



PSB

Reinforcement against punching failure of slabs

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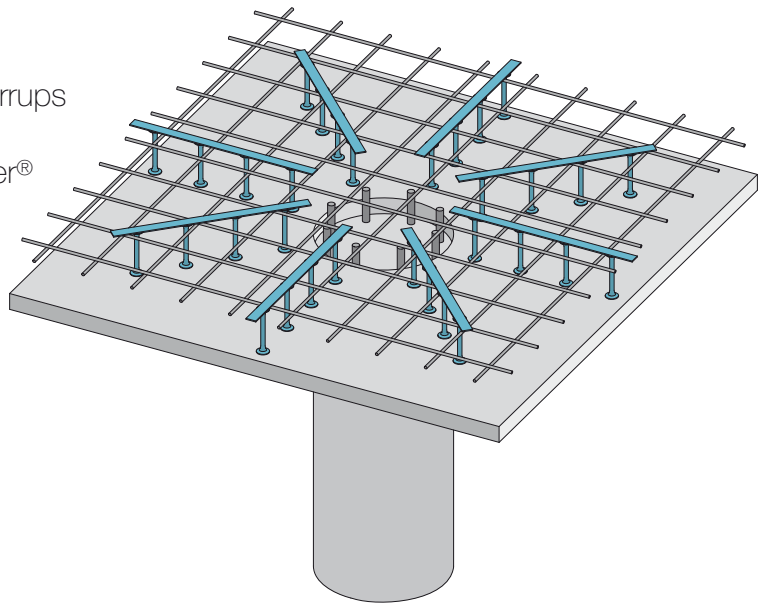


PSB

Reinforcement against punching failure of slabs

System benefits

- Higher resistances than stirrups
- Simple installation
- Available in Peikko Designer[®]



PSB is a building product used as vertical reinforcement in reinforced concrete structural members. It is mainly used as reinforcement to increase the punching resistance of flat concrete slabs, other applications (e.g. shear reinforcement in beams) are possible as well. The type, geometry and dimensions of PSB may be designed and the resistances of concrete members reinforced by PSB elements may be verified using Peikko Designer[®]. PSB is manufactured and delivered in form of reinforcement elements that consist of double headed steel studs connected by an assembly profile. Since the product is designed and pre-fabricated by Peikko, the installation of the product is much simpler than it is for other traditional reinforcement elements (stirrups). This applies for the case when PSB is used in cast-in situ or in pre-cast elements.

PSB reinforcement is fully integrated in the concrete slab and is thus an ideal reinforcement system for monolithic slim-floor structures or flat concrete slabs in general. The double headed studs used in PSB reinforcement elements enable the slab to develop a resistance that can be up to 30% higher than the resistance of a slab reinforced by traditional reinforcement techniques such as stirrups.

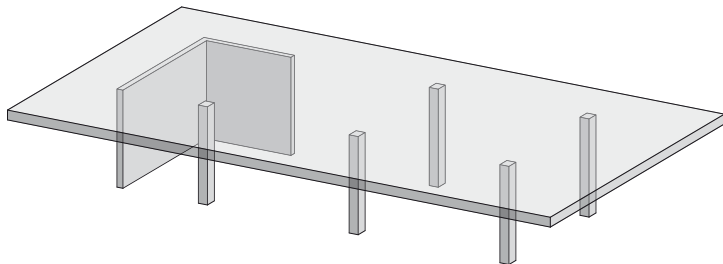
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1. Product Properties

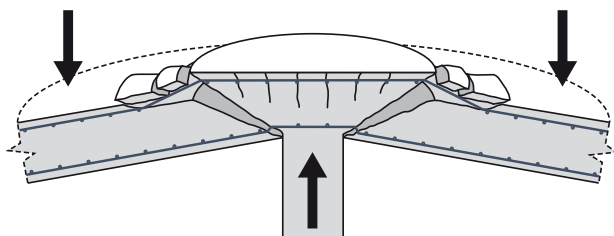
Reinforced concrete flat slabs are nowadays one of the most popular structural systems in residential, administrative, car park and many other types of buildings. The system usually consists of slabs locally supported by columns or walls without down stand beams. Such configuration allows optimizing the space on the floor area and to perform saving with regards to the total height of the building.

