Anstar®

Rebar bolts

User manual

Version 1/2020

Rebar bolts

Rebar bolts are used in industrial and office buildings for connecting concrete elements and steel frames to foundations and for column extensions. Connection solutions have been made for the bolts for connecting AHK® series column shoes and ASL® series wall shoes to cast-in-place foundations. The bolts can also be used to connect steel and composite columns to foundations. For designing concrete column connections, we have developed the A-COLUMN® dimensioning software. We also offer the ASTEEL software for designing steel column connections to foundations.

- The product has been tested and dimensioned to withstand demanding construction conditions
- Quick and easy dimensioning with A-COLUMN® or ASTEEL software
- Accident scenario calculation available with A-COLUMN® as first on the market
- Bolts are manufactured according to SFS-EN 1090-2:2018
- Components and blocks for both Tekla and AutoCAD software
- Extensive adjustability in worksite conditions
- Thread manufactured according to EN 898-1
- Quick alignment and installation on the site when using an MK frame
- Designed in accordance with the requirements of SFS-EN 1992-4:2018 European standards

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Revision O. June 26. 2020
Minor text editions. The representation of the durability of the erection state has been modified in Table 7.

Revision N. January 31. 2020
Rebar bolts have been calculated according to EN 1992-4:2018. Standard CEN/TS 1992-4-2 has been removed.
Chapter 4 and 5. Text has been updated.
Ultimate limit state: Concrete Cone, Blow-Out and Concrete Edge resistance values have been updated.
Accident limit state: Tension resistance values have been let a little down.
ACOLUMN® version 5.0 and ASTEEL version 2.0 has been updated to code EN 1992-4:2018.

Revision M – 31 December 2017
Instructions for using ATP® anchor bolts have been completely rewritten.
The ATP® and AHP® bolt selection have been extended.
ALP® bolts have been separated into their own manual.
Manufacture of AMP series bolts will be discontinued.
Bolt resistance values have been calculated according to CEN/TS 1992-4-2.
The new design software is ACOLUMN® for concrete column connections and ASTEEL for steel column connections.

This user manual only applies to designing and using Anstar Oy products included in this document. The manual or parts of it cannot be adapted or applied to designing other manufacturers' products or manufacturing or using concrete elements in anchor bolt connections.

1 REBAR BOLTS

Rebar bolts are used in industrial and office buildings for connecting concrete elements and steel frames to foundations and for element extensions with AHK column shoes and ASL-H wall shoes. The bolts can also be used to connect steel and composite columns as well as various steel structures and equipment to foundations. For designing concrete column connections, we have developed the ACOLUMN® software. For steel column connections, we offer the ASTEEL software.

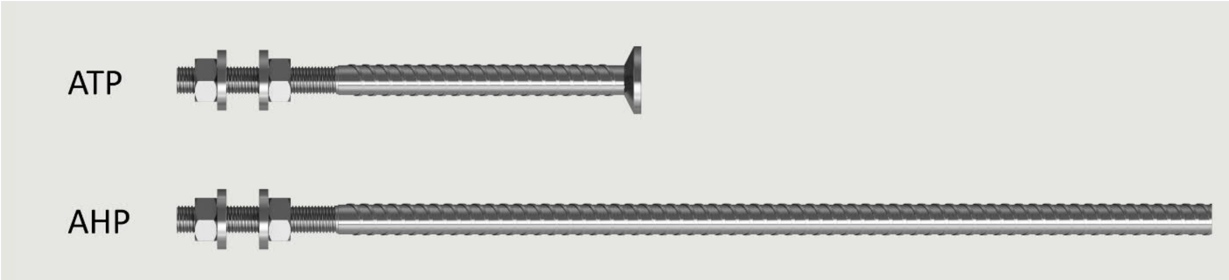


Figure 1. ATP® bolt with headed fastened anchor and AHP® bolt with rebar bond

2 BOLT APPLICATIONS

2.1 Concrete element frames of industrial buildings

Rebar bolts are used for extending light and medium-heavy concrete columns and connecting them to cast-in-situ foundations. The bolt connections can be used to transfer axial and shear forces and bending moments. More information is available in the user manual for AHK® shoes: AHK® Column shoes.

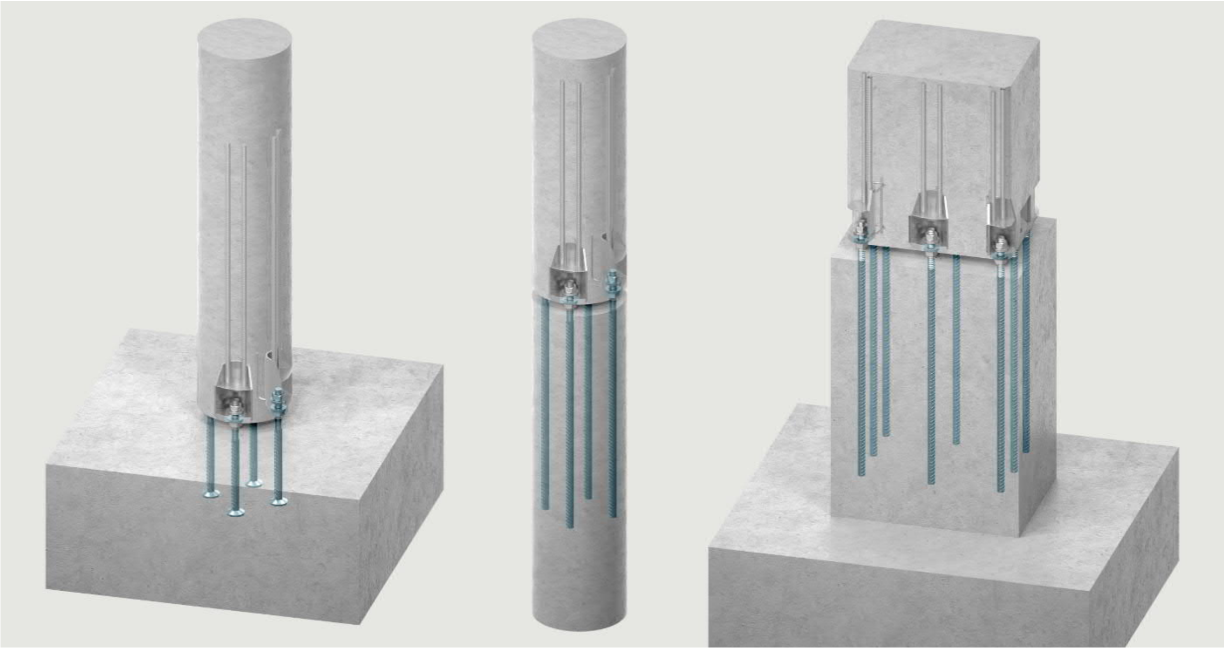


Figure 2. Rebar bolt connections in concrete columns with AHK® shoes

2.2 Composite column and steel frames of office and public buildings

ATP® and AHP® series bolts are used for steel and composite column connections transferring axial and shear forces and bending moments. The long AHP® bolt is suitable for column extensions and foundation column connections. The short ATP® bolt is suitable for column footings.

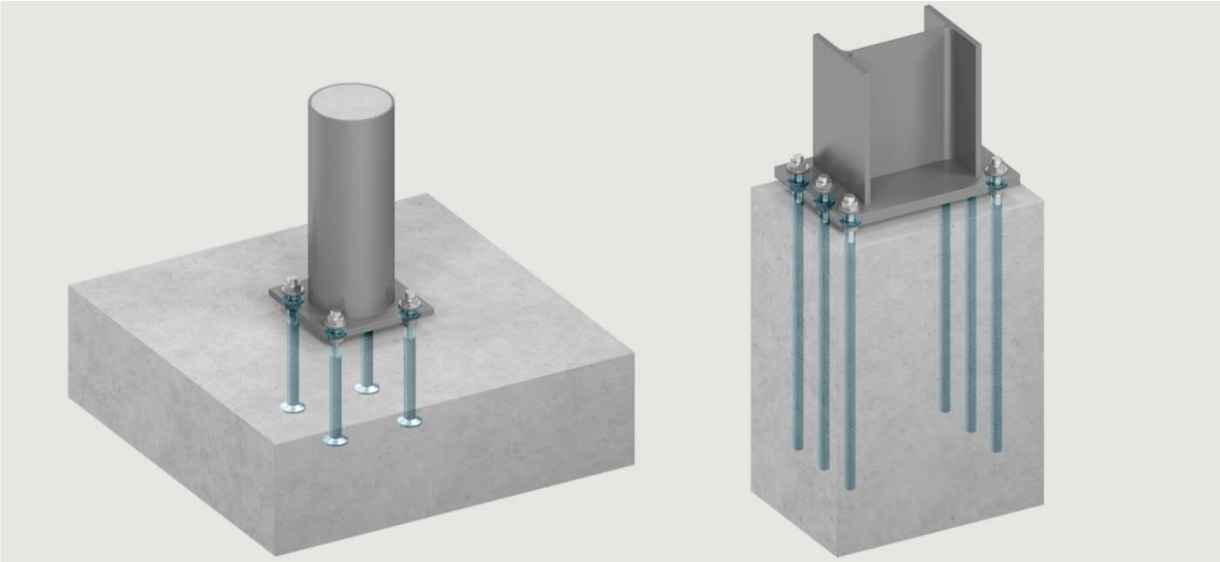


Figure 3. Rebar bolt connections in composite and steel columns

2.3 Shear walls in building frames

ATP® and AHP® series bolts can be used for extension and foundation connections of concrete element walls acting as shear walls bracing the building frame together with ASL®-H wall shoes. The connection only transfers the bolt's tensile force. More information is available in the user manual for shear wall shoes: ASL® Wall shoes

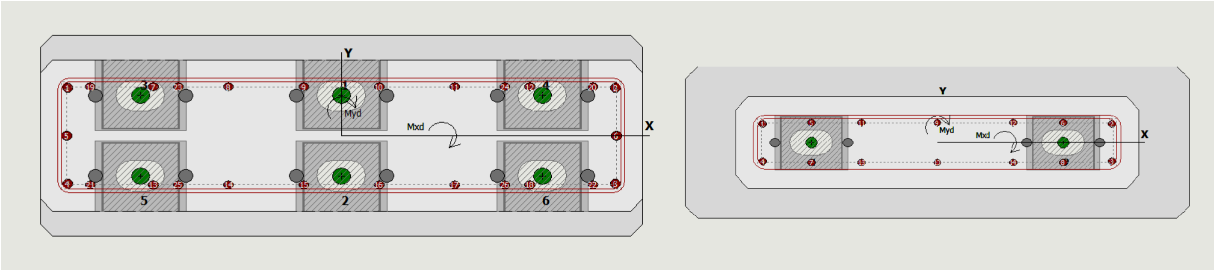


Figure 4. Rebar bolts in a shear wall shoe connection

2.4 Connecting steel structures and equipment to concrete

Rebar bolts can also be used to connect machinery and equipment to cast-in-situ equipment foundations or concrete element structures. The headed fastened of ATP® bolt requires sufficient space for the concrete failure cone. AHP® bolts can be bent to the bottom surface of the foundation, if necessary.

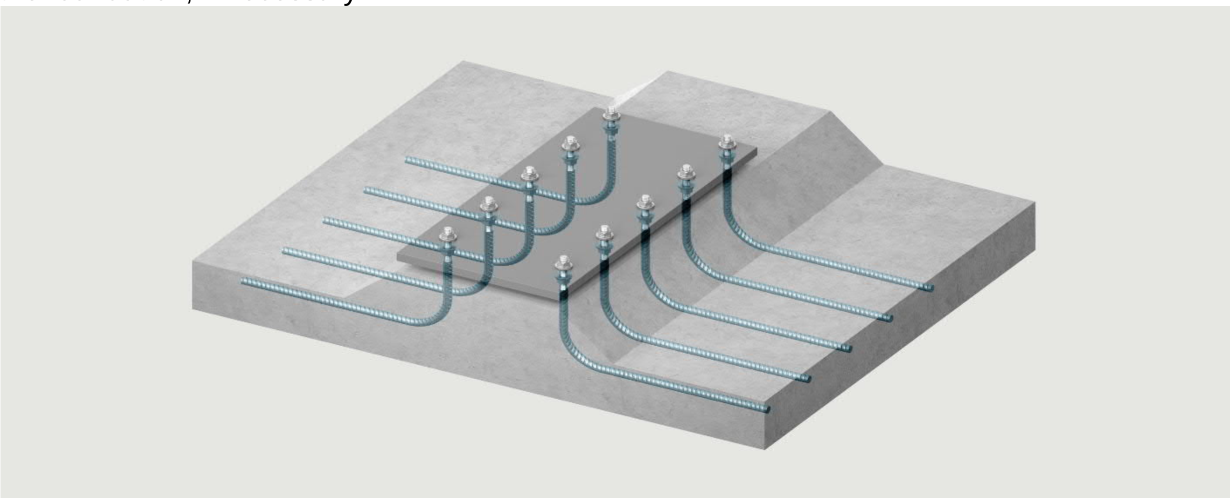


Figure 5. Rebar bolts in equipment foundations, principle drawing

2.5 Dimensions of rebar bolt products

2.5.1 ATP® rebar bolts

ATP® rebar bolts are used for connecting concrete, composite and steel columns to foundations in connections transferring axial and shear force and bending moment. ATP® bolts are suitable for a shallow column footing with sufficient width for the bolt's headed fastened.

ATP® rebar bolts are also suitable for other concrete element connections and machinery and equipment foundations requiring a very short anchoring length. However, the bolt's headed fastened requires space in the lateral direction for the concrete failure cone.

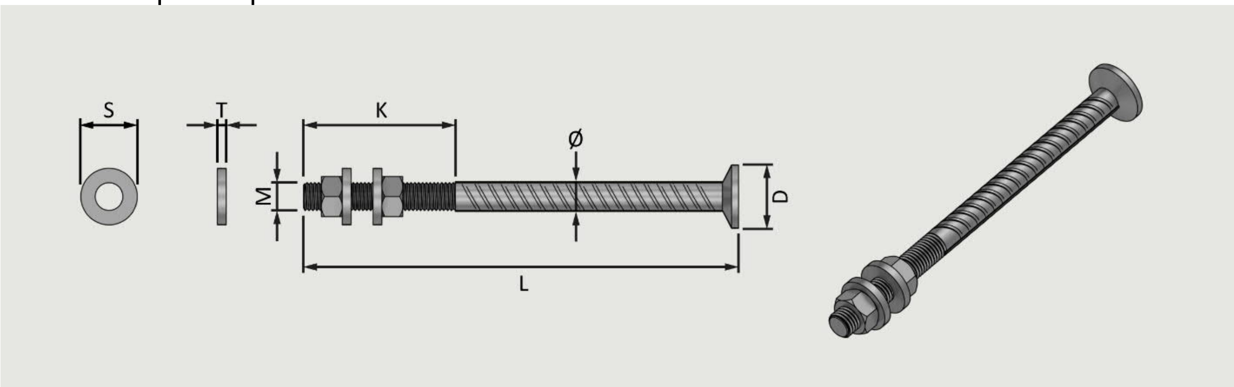


Figure 6. ATP® rebar bolt structure

Table 1. ATP® rebar bolt dimensions

Bolt	Colour code	L mm	K mm	A_s mm^2	M mm	ϕ mm	D mm	S mm	T mm	P kg
ATP16	yellow	280	100	157	M16	T16	36	40	6	0.62
ATP20	blue	350	120	245	M20	T20	46	46	6	1.15
ATP24	light grey	430	140	353	M24	T25	58	55	8	2.16
ATP30	green	500	170	561	M30	T32	73	65	10	4.08
ATP36	dark grey	600	170	817	M36	T32	73	80	10	5.64
ATP39	orange	700	190	976	M39	T40	100	90	12	9.42
ATP45	light green	760	190	1306	M45	T40	100	100	12	11.35

Legend:
L = Bolt length
K = Thread length
A_s = Thread stress area
M = Thread size
ϕ = Bolt bond size
S = Washer diameter
T = Washer thickness
D = Diameter of space required by bottom cone
P = Bolt weight

Surface treatment options for ATP® and AHP® bolts:

No treatment	Thread, bond and nut DIN 934-8 and washers, no surface treatment	standard delivery
Hot dip galvanised	Thread, bond and nut DIN 934-8 HDG and washers	standard delivery

ATP® and AHP® bolt TS models and AutoCAD blocks: www.anstar.fi

2.5.2 AHP® rebar bolts

AHP® bolts are used for connecting concrete and steel columns to foundations in connections transferring axial and shear force and bending moment. AHP® bolts are suitable for columns and foundation columns where the distance to the edge of the structure only equals the thickness of the protective concrete layer.

AHP® bolts are also suitable for concrete element connections where the bolt needs to be bent into a 90-degree hook. Bolts are bent by special order. They are bent according to EN 1992-1-1. The bolts are also delivered in stock lengths, which can be cut on the site into a bolt with sufficient anchoring resistance in accordance with the dimensions in Table 3.

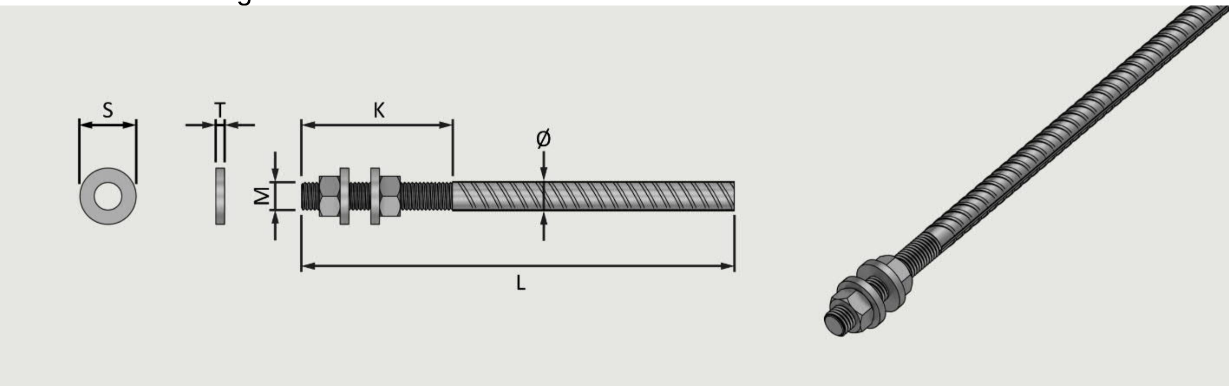


Figure 7. AHP® rebar bolt structure

Table 2. AHP® rebar bolt dimensions

Bolt	Colour code	Stock dimension L mm	L mm	K mm	A_s mm^2	M mm	ϕ mm	P kg
AHP16	yellow	1500	800	100	157	M16	T16	1.42
AHP20	blue	1500	1000	120	245	M20	T20	2.70
AHP24	light grey	1500, 2000	1150	140	353	M24	T25	4.83
AHP30	green	2000, 2500, 3000	1400	170	561	M30	T32	9.61
AHP36	dark grey	–	2000	170	817	M36	T32	13.40
AHP39	orange	–	2000	190	976	M39	T40	21.52
AHP45	light green	–	2700	190	1306	M45	T40	28.42

Table 3 shows the calculation of minimum lap length for AHP® bolts in concrete with design value $N_{Rd,s}$ for the bolt thread axial force. The bonding condition is good, η = 1.0. In the event of another bonding condition, η = 0.7, the values in the table must be divided by 0.7. With higher concrete strengths, the values can be corrected by multiplying them by the concrete tensile strength f_{ctd} design value's ratio $n_2 = f_{ctd\ Clask} / f_{ctd\ C25/30}$. The necessary thread length must be added to the total length of the bolt.

