PSB PLUS® – NEW PRODUCT IN CAST-IN-SITU PORTFOLIO

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Peikko has a long tradition in developing solutions that make the design and execution of slim floor structures safer and more efficient. One of the latest additions to Peikko's product portfolio is PSB PLUS®, a high-performance reinforcement solution for cast-in-situ flat slabs locally supported on columns. The system complements Peikko's offering in the punching shear reinforcement segment by providing a simple and cost-efficient solution for the reinforcement of slabs under extreme loads.

FLAT SLABS

Flat slabs locally supported on columns form a structural system that offers numerous practical benefits (e.g. optimized interior space, ease of installation) to different stakeholders involved in the construction supply chain. The load-bearing capacity of a flat slab is typically governed by its capacity to transfer vertical loads to columns. In the absence of vertical supports underneath the slab, the transfer of vertical forces relies on the so-called mechanism of aggregate interlock. Most of the modern design codes condition the activation of such mechanism by the use of adequate reinforcement that is designed and detailed in order to limit the opening of shear cracks in concrete (see Figure 1).

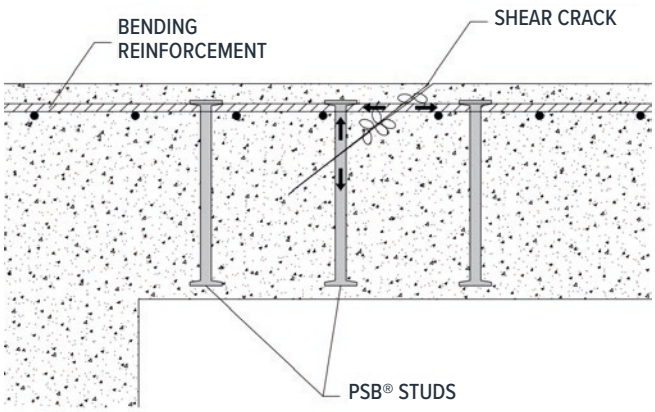


Figure 1. Figure of an inclined crack with vending and vertical reinforcement

According to the Eurocode EN 1992-1-1, the punching shear resistance of a flat slab is then determined as follows:

$$V_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \boldsymbol{\rho_l} \cdot f_{ck})^{1/3} \cdot d \cdot u_1 \qquad (1)$$

where $C_{Rd,c}$ and k are empirical factors, ρl is the bending reinforcement ratio, f_{ck} is the characteristic compressive strength of concrete, d is the effective height of slab and u_1 is the control perimeter. The formulation implies that the maximum amount of bending reinforcement (given as ρ_{max} = 2% by EN 1992-1-1) also governs the punching shear capacity of the slab. If necessary, the resistance of the slab can be further increased by placing vertical shear reinforcement through the potential shear crack. As the slabs are usually relatively thin, reinforcement elements using mechanical anchorages (e.g. headed studs) are more efficient that conventional bended stirrups.