Figure 1 Flat slab supported on columns and walls



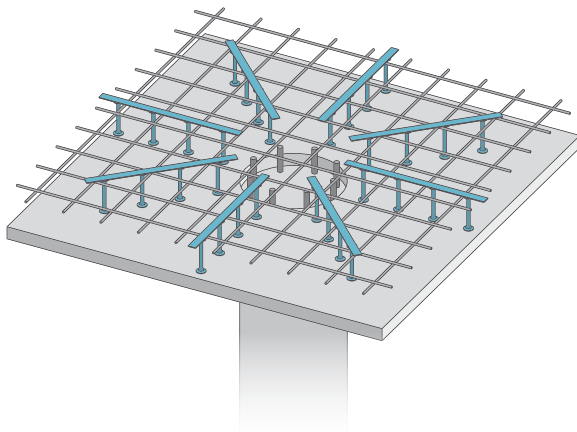
Between supports, the slab is usually designed as a two-way slab to resist bending moments in two orthogonal directions. In support area, the bending moments are combined with transverse loads – reactions from supports. Such combined loading results in a state of stress that may lead to failure of the slab by punching. The verification of the punching resistance of the slab is often decisive for the definition of the thickness of the concrete slab. Punching usually occurs so that a concrete cone is separated from the slab, bending reinforcement is pulled away from concrete and the slab falls down due to gravity forces (Figure 2). Experience shows that failure by punching is particularly dangerous since it is a brittle phenomenon that happens suddenly without any previous signs of warning (extensive deformations, cracks....). Moreover, the failure of one column may impact on adjacent columns and lead to an in-chain failure of the whole reinforced concrete floor.

Figure 2 – Failure of a slab by punching



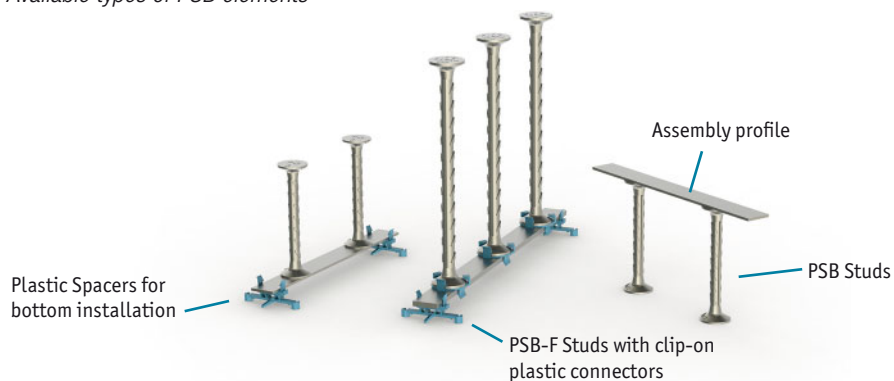
A slab without vertical reinforcement has only a very limited resistance against punching failure. This resistance may be increased by placing PSB elements in the concrete slab in such a manner that they prevent the concrete cone to develop (Figure 3). Besides increasing the resistance of the slab, PSB also increases its ductility. PSB is also used in foundation slabs in a similar manner as in floor slabs. Other applications (PSB used as shear reinforcement in beams) are possible as well.

Figure 3 Flat slab reinforced with PSB



PSB elements consist of steel double headed PSB studs connected together by assembly profiles (Figure 4). The assembly bar has no load bearing function; it only guarantees the correct spacing and positioning of the studs during their installation to concrete.

Figure 4 – Available types of PSB elements



1.1 Structural behavior

The static model of a locally supported slab without punching reinforcement is shown on Figure 5 and Figure 6. The external loads of the slab are balanced by a system of concrete struts and ties. The punching resistance of the slab is limited by the tensile strength of the ties.

Figure 5: Forces in the slab without PSB before failure

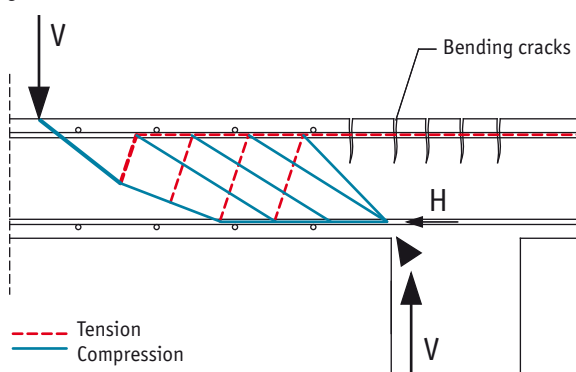
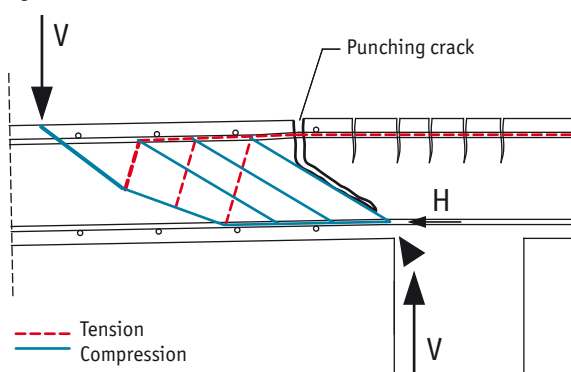


