Anstar®

Beam shoes

User manual

Version 8/2025

Beam shoes

APK-CM beam shoes are used in moment stiff beam-to-column connections of industrial concrete element frames. The shoes are also suitable for heavy-duty concrete element frame connections in office, commercial and public buildings. The connection consists of a prefabricated beam shoe that is installed in the beam's element formwork before casting. The column element has an anchoring bolt corresponding to the shoe as well as rebar coupler connection pieces. The shoe connection is in working order when its grouting concrete has reached the design strength. The connection can also be used to form continuous moment stiff beam frame structures in the concrete element frame.

- The product has been tested and dimensioned to withstand demanding construction conditions
- Quick and easy dimensioning with ACOLUMN software
- Accident scenario calculation available with ACOLUMN as first on the market
- Shoes are manufactured according to SFS-EN 1090-2:2018
- Components and blocks for both Tekla and AutoCAD software
- Extensive adjustability in worksite conditions
- No diagonal supports or welding on the site
- Quick installation at the plant thanks to the casting housing
- Excellent technical support
- Designed in accordance with the requirements of European standards

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Revision L – August 29, 2025

Small adjustments to the product dimension tables 1, 2 and 9. Table 10 removed; Required nominal value C_{nom} for the concrete cover.

Revision L – January 31, 2020

The new eurocode EN 1992-4:2018 has been taken into account with resistance calculation of beam shoe and anchor bolts.
Some uppdatingt to text. No uppdatingt to products.
ACOLUMN software has been uppdated to version 5.0.

Revision K – 29 March 2019

The structure of the APK-M beam shoe has been redesigned. The shoe's new name is APK-CM.
The user manual for the APK-CM beam shoe has been rewritten as a separate manual.
The resistance values for APK-CM shoes have been changed in accordance with the anchor bolt user manual.
New anchoring bolts, ALP-P2S and ALP-P2SM, have been designed for the beam shoe.
The structure and installation method of the moment connection have been changed.
The beam shoes have been added to the ACOLUMN software, and it is now possible to specify the tensile force for the connection.

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 beam shoe connections.

1 BEAM SHOE

APK-CM beam shoes are used in moment rigid beam-to-column connections of industrial concrete element frames. The shoes are also suitable for heavy-duty concrete element frame connections in office, commercial and public buildings. The connection consists of a prefabricated beam shoe that is installed in the beam formwork before casting. Rebar coupler bars are used on the top surface of the beam. The column element has anchoring bolts corresponding to the shoe as well as rebar coupler connection bolts. The shoe connection is in working order when its grouting concrete has reached the design strength. The shoe connection is used to form continuous moment rigid frame structures in the concrete element frame.

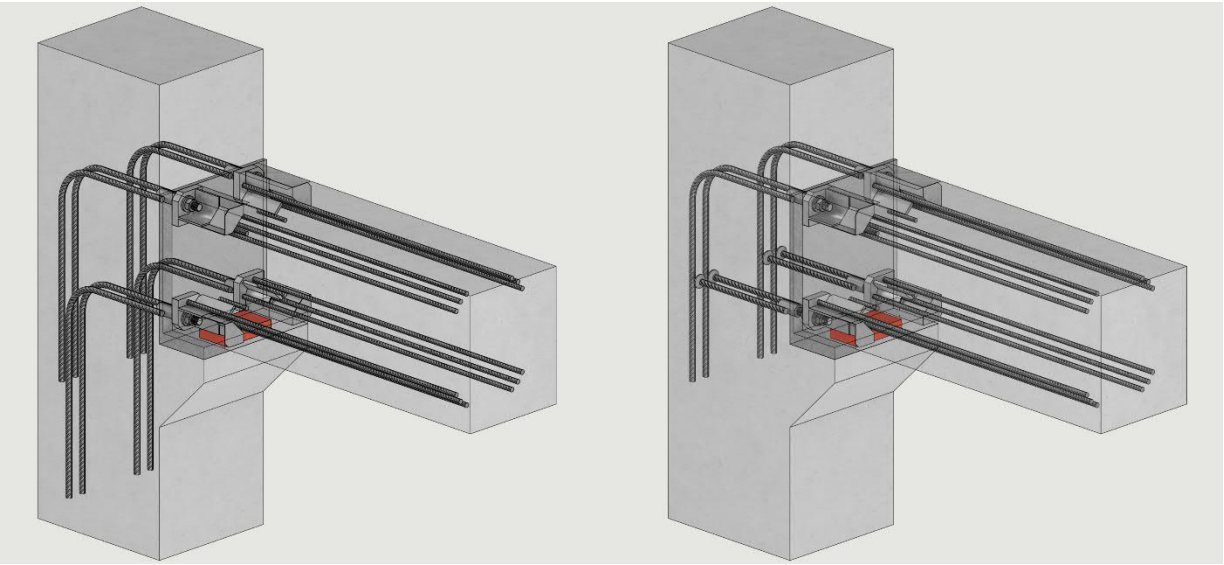


Figure 1. Typical structure of the APK-CM beam shoe in the rigid connection

2 SHOE APPLICATIONS

2.1 Heavy-duty element frames of industrial buildings

APK-CM beam shoes are used in rigid connections between element beams and columns in industrial and commercial buildings. The load-bearing intermediate floor is either a cast-in-situ composite slab or made of hollow-core or thin-shell slab elements. The shoes are suitable for prestressed or normally reinforced rectangular beam connections used to transfer the beam's reactive moment to the column. The beam is centred with the column or located with the necessary sides against each other.

A rigid connection is formed by placing APK-CM beam shoes at the bottom corners of the beam and ARJ rebar coupler tension bars on the top surface of the beam. Alternatively, beam shoes can be placed at both the bottom and top corners of the beam.

The shoe is connected to the column using a bent ALP-P2S anchoring bolt. The bolt has a removable thread that is installed in connection with installing the beam. The structure of the bolts has been minimised so that they fit the edge of the column, next to the main reinforcement. The ALP-P2SM anchoring bolt is used to form a continuous two-beam moment connection through a column. The ALP-P2SM bolt is used if there is no room for bending.

The tension connection on the top surface of the beam is made using an application of the ARJ rebar coupler. Space is provided on the top surface of the beam for the ARJ-L rebar coupler bars. Bent ARJ-R rebar coupler anchoring bolts are placed in the column. A moment

connection through the column is implemented using an ARJ-A anchoring bolt. The rebar coupler connection transfers the tensile forces of the beam's moment connection to the column.

The beam-to-column connection is dimensioned using the ACOLUMN software, which is also used to design the supplementary reinforcement for the beam and column in the connection area. The connection is designed with four shoes or alternatively with shoes on the bottom surface and a rebar coupler connection on the top surface of the beam.

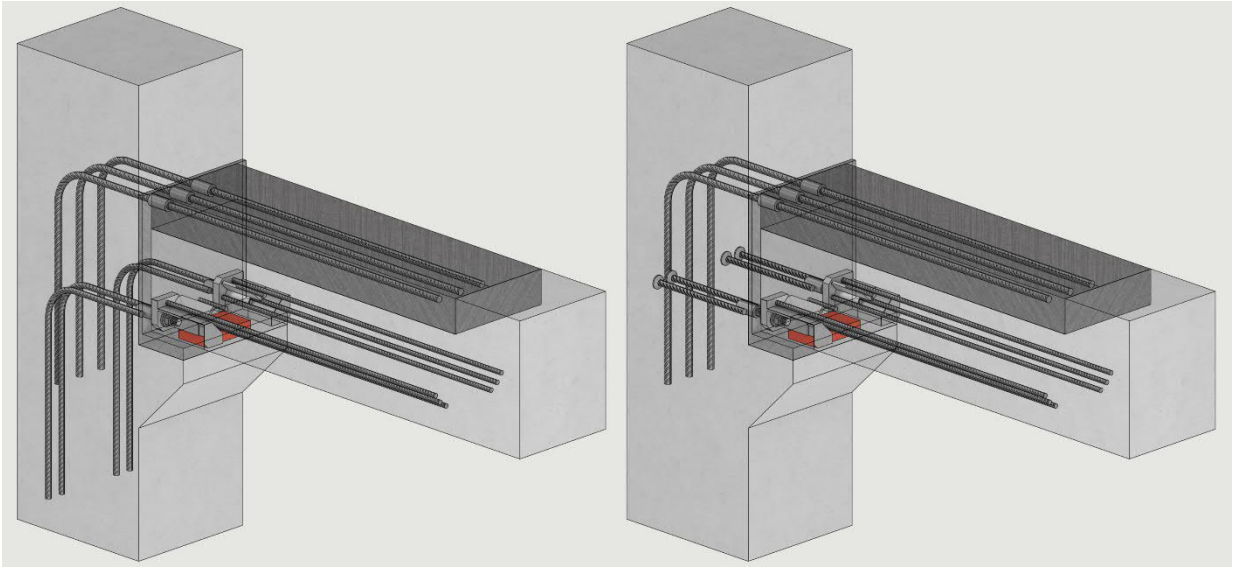


Figure 2. Beam shoe/rebar coupler connection in the rigid frame structure of a building

2.2 Element frames of commercial and office buildings

APK-CM shoes are used for rigid connections in the continuous beam frame structures of element frames of commercial and office buildings. The shoes are used to implement a connection in which the reactive moment of the element beam is transferred through the column using anchoring bolts. The beam is supported for vertical loads on the column bracket.

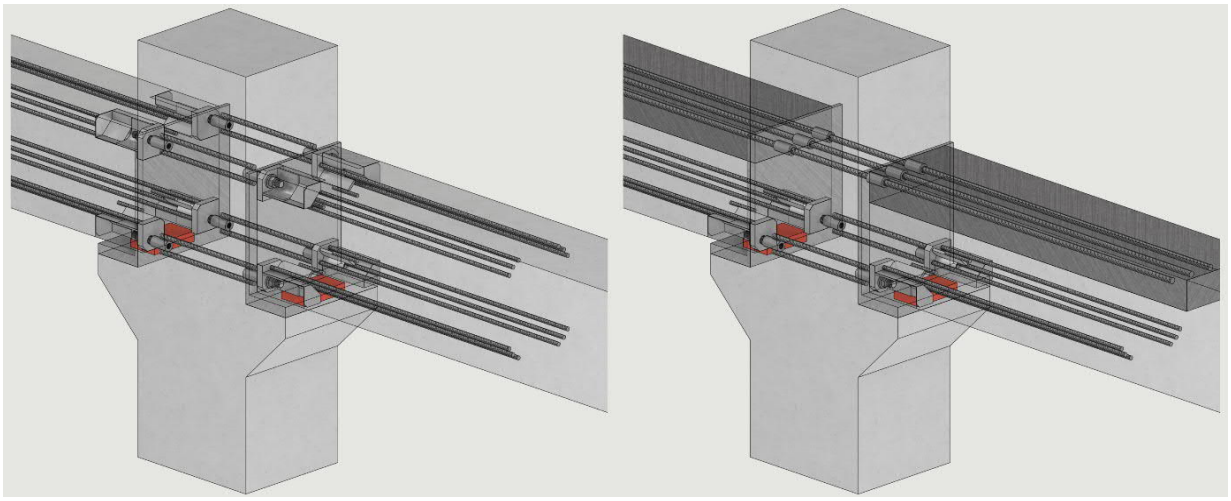


Figure 3. Rigid shoe connection and shoe-to-rebar coupler connection

Design principles for a rigid connection:

1. Calculation standard	- The beam shoe connection structures have been designed according to European standards EN 1992-1-1, EN 1993-1-1 and EN 1992-4:2018.
2. Connection type	- The connection type is a rigid connection between the beam and the column.

	- Refer to Section 4.3 for the operating principle of the connection.
3. Element beam structure	- The beam can be a normally reinforced concrete element. - The shoes are suitable for prestressed beam connections. - The floor structure may be cast in place or have a hollow-core or thin-shell slab structure.
4. Grouting	- The grouting of the connection constitutes the load-bearing structural concrete. - The grout for the connection can be selected from among several commercially available, CE-marked grouts. - The grouting constitutes the fire protection of the connection.
5. Anchoring bolts	- The anchoring bolts can be placed at the edge of the structure according to the protective concrete layer. - The software dimensions the anchoring bolts for forces coming from the shoe. - The bolts only transfer the shoe's Axial force; shear force is transferred through the concrete structure.
6. Supplementary reinforcement	- The software checks the beam's main reinforcement resistance required by the shoes and calculates the supplementary reinforcement required by the shoes and bolts.

2.3 APK-CM beam shoe

APK-CM beam shoes are used to form a rigid connection between a concrete element beam and a column. The connection is made using two or four separate shoes at the bottom and top corners of the beam. The shoe transfers the beam's bending moment to the column's anchoring bolts. The structure of the anchoring bolts has been minimised so that they can be placed next to the column's main pieces of rebar. The location of the shoes can be moved inward as necessary according to the anchoring bolts and column width.

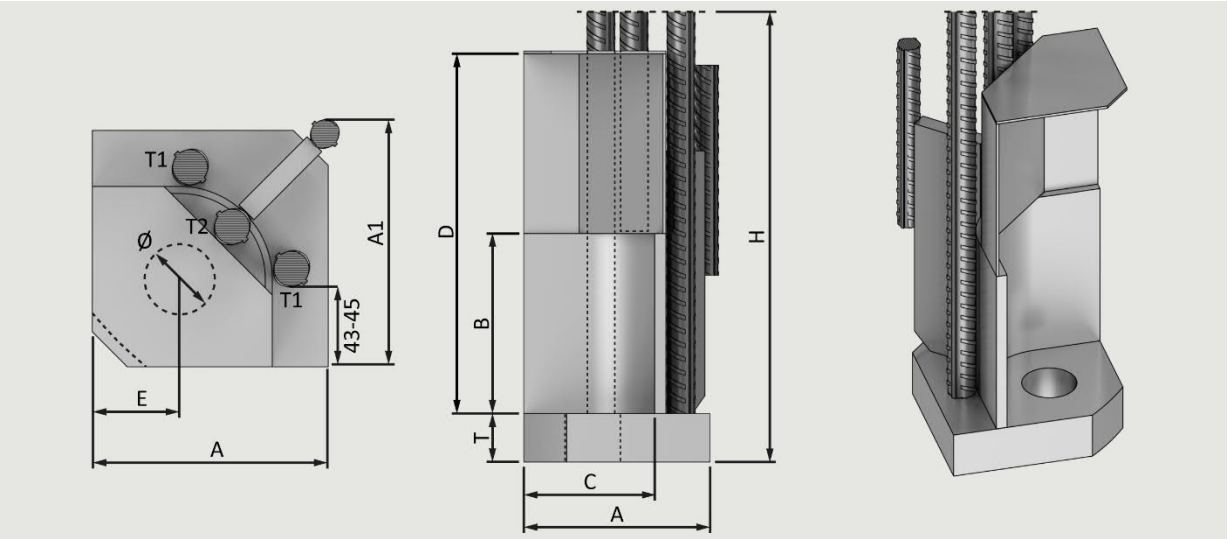


Figure 4. Structure of the APK-CM beam shoe

Table 1. APK-CM beam shoe dimensions

Shoe	Colour code	A mm	A1 mm	B mm	D mm	C mm	E mm	H mm	T1 mm	T2 mm	ϕ mm	T mm	P kg
APK24CM	Light blue	115	125	110	170	85	50	935	2T16	1T16	32	25	7.9
APK30CM	Black	135	140	120	200	95	50	1355	2T20	1T20	40	35	16.7
APK36CM	Red	160	180	130	230	110	60	1540	2T25	1T20	46	40	27.3
APK39CM	Brown	165	190	140	250	115	60	1680	2T25	1T25	50	40	31.4
APK45CM	Violet	180	225	140	270	120	60	1850	2T32	1T28	56	50	49.4
APK52CM	White	190	275	160	310	130	60	2420	2T32	1T32	64	60	69.0

Legend:
A = Base plate side length
A1 = Total width required by the shoe
B = Nut housing height
D = Overall height of installation housing for threaded bolt
C = Housing depth
E = Edge distance of bolt
H = Overall height of shoe
T1 = Shoe bonds on side of housing
T2 = Shoe bonds on top of housing
ϕ = Bolt hole diameter
T = Base plate thickness
P = Shoe weight
Colour code = Identifying colour of shoe base plate

Surface treatment options for APK-CM shoes:

Painting	The base plate is colour-coded with alkyd paint.	standard delivery
No surface treatment	The shoe is delivered without colour code painting.	special order
Hot-dip galvanisation	Hot-dip galvanised according to EN ISO 1461.	special order -HDG

TS and AutoCAD blocks for APK-CM shoes: *www.anstar.fi*

2.4 Anchoring bolts ALP-P2S and ALP-P2SM for beam shoe

ALP-P2S anchoring bolts are used with the beam shoes. The bolt has two straight bonds, which are bent to a 90-degree angle to the rear edge of the column. The bending is carried out according to the project-specific order, so the bolt is located near the rear edge of the column structure, at a distance equalling the thickness of the protective concrete layer. The ALP-P2SM bolt is used to form a rigid two-beam connection through a column. The bolts have a removable threaded section, enabling reliable protection of the thread. More information is available in the *Anchor Bolts* user manual.