Table 3. Minimum lap length $l_{0,min}$ of AHP® bolts according to SFS-EN 1992-1-1

Bolt embedment depth in concrete $l_{0,min}$	SFS-EN 1992-1-1 C25/30 grade 2		SFS-EN 1992-1-1 C35/45 grade 1	
Product (α_2 α_3 α_5) Lap joint coefficient α_6	0.7 1.5	1.0 1.5	0.7 1.5	1.0 1.5
AHP16	482	689	385	551
AHP20	602	860	481	687
AHP24	694	991	555	792
AHP30	862	1231	689	984
AHP36	1255	1793	1003	1433
AHP39	1304	1862	1042	1488
AHP45	1744	2492	1394	1991

3 MANUFACTURING INFORMATION

ANSTAR Oy has entered into a quality control agreement with DEKRA Industrial Oy regarding the manufacture of ATP® and AHP® bolts. The manufacturing information for the bolts is as follows:

1. Manufacturing markings	Bolt manufacturing markings: - Anstar's code - Manufacture according to EN 1090-2:2018 for steel parts. [2] - Bolt code is painted on the head with a colour code. - Packaging: pallet
2. Materials	Manufacturing materials: - Rebar EN 10080, SFS 1300, B500B - Nut DIN 934, strength 8 - Washer EN 10025 black/galvanised, S355J2+N - Impact test temperature for the materials: –20 °C
3. Manufacturing method	Bolt manufacture: - Bolts are manufactured according to the EN 1090-2:2018 standard in execution class EXC2. By special order, bolts can be manufactured in execution class EXC3. [2] - Thread EN ISO 898-2, rolling, headed fastened hot forming - Manufacturing tolerances EN 1090-2:2018 [2]
4. Surface treatment methods	Standard delivery 1: No treatment - Thread and bond without surface treatment, thread oiled - Nuts DIN 934, strength 8, no treatment - Washers S355J2+N, no treatment Standard delivery 2: Hot dip galvanised, order code HDG - Thread and bond hot-dip galvanised, EN ISO 10684 - Nuts DIN 934, strength 8, hot dip galvanised - Washers S355J2+N, hot dip galvanised.
5. Product approval and quality control	Product quality control: Certificate F-092-75 Product declaration: CE marking according to EN 1090-1. European Countries: Sweden, Denmark, Norway, Austria, Estonia, Latvia, Lithuania. Additional information: www.anstar.fi/en

Table 4. Anstar's bolt manufacturing programme and user manuals

	Bolts	User manual	Typical application
1	*ATP® AHP®*	*Rebar bolts*	*- Foundation bolt connections in office, commercial and public buildings. Concrete and steel frames as well as composite column frames. - Bolt connections of light industrial building foundations in concrete and steel frames - Light connections of machinery and equipment foundations to concrete*
2	*ALP®-LC ALP®-PC ALP®-P2 and S series with removable thread*	*Anchor bolts*	*- Heavy-duty foundation connections of industrial concrete element frames - Moment rigid beam-to-column connections in concrete element frames - Foundation connections in shear walls - Heavy-duty column-to-foundation connections in steel frames - Other heavy-duty bolt connections to concrete - Heavy-duty connections of machinery and equipment foundations to concrete*
3	*ARJ®*	*Reinforcement coupler*	*- Reinforcement coupler connection - Bolt applications in reinforcement couplers - Moment rigid beam-to-column connection*
4	*KL, AKL®, JAL®, AKLC*	*Anchor plates*	*- Standard anchor plates - Special anchor plates*

4 DESIGN CRITERIA

4.1 Design and manufacturing standards

1. **Finnish standards**

SFS-EN 1991-1+NA	Actions on structures. Part 1-1: General actions. [5]
SFS-EN 1992-1-1+NA	Design of concrete structures. Part 1-1: General rules and rules for buildings. [6]
SFS-EN 1993-1-1+NA	Design of steel structures. Part 1-1: General rules and rules for buildings. [7]
SFS-EN 1992-4:2018	Eurocode 2. Design of concrete structures. Part 4 Design of fastenings for use in concrete. [24]
SFS-EN 13670	Execution of concrete structures, execution class 2 or 3, [17]

2. **Other countries in the European Code area**

Basic Eurocode	EN-1992-1-1:2004/AC:2010
Sweden	SS-EN 1992-1-1:2005/AC:2010+A1/2014 + EKS 11
Germany	DIN-EN 1992-1-1 +NA/2013-04

3. **Bolt manufacture**

EN 1090-1	Execution of steel structures. Part 1: Requirements for conformity assessment of structural components. [1]
EN 1090-2:2018	Execution of steel structures. Part 2: Technical requirements for steel structures. Execution classes EXC2 and EXC3. [2]
EN 13670	Execution of concrete structures. Execution class 2 or 3. [17]
EN-ISO 5817	Welding. Fusion-welded joints in steel, nickel, titanium and their alloys. Weld classes. [11]
EN 17760-1	Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints. [16]

4.2 Bolt resistance values

4.2.1 Axial force resistance

1. **Design method**

The design value of a bolt's axial force resistance is determined by the resistance of its thread. The design value for the bolt's thread is calculated according to EN 1992-4:2018, Table 4.1. The design values for the axial force resistance are indicated in Table 5.

The bolt's shear resistance in the concrete of the foundations is calculated according to EN 1992-4:2018, Table 4.1. The shear force transfer method for the connection is selected in the ACOLUMN® or ASTEEL software to suit each situation; refer to Section 4.3.
The axial and shear force resistance of a bolt connection during installation before grouting is also calculated using the software. The calculation is provided in Section 4.2.4.

The axial and shear forces on the bolt are transferred to the foundation reinforcement. Supplementary reinforcement is specified for each failure criterion of the bolt. The joint action of supplementary stirrups and bolt bonds with the foundation concrete and main reinforcement is calculated using the software. The bolts are also subjected to accident resistance analysis.

Resistance values: Tables 5 and 7 has been determined with materials and edge distances given in text. Other situations shall be calculated always with software's.

2. Axial force resistance values of bolt

Table 5. Axial force resistance of rebar bolts ultimate and accident limit state.

Bolt ATP®, AHP®	Axial force resistance		ATP®-bolt, minimum edge distance	
	$N_{Rd,s}$ [kN]	$N_{Rd,sa}$ [kN]	With supplementary reinforcement C2 [mm]	Without supplementary reinforcement C3 [mm]
ATP16, AHP16	61,6	69,0	90	180
ATP20, AHP20	96,3	107,8	115	250
ATP24, AHP24	138,7	155,2	140	290
ATP30, AHP30	220,3	246,8	175	405
ATP36, AHP36	320,9	359,5	215	555
ATP39, AHP39	383,4	429,4	230	640
ATP45, AHP45	513,1	574,8	275	775

ATP bolt. Axial force resistance. Calculation principle.

$N_{Rd,s}$	- Axial force resistance. - Ultimate limit state. Thread, Steel failure.
$N_{Rd,sa}$	- Axial force resistance. - Accidental limit state. Thread, Steel failure.
C2	- ATP® bolt. Minimum edge distance for tension with supplementary reinforcement. - Blow-out resistance is decisive. Design criteria, $N_{Rd,cb} \geq N_{Rd,s}$
C3	- ATP® bolt. Minimum edge distance for tension without supplementary reinforcement. Concrete Cone resistance is decisive. Design criteria, $N_{Rd,c} \geq N_{Rd,s}$
When edge distance is ≤ C2 or ≤ C3 shall the resistance of bolt be calculated with software's. Material part factors are according to standard EN 1992-4:2018 table 4.1. Concrete C25/30-2. Good bonding conditions. Cracked concrete.	

3. Axial force resistance failure criterion in concrete

Resistance of bolt in concrete is based on the EN 1992-4:2018 [24] standard, according to which the bolt is subjected to the following failure criterion analyses for axial force resistance in concrete.

Failure criterion	Variable	Calculation method and applicable standard
1. Steel failure	$N_{Rd,s}$	The steel tensile resistance of the bolt is calculated using the partial safety factors of materials indicated in EN 1992-4:2018, Table 4.1.
2. Concrete cone	$N_{Rd,c}$	The concrete cone failure criterion is calculated for ATP® bolt in tension. - EN 1992-4:2018, (7.1). The anchoring of the AHP® bolt is based on the anchoring resistance of the rebar bond according to the standard: - EN 1992-1-1. Chapter 8.4.4 - Lapp length α_6 = 1.5, good bonding conditions.
3. Pull-out	$N_{Rd,p}$	The pull-out failure criterion is calculated for the ATP® bolt. - EN 1992-4:2018, (7.11).
4. Blow-out	$N_{Rd,cb}$	The Blow-out failure criterion is calculated for ATP® bolt at the edge of the structure. - EN 1992-4:2018, (7.25).
5. Tensile resistance of supplementary reinforcement.	$N_{Rd,re}$	The reinforcement and tensile resistance of the bolt are determined by the condition: - $N_{Rd,re} > N_{Rd,c}$
6. Tensile resistance of the bolt and bond.	N_{Rd}	The tensile resistance of the bolt determined as follows: <u>Non-reinforced structure:</u> - $N_{Rd} = \min(N_{Rd,s}; N_{Rd,c}; N_{Rd,p}; N_{Rd,cb})$ <u>Structure with tensile reinforcement:</u> - $N_{Rd} = \min(N_{Rd,s}; N_{Rd,re}; N_{Rd,p}; N_{Rd,cb})$, when $N_{Rd,re} > N_{Rd,c}$.

7. Surface plate stresses. Only ASTEEL software.	δ_{vert}	FEM analysis is conducted for the surface plate, and von Mises stress state is calculated for the forces coming through the profile to be connected. The plate's stress state safety factor lever and utilisation rate are calculated according to the standard: - EN 1993-1-1, Formula 6.1. - Elastic-plastic, semi rigid joint $\delta_{vert} = f_u/\gamma_{M2}$, γ_{M2}= 1,25 γ_{M2} = 1,25 - Elastic, rigid joint $\delta_{vert} = f_y/\gamma_{M}$, γ_M = 1,0 The geometry from deformations is calculated for the plate.
8. Design of the profile and weld. Only ASTEEL software.	$F_{w,Rd}$	The stress and utilisation rate are calculated for the profile to be welded to the anchor plate. The analysis is performed at the surface of the plate. - EN 1993-1-1, Section 6.2, Formula 6.1. This method does not perform slenderness analysis of the sheet metal parts for the profile. The profile's fillet weld to the plate is designed according to the standard: - EN 1993-1-8, Section 4.5, Formula 4. - The standard to be applied for butt and double-bevel butt welds is EN 1993-1-1, Formula 6.1.
9. Stress state of the base concrete.	δ_c	As regards the base concrete of the surface plate, the Axial force coming from the plate is subjected to stress analysis in the FEM calculation. - The design criterion for the compressive stress of the concrete has been limited to the value specified in EN 1992-1-1, $\delta_c \leq f_{cd}$ - For plates under heavy compressive loads, the concrete stress analysis can be performed even if the other resistances of the plate are not dominant.
10. Supplementary reinforcement stress state for characteristic value of loads.	δ_t	The stress state caused by characteristic value of loads is calculated for the plate's reinforcement, enabling concrete crack analysis at the edge of the structure.

4. Minimum edge distances for axial force in concrete

The bolt's minimum edge distance for axial force is determined by either the nominal value of the concrete cover or the concrete failure criteria of the bolt's headed fastened. The minimum distance requirements for the bolt are indicated in Table 6. The distance is from the centre of the bolt to the edge of the structure or to the centre of another bolt.

Table 6. Minimum edge and centre distances of rebar bolts for axial force.

Bolt	C1 [mm]	E1 [mm]
AHP16	53	40
AHP20	55	50
AHP24	58	60
AHP30	61	70
AHP36	61	90
AHP39	65	100
AHP45	65	110

Bolt	C1 [mm]	C2 [mm]	C3 [mm]
ATP16	63	90	180
ATP20	68	115	250
ATP24	74	140	290
ATP30	82	175	405
ATP36	82	215	555
ATP39	95	230	635
ATP45	95	275	775

The minimum edge and centre distances of the rebar bolt have been specified for the following boundary conditions.

C1	ATP® and AHP® bolts. Minimum edge distance for the bolt's concrete cover.	- The minimum distance of the centre of the bolt from the edge. C1 has been specified for exposure classes XC3–XC4 with concrete nominal value C_{nom} = 35 mm and 50-year service life and stirrup size T10 dimensions, C_{nom} = 45 mm - The value can be reduced when the design service life, concrete cover and exposure class change. Service life design is provided in Table 10.	The cover must not be lower than the minimum value.
E1	AHP® bolt. Minimum centre distance.	- The bolt's minimum centre distance has been specified according to the distance of the adjacent bolts' bonds and the space required by the bolt such that the bolt's bonds act as separate pieces of rebar, not rebar bundles.	The distance must not be lower than the minimum value.
C2	ATP® bolt. Minimum edge distance. Bolt with supplementary reinforcement.	- Minimum edge distance C2 for ATP® bolts have been determined according to blow-out resistance. - Bolt shall have tension reinforcement as well as blow-out reinforcement. Concrete C25/30. - Minimum center distance shall be E2 ≥ 2*C2. - When edge distance is on area C1 ⇔ C2 the resistance of bolt shall be calculated with ASTEEL or ACOLUMN® software.	If the value is lower than the minimum, blow-out resistance is reduced.
C3	ATP® bolt. Minimum edge distance for headed fastened of bolts. Without supplementary reinforcement	- Minimum edge distance C3 has been specified at the ATP® bolt's concrete cone failure criterion. - The bolt has not supplementary reinforcement and concrete is C25/30-2. - Value C3 is also minimum distance for full tension resistance in non-reinforced concrete. - Minimum center distance shall be E3 ≥ 2*C3.	The value must not be lower than the minimum.

4.2.2 Shear force resistance

1. Design method

The design value of the bolt's shear resistance is specified in the following situations:

1. Erection state. Grouting section.	- The steel shear resistance of the bolt thread is $V_{Rd,se}$ before grouting. - The shear resistance with the moment arm is determined according to equation 7.37 in EN 1992-4:2018.
2. Ultimate Limit state (ULS). Grouting section.	- The steel shear resistance of the bolt thread is $V_{Rd,se}$. - The shear resistance is designed as above but with the Ultimate limit state forces. - This failure will not be calculated if shear force is transmitted to foundation with friction or shear stud.
3. Ultimate Limit state (ULS.) Primary foundation concrete.	Rebar bolts have three shear force resistances: - Design situation is cracked concrete strength C25/30-2 - Edge distance C4 or C5 is to force direction and to opposite side direction. A. Steel shear resistance $V_{Rd,s}$, when edge distance is ≥ ≥ C5. No supplementary reinforcement. Top reinforcement is required. B. Concrete shear resistance $V_{Rd,c1}$ has been calculated without shear reinforcement for minimum edge distance C5 in table 7. C Concrete shear resistance $V_{Rd,c3}$ has been calculated using bolt-specific U-stirrup reinforcement for edge distance C4 in table 7. - When edge distance of bolt is on area C1 ⇔ C5 shear resistances shall be calculated always with ASTEEL and ACOLUMN® software's.
4. Accident limit state (ALS)	- Accident limit state (ALS) will be calculated in same way that in (ULS) state. Material partial factors are according to EN 1992-4:2018 table 4.1. Calculations will be done always with software's.

Table 7. Design values for the shear resistance of bolts, Ultimate Limit state, C25/30-2.

Bolt ATP®, AHP®	Ultimate limit state						Erection state	
	Steel resistance $V_{Rd,s}$ [kN]	Steel resistance $V_{Rd,sa}$ [kN]	Concrete resistance [kN] $V_{Rd,c1}$	Concrete resistance [kN] $V_{Rd,c3}$	Resistance, edge distance [mm] C4	Resistance, edge distance [mm] C5	Thread $V_{Rd,se}$ [kN]	Grout G mm
ATP16 AHP16	28,8	33,2	20,5	28,8	165	165	5,5	50
ATP20 AHP20	44,9	51,8	32,0	44,9	220	220	10,6	50
ATP24 AHP24	64,7	74,7	46,2	64,7	270	270	19,1	50
ATP30 AHP30	102,8	118,6	73,4	102,8	370	370	39,9	50
ATP36 AHP36	147,4	172,8	107,0	149,8	480	480	56,2	60
ATP39 AHP39	178,9	206,5	127,7	178,9	520	520	75,2	60
ATP45 AHP45	230,2	276,3	171,8	239,4	630	630	98,6	65

2. Rebar bolts shear resistance. Calculation method.

$V_{Rd,s}$	- Design value of shear resistance. Thread: Steel failure. - Ultimate limit state. Calculated with edge distance ≥C5.
$V_{Rd,sa}$	- Design value of shear resistance. Thread: Steel failure. - Accident limit state. Calculated with edge distance ≥C5.
$V_{Rd,c1}$	- Design value of shear resistance. Ultimate limit state, without supplementary reinforcement. Concrete edge failure. Calculated with edge distance C4.
$V_{Rd,c3}$	- Design value of shear resistance. Ultimate limit state, with supplementary shear reinforcement. Concrete edge failure. Calculated with edge distance C5.
$V_{Rd,se}$	- Steel shear resistance of the bolt thread before grouting. - For other grouting thicknesses, the resistance is calculated using the ASTEEL software.
C4	- Minimum edge distance of rebar bolt without supplementary reinforcement. - Concrete edge without supplementary reinforcement is decisive. $V_{Rd} = V_{Rd,c1} = V_{Rd,c3}/1.4$.
C5	- Minimum edge distance of rebar bolt with supplementary reinforcement. - Concrete edge with supplementary reinforcement. $V_{Rd} = V_{Rd,c3} \geq V_{Rd,s}$.
t_{grout}	- Minimum grouting thickness for shear resistance.
When edge distance is ≤ C4 or ≤C5 shear resistance of bolt shall be calculated with software's. When grouting thickness > 0,5 * D, the shear resistance of bolt be calculated witch software's. Material part factors are according to standard EN 1992-4:2018 table 4.1. Concrete C25/30-2. Good bonding conditions. Cracked concrete.	

3. Shear force resistance failures in concrete.

The following shear force failure criteria analyses according to standard [24] are conducted for the ATP® bolts. The same analyses, except for item 4, are conducted for AHP® bolts. The failure criteria take into account the distance of the bolt from the edge of the structure and other bolt. The calculation is performed for all bolts the most dominant of which determines the joint.

1. Steel failure	$V_{Rd,s}$	The steel shear resistance of the bolt is calculated using the partial safety factors indicated in EN 1992-4:2018, Table 4.1, and using Formula 7.34. When grouting thickness is 0 – D/2. (D=nominal diameter of thread).
2. Steel failure with lever arm. Erection state.	$V_{Rd,se}$	Steel resistance of bolt on erection state is calculated with EN 1992-4:2018 formula (7.37). When grouting thickness is ≥ D/2. Erection state loads and no grouting concrete.
3. Steel failure with lever arm. Ultimate limit state.	$V_{Rd,se}$	Steel resistance of bolt on ultimate limit state is calculated with EN 1992-4:2018 formula (7.37). Ultimate limit state loads and grouting concrete has been hardener. Concrete transfer also Axial force.
4. Pry-out	$V_{Rd,cp}$	The pry-out failure criterion is calculated for the ATP bolt - EN 1992-4:2018, Formula 7.39.
5. Concrete edge	$V_{Rd,c}$	The bolt's edge compression resistance $V_{Rd,c}$ is determined according to EN 1992-4:2018, Formula 7.40. Reinforcement coefficient $\psi_{re,V}$ = 1.0. The value is calculated for the bolt

Edge compression resistance. Without shear reinforcement		towards the nearest edge or in the direction of the shear force. Minimum shear resistance of the bolt: $V_{Rd,c,\ min} = min(V_{Rd,s}\ ;\ V_{Rd,cp}\ ;\ V_{Rd,c})$ Joint shear resistance: $V_{Rd,c,\ levy} = n\ *\ V_{Rd,c,\ min,}$ where n = number of bolts per joint and $V_{Rd,c,\ min}$ = minimum shear resistance of the bolts.
6. *Concrete edge* *Edge compression resistance. With shear reinforcement*	$V_{Rd,c}$	The bolt's edge compression resistance $V_{Rd,c}$ is determined according to EN 1992-4_2018, Formula 7.40. Reinforcement coefficient $\psi_{re,V}$ = 1.4. The value is calculated for the bolt closest to the edge and in the direction of the shear force. Minimum shear resistance of the bolt, reinforced: $V_{Rd,c,\ min} = min(V_{Rd,s}\ ;\ V_{Rd,cp}\ ;\ V_{Rd,re})$, when $min(V_{Rd,c})_n$ Joint shear resistance: $V_{Rd,c,\ levy} = n\ *\ V_{Rd,c,\ min}$, where n = number of bolts per joint $V_{Rd,c,\ min}$ = minimum shear resistance of the bolt. The shear force is transferred using supplementary reinforcement.
7. *Reinforcement resistance*	$V_{Rd,re}$	The reinforcement of the bolt for shear force is determined by the condition: - $V_{Rd,re} \geq V_{Rd,c}$

4.2.3 Combining axial and shear force resistance.

The tensile and shear force failure criteria are combined for the bolts according to the following principles. The designing is performed for each individual bolt, the largest of which is dominant in terms of the resistance of the connection.

