

WALL SHOES

TECHNICAL MANUAL

EXMET
PRECAST ACCESSORIES

Version 1.0

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TABLE OF CONTENTS

1. PRODUCT PROPERTIES	3
General	3
Materials	6
Markings	6
Production tolerances	7
Environmental conditions	7
2. PRODUCT DIMENSIONS	8
Plate washers	9
Wall thickness, edge to edge distance and other details	9
3. RESISTANCES	11
Structural behavior	11
Fire resistance	12
4. INSTALLATION OF WALL SHOES	12
Welding	13
Bending	14
Appendix 1, Special reinforcement design	14

1. PRODUCT PROPERTIES

GENERAL

Exmet produces anchor bolts in two capacity categories: Normal Capacity Bolts (NKP bolts) and High Strength Bolts (SKP Bolts). For NKP anchor bolts the matching wall shoes are NSK type, while for SKP anchor bolts the matching wall shoes are SSK.

Use of bolted wall connection offers following benefits:

- ✓ Simple connecting process for elements through bolting.
- ✓ Immediate initial tensile force transfer once nuts are tightened.
- ✓ Reduced need for temporary supports.
- ✓ Faster and easier adjustment of walls in installation in vertical direction and lining.
- ✓ A bolted connection offers enhanced potential for reusing elements in a circular economy.

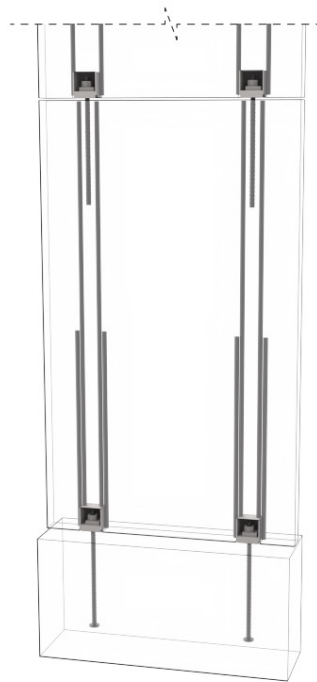


Figure 1:
Bolted wall - wall- foundation connection
with NKP anchor bolts and NSK wall shoes

Bolted connection with NSK/SSK wall shoes and corresponding anchor bolts NKP/SKP is designed to take on the tensile forces in the structure. Design of connection with slotted holes in shoe and with additional thick plate washer is done for eliminating shear force transfer via bolted connection. Filling slotted holes with concrete or welding washers to wall shoes will cancel the original design idea and reduce tensile capacity declared in Table 8. This modification will result in combined shear and tensile loads acting on the connector. To fully utilize the tension capacity of the connection and effectively transfer shear forces in the horizontal joint, the joint must be fitted with concrete shear keys, steel dowels, or a combination of both, in addition to the wall shoes. Without these additional measures, the slotted hole shoe may permit minor lateral movement if the friction in the joint is insufficient to prevent it. The design of shear keys or dowels for the horizontal joint falls under the responsibility of the structural designer and must be performed in accordance with stability calculations, considering the building's consequence class and earthquake zone.

Bolted connections with NKP/SKP anchor bolts and NSK/SSK shoes (Fig.1) are designed for connecting structural concrete walls with each other or wall elements and cast in-situ structures in quasi-static loading. The complete tension transfer system, including wall shoes and bolts (Figure 2), consists of the following components:

- ▶ Bolt in the below structure
- ▶ Wall shoe at the bottom of the element
- ▶ Plate washer and a nut for connection of bolt and shoe
- ▶ The reinforcement cage in the wall element, which matches the capacity of the bolt and shoe and directs the tension force through the element
- ▶ A bolt located on the upper side of the wall for connecting with the next element

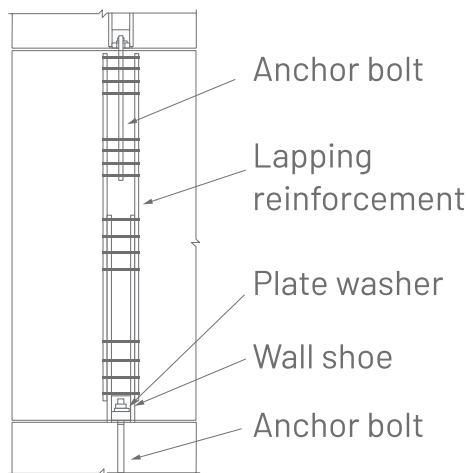


Figure 2:
Tension tie between wall elements

The bolt and corresponding shoe are designed with equal capacity, and the overall system capacity is determined by the weakest link. The reinforcement quantities listed in Table 12 are based on the capacity of the connectors. If the required capacity is less than that of the connectors, the connecting reinforcement may be reduced according to design calculations.