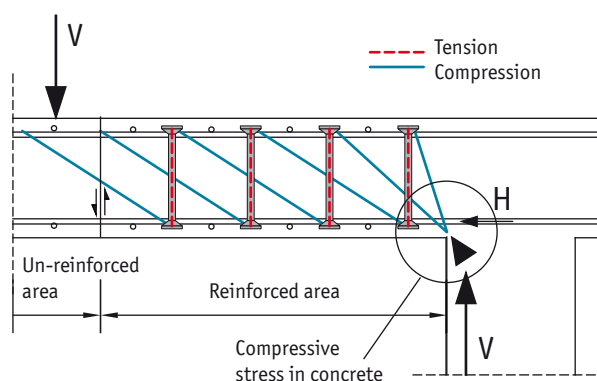
Figure 6: Forces in the slab without PSB at failure



The reinforcing of the slab with PSB consists in replacing the concrete ties by vertical steel reinforcement elements (Figure 7). The tensile force is developed in the shank of the PSB studs and anchored to concrete at both ends of the studs by the heads. The diameter and number of steel elements to be placed in the slab has to be determined so that:

- PSB studs adjacent to the loaded area/column have sufficient resistance to prevent the development of a punching cone
- PSB elements spread the load further on to the span of the slab

Figure 7: Forces in a slab with PSB punching reinforcement



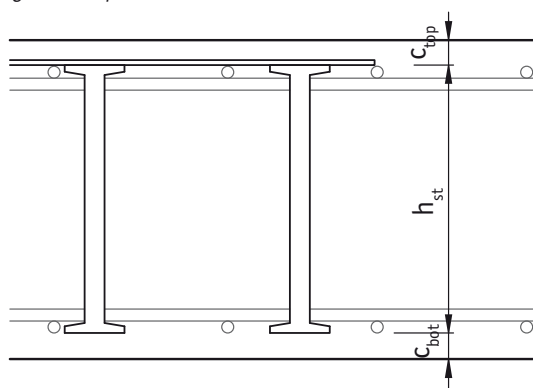
1.2 Limitations for application

The PSB studs act as vertical tensile component within the system of internal forces in the slab. They have a limited influence on the resistance of the compressive component of this system (concrete struts). For this reason, the maximum resistance of the slab with PSB reinforcement has to be limited by a value $V_{Rd,max}$. This value corresponds to the compressive resistance of concrete struts around the column.

According to current experience, the maximum resistance of a slab reinforced by double-headed studs corresponds to about 190% of the resistance of a slab without punching reinforcement while it is only about 150% in the case of slabs reinforced by conventional stirrups. The verification of the maximum resistance of the slab is included in the design procedures available in Peikko Designer®.

The depth of the PSB studs depends on the depth of the slab and concrete cover of the bending reinforcement of the slab (Figure 8). It is recommended to use PSB reinforcement in slabs with thickness $h \geq 180$ mm. In such case, the head of the studs is considered to be fully anchored into concrete and maximum tensile resistances of PSB studs may be developed.

Figure 8 Depth of PSB within the slab



The correct detailing of the reinforcement is essential for a proper functioning of the reinforced slab. The rules for detailing of the reinforcement (maximum and minimum spacing of studs in radial and orthogonal directions) are defined by design standards or technical approvals valid in different countries. The verification of these rules is done automatically when designing PSB using Peikko Designer®.

1.3 Other properties

The PSB studs and assembly bar have the following material properties:

Assembly bar	S235	EN 10025-2
PSB studs	B500B / BSt500S	EN 10080 DIN 488, EN 10080

Peikko Group's production units are externally controlled and periodically audited on the basis of production certifications and product approvals by various organizations, including Inspecta Certification, VTT Expert Services, Nordcert, SLV, TSUS and SPSC among others.

2. Resistances

The resistances of individual PSB studs are summarized in Table 1. The resistance of a concrete member reinforced by PSB has to be verified case-by-case for each project. Peikko Designer® may be used to design PSB and verify the resistances of concrete members reinforced by PSB against regulations valid in different European countries.

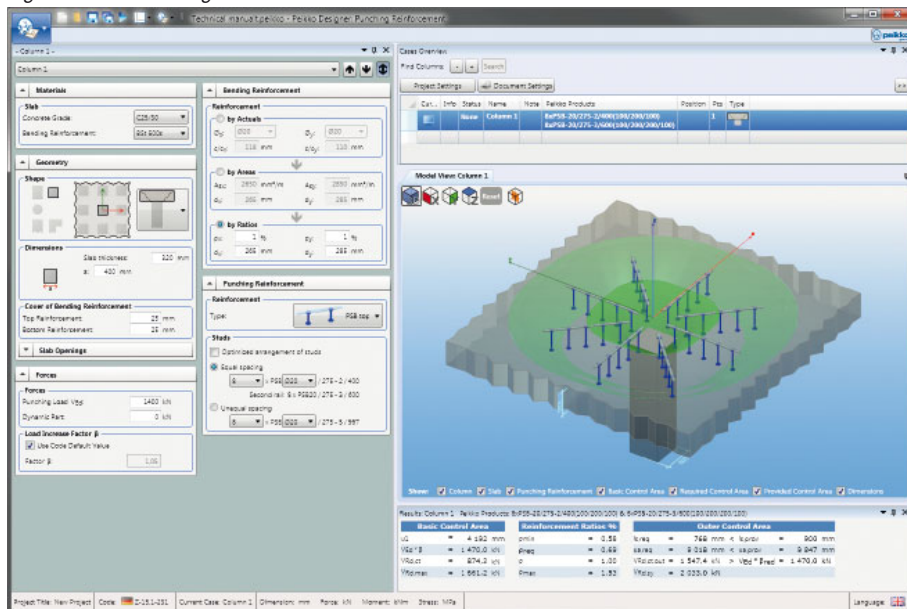
Table 1 Tensile resistances of PSB studs

