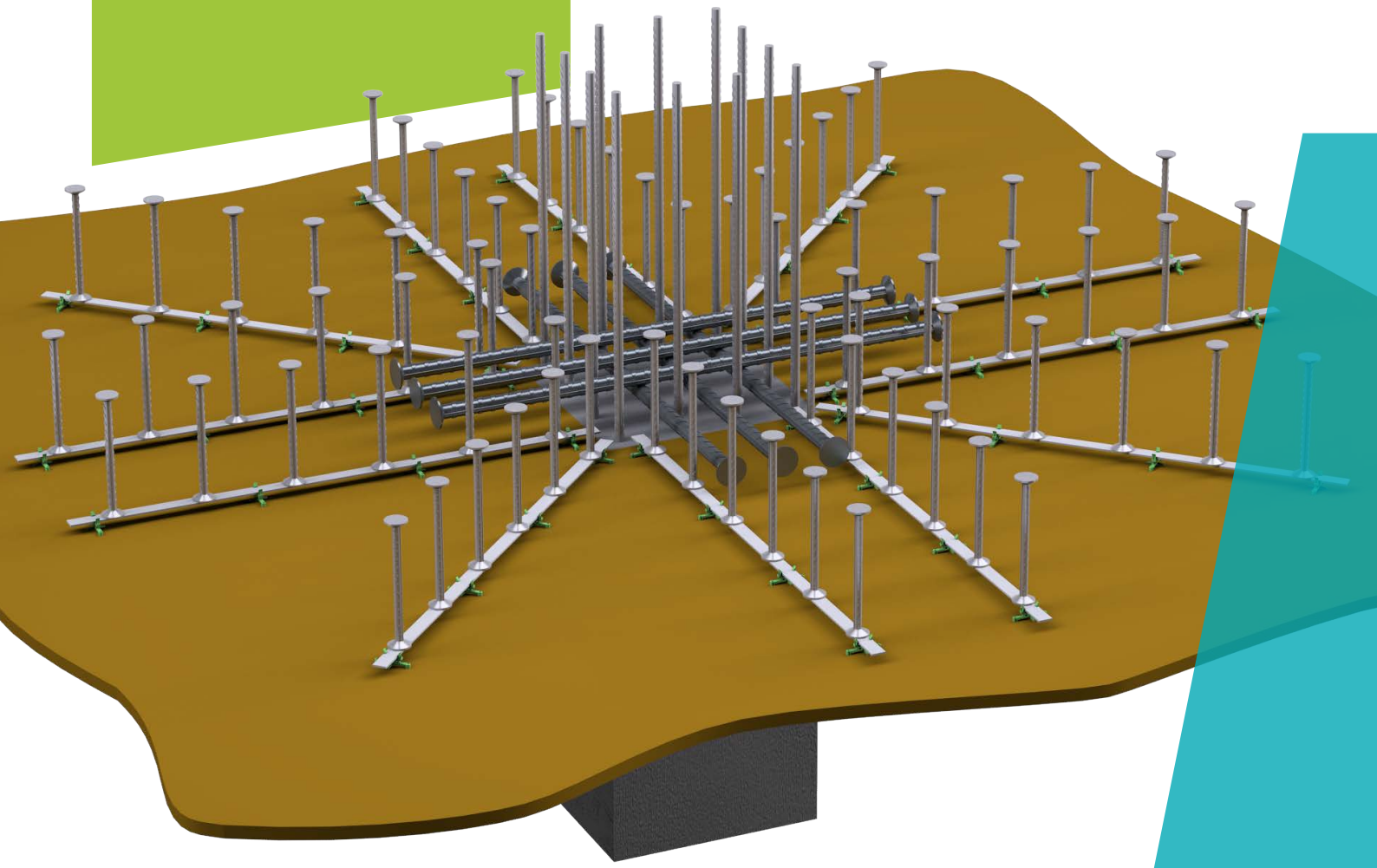
TECHNICAL MANUAL



PSB PLUS®

High Capacity Punching Prevention System

Version PEIKKO GROUP 04/2019

peikko®

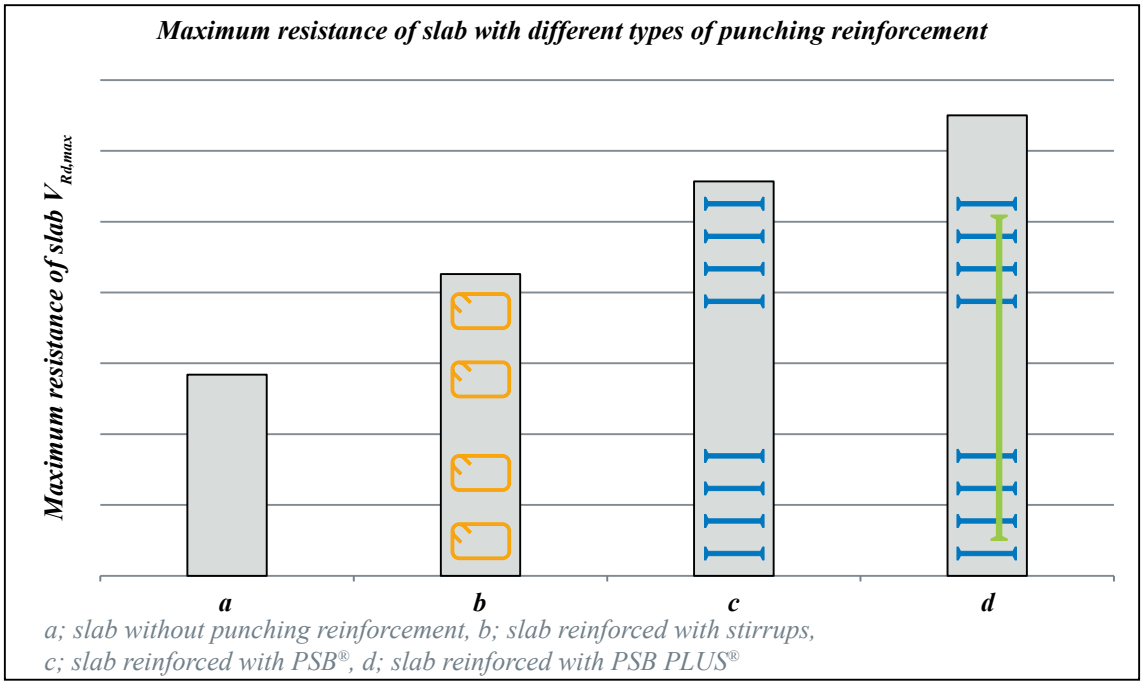
PSB PLUS®

High Capacity Punching Prevention System

- High punching shear resistance
- Reliable tested design
- Cost-efficient concrete construction
- Standardized elements pre-assembled in factory