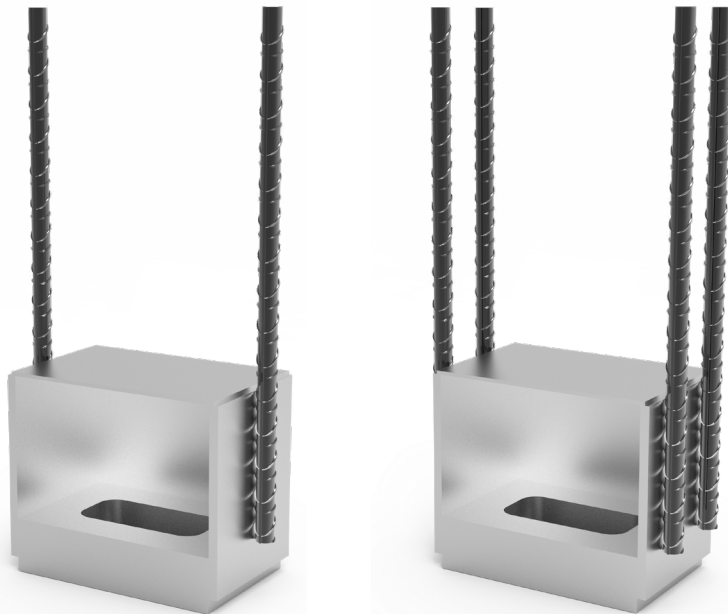


Figure 3:
Wall shoe type NSK (left) and SSK (right)

The wall shoe (Figure 3) features a thick base plate with a rectangular opening, side plates, top and bottom recess protection plates, and, depending on the capacity, either 2 or 4 reinforcement bars. All components are welded together. The resistance of a single NSK wall shoe matches the tensile capacity of the NKP anchor bolt, while the resistance of an SSK wall shoe corresponds to the tensile resistance of the SKP anchor bolts. For further details on anchor bolts, please refer to the NKP/SKP anchor bolts user manual.

The number of wall shoes and anchor bolt pairs required for a wall connection depends on the tension force in the connection. Placement of tension ties in wall elements must allow sufficient space for the reinforcement around the wall shoe and accommodate additional reinforcement for tie continuity. If the wall shoe is used as a tension connector in stabilizing walls subjected to moments in both directions, connectors are required at both ends of the wall. While wall shoes and anchor bolts transfer tension forces, compression is transferred through the horizontal filled joint between wall elements.

The placement and size of anchor bolts and wall shoes should be determined based on design loads and the structure's geometry. To simplify the connection, it is highly recommended to use symmetric placement of bolts and shoes within the section and to ensure uniform bolt sizes. For minimum wall thickness, edge distance, and spacing between wall shoes, please refer to Table 6.

MATERIALS

Type NSK wall shoes are manufactured from following materials:

	Part	Material quality	Standard
Table 1	Ribbed reinforcement bars	B500B	EN10080:2006
	Anchor plates	S355J2+N	EN10025-2:2019

Anchor plates are welded to the rebars and the execution of production is performed according to EN1090-2:2018.

MARKINGS

Shoes are equipped with an identification tag that contains the following information: Shoe type (NSK/SSK), thread Size, year of the manufacturing, and batch number.

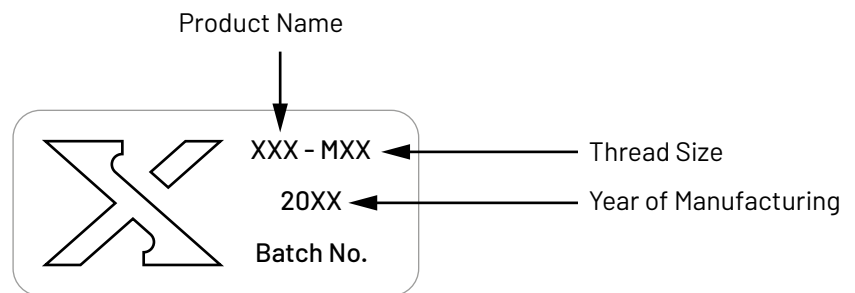


Figure 4: Identification tag for wall shoe

In addition to the identification tags, all shoes are marked with a color code to facilitate the identification of the shoe type after it has been cast into concrete.