Diameter	mm	10	12	14	16	20	25
Resistance	kN	34,1	49,2	66,9	87,4	136,6	213,4

Selecting PSB

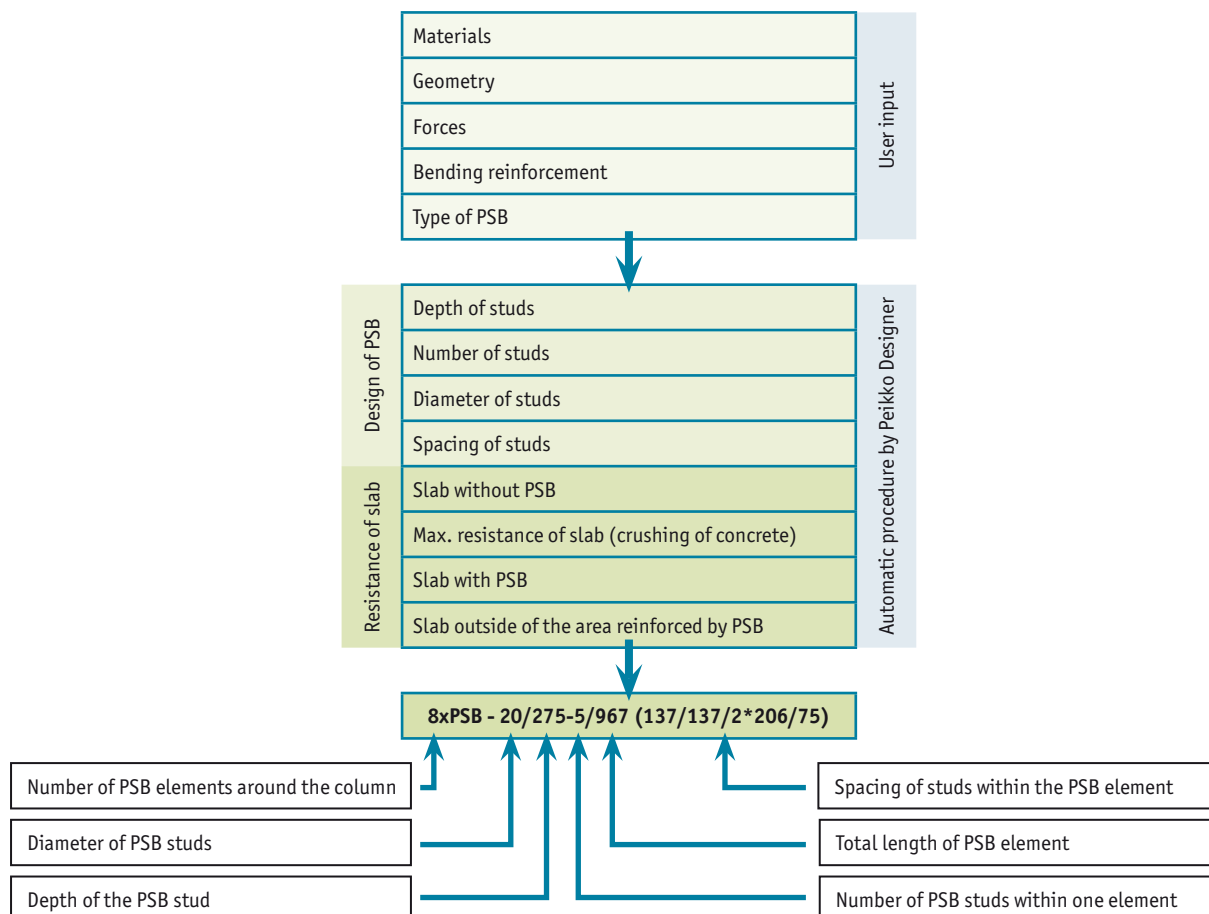
It is recommended to select the appropriate reinforcement with PSB using Peikko Designer® individually for each separate case. Peikko Designer® is a design software developed by Peikko, and it is freely available from www.peikko.com.