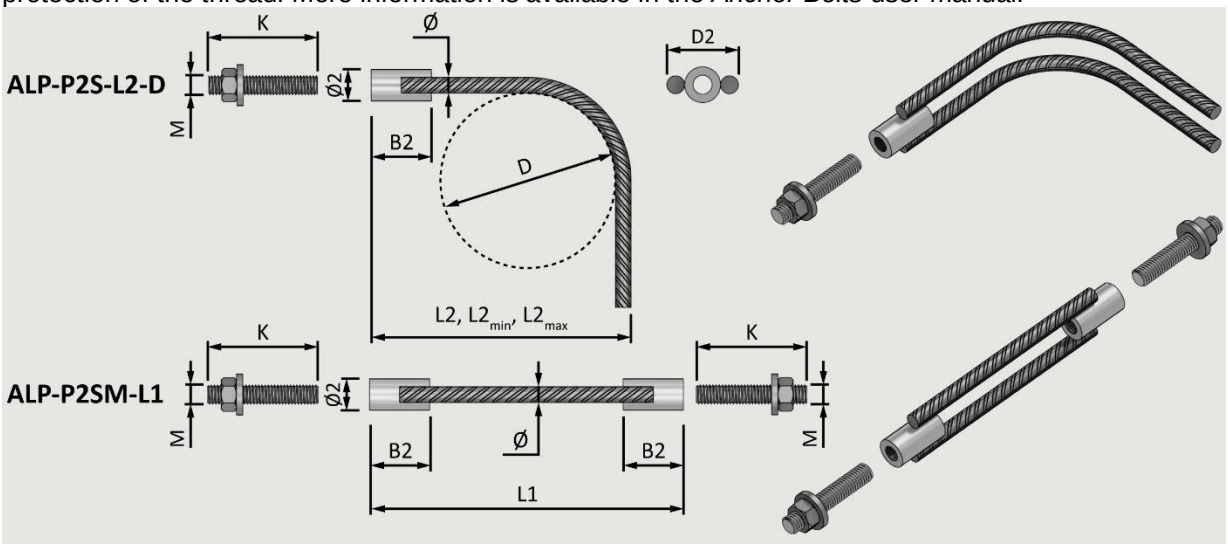


Figure 5. ALP-P2S and ALP-P2SM bolt structure

Table 2. ALP-P2S and ALP-P2SM bolt dimensions

Bolt	Colour code	$L2_{max}$ mm	$L2_{min}$ mm	K1 mm	K mm	M mm	A_s mm^2	Ø mm	Ø2 mm	B2 mm	D mm	D_2 m	T/S mm
ALP22P2S, -P2SM	Light blue	800	285	165	130	M22	303	2T16	35	85	200	70	8/55
ALP30P2S, -P2SM	Black	900	385	195	150	M30	561	2T25	50	95	300	105	10/65
ALP36P2S, -P2SM	Red	1180	400	220	170	M36	817	2T28	60	105	300	125	10/80
ALP39P2S, -P2SM	Brown	1450	410	240	190	M39	976	2T28	65	115	300	130	12/90
ALP45P2S, -P2SM	Violet	1680	455	260	200	M45	1306	2T32	75	125	400	150	12/100
ALP52P2S, -P2SM	White	1935	595	300	235	M52	1758	2T40	90	135	500	180	12/110

Legend:
- L1 = Order length of a bolt going through a column
- $L2_{max}$ = Maximum length of standard bolt ALP-P2S that can be bent with diameter D
- $L2_{min}$ = Minimum length of standard bolt ALP-P2S that can be bent with diameter D
- K1 = Overall length of the removable threaded section
- K = Visible length of the thread from the sleeve surface
- M, A_s = Thread size and stress area
- Ø = Size and number of bolt bonds
- Ø2 = Threaded sleeve outer diameter
- B2 = Threaded sleeve length
- D = Bond bending mandrel diameter in the standard delivery
- D_2 = External width of the bonds on the sleeve surface.
- T, S = Thickness and diameter of the washer. The same washer as for ALP-C bolts.

The colour code is painted on the end of the sleeve. Also identifiable after casting.

Bolt order codes:

ALP-P2S-L2-D	The bolt dimensions must be mentioned in the order: length, D = bending mandrel diameter. Example of an order code: *ALP30P2S-540-D300*.	L2 = horizontal bending
ALP-P2SM-L1	The bolt length must be mentioned in the order: width. Example of an order code: *ALP36P2SM-580*.	L1 = Bolt length = column

Surface treatment options for ALP-P2S bolts:

No treatment	Bolt, threaded rod, nuts and washers, no treatment.	standard delivery
Hot-dip galvanised	HDG threaded rod and nut + washer. Bolt body, no treatment.	special order

ALP-P2S bolt TS models and AutoCAD blocks: *www.anstar.fi*

2.5 ARJ rebar coupler for the beam shoe

The tension-side moment connection on the top surface of the beam is made using an application of the ARJ rebar coupler. Space is provided on the top surface of the beam for the ARJ-L rebar coupler. A bent ARJ-R rebar coupler is placed in the column. An ARJ-A spacer is placed in the connection through the column. The forces of the beam's bending moment are transferred from the main pieces of rebar on the top surface of the beam to the rebar coupler and on to the column rebar coupler. More information is available in the *Rebar Coupler* user manual. Rebar coupler sleeve products are always delivered with a protective plug for protection and identification of the thread. The plug must be removed before installation in the column formwork.

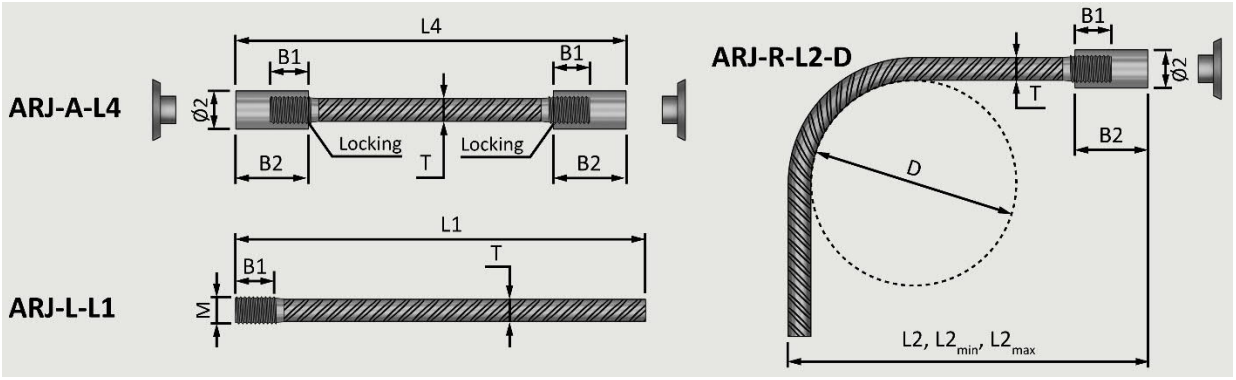


Figure 6. Structure of rebar coupler products in the beam shoe connection

Table 3. Rebar coupler dimensions

Rebar coupler products in the beam shoe connection	Colour code	$L2_{max}$ mm	$L2_{min}$ mm	T mm	M mm	A_s mm^2	B1 mm	B2/Ø2 mm	D mm
ARJ16L-1200, ARJ16A-L4, ARJ16R-L2-D	Yellow	1065	210	16	M20	245	25	50/30	200
ARJ20L-1500, ARJ20A-L4, ARJ20R-L2-D	Blue	1340	250	20	M24	353	30	60/35	300
ARJ25L-1700, ARJ25A-L4, ARJ25R-L2-D	Black	1500	320	25	M30	561	35	70/40	300
ARJ32L-2400, ARJ32A-L4, ARJ32R-L2-D	Grey	2150	420	32	M39	976	45	90/55	400
ARJ40L-3800, ARJ40A-L4, ARJ40R-L2-D	Violet	3500	530	40	M48	1567	60	120/70	500

Legend: L1, L4 = Manufacturing length of the straight rebar coupler or spacer through the column in the order
$L2_{max}$ = Maximum length of standard coupler ARJ-L that can be bent with diameter D
$L2_{min}$ = Minimum length of standard coupler ARJ-L that can be bent with diameter D
T = Rebar size
M, A_s = Thread size and stress area
B1 = Bar thread length
B2, Ø2 = Sleeve length and diameter
D = Bond bending mandrel diameter in the standard delivery
The colour code is in the protective plug or painted on the end of the sleeve. (=ARJ40)

Order markings:

ARJ-L-L1	The bar length must be mentioned in the order: L1 = stock lengths at the beginning of Table 3. The order code, such as ***ARJ20L-1500***
ARJ-A-L4	The bar length must be mentioned in the order: L4 = coupler length = column width The order code, such as ***ARJ25A-480***
ARJ-R-L2-D	The bar dimensions must be mentioned in the order: L2 = horizontal bending length, D = bending mandrel diameter. Example of an order code: ***ARJ32R-530-D400***. Also see *Table 9*.

Surface treatment options for ARJ-L, ARJ-A and ARJ-R rebar couplers:

No treatment	Threaded rod, nuts DIN 934-8 and washers, no surface treatment	standard delivery

Rebar coupler TS models and AutoCAD blocks: *www.anstar.fi*

3 MANUFACTURING INFORMATION

ANSTAR Oy has entered into a quality control agreement with Kiwa Oy regarding the manufacture of APK-CM beam shoes.
The manufacturing information for the shoes is as follows:

1. *Manufacturing markings*	Shoe manufacturing markings: - Anstar's code - The shoe code is painted on the base plate with a colour code. - The bolts have a colour code on the sleeve or a protective plug for identification. - Packaging: shrink-wrapped on a pallet
2. *Materials*	Manufacturing materials: - Base plate EN 10025-2 S355J2+N - Housing EN 10025-2 S355J2+N - Rebar EN 10080, SFS 1300:2017 B500B - Impact test temperature for the materials: –20 °C
3. *Manufacturing method*	Shoe manufacture: - Manufactured according to the EN 1090-2:2018 standard in execution class EXC2. By special order, they can be manufactured in execution class EXC3. [2] - The welding class is C as standard and B by special order, EN ISO 5817. - Rebar welding EN 17660-1 [14] - Manufacturing tolerances EN 1090-2:2018 [2]
4. *Surface treatment methods*	Surface treatment methods for shoes: - The bottom surface of the base plate is colour-coded by painting. [10] - Delivery without colour code painting by special order. - Shoes are hot-dip galvanised by special order according to EN-ISO 1461. [11]
5. *Product approval and quality control*	Product quality control: Certificate 0875-CPR-FIN542. 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 shoe manufacturing programme and user manuals.

	Shoe	User manual	Typical application
1	*AHK AHK-K*	*AHK Column Shoes*	*Light element frames in office and commercial buildings. AHK shoes are used as corner shoes in rectangular columns, and AHK-K shoes are used as middle shoes in rectangular columns and shoes in round columns. The shoes are suitable for column extension and foundation connections. The anchor bolts used are ATP and AHP rebar bolts.*
2	*APK-C APKK-C*	*APK-C Column Shoes*	*Heavy-duty column-to-foundation connections in element frames of industrial buildings. Heavy-duty foundation connections in office and commercial buildings. Corner and middle shoes in rectangular columns. The bolts used are ALP-C and S series anchor bolts.*
3	*APK-CM ARJ*	*Beam Shoes*	*Rigid beam-to-column connections in the element frames of industrial and commercial buildings. ALP-P2S and ALP-P2SM anchoring bolts as well as ARJ rebar coupler applications ARJ-A and ARJ-R are used.*
4	*ASL-H ASL-P*	*Wall Shoes*	*Extension and foundation connections of wall elements used for bracing concrete element frames. The connection transfers the tensile and shear forces of the shear wall. The bolts used are ATP and AHP rebar bolts and ALP-P2 anchor bolts.*

4 DESING 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+NA	Design of steel structures. Part 1-1: General rules. [7]
SFS-EN 13670	Execution of concrete structures, execution class 2 or 3, [15]
SFS 5975	Use of standard SFS-EN 13670 in Finland [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. Shoe 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 ISO 5817	Welding. Fusion-welded joints in steel, nickel, titanium and their alloys. Weld classes.[9]
EN 17760-1	Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints. [14]

4.2 Beam shoe resistance values

4.2.1 Beam-to-column connection design principle

Beam-to-column moment connections must be designed for the following forces. The forces must be determined using separate frame structure calculation software. Calculation for the connection is performed using the ACOLUMN software.

1. *Axial force* N_d	- The beam's axial force from the frame structure calculations is specified for the connection. In the ACOLUMN software, axial force can be compression (–) or tension (+).
2. *Bending moment* M_{xd}	- The connection is dimensioned for the beam's vertical reactive moment, whose bending direction may have a ± sign. Moment transfer: see Section 4.3, item 1. - The beam shoes do not transfer compressive force to the bolts, since the anchoring bolt has no nut under the shoe base plate. - The shoe transfers the compressive force to the column through concrete pressure. The rebar coupler connection transfers tensile and compressive forces on the top surface of the beam.
3. *Bending moment* M_{yd}	- The shoe connection can transfer horizontal bending moment. - However, this moment results in torsion on the column. - Nevertheless, the impact of the M_{yd} moment can be calculated in the shoe connection.
4. *Vertical shear force* Q_{yd}	- The beam is supported on the column bracket, which transfers the shear force to the column. - The shoe connection does not transfer the vertical shear force of the beam. The beam/bracket support surface must be dimensioned for the beam's support reaction. The beam is designed for the shear force.
5. *Horizontal shear force* Q_{xd}	- The shoe/bolt connection does not transfer the shear force horizontally from the beam to the column. The shear force must be transferred through the plane structure of the beam's top surface.

4.2.2 Axial force resistance of shoes

The design value of a shoe's axial force resistance is determined according to the resistance of the anchoring bolt corresponding to the shoe. The design value of the bolt's thread has been calculated according to EN 1992-4:2018 [20]. The design values for the axial force resistance of shoes are shown in Table 5.

Table 5. Design value of the APK-CM shoe's axial force resistance.

Beam shoe	Axial force resistance		Anchoring bolts suitable for the shoe in the column
	N_{Rd} [kN]	$N_{Rd,a}$ [kN]	
APK24CM	161.0	184,7	ALP22P2S, ALP22P2SM, APL22LS
APK30CM	299.2	341,9	ALP30P2S, ALP30P2SM, APL30LS
APK36CM	435.7	498,0	ALP36P2S, ALP36P2SM, APL36LS
APK39CM	520.5	594,9	ALP39P2S, ALP39P2SM, APL39LS
APK45CM	696.5	796,0	ALP45P2S, ALP45P2SM, APL45LS
APK52CM	937.6	1071,5	ALP52P2S, ALP52P2SM, APL52LS

N_{Rd} = Axial force resistance value, ultimate limit state, concrete strength C30/37-2.
$N_{Rd,a}$ = Axial force resistance value, accidental limit state, concrete strength C30/37.

Erection state resistance values are not calculated for the shoe connection. However, before the connection is grouted, the shoe/bolt connection can transfer the tensile force from the beam to the column, preventing the beam from falling. The software is used to calculate supplementary reinforcement for the shoe as well as the joint action of the bonds with the beam's main reinforcement.

4.2.3 Axial force resistance of the rebar coupler

The design value of a rebar coupler's axial force resistance is determined by the resistance of the rebar. Design value $N_{Rd,1}$ for the coupler has been calculated according to EN 1992-1-1, Annex A, Section A.2.1 [6]. Design value $N_{Rd,2}$ has been calculated according to the basic values in the European standard.
The design values for the axial force resistance of the ARJ coupler are shown in Table 6.

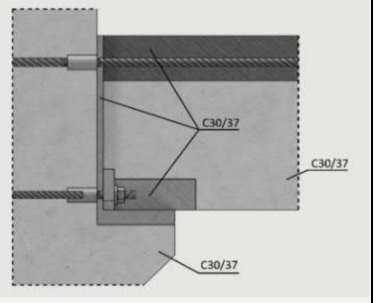
Table 6. Design value of the ARJ coupler's axial force resistance.

Reinforcement coupler on the beam's top surface	Axial force resistance			Coupler anchoring bolts in the column
	$N_{Rd,1}$ [kN]	$N_{Rd,2}$ [kN]	$N_{Rd,a}$ [kN]	
ARJ16L	91,4	87.4	100.5	ARJ16A, ARJ16R
ARJ20L	142,7	136.5	157,0	ARJ20A, ARJ20R
ARJ25L	223,2	213.5	245.5	ARJ25A, ARJ25R
ARJ32L	365,5	349.5	402.0	ARJ32A, ARJ32R
ARJ40L	570,9	546.1	628.0	ARJ40A, ARJ40R

$N_{Rd,1}$ = Axial force resistance value, ultimate limit state, concrete strength C30/37-1.
$N_{Rd,2}$ = Axial force resistance value, ultimate limit state, concrete strength C30/37-2.
$N_{Rd,a}$ = Axial force resistance value, accidental limit state, minimum strength C30/37.

4.2.4 Concrete strength of the shoe connection

The resistance of the shoes has been designed for the following minimum concrete strengths:

1. *Beam element*	The beam shoes have been designed for concrete C30/37. - This is the minimum concrete strength for the beam in the shoe connection. - A higher concrete strength does not affect the calculation values for the shoe's axial force resistance. - Instead, the resistance graph for the beam shoe is calculated in the *ACOLUMN* software according to the actual concrete strength and class. - In particular, a higher strength is utilised when rebar bundles are used for the beam reinforcement, in which case the force is transferred from the shoe bonds to the rebar bundles.	
2. *Column element*	In a column, the anchoring bolts have been designed for concrete C30/37. - This is the column's allowable concrete strength for anchoring bolts. - A higher concrete strength does not affect the calculation values for the axial force resistance of the anchoring bolts. If necessary, it can only be used to influence the anchoring lengths of the bolt's bond.	
3. *Shoe grouting*	The strength of shoe grouting is specified as follows: - The minimum strength of the beam end grouting is C30/37, grade 2, but the grouting strength must be at least equal to the strength of the beam and column. The default thickness is 20 mm. - Using grouting concrete with a strength higher than that of the beam does not increase the resistance of the shoe connection, so computationally it is necessary to use the same strength for grouting as for the beam/column, even if the grouting material strength would otherwise be higher. - The grouting of the nut slot transfers the beam's compressive force, and the grouting constitutes fire protection. - We recommend using non-shrinking, CE-approved grouting concrete whose strength is at least equal to that of the concrete of the column. - The quality control of grouting concrete follows the regulations for load-bearing concrete.	

4.2.5 Minimum dimension of the beam and column connection

The minimum dimensions of the beam and column in the shoe connection are in Table 7.

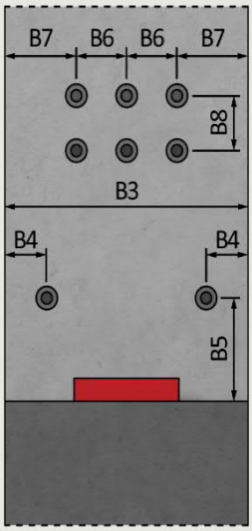
1. *Beam's minimum width B1 and supporting rib B2*	- The beam's minimum width B1 has been specified with the shoe placed at the edge. - On the bottom surface of the beam, concrete supporting rib B2 is left between the shoe's nut slots, where the erection support block is placed. B2 is the minimum beam support block width.
2. *Column's minimum width B3*	- The column's minimum width B3 has been specified such that, with the beam's minimum width, the bolts are placed past the column's main piece of rebar T25 with a protective concrete layer of 35 mm. Stirrup = T10.
3. *Bolt's minimum edge distance B4*	- The bolt's minimum edge distance in the column has been specified such that the bolt passes the column's main piece of rebar T25 with a protective concrete layer of 35 mm and stirrup size of T10.
4. *Column bracket's projection length B9*	- The column bracket's projection length has been specified such that the shoe's nut slots are placed inside the bracket to facilitate the grouting. Therefore, dimension B9 is indicative only.

Table 7. Minimum beam and column dimensions of the shoe connection

Shoe APK-CM	Beam's minimum width B1	Beam's support rib width B2	Column's minimum width B3	Column bracket's recommended projection length B9	Bolt's minimum distance from column edge B4. Bolt ALP-P2S	Bolt's minimum distance from column edge B4. Bolt ALP-P2SM
APK24CM	260	90	380	220	110	95
APK30CM	280	90	420	250	120	95
APK36CM	360	140	500	280	130	100
APK39CM	360	130	510	300	135	100
APK45CM	460	220	630	330	145	125
APK52CM	540	280	740	360	160	140

ARJ-L rebar couplers are placed at the top edge of the beam. In practice, the minimum centre and edge distances are determined by the space required for erecting the bar.