PSB PLUS® system is a new solution for reinforcement of reinforced concrete flat slabs against punching shear failure. PSB PLUS® is a combination of vertical PSB® studs with horizontal PSH studs. This solution allows a flat slab higher resistance than what can be achieved when reinforced with PSB® studs only.

While the performance provided by vertical PSB® studs only is sufficient for a cost-efficient design of the most common layouts of flat slab structures, in some cases (e.g. composite columns with small dimensions) higher resistances may be required. The traditional solution is combining the PSB® studs with massive steel mushrooms. PSB PLUS® allows resistances comparable to those of such steel mushrooms while being significantly lighter thanks to a unique design. PSB PLUS® is thus a cost-efficient and practical solution for flat slabs subjected to extreme loads.



a; slab without punching reinforcement, b; slab reinforced with stirrups, c; slab reinforced with PSB®, d; slab reinforced with PSB PLUS®

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CONTENTS

About PSB PLUS®

1. Product properties

PSB PLUS® (*Figure 1*) is a next-generation punching reinforcement system developed by Peikko Group. PSB PLUS® consists of vertical PSB® studs (*Figure 2*) combined with horizontal PSH studs (*Figure 3*). PSH horizontal studs are double headed bars made of B500B reinforcing steel. PSH horizontal studs are installed in two perpendicular layers that cross the area of the column.

Figure 1. PSB PLUS® Punching Reinforcement system.

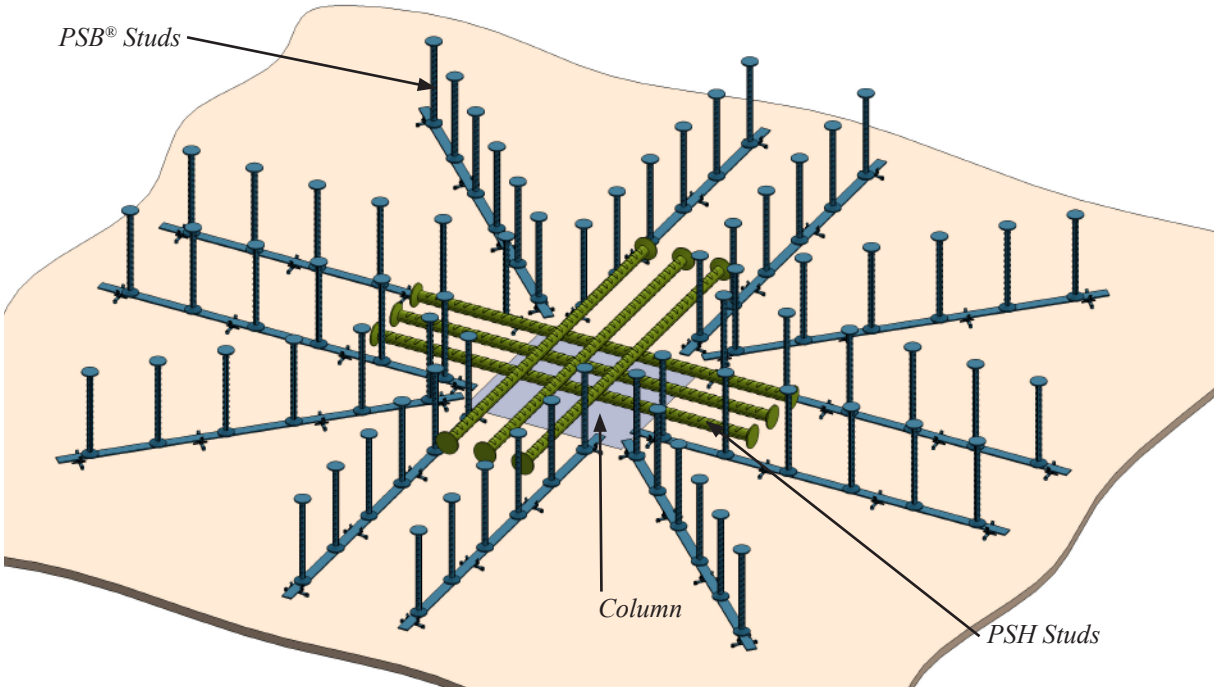
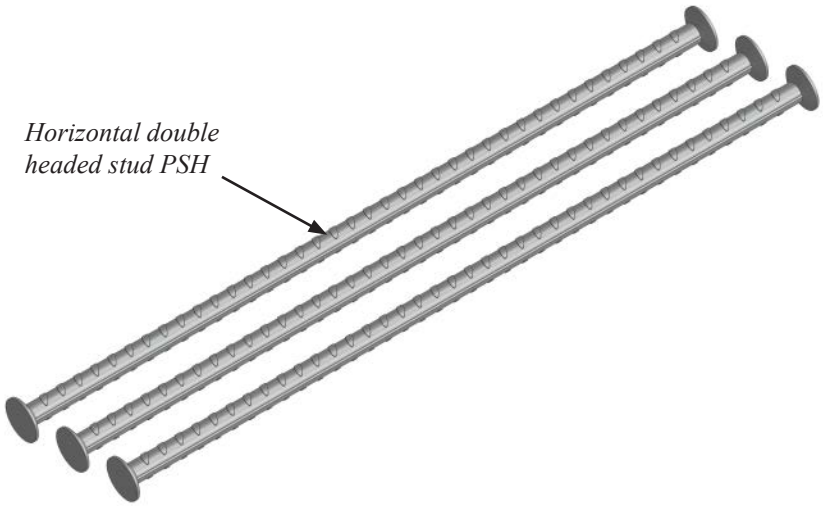


Figure 2. PSB® studs.