Figure 9 Peikko Designer®



The typical procedure to select the appropriate type of PSB using Peikko Designer® is illustrated on the diagram in Figure 10.

Figure 10 Procedure to select PSB reinforcement



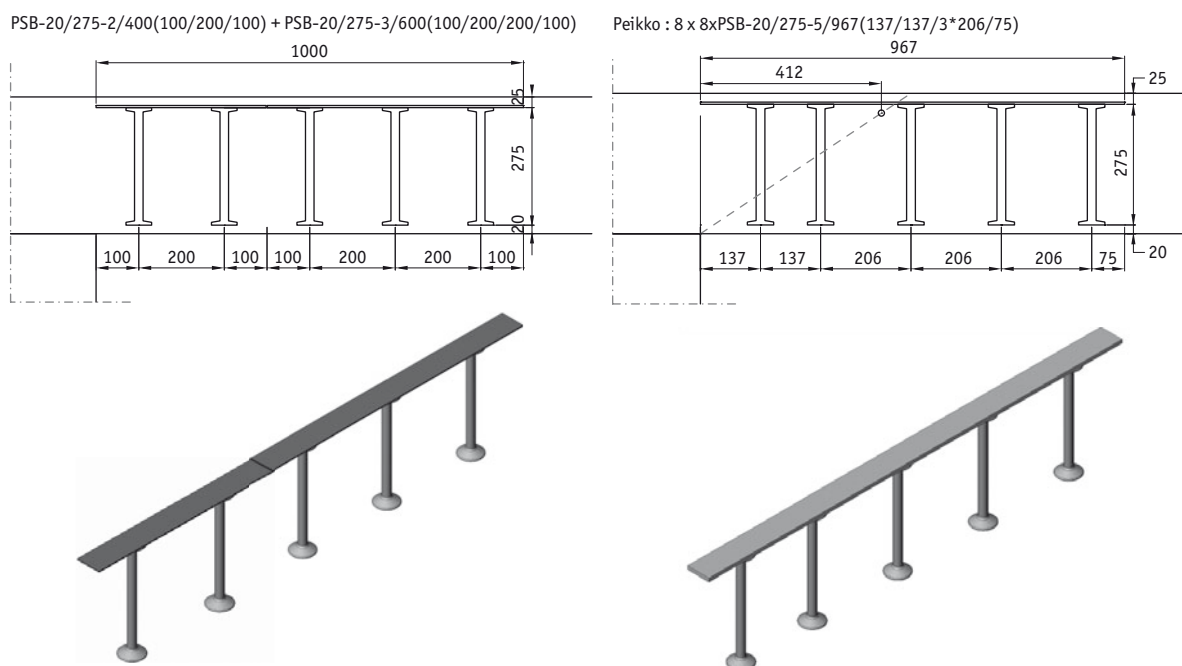
The resulting type and layout of the reinforcement proposed by Peikko Designer® is the most economical one. If needed, the diameter of studs and the number of PSB elements may be modified manually by the user.

The selected PSB elements are described by a specific code. Plan and section drawings of the selected PSB reinforcement are also available in the printed outputs of Peikko Designer® or may be exported to DXF files. The printed output of Peikko Designer® also includes a summary of input data and static verifications of resistances for each individual case within each single project. The list of recommended accessories for the installation of PSB is also available in the printed output of Peikko Designer®.

When used for other applications than reinforcement of slabs against punching failure, PSB is designed as shear reinforcement according to EN 1992-1-1:2004.

PSB elements are available with equal spacing and un-equal spacing. The elements with un-equal spacing have all the PSB studs welded on one single assembly profile. The elements with equal spacing are available with 2 or 3 studs welded to one assembly profile. In cases where more than 3 studs are needed in row, the necessary number of studs may be obtained by using elements with two or three studs (see Figure 11 for equivalence between elements with unequal and equal spacing).

Figure 11 Equivalent element(s) with equal and un-equal spacing

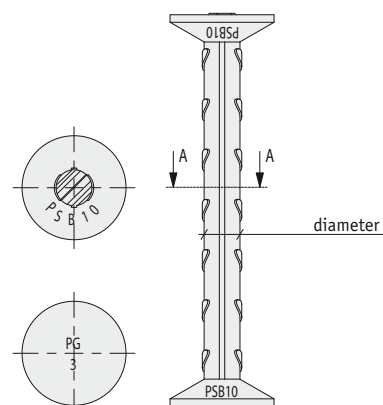


Installation of PSB

PSB reinforcement is installed in the mould according to design plans. Each PSB element is identified by a code that is printed on a sticker at the assembly profile.

Double headed PSB studs are marked with symbol PG; the symbol PSB with corresponding diameter of the stud is marked on the opposite side of the head.