1. *ARJ bar distance B6*	- Distances B6 between ARJ-L rebars must be determined according to EN 1992-1-1, sections 8.2 and 8.7, such that the bars work as individual pieces, they can be erected and cast, and spliced bars can be placed between them on the beam's top surface. Recommendation $B6_{min}$ = 6 * bar diameter
2. *Bar and ALP bolt edge distance B7, B4*	- An ARJ bar's minimum edge distance B7 in the beam is determined with the column's minimum dimensions B3, however, such that the main piece of rebar on the beam's top surface must be outside the ARJ bar. There must be room for the ALP bolt to go past the column bars. Distance B4
3. *Bar row vertical distance B8*	- The vertical distance of ARJ bar rows must be determined according to the bar install ability and casting. Recommended distance for bar rows: B8 = 4 * bar diameter.
4. *Distance from column bracket B5*	- The shoe distance from bracket B5 is determined by the grouting (support block) and vertical indentation of the shoe.
5. *Bar anchoring to column*	- The rebar coupler is anchored to the column by bending the bar to the rear edge of the column using the bending mandrel diameters specified in tables 2 and 3.



4.3 Design instructions for the main civil engineer

The shoe connection is designed using Anstar's ACOLUMN software. Due to the calculation method, no instructions are provided for manual calculation, and the use of shoes in detail design with approximate calculation methods is not recommended. Anstar's shoes are designed for the following connection types:

1. *Column shoe connections*	Frame column connections: - Shoe connections in element column extensions, rectangular and round columns - Shoe connections to foundation columns and cast-in-situ footings - 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. *Moment rigid connections*	Moment rigid beam-to-column connection: - Moment rigid beam-to-column connections in concrete element frames. - APK-CM beam shoes and ALP-P2S anchoring bolts and ARJ series products.

4. Steel column connection to foundations	Steel column foundation connection. The design software is ASTEEL. - Anchor bolt connections of steel columns to cast-in-situ foundations - Base plate and shear dowel connections

Design criteria and standards are taken into account in beam shoe connections:

1. Design standards, calculating the forces on the connection and moment transfer	- The beam shoe connection is designed according to the EN 1990 series European standards. Before using the *ACOLUMN* software, separate frame structure calculation software is used to calculate the force combinations acting on the beam-to-column connection as well as their partial safety factors for loads during the ultimate and accidental limit state. - Design in accordance with the linear elasticity theory can be used when the moments are redistributed according to EN 1992-1-1, Section 5.5. - In this case, however, the tension side structures of the connection must be designed using ARJ rebar coupler products. - Moment transfer can be used for designing the connection when APK-CM beam shoes are used on the beam's top surface on the tension side. The software does not transfer the moment.
2. Design for the erection state	- The beam-to-column connection acts as a swivel joint during the erection state, before grouting. - The beam's support reaction is transferred to the column bracket using the mounting block under the end of the beam. - The beam shoe is fastened to the column's anchoring bolts with the nut on the shoe housing side only, which prevents the beam from falling. - The shoe connection transfers the tensile force acting on the beam during the erection state to the column, but not the compressive force. - The rebar coupler on the beam's top surface does not transfer the beam's forces during the erection state.
3. Design for the ultimate limit state (ULS)	- The factors of consequence classes CC1–CC3 are already taken into account in the load combination. The shoe/bolt connection works during the ultimate limit state when the grouting of the connection has hardened. The connection is calculated as a bent structure where the tensile force is transferred through the bolt/shoe and the compressive force is transferred through the concrete of the column. The shoe's bolts do not transfer the compressive force to the column. The shear force on the connection is transferred according to the principles indicated in Section 4.2.1. - The user specifies the main reinforcement of the beam at the shoe connection, and the software checks the main reinforcement's axial force resistance against forces coming from the shoes and the sufficiency of the lap length of the beam's rebar for the shoe bonds. The effect of the cross-section's slenderness is not calculated, so the resistance graph of the cross-section only represents the resistance of the beam's cross-section at the shoe connection. The software calculates the necessary supplementary stirrups in the shoe area and performs the design of the bolts and their required supplementary reinforcement in the column.
4. Design for fire	- The shoe connection is designed in the same fire resistance class as the frame. - In the desig software, the fire resistance class and the structurally necessary fire protection methods for the connection are determined in accordance with Section 5.3.2 of these instructions. - The software will soon feature calculated FEM fire design of the grouting cross-section.

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. The design is performed using loads calculated as static.
6. Loads caused by earthquakes	- Earthquake design is taken into account in calculating the ultimate limit state according to EN 1991-1 in formulas for the load combination [5]. A separate software application is used to calculate the connection forces

	for the load combination for earthquakes. The design is performed for the forces calculated in this way as a static state. The partial safety factor level of the load is selected in accordance with the European standards.
7. Fatigue actions	- The resistance values of APK-CM shoes have not been specified for fatigue actions. Fatigue design is performed separately on a case-specific basis according to the principles in EN 1990-1, Section 4.1.4. [4] -
8. Design for accidental state (ALS)	- A design analysis for accidental limit state is performed for the shoe connection according to EN 1992-1-1, Section 2.4.2.4, by using the partial safety factors of materials in accidental limit state indicated in Table 2.1N of the standard to determine the resistance of the connection in exceptional situations. The calculation is performed using accidental loads. The partial safety factor level of material is in accordance with the factors specified in the EN 1992-1-1, EN 1993-1-1 and EN 1992-4:2018 standards. - The analysis is performed using the *ACOLUMN* software. The combination of forces in accidental state is calculated using a separate software application, and the forces on the connection are provided as "Loads in accidental limit state". The software calculates the accidental resistance values and utilisation rates for various parts of the connection. The partial safety factor level of the shoe materials in accidental state is: concrete γc = 1.2 and sleeve and rebar steel γs = 1.0. The partial safety factor level of the anchoring bolt materials is in accordance with EN 1992-4:2018.
9. Design the anchoring bolts	- The software calculates the bolt resistances in all design states at the grouting and in the column according to EN 1992-4:2018 [20]. More detailed instructions for bolt calculations are provided in the *ALP-C Anchor Bolts* user manual.
10. Using the shoes at low temperatures	- The impact strength of the shoe material is sufficient for –20 °C with the design values specified in Table 5. At lower temperatures, the minimum operating temperature corresponding to the base plate is determined in accordance with EN 1993-1-10, Section 2.3.2 and Table 2.1.[8] - In the combination case, the ratio of the shoe material stress level δ_{Ed} is determined using the formula: δ_{Ed} = $N_{Ed}/N_{Rd} * f_y(t)$. N_{Ed} = Calculation value for the shoe's axial force. N_{Rd} = Design value for the shoe's axial force resistance. $f_y(t)$ =The base plate material is $f_y(t)$ = S355J2, so, based on the calculated ratio N_{Ed}/N_{Rd} and shoe base plate thickness, the lowest operating temperature is determined according to EN 1993-1-10 [8], Table 2.1. The shoe can be used down to this temperature without any other examination. The quality class of the base plate material can be increased by special order.
11. Supplementary reinforcement required for the shoes' operation	- The software calculates the supplementary reinforcement required by the shoe in the beam on the basis of the forces on the connection, and the required minimum reinforcement amounts are output in the calculations. Another option is to use standard supplementary reinforcements calculated according to the shoe's resistance values. Section 5.4.3. - The resistance and lap length of the beam's main pieces of rebar are checked in the shoe area so that the calculation forces are transferred from the shoe bonds to the beam's main pieces of rebar in accordance with the European standards.
12. Shoes' service life and durability design	- The service life and durability design for shoes is made according to the instructions in EN 1992-1-1, Section 4. The principles and recommended implementation methods are presented in Section 5.6 of this manual.

5 DETAIL DESIGN

5.1 Design stages and parties

APK-CM shoes are Anstar's products whose final use must be designed by the civil engineer of the concrete element frame. For detail design of the beam shoe connection, we have prepared this user manual as well as the ACOLUMN software.

The final detail design of the beam shoe/bolt connection must be performed using the ACOLUMN software. The joint action of the connection components has been specified according to the European standards and EN 1992-4:2018 [20].

The software checks that the calculation forces of the shoes and bolts are transferred to the concrete of the beam and column and their main reinforcement 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 shoes with only approximate calculation methods is not recommended.

The software calculates the shoes for six different types of shoe/bolt connections and produces calculation documentation for building control. If necessary, further instructions for using the software as well as shoe/bolt products are available from Anstar's technical design department. *anstar@anstar.fi.*

The software can be downloaded from our website at *www.anstar.fi*. The software can be used on Windows 10. *This user manual requires software version 5.0.*

5.2 Beam-to-column connection design software *ACOLUMN*

1. User interface menus

1. General	- The main window shows the cross-section of the column at the top surface of the shoe connection's base plate as well as the dimensions of the foundations below, the bolts in the connection and the main reinforcement of the column. The menu structure of the main window consists of the following functions:
2. File	- Menu includes selections for the project folder, file management and printing.
3. Initial data...	- First, you select the cross-section type to be calculated and enter the geometry and material data for the cross-section.
4. Loads	- This function is used to enter the forces calculated from the load combinations on the connection for the ultimate and accidental limit state.
5. Shoes/Bolts /Rebars...	- This function is used to place shoes and bolts in the connection and position the main reinforcement for the beam in the shoe area.
6. Calculate...	- The selection performs the calculation for the connection. - This function is used to select for the ultimate and accident state.
7. Calculation results...	- The calculation results are viewed for shoes and bolts as well as design quantities for various situations.
8. Software settings	- The menu is used to enter parameters that control the use of the software and calculation.

2. Information controlling the calculation

9. Calculation code	- The bottom left corner of the window shows the flag symbol of the calculation code used for the project folder.
10. 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.

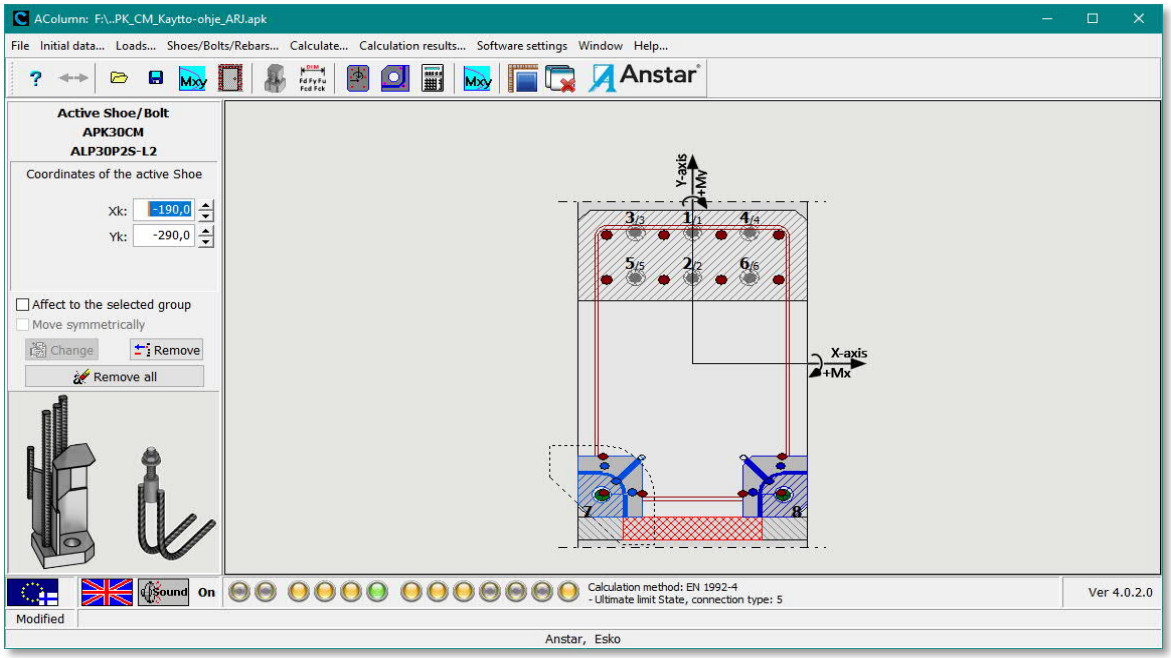


Figure 7. Main window with the APK-CM beam shoe and ARJ rebar coupler connection

3. Quick review of the calculation results

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

Utilisation rate indicator lights

1. General	The bottom bar of the window includes round indicator lights showing the utilisation rates of calculation quantities. The colours of the calculation quantities have the following meanings:
2. Green	The utilisation rate is acceptable within the range of 0–0.95.
3. Yellow	The utilisation rate is acceptable within the range of 0.951–1.0.
4. Red	The utilisation rate is > 1.01, excessive.
5. 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.
6. Light beam	 The utilisation rate indicator lights are activated when the connection forces have been specified and the connection calculated.

Utilisation rate acceptance

1. General	- 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:
2. Meaning	- The designing quantity of each indicator light is displayed below the light bar when you point the mouse at the light.
3. 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.
4. Acceptance	- When all the lights are green, yellow or grey, - the connection has been accepted. - A red light means that the utilisation rate has been exceeded. - The final acceptance is the responsibility of the engineer.

Shoe code and reinforcement in the area affected by the shoe

5. Raster area	- When you have performed the calculation and click the raster area of the shoe, the shoe is activated, and the software shows the shoe and bolt type and the bolt's coordinate.

6. Dash dot line area	- A dashed line polygon appears around the active shoe, encircling the pieces of rebar that belong to the column reinforcement to which the forces are transferred from the shoe bonds. - Window 2/4 shows the same situation on a shoe-specific basis. - The shoe's reinforcement must be located inside the area.

5.3 Design of shoe connection

5.3.1 Project folder and calculation standard

1. General

This user manual presents the initial data necessary for calculating shoe connections as well as the shoe calculation results. Instructions for anchoring bolt calculations are provided in the *Anchor Bolts* user manual.

2. 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 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. - This will be output at the beginning of the calculation file.

3. Calculation standards

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

4. Project information:

In these fields, you provide general information about the project in the folder. This will be printed at the beginning of each calculation printout.

5. Print

***1.** Printing*	- To print the calculation on paper, select the information you wish to print. - The print job is sent to the default printer selected. - The printout language is selected from the menu

5.3.2 Selecting the connection type and materials

1. Selecting the connection

1. Connection type	- Select column joint connection by choosing Connection selection from the Initial data menu. The menu shown in Figure 8 opens in the window, showing the connection types available in the software. 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	- 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 1992-4:2018 standard, which provides slightly more conservative calculation results.

2. Connection type for beam shoes

1. Beam-Column shoe/shoe	- A connection between an element beam and column. The beam shape is rectangular. Select square or rectangular as the column shape. The beam location is either in the centre or with the selected vertical edges tangential to the column.
2. Beam-Column shoe/reinforce.	- The beam is connected using two shoes, one at each bottom corner, and an ARJ rebar coupler connection on the beam's top surface.

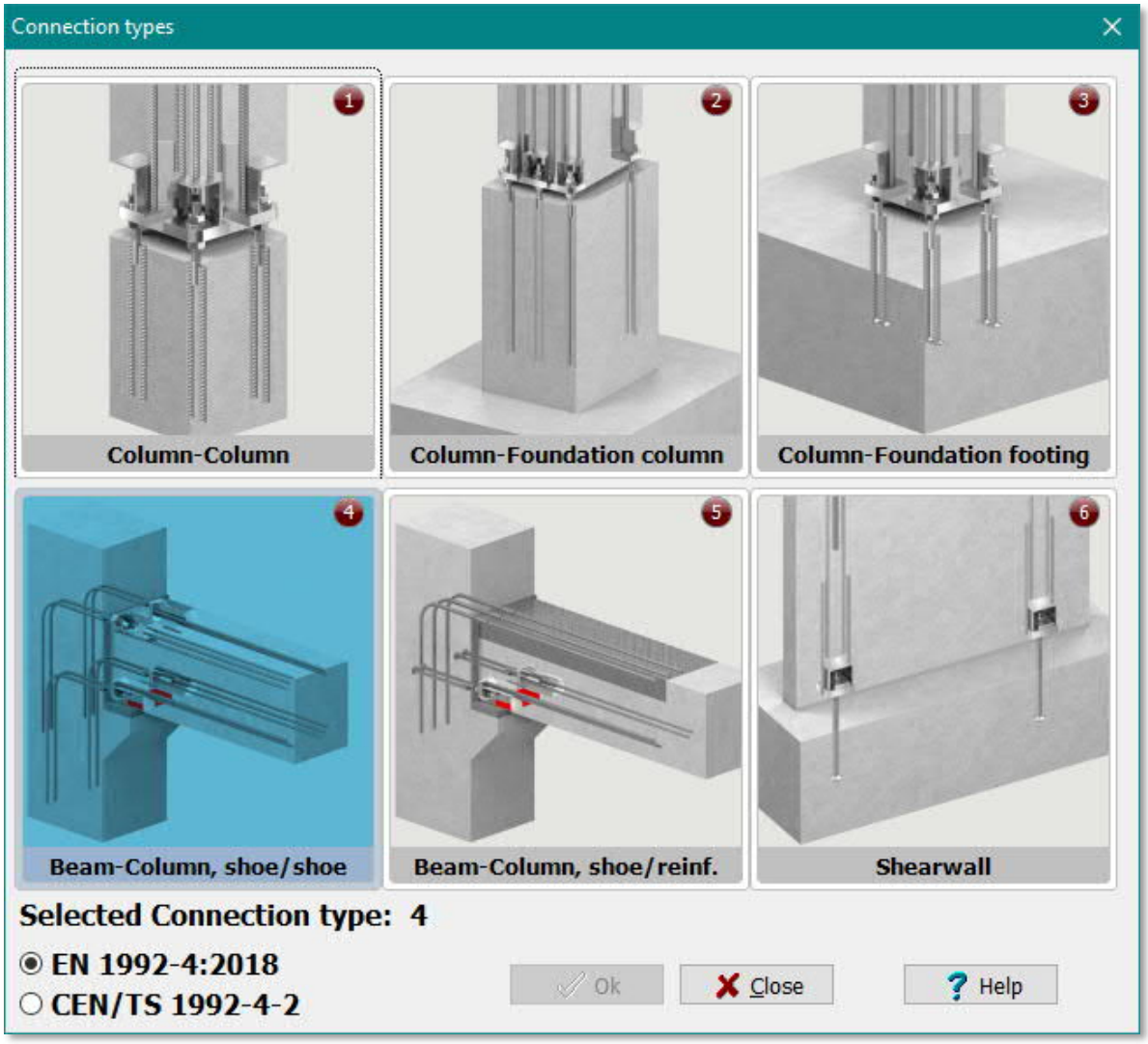


Figure 8. ACOLUMN software connection types

5.3.3 Initial data

1. Menu bar structure

1. Menu bar	- The initial data for the Beam shoe connection, structure of the connection and materials are provided in the Initial data menu, which includes six tabs.
2. Initial values	- We recommend entering the initial data in the right order, either by changing the values or accepting the default values. - This adjusts the other tabs and their calculation parameters
3. Acceptance	- When you click Accept, the selection updates the main window according to the dimensions selected.