Figure 3. PSH horizontal studs.



1.1 Limitations for application

Punching prevention system in form of PSB PLUS® can be used in flat slabs with a minimum concrete grade of C30/37 and a minimum effective depth of slab 200mm.

1.1.1 Loading and environmental conditions

The concrete cover of all parts of PSB PLUS® Punching Reinforcement system must fulfil the requirements given in EN 1992-1-1.

1.1.2 Positioning of the PSB PLUS® Punching Reinforcement

The minimum requirements for placing the PSB PLUS® Punching Reinforcement system are presented below.

Figure 4. Top view of PSB PLUS® in a floor slab with large column, n_{PSH} = 8pcs.

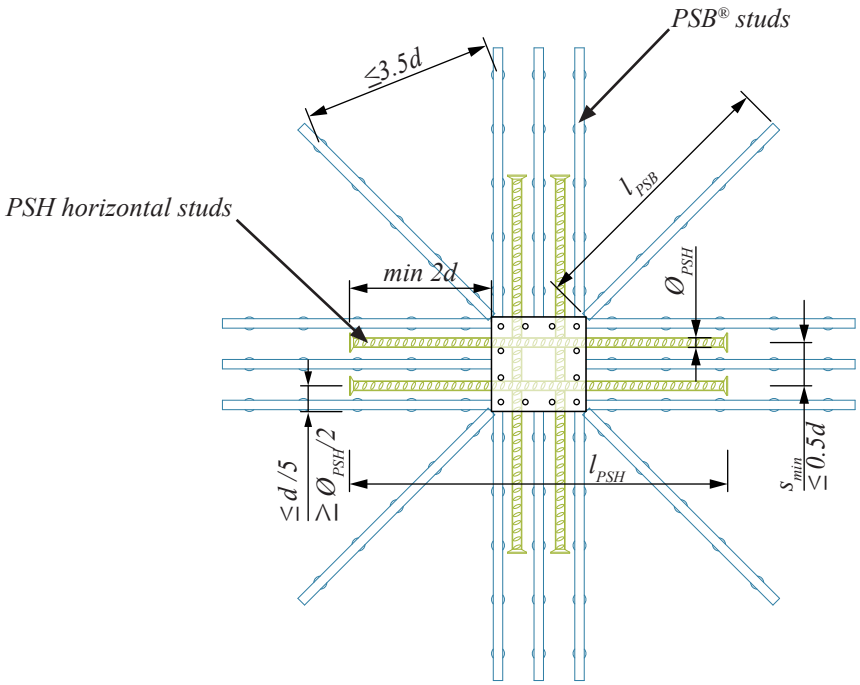


Figure 5. Top view of PSB PLUS® in a floor slab with small column, $n_{PSH} = 12pcs.$

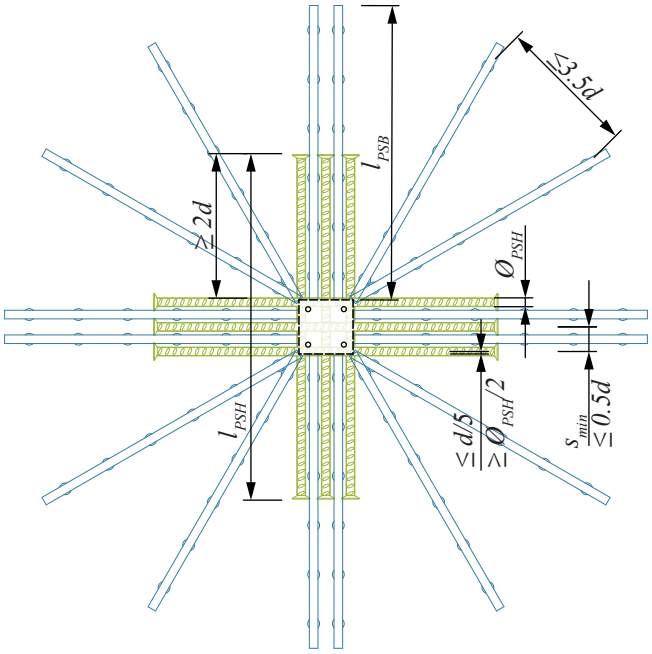
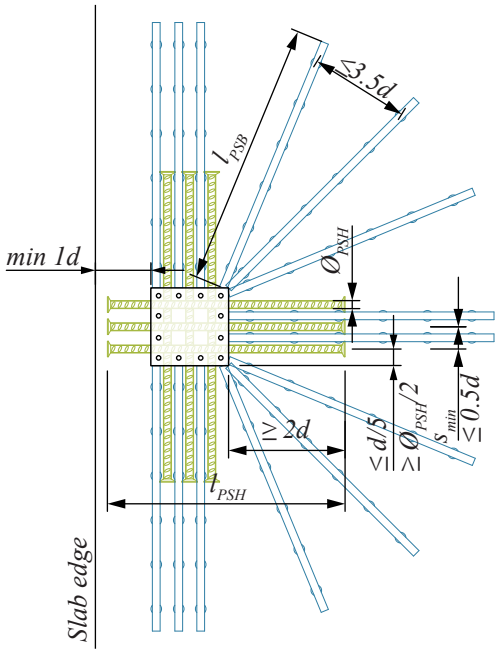


Figure 6. Top view of PSB PLUS® in a floor slab with edge column, $n_{PSH} = 9pcs.$



1.2 Other properties

PSH studs are available in various models presented in *Table 1*.

Table 1. Available dimensions for PSH horizontal studs.