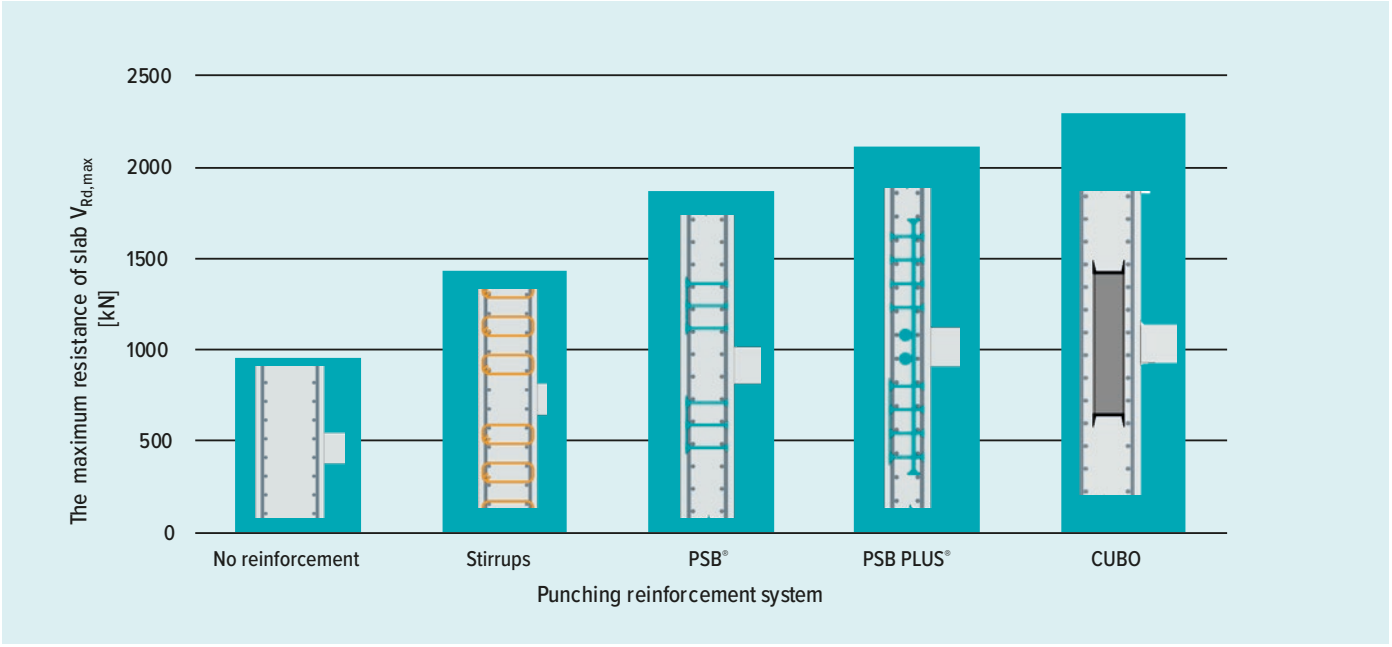


Figure 2. Maximum shear resistance of slab with different punching prevention systems

This has been demonstrated by research (e.g. tests of PSB® studs) and is already interpreted by current design codes, where the resistances of slabs reinforced by stirrups and studs are formulated respectively as:

$V_{Rd,max} = 1{,}5.V_{rd,c}$ for stirrups acc. to EN 1992-1-1 (2015)

$V_{Rd,max} = 1{,}96.V_{rd,c}$ for PSB® studs acc.to ETA 13/0151

A slab reinforced by double-headed studs thus has a punching shear resistance that is about two times higher than the resistance of a slab without vertical reinforcement. Such resistance is typically enough to accommodate loads most commonly present in buildings.

However, in extreme cases, even resistances provided by double-headed studs might not be sufficient. A common solution to support flat slabs in such cases is using massive steel profiles bearing on columns and integrated to the depth of the slab. These profiles are designed to act as stiff supports and accommodate the whole reaction of the slab, neglecting the load-bearing capacity of concrete. Welded steel profiles (e.g. CUBO) allow accommodation of extremely high loads, but are also significantly heavier, more expensive and more difficult to install than studs.

PSB PLUS®

Working together with our customers, Peikko's sales and product development teams identified a need for a solution that would fill the gap between punching shear systems and welded steel profiles. The main ambition was to develop a solution that will allow for a moderate increase of capacity in comparison to studs, but at the same time would be more practical and cost-efficient than welded steel profiles. Once practical needs were identified, a certain number of technical solutions were studied and prototyped by Peikko's product development team.

The result of the development, PSB PLUS®, combines vertical PSB® studs with PSH horizontal headed bars located in the bottom part of the slabs and crossing the column area (Figure 3).

First prototypes of the system have been pre-tested at the University of Žilina in Slovakia. These tests confirm that the system enables the slab to reach resistances significantly higher than those provided by mere vertical studs. Thereafter, an extensive experimental campaign has been performed at the EPFL Lausanne in Switzerland (Figure 4) with the target to identify the basic behavior patterns of the system and to develop reliable design recommendations.

