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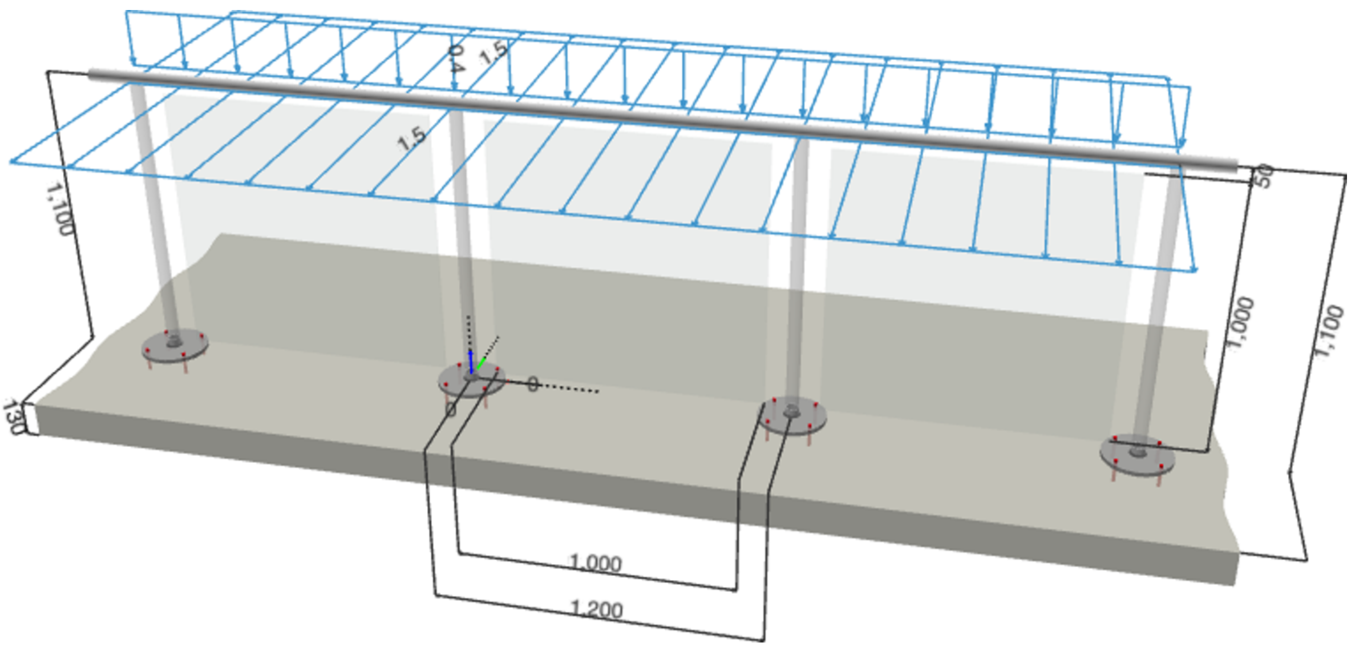
Specifier's comments:

1 Geometry and Application

Handrail construction

Handrail application	concrete plate with a baseplate on the top side
Load category type	loads for public areas.
System	statical system with multiple spans
Environment	Inside
Post distance	1,200.0 [mm]
Height of handrail	1,100.0 [mm] Caution: You need to check this value against your regulations.
Post profile	Pipe, RO 48.3x3 (EN 10219-2)
Rail profile	Pipe, RO 48.3x3 (EN 10219-2)