PSH model	$Ø_{PSH}$ [mm]	s_{min} [mm]
PSH - A	Ø 25	100
PSH - B		
PSH - D	Ø 32	128
PSH - E		
PSH - F		
PSH - G	Ø 40	160
PSH - H		
PSH - I		
Length l_{PSH} [mm]	Determined by design	

PSB® studs and PSH studs are produced from following materials:

Assembly bar	S235JR	EN 10025-2
Double headed studs PSB®, PSH	B500B	EN 10080

Peikko Group's production units are externally controlled and periodically audited on the basis of production certifications and product approvals by various independent organizations.

2. Resistance

The structural performance of PSB PLUS® has been demonstrated by extensive research performed by Prof. Aurelio Muttoni at the Swiss Federal Institute of Technology (EPFL) in Lausanne. The research allowed the development of design recommendations that have been used to determine single resistance of the one horizontal PSH stud (*Table 2*). Maximum punching resistance of slab reinforced by PSB PLUS® punching reinforcement system is defined in accordance with equation (1). Precise design of PSB PLUS® Punching Reinforcement according to customer requirements is done by the Customer Engineering Office of Peikko.

The results of a case study of potential benefits provided by PSB PLUS® are presented in *Figure 7* and *Figure 8*.

Figure 7. Maximum resistances of slabs reinforced by PSB PLUS®, PSB® studs and slabs with no punching shear reinforcement.

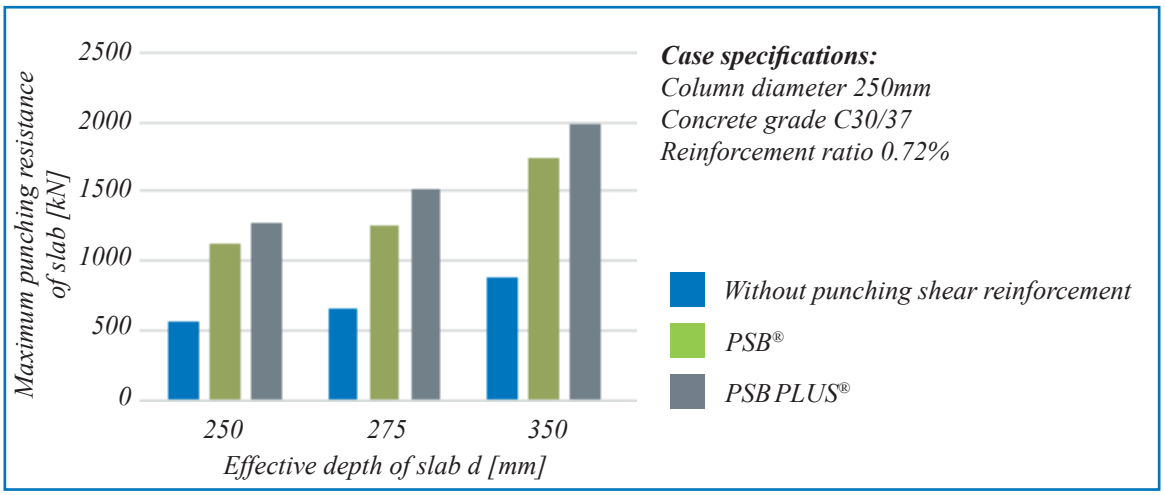
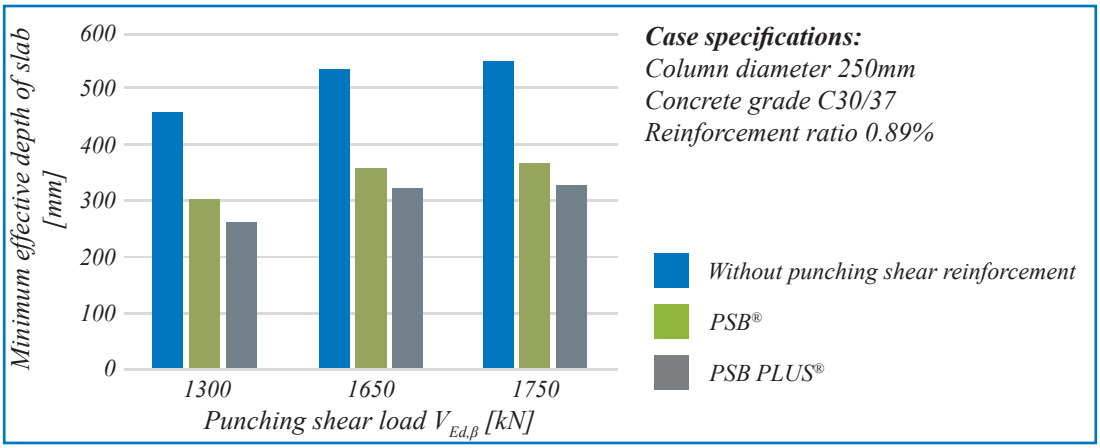


Figure 8. *Minimum effective depth of slabs reinforced by PSB PLUS®, PSB® studs and slabs with no punching shear reinforcement.*



Shear resistance of single horizontal PSH stud has been determined for several concrete grades and axial distance of PSH studs from bottom of the slab, presented in following table.

Table 2. *Shear resistance of one PSH stud.*

Effective height of slab	PSH model	Axial distance of PSH stud to bottom of the slab	Design value of shear resistance for one shear section of PSH stud				
			C30/37	C35/45	C40/50	C45/55	C50/60
d [mm]	-	c_d [mm]	$V_{Rd,dow}$ [kN]	$V_{Rd,dow}$ [kN]	$V_{Rd,dow}$ [kN]	$V_{Rd,dow}$ [kN]	$V_{Rd,dow}$ [kN]
200-260	PSH-A, PSH-B	46.5	24.6	25.2	25.7	26.2	26.6
		70	21.0	21.4	21.8	22.1	22.4
		90	18.5	18.8	19.1	19.3	19.5
< 260-320	PSH-D, PSH-E, PSH-F	50	40.0	41.1	42.0	42.9	43.6
		70	36.2	37.1	37.8	38.5	39.1
		90	32.9	33.6	34.2	34.7	35.1
>320	PSH-G, PSH-H, PSH-I	54	56.8	59.5	61.9	64.2	66.2
		70	54.1	56.6	58.8	60.8	62.7
		90	50.8	53.0	55.0	56.8	57.9
		120	46.1	47.8	49.4	50.8	51.4