Table 2

Wall shoe types	Product	
Normal capacity wall shoe NSK	NSK M16	●
	NSK M20	●
	NSK M24	●
	NSK M30	●
	NSK M39	●
High-capacity wall shoe SSK	SSK M30	●
	SSK M36	●
	SSK M39	●
	SSK M45	○
	SSK M52	●



NSK wall shoes are designed to be compatible with Exmet NKP L/P anchor bolts, while SSK wall shoes are designed for use with Exmet SKP L/P anchor bolts. The placement rules for bolts and shoes, the height of the bolt head from the base level, and the need for additional reinforcement in both the base structure and the wall for effective force transfer are based on using Exmet products at their declared capacities for the entire structural connection.

However, wall shoes can also be used in all bolted connections where the bolt capacity, material, and operational methods match the capacities declared in Table 8. In such cases, the final structure's designer must ensure that the bolt location, height of the bolt head in the base structure, and the size of the bolts or holes in the added structure are compatible with the size and type of Exmet wall shoes used. Please note that the standard solution with wall shoes is intended for handling only axial tension forces.

PRODUCTION TOLERANCES

Allowed deviation for wall shoe total lengths for all sizes in manufacturing: $\pm 10\text{mm}$.
Base plate dimensions and hole size $+2, -1\text{mm}$

ENVIRONMENTAL CONDITIONS

The default design of the wall shoe is carried out for dry indoor environmental conditions. The lowest operational temperature for standard wall shoe is -20°C .

When wall shoe is used in other conditions, the surface treatment, concrete cover or material of wall shoe must be adequate to environmental exposure class and intended operating life. Wall shoes are typically casted into concrete before installation of structures. Geometry of connection is after that providing resistance to corrosion if concrete cover is sufficient according to environmental exposure class and intended operating class.

In addition to protecting with casting Exmet offers bolts and shoes in hot dip galvanized versions (EN ISO 1461:2022) or with protective paint for more demanding conditions. In case of hot dip galvanized bolts and shoes, galvanized nuts and washers are used instead of standard set. Additional protecting painting on site by installation team after installation could improve protection of bolts and shoes against corrosion. Covering of bolts and side plates of wall shoe with cast in situ concrete is needed as well for ensuring fire safety of connection. Standard location of bolt and shoe ensures R60 fire resistance of connection after casting. For higher fire resistance ratings, bolts and shoes must be repositioned during the design phase according to structural calculations and the utilization rate of the connection.

The allowable deviation of concrete cover ($c_{dev}=\pm 10\text{mm}$) and the required concrete covers for wall shoe plates (c_{nom}) are detailed in the following table.

Table 3:

Exposure class	c_{nom} [mm] for shoe plates Structural class S4, Lifetime 50 years	Alternative additional protection for environment	c_{nom} [mm] Lifetime 100 years
X0	-	-	30
XC1	25	HDG	35
XC2/XC3	35	HDG	45
XC4	40	HDG	50
XD1/XS1	45	HDG	55
XD2/XS2	50	HDG	60
XD3/XS3	55	HDG	65

2. PRODUCT DIMENSIONS

Wall shoe NSK and SSK basic dimensions:

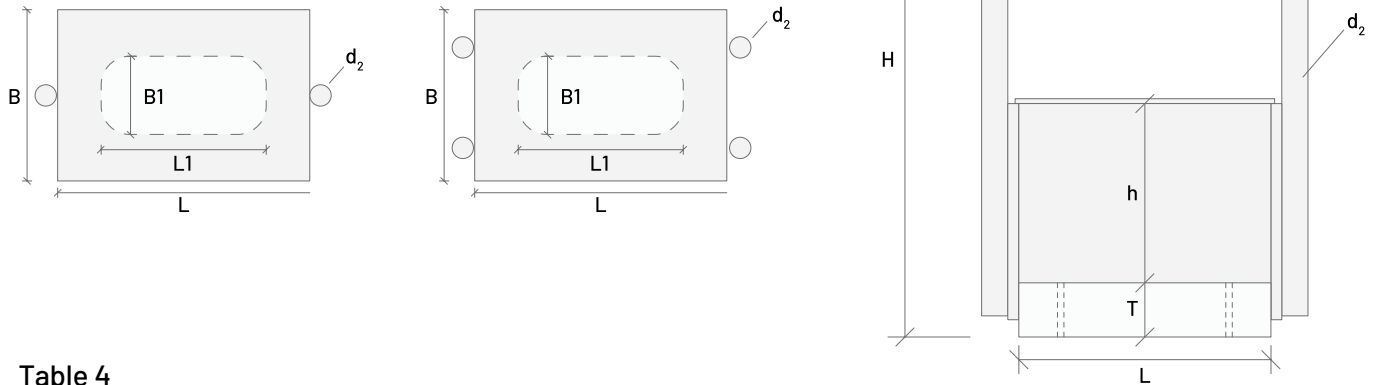


Table 4

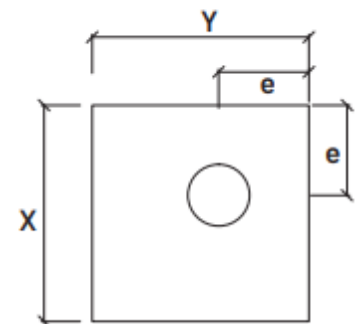
Shoe type	H [mm]	Side B [mm]	Side L [mm]	Hole Side B1 [mm]	Hole Side L1 [mm]	Recess Height h [mm]	Base Plate T [mm]	Washer	Anchor $\varnothing d_2$ [mm]	Color code
NSK-M16	600	80	119	36	76	80	30	PLW-NSK-M16	2× $\varnothing 12$	Yellow
NSK-M20	820	90	124	40	80	90	35	PLW-NSK -M20	2× $\varnothing 16$	Blue
NSK-M24	1185	110	129	49	84	105	35	PLW-NSK -M24	2× $\varnothing 20$	Grey
NSK-M30	1390	120	144	55	90	115	40	PLW-NSK -M30	2× $\varnothing 25$	Green
NSK-M39	1910	145	165	64	99	140	50	PLW-NSK -M39	2× $\varnothing 32$	Orange
SSK-M30	1460	130	145	55	90	120	45	PLW-SSK -M30	2× $\varnothing 25$	Yellow
SSK-M36	1765	150	164	61	96	140	55	PLW-SSK -M36	2× $\varnothing 32$	Blue
SSK-M39	1650	150	165	64	99	147	60	PLW-SSK -M39	4× $\varnothing 25$	Grey
SSK-M45	2015	175	180	75	105	162	70	PLW-SSK -M45	4× $\varnothing 32$	Green
SSK-M52	2215	230	210	82	112	200	80	PLW-SSK -M52	4× $\varnothing 32$	Orange

PLATE WASHERS FOR WALL SHOE.

For NSK and SSK wall shoes, Exmet provides plate washers (PLW) that are sized to match the shoe type and size. The plate washers are typically delivered to site along with the matching anchor bolts. The off-center placement of the bolt hole in the plate washer allows for optimal positioning of the washer, accommodating production and installation tolerances. Dimensions and ordering codes for PLW washers are detailed in Table 6.

Washer	Side X [mm]	Side Y [mm]	e [mm]	Thickness T [mm]
PLW-NSK -M16	60	60	25	12
PLW-NSK -M20	65	65	27	15
PLW-NSK -M24	80	80	30	20
PLW-NSK -M30	95	95	37	20
PLW-NSK -M39	115	115	47	30
PLW-SSK -M30	95	95	37	20
PLW-SSK -M36	110	110	45	30
PLW-SSK -M39	115	115	47	30
PLW-SSK -M45	130	130	55	35
PLW-SSK -M52	155	155	67	40