Typical shape of a PSB stud

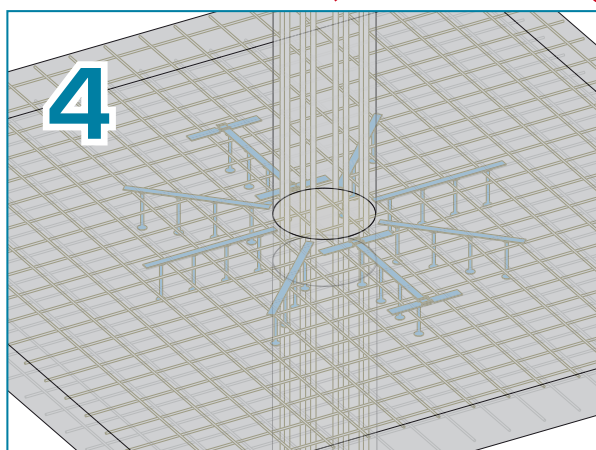
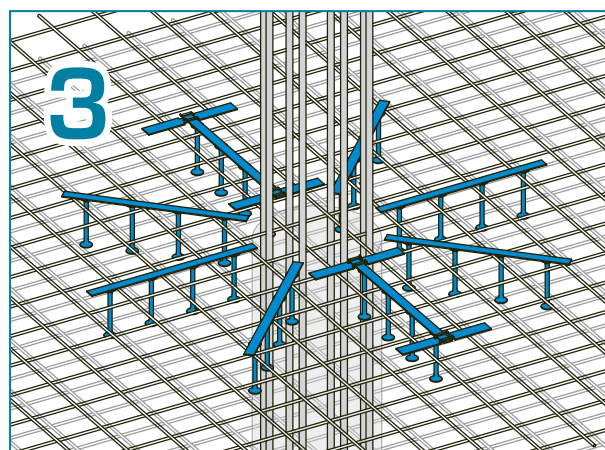
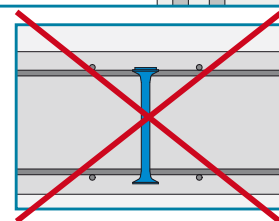
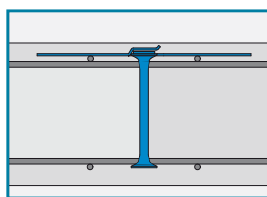
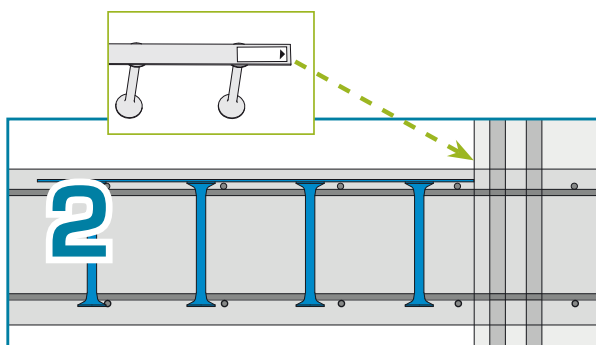
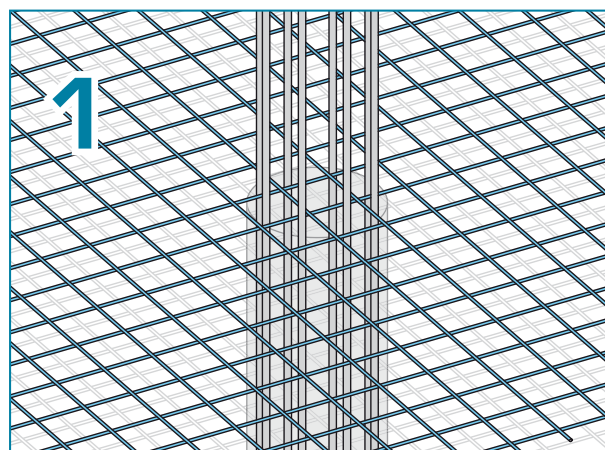
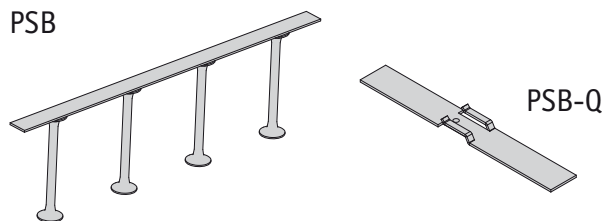