Figure 9. *Average value of axial diistance to bottom of the slab for PSH stud.*

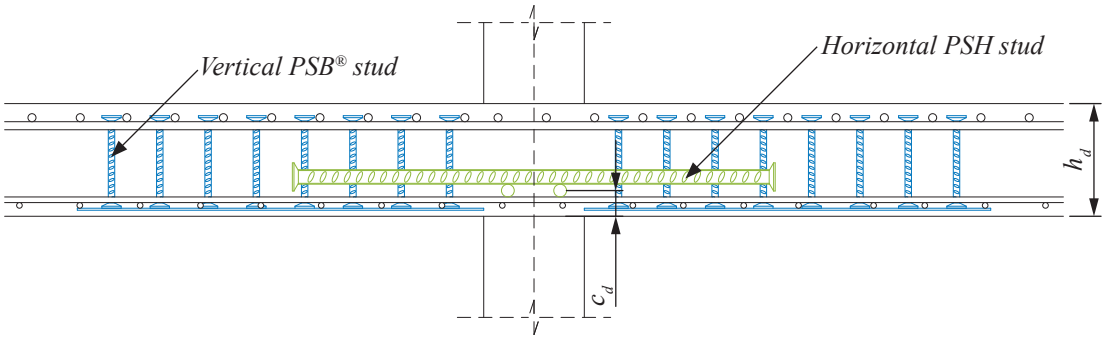
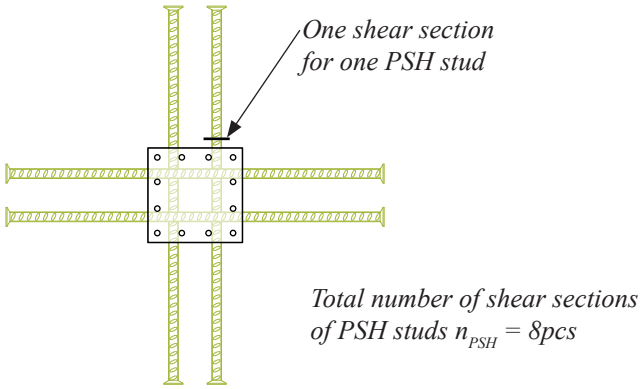


Figure 10. Number of shear section of PSH studs around column.



Selecting PSB PLUS®

The punching shear resistance of a slab reinforced by PSB PLUS® is verified as follows:

$$\beta \cdot V_{Ed} \leq V_{Rd,max,ETA} + \frac{\Sigma V_{Rd,dow}}{2} \quad (1)$$

$$\Sigma V_{Rd,dow} = n_{PSH} \cdot V_{Rd,dow} \quad (2)$$

$$V_{Rd,max,ETA} = 1.96 \cdot V_{Rd,c} \quad (3)$$

Where:

$V_{Rd,max,ETA}$ = The maximum resistance of slab reinforced with PSB®, according to ETA 13/0151 [kN]
$V_{Rd,dow}$ = The shear resistance of one PSH stud, *Table 2* [kN]
n_{PSH} = Number of shear sections of PSH around column, *Figure 10* [pcs]
V_{Ed} = The design value of the vertical load in the column [kN]
β = Load distribution factor [-]

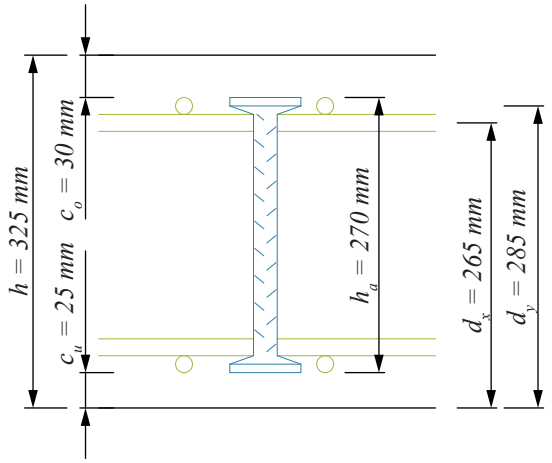
The maximum resistance of slab with PSB PLUS® Punching Reinforcement is defined by Eq. (1). The maximum resistance of slab is determined by the maximum resistance of slab reinforced by PSB® punching reinforcement plus increased by shear resistance of horizontal PSH studs. If the verification from Eq. (1) indicates that PSB PLUS® may provide sufficient resistance to the slab to column connection, please contact Peikko's Customer Engineering Office, who will perform a detailed static verification and create installation drawings for PSB PLUS®.

Example

The following is an example of the design procedure for a slab reinforced with PSB PLUS® Punching Reinforcement:

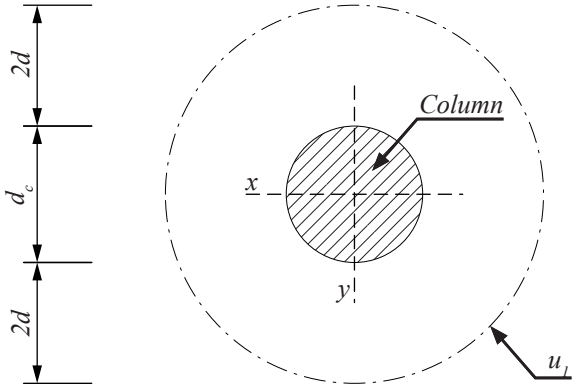
1) Design of flat slab reinforced with PSB® (in accordance with ETA 13/0151).