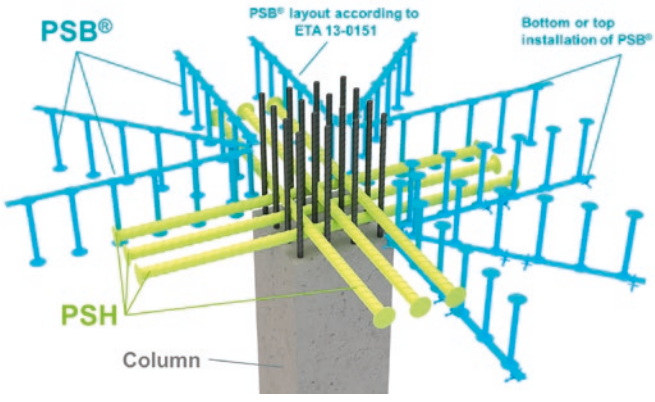


Figure 3. PSB PLUS® 3D model

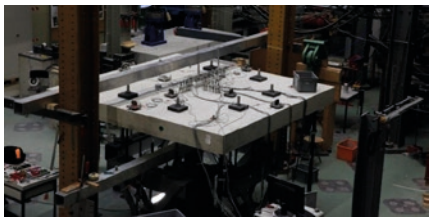


Figure 4. Tests of PSB PLUS® system at the EPFL Lausanne in Switzerland

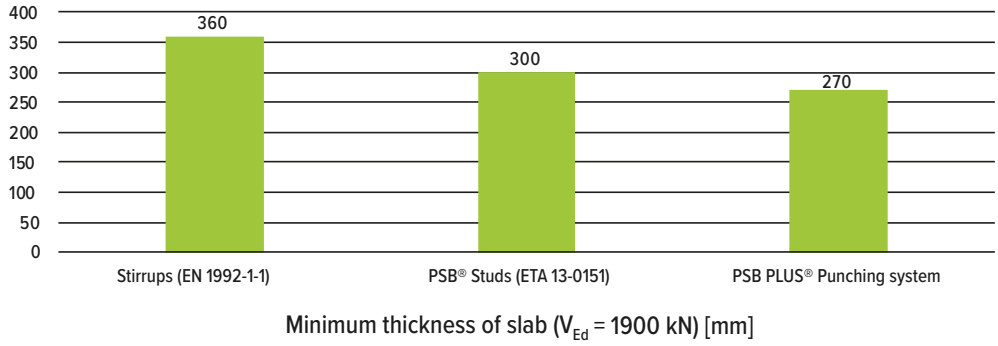


Figure 5. Comparison of punching reinforcement system performance

Technical details of the research program will be published in the journal of the American Concrete Institute (ACI) in fall 2019. The experiments identified that the PSH horizontal bars do contribute to the load-bearing capacity of the joint by activating a doweling mechanism, and the design value of the load-bearing capacity of the slab can thereafter be formulated as:

$$V_{Rd,max,PLUS} = V_{Rd,max} + \frac{\sum V_{Rd,dow}}{2} \qquad (2)$$

where $V_{Rd,max}$ is the resistance of a slab reinforced with PSB® studs only and $V_{Rd,dow}$ is the increase of resistance provided by PSH bars. The design method of PSB PLUS® has been assessed by DIBt in the technical approval Z-15.1-333 issued in 2019.

PRACTICAL BENEFITS

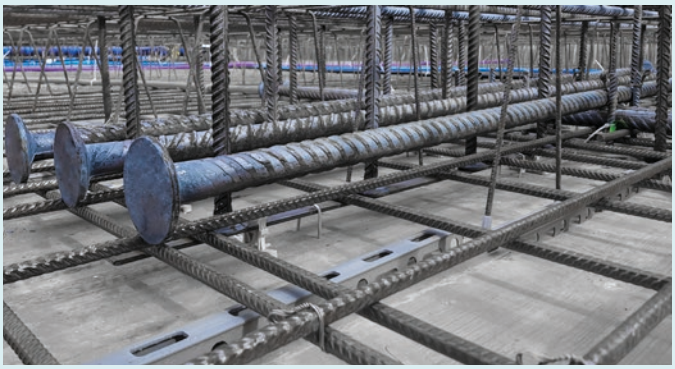
An example of the practical benefits provided by PSB PLUS® is illustrated in Figure 5. The chart represents a minimum thickness of the slab required to resist a load of 1,900 kN using different types of reinforcement systems. By increasing the local resistance of the slab around the column, PSB PLUS® can significantly optimize the cost-efficiency and sustainability of the entire structure.

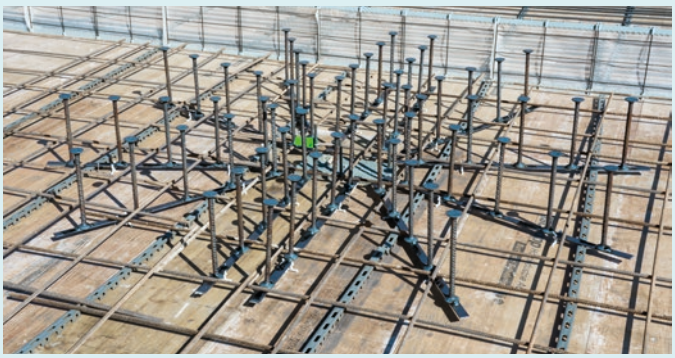
One of the first PSB PLUS® projects was the extension of a school in Winkel, Switzerland in summer 2018. In this project, PSB PLUS® was designed to provide an alternative to a welded steel profile. While the installation of such welded profile would have to be done by crane, PSB PLUS® was installed by a single worker in less than 10 minutes, proving the practical benefits of PSB PLUS® on site.