2. Calculation ID, tab1

The identifying information output in the calculations is entered in the fields.

3. Material strength, 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

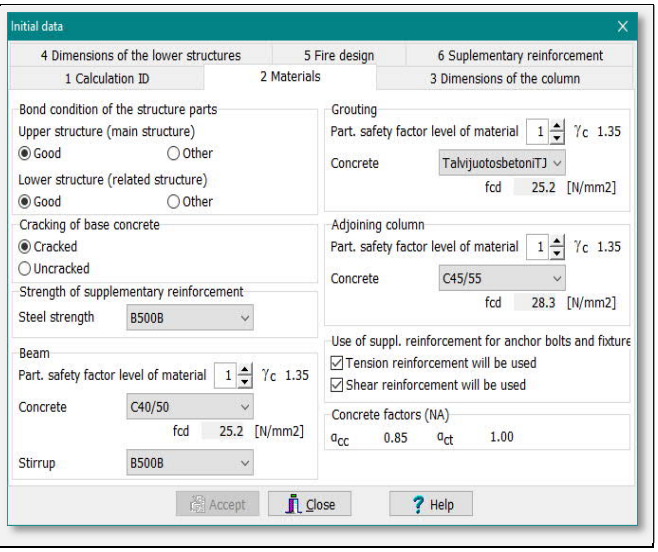


Figure 9. Tab 2. Material strengths, concrete cracking state and reinforcement

4. Dimensions of the structure, tab 3

1. *Beam dimensions*
   - The dimensions to be selected
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.

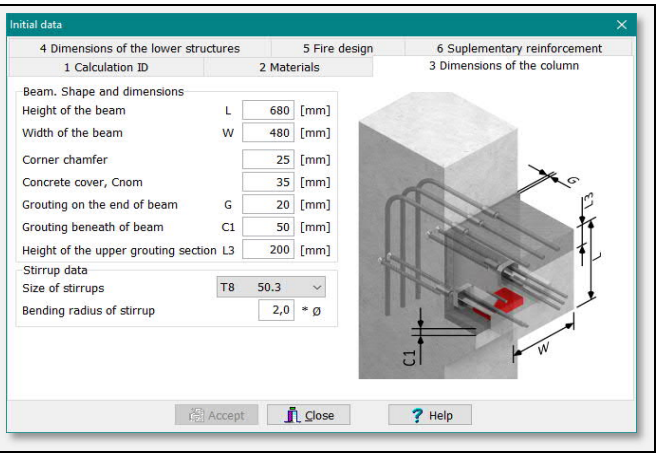


Figure 10. Tab 3. Dimension of beam

5. Dimensions of the column structures, tab 4

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

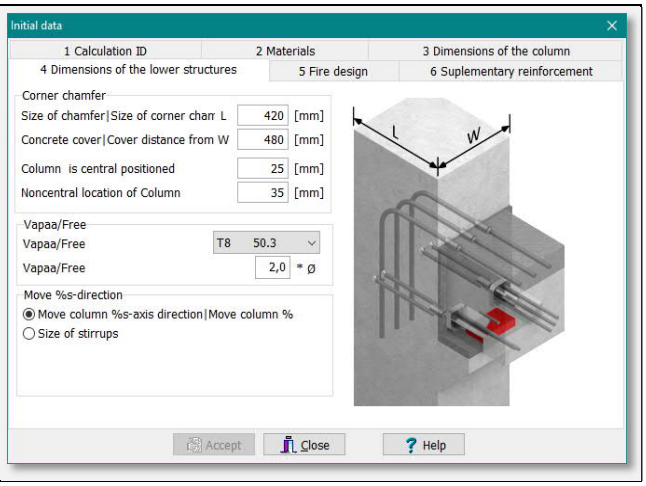


Figure 11. Tab 5. Selecting the base dimensions

6. Supplementary reinforcement, tab 6

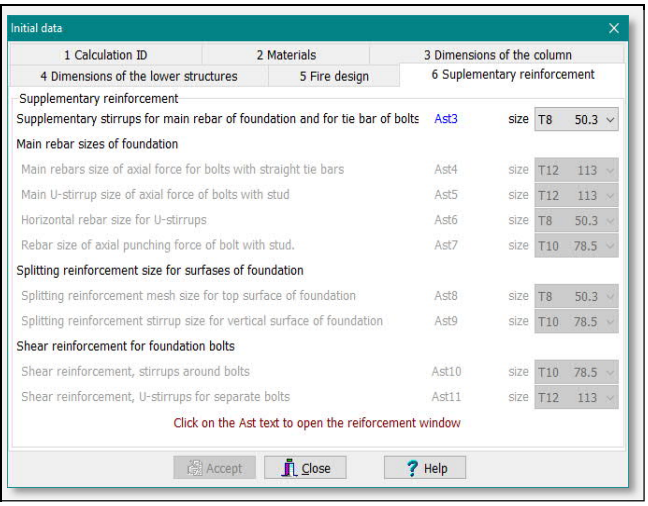
1. *Supplementary reinforcement* - The size of the anchor bolts reinforcement can be selected on Tab 6. - The window shows the reinforcing units available for each connection type. - The reinforcement principle drawing can be opened by clicking the Ast code. - The software calculates the amount of supplementary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

Figure 12. Tab 6. Size of supplementary reinforcement

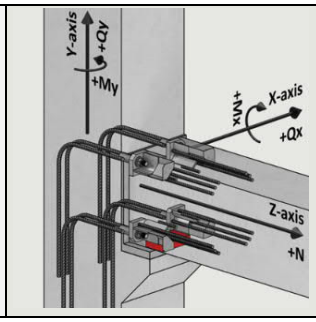
7. Accepting the initial data

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 Calculation forces

1. Combining the calculation forces for the connection

1. *Defining forces*	- The calculation forces for the connection are first calculated using a separate statistics application. - These results are used to form the combinations of forces, from which the most dominant forces are provided as initial data. - The forces to be provided already include the partial safety factors of loads in accordance with the calculation standard.
2. *Erection state*	The erection state is not calculated for the beam-to-column connection. The forces are not specified.
3. *Ultimate Limit State (ULS)*	A maximum of eight combinations of forces may be provided for the connection for the ultimate limit state.
4. *Accidental Limit State (ALS)*	A maximum of eight combinations of forces may be provided for the connection for accidental limit state.

5. *The design forces for the connection* - N = Beam's axial force. The compressive force is negative. A positive tensile force can be specified for the beam. - Mx, My =Beam's bending moments in relation to the axes, positive direction as shown in the figure. The calculation forces affect at the level of the shoe base plate. The same rules of signs apply to the erection state.	

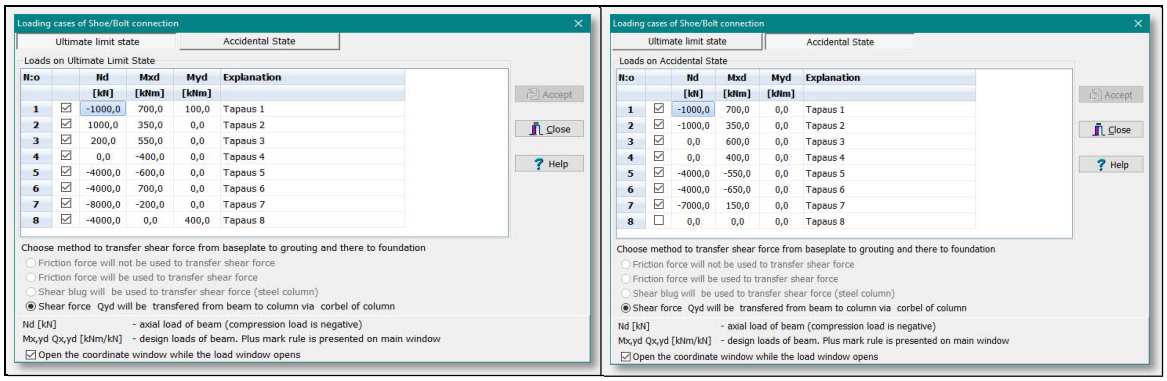


Figure 13. Forces on the connection during the ultimate limit state and accidental state.

2. Shear forces on the connection

- Shear forces are not specified for the shoe connection.
- For the calculation theory, refer to Section 4.2.1.
- The beam's concrete shear resistance must be calculated separately. The software does not calculate it.

3. Approving the calculation forces

1. *Acceptance*	- All forces that have been provided or modified must be accepted by clicking the Accept button before calculation.

5.3.5 Placing the shoes and bolts

1. Placing the shoes

1. General	- The shoes and bolts are positioned in the connection using the menus shown on the right in Figure 15. - The menu can be opened by selecting Shoes/Bolts/Rebars.../Place Shoes/Select Column Shoe, under which you select the AHK shoe.
2. Placing beam shoes (Both connection type options)	- Selecting the APK-CM shoe displays the bolts suitable for the shoe. - Only the ALP-C series bolts that are suitable for the shoe will be available for selection. - The ALP-P2S bolt bonds are bent downward in the column. - The ALP-P2SM bolt goes through the column in a continuous beam frame structure. - ALP-LS upset bolt for a column when there is no tension on the bolt.
3. Placing rebar couplers (Beam shoe-reinforcement coupler connection only)	- Selecting the ARJ-L coupler displays the bolts suitable for the coupler. - Only the ARJ series bolts that are suitable for the coupler will be available for selection. - The ARJ-R anchoring bolt bond is bent downward in the column. - The ARJ-A bolt goes through the column in a continuous beam frame structure.
4. Beam rebar	- Selecting the beam rebar displays the rebar table, from which you select the size of the reinforcement to be placed in the beam.

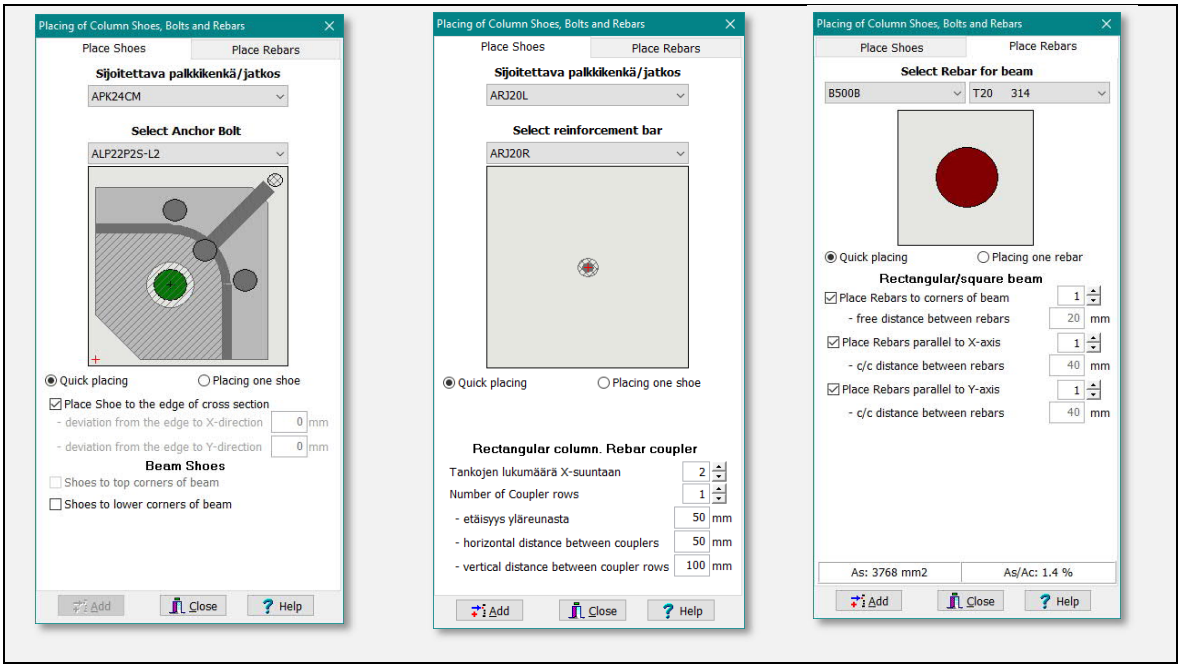


Figure 14. Windows for placing the shoes, anchoring bolts and beam's main of rebars

2. Placing the shoes

1. Principle	- The shoes and bolts are positioned in the cross-section by selecting Add. - The shoes are positioned in the cross-section scaled correctly, so collisions can be checked in the main window. - The software checks for and prevents double placement. The selected bolt is placed with the shoe. - The placement may be performed several times, changing the shoe type in between.

3. *Quick placing*

1. General	- Several shoes are placed symmetrically in the connection according to the selections made. This placement always forms one symmetrical shoe group in the cross-section.
2. Deviation from the edge in the x direction	- The shoes are moved horizontally inward from the edge of the beam by the distance specified. - Symmetrically inward
3. Deviation from the edge in the y direction	- The shoes are moved vertically inward from the edge of the beam by the distance specified. - Symmetrically inward
4. Place shoes to bottom corners of beam	- The shoes are placed in the bottom corners of the beam, the specified distance away from the edge. - Middle shoes at the bottom cannot be specified for this connection.
5. Place shoes to top corners of beam	- The shoes are placed in the top corners of the beam, the specified distance away from the edge. - Middle shoes at the top cannot be specified for this connection.

4. *Place one shoe*

1. General	- Use the mouse to drag one shoe from the icon to the connection. - This method is used to create an asymmetrical shoe connection. - First create a symmetrical connection and then change one shoe using this method.
2. Place Shoe to the edge of cross section	- When you drag the shoe to the connection, it is placed at the edge of the beam in the location pointed by the mouse.
3. Deviation from	- When you drag the shoe to the connection, it is moved

the edge in the x direction	horizontally inward by the distance specified from the edge of the beam in the location pointed by the mouse. - The location can be fine-tuned by clicking the shoe to make it active and changing the bolt's coordinate.

5. Viewing/removing and moving shoes

1. General	- The shoe cross-section can be made symmetrical or asymmetrical, and various shoes can be located on different sides of the cross-section. - The location of one shoe or all shoes may be freely changed using the following functions: (Close the Shoes/Bolts/Rebars... window before using this function.)
2. Active Shoe/Bolt	To view the shoe and bolt information, make the shoe active by clicking its raster area in the main window; this changes the colour of the shoe/bolt selected and displays its information in the top left corner of the main window. - The image of the selected, active shoe and bolt is shown on the left side of the window. - The selected shoe's coordinates from the origin of the cross-section are shown in the window. - The selection shows all the other shoes belonging to the same group with a different raster colour.
3. Remove	- This function only removes the active shoe and bolt from the group.
4. Remove all	- This function removes all shoes and bolts that belong to the active group.
5. Change	- First, select one shoe to make it active. - Change the coordinates of the shoe to the extent that you want to move it. - The Change function moves the selected shoe to the new coordinates.
6. Change/Affect the selected group	- The Change function moves all the shoes in the group in the horizontal/vertical direction according to the relative displacement selected. Moves the entire group linearly.
7. Change/Move symmetrically	- The Change function moves all the shoes in the group symmetrically in relation to the main axes by the distance selected. Moves the entire group symmetrically.

5.3.6 Placing beam rebars

1. Placing the main pieces of rebar for the beam

1. Principle	- The main pieces of rebar for the beam are placed in the connection using the menu shown in Figure 14. - The pieces of rebar are positioned in the cross-section scaled correctly, so collisions can be checked in the main window. - The software checks for and prevents double placement. - The placement may be performed several times and the rebar size can be changed. The placement of rebar is controlled using two selection methods: Figure 14

2. Quick placing

1. General	- Several pieces of rebar are placed symmetrically in the connection according to the selections made. - This placement always forms one symmetrical rebar group in the cross-section.
2. Place Rebars to corners of beam	- The pieces of rebar are placed in the corners of the beam. There may be 1–5 pieces of rebar per corner, and they are placed symmetrically at the specified distance from each other.
3. Free distance between rebars	- This option is used to adjust the free distance between the pieces of rebar in the corner of the beam. The default distance is the low limit for the bundle property of the rebar selected.
4. Place Rebars	- 1–99 pieces of rebar are placed on the horizontal sides of the

parallel to X-axis	beam, symmetrically at the c/c distance specified. This forms one rebar group.
5. *Place Rebars parallel to Y-axis*	- 1–99 pieces of rebar are placed on the vertical sides of the beam, symmetrically at the c/c distance specified. This forms one rebar group.
6. *c/c distance between rebars*	- Specify the c/c distance between pieces of rebar to place several pieces of rebar symmetrically in the cross-section. You must ensure that the pieces of rebar fit the shoe bonds.

3. Placing one rebar

1. *Placing one rebar*	- Use the mouse to drag one piece of rebar from the icon to the connection. This method is used to create asymmetrical reinforcement.
2. *Place rebar close to stirrup*	- The pieces of rebar are placed such that they touch the beam's stirrup, according to the selected stirrup size and protective concrete layer, in the location pointed by the mouse. - If this selection is not made, the piece of rebar is placed where you drag it with the mouse.

4. Principle of placing pieces of rebar in the beam

1. *Rebars*	- The bonds of APK-CM shoes are separate pieces of rebar (not rebar bundles). - For selecting the main pieces of rebar for the beam, it is recommended that separate pieces of rebar (instead of rebar bundles) be used in the shoe area in the beam. - The shoe's axial forces are transferred from the shoe bonds to the beam's nearest main pieces of rebar, and this design is performed by the software. - Rebar bundles may be used, and the lap length is also checked for rebar bundles, but the shoe bonds are not necessarily sufficient in all cases.
2. *Lap length*	- The lengths of the shoe bonds have been specified with the lap length factor 1.5 with the bonding condition "other condition" for concrete C30/37, grade 2. - The lap length factor for the main pieces of rebar in the beam is 1.5 with the bonding condition "other condition". - However, the required rebar lap length is calculated according to the concrete strength selected for the beam. - A higher concrete strength enables the use of rebar bundles in the beam. - The software outputs the correspondence of the shoe bonds and beam rebar coupler lengths for the design forces specified and for the main reinforcement rebar bundles.

5. Viewing/removing and moving pieces of rebar

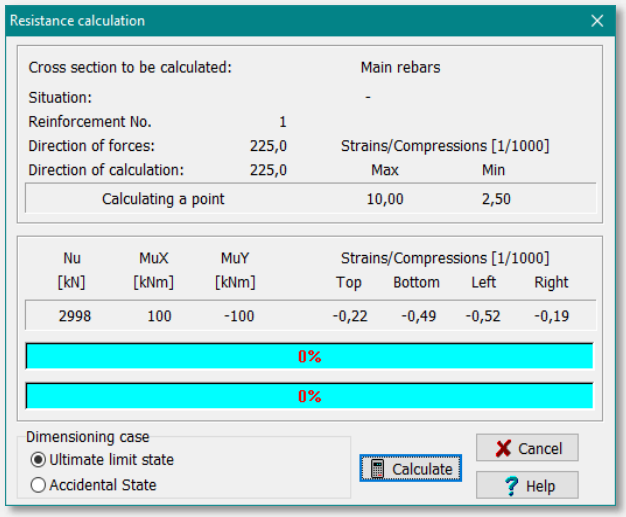
1. *General*	- The rebar cross-section can be made symmetrical or asymmetrical, and various pieces of rebar can be located on different sides of the cross-section. - The location of one piece of rebar or all pieces may be freely changed using the following functions: (Close the Place Shoes window before using this function.)