Column dimension	d_c	=	250 mm
Concrete grade	C30/37		
Height of slab	h	=	325 mm
Effective height of slab	d_x	=	265 mm
	d_y	=	285 mm
Concrete cover bottom	c_u	=	25 mm
Concrete cover top	c_o	=	30 mm
Reinforcement ratio	ρ_x	=	0.78%
	ρ_y	=	0.82%
Applied load	V_{Ed}	=	1287 kN
Position of column	Internal column		



Basic control perimeter (u_1)
(EN 1992-1-1 6.4.2)

$$u_1 = \pi \cdot (d_c + 4d) = 4241\ mm$$
$$u_0 = \pi \cdot d = 785.4\ mm$$



Load increase factor β (ETA-13/0151)
Recommended value for internal column β = 1.15

Position	β values
Internal column	1.15

$$\beta \cdot V_{Ed} = 1480.05\ kN$$

Punching shear resistance of slab without punching reinforcement (ETA-13/0151)

$$V_{Rd,c} = \left\{ \begin{matrix} \left[C_{Rd,c} \cdot k_d \cdot (\rho_l \cdot f_{ck})^{1/3} \right] \\ \frac{0.0525}{\gamma_c} \cdot k_d^{3/2} \cdot f_{ck}^{1/2} \end{matrix} \right\} \cdot u_1 \cdot d = 697.3\ kN$$

$$k_d = min \left\{ \begin{matrix} 2.0 \\ 1 + \sqrt{\frac{200}{d}} \end{matrix} \right\} = 1.85$$

$$C_{Rd,c} = \frac{0.18}{\gamma_C} = 0.12$$

$$C_{Rd,c} = \frac{0.18}{\gamma_C}$$

If: $u_0 / d < 4$

$$C_{Rd,c} = \frac{0.18}{\gamma_C} \cdot \left(0.1 \cdot \frac{u_0}{d} + 0.6 \right) \geq \frac{0.15}{\gamma_c}$$

(ETA-13/0151)

$$\gamma_c = 1.5$$

(EN 1992-1-1 2.4.2.4)

Maximum resistance of slab with PSB® punching reinforcement (ETA-13/0151)

$$V_{Rd,max} = k_{max} \cdot V_{Rd,c} = 1366.7\ kN$$

Flat slab

$$k_{max} = 1.96$$

Load bearing capacity of the slab

$$V_{Rd,c} < \beta \cdot V_{Ed} < V_{Rd,max}$$
$$697.3kN < 1480.05kN > 1366.7\ kN$$

No PSB® reinforcement is needed if:

$$V_{Rd,c} \geq \beta \cdot V_{Ed}$$

PSB® reinforcement can be used if:

$$V_{Rd,c} < \beta \cdot V_{Ed} < V_{Rd,max}$$

PSB PLUS® can be used if:

$$\beta \cdot V_{Ed} > V_{Rd,max}$$

If maximum resistance of the slab reinforced with PSB® punching reinforcement is not sufficient. Recommended solutions to improve slab's loadbearing performance is:

1. **Use PSB PLUS® Punching Reinforcement.**

2. **Based on dimension of column and positioning of PSH studs, section 1.1.2, define needed number and diameter of PSH studs.**
   Two horizontal PSH studs model PSH-D are selected for each direction of slab. Number of shear cross sections $n_{PSH} = 8pcs$.

3. **Define resistance of PSH for selected diameter of horizontal stud.**

$$\sum V_{Rd,dow} = n_{PSH} \cdot V_{Rd,dow} \tag{4}$$
$$\sum V_{Rd,dow} = 8 \cdot 40 = 320kN$$

According to maximum resistance of slab with PSB PLUS® Punching Reinforcement it is possible to reinforce abovementioned slab:

$$\beta \cdot V_{Ed} < V_{Rd,max} + \frac{\sum V_{Rd,dow}}{2} \tag{5}$$
$$1480.05 < 1366.7 + \frac{320}{2} = 1526.7kN$$

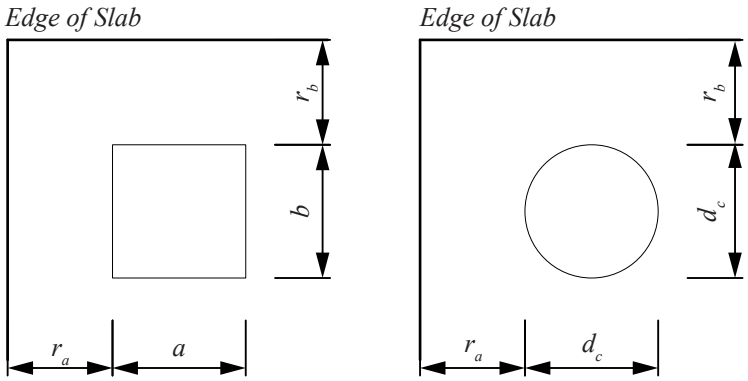
Please fill the "Design form" in annex A and send to Customer Engineering office for detailed design.

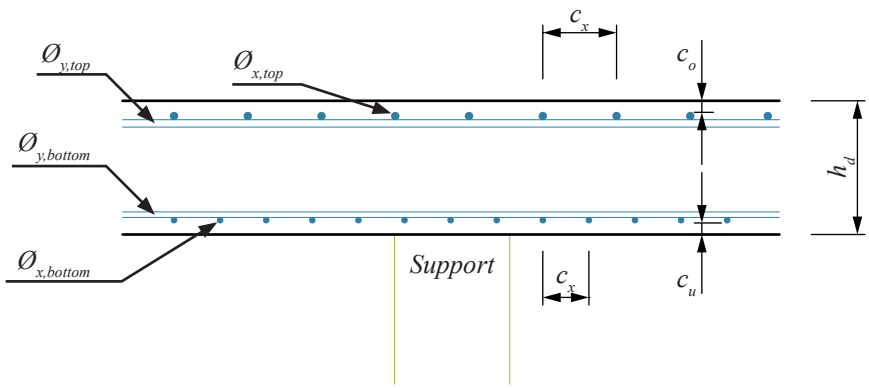
Annex A – Design form

For a design of the PSB PLUS®, please fill in this form and contact Peikko's Customer Engineering Office.