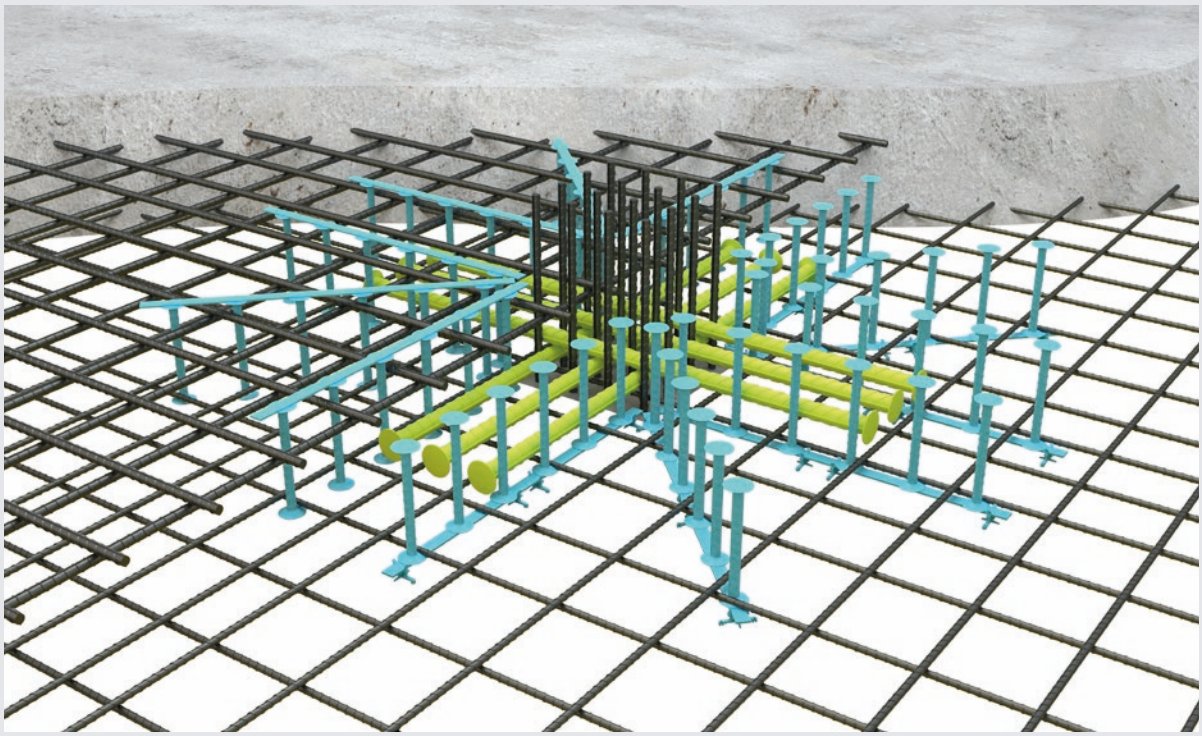
CONCLUSIONS

Peikko's ambition to make the construction process faster, safer and more efficient can be fulfilled only if our offering responds to customer needs. PSB PLUS® is a solution that meets the practical needs that have been known for years using the latest technical knowledge. Being extremely simple, cost-efficient and technically unique, we are confident it will be able to provide genuine added value for our customers.

Figure 6. Extension of an elementary school in Winkel, Switzerland







SIMPLE INSTALLATION WITH HIGHER CAPACITY

As the demand for higher load capacities and slimmer slabs increases, advanced solutions are needed to protect concrete slabs against punching shears.

PSB PLUS® Punching Reinforcement System is a combination of vertical PSB® studs with unique horizontal PSH studs placed on top of the column. With PSB PLUS® it is possible to achieve higher capacity against punching shear failure, compared to a solution with vertical PSB® studs only. Together with simple installation of horizontal elements, this makes it a cost-efficient and practical solution for flat slabs subjected to extreme load requirements.

PSB PLUS® SYSTEM BENEFITS

- Easy on-site handling and installation
- Higher capacity than with a standard vertical solution
- Thoroughly tested, approved design
- Simple structural design process
- Superior technical support

Slim floors mean better space efficiency – more room height, less overall building height and weight, or more floors for a given building height.