3. *Active Rebar*	To view the beam's rebar information, make the piece of rebar active by clicking it in the main window; this changes the colour of the rebar selected and displays its information in the top left corner of the main window. - The selected rebar's coordinates from the origin of the cross-section are shown in the window. - The selection shows all the other pieces of rebar belonging to the same group with a different raster colour.
4. *Remove*	- This function only removes the active piece of rebar, even though it is part of a group.
5. *Remove all*	- This function removes all pieces of rebar belonging to the same group as the active piece.

6. Change	- First, select one piece of rebar to make it active. - Change the coordinates of the piece of rebar to the extent that you want to move it. - The Change function moves one piece of rebar to the new coordinates.

6. Calculating the connection

1. General	- To calculate the connection, select Calculate. This opens the Resistance calculation window, where you first select the design situation. There are two design situation options available:

2. Ultimate Limit State - This selection performs the calculation using erection and ultimate limit state loads	
3. Accidental Limit State - This selection performs the calculation using erection and ultimate limit state loads	
4. Calculation results - When you want to save the results for both calculations, you need to print out the results of the first calculation on paper/in a file before performing the second calculation. - If the loads in accidental state have not been specified, the state cannot be calculated.	

5.4 Ultimate limit state. Calculation results. Shoes

5.4.1 Presentation of the results

1. Menus

1. General	The shoe/bolt connection calculation results can be viewed from the Calculation results menu. The menu is divided into three sub-areas:
2. Ultimate Limit State/shoes	Shoe resistance during the ultimate limit state and the element's main reinforcement resistance at the shoe connection. Supplementary reinforcement required by the shoes.
3. Ultimate Limit State/bolts	Bolt resistance during the ultimate limit state in the column and in the grouting cross-section. Supplementary reinforcement required by the bolts.

2. Calculation coordinate system

4. General	- 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. - Skew bending is calculated as a combination of the forces in the direction of the main axes for the combination in question.

3. Utilisation rates

General	- The row featuring the utilisation rates has acceptance indicators with the following colour codes:
Green	- The utilisation rate of the quantity is 0–0.95.
Yellow	- The utilisation rate of the quantity is 0.951–1.00.
Red	- The utilisation rate of the quantity is > 1.00.
Grey	- The quantity has not been calculated or does not belong to the shoe'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.

4. Numbering of the structures

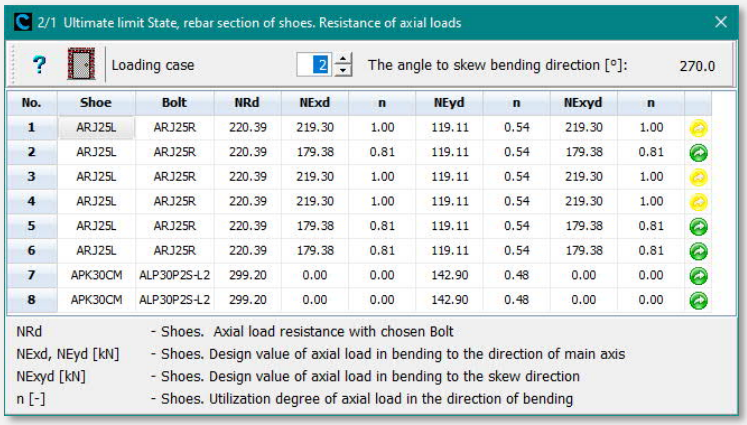
1. Principle	- After the calculation, numbers will be displayed in the main window at the bolt and shoe bonds and the beam's main pieces of rebar. - These numbers will be displayed next to the corresponding part/row in the printout windows. - The information on the printout row can be traced to a structure in the main window. - The numbers will be displayed after the calculation

5.4.2 Axial force resistance. Shoe

1. Calculation principle

1. Principle	- The calculation results for the column and shoes during the ultimate limit state are indicated using four indicator lights in the bottom bar. (Lights 3–6.) Drop-down menu Calculation results/Ultimate limit State/shoes. Printout menus 2/1–2/5. - NOTE: Accidental limit state calculation is selected from the Calculate menu. In this case, the calculation results presented in sections 5.5 and 5.6 apply to design for accidental limit states. The texts on the windows and menus also change accordingly:

2. Window 2/1. Shoes. Rebar section of shoes.

1. Presentation of results	- The calculation forces and axial force resistance of shoes and top surface rebar couplers are displayed by combination case as shown in Figure 15. - The information displayed for a rebar coupler includes the force on the rebar in the beam and the anchoring resistance.
2. Utilisation rates	- The utilisation rates are calculated in the directions of the main axes and combined for skew bending. - Shear resistances are not calculated for this connection type. - When the utilisation rate is exceeded, the shoe must be replaced, or the beam's concrete strength must be increased.
3. Resistance	

No.	Shoe	Bolt	NRd	NExd	n	NEyd	n	NExyd	n
1	ARJ25L	ARJ25R	220.39	219.30	1.00	119.11	0.54	219.30	1.00
2	ARJ25L	ARJ25R	220.39	179.38	0.81	119.11	0.54	179.38	0.81
3	ARJ25L	ARJ25R	220.39	219.30	1.00	119.11	0.54	219.30	1.00
4	ARJ25L	ARJ25R	220.39	219.30	1.00	119.11	0.54	219.30	1.00
5	ARJ25L	ARJ25R	220.39	179.38	0.81	119.11	0.54	179.38	0.81
6	ARJ25L	ARJ25R	220.39	179.38	0.81	119.11	0.54	179.38	0.81
7	APK30CM	ALP30P2S-L2	299.20	0.00	0.00	142.90	0.48	0.00	0.00
8	APK30CM	ALP30P2S-L2	299.20	0.00	0.00	142.90	0.48	0.00	0.00

Figure 15. Ultimate Limit State. Axial force resistances of shoes and couplers.

3. Window 2/2. Shoes. Bottom surface of base plate

1. Presentation of results	- The shoes' axial force at the bottom surface of the base plate is displayed Figure 16. - The rebar couplers' force is calculated at the outer surface of the beam's end.
2. Utilisation	- The forces and utilisation rates are calculated in the skew bending

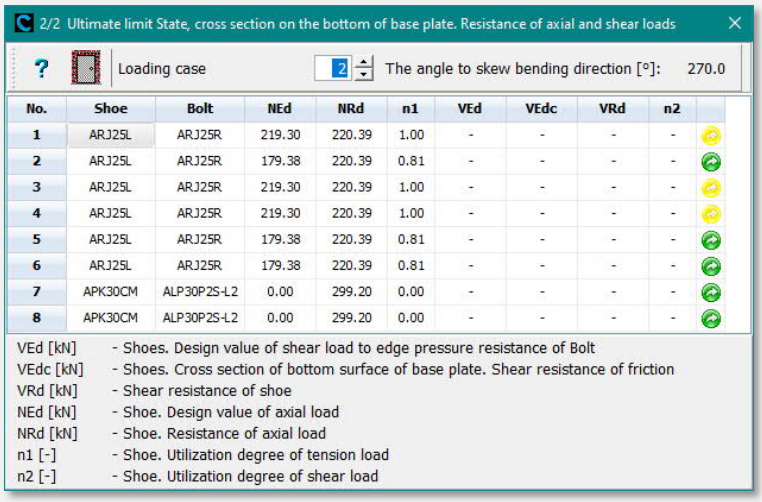
rates	direction if such a case has been specified. Otherwise, the calculation is in the bending direction, M_x. - Shear resistances are not calculated for this connection type. - When the utilisation rate is exceeded, the shoe must be replaced or the beam's concrete strength must be increased.
3. Resistance	

Figure 16. Ultimate Limit State. Axial force resistance of shoes and rebar couplers

4. Window 2/3. Tie bar section of shoe. Utilization degree of axial loads.

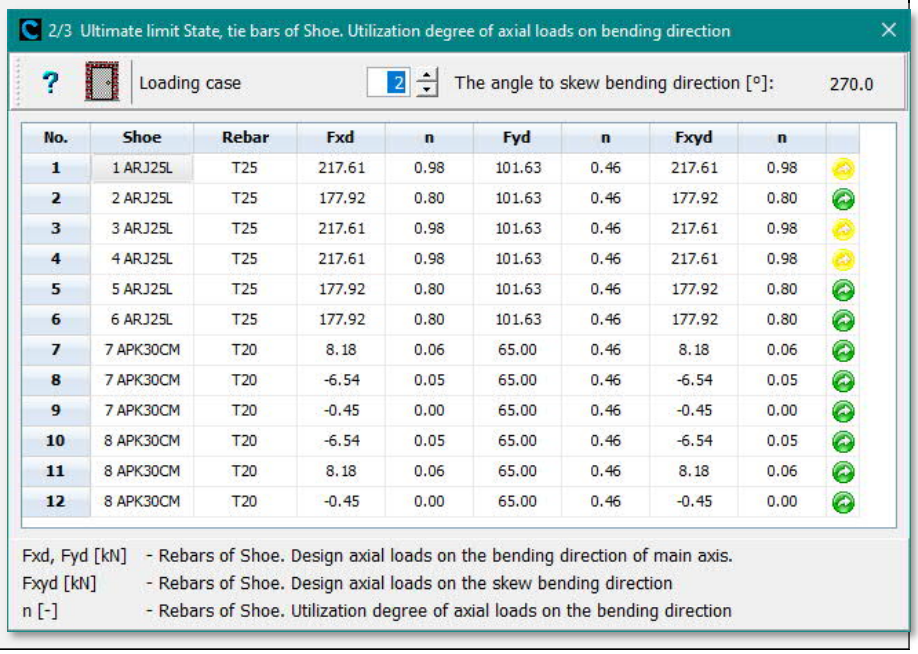
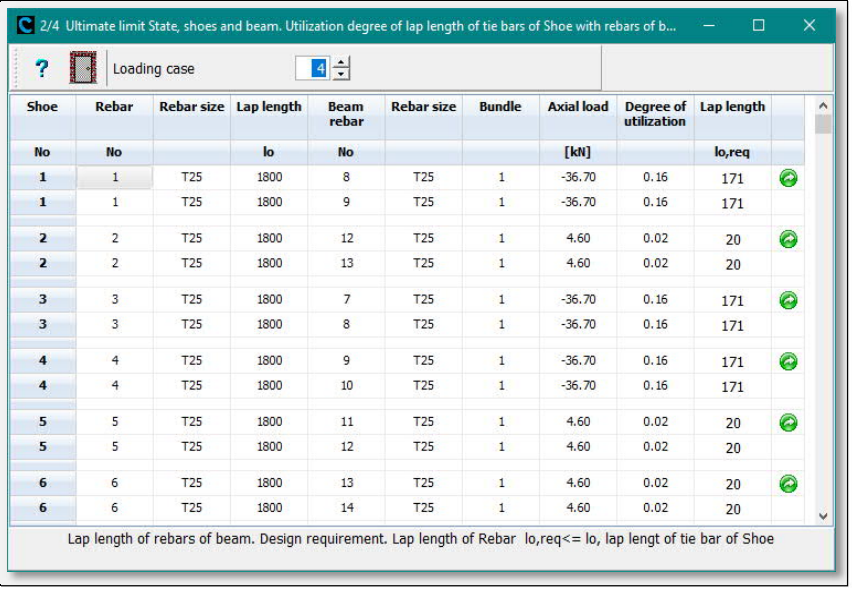
1. Presentation of results	- The review is particularly necessary for skew bending, where the shoe bonds are sometimes unfavourably located at the corner of a heavily bent beam. - The forces and utilisation rates of the beam bonds are displayed as shown in Figure 17 (numbers 1–6). - The top surface rebar coupler type and its bond size are numbers 7–12.
2. Utilisation rates	- The forces and utilisation rates of the bond are displayed for the corresponding bending directions. - When the utilisation rate is exceeded, the shoe must be replaced, or the concrete strength must be increased.
3. Resistance	

Figure 17. Ultimate limit State. Shoe bonds and rebar couplers. Utilisation degrees.

5. Window 2/4 Ultimate Limit State. Shoes and beam. Utilization degree of lap length.

1. Presentation of	- The software finds the beam rebar in the shoe/coupler area and

results	allocates the shoe/coupler forces to the selected pieces of rebar. - The software shows whether the rebar is an individual piece (= 1) or bundle (= 2). - The forces and utilisation rates of the beam rebar are displayed as shown in Figure 18.
2. Utilisation rates	- The software calculates the required lap splice length of the rebar corresponding to the shoe. - The results are shown at the end of the line with colour coding:
3. Green colour	- The resistance and lap length of rebar in the area are sufficient for transferring the force from the shoe bonds and rebar coupler to the pieces of rebar in the beam.
4. Red colour	- The resistance and lap length of rebar in the area are insufficient for transferring the force from the shoe bonds and rebar coupler to the pieces of rebar in the beam. - Add pieces of rebar to the shoe area or reduce the rebar size or remove the rebar bundles. - Increasing the concrete strength also helps reduce the required lap length.
5. Resistance	

Shoe	Rebar	Rebar size	Lap length	Beam rebar	Rebar size	Bundle	Axial load	Degree of utilization	Lap length	
No	No		lo	No			[kN]		lo,req	
1	1	T25	1800	8	T25	1	-36.70	0.16	171	
1	1	T25	1800	9	T25	1	-36.70	0.16	171	
2	2	T25	1800	12	T25	1	4.60	0.02	20	
2	2	T25	1800	13	T25	1	4.60	0.02	20	
3	3	T25	1800	7	T25	1	-36.70	0.16	171	
3	3	T25	1800	8	T25	1	-36.70	0.16	171	
4	4	T25	1800	9	T25	1	-36.70	0.16	171	
4	4	T25	1800	10	T25	1	-36.70	0.16	171	
5	5	T25	1800	11	T25	1	4.60	0.02	20	
5	5	T25	1800	12	T25	1	4.60	0.02	20	
6	6	T25	1800	13	T25	1	4.60	0.02	20	
6	6	T25	1800	14	T25	1	4.60	0.02	20	

Figure 18. Ultimate Limit State. Beam rebar utilisation rates in the shoe/coupler area

5.4.3 Supplementary reinforcement for the shoe connection

1. Reinforcement principle of beam shoes.

1. Maximum reinforcement	- Place the maximum reinforcement in the connection in accordance with the shoe's design value: Table 8.
2. Calculated reinforcement	- Or use reinforcement output by the software as calculated according to the forces on the connection.
3. Pretensioned beam	- For prestressed beams, the same instructions are followed for the supplementary reinforcement of shoes and rebar couplers.
4. Other reinforcement	- The rebar amount, size and placement can be applied and combined with the other reinforcement of the beam.

2. Supplementary reinforcement according to the resistance value of beam shoes

The reinforcement principle is presented in tables 19 and 20. The figures do not show all the pieces of rebar that are part of the beam's axial reinforcement, only the recommended minimum main reinforcement

Beam shoes:

A_{st1}	- At least the minimum number of vertical and horizontal stirrups 1 + 1 pc. according to Table 8 is always placed symmetrically on both sides of the shoe. The stirrup

	can be combined with the other stirrup reinforcement required at the end of the beam, in which case separate supplementary stirrups are not needed. - The stirrup anchoring length begins from outside the shoe housing.
A_{st2}	- The stirrups bind the vertical forces caused by the eccentric axial force of the shoe. - The stirrups are placed immediately above the shoe housing as a bundle. Table 8.
A_{st3}	- The stirrups are located at the beginning and end of the shoe bonds according to EN 1992-1-1, Section 8.7.3.1. - The stirrups are needed when the shoe's bond or beam's main piece of rebar in the shoe area is ≥ T20. - The distance between stirrups is ≤ 150 mm. The number of stirrups/location area = A_{st3}, which has been calculated according to the size of the shoe's bond.
A_{st}	The beam's main reinforcement is designed for the shear force. EN 1992-1-1, part 6.18. - The shoe's bonds must not be used to transfer additional tensile force according to the formula. - The force must be transferred through the beam's main pieces of rebar as well as A_{st1}-type main reinforcement anchor links placed at the end of the beam. The designer specifies the necessary reinforcement. The beam's shear reinforcement is designed as follows in accordance with EN 1992-1-1, Section 6.2.3. - The beam's acting concrete cross-section for the shear force is calculated without the concrete casting of the nut housings. If the rebar coupler grouting area is used to transfer the beam's shear force, it must be separately confirmed that the grouting works for shear.

Rebar coupler:

A_{st3}	- The stirrups are located at the beginning and end of the rebar coupler bar according to EN 1992-1-1, Section 8.7.3.1. - The stirrups are needed when the rebar coupler or beam's main piece of rebar is ≥ T20. - The distance between stirrups is ≤ 150 mm. - The number of stirrups/location area = A_{st3}, which has been calculated according to the size of the rebar coupler. - These stirrups can be combined with the corresponding stirrups required for the shoes on the beam's bottom surface.