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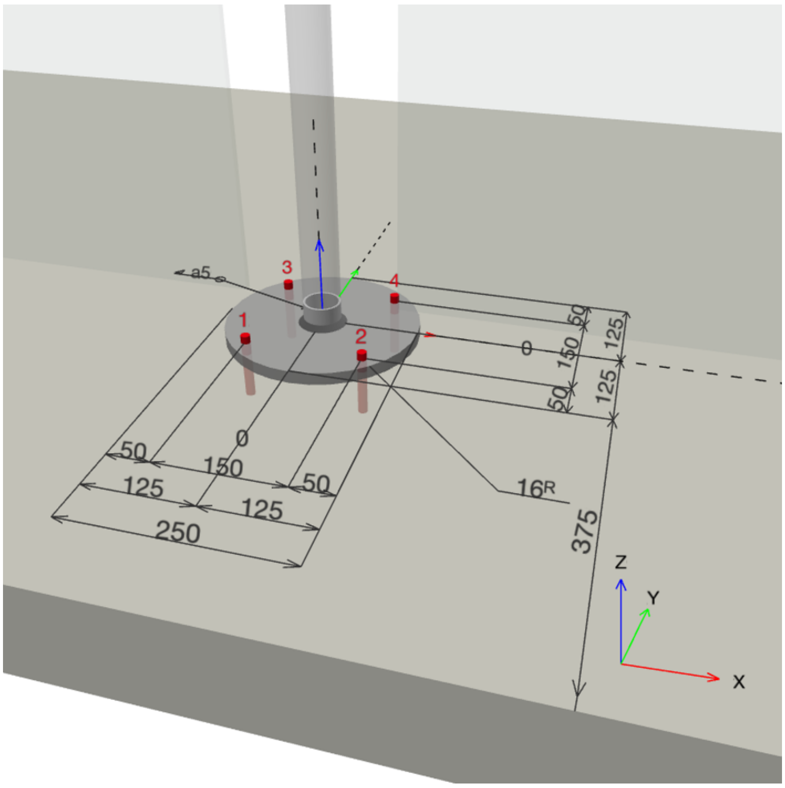
2 Handrail fastening details



For the design below, we refer to the following documents:

- EN 1990: Basis of structural design and EN 1991-1-1: Densities, self-weight, imposed loads for buildings
- German guideline for steel companies, Bundesverband Metall
- ETB-Guideline - Safe constructions for fall protection

Moreover, the following has to be taken into account

- The proof of the steel construction is not part of this calculation and must be done separately.
- The user is responsible to check the result of the design including load combinations.

3 Loads

3.1 Dead load

Dead load (inkl. post, rail, cladding and flower box)	g = 0.40 [kN/m]

3.2 Handrail loads (BS EN 1991-1-1 2002, NA)

Horizontal line load, inwards	$q_{h,i}$ = 1.50 [kN/m]
Height of horizontal line load, inwards	$h_{h,i}$ = 1,100.0 [mm]
Horizontal line load, outwards	$q_{h,o}$ = 1.50 [kN/m]
Height of horizontal line load, outwards	$h_{h,o}$ = 1,100.0 [mm]

4 Load combinations

4.1 Ultimate Limit State (ULS)

Load case	Direction	Loads	Load, combination and safety factors
1.1 -i/-o	in + out	dead load + horizontal	$\gamma_{g,sup} \cdot g + \gamma_{q,h} \cdot q_h$
1.2 -i/-o	in + out	dead load + horizontal	$\gamma_{g,inf} \cdot g + \gamma_{q,h} \cdot q_h$
2.1 -i/-o	in + out	dead load + horizontal + vertical	$\gamma_{g,sup} \cdot g + \gamma_{q,h} \cdot q_h + \gamma_{q,v} \cdot q_v$
2.2 -i/-o	in + out	dead load + horizontal + vertical	$\gamma_{g,inf} \cdot g + \gamma_{q,h} \cdot q_h + \gamma_{q,v} \cdot q_v$
5.3.1 -i/-o	in + out	dead load	$\gamma_{g,sup} \cdot g$
6.1		dead load + vertical	$\gamma_{g,sup} \cdot g + \gamma_{q,v} \cdot q_v$
6.2		dead load + vertical	$\gamma_{g,inf} \cdot g + \gamma_{q,v} \cdot q_v$