1. *Steel resistance of the bolts.*	The combined steel tensile and shear resistance is calculated for the bolt. - EN 1992-4:2018, Formula 7.54. - $(N_{Ed}/N_{Rd,s})^2 + (V_{Ed}/V_{Rd,s})^2 \leq 1$ (7.54)
2. *Concrete resistance of the bolt*	Combined concrete tensile and shear resistance is calculated for the bolt using formulas 7.55 and 7.56 in a situation where reinforcement is not used or where both force components are transferred through the reinforcement. The formula takes into account steel resistance, if it is determining. $(N_{Ed}/N_{Rd,i})^{1.5} + (V_{Ed}/V_{Rd,i})^{1.5} \leq 1$ (7.55) or $(N_{Ed}/N_{Rd,i}) + (V_{Ed}/V_{Rd,i}) \leq 1.2$ (7.56)
3. *Concrete resistance of the bolt*	Combined concrete tensile and shear resistance is calculated for the bolt using formula 7.57 in a situation where only one force component (tensile or shear) is transferred through the reinforcement and the other through the bolt. Exponent k_{11} = 0.67. The formula takes into account steel resistance, if it is determining. $(N_{Ed}/N_{Rd,i})^{k11} + (V_{Ed}/V_{Rd,i})^{k11} \leq 1$ (7.57)
4. *Bolt resistance*	The bolt resistance is determined by the highest utilisation rate in the combination of the failure criteria. When shear force is transferred with friction and in steel column connect with shear stud, bolts do not have shear force and value β_V = 0.

4.3 Transfer shear force to the grouting.

The column's shear force is transferred from the column through the grouting to the foundations using three different methods, whose use is selected by the designer in the software's load combination.

1. *Friction force*	The shear force is transferred from the column to the grouting and foundations through friction force: - The shear force is transferred through the friction of the concrete of the column and the bottom surface of the shoe base plate to the grouting and from there to the concrete of the foundations. - The bolts do not computationally take part in transferring the shear force. - <u>Shear wall connection</u>: The friction force is calculated according to the resistance at the interface between concrete cast at different times under EN 1992-1-1, Section 6.2.5. - <u>Column shoe and steel column connection</u>: The friction force is calculated with

	friction coefficient μ = 0.2 under EN 1993-1-8, Section 6.2.2. The rest of the shear force is transferred through the bolts. - The methods are applied when the axial force of the column remains compressed and the friction force coming from the axial force is sufficient for transferring the shear force.
2. *Anchor bolts*	Shear force is transferred with anchor bolts.
3. *Shear stud.*	The shear force is transferred using a steel headed fastened: - This method is used in steel column connections where a steel profile has been welded to the bottom surface of the base plate, and its headed fastened effect transfers the shear force through the grouting directly to the concrete of the foundations. - The anchor bolts do not computationally take part in transferring the shear force.

4.4 Bolt connection design instructions for the main civil engineer

The bolt connection is designed using the *ACOLUMN*® version 5.0 and ASTEEL version 2.0 design software. Due to the calculation method, no instructions are provided for manual calculation and the use of bolts in detail design with approximate calculation methods is not recommended. The software is used for designing bolts in the following connection types:

1. *Column shoe connections*	Frame column connections: - Shoe connections in element column extensions - Shoe connections to foundation columns and cast-in-situ footings - Rectangular and round columns - APK®-C, APKK-C and AHK®, AHK-K shoes
2. *Wall shoe connections*	Bracing wall - Extension and foundation connections of bracing element walls - ASL®-H and ASL®-P wall shoes
3. *Rigid beam-to-column connections*	Rigid beam-to-column connection - Rigid beam-to-column connections of concrete element frames - APK®-MC beam shoes and ALP®-P2 series anchor bolts.
4. *Steel column connection to foundations*	Steel column foundation connection - Anchor bolt connections of steel columns to cast-in-situ foundations. - Base plate and shear headed fastened connections
5. *Anchor plates*	Standard and special anchor plates of Anstar.
6. *Bracing Truss Coupler*	Bracing ADE® and ADK® Truss Couplers of Anstar.

The following calculation methods are taken into account in designing bolt connections:

1. *Design standards and load combination.*	- The bolt connection is designed according to the EN 1992-4:2018 standard, applying other European standards. - Before using the software, the force combinations acting on the bolt connection are calculated using separate design software applications. - The software can also be used to design the connection using the Basic Eurocode and according to the Swedish and German National Annex.
2. *Design for the erection state*	- The bolt connection works during the erection state without grouting. - The shoe and bolt resistances are calculated for the forces provided for the erection state using the ACOLUMN® and ASTEEL software. - The axial force on the connection is transferred through the bolts and the shear force through the bolts' bending and shear. - Grouting thickness and bending resistance of the bolts is taken into account according to the grouting thickness.
3. *Design for the Ultimate Limit state (ULS)*	- The factors of consequence classes CC1–CC3 are taken into account in the load combination. - The bolt connection works during the ultimate limit state when the concrete of the foundations and grouting of the connection have hardened. - The software calculates the bolt resistances for axial and shear force. - The software calculates the connection as a bent and compressed

	structure where the tensile force is transferred through the bolt/shoe and the compressive force is transferred through the concrete of the column and the shoe/anchor bolts. - The shear force on the connection is transferred according to the principles indicated in Section 4.2.2. - Software calculates supplementary reinforcement for bolts.
4. Design for fire.	- The fire resistance class of the anchor plate is the same with the connected profile. - The connected profile and surface plate must be fire-protected. - The designer specifies the fire resistance class and fire protection.
5. Dynamic loads	- Dynamic loads are calculated according to EN 1990-1, Section 4.1.5, by multiplying the static specific loads by the dynamic factors.
6. Loads caused by earthquakes	- The loads are specified in the load combination. - With the forces calculated in this way, the design is performed as a static situation. - The performance of the connection has not been tested in structures in earthquake zones. Its use must be considered by the designer.
7. Fatigue actions	- The bolt resistance values have not been specified for fatigue actions. Fatigue design is performed on a case-specific basis according to the principles in EN 1990-1, Section 4.1.4. [4]
8. Design for accident limit state (ALS)	- A design analysis for accident limit state can be performed for the bolt connection according to EN 1992-1-1, Section 2.4.2.4, by using the partial safety factors of materials in accident limit state indicated in Table 2.1N of the standard to determine the resistance of the connection in exceptional situations. - The analysis is performed using the ACOLUMN® software. The combination of forces in accidental states is calculated using a separate software application, and the forces on the connection are provided as “Loads in accidental states”. - The software calculates the accidental state resistance values and utilisation rates for various parts of the connection using the characteristic material values for steel where rebar and anchor bolt steel can yield. Concrete has a low $\gamma c = 1.2$ safety left against brittle failure.
9. Design for low temperatures	- No separate operating temperature examination is necessary for the bolts. The low temperature design methods specified for rebar are followed.
10. Supplementary reinforcement required for the bolt	- The software calculates the bolt reinforcement for the forces on the connection, and the minimum reinforcement amounts are output in the calculations. - Another option is to use maximum reinforcements calculated according to the bolt’s resistance values. Section 5.6.
11. Minimum edge distances for the bolt	- The software calculates the edge distances for failure criteria as specified in EN 1992-4:2018, Section 6.2 for axial force and Section 6.3 for shear force. - When the edge distance becomes dominant, the bolt’s axial and shear force resistance are reduced according to the bolt’s actual edge distance. - The edge distance does not determine the bolt’s location; the bolt’s resistance is reduced according to the failure criterion to be calculated. - The minimum distances provided in Table 7 are based on the bolt’s structural dimensions and protective concrete layer Cmin = 35 mm + 10 mm stirrup.
12. *Serviceability limit state design (SLS)*	- The serviceability limit state design for the connection is performed according to EN 1992-1-1, Section 4. The principles are specified in Section 5.7 of this manual.

5 DETAIL DESIGN

5.1 Design stages and parties.

Rebar bolts are Anstar products whose final use must be designed by the civil engineer. For detail design of the connection, we have prepared this user manual as well as the design software ACOLUMN® for concrete column connections and ASTEEL for steel column connections.

The final detail design of the bolt connection must be performed using Anstar's design software. The joint action of the various connection components has been specified according to EN 1992-4:2018.[24]. The software calculates the bolt resistances with the connection materials and dimensions using the calculation forces given for the connection. The software checks that the bolt's calculation forces are transferred to the concrete and reinforcement of the foundations in accordance with the European standards. Due to the extensiveness of the calculation method, no instructions are provided for manual calculation and the use of bolts with approximate manual calculation methods is not recommended. The software designs in the concrete and steel column bolt connections and produces calculation materials for building control. Further instructions for using bolt products are available from Anstar's technical design department. *anstar@anstar.fi*.

The software can be downloaded from *www.anstar.fi.* Software can be used on Windows 10. The main window shows the cross-section of the column at the top surface of the connection's base plate as well as the dimensions and bolts of the foundations below. The menu structure of the main window consists of the following functions:

5.2 ACOLUMN software

1. User interface

1. File	- This menu includes selections for the project folder, file management and printing.
2. Initial data...	- First, you select the Connection joint type to be calculated. - Second you enter the geometry and material data for the cross-section.
3. Loads	- This function is used to enter the forces calculated from the load combination on the frame for the erection and Ultimate Limit state and for fire design.
4. Shoes/Bolts/Rebars...	- This function is used to place shoes and anchor bolts in the connection and position the main reinforcement in the shoe area.
5. Calculate...	- The selection performs the calculation for the connection. - This function is also used to select calculation for the Ultimate and accident limit state.
6. Calculation results...	- The calculation results are viewed for shoes and bolts as well as design quantities for various situations.
7. Software settings	- The menu is used to enter parameters that control the use of the software and calculation.

2. Information controlling the calculation.

1. Calculation standard	- The main window includes information controlling the calculation: - The bottom left corner of the window shows the flag symbol of the calculation standard used for the project folder.
2. User interface language	- The user interface language is indicated by the flag symbol next to the standard flag. The language options available are Finnish, Swedish, English and German, and the same options are also available for printing. The user interface and printing languages can be selected separately.

3. Suitability of bolts for various connection types in foundation structures

Table 8 shows the suitability of ATP® and AHP® bolts for various foundation structures. The selection of the application is affected by the bolt length, protective concrete layer requirements and the edge distance required by the short headed fastened bolt's failure cone design.

Table 8. Suitability of Rebar bolts for various foundation structures

Bolt	Column-to-column connection	Column-to-foundation connection	Column-to-footing connection
ATP®	The bolt is not suitable for the connection due to the great edge distance of the headed fastened bolt head.	The bolt is not suitable for the connection due to the great edge distance of the headed fastened bolt head.	The bolt is well-suited to a shallow footing, and the edge distance of the bolt's headed fastened head is sufficient.
AHP®	The bolt is well-suited even to columns of the same size.	The bolt is well-suited if the foundation column is high enough. The edge distances are sufficient.	The bolt is suitable if the bond is bent to the bottom surface of the footing or if the footing is high enough.

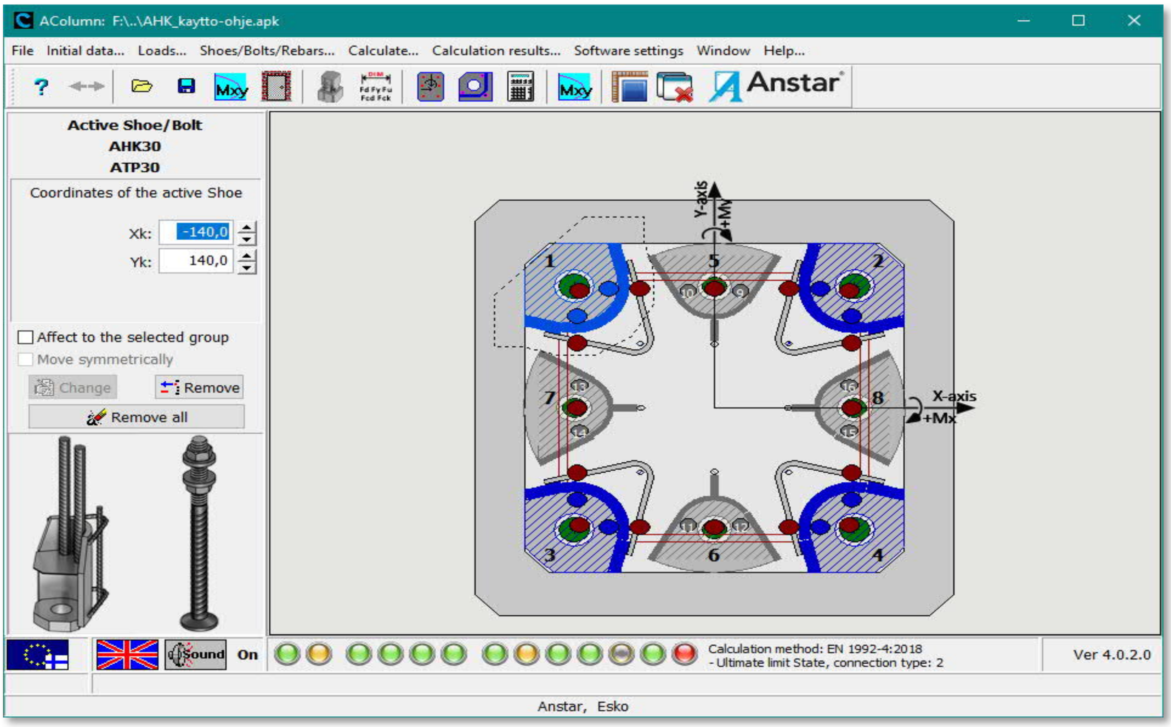


Figure 8. Main window the AHK® column shoes and Rebar bolts

4. Quick review of the calculation results

The main window includes information enabling quick review of the calculation results:

Utilisation rate indicator lights

The bottom bar of the window includes round indicator lights showing the utilisation rates of various calculation quantities. The colours of the calculation quantities have the following meanings:	
1. Green	The utilisation rate is acceptable within the range of 0–0.95.
2. Yellow	The utilisation rate is acceptable within the range of 0.951–1.0.
3. Red	The utilisation rate is > 1.01, excessive.
4. Grey	If the colour is grey, the quantity has not yet been calculated or does not belong to the design values for the connection type. If the erection loads are not provided, the erection is not calculated.
5. Light beam	 The utilisation rate indicator lights are activated when the connection forces have been specified and the connection calculated.

Utilisation rate acceptance

The bottom bar of the window includes indicator lights showing the utilisation rates of various calculation quantities. The colours of the calculation quantities have the following meanings:		
1. Meaning	- The designing quantity of each indicator light is displayed below the light bar when you point the mouse at the light.	
2. Utilisation rate	- When you click a light, the output window for the quantity in question is opened, showing the most dominant load case and calculation quantity. - The light bar shows the utilisation rates of the connection's calculation quantities.	
3. Acceptance	- When all the lights are green, yellow or grey, the connection has been accepted. - A red light means that the utilisation rate of the calculation quantity has been exceeded. - The final acceptance is the responsibility of the person performing the calculation.	

5.3 Column connection design

5.3.1 Project folder and calculation standard of software

1. Project folder

1. General	- Start the calculation by creating a project folder in which the calculation standard and files are saved. - The user manuals provide a more detailed description of the software's initial data for calculation and calculation methods as well as the calculation theory and results. - This user manual only provides connection-specific information.
2. Calculation standard selection	- Start by creating a project folder in the *File/Project folder* menu. - The software prompts you to select the country-specific calculation standard to be copied to the folder and used for calculating the file in the folder. The standard is selected once for each new folder. (The calculation standard for bonds is selected in the connection selection window.) - The calculation will use the standard selected in this folder. - You can change the standard by creating a new folder and selecting another standard for it.
3. Project information	- In these fields, you provide general information about the project in the folder. - This will be output at the beginning of the calculation file.

2. Calculation standard of software

EN 1992-1-1:2004 and EN 1992-4:2018	Basic Eurocode and the latest part, no. 4
SFS-EN 1992-1-1:2005+NA	Finnish Eurocode + NA
SS-EN 1992-1-1:2005/AC:2010+A1/2014 + EKS 11	Swedish Eurocode + EKS 11
DIN-EN 1992-1-1:2011-01+A1/2014	German Eurocode + NA

5.3.2 Connection type

1. Connection type	- Select an anchor plate connection by choosing Connection selection from the Initial data menu. - The menu shown in Figure 13 opens in the window, showing the connection types available in the software. - Connection type 8 is only available to Anstar Oy. - Connection types 3–6 are coming soon. The connection type is selected first. The selection adjusts the software's main window and other windows according to the connection selected.
2. Calculation code of joint	- Select the calculation standard for the rebar bolts from the window. - The default standard is EN 1992-4:2018, and the calculation can also be performed using the older CEN/TS 1992-4-2 standard, which provides slightly more conservative calculation results.

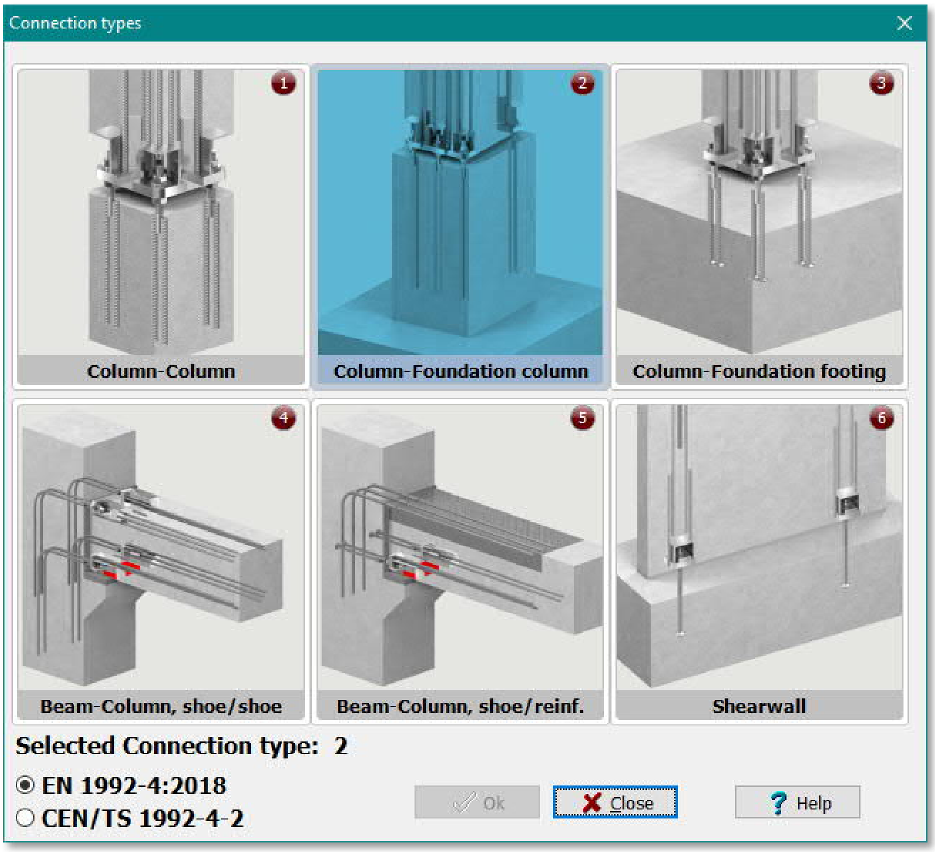


Figure 9. ACOLUMN software connection types

5.3.3 Dimension and material data

The dimensions of the connection are specified in the *Dimension and material data* menu, which has six tabs. Enter the initial data in the numerical order of the tabs, either by changing the values or accepting the default values. Some of the standard values are visible, but the field is grey, meaning that they cannot be changed. When you click *Accept*, the main window is updated according to the dimensions of the selected connection type.