Table 6

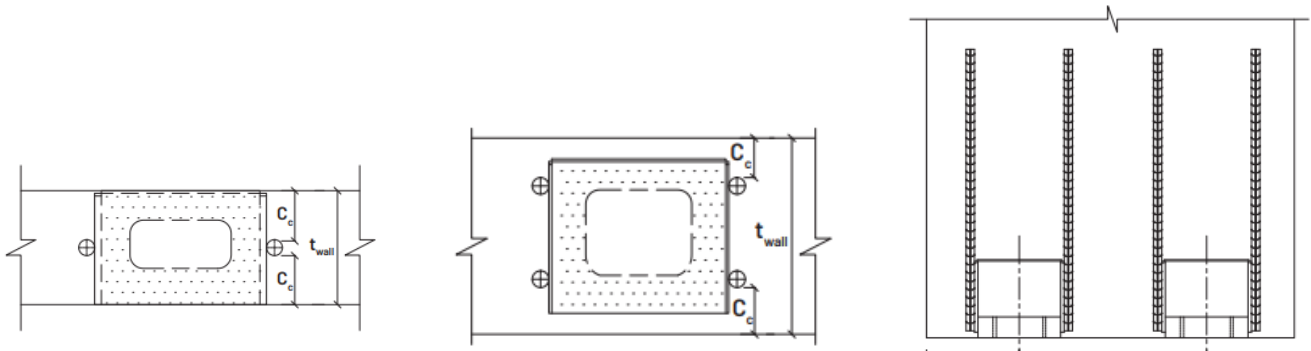


MINIMUM WALL THICKNESS, EDGE TO EDGE DISTANCE, CONCRETE COVER AND CONCRETE STRENGTH.

The minimum wall thickness for centrally located wall shoe as well as a minimum edge and center to center distance are specified in Table 7. Minimum concrete strength of wall is C25/30. Wall shoes are designed to align with anchor bolts, and the configuration of the bolt hole ensures that the wall shoe and bolt are positioned correctly. This setup allows the connection to handle only tensile forces, thereby utilizing the full tensile design capacity of the anchor bolt. Please note that the side plates and cover plates are exposed and will require additional protection against fire and environmental factors.

The length of wall shoe anchor bars is calculated for C25/30 concrete based on the capacity of NKP and SKP anchor bolts. Increasing the concrete strength in the wall does not enhance the design capacity of the connection, as the steel capacity of the bolted connection is the determining factor. The concrete strength of the in-situ concrete joint should be at least equal to the concrete strength of the wall. To achieve the full capacity of the connection, supplementary reinforcement in the anchorage area must adhere to the layout and quantities specified in Table 11.

Table 7



Wall shoe	Minimum wall thickness (with extra protective measures*) t _{wall} [mm]	Concrete cover cc at minimum wall thickness [mm]	Minimum edge distance ED [mm]	Minimum c/c Distance C/C [mm]
NSK M16	90*	39	140	220
NSK M20	90*	37	150	240
NSK M24	110*	45	160	250
NSK M30	120	47	170	280
NSK M39	145	56	200	320
SSK M30	130	52	180	280
SSK M36	150	59	200	320
SSK M39	190	42	170	300
SSK M45	210	46	200	320
SSK M52	250	43	220	350

3. RESISTANCES

Resistances of connection with wall shoes is calculated according to the following standards:

EN 1992-1-1: 2004

EN 1992 -4: 2018

EN 1993-1-1: 2005

EN 1993-1-8: 2005

Tensile capacity of NSK/SSK wall shoe corresponds to NKP/SKP anchor bolt capacity. In order to achieve full design capacity in connection and ensure proper work of connection, use of supplementary reinforcement in concrete detail is needed to ensure transfer of forces from bolted connection to concrete. Presented in tables below supplementary reinforcement quantities are estimated on base of steel part capacity, additional checks for main reinforcement of wall and foundation and EQV must be carried out by structural designer.

Combined application of shear load and axial tension load in wall shoe connection leads to reduction of bolt capacity and must be avoided. (Combined application will apply if holes in shoe are filled with concrete or PLW washers are welded to the bottom plate of the shoe. Both measures are not needed for force transfer and not taken into account in design of connectors by Exmet. If welding or filling is used to fix the installation or prefabrication errors, combined loading must be managed according to the EN1992-4 standards for steel and concrete verification by the general designer. All capacities presented in Table 8 are valid for quasi-static loads only. For dynamic loads, the designer must account for fatigue and dynamic impact according to the type of dynamic load, and the connection capacities may need to be reduced accordingly.