4.2 Serviceability Limit State (SLS)

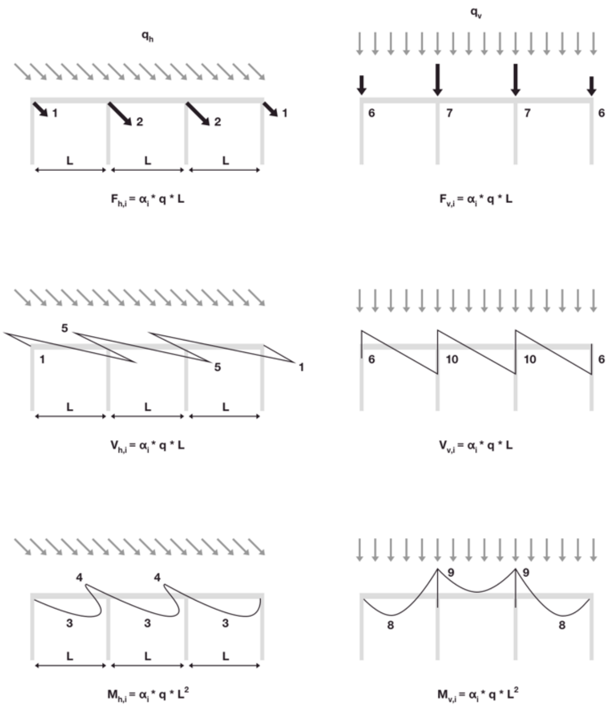
Load case	Direction	Loads	Load, combination and safety factors
SLS	Out	dead load + horizontal + vertical	$1.0 \cdot g + 1.0 \cdot q_h + \psi_{0,v} \cdot 1.0 \cdot q_v$

4.3 Partial safety factors and combination factors

Dead loads:	$\gamma_{g,sup}$	= 1.350
	$\gamma_{g,inf}$	= 1.000
Variable horizontal loads:	$\gamma_{q,h}$	= 1.500
	$\psi_{0,h}$	= 0.700
Variable vertical loads:	$\gamma_{q,v}$	= 1.500
	$\psi_{0,v}$	= 0.700

5 Post and horizontal handrail member loading coefficients

Statical system with multiple spans



5.1 Distribution of horizontal line loads

Stiffness constant: C = 54.41 [kN/m]
Post distance: e_p = 1,200.0 [mm]

α_1	α_2	α_3	α_4	α_5
-	1.067	0.180	0.071	0.532

5.2 Distribution of vertical line loads (selfweight of profile)

α_6	α_7	α_8	α_9	α_{10}
-	1.200	0.101	0.121	0.621

6 Design results

6.1 Overview

	Governing LC	Max. Utilisation	Status
Anchor Design	2.2-o	80	OK

6.2 Anchor Verifications

Load combinations (loads acting at the baseplate in the centre of gravity of the profile)

Load combinations	Forces [kN] / Moments [kNm]						Max. Util. Anchor [%]
1.1-i	V_x = 0.000;	V_y = 2.882;	N = -0.778;	M_x = -3.124;	M_y = 0.000;	M_z = 0.000	79
1.2-i	V_x = 0.000;	V_y = 2.882;	N = -0.576;	M_x = -3.124;	M_y = 0.000;	M_z = 0.000	80
2.1-i	V_x = 0.000;	V_y = 2.882;	N = -0.778;	M_x = -3.124;	M_y = 0.000;	M_z = 0.000	79
2.2-i	V_x = 0.000;	V_y = 2.882;	N = -0.576;	M_x = -3.124;	M_y = 0.000;	M_z = 0.000	80
5.3.1-i	V_x = 0.000;	V_y = 0.000;	N = -0.778;	M_x = 0.000;	M_y = 0.000;	M_z = 0.000	-
1.1-o	V_x = 0.000;	V_y = -2.882;	N = -0.778;	M_x = 3.124;	M_y = 0.000;	M_z = 0.000	79
1.2-o	V_x = 0.000;	V_y = -2.882;	N = -0.576;	M_x = 3.124;	M_y = 0.000;	M_z = 0.000	80
2.1-o	V_x = 0.000;	V_y = -2.882;	N = -0.778;	M_x = 3.124;	M_y = 0.000;	M_z = 0.000	79
2.2-o	V_x = 0.000;	V_y = -2.882;	N = -0.576;	M_x = 3.124;	M_y = 0.000;	M_z = 0.000	80
5.3.1-o	V_x = 0.000;	V_y = 0.000;	N = -0.778;	M_x = 0.000;	M_y = 0.000;	M_z = 0.000	-
6.1	V_x = 0.000;	V_y = 0.000;	N = -0.778;	M_x = 0.000;	M_y = 0.000;	M_z = 0.000	-
6.2	V_x = 0.000;	V_y = 0.000;	N = -0.576;	M_x = 0.000;	M_y = 0.000;	M_z = 0.000	-

