



Figure 2: PSB punching reinforcement in formwork



Figure 3: Peikko PSB punching reinforcement

PSB – punching reinforcement against punching failure of slabs

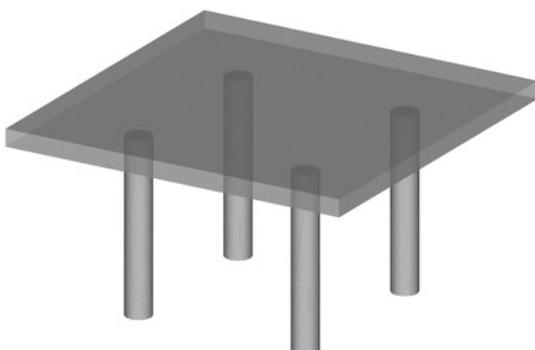
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1. Introduction

Point formed, reinforced concrete flat slabs (Figure 1) are one among the most popular floor systems used in residential buildings, car parks, and many other structures. They represent elegant and easy-to-construct floor systems without the support of down stand beams or walls, but only columns without enlarged column heads. They are regarded as an economical construction with aesthetic appeal that offers the industry as well as commercial construction several advantages:

- Optimum use of space by free floor area, full use of storey height
- Greatest flexibility with possibility of non-load bearing partition walls
- Lower noise and reinforcement expenditure
- Obstruction free extension below the ceiling

Figure 1: Point formed, reinforced concrete flat slab



For this type of construction, the PSB punching reinforcement is absolutely predestinated. It enables the solving of the normal critical risk of punching failure in an extremely cost-effective and sure way.

Without shear reinforcement, a concrete slab has only a limited resistance against such type of failure. The punching capacity of the slab may be increased by various methods, e.g. by stirrup reinforcement by 50 %. But the use of Peikko PSB punching reinforcement (Figure 2+3) enables increasing of the capacity by 90 %.

2. Failure of the slab by punching

Failure by punching is usually associated with concentrated loads acting on a reinforced concrete slab and should be treated with special care in flat slabs locally supported by columns, foundation slabs, or column footings. 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 etc). Moreover, the failure of one column may impact on adjacent columns and lead to an in-chain failure of the whole reinforced concrete floor.

The failure of a slab by punching usually occurs at locations where transverse load is combined with bending moments in two orthogonal directions. Such combined loading results in a state of stress that may lead to the failure of the slab even before the bending capacity is achieved in spans between the columns. Failure usually occurs so that a concrete cone is separated from the slab, bending reinforcement is pulled away from the concrete and the slab falls down due to the gravity force (Figure 4).

Although several concepts to describe punching failure of a slab do exist, they generally make reference to a truss

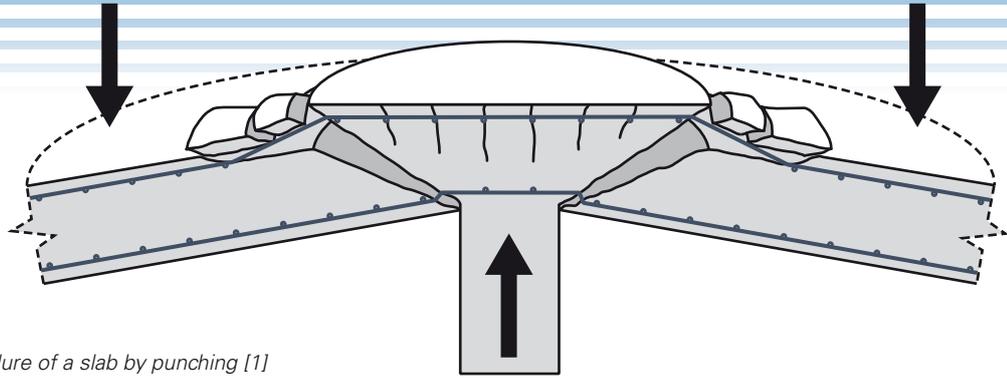


Figure 4: Failure of a slab by punching [1]

“Punching in reality”- one good example of how to “save” more costs than by using Peikko PSB in particular by leaving out PSB.



model shown in Figure 5 and Figure 6. In such models, the shear force is transferred from the slab to the column by a system of strut and ties. The punching capacity of the column is limited by the tensile strength of the first inclined diagonal.