STRUCTURAL BEHAVIOR

Wall connection with shoes and anchor bolt is designed as structural connection, which is able to transfer the tensile forces. Estimation of tensile resistance of bolted connection is based on EN -1993-1-8 and EN 1992-4.

Tensile capacity of threaded bar:

$$N_{Rd0} = N_{Rd} = 0,9 \frac{f_{ub} A_s}{\gamma_{Mb}}$$

Where A_s - minimum area of threaded bar, f_{ub} - material tensile strength of threaded bar and γ_{Mb} - safety factor for material of the bolt ($\gamma_{Mb} = 1,25$).

1. Steel failure of bolt (shoe): $\left(\frac{N_{Ed}}{N_{Rd,s}} \right) \leq 1$, verification shall be done for every bolt in the wall

All verification for concrete element subjected to tensile force from shoe or bolt shall be executed by structural designer.

Wall shoe/ (Anchor bolt)	Tension capacity $N_{Rd,s}$ [kN]	Wall shoe / (Anchor bolt)	Tension capacity $N_{Rd,s}$ [kN]
NSK- M16 (bolt NKP L/P - M16)	62	SSK- M30 (bolt SKP L/P - M30)	299
NSK -M20 (bolt NKP L/P - M20)	97	SSK -M36 (bolt SKP L/P - M36)	435
NSK -M24 (bolt NKP L/P - M24)	140	SSK -M39 (bolt SKP L/P - M39)	520
NSK -M30 (bolt NKP L/P - M30)	220	SSK -M45 (bolt SKP L/P - M45)	695
NSK - M39 (bolt NKP L/P - M39)	385	SSK - M52 (bolt SKP L/P - M52)	938

FIRE RESISTANCE

The fire resistance of bolted connections should be verified in accordance with EN1992-1-2. If the fire resistance of the connection is insufficient, either increase the concrete cover or implement other fire protection measures, such as using external fireproof covers. If the wall section is adequate, the simplest solution for enhancing fire resistance is to increase the concrete cover around the reinforcement cage and wall shoe. For removable structures, using fireproof covers can provide easier future access to bolts.

4. INSTALLATION OF WALL SHOES

Installation shoes in factory must be carried out according to production drawings. Wall shoes are placed into reinforcement of the wall and fixed to wall bottom formwork with installation bolts. Installation tolerance of wall shoe in plane is $\pm 2...4$ mm for perpendicular direction to wall and ± 5 mm along the wall. Wall shoes position in formwork must be secured against movements.

If NSK/SSK shoe is installed at the bottom of the wall, then corresponding bolt heights in foundation or lower wall for achieving proper connection are presented in Table 9 and Figure 5. For easier designer TEKLA components are available for ensuring proper positioning of the bolts and shoes in design.

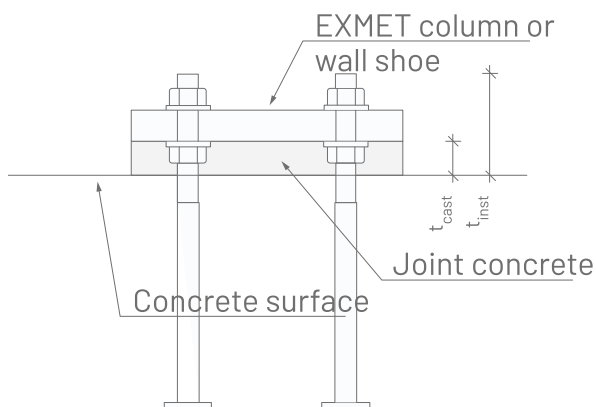


Figure 5: Installation heights for Exmet bolts if shoe is located at bottom of the wall

Table 9

Wall shoe NSK			Wall shoe SSK		
Bolt type	Height from casting t_{inst}	Thickness of joint t_{cast}	Bolt type	Height from casting t_{inst}	Thickness of joint t_{cast}
NKP L/P – M16	100	20	SKP L/P – M30	145	20
NKP L/P – M20	110	20	SKP L/P – M36	165	20
NKP L/P – M24	115	20	SKP L/P – M39	185	20
NKP L/P – M30	135	20	SKP L/P – M45	195	20
NKP L/P – M39	160	20	SKP L/P – M52	220	20

After installing the wall, all bolts should be tightened once the vertical alignment of the element is confirmed. A torque wrench should be used to ensure that the torque is at least equal to the minimum specified in the table below and does not exceed the maximum allowed torque, T_{max} .