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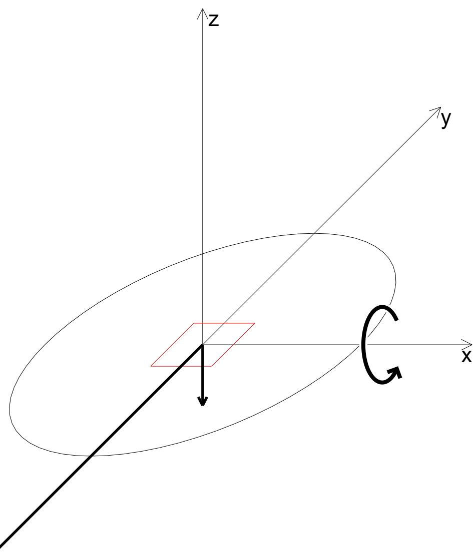
6.2.1 Input data

Anchor type and size:	**HIT-HY 200-A + HIT-Z 100 Years M12**
Return period (service life in years):	100
Item number:	2018411 HIT-Z M12x105 (insert) / 2022696 HIT-HY 200-A (mortar)
Effective embedment depth:	$h_{ef,opti}$ = 60.0 mm ($h_{ef,limit}$ = 70.0 mm)
Material:	DIN EN ISO 4042
Approval No.:	ETA 12/0006
Issued I Valid:	28/10/2020 | -
Proof:	Design Method Extended EN 1992-4, Mechanical
Stand-off installation:	e_b = 0.0 mm (no stand-off); t = 16.0 mm
Baseplate^R :	l_x x l_y x t = 250.0 mm x 250.0 mm x 16.0 mm; (Recommended plate thickness: not calculated)
Profile:	Pipe, RO 48.3x3 (EN 10219-2); (L x W x T) = 48.3 mm x 48.3 mm x 3.0 mm
Base material:	cracked concrete, C25/30, $f_{c,cyl}$ = 25.00 N/mm^2; h = 130.0 mm, Temp. short/long: 40/24 °C, partial material safety factor γ_c = 1.500
Installation:	**hammer drilled hole, Installation condition: Dry**
Reinforcement:	No reinforcement or Reinforcement spacing >= 150 mm (any Ø) or >= 100 mm (Ø <= 10 mm)
	no longitudinal edge reinforcement

^{R} - The anchor calculation is based on a rigid baseplate assumption.

Geometry [mm] & Loading [kN, kNm]



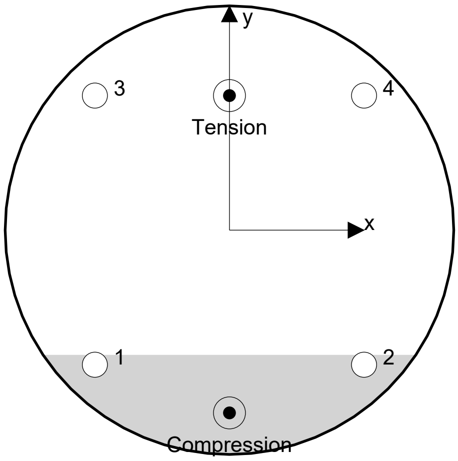
Schematic sketch of baseplate and profile!

Design loads (Load combination 2.2-o)

	Loading
N	0.576
V_x	0.000
V_y	2.882
M_z	0.000
M_x	3.124
M_y	0.000

Eccentricity (structural section) [mm]
e_x = 0.0; e_y = 0.0

6.2.2 Load case/Resulting anchor forces



Anchor reactions [kN]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	0.000	0.720	0.000	-0.720
2	0.000	0.720	0.000	-0.720
3	8.666	0.720	0.000	-0.720
4	8.666	0.720	0.000	-0.720

max. concrete compressive strain: 0.18 [‰]
max. concrete compressive stress: 5.54 [N/mm^2]
resulting tension force in (x/y)=(0.0/75.0): 17.332 [kN]
resulting compression force in (x/y)=(-0.0/-101.8): 17.908 [kN]

Anchor forces are calculated based on the assumption of a rigid baseplate.