Cast in-situ monolithic slabs

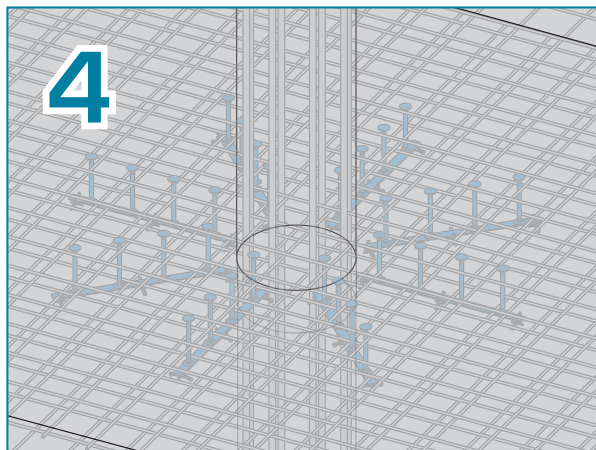
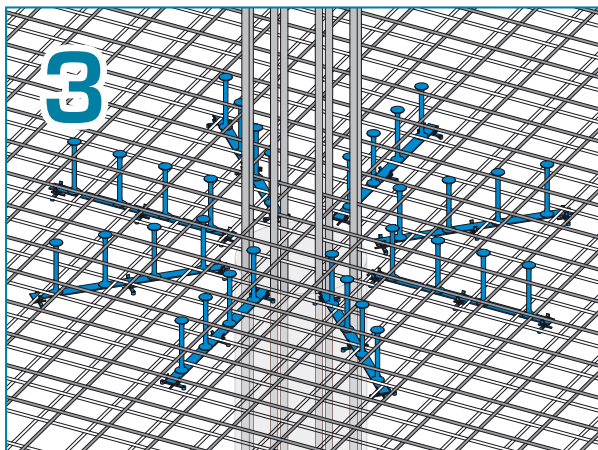
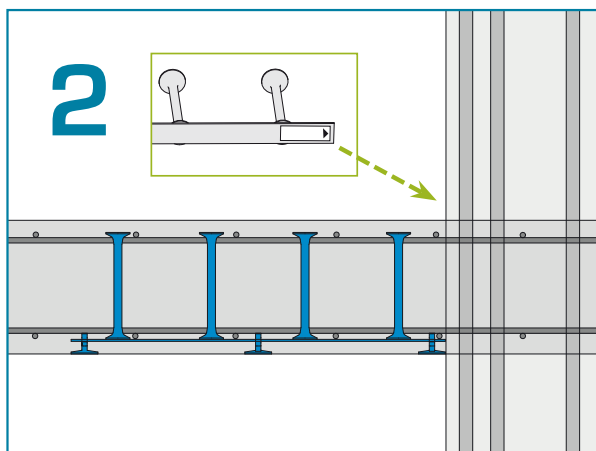
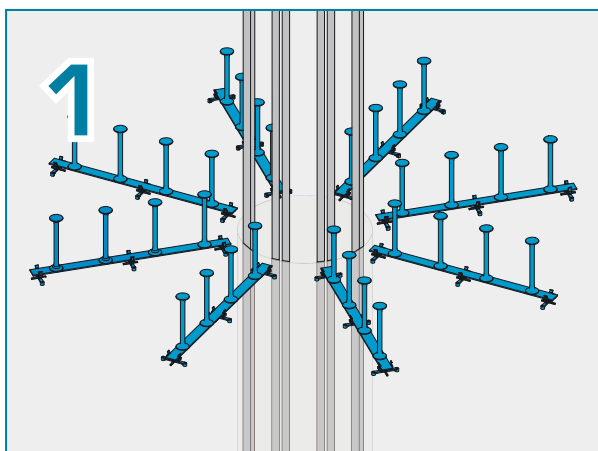
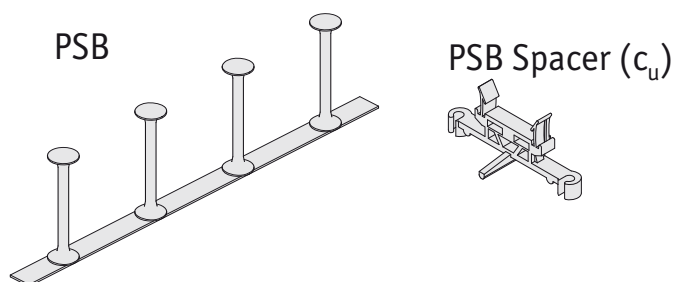
PSB elements may be installed to cast in-situ monolithic slabs:

- **Top installation:** The PSB elements are hanged to the main reinforcement of the slab. The whole bending reinforcement is installed to the mould prior to PSB. The proper mounting position of the PSB elements is ensured by using the PSB-Q cross connector (Figure).

