N0}	[mm]	0,5	0,5	1,3	0,5
	$\delta_{N\infty}$	[mm]	1,2	1,6	1,8	1,6
Tension load in uncracked concrete	N	[kN]	7,6	11,9	16,7	24,1
Displacement	δ_{N0}	[mm]	0,2	0,3	1,2	1,5
	$\delta_{N\infty}$	[mm]	1,1	1,1	1,1	1,1
Shear load						
Shear load in cracked concrete	V	[kN]	13,9	21,1	34,7	50,8
Displacement	δ_{V0}	[mm]	3,4	4,9	4,8	6,7
	$\delta_{V\infty}$	[mm]	5,1	7,4	7,1	10,1

*Table 4-8: Displacements for the MKT anchor SZ made of A4-Stahl in **steel fibre reinforcement (shear loading)**.*