1. Calculation ID, tab1
The identifying information output in the calculations is entered in the fields.

2. Material strengths, tab 2

1. *Column and base concrete cracking and bonding state*
   - Use cracking concrete.
   - The bonding condition is selected according to the casting state of the base. EN 1992-1-1.
2. *Using supplementary reinforcement for the bolt/bond*
   - The use of reinforcement is selected on a case-specific basis for both tension and/or shear.
   - By default, reinforcement is used.
3. *Concrete material strengths*
   - Specify the concrete strength of the column, grouting and foundation. Minimum concrete strength C25/30

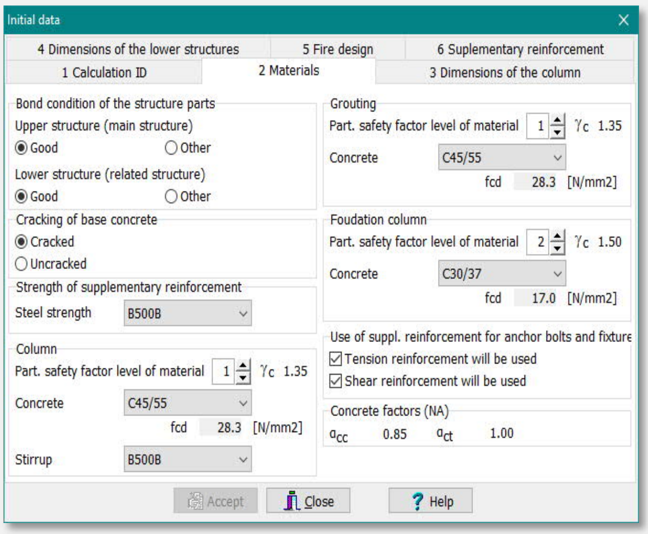


Figure 10. Tab 2. Material strengths, concrete cracking state and reinforcement

3. Dimensions of the structure, tab 3

1. *Column shape and dimensions*
   - The dimensions to be selected are square, rectangular and round for upper column
2. *Grouting and concrete cover*
   - Grouting thickness is depending of bolt type. It can be changed.
   - Concrete cover and chamfer will be user to main window.

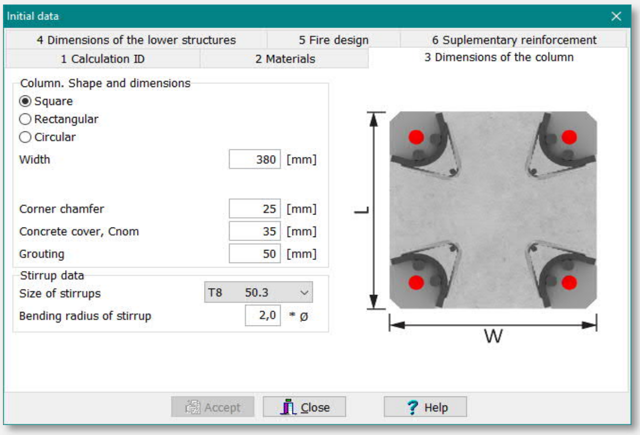


Figure 11. Tab 3. Dimension of column

4. Dimensions of the lower structures, tab 4

3. *Base dimensions*
   - Dimensions of base structure is given according to pictures.
   - The column can be placed such that it touches the edge of the base structure. Resistances are always calculated with the placement.
4. *Base depth*
   - The calculation of bolts is influenced by the base depth, i.e. the thickness of the structure. Specify the actual depth.
5. *Corner bevel and stirrup.*
   - This only influences the graphics in the main window.

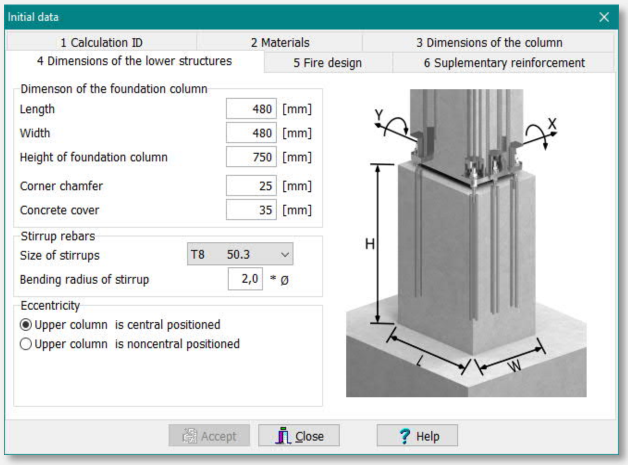


Figure 12. Tab 5. Selecting the base dimensions

5. Supplementary reinforcement, tab 6

1. *Supplementary reinforcement*
   - The size of the anchor bolts reinforcement can be selected on Tab 6.
   - The window shows the reinforcing units available for each connection type.
   - The reinforcement principal drawing can be opened by clicking the Ast code.
   - The software calculates the amount of supplementary reinforcement with the selected rebar size.
   - The default rebar size selected is output to the calculation file.

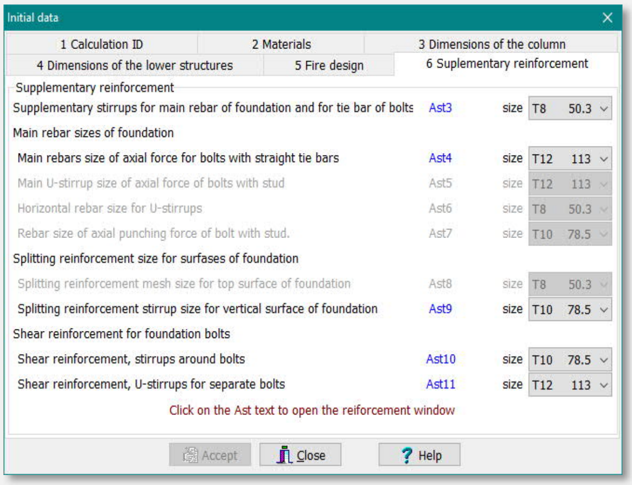


Figure 13. Tab 6. Size of supplementary reinforcement

6. Accepting the initial data

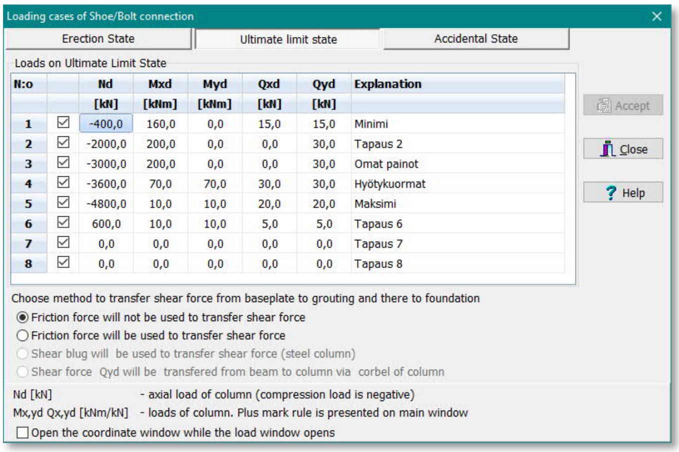
1. *Acceptance*	- All calculation data that has been selected/modified must be accepted by clicking the *Accept* button. - The button accepts all the tabs of the *Initial data* window at the same time.
2. *Changes*	- The dimensions and materials can be changed and tried out quickly between calculations.

5.3.4 Forces on the connection

1. Forces on the connection and combinations

1. *Specifying the calculation forces*	- The forces on the connection are calculated using a separate statistics application. - These are used to form the combinations of forces, the most dominant of which is provided. - The forces already include the partial safety factors of loads in accordance with the calculation standard as well as the factor of the consequence class. - The forces are specified by load combination, where the tensile force and/or bending moment usually forms the most dominant combination. - All the forces acting at the same time must be provided for the same case. Changing moment and shear directions must be analysed.
2. *Accident limit state (ALS)*	- The accident limit state (ALS) is specified as specific loads or what is to be calculated. - The software does not add partial safety factors for loads to the calculation.
3. *Acceptance*	- All forces that have been specified or **modified** must be accepted by clicking the *Accept* button.

4. *Axial force N_d*	- The connected column's Axial force is specified for the connection. - The most dominant case of the column's compressive force must be also calculated. The force is usually transferred to the concrete through the grouting and bolts, in which case the compressive stress of the concrete under the column may become dominant. The compressive force is distributed between the bolt and concrete according to the rigidity of column end. - The software does not calculate the punching resistance of the structure.
5. *Bending moments M_{xd}, M_{yd}*	- The profile's bending moments are specified for the connection. - For moments with the same value, the (+, –) directions need to be calculated. - The anchor plate is also calculated in the skew bending direction.
6. *Shear force Q_{xd}, Q_{yd}*	- Shear forces are calculated in the directions of the main axes. - The most dominant shear force comes towards the nearest edge of the structure. - The highest shear force is also calculated, even though its direction is away from the edge. - The steel shear resistance of the bond is analysed. in the direction of the shear resultant for both shear and torsion.
7. *Moment T_d*	- The torsional moment T_d cannot be given to connection.
8. *Proportion of permanent loads G_k*	- The relative proportion of permanent loads G_k of the total load. The value is used for calculating the reinforcement stress state with the specific loads. Refer to Section 5.7, Serviceability limit state design. The default value can be changed.



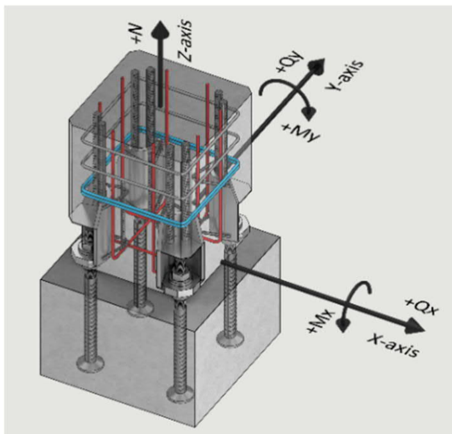


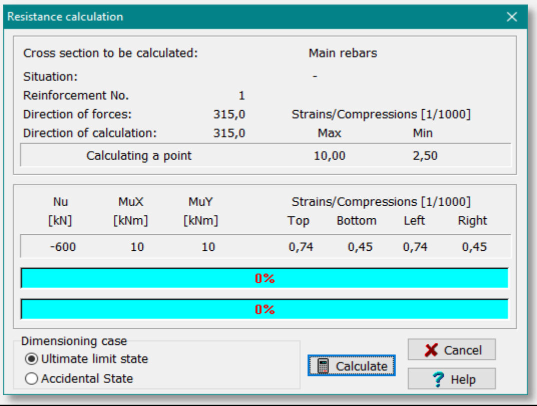
Figure 14. Column connection calculation forces and coordinate system

5.3.5 Column connection calculation

1. Selecting the calculation method

To calculate the bolt connection, select *Calculate*, which will open the *Resistance calculation* window.
The calculation is performed for the following anchor plate structures:
- Calculating the cross-section resistance graphs of the column.
- Calculating the column's stress state/deformed geometry using the FEM method.
- Calculating column shoes.
- Calculating the anchor bolts axial force and shear criteria in accordance with EN 1992-4.
- Calculating the anchor plate reinforcement for tensile and shear forces.

1. *Case to be calculated.*
   This selection performs the calculation in the following calculation states:
   - *Ultimate limit state (ULS)*
   - *Accident limit state (ALS)*
   - When you want to output both calculations, you must first output the ultimate limit state to a file.
   - If the accident limit state loads have not been specified, the state cannot be calculated.



5.4 Erection state calculation. Bolts

5.4.1 Presentation of the results

1. Menu structure

The bolt connection calculation results can be viewed from the *Calculation results* menu. The menu is divided into three sub-areas:

1. *Erection state*	- Bolt resistance during the erection state in the grouting cross-section.
2. *Ultimate limit state. Shoes*	- Column shoe resistance during the Ultimate Limit state and the column's main reinforcement resistance at the shoe connection. - Supplementary reinforcement required by the shoes. - These results are in the corresponding manuals for APK®-C and AHK® shoes.
3. *Ultimate limit state. Bolts*	- Bolt resistance during the Ultimate Limit state in the foundations and in the grouting cross-section. - Supplementary reinforcement required by the bolts.
4. *Accident limit state*	- When accident limit state has been calculated, results are on the same windows.

2. Calculation results

1. *Results*	- The windows show the strengths and utilisation rates for each calculation quantity by combination case as well as the calculation parameters. The results are shown in the directions of the main axes and in the XY direction of skew bending
2. *Bending direction*	- Skew bending is calculated as a combination of the forces in the direction of the main axes for the combination in question.
3. *Numbering of the structures*	- After the calculation, numbers will be displayed in the main window at the bolt and shoe bonds and the column's main rebars. - These numbers will be displayed next to the corresponding part/row in the printout windows. - The information on the printout row can be traced to a structure in the main window. - The numbers will be displayed after the calculation.

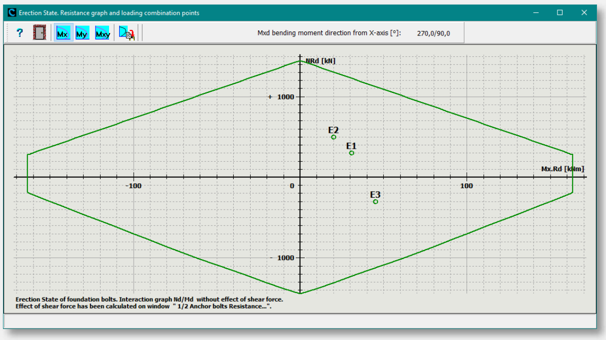
3. Utilisation rates

The row featuring the utilisation rates has acceptance indicators with the following colours:	
Green	- The utilisation rate of the quantity is 0–0.95.
Yellow	- The utilisation rate of the quantity is 0.95–1.00.
Red	- The utilisation rate of the quantity is > 1.00.
Grey	- The quantity has not been calculated or does not belong to the bolt's design values.
Maximum utilisation rate of the quantity	- Clicking an indicator light opens a window showing the combination case for the maximum utilisation rate. - Excess values can be found easily, and also the maximum acceptable utilisation rate for each quantity and the combination in which it occurs.

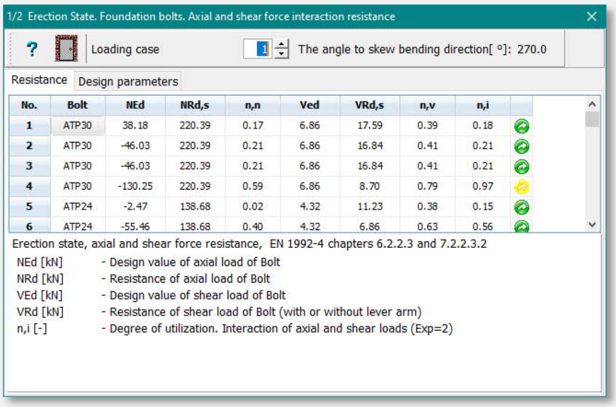
5.4.2 Erection state resistance

1. Resistance values and acceptance

1. Design loads	- Design is done according to EN 1992-4:2018, chapter 6.2.2.3. Shear loads with lever arm. - Connection is calculated for erection state loads. - All loads will be transferred through the bolts. - If erection loads has not been given. Calculation is not performed.
2. Resistance graph of connection. Window 1/1	- In window 1/1 is presented design graphs for erection state of bolts in grouting section for erection state loads. - Resistance graph of bolts is calculated with compressed and bended structure according to the grouting thickness. - Calculation is performed to direction of main axis. - Resistance graph is presented as axial force/bending moment graph and there is not included shear force.



3. Acceptance	- Loading points shall be inside the graphs.
4. Resistance of bolts. Window 1/2	- Ikkunassa 1/2 on liitoksen pulttien asennustilanteen kestävyys. - Pultti mitoitetaan normaalivoiman, momentin ja leikkauksen yhteisvaikutukselle.



5. Acceptance	- The resistance of bolts is adequate if utilization ratios are on acceptable levers. - In the window 1/2 there is design parameters used in calculation.

5.5 Ultimate limit state. Rebar bolts

5.5.1 Column connection. Resistance to axial force

1. Combined effect graphs

1. *Specifying the graphs*	- Window 3/1 shows the resistance graphs and loading points of the of the column connection. Figure 15. - The axial force resistance graphs are output in the bending directions of the X- and Y-axes as well as the skew bending direction.
2. *Acceptance*	- The ultimate and accident limit state loading points, C1–C8 (**blue**), must be located inside all the graphs and the red dashed line. - The red, green and blue graph may locally intersect each other. - In addition to this, it is also necessary to check the local resistance of the bolts and concrete stress state.

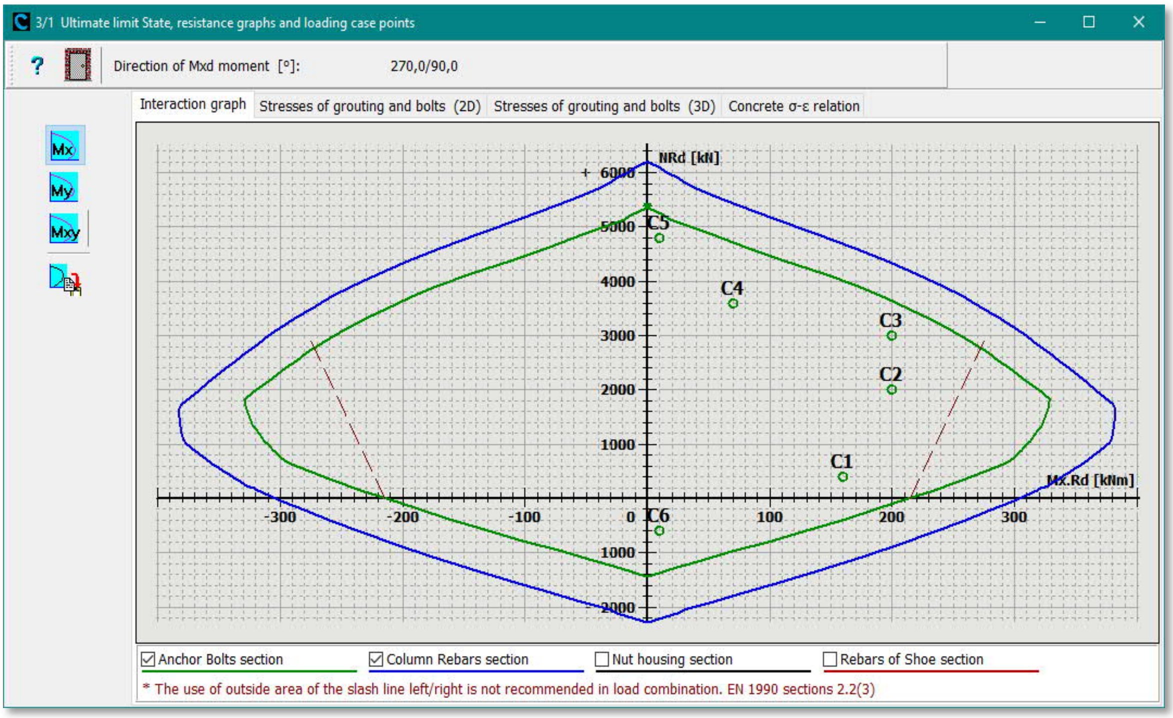
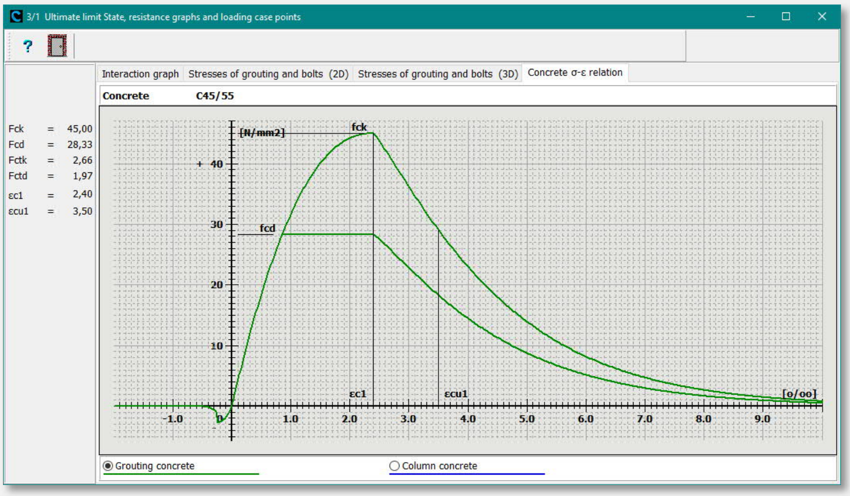


Figure 15. Ultimate limit state. Resistance graphs and loading points. X-axis direction.