PSB



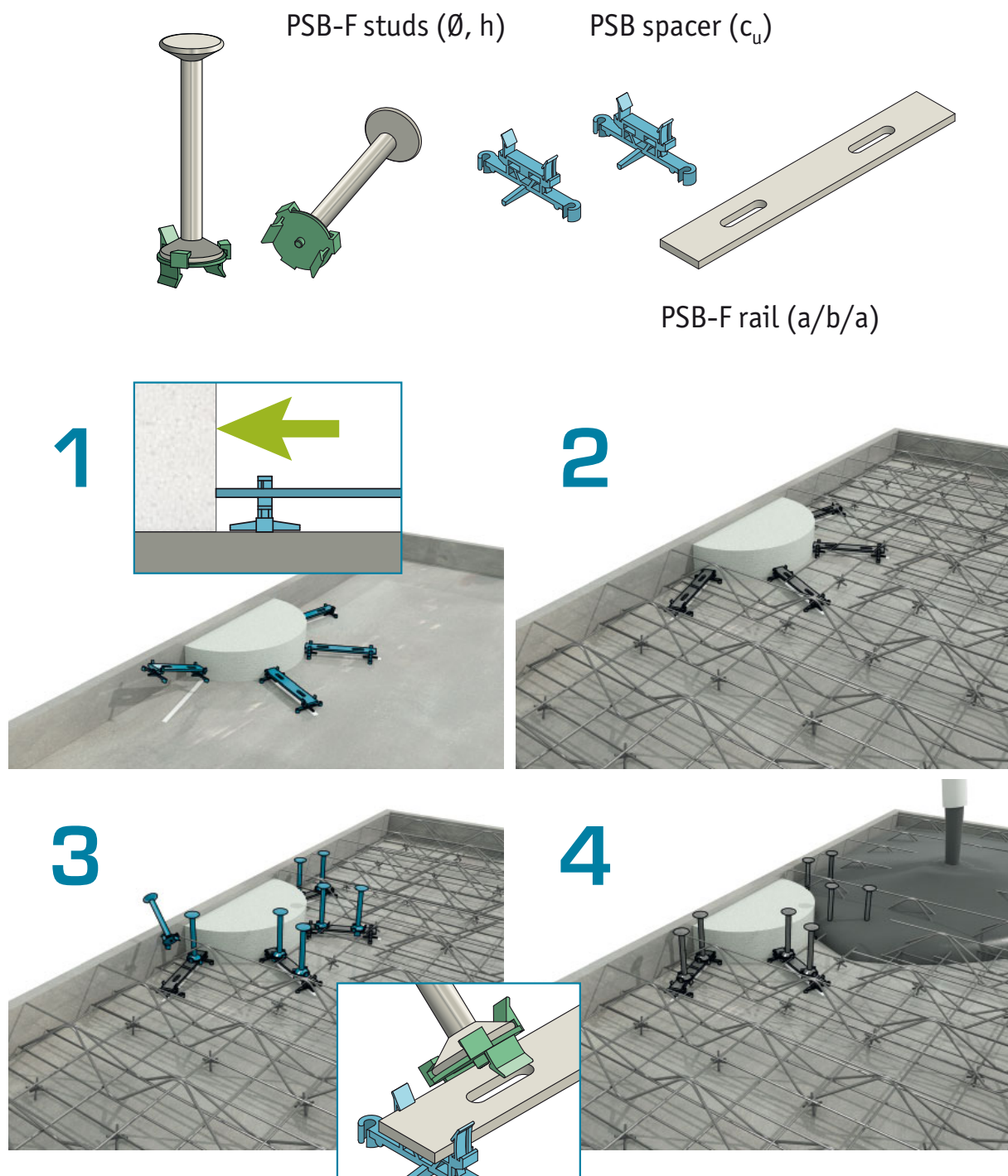
- **Bottom installation:** PSB elements are placed to the mould of the slab from bottom prior to the installation of the bending reinforcement. In order to achieve sufficient concrete cover of the headed studs, PSB plastic spacers are mounted to the assembly profile of the PSB elements. The spacers have to be ordered separately from the PSB elements (Figure).



The type and number or recommended accessories (spacers, cross connectors) for both types of installation are available in the printed outputs of Peikko Designer®.

In precast factory

A special type of PSB elements (PSB-F) is available for the use within filigree slabs. The assembly profile of the PSB-F elements is installed to the formwork from bottom on plastic spacers prior to the reinforcement of the filigree slab. The reinforcement of the filigree slab (bending reinforcement and lattice girders) may thereafter be installed manually or by automatized process without being limited by the presence of studs. The studs are installed on the assembly profile only once the reinforcement process of the filigree slab is finished. They are simply clicked on the assembly profiles; the slotted holes on the assembly profiles offer mounting tolerances to ensure the proper installation of the studs.





PEIKKO GROUP CORPORATION

Peikko Group, founded in 1965, is a family owned company specializing in composite beams and fastening products for concrete connections. Peikko provides innovative solutions to help customers make their building process faster, easier and more reliable. Precasters, builders, constructors, developers, flooring specialists, machine manufactures, power plant designers, architects and structural designers can all enjoy and take advantage of the Peikko solutions.

Peikko Group has offices in 30 and factories in 9 countries in Europe, North America and Middle East. Peikko Group, with headquarters in Lahti, Finland, employs more than 800 persons.