6.2.3 Tension load (EN 1992-4, Section 7.2.1)

	Load [kN]	Capacity [kN]	Utilization β_N [%]	Status
Steel failure*	8.666	36.667	24	OK
Pull-out failure*	8.666	32.000	28	OK
Concrete Breakout failure**	17.332	21.869	80	OK
Splitting failure**	N/A	N/A	N/A	N/A

* highest loaded anchor **anchor group (anchors in tension)

6.2.3.1 Steel failure

$$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{M,s}}$$ EN 1992-4, Table 7.1

$N_{Rk,s}$ [kN]	$\gamma_{M,s}$	$N_{Rd,s}$ [kN]	N_{Ed} [kN]
55.000	1.500	36.667	8.666

6.2.3.2 Pull-out failure

$$N_{Ed} \leq N_{Rd,p} = \frac{\psi_c \cdot N_{Rk,p}}{\gamma_{M,p}}$$ EN 1992-4, Table 7.1

$N_{Rk,p}$ [kN]	ψ_c	$\gamma_{M,p}$	$N_{Rd,p}$ [kN]	N_{Ed} [kN]
48.000	1.000	1.500	32.000	8.666

6.2.3.3 Concrete Breakout failure

$$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{M,c}}$$ EN 1992-4, Table 7.1

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$$ EN 1992-4, Eq. (7.1)

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$$ EN 1992-4, Eq. (7.2)

$$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$$ EN 1992-4, Eq. (7.3)

$$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$$ EN 1992-4, Eq. (7.4)

$$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,N}}\right)} \leq 1.00$$ EN 1992-4, Eq. (7.6)

$$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,N}}\right)} \leq 1.00$$ EN 1992-4, Eq. (7.6)

$$\psi_{M,N} = 1$$ EN 1992-4, Eq. (7.7)

$A_{c,N}$ [mm^2]	$A^0_{c,N}$ [mm^2]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	$f_{c,cyl}$ [N/mm^2]
59,400	32,400	90.0	180.0	25.00

$e_{c1,N}$ [mm]	$\psi_{ec1,N}$	$e_{c2,N}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$
0.0	1.000	0.0	1.000	1.000	1.000

z [mm]	$\psi_{M,N}$	k_1	$N^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]
176.8	1.000	7.700	17.893	1.500	21.869	17.332

6.2.4 Shear load (EN 1992-4, Section 7.2.2)

	Load [kN]	Capacity [kN]	Utilization β_V [%]	Status
Steel failure (without lever arm)*	0.720	21.600	4	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout failure**	2.882	117.074	3	OK
Concrete edge failure in direction y-**	2.882	33.622	9	OK

* highest loaded anchor **anchor group (relevant anchors)

6.2.4.1 Steel failure (without lever arm)

$$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{M,s}}$$ EN 1992-4, Table 7.2

$$V_{Rk,s} = k_7 \cdot V^0_{Rk,s}$$ EN 1992-4, Eq. (7.35)

$V^0_{Rk,s}$ [kN]	k_7	$V_{Rk,s}$ [kN]	$\gamma_{M,s}$	$V_{Rd,s}$ [kN]	V_{Ed} [kN]
27.000	1.000	27.000	1.250	21.600	0.720

6.2.4.2 Pryout failure

$$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{M,c,p}}$$ EN 1992-4, Table 7.2

$$V_{Rk,cp} = k_8 \cdot N_{Rk,c}$$ EN 1992-4, Eq. (7.39a)

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$$ EN 1992-4, Eq. (7.1)

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$$ EN 1992-4, Eq. (7.2)

$$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$$ EN 1992-4, Eq. (7.3)

$$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$$ EN 1992-4, Eq. (7.4)

$$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,1}}{s_{cr,N}}\right)} \leq 1.00$$ EN 1992-4, Eq. (7.6)

$$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,2}}{s_{cr,N}}\right)} \leq 1.00$$ EN 1992-4, Eq. (7.6)

$$\psi_{M,N} = 1$$ EN 1992-4, Eq. (7.7)

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	k_8	$f_{c,cyl}$ [N/mm²]
108,900	32,400	90.0	180.0	2.920	25.00

$e_{c1,V}$ [mm]	$\psi_{ec1,N}$	$e_{c2,V}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$	$\psi_{M,N}$
0.0	1.000	0.0	1.000	1.000	1.000	1.000

k_1	$N^0_{Rk,c}$ [kN]	$\gamma_{M,c,p}$	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]
7.700	17.893	1.500	117.074	2.882