2. Resistance graphs of the column connection

1. Green graph	*Column resistance.* - The graph is calculated for an area of concrete column size with the steel tensile resistance of the bolt's and the calculation strength of the grouting. - The effect of shear force is not included here. - The graph does not take into account the edge distances of the base.
2. Blue graph	*Resistance of the connected column.* - The graph shows axial force and bending moment resistance of the column. - Blue graph has been calculated above the connection with column reinforcement without column slenderness. - The blue graph may intersect the green graph or be located inside it.
3. *Loading points*	*Loading points by load case.* - Loading points C1–C8 must be located inside the graphs and the red line. - The distance of loading points C1–C8 from the closest graph represents the lever of the connection's utilisation rate. - On the graph, the loading point's utilisation rate is 1.0.
4. *Red dashed line*	*The acceptable area is between the dashed lines.* - The loading points must not be located in the area of the graphs outside the red dashed line. EN 1990, Section 2.2(3) (= development of the load history)

3. Stress state of grouting concrete

1. Presentation of results	The stress state of the base concrete is shown on the second and third tab of window 3/1.
2. Element data	- In the 2D window, the stress state and utilisation rates of an individual concrete calculation element can be checked with the mouse. - The force and stress state of the bolts is shown in the window. - The 3D graph for the concrete shows the distribution of the stresses under the plate, the maximum value calculated as well as the calculation strength and utilisation rate of the concrete. - In the area shown in grey, the stress lever is zero or the plate has come loose from the concrete. - The colour palette represents the utilisation rates of compressive stresses. 
3. Acceptance of results	- The compressive stress of the concrete must not exceed the calculation strength f_{cd}. - The surface of column end is allowed to come loose from the concrete if this is acceptable in terms of corrosion.

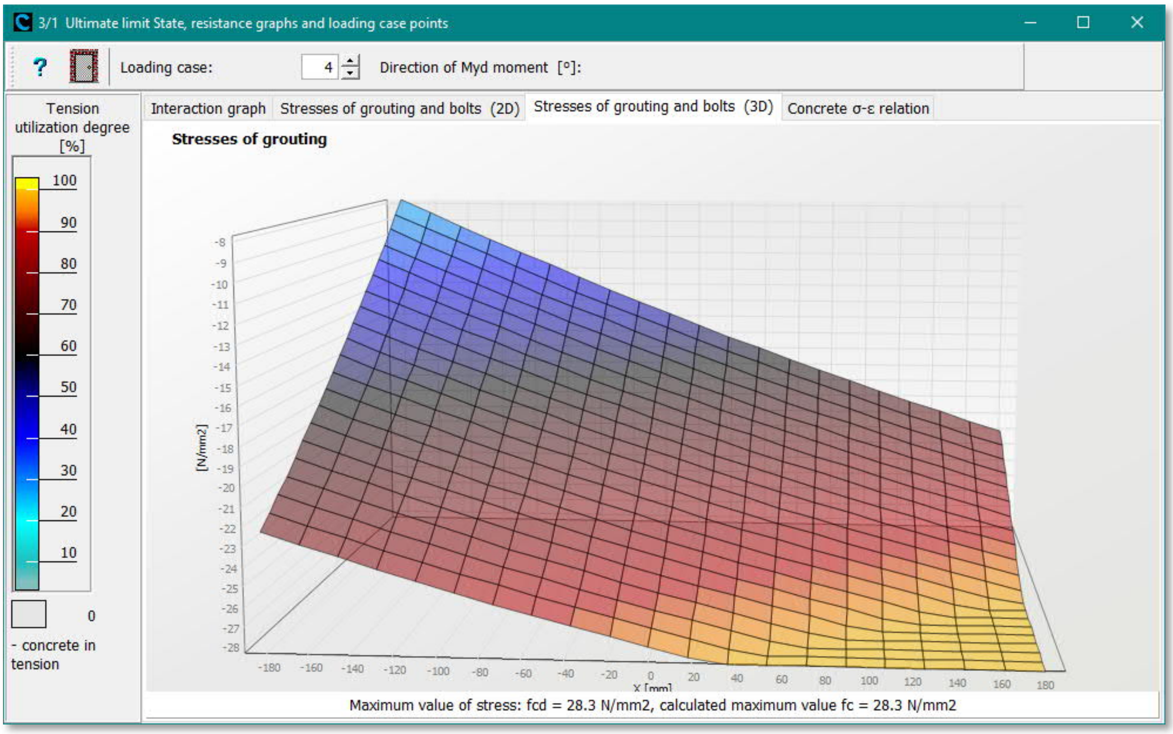


Figure 16. Ultimate limit state. Stress state of the column grouting concrete, 3D image.

5.5.2 Grouting section. Ultimate limit state resistance.

1. Resistance values and acceptance

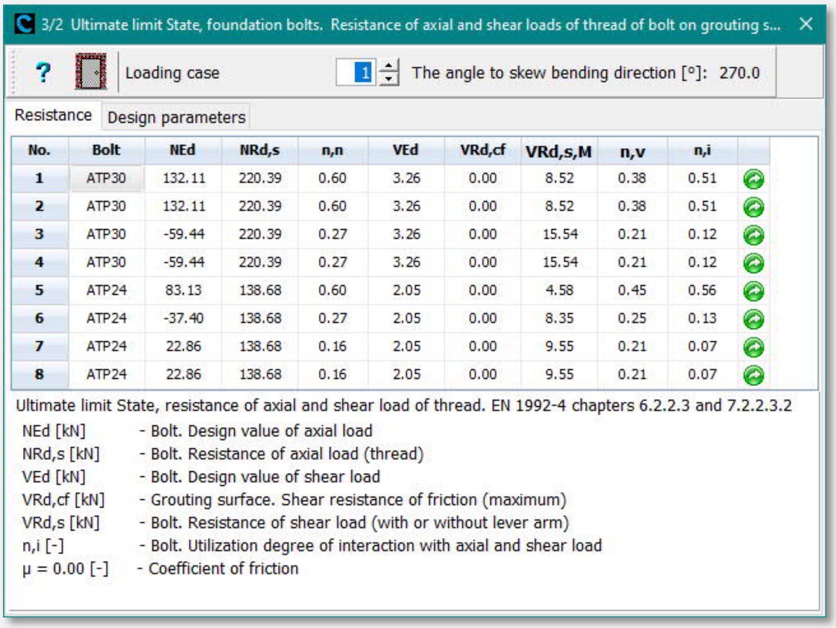
<table>
<tr><td>1. Design loads</td><td>- Design is done according to EN 1992-4:2018, chapter 6.2.2.3. Shear loads with lever arm.
- Connection is calculated to ultimate limit state loads. Picture 14.
- Connection has been grouted and concrete has been hardened.
- Axial forces will be transferred through the concrete and the bolts.
- If shear for is transferred with friction or shear stud bolt shall not have shear force.</td></tr>
<tr><td>2. Resistance graph of connection. Window 3/1</td><td>- In window 3/1 is presented green graph for ultimate state of bolts in grouting section for ultimate state loads.
- Calculation is performed to direction of main axis and to skew direction.
- Resistance graph is presented as axial force/bending moment grap and there is not included shear force.</td></tr>
<tr><td>3. Acceptance</td><td>- Loading points shall be inside the graphs.</td></tr>
<tr><td>4. Resistance of bolts. Window 3/2</td><td>- In the window 3/2 there is ultimate limit state resistances of bolt.
- Bolt is calculated combined forces of axial bending and shear force.

</td></tr>
<tr><td>5. Acceptance</td><td>- The resistance of bolts is adequate if utilization ratios are on acceptable.
- In the window 3/2 there is design parameters used in calculation.</td></tr>
</table>

Figure 17. Ultimate limit state, grouting section. Bolt resistances and combination.

5.5.3 Axial force resistance of bolt in concrete

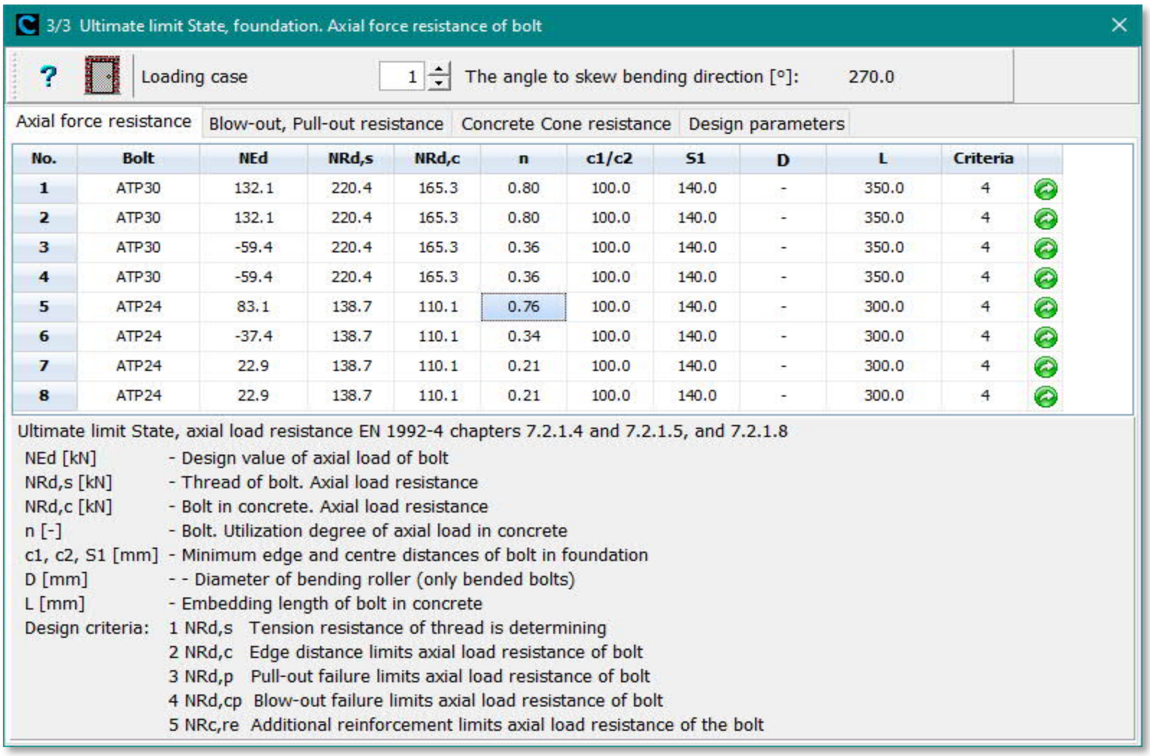
1. Resistance calculation principle

Rebar bolt's in concrete	The following failure criteria and resistances are calculated for the bolts.
1. Presentation of the resistances	The resistances are presented in windows 3/3, 3/4 and 3/5 as follows: - The force quantities, resistances and utilisation rates of the connection are shown on the first row of the table. - The connection resistance cannot be calculated for certain failure criteria. - The force quantities, resistances and utilisation rates of each bolt are shown on table rows 2–n. - The bolts are numbered in the main window.
2. Designing for axial force	Axial force resistance of the bolts. - Steel resistance - Blow-out and pull-out resistance - Concrete cone resistance - Supplementary reinforcement resistance
3. Designing	Shear resistance of the bolts.

for shear force	- Steel resistance - Pry-out resistance - Concrete edge resistance - Supplementary reinforcement resistance
4. Axial and shear force combination	- The Axial and shear force combination in the directions of the main axes is calculated for all bolts. - The steel resistance of the shear force and torsion are calculated in the direction of the force resultant. - The software finds the most dominant combinations of these.
5. Acceptance of results	*Acceptance of the results.* - The resistance is acceptable when the main window indicator lights 3/3, 3/4 and 3/5 are green, yellow or grey. *Acceptance criteria:* - The connection is acceptable when the light is green or yellow. A green utilisation rate is in the range of 0–0.95 and yellow 0.951–1.0. - Grey means that the quantity in question is not calculated for the plate. - A red light means that the utilisation rate has been exceeded. - The designing quantity value is a dash (-). The failure criterion or quantity has no significance for designing or cannot be calculated for the load case in question. (No actions.) - The designing quantity value is zero (0.0). A calculated value cannot be determined for the failure criterion or quantity in this structure or load case, or its calculation value is zero. (No actions.

2. Design value for axial force resistance

Tab 1 of Window 3/3 shows the most dominant axial force resistance of the bolts from tabs 2, 3 as well as the utilisation rate by load case.	
1. N_{Ed}	Calculated tensile force of the bolt by load case.
2. $N_{Rd,s}$	Steel tensile resistance of the bolt arm.
3. $N_{Rd,c}$	Design axial force failure criterion resistance of the bolt. The design value is calculated from the condition: - $N_{Rd,c}$ = min($N_{Rd,s}$; $N_{Rd,c}$; $N_{Rd,p}$; $N_{Rd,cb}$) Without tensile reinforcement. - $N_{Rd,c}$ = min($N_{Rd,s}$; $N_{Rd,re}$; $N_{Rd,p}$; $N_{Rd,cb}$) With tensile reinforcement.
4. Utilisation rate	Designing axial force utilisation rate of the bolt. Calculated from the most dominant failure criterion in item 3.
5. Criterion	The description can be used to review which failure criterion became dominant for each bolt. Criterion = the minimum of cases 1–5. The designing criterion is assessed as follows: 1. $N_{Rd,s}$ The steel tensile resistance of the bolt is determining. The bolt is so far from the edge that the steel resistance is determining. If exceeded, change the bolt. 2. $N_{Rd,c}$ The edge distance (concrete) restricts the bolt's tensile resistance. If exceeded, add supplementary reinforcement or change the bolt. 3. $N_{Rd,p}$ Pull-out restricts the bolt's tensile resistance. This failure criterion determines the bolt. If exceeded, change the bolt. 4. $N_{Rd.cp}$ Blow-out restricts the bolt's tensile resistance. The bolt is so close to the edge of the structure that blow-out is determining. If exceeded, change the bolt, modify the structure. 5. $N_{Rd,re}$ Supplementary reinforcement determines the tensile resistance of the bolt. If exceeded, the bolt will not withstand even with reinforcement; change the bolt.
6. Acceptance	The light at the end of a row depicts the acceptance utilisation rate and limit for the bolt in question. The limits are presented in item 5 of the previous table.



3/3 Ultimate limit State, foundation. Axial force resistance of bolt

Loading case 1 The angle to skew bending direction [°]: 270.0

Axial force resistance | Blow-out, Pull-out resistance | Concrete Cone resistance | Design parameters

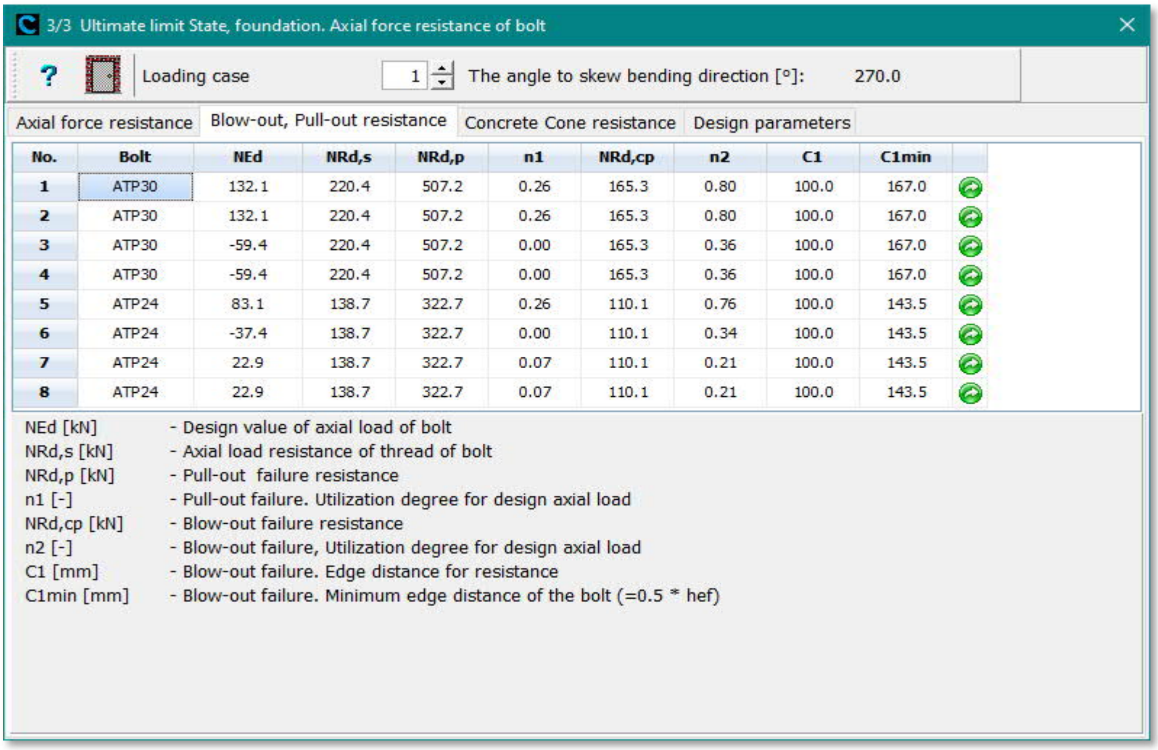
No.	Bolt	NEd	NRd,s	NRd,c	n	c1/c2	S1	D	L	Criteria
1	ATP30	132.1	220.4	165.3	0.80	100.0	140.0	-	350.0	4
2	ATP30	132.1	220.4	165.3	0.80	100.0	140.0	-	350.0	4
3	ATP30	-59.4	220.4	165.3	0.36	100.0	140.0	-	350.0	4
4	ATP30	-59.4	220.4	165.3	0.36	100.0	140.0	-	350.0	4
5	ATP24	83.1	138.7	110.1	0.76	100.0	140.0	-	300.0	4
6	ATP24	-37.4	138.7	110.1	0.34	100.0	140.0	-	300.0	4
7	ATP24	22.9	138.7	110.1	0.21	100.0	140.0	-	300.0	4
8	ATP24	22.9	138.7	110.1	0.21	100.0	140.0	-	300.0	4

Ultimate limit State, axial load resistance EN 1992-4 chapters 7.2.1.4 and 7.2.1.5, and 7.2.1.8
NEd [kN] - Design value of axial load of bolt
NRd,s [kN] - Thread of bolt. Axial load resistance
NRd,c [kN] - Bolt in concrete. Axial load resistance
n [-] - Bolt. Utilization degree of axial load in concrete
c1, c2, S1 [mm] - Minimum edge and centre distances of bolt in foundation
D [mm] - - Diameter of bending roller (only bended bolts)
L [mm] - Embedding length of bolt in concrete
Design criteria: 1 NRd,s Tension resistance of thread is determining
2 NRd,c Edge distance limits axial load resistance of bolt
3 NRd,p Pull-out failure limits axial load resistance of bolt
4 NRd,cp Blow-out failure limits axial load resistance of bolt
5 NRc,re Additional reinforcement limits axial load resistance of the bolt

Figure 18. Ultimate limit state. Tensile resistance and utilisation rate of the bolt.