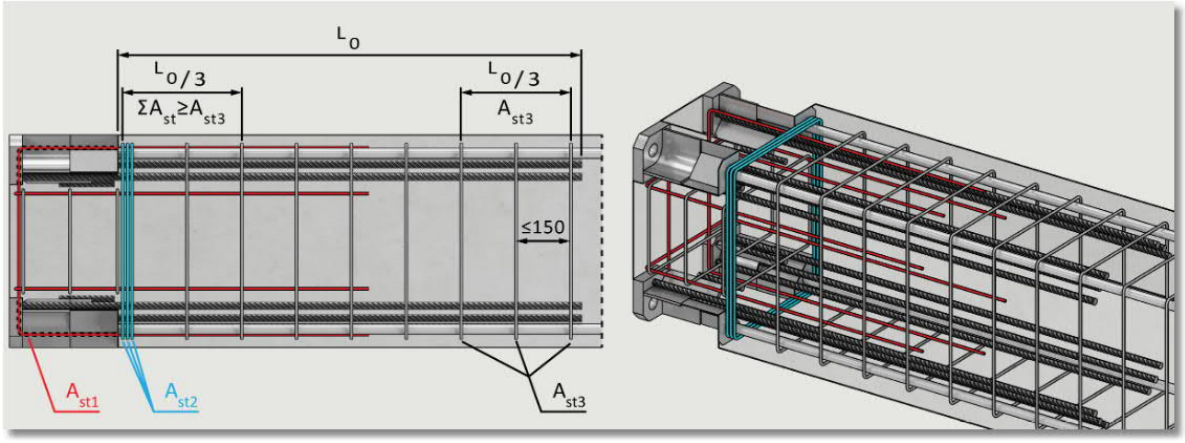


Figure 19. Supplementary reinforcement for the APK-CM shoe. Shoes in all corners

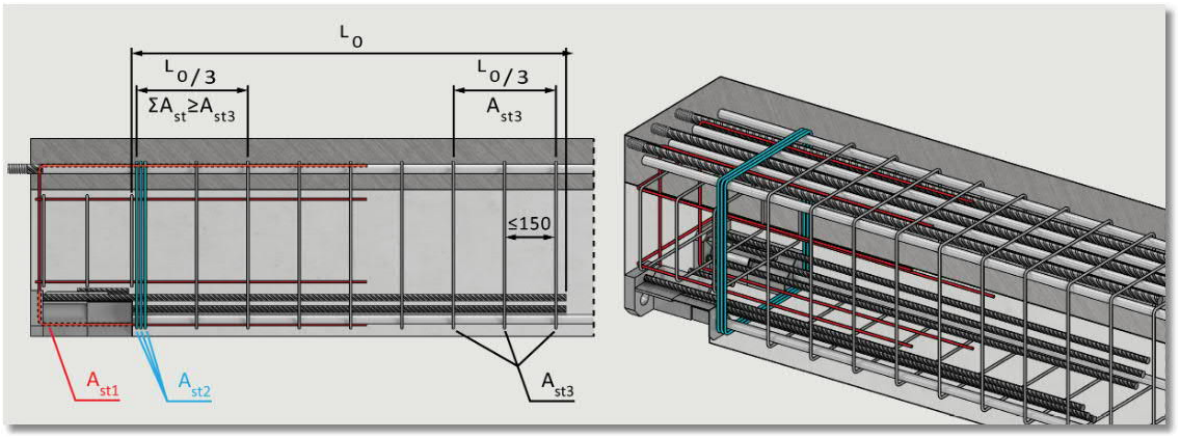


Figure 20. Supplementary reinforcement for the APK-CM shoe. Rebar coupler on the top.

Table 8. Supplementary reinforcement for APK-CM shoes with the shoe design values

Shoe connection	A_{st1} T	A_{st2} T	A_{st3} mm²
APK24CM	2T8	2T8	–
APK30CM	2T8	3T10	157
APK36CM	2T10	4T10	245
APK39CM	2T10	4T10	245
APK45CM	2T12	5T12	402
APK52CM	2T12	6T12	402

Reinforcement coupler connection	A_{st1} T	A_{st2} T	A_{st3} mm²
ARJ16L	–	–	–
ARJ20L	–	–	157
ARJ25L	–	–	245
ARJ32L	–	–	402
ARJ40L	–	–	628
–	–	–	–

3. Supplementary reinforcement calculated according to the forces. Window 2/5

The software calculates the supplementary reinforcement required by the shoes according to the shoe structure and the forces on the connection. This information is output in Window 2/5. Figure 21.

- The number of supplementary stirrups A_{st1} is at least the minimum number according to Table 8 with the stirrup size selected.
- The number of stirrups is determined by the connection's largest corner shoe.
- The number of stirrups A_{st2} depends on the connection's largest shoe, minimum number in Table 8 and stirrup size selected.
- The number of stirrups A_{st3} is in accordance with the minimum number in Table 8 with the stirrup size selected.

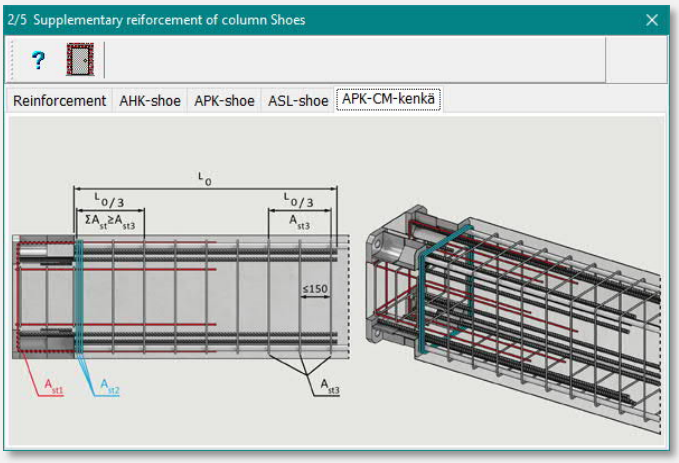


Figure 21. Supplementary reinforcement calculated for the shoe connection

5.5 Ultimate limit state. Calculation results. Anchor bolts

5.5.1 Resistance graph for the beam and grouting cross-section

1. Calculation results

- The calculation results for bolts are presented in windows 3/1–3/6, which you can open by selecting *Calculation results/3 Ultimate Limit state/Bolts*.
- The indicator light bar at the bottom of the main window can be used to display the most dominant combination case and the other calculation quantities.
- The calculation results are presented in more detail in the *Anchor Bolts* user manual.

2. Resistance graphs

- The resistance graphs for beam shoe connections and the combination case loading points at the connection are shown in printout window 3/1. The shoe connection is acceptable if the following criteria are met:	
1. Blue graph	- The blue graph is the column's axial force/bending moment resistance without the effect of slenderness in the main reinforcement of the shoe area and with the calculation strength of the concrete of the beam. The blue graph must be located outside the green graph. - The blue graph may very locally intersect the green graph.
2. Green graph	- The bolts' resistance graph at the grouting intersection calculated with the tensile resistance of the bolt's thread and the calculation strength of the grouting.
3. Loading points	- Ultimate Limit State loading points C1–C8 must be located inside the green graph. - The distance of points C1–C8 from the green graph represents the level of the connection's utilisation rate.
4. Red dashed line	- The loading points must not be located in the area of the peak of the graph, which is left outside the line. EN 1990, Section 2.2(3).
5. Tension side graph	- The tension side graph is only calculated and displayed if the tensile force has been specified.

3. Resistance graph calculation method

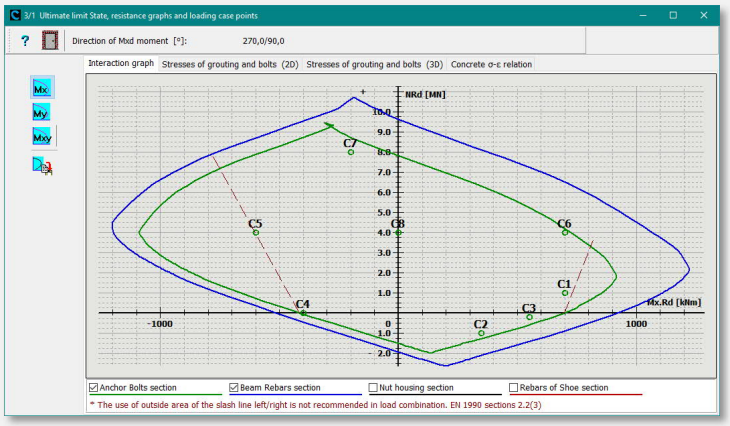
6. Calculation	- Cross-section resistance graphs Mx, My are displayed in the main axis bending directions. - The direction angle of the skew Mxy bending direction is determined by the ratio of moments Mx/My. - The skew bending direction and graphs are calculated and displayed in the positive quarter.
7. Presentation	- The resistance graph and loading points of a beam in compression are displayed above the X-axis. - The resistance graph and loading points of a beam in tension are displayed below the X-axis. - With the APK-CM shoe and ARJ-L rebar coupler, the resistance graph is highly asymmetrical because the cross-section's geometric centre of gravity is not in the material centre.
8. Resistance	

Figure 22. Ultimate Limit state. Cross-section resistance graph and loading points

5.5.2 Stress of the beam grouting cross-section

1. Resistance graph calculation method

1. Results	- Tab 2 of window 3/1 shows the ultimate limit state force/stress/deformation of the beam end's grouting cross-section by load case as well as its utilisation rates in the skew bending direction. - The information of an individual element can be viewed by clicking the calculation element with the mouse in the 2D window.

2. Colour code	- The colour codes and calculation quantities have the following meanings:

1. Grouting section. Concrete strength 2D picture.

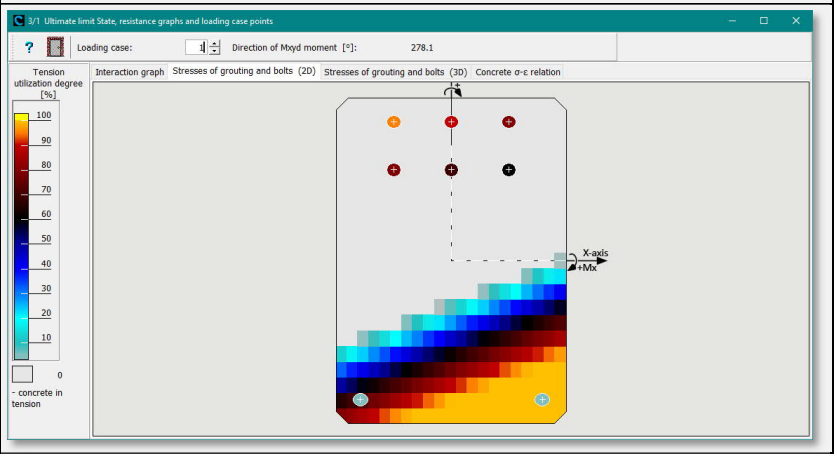
1. Concrete calculation element. Point the element with mouse. It shows the force and tension of element	- Grey: The concrete is in tension. - Other colours: The compressive stress of the concrete is in the range $0 < f_c \leq f_{cd}$. - The software calculates compression ε_c of the concrete as shown in Figure 23 according to the deformation graph shown in Figure 24. - Yellow: Calculation stress f_c of the concrete reaches its calculation strength $f_{cd.}$ with concrete deformation ε_c. - Utilisation rate: Utilisation rate of the compressive strength of the concrete = f_c/f_{cd}. -
2. Bolt calculation element. Point the element with mouse. It shows the force and tension of element	

Figure 23. Ultimate Limit State. 2D stress/deformation state of the grouting cross-section

2. Resistance graph calculation method

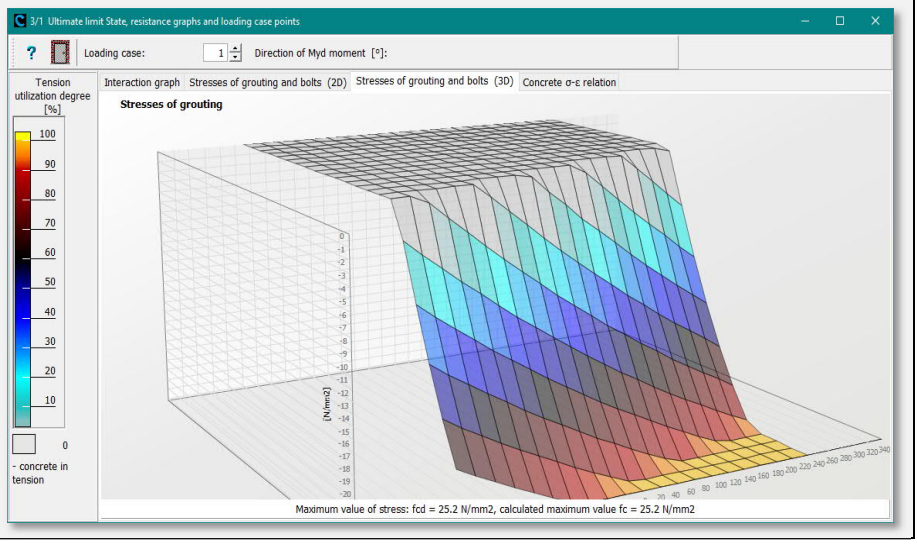
1. Results	- Tab 3 of window 3/1 shows the stress distribution of the grouting used in the calculation at the end of the beam as a 3D diagram along with the material calculation values. The diagram shows concrete in tension and concrete in yield as horizontal areas.
2. 3D stress figure	

Figure 24. Ultimate Limit State. 3D stress state of the grouting cross-section

3. Resistance graph calculation method

1. Concrete	- Tab 4 of window 3/1 shows the stress/deformation graph of the concrete used in the calculation (beam and grouting) as well as the material calculation values.

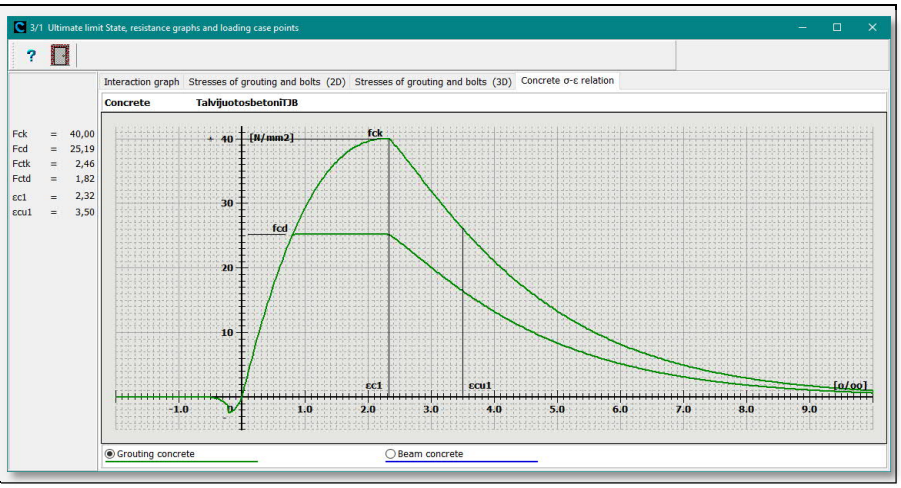
2. Concrete δ-ε relation	

Figure 25. Stress/deformation graph of the beam and grouting concrete

5.5.3 Anchoring bolt design in the column

1. Bent anchoring bolts ALP-P2S and ARJ-R. Design principles.

Bent anchoring bolts are placed in the column as shown in Figure 26.	
1. Bolt suitability	- These bolts and rebar coupler are only used for one-sided beam connections. - The bolt's forces are anchored to the column. - These bolts cannot be used for two-sided beam connections, since the column has no room for bolt bonds. - The model that goes through the column must be used for two-sided connections.
2. Distance to edge	- The bolts and rebar coupler are placed in the column such that they go past the main reinforcement in the corner of the column. The bolt's anchoring resistance may be restricted if it is placed at the edge. - The bolt's placement at the edge requires splitting stirrup reinforcement A_{st12} of the column.
3. Distance to rear edge	- The bolt's bent bond is placed at the rear edge of the column, inside the stirrups. - In a large column, the bending can be placed more inward in the centre area of the column. - The bolt's bending dimensions are determined by the designer. See Figure 27 and Table 9.
4. Bolt bending	- The standard size of the bond's bending mandrel diameter is provided in Table 9. - The straight section of the bending link must extend at least 5 * T downward. - 90-degree bending is used, and the hook is directed downward in the column.
5. Bolt design forces	- The bolts at the top edge are dimensioned for the tensile force of the shoes/rebar coupler. - The compressive force is transferred directly from the shoe to the concrete of the column. The force is not transferred through the bolt. - The bolts at the bottom edge are dimensioned for the tensile force of the shoes on the bottom surface, in the event that such a load case occurs. The compressive force is transferred directly from the shoe to the concrete of the column. The compressive force is not transferred through the bolt. - Therefore, smaller sizes can be used for the bottom surface bolts/shoes if necessary.
6. Column's main reinforcement and shear	- The column's main reinforcement must be checked for the combination of axial force, bending moment and shear force in the connection area. The software does not check this. - If necessary, the column must be provided with shear reinforcement for

reinforcement	the shear force obtained from the beam frame structure calculations.
7. Bolt's splitting stirrup reinforcement A_{st12}	- Splitting stirrup reinforcement is placed in the bolt bond's bending area, Table 9. - Unless more accurate methods are used, the number of stirrups A_{st12} can be calculated according to EN 1992-1-1, Formula 8.12. ($A_{sv} = 0.25\ A_s\ n_1$) - Splitting stirrup reinforcement A_{st12} can be adapted to the other stirrup reinforcement of the column.

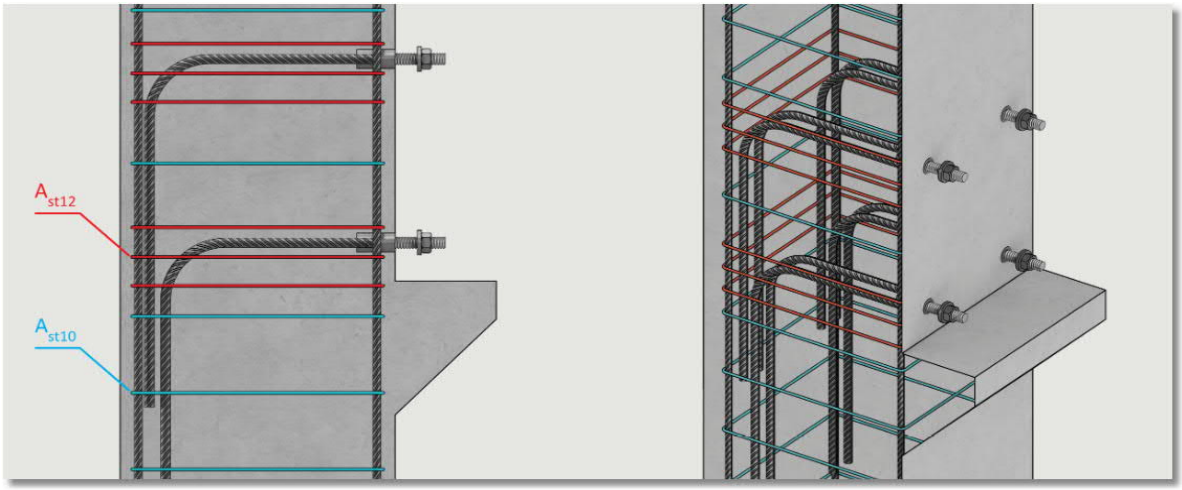


Figure 26. Placement of a bent anchoring bolt and reinforcement in the column

2. Bent anchoring bolts ALP-P2S and ARJ-R. Bolt bending dimensions.

- Bent anchoring bolts are placed in the column with the following conditions: Table 9 and Figure 27. - Note: The software displays the bolt bending data according to the calculation on the *Bolt bending data* tab of window 3/6. The bolt's order length can be determined using these dimensions.	
1. Bolt's straight length L	- The standard bolt's straight length in the concrete before bending. - The standard bolt fits the structure straight with this length.
2. Maximum horizontal length $L2_{max}$	- The bolt's maximum horizontal length that can be bent from the standard bolt using mandrel diameter D and a hook in accordance with the standard.
3. Column width B_{max}	- The column depth that the bolt fits with maximum bending length $L2_{max}$. - In a column larger than this, the bent bolt is left in the inner part of the column.
4. Minimum horizontal length $L2_{min}$	- The bolt's minimum horizontal length that can be bent with mandrel diameter D. - The bolt cannot be manufactured shorter than this.
5. Column depth B_{min}	- The minimum column depth that the bolt fits bent with minimum length $L2_{min}$ and mandrel diameter D.
6. Mandrel diameter D	- Anstar's standard mandrel for various pieces of rebar.
7. Splitting stirrups A_{st12}	- Splitting stirrups placed in the bent bolt area at the edge of the column.