Figure 5: Forces in the slab before failure

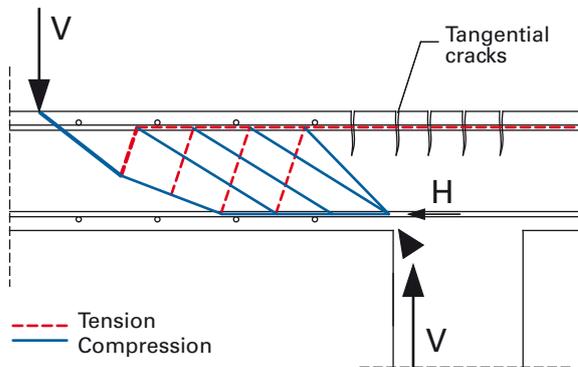
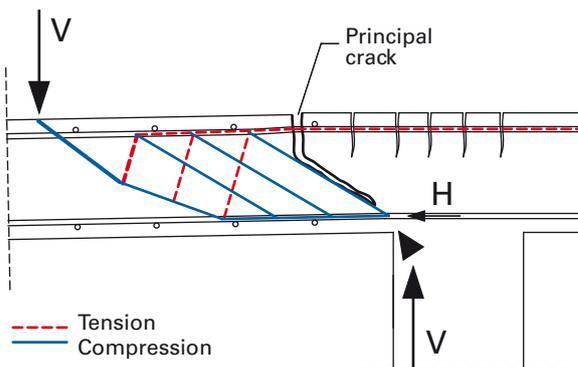


Figure 6: Forces in the slab at failure

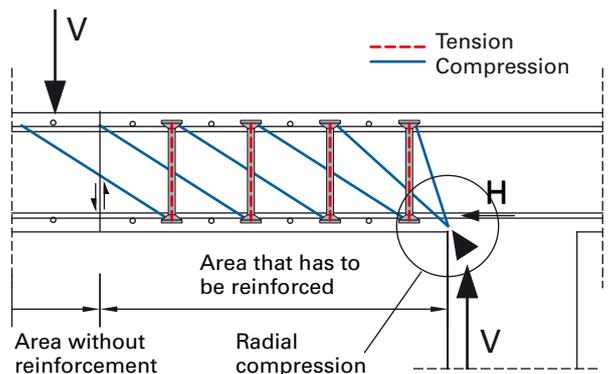


Even before the failure by punching, bending cracks appear in the upper layer of the slab. This cracking is controlled by the bending reinforcement of the slab. When the punching capacity of the slab is exceeded, the first tie located at the perimeter of the column fails and an inclined crack parallel to the first compressed strut appears (Figure 6). Together with the bending crack, the inclined crack spreads around the loaded perimeter forming a concrete cone and leading to the failure of the slab.

3. Reinforcement of the slab against failure by punching

The basic idea of strengthening the slab against failure by punching consists in replacing the concrete ties in the truss model by vertical steel links (Figure 7).

Figure 7: Forces in a slab with PSB punching reinforcement [2]



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Figure 8: Different types of PSB

The required number of steel links is determined by two conditions:

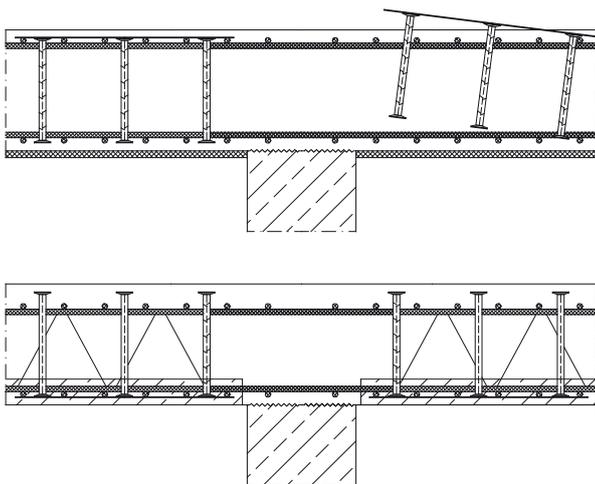
- The steel links adjacent to the loaded area/column must have a sufficient tensile capacity to prevent the shear crack from developing
- The reinforcement must spread the concentrated load from the loaded area/column further on to the slab

The capacity of one single stud is determined by the diameter of its shank. The diameters of the heads are determined so that the anchorage capacity is sufficient to transfer the maximum tensile load from the shank to the concrete.

4. The Peikko PSB product portfolio and its installation

The Peikko PSB shear and punching reinforcement consists of double headed ribbed studs (BSt 500 S), welded to a spacer bar (flat steel, S 235 or two rebars, BSt 500 S), which ensures their position with regards to the main reinforcement of the slab (Figure 8).

Figure 9: Installation of PSB



The so-formed stud rails are preferably inserted from the top (Figure 9+10) after laying the main reinforcement of the slab, or may be inserted from below (Figure 9+11) by being placed on the formwork by special Peikko spacers (Figure 11).