Table 10

Bolt	T_{min} [Nm]	T_{max} [Nm]
NKP L/P – M16	120	200
NKP L/P – M20	150	250
NKP L/P – M24	200	350
NKP L/P – M30	250	450
NKP L/P – M39	350	1000
SKP L/P – M30	250	700
SKP L/P – M36	300	1200
SKP L/P – M39	350	1400
SKP L/P – M45	400	2000
SKP L/P – M52	450	3300
SKP L/P – M60	500	3800

WELDING OF SHOE ANCHOR BARS TO MAIN REINFORCEMENT

As a rule, welding of anchor bars of shoe or anchor bolts to main reinforcement of concrete element is not recommended and not needed. However, materials used in shoe anchor bars are weldable and welding has been used in the production of shoes. If there will be need to weld anchor bars of shoe to main reinforcement cage (e.g due to product geometry or handling of cage in production), requirements and instructions of standard EN 17660 -1 Welding of reinforcing steel, must be followed during work planning, execution and supervision.

BENDING OF WALL SHOE ANCHOR BARS

Rebar anchors of NSK/SSK shoes are made from B500B reinforcement steel. If the standard wall shoe cannot be installed due to product geometry, the anchor bar geometry may be adjusted by bending to fit the prefab product. Bending must comply with the requirements of EN1992-1-1, with a minimum straight section of 300 mm before the bend begins. The mandrel diameter for bending should follow Table 8.1N of EN1992-1-1. Since there are typically at least two rebars connected to the shoe, bending the final product can be complex. Therefore, it is advisable to order a custom product based on the required bent shape drawing. The connection capacities listed in Table 8 are for the unmodified product and cannot be directly applied to modified products.

The capacity for modified connections, as well as the appropriate shoe and bolt sizes, must be assessed by a structural designer based on the modified connection shape and the actual geometry and reinforcement of the prefab element.

APPENDIX 1, SPECIAL REINFORCEMENT DESIGN QUESTIONS IN BOLTED CONNECTIONS

Reinforcement design for connections with anchor bolts and wall shoes follows for concrete design rules according to EN1992-1-1 and due to transfer of load via connectors some additional rules from and EN 1992-4:2018 will apply for neighborhood of bolt. If pull out concrete cone or break out concrete cone conditions are not fulfilled for full development of cone according to EN1992-4:2018, supplementary reinforcement for anchor bolt neighborhood must be designed as per EN1992-4:2018 supplementary reinforcement design rules. Rules for bolts are presented in Exmet anchor bolts manual. To achieve equal capacity with bolt, wall shoe anchor bars will need additional reinforcement according to Table 11 and Figures 6-1, 6-2.

The bolted connection functions as a lapping joint, beginning with the shoe and bolt and extending to the overlap of the anchor bars with the main reinforcement of the wall. All reinforcement lapping rules from EC2 apply to the overlap between the shoe anchor bars and the main reinforcement. To achieve the full capacity of the lapping joint, the number of stirrups in the lapping zone should comply with the requirements specified in EN1992-1-1, section 8.7.