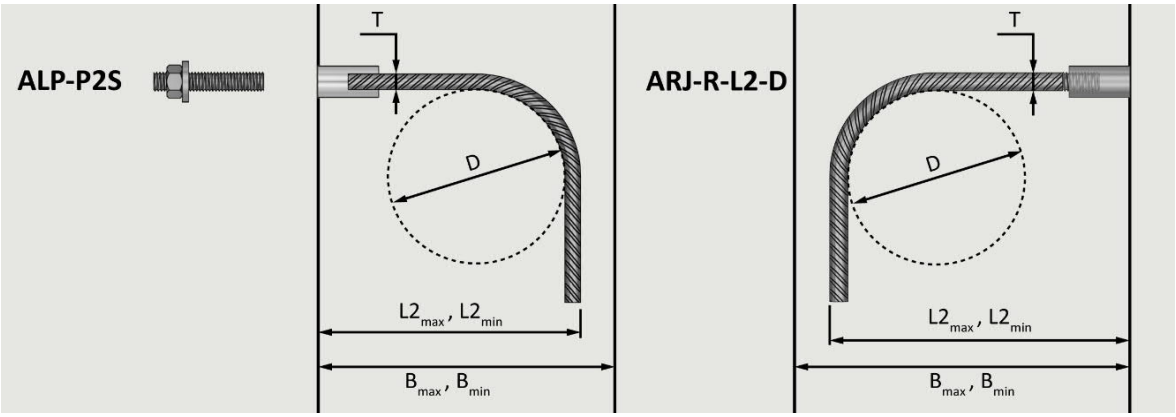


Figure 27. ALP-P2S bolt and ARJ-R rebar coupler bending dimensions

Table 9. ALP-P2S bolt and ARJ-R rebar coupler bending dimensions in the order

ALP-P2S	Colour code	L mm	$L2_{max}$ mm	B_{max} mm	$L2_{min}$ mm	B_{min} mm	T mm	D mm	A_{st12}
ALP22P2S	Light blue	935	800	870	285	355	2T16	200	2T8
ALP30P2S	Black	1095	900	970	385	455	2T25	300	2T8
ALP36P2S	Red	1415	1180	1250	400	470	2T28	300	3T8
ALP39P2S	Brown	1685	1450	1520	410	480	2T28	300	3T8
ALP45P2S	Violet	1965	1680	1750	455	525	2T32	400	4T8
ALP52P2S	White	2295	1935	2005	595	665	2T40	500	5T8

ARJ-R	Colour code	L mm	$L2_{max}$ mm	B_{max} mm	$L2_{min}$ mm	B_{min} mm	T mm	D mm	A_{st12}
ARJ16R	Yellow	1200	1065	1135	250	320	16	200	2T8
ARJ20R	Blue	1500	1300	1370	250	320	20	300	2T8
ARJ25R	Black	1700	1500	1570	360	430	25	300	3T8
ARJ32R	Grey	2400	2110	2180	420	490	32	400	4T8
ARJ40R	Violet	3800	3440	3510	570	640	40	500	5T8

3. ALP-P2SM and ARJ-A anchoring bolts through the column.

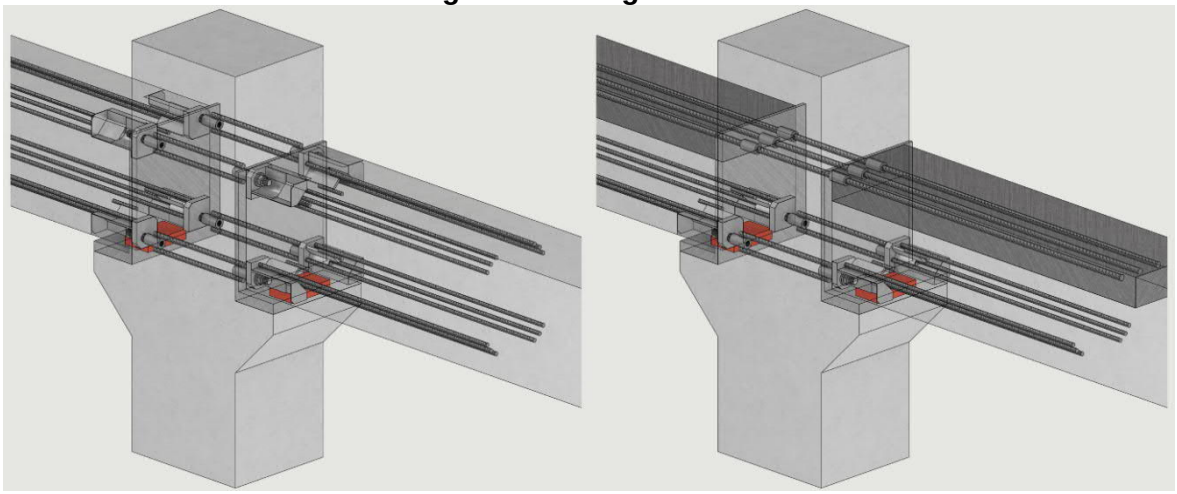


Figure 28. Placement principle of a anchoring bolt in a column connection.

Straight anchoring bolts are placed in the column as shown in Figure 28.	
1. Bolt suitability	- These bolts and rebar couplers are only used in two-sided beam connections where the forces are transferred to the next beam through the column. - The bolt's forces are not anchored to the column. - These bolts must not be used for one-sided beam-to-column connections, since the bolt's anchoring properties are not sufficient for

	transferring the forces to the column. - One-sided connections must be implemented using bent bolts only.
2. Distance to edge	- The bolts and rebar coupler can be placed at the edge of the column such that they go past the main reinforcement in the corner of the column.
3. Bolt design forces	- The top edge rebar couplers are designed for tensile and compressive force. - The bolts at the bottom edge are designed for the tensile force of the shoes on the bottom surface, in the event that such a load case occurs. The compressive force is transferred directly from the shoe to the concrete of the column. The compressive force is not transferred through the bolt. - Smaller shoe sizes can be used on the bottom surface if necessary. - In both cases, the dominant design force of the coupler/shoe is generated in the beam on the side with the highest bending moment + tensile force.
4. Column's main reinforcement and shear reinforcement	- The column's main reinforcement must be checked for the combination of the column's axial force, bending moment and shear force in the connection area. - The software does not check this. - If necessary, the column must be provided with shear reinforcement for the shear force obtained from the beam frame structure calculations.
5. Column's supplementary stirrups	- Anchoring bolts going through the column do not require supplementary stirrups in the column. - The column's axial stirrup reinforcement is sufficient for bolts going through the column.

5.6 Shoe 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. - 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. Hot dip galvanizing	- Anchor bolts can be hot dip galvanized - Only thread can be hot dip galvanized or alternative whole bolt as special order. - The thread of bolt can be removable part and material can be selected according to corrosion requirements.
2. Concrete cover	- According to EN 1992-1-1 - The standard location of APK-CM shoes' bonds is at a distance of 43–45 mm from the edge of the base plate
3. Structural protection	- The fire protection and structural location of the housing and base plate are utilised in the analysis. - The following structural protection methods are used for shoes in addition to the required concrete cover: - Water must be prevented from entering the enclosed structure of the shoe by means of a structural solution. - In structures exposed to the cold and moisture, the shoes are hot-dip galvanised.

	- In structures exposed to chlorides or chemical stress, the shoes are placed more inward in the beam.

3. Service life design

4. Codes	- Service life and durability design for a beam shoe connection is performed according to EN 1992-1-1, [6] Section 4. In addition, the instructions in the EN 13670 [15] standard and Finnish National Annex SFS 5796 [17] can be applied. For element structures, the EN 13369:2018 [16] standard and Finnish National Annex SFS 7026 are applied.
5. Structure	- The analysis is performed according to the beam's exposure class separately for the shoe bonds and the housing and base plate.

6 MANUFACTURING AT THE CONCRETE PRECAST FACTORY

6.1 Shoe delivery, storage and identification

The shoes are delivered shrink-wrapped on a pallet. Longer-term storage protected from rain. Hot-dip galvanised shoes are stored outdoors for at least four weeks after the galvanisation. This storage period before casting is necessary to avoid a hydrogen reaction, which would weaken the bond. The shoe type and size can be identified as follows:

The pallet is equipped with identifying information and each shoe with a product label. The shoes can be identified as follows: - **Painted shoes:** The size of the shoe is indicated by the colour code of its base plate. The colour codes are presented in tables 1, 2 and 3. - **Galvanised shoes:** Galvanised shoes have no colour code. They are identified by the product label.	

6.2 Erecting the shoes into the beam formwork

1. Assembling a shoe group	- APK-CM shoes are assembled into a group by welding them together with a piece of rebar or flat steel from the edge of the shoe base plate. The distance tolerances of the shoes must be ascertained during welding.
2. Erecting a group	- Erect the shoe group in a pre-assembled beam reinforcement by pushing it in from the end of the reinforcement element. - The shoe bonds can be tied to the main pieces of rebar in the beam. Welding must not be used. - Erect the supplementary stirrup reinforcement for the shoes. The reinforcement instructions are provided in Section 5.4. - Lift the beam reinforcement into the formwork. - Place the edge of the shoe base plate on the surface of the beam's edge, unless the shoes must be placed more inward according to the plans. - The bottom surface of the base plate must be against the end of the formwork and perpendicular to the beam's longitudinal axis.
3. Fastening	- The shoe group is fastened to the end of the formwork from the shoe base plate with a clamp. - Shoes may be fastened to the end of the formwork with screws through the bolt holes. - The shoe group must be fastened to the formwork such that it cannot move during casting.

4. Supplementary reinforcement	- Ensure that the supplementary stirrups required by the shoes have been erected. - Ensure that the beam's main pieces of rebar in the connection area are in accordance with the plans.
5. Tolerances	- The shoe group is erected into the formwork with the following tolerances:

Shoe location tolerances in the beam formwork:

1	Location of the shoe group's bolt holes in relation to the beam centre line	± 2 mm
2	Mutual distance and cross-measure of the shoe group's bolt holes	± 2 mm
3	Shoe erected against the end of the beam formwork, maximum play	–0, +2 mm
4	The shoe base plate is erected perpendicular to the beam's longitudinal axis, allowable deviation	± 2 mm/m

6.3 Casting protection for the shoes and casting the beam

APK-CM shoes are equipped with a nut housing that acts as a casting formwork as well as a protective cover. With these, casting protection is carried out as follows in various cases:

1. Erecting the shoe on the beam surface	**When the shoe is erected on the beam surface, casting protection is carried out as follows:** - APK-CM shoes are equipped with a nut housing and cover as standard, enabling the shoe to be erected at the corner of a rectangular beam without separate casting protection.
2. Moving the shoe inward from the beam surface	**When the shoe is erected more inward from the surface, casting protection is carried out as follows:** - Erecting an APK-CM shoe more inward in the corner of a rectangular beam requires casting protection inside the nut housing. The protection is carried out using a piece of plywood whose thickness corresponds to the moving distance, against which the shoes are placed in the formwork. Other methods can also be used.
3. Erecting shoes in a prestressed beam	**The shoes are used in a prestressed beam as follows:** - The shoes must give way for the prestressing wires. The base plate must not be notched. - If necessary, the wire can be pulled through the hole in the shoe base plate. - The shoe group is lifted higher above the wire bundle.
4. Rebar coupler and bay on the beam's top surface.	**Structure of the bay:** - A sufficient bay is to be left on the top surface of the beam for the ARJ-L rebar. - The bay is made in accordance with the beam's structural plans. - The beam's stirrups must reach the area of the bay or supplementary stirrups must be used. - Pieces of ARJ-L rebar are lap-spliced to the main pieces of rebar on the beam's top surface.

However, the tightness of the nut housing and the edge of the cover must be ensured before casting. Figure 29 shows principles of casting protection for APK-CM shoes. A piece of plywood is only needed on those sides of the beam where the shoe is placed more inward. The shoes are only moved inward in the necessary directions.

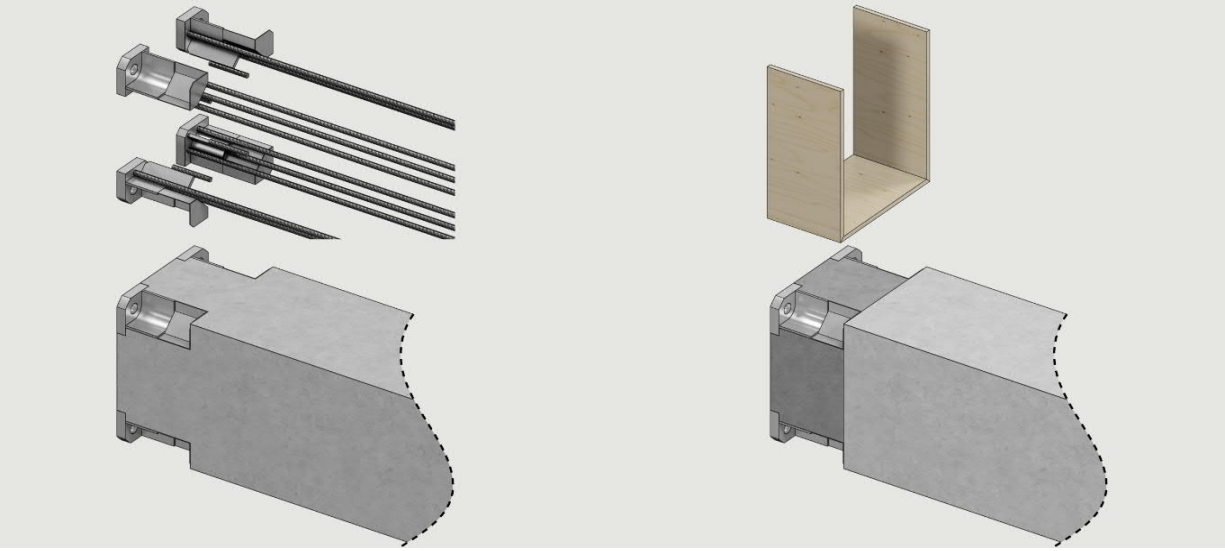


Figure 29. Methods for protecting the shoes during casting

6.4 Erecting the anchoring bolts into the column formwork

1. *Anchoring bolts ALP-P2S ALP-P2SM* 2. *Rebar couplers ARJ-A and ARJ-R*	**Erecting the anchoring and rebar coupler bolts into the column framework: Figure 30.** - The bolt is identified based on the colour of the plastic cover or the colour code on the end of the sleeve. - The plastic cover of the thread is removed from rebar coupler bolts. - The bolts must be tied into a group so that they cannot move during casting. If necessary, the bolts and rebar couplers can be manufactured as a fixed group. - The bolt's sleeve is placed tightly against the inner surface of the formwork. - Fastening is carried out using a hex screw erected through the formwork and tightened against the formwork, or the bolt group can be tied to the reinforcement so that it cannot move. - The thread of the sleeve must be protected from concrete grouting. - The bolt must be placed perpendicular to the surface of the formwork to enable erecting the threaded rod. - The bolt's location on the surface of the column bracket must be in accordance with the tolerances. - Supplementary reinforcement in accordance with the plans is placed in the column for the bolts. - The bending of the bolt bond is directed downward in the column unless otherwise specified in the plans. - After grouting, remove the formwork and bolt fastening screw, ensure that the thread is clean and fasten the bolt extension thread to the sleeve with a screw for transport.

Anchoring bolt and rebar coupler location tolerances in the column formwork:

1	Location of the bolts in relation to the column centre line	± 2 mm
2	Mutual distance and cross-measure of the bolts	± 2 mm
3	The bolt's threaded sleeve is erected against the formwork surface, maximum allowable clearance.	–0, +2 mm
4	The bolt is erected perpendicular to the column surface, allowable skew deviation.	± 2 mm/m
5	Distance of ALP-P2S and ALP-P2SM bolts from the top surface of the column bracket.	± 5 mm
6	Distance of the rebar couplers from the top surface of the column bracket	± 5 mm

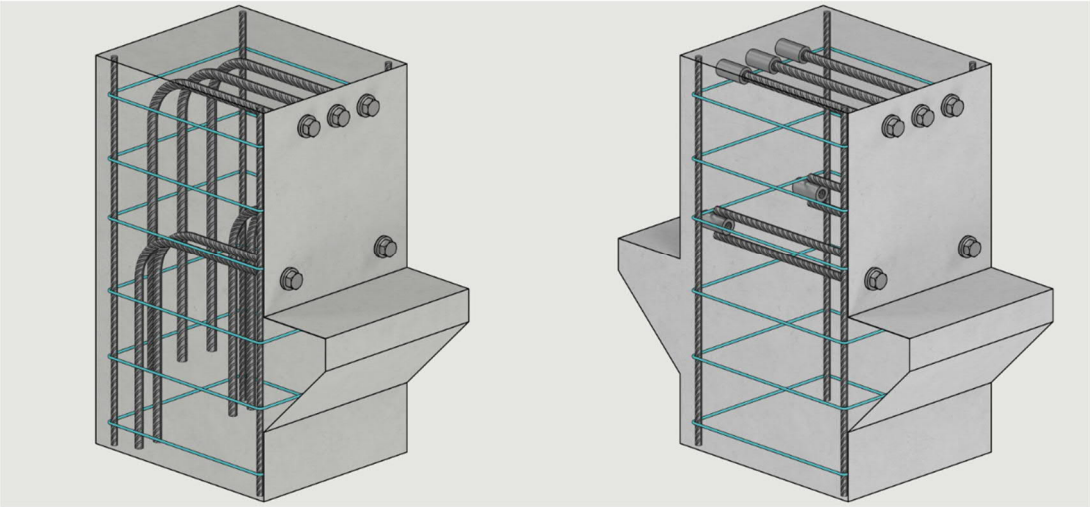


Figure 30. Fastening the anchoring bolts to the column formwork

6.5 Corrective measures allowed for shoes at the factory

The structures of the shoe must not be modified without the shoe manufacturer's permission. Non-conformity reports must be prepared for any modifications. Corrective measures allowed for shoes at the concrete prefabrication factory are:

1. *Allowable corrective measure*	- Shoes are assembled into groups by welding a piece of flat steel to the top surface of the base plate. However, the weld must not reach the area of the shoe's structural weld. - The shoe's protective housing for casting can be complemented by spot welding or otherwise fastening filler plates to the current housing. - The filler plates must not restrict the internal size of the casting housing.
	- The shoe's bond may be bent at the top end of the shoe to avoid the structural reservation in the beam. The bending is performed using the bending radii and work methods allowed for rebar. Before bending, confirm with the designer that the lap length of the beam's rebar is sufficient for the new situation. - The shoe bonds are bent to make way for the beam's main piece of rebar. - Beam reinforcements may be welded to the shoe bonds, if spot welds are used and the purpose is to fasten the reinforcement/shoe to the formwork during the erection. - Load-bearing joints must not be welded to the shoe bonds.