3. Blow-out and pull-out resistance

Tab 2 of Window 3/3 shows the pull-out and blow-out resistance.	
1. N_{Ed}	Calculated tensile force of the bolt by load case.
2. $N_{Rd,s}$	Steel tensile resistance of the bolt arm.
3. $N_{Rd,p}$, $N_{Rd,cp}$	Pull-out and blow-out resistance of the bolt.
4. *Utilisation rate*	Bolt utilisation rate for these failure criteria.
5. *Acceptance*	The acceptance rate of the pull-out and blow-out failure criteria is at the end of the row.



3/3 Ultimate limit State, foundation. Axial force resistance of bolt

Loading case 1 The angle to skew bending direction [°]: 270.0

Axial force resistance | Blow-out, Pull-out resistance | Concrete Cone resistance | Design parameters

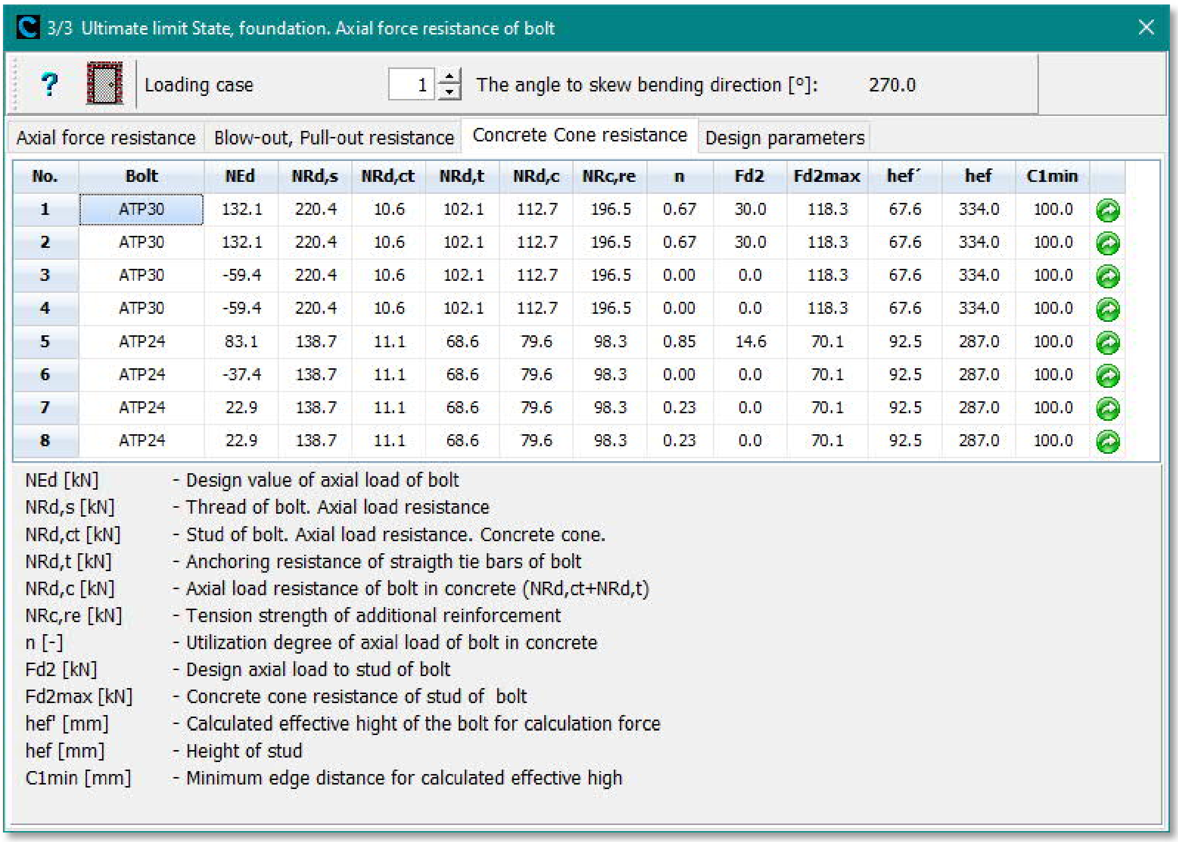
No.	Bolt	NEd	NRd,s	NRd,p	n1	NRd,cp	n2	C1	C1min
1	ATP30	132.1	220.4	507.2	0.26	165.3	0.80	100.0	167.0
2	ATP30	132.1	220.4	507.2	0.26	165.3	0.80	100.0	167.0
3	ATP30	-59.4	220.4	507.2	0.00	165.3	0.36	100.0	167.0
4	ATP30	-59.4	220.4	507.2	0.00	165.3	0.36	100.0	167.0
5	ATP24	83.1	138.7	322.7	0.26	110.1	0.76	100.0	143.5
6	ATP24	-37.4	138.7	322.7	0.00	110.1	0.34	100.0	143.5
7	ATP24	22.9	138.7	322.7	0.07	110.1	0.21	100.0	143.5
8	ATP24	22.9	138.7	322.7	0.07	110.1	0.21	100.0	143.5

NEd [kN] - Design value of axial load of bolt
NRd,s [kN] - Axial load resistance of thread of bolt
NRd,p [kN] - Pull-out failure resistance
n1 [-] - Pull-out failure. Utilization degree for design axial load
NRd,cp [kN] - Blow-out failure resistance
n2 [-] - Blow-out failure, Utilization degree for design axial load
C1 [mm] - Blow-out failure. Edge distance for resistance
C1min [mm] - Blow-out failure. Minimum edge distance of the bolt (=0.5 * hef)

Figure 19. Ultimate limit state. Pull-out and blow-out resistance of the bolt.

4. Concrete cone resistance and supplementary reinforcement

Tab 3 of Window 3/3 shows the steel resistance, concrete cone and supplementary reinforcement resistance of the individual bolts.	
1. N_{Ed}	Calculated tensile force of the bolt by load case.
2. $N_{Rd,s}$	Steel tensile resistance of the bolt arm.
3. $N_{Rd,c}$	Concrete tensile resistance of the bolt. Minimum value from the concrete cone resistance.
4. $N_{Rd,re}$	Tensile resistance of the bolt reinforcement. Criterion $N_{Rd,re} > N_{Rd,c}$. The value is calculated for the selected tensile reinforcement in Window 3/6, Tab 1. If there is no reinforcement, this value is zero.
5. Utilisation rate	Bolt utilisation rate for the dominant tensile force failure criteria.
6. Acceptance	Acceptance rate for the minimum failure criteria determines the Axial force and bending moments at the end of the row.



No.	Bolt	NEd	NRd,s	NRd,ct	NRd,t	NRd,c	NRc,re	n	Fd2	Fd2max	hef´	hef	C1min
1	ATP30	132.1	220.4	10.6	102.1	112.7	196.5	0.67	30.0	118.3	67.6	334.0	100.0
2	ATP30	132.1	220.4	10.6	102.1	112.7	196.5	0.67	30.0	118.3	67.6	334.0	100.0
3	ATP30	-59.4	220.4	10.6	102.1	112.7	196.5	0.00	0.0	118.3	67.6	334.0	100.0
4	ATP30	-59.4	220.4	10.6	102.1	112.7	196.5	0.00	0.0	118.3	67.6	334.0	100.0
5	ATP24	83.1	138.7	11.1	68.6	79.6	98.3	0.85	14.6	70.1	92.5	287.0	100.0
6	ATP24	-37.4	138.7	11.1	68.6	79.6	98.3	0.00	0.0	70.1	92.5	287.0	100.0
7	ATP24	22.9	138.7	11.1	68.6	79.6	98.3	0.23	0.0	70.1	92.5	287.0	100.0
8	ATP24	22.9	138.7	11.1	68.6	79.6	98.3	0.23	0.0	70.1	92.5	287.0	100.0

NEd [kN] - Design value of axial load of bolt
NRd,s [kN] - Thread of bolt. Axial load resistance
NRd,ct [kN] - Stud of bolt. Axial load resistance. Concrete cone.
NRd,t [kN] - Anchoring resistance of straigth tie bars of bolt
NRd,c [kN] - Axial load resistance of bolt in concrete (NRd,ct+NRd,t)
NRc,re [kN] - Tension strength of additional reinforcement
n [-] - Utilization degree of axial load of bolt in concrete
Fd2 [kN] - Design axial load to stud of bolt
Fd2max [kN] - Concrete cone resistance of stud of bolt
hef' [mm] - Calculated effective hight of the bolt for calculation force
hef [mm] - Height of stud
C1min [mm] - Minimum edge distance for calculated effective high

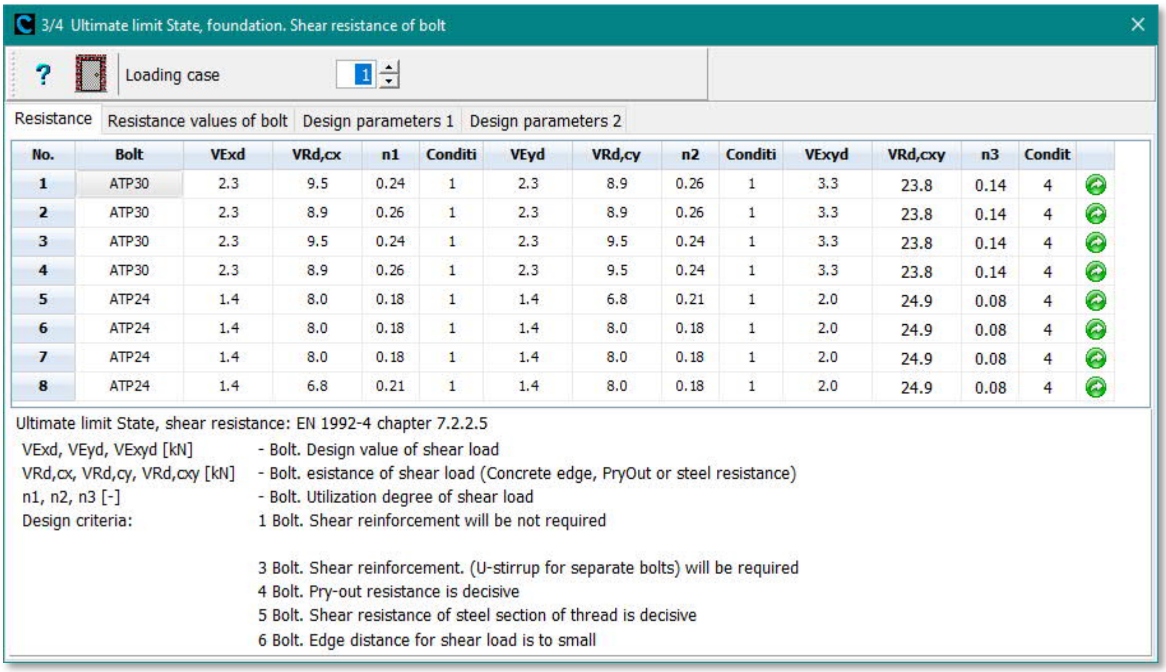
Figure 20. Ultimate limit state. Concrete cone resistance of the bolt

5.5.4 Rebar bolt plate shear resistance

1. Shear resistance design value

Tab 1 of Window 3/4 shows the most dominant shear resistance of the rebar bolt from Tab 2 as well as the utilisation rate by load case in the directions of the main axes	
1. V_{Exd}, V_{Eyd}, V_{Exyd},	Calculation value of the bolt's shear force by load case in the directions of the main axes and shear resultant. The external shear force and torsional moment as well as the torsion caused by the column location's eccentricity are calculated in the shear force value.
2. $V_{Rd,cx}$ $V_{Rd,cx}$ $V_{Rd,cxy}$	Shear resistance of the bolt. The values are output according to whether shear reinforcement has been selected for use. - Minimum shear resistance of the bolt without shear reinforcement: $V_{Rd,cx}$, $V_{Rd,cy} = \min(V_{Rd,s}\ ;\ V_{Rd,cp}\ ;\ V_{Rdx,c1};\ V_{Rdy,c1})$ - Minimum shear resistance of the bolt with shear reinforcement:

	$V_{Rd,cx}$, $V_{Rd,cy}$ = min($V_{Rd,s}$; $V_{Rd,cp}$; $V_{Rdx,c3}$; $V_{Rdy,c3}$) - Minimum shear resistance of the bolt in the direction of the resultant: - $V_{Rd,cxy}$ = min($V_{Rd,s\ resultant}$) - Connection shear resistance: - $V_{Rd,cx}$, $V_{Rd,cy}$ = n * min($\Sigma V_{Rd,cx1}$, $\Sigma V_{Rd,cy1}$), where n = number of bolt on connection. The shear resistance of the connection is determined by the shear resistance of the bolt closest to the edge. This minimum value is entered for the other bonlts when specifying the resistance of the connection.
3. *Utilisation rate n_1, n_2, n_3,*	Bolt utilisation rate for the design failure criteria.
4. *Criterion*	The description can be used to review which failure criterion became dominant for each bolt. Criterion = the minimum of cases 1–6. 1. Shear reinforcement is not needed. The bolt withstands in the concrete without shear reinforcement. 3. Bolt-specific shear stirrups are needed. The bolt must be provided with shear reinforcement for shear force. If the resistance is exceeded, the bolt will not withstand even with shear reinforcement. 4. Pry-out resistance is dominant. Change the bolt. 5. The steel shear resistance of the bolt is dominant. The bolt is so far from the concrete edge that the bolt's steel shear resistance is determining. If this is exceeded, change the bolt. 6. The bolt is too close to the concrete edge for shear force. The bolt resistance is exceeded. Add shear reinforcement. If the message was received with shear reinforcement, the bolt will not withstand, and the structure must be changed.
5. *Acceptance*	The acceptance rate for the minimum failure criteria determining the shear force and torsion in the directions of the main axes and resultant is shown at the end of the row.



No.	Bolt	VExd	VRd,cx	n1	Conditi	VEyd	VRd,cy	n2	Conditi	VExyd	VRd,cxy	n3	Condit
1	ATP30	2.3	9.5	0.24	1	2.3	8.9	0.26	1	3.3	23.8	0.14	4
2	ATP30	2.3	8.9	0.26	1	2.3	8.9	0.26	1	3.3	23.8	0.14	4
3	ATP30	2.3	9.5	0.24	1	2.3	9.5	0.24	1	3.3	23.8	0.14	4
4	ATP30	2.3	8.9	0.26	1	2.3	9.5	0.24	1	3.3	23.8	0.14	4
5	ATP24	1.4	8.0	0.18	1	1.4	6.8	0.21	1	2.0	24.9	0.08	4
6	ATP24	1.4	8.0	0.18	1	1.4	8.0	0.18	1	2.0	24.9	0.08	4
7	ATP24	1.4	8.0	0.18	1	1.4	8.0	0.18	1	2.0	24.9	0.08	4
8	ATP24	1.4	6.8	0.21	1	1.4	8.0	0.18	1	2.0	24.9	0.08	4

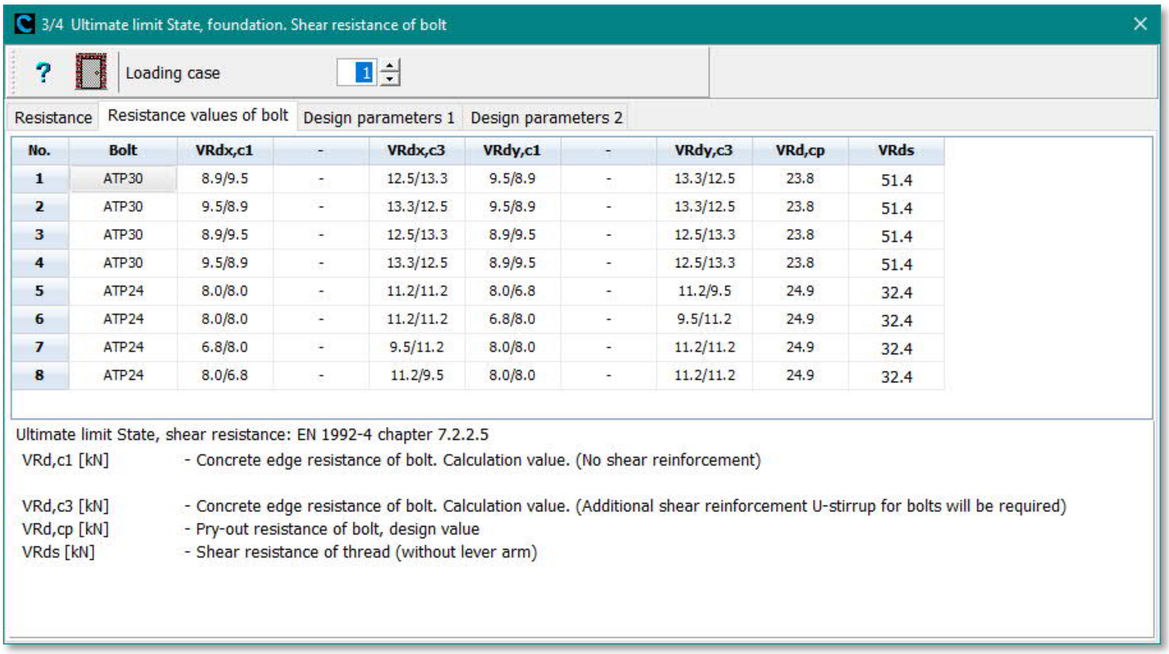
Ultimate limit State, shear resistance: EN 1992-4 chapter 7.2.2.5
VExd, VEyd, VExyd [kN] - Bolt. Design value of shear load
VRd,cx, VRd,cy, VRd,cxy [kN] - Bolt. esistance of shear load (Concrete edge, PryOut or steel resistance)
n1, n2, n3 [-] - Bolt. Utilization degree of shear load
Design criteria: 1 Bolt. Shear reinforcement will be not required

3 Bolt. Shear reinforcement. (U-stirrup for separate bolts) will be required
4 Bolt. Pry-out resistance is decisive
5 Bolt. Shear resistance of steel section of thread is decisive
6 Bolt. Edge distance for shear load is to small

Figure 21. Ultimate limit state. Shear and torsional resistance of bolt.

2. **Shear resistances, pry-out, concrete edge and steel shear**

Tab 2 of Window 3/4 shows the failure criterion shear resistances of the bolts.	
1. $V_{Rdx,c1}$ $V_{Rdy,c1}$	Bolt's concrete edge shear resistance without reinforcement. The resistances are output in the +,– directions of both axes. - The first number is the bolt's shear resistance in the directions of the +X- and +Y-axis without reinforcement. - The second number is the bolt's shear resistance in the directions of the –X- and –Y-axis without reinforcement. - The connections shear resistance by direction is min $(V_{Rdx,c1})_i$; min $(V_{Rdy,c1})_i$ If this is exceeded, the connection must be provided with shear reinforcement.
2. $V_{Rdx,c3}$ $V_{Rdy,c3}$	Bolt's concrete edge shear resistance with supplementary reinforcement. - The first number is the bolt's shear resistance in the directions of the +X- and +Y-axis with supplementary reinforcement. - The second number is the bolt's shear resistance in the directions of the –X- and –Y-axis with supplementary reinforcement. - The connection shear resistance by direction is min $(V_{Rdx,c3})_i$; min$(V_{Rdy,c3})_i$ If this is exceeded, change the connection or modify the structure.
3. $V_{Rd,cp}$	Pry-out failure criterion resistance of the bolt. If exceeded, change the bolt.
4. $V_{Rd,s}$	Steel shear resistance of the bolt. If exceeded, change the bolt.