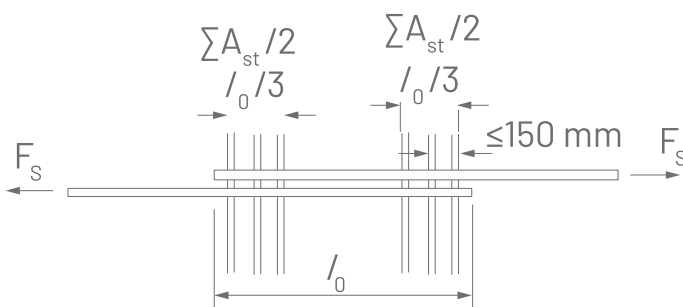
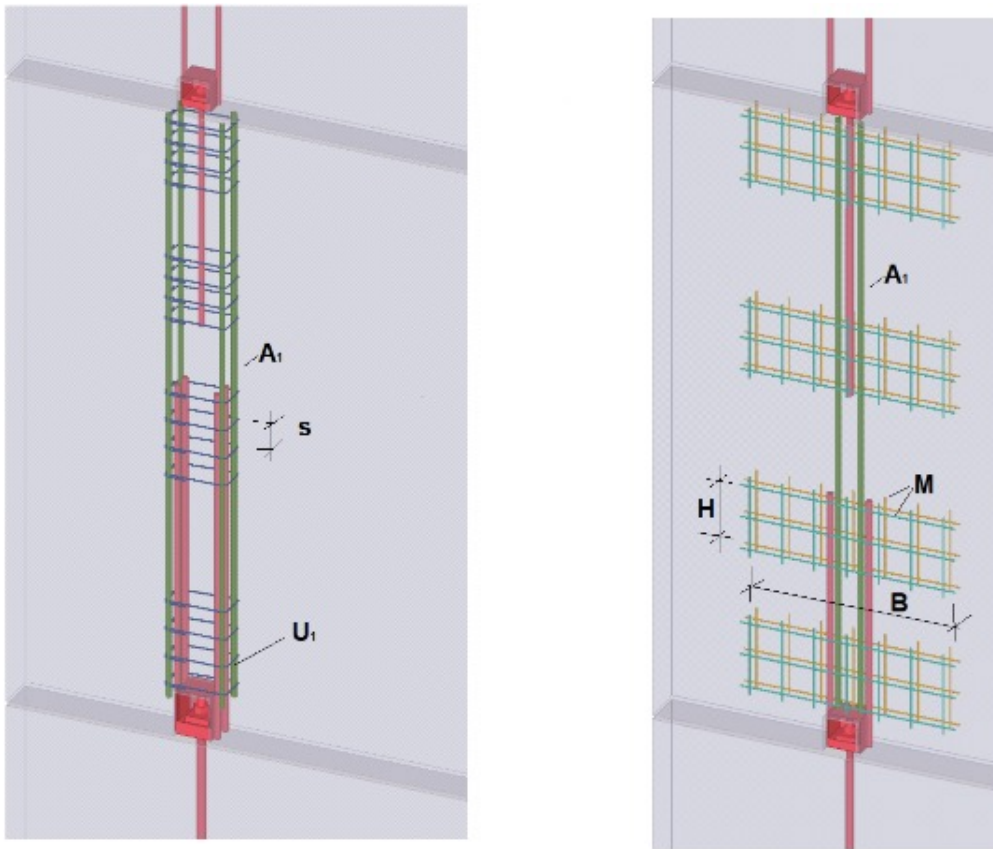


Figure 6-1: General reinforcement demand in shoe / reinforcement cage overlap according to EC2.

Figure 6-2: Wall shoes and reinforcement overlap with stirrups and bars or with bars and meshes



Lapping bar reinforcement for wall shoes

Table 11

Shoe	A1 (longitudinal bars)	U1 (per one overlap/ step in overlap)	B (mm)	H (mm)	mesh (Overlap on both sides)	Ast in wall shoe anchors
NSK-M16	1+1Ø12	3Ø8 /S=150	760	240	#Ø6-100	226 mm ²
NSK-M20	1+1Ø16	3Ø8 /s=100	760	240	#Ø6-100	400 mm ²
NSK-M24	1+1Ø20	3Ø8 /s=100	760	320	#Ø8-100	628 mm ²
NSK-M30	1+1Ø25	3Ø10 /S=100	860	350	#Ø8-150	980 mm ²
NSK-M39	1+1Ø32	4Ø10 /S=100	860	550	#Ø10-100	1600 mm ²
SSK-M30	1+1Ø25	5Ø8 /S=100	760	570	#Ø8-100	980 mm ²
SSK-M36	1+1Ø32	5Ø10 /s=100	760	570	#Ø10-100	1600 mm ²
SSK-M39	2+2Ø25	3Ø8 /s=100	-	-	-	1960 mm ²
SSK-M45	2+2Ø25	3Ø10 /S=100	-	-	-	1960 mm ²
NSK-M52	2+2Ø32	4Ø10 /S=100	-	-	-	3200 mm ²

The overlap reinforcement specified in the table is required to achieve the full capacity of the connection. However, the quantity of reinforcement can be reduced based on the utilization ratio.

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