Basic Dimensions

Position of the column		Column Type	
Middle Column	☐	Rectangular	a = _____ mm b = _____ mm
Edge Column	☐	Circular	d_c = _____ mm
Corner Column	☐		
Edge Distance	r_a = _____ mm r_b = _____ mm		



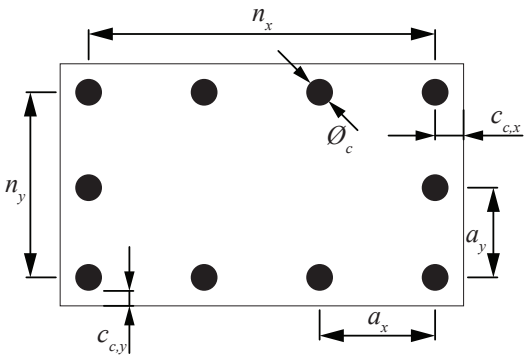


Floor slab	Thickness of the slab	h_d = _____ mm
	Concrete cover	c_o = _____ mm c_u = _____ mm
Flexural reinforcement	Top Reinforcement	$Ø_{x,top}/c_x$ = _____ mm/mm $Ø_{y,top}/c_y$ = _____ mm/mm
	Bottom Reinforcement	$Ø_{x,bottom}/c_x$ = _____ mm/mm $Ø_{y,bottom}/c_y$ = _____ mm/mm
Material data	Concrete grade of the slab	C _____
	Steel grade of the bending reinforcement	B _____
Loads	Punching shear force	V_{Ed} = _____ kN
	Unbalanced bending moments*	$M_{Ed,x}$ = _____ kNm $M_{Ed,y}$ = _____ kNm

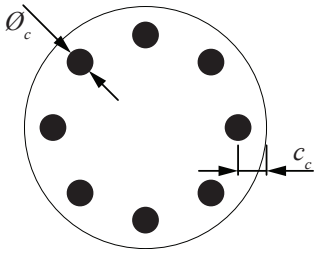
*Unbalanced bending moments are needed only for exact design of load increase factor.

ANNEX A

Position of the reinforcement in column:



Rebar diameter in column	$Ø_c$	=_____mm
Concrete cover	$c_{c,x}$	=_____mm
	$c_{c,y}$	=_____mm
Axial rebar distance	a_x	=_____mm
	a_y	=_____mm
Number of rebar in x direction	n_x	=_____mm
Number of rebar in y direction	n_y	=_____mm



Rebar diameter in column	$Ø_c$	=_____mm
Concrete cover	c_c	=_____mm
Number of rebar in column	n	=_____mm

Necessary for creating installation drawing of PSB PLUS®

Installation of PSB PLUS®

INSTALLING THE PRODUCT – CONSTRUCTION SITE

Horizontal PSH studs and vertical PSB® studs are installed according to project drawing at building site. Each PSH and PSB® element is identified by a code that is printed on a sticker as the assembly profile.

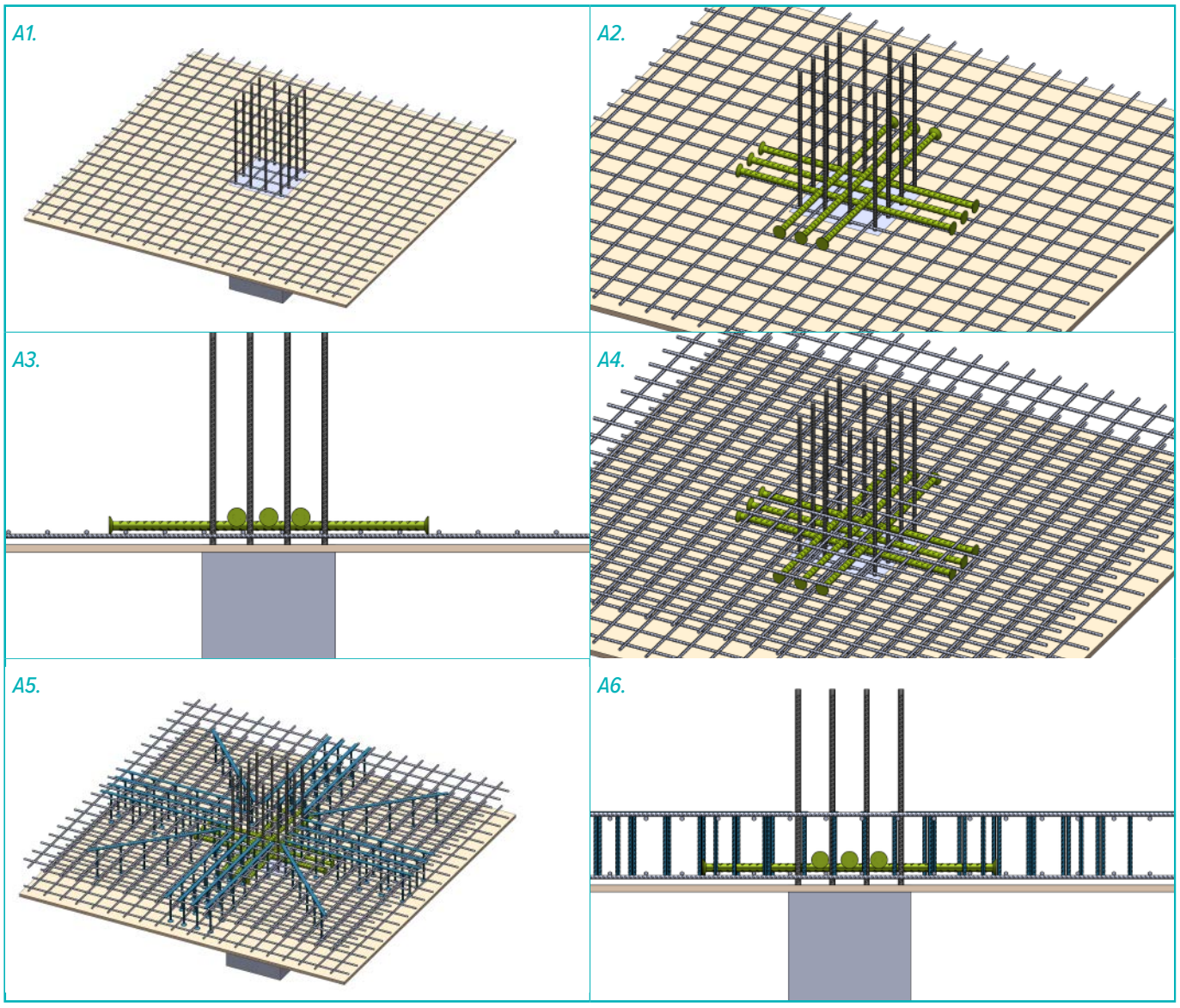
The method of installation of PSB PLUS® to slab depends on the installation of PSB® double headed studs. For PSB®, two types of installation can be used:

A) Top installation of PSB®
B) Bottom installation of PSB®

Top installation

Bottom bending reinforcement is placed to clean surface of formwork (A1). Spacers will secure proper concrete cover for bending reinforcement. Bottom layer of PSH horizontal studs are placed directly on bottom bending reinforcement in cruciform layout above the column (A2). The bottom layer of PSH studs follows the direction of bending reinforcement in stronger direction of slab, the second layer is placed in perpendicular direction (weaker direction of slab) (A3).

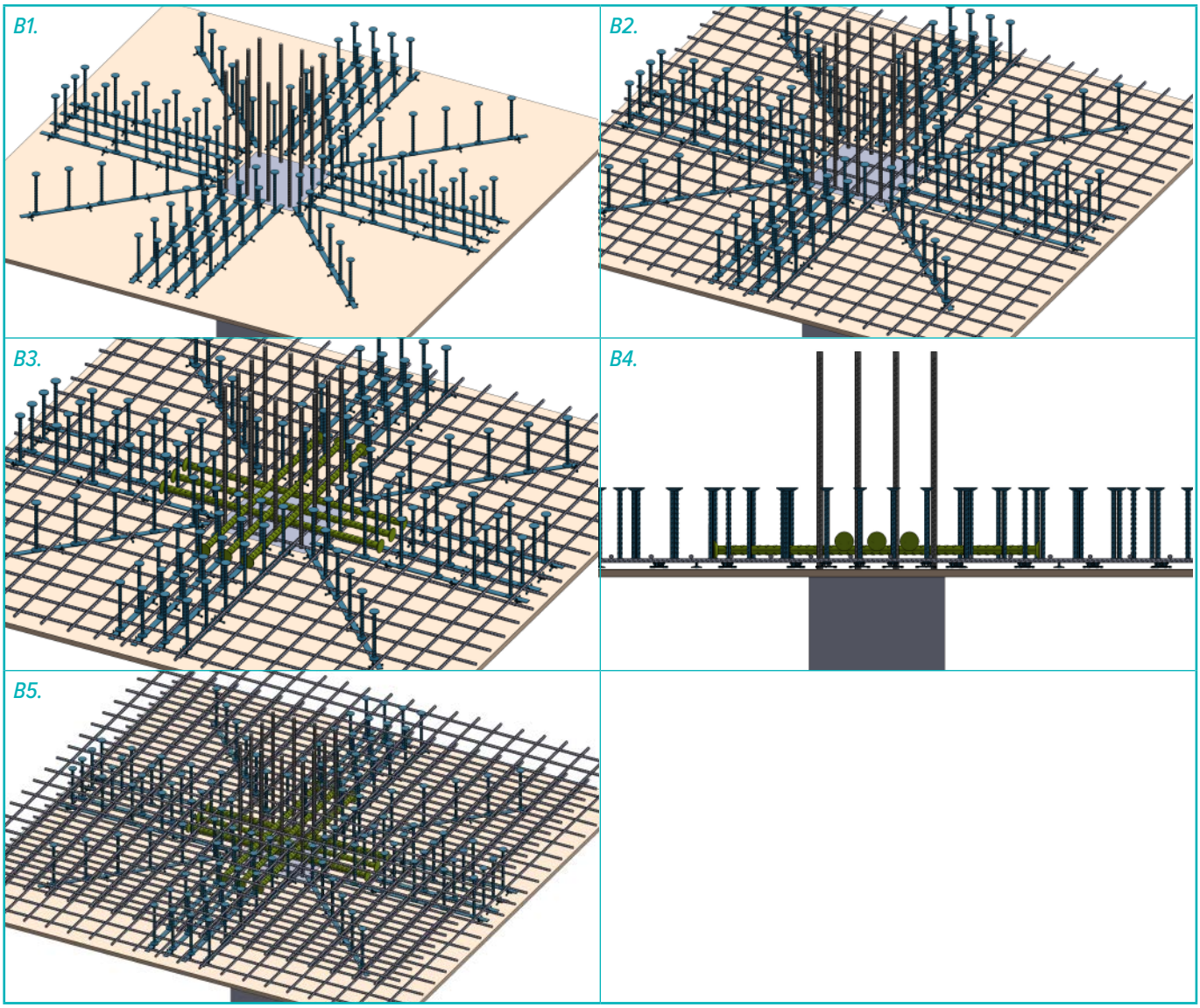
Top bending reinforcement is installed (A4). PSB® studs are then placed according to installation drawing to reinforcing mesh from top side of slab (A5 - A6).



Bottom installation

PSB® studs are placed with spacers on the clean surface of formwork in accordance with installation drawing (B1). The bottom layer of bending reinforcement is installed in both directions (B2). Horizontal PSH studs are placed directly on bottom bending reinforcement right above column (B3). Layers of PSH horizontal studs follow orientation of bending reinforcement (B4). The bottom layout horizontal PSH studs follow direction of bending reinforcement in stronger direction of slab, the second layer is placed in the perpendicular direction.

Top bending reinforcement is installed (B5). It is important to place bending reinforcement and PSH horizontal studs right above each other and to secure proper clear distance rebars for casting of concrete.



NOTES

Technical Manual Revisions

Version: PEIKKO GROUP 03/2019. Revision: 001

- First publication

Resources

DESIGN TOOLS

Use our powerful software every day to make your work faster, easier, and more reliable. Peikko design tools include design software, 3D components for modeling programs, installation instructions, technical manuals, and product approvals of Peikko's products.

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Our technical support teams around the world are available to assist you with all of your questions regarding design, installation etc.

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Environmental Product Declarations and management system certificates can be found at the quality section of our websites.

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