No.	Bolt	VRdx,c1	-	VRdx,c3	VRdy,c1	-	VRdy,c3	VRd,cp	VRds
1	ATP30	8.9/9.5	-	12.5/13.3	9.5/8.9	-	13.3/12.5	23.8	51.4
2	ATP30	9.5/8.9	-	13.3/12.5	9.5/8.9	-	13.3/12.5	23.8	51.4
3	ATP30	8.9/9.5	-	12.5/13.3	8.9/9.5	-	12.5/13.3	23.8	51.4
4	ATP30	9.5/8.9	-	13.3/12.5	8.9/9.5	-	12.5/13.3	23.8	51.4
5	ATP24	8.0/8.0	-	11.2/11.2	8.0/6.8	-	11.2/9.5	24.9	32.4
6	ATP24	8.0/8.0	-	11.2/11.2	6.8/8.0	-	9.5/11.2	24.9	32.4
7	ATP24	6.8/8.0	-	9.5/11.2	8.0/8.0	-	11.2/11.2	24.9	32.4
8	ATP24	8.0/6.8	-	11.2/9.5	8.0/8.0	-	11.2/11.2	24.9	32.4

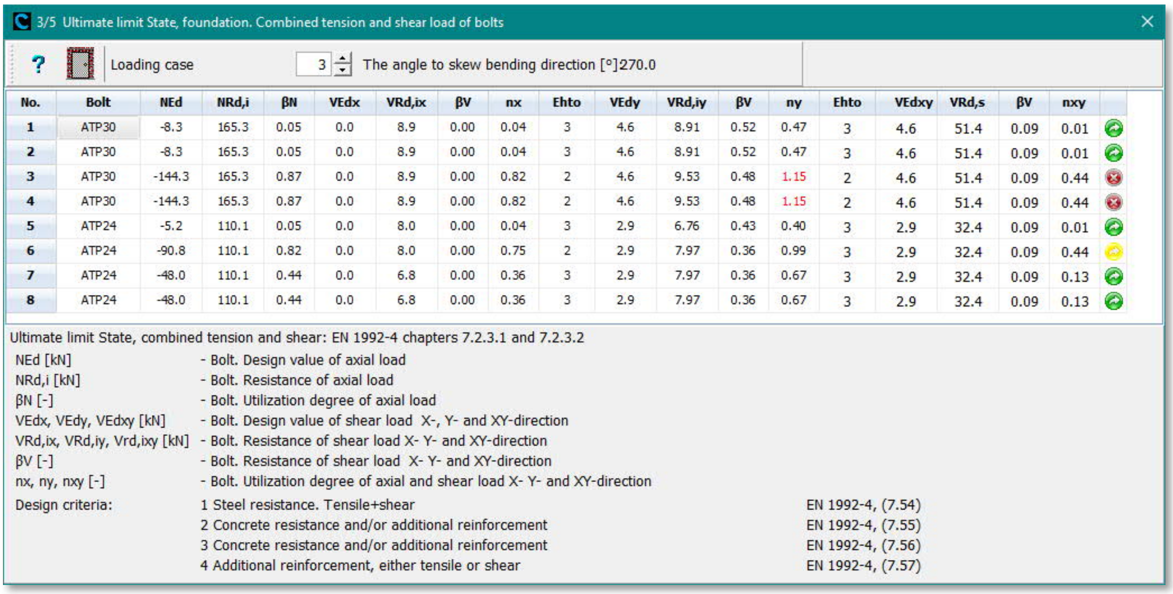
Figure 22. Ultimate limit state. Bolt's concrete shear resistance with reinforcement.

5.5.5 Combining the bolts' axial force and shear resistance

1. **Combination of resistances**

Window 3/5 shows the combination of the bolt's axial and shear force resistances in the directions of the main axes and in the skew bending direction.	
1. N_{Ed}, V_{Exd}, V_{Eyd}, V_{Exyd},	- Calculation value of the bolt's axial and shear force by load case in the directions of the main axes and shear resultant.
2. N_{ED}, $N_{Rd,I}$, β_N	- Bolt's axial force calculation value, resistance and utilisation rate.
3. V_{Exd}, V_{Eyd}, V_{Exyd} $V_{Rd,ix}$, $V_{Rd,iy}$, $V_{Rd,s}$ β_V	- Bolt's shear force calculation value, resistance and utilisation rate in the directions of the X- and Y-axes. - Bolt's skew direction shear resultant, steel shear resistance and utilisation rate.

4. Utilisation rate *n_x, n_y, n_{xy}*	- Utilisation rate of the bolt's axial force and shear combination in the directions of the X- and Y-axes and skew resultant.
5. Criterion	The description can be used to review which combination criterion became dominant for each bolt. Combination formulas EN 1992-4:2018, Section 7.2.3.1 Criterion = min (from cases 1–4). 1. The bolt's steel resistance is determining. Tension + shear. Formula EN 1992-4:2018 (7.54) 2. The bolt's concrete resistance is determining. Tension + shear. Either only concrete resistance or both tensile and shear supplementary reinforcement are used. Formula EN 1992-4:2018 (7.55) 3. The bolt's concrete resistance is determining. Tension + shear. Either only concrete resistance or both tensile and shear supplementary reinforcement are used. Formula EN 1992-4:2018 (7.56) 4. The bolt's concrete resistance is determining. Tension + shear. Either concrete resistance or only tensile or shear supplementary reinforcement is used. Formula EN 1992-4:2018 (7.57)
6. Acceptance	- If the acceptance rate in this window is green or yellow, the bolt is accepted. - Thereby, the highest individual bolt utilisation rate also represents the connection utilisation rate, and the bolt's Criterion shows which criterion will become dominant for the connection.



3/5 Ultimate limit State, foundation. Combined tension and shear load of bolts

Loading case 3 The angle to skew bending direction [°]270.0

No.	Bolt	NEd	NRd,i	βN	VEdx	VRd,ix	βV	nx	Ehto	VEdy	VRd,iy	βV	ny	Ehto	VEdxy	VRd,s	βV	nxy
1	ATP30	-8.3	165.3	0.05	0.0	8.9	0.00	0.04	3	4.6	8.91	0.52	0.47	3	4.6	51.4	0.09	0.01
2	ATP30	-8.3	165.3	0.05	0.0	8.9	0.00	0.04	3	4.6	8.91	0.52	0.47	3	4.6	51.4	0.09	0.01
3	ATP30	-144.3	165.3	0.87	0.0	8.9	0.00	0.82	2	4.6	9.53	0.48	1.15	2	4.6	51.4	0.09	0.44
4	ATP30	-144.3	165.3	0.87	0.0	8.9	0.00	0.82	2	4.6	9.53	0.48	1.15	2	4.6	51.4	0.09	0.44
5	ATP24	-5.2	110.1	0.05	0.0	8.0	0.00	0.04	3	2.9	6.76	0.43	0.40	3	2.9	32.4	0.09	0.01
6	ATP24	-90.8	110.1	0.82	0.0	8.0	0.00	0.75	2	2.9	7.97	0.36	0.99	3	2.9	32.4	0.09	0.44
7	ATP24	-48.0	110.1	0.44	0.0	6.8	0.00	0.36	3	2.9	7.97	0.36	0.67	3	2.9	32.4	0.09	0.13
8	ATP24	-48.0	110.1	0.44	0.0	6.8	0.00	0.36	3	2.9	7.97	0.36	0.67	3	2.9	32.4	0.09	0.13

Ultimate limit State, combined tension and shear: EN 1992-4 chapters 7.2.3.1 and 7.2.3.2

NEd [kN] - Bolt. Design value of axial load
NRd,i [kN] - Bolt. Resistance of axial load
βN [-] - Bolt. Utilization degree of axial load
VEdx, VEdy, VEdxy [kN] - Bolt. Design value of shear load X-, Y- and XY-direction
VRd,ix, VRd,iy, Vrd,ixy [kN] - Bolt. Resistance of shear load X- Y- and XY-direction
βV [-] - Bolt. Resistance of shear load X- Y- and XY-direction
nx, ny, nxy [-] - Bolt. Utilization degree of axial and shear load X- Y- and XY-direction

Design criteria:
1 Steel resistance. Tensile+shear EN 1992-4, (7.54)
2 Concrete resistance and/or additional reinforcement EN 1992-4, (7.55)
3 Concrete resistance and/or additional reinforcement EN 1992-4, (7.56)
4 Additional reinforcement, either tensile or shear EN 1992-4, (7.57)

Figure 23. Ultimate limit state. Combining the bolt's axial and shear force resistance.

5.6 Reinforcement of bolts

5.6.1 Reinforcement of bolts for axial force

The reinforcement principle for AHP® bolts in foundation columns is shown in Figure 24. The shear reinforcements needed for foundation columns are shown in the figure 28. The same reinforcements are also used in the lower column in column extensions.

1. AHP bolts' reinforcement for axial force in foundation columns

1. Splitting stirrups A_{st3}	**Splitting stirrups for bolts** - The stirrups are located at the bottom and top ends of the bond according to EN 1992-1-1, Section 8.7.3.1. - The stirrups are needed when the bolt's bond or column's main bar is ≥ T20. - The distance between stirrups is ≤ 150 mm. The stirrups are selected according to the column/foundation stirrups and matched to the stirrup size. - The number of stirrups/location area = A_{st3}, which has been calculated according to the size of the bolt's bond.
2. Main rebars A_{st4}	**Bolts' main reinforcement in foundation columns** - The vertical rebars are the AHP® bolt's main reinforcement for axial force in a foundation column. - The reinforcement usually also constitutes the main reinforcement of the foundation column, unless the large size of the foundation column requires separate bonds. - The main reinforcement is located in the area affected by the bolt's axial force in accordance with minimum distances between bars as specified by the standard. The main reinforcement consists of separate pieces of rebar, not rebar bundles. The design criterion is a good bonding condition, product (α_2 α_3 α_5) = 1.0 and lap factor α_6 = 1.5. - Figure 24 shows the maximum main reinforcement calculated according to the design value for axial force resistance. The reinforcement may also be made according to the actual bolt force calculated by the software. The rebar size may be selected according to the other reinforcement of the column.

Bolt	A_{st3} mm^2	A_{st4} mm^2	A_{st4} T
AHP16	0	142	2T12
AHP20	157	222	2T12
AHP24	245	319	3T12
AHP30	402	507	3T16
AHP36	402	727	3T20
AHP39	628	882	2T25
AHP45	628	1135	3T25

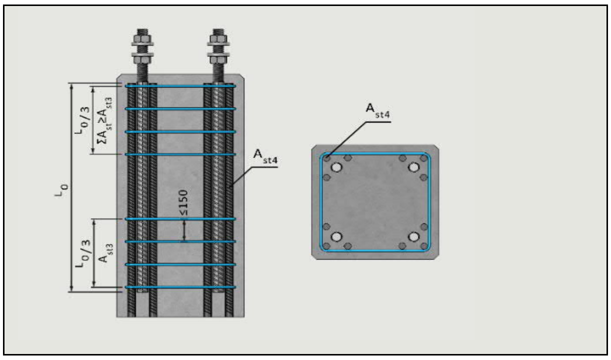


Figure 24. AHP® bolt's reinforcement for axial force resistance

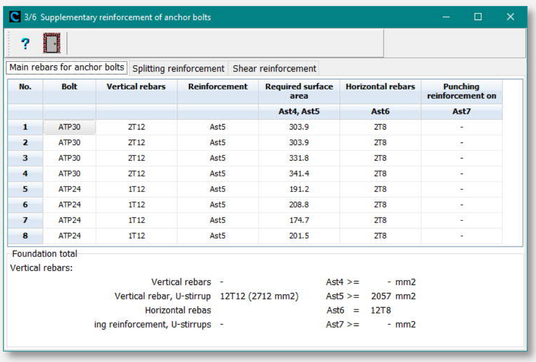
1. Main reinforcement of AHP®-bolt - The software displays the reinforcement of ATP® and AHP® bolts for axial force in window 3/6. - The size and number of reinforcements is calculated according to the default rebars. - These reinforcements are the minimum amounts calculated on the basis of bolt-specific forces. - Foundation will be reinforcer according to maximum bolt.	

Figure 25. AHP® bolts' reinforcement for calculated axial force in foundation.

2. ATP® bolts' reinforcement for axial force in column footings

The principle for reinforcing ATP bolts is shown in Figure 26, which presents the failure cone reinforcement of one tensile bolt (blue) and one compressed bolt (red).	
1. Tension rebars A_{st5}	**Vertical rebars of the Concrete Cone. Foundation column and footing.** - Vertical stirrup reinforcement is placed in each bolt's failure cone area, calculated according to the bolt's tensile force. The stirrups are positioned symmetrically around the bolt. - The bolt can be reinforced using maximum reinforcement A_{st5} calculated on the basis of the bolt's axial force resistance as indicated in Table 9, or the area calculated by the software can be used. - The calculated reinforcement area A_{st5} is towards one leg of the U-stirrup. - The U-stirrups are positioned around the bolt and anchored to the bottom.
2. Edge rebars A_{st6}	**Rebars at the corners of vertical stirrups.** - Corner steels located at the top and bottom ends of vertical stirrups A_{st5}. - The rebar size can be selected according to the A_{st8} reinforcement. - The rebars can be included in the A_{st8} reinforcement amounts.
3. Tension reinforcement A_{st7}	**Failure cone reinforcement of the bolt's bottom surface. Column footing.** - Vertical stirrup reinforcement is placed on the bottom surface. - The calculated area A_{st7} is towards one leg of the U-stirrup, and the stirrup can be combined with stirrup A_{st5}. - Reinforcement is not needed when the amount of concrete below the bolt is ≥ h_{min}, Table 9.
4. Splitting rebars A_{st8}	**Splitting reinforcement of the top surface of the foundations. Foundation column and footing.** - Splitting reinforcement is required at the top surface of the foundations, consisting of mesh reinforcement A_{st8} positioned in the failure cone area of tensile bolts. The width of the reinforced area is 3*h_{ef}, where h_{ef} is the bolt embedment depth. - Reinforcement is required symmetrically in both directions at tensile bolts. A_{st8} is the total area of the mesh per direction. - In Table 11, reinforcement A_{st8} has been calculated on the basis of the tensile resistance of one bolt. The total amount of mesh is the total combined amount based on the tensile bolts, positioned symmetrically in the failure cone areas of the bolts. - From reinforcement A_{st8}, two/four rebars/bolt line/direction can be used for reinforcement A_{st6}.
5. Blow-out stirrups A_{st9}	**Splitting reinforcement for the bolt's headed fastened for blow-out failure. Foundation column.** - In a foundation column, splitting reinforcement is positioned at the bottom end of the bolt, in the headed fastened area. - The supplementary stirrups are shown in Table 9.Stirrups are needed only when edge distance of bolt is ≤ C2 table 5.

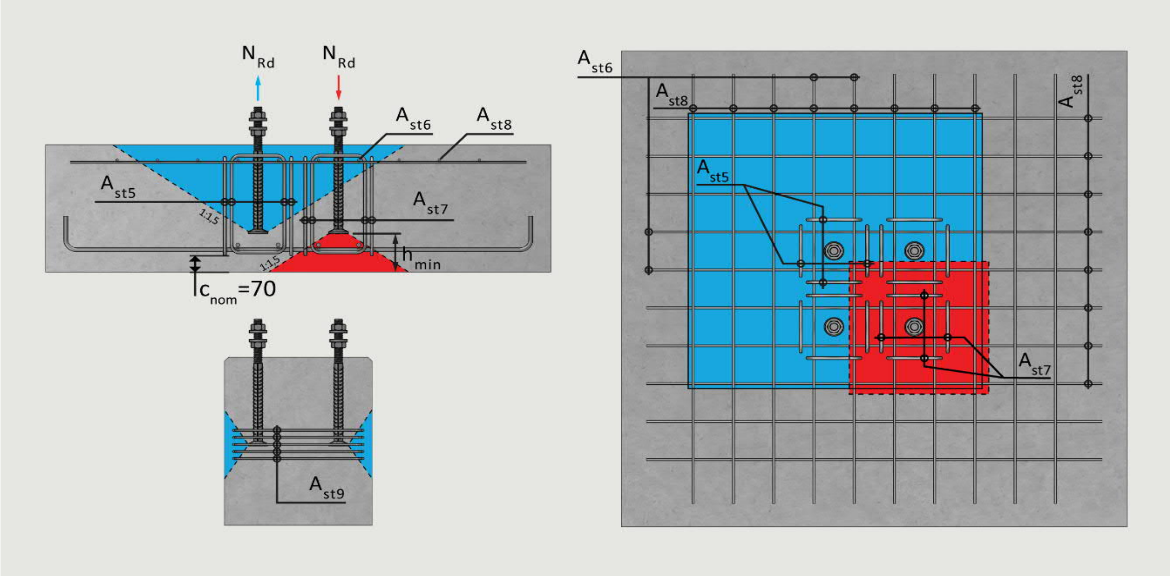


Figure 26. ATP® bolt's axial force and splitting reinforcement in a column footing

Table 9. ATP® bolt's axial force and splitting reinforcement.

Bolt	A_{st5} mm²	A_{st5} T	A_{st6} T	A_{st7} mm²	A_{st7} T	h_{min} mm	A_{st8}/A_{st9} mm²	A_{st8}/A_{st9} T
ATP16	71	2T10	2T8	44	2T10	88	71	2T8
ATP20	111	2T10	2T8	68	2T10	117	111	3T8
ATP24	159	2T10	2T8	92	2T10	143	159	4T8
ATP30	253	4T12	2T8	153	2T12	203	253	5T8
ATP36	365	4T12	2T10	234	4T12	267	365	5T10
ATP39	441	4T12	2T10	265	4T12	291	441	6T10
ATP45	568	6T12	2T12	361	4T12	314	568	5T12

5.6.2 Reinforcement of bolts for shear force

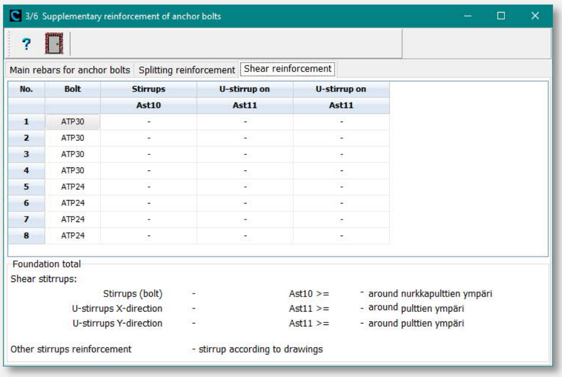
The shear reinforcement for AHP® and ATP® bolts is shown in Figure 27. Bolts require shear reinforcements, which are calculated by the software according to the following principles:

1. Bolts AHP® and ATP® shear reinforcement.

1. No reinforcement Ast	**The software does not output shear reinforcement.** - If the column's shear force is transferred to the foundation column through friction or using a shear headed fastened, shear stirrup reinforcement calculated according to EC2 is enough for the foundations. In this case, reinforcements A_{st10} and A_{st11} are not output in window 3/6. The designer specifies the necessary stirrups separately. - When the shear force on the column is so small that shear reinforcement is not needed for the bolts, it is sufficient to have standard minimum stirrups A_{st} in the foundations. In this case, the software does not output shear stirrups A_{st10} and A_{st11} in window 3/6. - The designer specifies the necessary stirrups separately.
2. Shear-stirrups A_{st10} Only CEN/TS 1992-4-2	**Shear force is transferred using a stirrup positioned around the bolts.** **NOTE: These stirrups are not used in design EN 1992-4:2018.** - The largest number of shear stirrups calculated for an individual bolt are positioned around all corner bolts. The number of intermediate stirrups calculated in the software are positioned at the middle bolts. - The stirrups are positioned on the top surface of the foundations as a bundle and adapted to the other stirrups. - If the bolts are deeper inside the column, the shear stirrups are positioned separately around the bolts.
3. Bolt shear stirrup A_{st11}	**Shear force is transferred using a bolt-specific U-shear stirrup.** - If closed stirrups are not sufficient, the software calculates bolt-specific U-shear stirrups for the bolts. - The stirrups are positioned on the top surface of the foundations,

around the bolt in the direction of the shear force and anchored to the rear edge of the foundations.