The following corrective measures are not allowed.

2. *Non-allowable corrective measure*	- The load-bearing structure of the shoe must not be modified by cutting or welding. - The shoe bonds must not be cut or shortened. - The shoe bonds must not be bent such that the bending begins at the bond's weld. - No force-bearing parts may be welded to the shoe base plate or bonds.

6.6 Manufacture quality control

Manufacture quality control for beam-to-column connections is carried out in accordance with the concrete prefabrication factory quality system and/or any separate element quality control plan prepared for the project. The structural and dimensional inspections specified in the quality system/inspection plan are performed on the shoes. For concrete and shoe connection structures, the instructions provided in EN 13670 are followed. The quality control measures to be performed for shoe connections include:

1. *Measures before casting*	- Check that the shoe is as planned and not damaged. - Ensure that the shoe group is correctly located in the formwork. - Ensure that the shoe has been securely fastened and the nut slots protected. - Ensure that the supplementary reinforcement required by the shoes has been erected.
2. *Measures after casting*	- Measure the location of the shoe's bolt holes to correspond to the planned tolerances and check that the casting has been successful and the shoe is clean.

6.7 Final documentation of manufacture quality control

When the job has been accepted, the element manufacturer is required to provide the client with the inspection and quality control documentation created during manufacture. In addition, the delivery must include any as-built documentation and non-conformity reports made during manufacture.

7 ERECTING THE SHOE CONNECTION ON THE SITE

7.1 Standards and instructions to be followed during erection

The following instructions and project plans are to be followed when installing the shoe connection.

1. *Standards Implementation breakdown Quality plan*	- Installation plan prepared by the frame erecter. - Concrete structure implementation breakdown prepared for the project and site. - Quality inspection plan prepared for the project and site. - EN 13670 Execution of concrete structures [15] - SFS 5975 Execution of concrete structures. Use of standard EN 13670 in Finland - EN 13369:2018 Common rules for precast concrete products [16]
2. *Drawings*	- Drawings prepared by the frame designer. - Structure sections and installation details prepared by the frame designer.
3. *Erection instructions*	- User manual for APK-CM shoes, whose sections 7, 8 and 9 apply to erecting a shoe connection on the site. [18]

7.2 Erection dimensions of the threaded bolts and tightening the nut

APK-CM beam shoes are erected in the column in accordance with the dimensions specified in Table 10. The dimensions in the table have been prepared for 20 mm grouting of the beam end and 50 mm grouting of the bracket's top surface. If the grouting thicknesses differ from this, the dimensions must be changed. Dimensions in Figure 31.

1. *Grouting of the beam end. Dimension G*	- Beam end's minimum grouting thickness G = 20 mm. The maximum is 50 mm. - Within the limits of variation, the length of the threaded rod is sufficient for tightening the rod to the bolt.
2. *Column bracket's top surface grouting. Distance C1*	- Default grouting thickness C1 = 50 mm. The limits of variation are 30–70 mm. - The grouting thickness is specified in the structural plans. - The grouting thickness determines the thickness of the beam's support block. - The beam's support block is part of the site acquisitions.
3. *Shoe fitting dimension B with 20 mm grouting*	- A piece of plywood is erected on the surface of the column for adjusting the distance of the beam end from the column. The shoe base plate is supported against the piece of plywood when the nuts are tightened.

4. *Threaded bolt fitting dimension C with 20 mm grouting*	- The washer and nut of the threaded rod are fitted to the rod according to dimension C. - Dimension C determines the erection length of the threaded rod with 20 mm grouting and fits the rod deep enough into the bolt's sleeve. The dimension includes a clearance of + 5 mm. - Dimension C must be adjusted with grouting thicknesses higher than the standard.
5. *Threaded bolt verification dimension A with all grouting thicknesses*	- After tightening the nut, dimension A is used to verify that the threaded rod is deep enough in the bolt's sleeve. Deviations from the dimension must be analysed. - Dimension A in Table 10 does not depend on the grouting thickness.
6. Threaded bolt tightening torque $M_{r,1}$	- The nuts are tightened using torque Mr,1 in the table. - After the tightening, at least one pitch of the bolt's thread must be visible. The tightening is enough to lock the nut. - The thread dimension must not be lower than this, and a repair plan must be made if this happens.

Table 10. Beam shoe connection's erection dimensions, grouting and bolt tightening torque

Shoe	Anchoring bolt	G mm	C1 mm	B mm	C mm	A mm	$M_{r,1}$ N_m
APK24CM	ALP22P2S	20–50	30–70	45	80	130	200
APK30CM	ALP30P2S	20–50	30–70	55	100	150	200
APK36CM	ALP36P2S	20–50	30–70	60	110	170	200
APK39CM	ALP39P2S	20–50	30–70	60	110	190	300
APK45CM	ALP45P2S	20–50	30–70	70	130	200	300
APK52CM	ALP52P2S	20–50	30–70	80	145	235	400

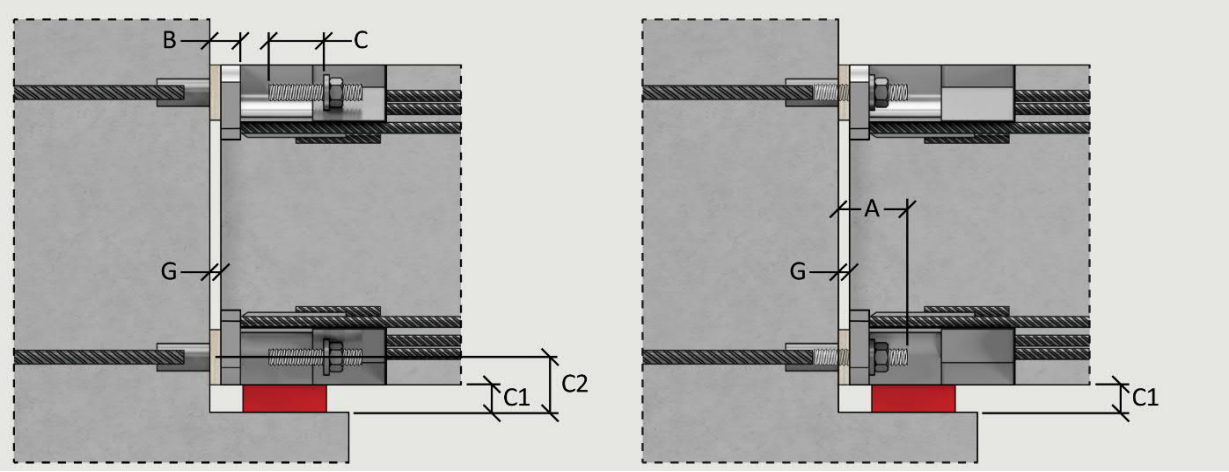


Figure 31. Erection dimensions of the beam shoe's threaded rod

7.3 Beam erection and grouting

Preparatory work for the element beam and column erection	
1. *As-built measurements*	- Ensure that the location of the anchoring bolts and rebar coupler bolts on the surface of the column corresponds to the plans. - Ensure that the top surface of the column bracket grouting (C2) is at the correct elevation and the thickness of the filler plate under the beam (C1) is in accordance with the plans.
2. *Inspecting the bolts*	- Ensure that the bolt sleeve threads are undamaged and clean. - Ensure that the surface treatment of the bolt threads corresponds to the plans. - Ensure that nuts and washers have been used in accordance with the plans.
3. *Safety*	- See the plan for the erection order and need for supporting the

requirements	column/beam. - Find out about other safety measures and the stability requirements for the frame to be erected.

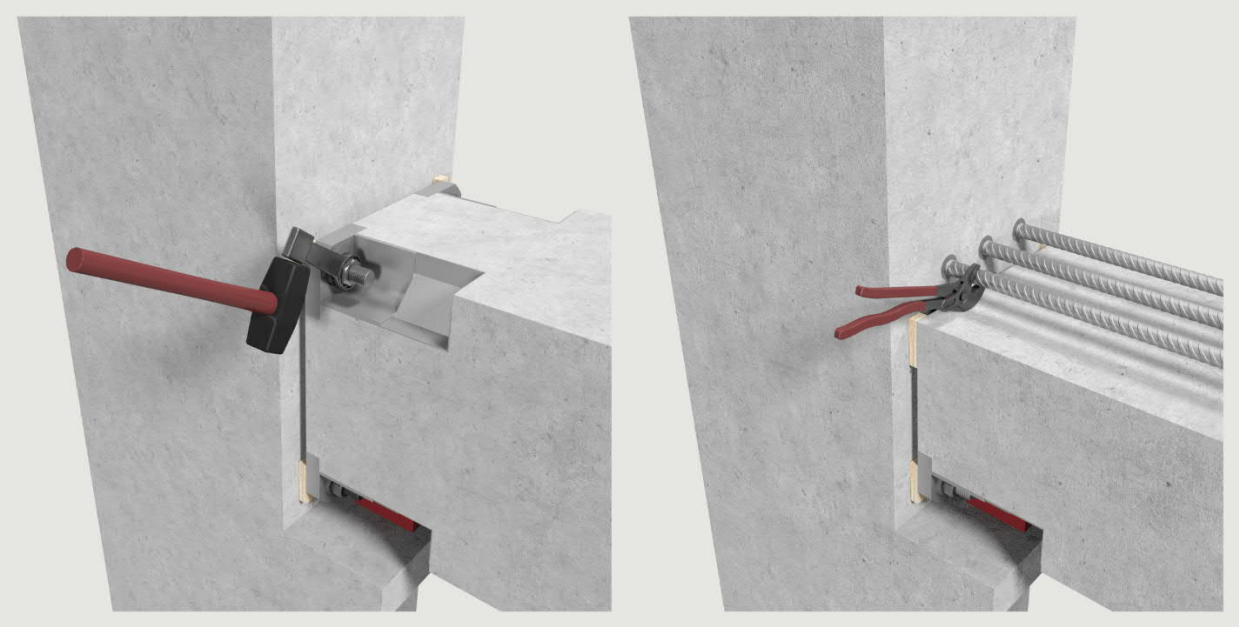


Figure 32. Erecting the beam and tightening the shoe-to-rebar coupler connection screws

Erecting the element beam	
4. *Mounting blocks and threaded rod*	- Erect plywood mounting blocks at the shoe base plates to adjust the beam end's grouting thickness according to the plan. - Erect a steel mounting block on top of the column bracket, at the elevation of the beam's bottom surface. - Remove the threaded rod of the shoe anchoring bolts from the column. - Adjust the distance of the threaded rod's washer according to dimension C in Table 11.
5. *Lifting*	- Lift the beam into place on the bracket mounting block. - Remove the lower nut and washer (included in the standard delivery) from the threaded rod. - Erect the threaded rod into place and screw it into the sleeve. - The threaded rod must be screwed in all the way to the bottom. The removed nut can be used for the tightening. - The nut slots in the shoes have been dimensioned for a DIN 7444 striking wrench.
6. *Fastening the shoe to the column*	- Tighten all the nuts to the required torque. Table 10. - Grouting is sufficient for locking the nuts, unless the civil engineer provides other locking instructions.
7. *Supporting the beam*	- Erect any erection supports required for the beam. - Unhook the crane from the beam.
8. *Erecting the rebar coupler*	- Check that the sleeve thread is clean. - Erect the rebar coupler bars in the column's sleeve such that no thread remains visible. - Tighten the bar against the bottom of the sleeve. - Erect the supplementary reinforcement on the beam's top surface according to the structural plans.

Grouting the connection	
9. *Preparatory work*	- Check the structural plans to confirm the time at which the grouting is to be performed. - Ensure that the strength of the grout is at least equal to that of the

	concrete of the beam and that the frost resistance of the grout is sufficient. Use heating if necessary. - Ensure that the anchoring bolt nuts have been fastened and tightened. - Ensure that the rebar couplers have been tightened.
10. Formwork	- Prepare the formwork in accordance with the structural plans.
11. Grouting	- Perform the grouting as pressure grouting with sufficiently viscous grout. - The grout must not be allowed to freeze, and heating must be used if necessary.
12. Inspections	- After disassembling the formwork, ensure that the grout has filled the nut housings as well as the space between the beam end, column bracket and beam. - The grouting is performed by following the quality control procedures for structural concrete.

Fire protection of the connection	
13. Methods	- See the structural plans for the planned fire protection methods for shoe connections.
14. Fire protection of the connection	- The grouting of the shoe's nut slots usually constitutes sufficient fire protection. - The grouting of the beam's top surface provides sufficient fire protection for the rebar coupler. - In other cases, follow the instructions in the structural plans.

7.4 Erection tolerances for the shoe connection

The erection tolerances for the frame are in accordance with EN 13670. The final location of the beam is determined on the basis of the manufacturing tolerances of the shoe group and the erection tolerances of the bolts.

The location of the beam can only be influenced with the play in the shoe's bolt hole. The play of the hole in the APK-CM shoe's base plate is 9–15 mm. Within the limits allowed by these tolerances, the location of the beam can be adjusted during the erection using the play of the shoe hole. The beam is set in relation to the column lines with the tolerances specified in Table 11.

Table 111. Allowable deviations for the beam, column and connection

1	Horizontal location of the beam's centre line in relation to the module line	deviation ± 5 mm
2	Vertical displacement of the beam	deviation ± 5 mm
3	Allowable deviation of the grouting thickness of the beam end	deviation ± 10 mm
4	Deviation of the grouting thickness of the beam's bottom surface	deviation ± 10 mm
5	Deviation of the bolt's tightening torque from the value in Table 11 or from value $M_{r,1}$ as specified in the structural plans.	deviation ± 30%

7.5 Corrective measures allowed for the shoe connection on the site

The structures of the shoe connection must not be modified without the designer's and/or shoe manufacturer's permission. Non-conformity reports must be prepared for any modifications. The following changes in the load-bearing structure of the shoe are allowed on the site. The changes must be documented in the project's quality documentation.

1. *Allowable corrective measure*	- If necessary, the shoe's protective housing for casting can be complemented by spot welding additional plates to the current housing.
	- If the bolt's washer touches the shoe housing, 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 erected 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 erected 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, provided that the bolt manufacturer's washer is kept lowermost against the surface of the base plate.

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

2. *Non-allowable corrective measure*	- The load-bearing structure of the shoe must not be modified by cutting or welding. - Reaming the hole in the shoe's base plate requires a separate non-conformity plan and the shoe manufacturer's approval.
	- The bolt's threaded section must not be bent or heated. - No other force transfer structures may be welded to the bolt. - The bolt and its bonds must not be cut and welded to a new location.
	- The bolt must not be welded to the shoe base plate. - The bolt's washer must be supplied by the bolt manufacturer. - The washers must not be replaced. - The nut may never erect without the bolt's own washer.
	- If the hole in the shoe base plate has been reamed, the washer must be replaced with a larger one.
	- The nuts of a hot-dip galvanised bolt must not be replaced with nuts based on another 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.

8 SAFETY MEASURES

8.1 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 shoe connection erections:

1. Erection	- Columns and beams are erected by following the working order in the contractor's erection plan and the requirement for frame stability during erection determined by the designer. - The time at which the column's base plate is to be grouted must be specified before erecting the beam. The column must be grouted before erecting the beams if this required in the erection plan.
	- The falling of the beam and incorrect loading of the bolt connection during erection must be prevented by the following measures: - Lifting equipment must be used for lifting the beam. - The beam must not be moved or lifted from the shoe bolt hole.
	- During the lifting of the beam, the shoe base plate must not hit/rest on the ground or another fixed structure.
	- The lifting equipment can be unhooked when the beam is in place and has been fastened to all shoe anchoring bolts.
	- The anchoring bolts must not be loaded in ways and with forces deviating from the plan.

2. Stability	- The beam must never be unhooked from the crane without fastening it with a threaded rod through the shoe to the column's anchoring bolts.
	- The frame stability under exceptional natural forces must be ensured at the end of the shift.
	- The overall stability of a partially erected frame must always be ensured.

3. Structure	- The time at which the shoe connection is to be grouted must be specified in the erection plan. The loading of the floor carried by the beam must not be continued before the grout has hardened.
	- The grouting concrete is part of the moment rigid load-bearing structure of the connection, so the grouting materials and work methods must be selected such that the grout cannot freeze.
	- Any erection supports used for the beam are removed in accordance with the erection plan, at the earliest after the grout in the connection has hardened.

8.2 Commissioning a beam shoe connection during construction

The moment rigid beam connection is separately designed for erection state forces for the frame. There are highly significant differences between these two states in how the beam-to-column connection works. The moment rigid connection will only reach the ultimate limit state resistance when the joint between the beam and the column and the grouting concrete of the nut slots and the beam base have reached the design strength. Until then, the beam connection and its resistance must only be reviewed using the erection state resistance values. Any erection supports used for the beam must be removed only after the grout has hardened.

The time at which grouting is to be performed is specified in the erection plan. The grouting must not be postponed, and the beam commissioning permit required for continuing with the erection of the upper structure and for additional loading is determined by means of a review.

9 ERECTION QUALITY CONTROL

9.1 Instructions for monitoring beam erections

Erection quality control for beam 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 element frame. For concrete structure requirements, the instructions provided in EN 13670 [15] are followed.

An inspection report is prepared for the element frame's quality control and dimensional inspections and saved in the project's quality documentation. The inspection measures to be observed for shoe connections are:

1. *Before beam erection*	- Ensure that the bolts are not damaged. - Following the erection plan regarding the erection order of the elements. - Need for supporting the column and beam during erection. - Checking the elevation of the column brackets and bolts.
2. *After beam erection, before grouting*	- Check that the connection has been erected 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 at least 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 erecter deviates from the approved plans and documents in any of the following tasks: - quality control - performing the erection work, lifting and transfers - erection materials - structure tolerances and dimensional inspection of the frame - required inspections and their documentation, the erecter 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.

9.2 Final documentation of erection quality control

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

1. *Readiness inspection records*	- As-built dimension record for the bolt locations. - Commissioning inspection of the beams and columns after the grouting of the connection.
2. *Non-conformity reports*	- Any non-conformity reports prepared during the erection of the shoe 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.

REFERENCES

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[9] *EN ISO 5817, Welding. Fusion-welded joints in steel, nickel, titanium and their alloys. Weld classes.*
[10] *EN ISO 12944, Paints and varnishes. Corrosion protection of steel structures by protective paint systems.*
[11] *EN ISO 1461, Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods.*
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[15] *EN 13670 Execution of concrete structures*
[16] *EN 13369:2018 Common rules for precast concrete products*
[17] *SFS 5975. Execution of concrete structures. Use of standard EN 13670 in Finland*
[18] *Anstar Oy. Beam Shoes user manual*
[19] *Anstar Oy. Anchor Bolts user manual*
[20] *EN 1992-4:2018, Eurocode 2. Design of concrete structures. Part 4: Design of fastenings for use in concrete*

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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SMART STEEL.
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ANSTAR OY
Erstantie 2
FIN-15540 Villähde

Tel. +358 3 872 200
anstar@anstar.fi
www.anstar.fi