6.2.4.3 Concrete edge failure in direction y-

$V_{Ed} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{M,c}}$ — EN 1992-4, Table 7.2

$V_{Rk,c} = k_T \cdot V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$ — EN 1992-4, Eq. (7.40)

$V^0_{Rk,c} = k_9 \cdot d^{\alpha}_{nom} \cdot l^{\beta}_f \cdot \sqrt{f_{ck}} \cdot c_1^{1,5}$ — EN 1992-4, Eq. (7.41)

$\alpha = 0.1 \cdot \left(\frac{l_f}{c_1}\right)^{0,5}$ — EN 1992-4, Eq. (7.42)

$\beta = 0.1 \cdot \left(\frac{d_{nom}}{c_1}\right)^{0,2}$ — EN 1992-4, Eq. (7.43)

$A^0_{c,V} = 4.5 \cdot c_1^2$ — EN 1992-4, Eq. (7.44)

$\psi_{s,V} = 0.7 + 0.3 \cdot \frac{c_2}{1.5 \cdot c_1} \leq 1.00$ — EN 1992-4, Eq. (7.45)

$\psi_{h,V} = \left(\frac{1.5 \cdot c_1}{h}\right)^{0,5} \geq 1.00$ — EN 1992-4, Eq. (7.46)

$\psi_{ec,V} = \frac{1}{1 + \left(\frac{2 \cdot e_V}{3 \cdot c_1}\right)} \leq 1.00$ — EN 1992-4, Eq. (7.47)

$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos \alpha_V)^2 + (0.5 \cdot \sin \alpha_V)^2}} \geq 1.00$ — EN 1992-4, Eq. (7.48)

l_f [mm]	d_{nom} [mm]	k_9	α	β	$f_{c,cyl}$ [N/mm^2]
60.0	12.00	1.700	0.038	0.049	25.00

c_1 [mm]	$A_{c,V}$ [mm^2]	$A^0_{c,V}$ [mm^2]
425.0	185,250	812,812

$\psi_{s,V}$	$\psi_{h,V}$	$\psi_{\alpha,V}$	$e_{c,V}$ [mm]	$\psi_{ec,V}$	$\psi_{re,V}$
1.000	2.214	1.000	0.0	1.000	1.000

$V^0_{Rk,c}$ [kN]	k_T	$\gamma_{M,c}$	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
99.925	1.0	1.500	33.622	2.882

6.2.5 Combined tension and shear loads (EN 1992-4, Section 7.2.3)

Steel failure

β_N	β_V	α	Utilization $\beta_{N,V}$ [%]	Status
0.236	0.033	2.000	6	OK

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

Concrete failure

β_N	β_V	α	Utilization $\beta_{N,V}$ [%]	Status
0.793	0.086	1.500	74	OK

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

6.2.6 Displacements (highest loaded anchor)

Short term loading:

N_{Sk} = 0.000 [kN] δ_N = - [mm]

V_{Sk} = 0.534 [kN] δ_V = 0.0267 [mm]

δ_{NV} = - [mm]

Long term loading:

N_{Sk} = 0.000 [kN] δ_N = - [mm]

V_{Sk} = 0.534 [kN] δ_V = 0.0427 [mm]

δ_{NV} = - [mm]

Comments: Tension displacements are valid with half of the required installation torque moment for uncracked concrete! Shear displacements are valid without friction between the concrete and the baseplate! The gap due to the drilled hole and clearance hole tolerances are not included in this calculation!

The acceptable anchor displacements depend on the fastened construction and must be defined by the designer!

6.2.7 Warnings

- The anchor design methods in PROFIS Engineering require rigid baseplates per current regulations (AS 5216:2021, ETAG 001/Annex C, EOTA TR029 etc.). This means load re-distribution on the anchors due to elastic deformations of the baseplate are not considered - the baseplate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the design loading. PROFIS Engineering calculates the minimum required baseplate thickness with CBFEM to limit the stress of the baseplate based on the assumptions explained above. The proof if the rigid baseplate assumption is valid is not carried out by PROFIS Engineering. Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Checking the transfer of loads into the base material is required in accordance with EN 1992-4, Annex A!
- The design is only valid if the clearance hole in the fixture is not larger than the value given in Table 6.1 of EN 1992-4! For larger diameters of the clearance hole see section 6.2.2 of EN 1992-4!
- The accessory list in this report is for the information of the user only. In any case, the instructions for use provided with the product have to be followed to ensure a proper installation.
- For the determination of the $\psi_{re,v}$ (concrete edge failure) the minimum concrete cover defined in the design settings is used as the concrete cover of the edge reinforcement.
- The characteristic bond resistances depend on the return period (service life in years): 100

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Fastening meets the design criteria!