- If U-stirrups are not output, they are not needed either.
- However, if the bolt’s shear resistance is exceeded in Figure 21 and no stirrups are output in Figure 27, the shear force on the bolt is so great that it cannot be transferred using stirrup reinforcement.
- Replace the bolt, change the structure dimensions or concrete strength, or change the shear force transfer method to friction force or steel stud.



4. Reinforcement principle.

- On the Shear reinforcement tab of window 3/6, bolt-specific shear reinforcement Ast10–Ast11 is output. If the window is empty, the foundations only require standard stirrup reinforcement Ast calculated on the basis of the foundation loads.
- Figure 28 shows the shear reinforcement principles for AHP® and ATP® bolts. The figure does not include other reinforcement of the foundations. These shear reinforcements are positioned if the calculation outputs bolt-specific shear reinforcements Ast10–Ast11 in window 3/6.

- After this, the full reinforcement of the foundations consists of axial force reinforcement as shown in Figure 24 or 26 and bolt-specific shear reinforcement as shown in Figure 27.

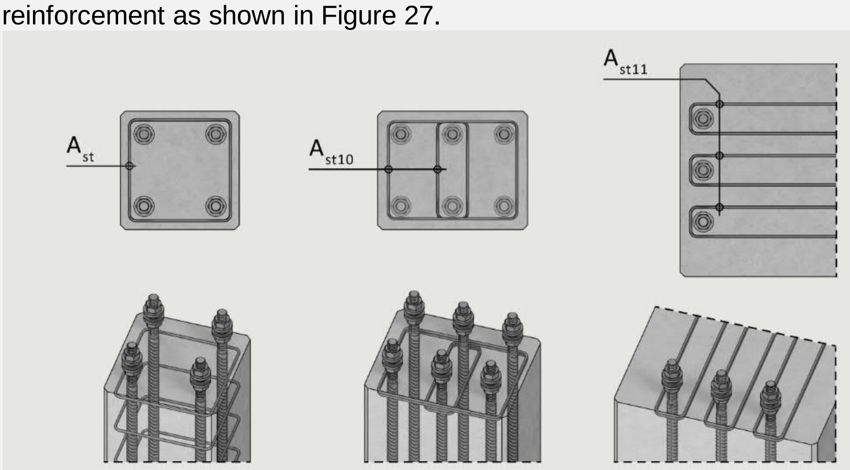


Figure 27. Shear force reinforcement principles for ATP® and AHP® bolts

5.7 Bolt connection's service life design

1. Splitting analysis of the anchor plate's base concrete with the specific loads.

1. *Concrete and supplementary reinforcement*	The following analysis is performed on the splitting of the anchor plate's base concrete: - Tab 1 of Window 3/6 shows the stress state of the tensile reinforcement calculated for the anchor plate with specific loads $\delta_{t,nom}$. - Tab 3 of Window 3/6 shows the stress state of the shear reinforcement calculated for the anchor plate with specific loads $\delta_{t,nom}$. - The specific load has been determined by dividing the calculation load by a factor specified with the load ratio factor G_k in the Loads window.
2. *Splitting design*	- Splitting design is performed for the anchor plate's base concrete at the edge of the structure by using these stress states as the basis for the calculation along with the structure's dimensions and other loads. - The splitting design is performed by applying the instructions in EN 1992-1-1,[6] Section 7.3.

2. Recommended concrete covers and surface treatments.

1. *Connection piece cast in concrete*	- Anchor bolts can be hot dip galvanized. - Only thread can be hot dip galvanized or alternative whole bolt. - The thread of bolt can be removable part and material can be selected according to corrosion requirements.
2. *Concrete cover*	- Table 10 shows the nominal value C_{nom} required for the concrete cover of the bolt's bonds by exposure class according to minimum value $C_{min,cur}$ in EN 1992-1-1. - The nominal value for the concrete cover of the bolt's bonds and threaded section is $C_{nom} = C_{min,cur} + \Delta_{cdev}$ (= 10 mm) + stirrup T10. - Table 10 shows the bolt's minimum edge distances with stirrup size T10 in various exposure classes. - The table also shows the recommended surface treatment methods for the bolt in various exposure classes.

Table 10. Required nominal value C_{nom} for the concrete cover and surface treatment

Exposure class BY 65 Concrete Code	50-year service life C_{nom} + T10 mm	100-year service life C_{nom} + T10 mm	Recommended thread material and surface treatment options for bolts	
			Thread material or surface treatment	Surface treatment of bolt's bond
X0	30	30	No surface treatment	No surface treatment
XC1	30	40	No surface treatment	No surface treatment
XC2	40	50	No surface treatment	No surface treatment
XC3–XC4	45	55	Hot-dip galvanised	Hot-dip galvanised
XS1–XD1	50	60	Hot-dip galvanised	Hot-dip galvanised
XD2	55	65	Hot-dip galvanised	Hot-dip galvanised
XD3	60	70	Hot-dip galvanised	Hot-dip galvanised
XS2–XS3 XA1–XA3 XF1–XF4	–	–	The bolts can be used on the basis of site-specific special analyses. The bolt's thread material, bond surface treatment and concrete cover nominal value are specified according to the site requirements.	

6 INSTALLING THE BOLTS ON THE SITE

6.1 Standards and plans to be followed during erection

The following standards, instructions and project structural plans are to be followed when installing the bolts.

1. Implementation breakdown Quality plan	- Installation plan prepared by the frame installer. - Concrete and steel structure implementation breakdowns prepared for the project. - Quality inspection plan prepared for the project and site.
2. Drawings	- Installation drawings prepared by the frame designer. - Structure sections and installation details prepared by the frame designer.
3. Installation instructions	- User manual for ATP® and AHP® rebar bolts, whose sections 6, 7 and 8 apply to installing a bolt connection on the site. [22]

6.2 Bolt delivery, storage and identification.

The bolts are delivered on a pallet. Longer-term storage protected from rain. Hot-dip galvanised bolts must be stored for at least a month after the galvanisation before use. This storage period is necessary to avoid a hydrogen reaction, which would weaken the bond. The bolt type and size can be identified as follows:

The pallet is equipped with identifying information and each bolt has a colour code. The bolts can be identified as follows: - **Untreated bolts:** The size of the bolt is indicated by the colour code painted on its head. The colour codes are shown in tables 1 and 2. - **Galvanised bolts:** Also identified by the colour code on the bolt's head. This means that bolts can also be identified after casting.	

Figure 28. Bolt markings, identifying information and packaging.

6.3 Installing the bolts in a foundation formwork

The bolts are assembled into a group using an AAK installation frame. The frame ensures the correct distance and direction of each bolt in relation to the lines of the building. In addition, the frame ensures the correct elevation of each bolt and protects the threads during casting. The order code for the installation frame is AAK M H*B, where M is the bolt size and H*B are the distances between bolts in the frame.

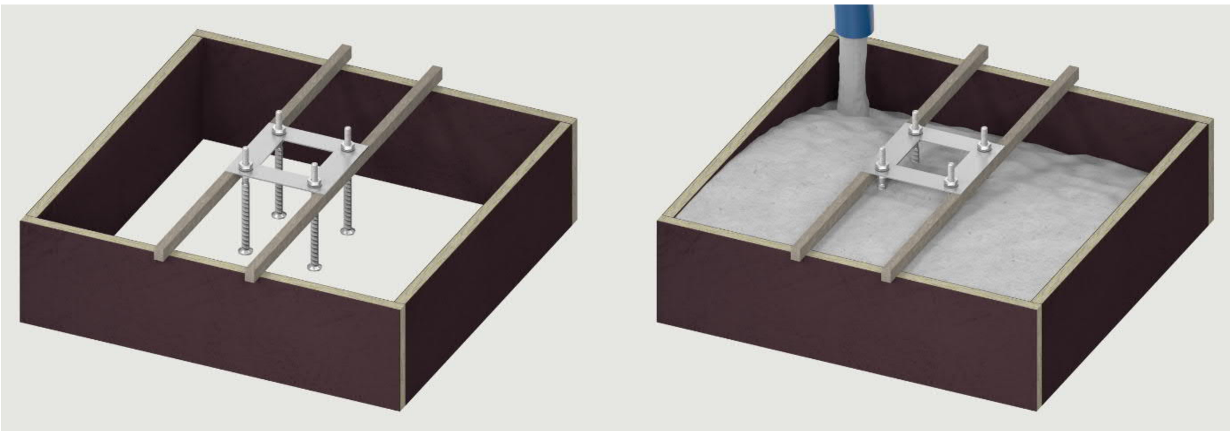


Figure 29. Installing the bolts using a frame and casting the foundations

Before starting the work, the installer of the building frame performs an acceptance inspection, ensuring that the bolt locations are correct. The inspection may either be carried out on the basis of as-built dimension records prepared by the concrete contractor, or the as-built measurements may be performed by the installer. A record will be made of the inspection, transferring the responsibility for the bolt locations to the installer of the structures.

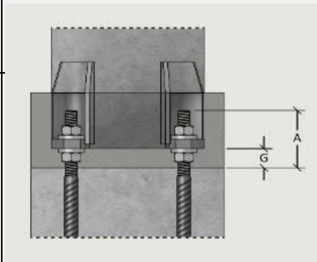
Table 11. Bolt group's installation tolerances.

1	Bolt's mutual location and cross-measure in a finished anchor bolt frame	± 2 mm
2	Anchor bolt frame's centre line location in relation to the module line	± 5 mm
3	Anchor bolt frame's twist at the outer corner of the frame	± 5 mm
4	Mutual displacement between two adjacent frames	± 5 mm
5	Maximum mutual deviation between two frames in the column line direction	± 5 mm
6	Maximum deviation of two frames in the main girder direction	± 5 mm
7	Elevation deviation of the bolt's head	± 10 mm
8	Bolt's straightness (inclination) from the theoretical (L = entire bolt length)	± L/150

Bolts according to Table 14 are used in AHK® and AHK-K shoes. The table shows the elevation of the bolts and grouting from the rough cast surface as well as the nut torque. Tightening the nut has been specified according to EN 1090-2:2018, Section 8.5.1, such that preload force $F_{c,p}$ of the bolt is 50% of the breaking force of the bolt's thread. The nuts are tightened to the torque $M_{r,1} = 0.125*d*F_{p,c}$, where $F_{p,c} = 0.5*f_{ub}*A_s$. After the tightening, at least one pitch of the bolt's thread must be visible.

Table 12. Bolts' elevation in the shoe connection, grouting thickness and torque

Column shoe	Anchor bolt	A mm	G mm	$M_{r,1}$ Nm
AHK16, -K	ATP16 AHP16	105	50	85
AHK20, -K	ATP20 AHP20	115	50	170
AHK24, -K	ATP24 AHP24	130	50	290
AHK30, -K	ATP30 AHP30	150	50	580
AHK36, -K	ATP36 AHP36	170	60	1000
AHK39, -K	ATP39 AHP39	180	60	1300
AHK45, -K	ATP45 AHP45	190	65	2000



Legend: A = Thread elevation from rough cast surface.
G = Base plate casting's standard height with AHK®, -K shoes.
M_v = Nut torque Nm, allowed tolerance ± 30%.

6.4 Installing an anchor bolt connection

1. Column elevation adjustment	- Remove the top nut and washer and check that the bolt's thread is intact. - Adjust the top surface of the washer of the bolt's bottom nut to the planned column lever. - Lever the top surface of the other bolts' washers to the same lever. - Only use the bolt supplier's washers.
2. Lifting the column and installing the nuts	- Lift the column into place and fasten the top nuts and washers. - If necessary, adjust the column upright by turning the bottom nuts of bolts. - The nut holes in the shoes have been dimensioned for a DIN 7444 striking wrench. - The top nuts of the bolts are tightened to the torques shown in Table 14. - The values have been specified in accordance with EN 1090-2:2018 to correspond to tightening that equals 50% of the breaking force of ATP® bolts' thread.
3. Unhooking the crane	- Ensure that the plans do not require installation support for the column. - The crane can be unhooked from the column after providing any installation support required. - Check that none of the bottom nuts are left loose.
4. Checking the connection	- When the column has been installed and the nuts tightened, at least two pitches of the bolt's thread must be visible.

	- Check that all the nuts have been installed, tightened and locked and that none of the bottom nuts have been left loose. - If the thread dimension is lower than this, a non-conformity report must be prepared, and corrective measures taken.
5. Performing the grouting	- Check the plans to confirm the time at which the grouting is to be performed and perform the grouting.

The following methods can be used for locking the (top) nuts: A method suitable for the project must be selected in the structural plans.

1. Locking the bolt's thread to the nut	- Tighten the top nut to the torque specified in Table 14 and hit the bolt's thread at the root of the nut and thread to break it. - If necessary, the torque value can be changed by entering a new percentage in the formula $F_{p,c} = 0.5*f_{ub}*A_{sj}$ instead of the value 0.5 for the preload force required.
2. Pretensioning and concrete casting	- Tighten the top nut to the torque specified in Table 14. For locking the nut, it is enough to cast concrete in the connection around the bolt.
3. Double nut	- When dynamic forces are acting, a double nut is used for locking when no concrete is cast in connection or when it must be possible to remove later.

6.5 Corrective measures allowed for bolts on the site

The structures of the bolt connection must not be modified without the designer's and/or bolt manufacturer's permission. The following measures are allowed on the installation site. A non-conformity report must be prepared for each change, and the changes must be documented in the project's quality documentation.

1. Allowable corrective measure	- If necessary due to installation space requirements, the rebar bond of AHP bolts may be bent (= 10–50 mm) on the site. However, the bend must not reach the bolt's threaded section.
	- Foundation reinforcements may be welded to the bolt's bond, if spot welds are used and the purpose is to fasten the bolt to the formwork during the installation. - Load-bearing joints must not be welded to the bolt's bond.
	- If the washer touches the shoe housing or steel column profile, some material can be removed from that part of the washer such that the washer sits suitably tightly against the top surface of the base plate. - The washer must not be left in a slanted position.
	- When a bolt is installed in a slanted position, the nut must not be left in a slanted position such that it touches the washer on one side only. - For such cases, an oblique washer is made that can be installed between the nut and a standard washer to provide the nut with an even contact surface against the washer.
	- Standard washers may be added to the connection, if necessary, provided that the bolt manufacturer's washer is kept lowermost.

The following corrective measures are not allowed. Changes require a separate non-conformity plan and the designer's or bolt manufacturer's approval.

2. Non-allowable corrective measure	- The bolt's threaded section must not be bent or heated.
	- No other force transfer structures may be welded to the bolt.
	- A headed fastened bolt's bond must not be bent.
	- The bolt and its bonds must not be cut and welded to a new location.
	- The bolt must not be welded to the base plate of a shoe or steel column. - The bolt's washer must be supplied by the bolt manufacturer. - The washer must not be replaced.
	- The nut may never have installed without the bolt's own washer.
	- If the hole in the column's base plate has been reamed, the washer must be replaced with a larger one. - In this case, it is usually necessary to make a special washer.

	- The nut of a hot-dip galvanised bolt must not be replaced with a nut based on another standard. - A hot-dip galvanised bolt requires a hot-dip galvanised m8 nut in accordance with the DIN 934 standard.
	- When the nut has been tightened into place, at least two pitches of the bolt's thread must be visible. - If the thread dimension is lower than this, a non-conformity report must be prepared, and corrective measures approved by the civil engineer.

7 SAFETY MEASURES

7.1 Information for preparing work safety instructions for the site

Appointed by the developer, the project's work safety coordinator is responsible for ensuring work safety during the building work. When preparing work safety instructions for the project, the following must be taken into account in anchor bolt connection installations:

1. *Installation*	- Columns are installed by following the working order in the contractor's installation plan and the requirement for frame stability during erection determined by the designer.
	- The falling of the column and incorrect loading of the bolt connection during installation must be prevented by the following measures:
	- The column is lifted using lifting lugs/equipment. - The column must not be moved or lifted from the shoe bolt hole.
	- During lifting, the shoe base plate must not hit/rest on the ground or another fixed structure.
	- The lifting equipment is unhooked from the column when the column is in place, fastened to all bolts and provided with installation support in accordance with the plans.
	- The bolts must not be loaded in ways and with loads deviating from the plan.

2. *Stability*	- The column must never be left standing without fastening it to the bolts with all nuts.
	- The frame stability under exceptional natural loads must be ensured at the end of the shift.
	- The overall stability of a partially installed frame must be ensured.

3. *Structure*	- The time at which the shoe connection is to be grouted must be specified in the installation plan. - Installation of the upper frame must not be continued before the grout has hardened.
	- The grouting concrete is part of the load-bearing structure of the connection, so the materials and work methods must be selected such that the grout cannot freeze.
	- Any installation supports used for the column are removed after the grout in the connection has hardened.

7.2 Commissioning a bolt connection during construction

The bolt connection is designed for erection state loads and Ultimate Limit state loads for the frame. There are significant differences in the connection's loading capacity between these two states. The bolt connection will only reach the Ultimate Limit state load-bearing capacity when the connection's grouting concrete has reached the design strength. Until then, the column connection and its loading capacity must be reviewed using the erection state resistance values. The time at which grouting is to be performed is specified in the installation plan. The grouting must not be postponed, and the column commissioning permit required for continuing the installation of the upper structures and for additional loading of the column is determined by means of a review.

8 INSTALLATION QUALITY CONTROL

8.1 Instructions for monitoring column installations

Installation quality control for column connections is carried out in accordance with the quality control plan prepared for the project and site. The structural and dimensional inspections specified in the implementation breakdown are performed on the building frame. The instructions to be followed are in EN 13670 for the requirements for concrete structures and in EN 1090-2:2108 for the steel frame.
An inspection report is prepared for the frame's quality control and dimensional inspections and saved in the project's quality documentation. The following inspection measures are performed for bolt connections:

1. Before column installation	- Ensure that the bolts are not damaged. - Following the installation plan regarding the installation order of the elements. - Need for supporting the columns during installation. - Checking the elevation of the bottom ends of the columns and the bolts.
2. After column installation, before grouting	- Check that the column connection has been installed at the elevation specified in the plans. - Ensure that the correct washers have been used and the nuts have been tightened to the torque specified. - Ensure that two pitches of the bolt's thread are visible from the nut. - Ensure that the strength of the grouting concrete is in accordance with the plans.
3. After grouting the connection	- Check that the nut holes and joint grouting have been made appropriately and with the concrete strength according to the plans. - Ensure that all the nut holes and the grouting joint have been filled with concrete. - Ensure that the grouting of the connection meets the fire protection requirements for the connection.
4. Deviations	If the frame installer deviates from the approved plans and documents in any of the following tasks: - quality control - performing the installation work, lifting and transfers - installation materials - structure tolerances and dimensional inspection of the frame - required inspections and their documentation, the installer is obliged to start documenting the non-conformity upon observing the deviation from the plan and to have the client approve the resulting measures. Non-conformity reports are saved in the project's quality documentation.

8.2 Final documentation of installation quality control

When the job has been accepted, the frame installer is required to deliver the inspection and quality control documentation created during the installation work to the client.

1. Readiness inspection records	- As-built dimension record for the bolts. - Loading capacity and commissioning inspection of the columns after grouting.
2. Non-conformity reports	- Any non-conformity reports prepared during the installation of the bolt connection are handed over.
3. Product approval as-built	- CE marking certificates or corresponding product approval information for materials purchased for the site. - As-built documentation for changes made to the structure.

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LIST OF TABLES

PICTURES

Anstar Oy is a Finnish family business specialising in the sales and manufacture of concrete structure connections and composite beams. We are an international operator, and one of the pioneers in the field. Anstar will help you with all your questions relating to concrete connections. Anstar's specialists may also develop solutions to customer-specific connection problems.

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