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6.2.8 Installation data

Baseplate, steel: S 275; E = 210,000.00 N/mm^2; f_{yk} = 275.00 N/mm^2

Profile: Pipe, RO 48.3x3 (EN 10219-2); (L x W x T) = 48.3 mm x 48.3 mm x 3.0 mm

Hole diameter in the fixture (pre-setting) : d_f = 14.0 mm

Hole diameter in the fixture (through fastening) : d_f = 16.0 mm

Plate thickness (input): 16.0 mm

Recommended plate thickness: not calculated

Drilling method: Hammer drilled

Cleaning: No cleaning of the drilled hole is required

Anchor type and size: HIT-HY 200-A + HIT-Z 100 Years M12

Item number: 2018411 HIT-Z M12x105 (insert) / 2022696 HIT-HY 200-A (mortar)

Maximum installation torque: 40 Nm

Hole diameter in the base material: 14.0 mm

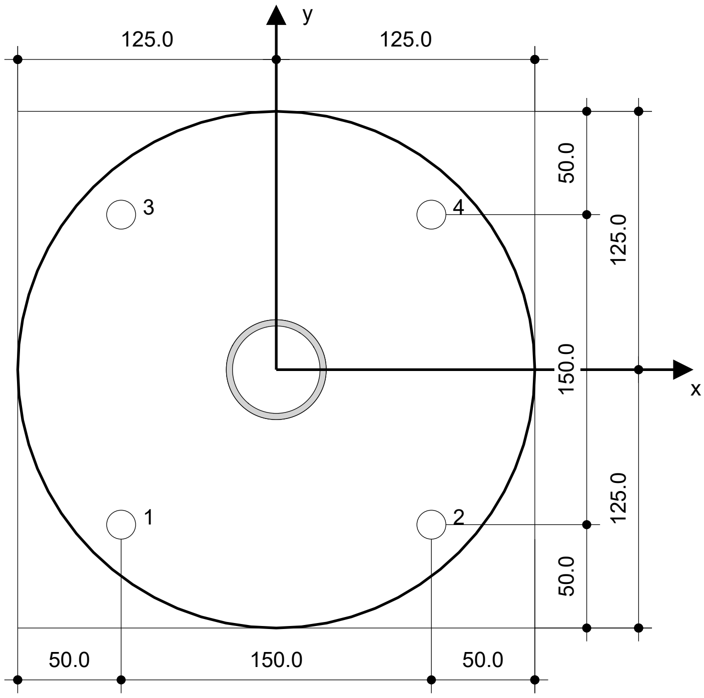
Hole depth in the base material: 90.0 mm

Minimum thickness of the base material: 120.0 mm

Hilti SAFEset HIT-Z non-cleaning bonded expansion anchor with HIT-HY 200 injection mortar with 60 mm embedment h_ef, M12, Steel galvanized, Hammer drilling installation per ETA 12/0006

6.2.8.1 Recommended accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer • Properly sized drill bit	• No accessory required	• Dispenser including cassette and mixer • Torque wrench



Coordinates Anchor [mm]

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	-75.0	-75.0	-	-	425.0	-
2	75.0	-75.0	-	-	425.0	-
3	-75.0	75.0	-	-	575.0	-
4	75.0	75.0	-	-	575.0	-

7 Remarks; Your Cooperation Duties

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- You must take all necessary and reasonable steps to prevent or limit damage caused by the Software. In particular, you must arrange for the regular backup of programs and data and, if applicable, carry out the updates of the Software offered by Hilti on a regular basis. If you do not use the AutoUpdate function of the Software, you must ensure that you are using the current and thus up-to-date version of the Software in each case by carrying out manual updates via the Hilti Website. Hilti will not be liable for consequences, such as the recovery of lost or damaged data or programs, arising from a culpable breach of duty by you.