Figure 10: Installation from the top

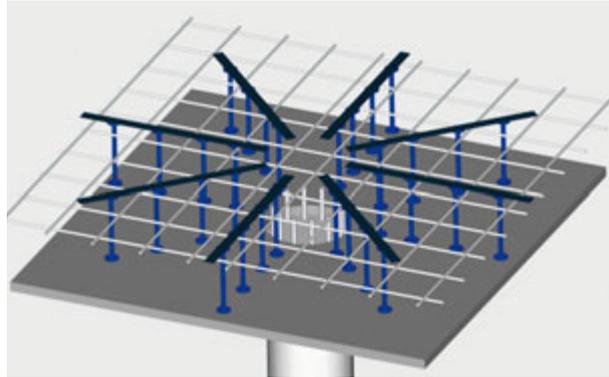
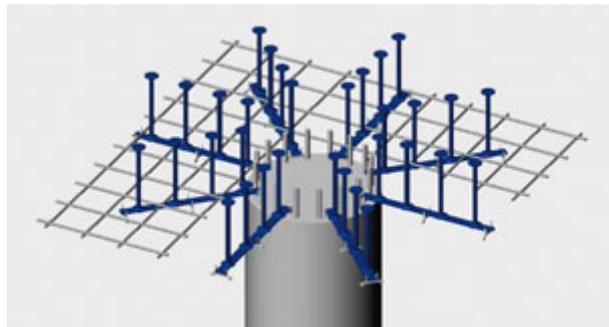


Figure 11: Installation from below



Each stud rail is manufactured individually corresponding to the static requirements just in time. In order to guarantee short delivery times and optimum flexibility, Peikko Group doubled its PSB manufacturing capacity for PSB punching reinforcement in its factory in Kralova nad Vahom, Slovakia and additionally in Waldeck, Germany.

5. Design of PSB

The PSB punching reinforcement should be designed using a concept initially developed by the DIBt institute in Germany. This design approach takes in account the specific properties of the product and has already been approved also outside Germany (Austria, CEE countries...). The fact that there exists a technical approval for the PSB punching reinforcement has principally the following meanings:

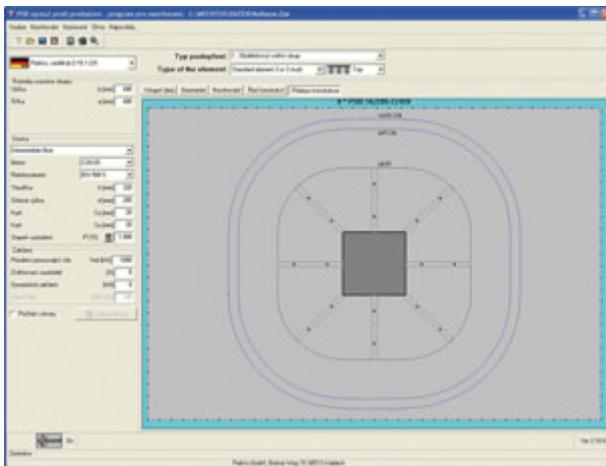
- PSB is officially recognized as a product that may be used to strengthen slabs against failure by punching
- The approved design concept makes PSB more competitive compared to traditional types of reinforcement

The design of PSB punching reinforcement is usually performed using the software PeikDur (Figure 12). At present, the software works on the basis of two design concepts:

- Z-15.1-231 – German technical approval
- MA64-8635/2006 – Austrian technical approval

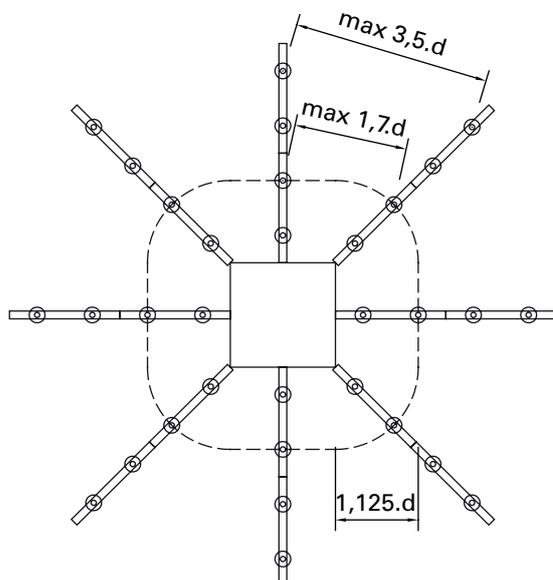
The design in other countries may also be performed using the design concept Z-15.1-231, since with the exception of certain national parameters (that can be edited in the software), the design concepts of National approvals are identical to approval Z-15.1-231.

Figure 12: Software PeikDUR for the design of PSB



The basic design principles of the approval Z-15.1-231 are summarized in the following:

Figure 13: Structural provisions for PSB acc. to Z-15.1-231



- Capacity of the slab with punching reinforcement:

the contribution of concrete to the punching capacity of the slab is neglected; only the capacity of the first two perimeters of steel reinforcement is considered:

$$V_{Rd,sy} = \frac{2 \cdot m_c}{\eta} A_{si} f_{yd}$$

where

η is a factor that takes account of the thickness of the slab

m_c is the number of rails of reinforcement

A_{si} is the sectional area of one reinforcement link

f_{yd} is the tensile strength of the reinforcement link

- Maximum capacity of the slab with punching reinforcement:

$$V_{Rd,max} = 1,9 \cdot V_{Rd,c}$$

where

$V_{Rd,c}$ is the capacity of the slab without reinforcement

6. Conclusion

In conclusion, the PSB punching reinforcement is a simple and reliable method to increase the resistance of slabs against failure by punching. Furthermore, the design of PSB punching reinforcement is much more economical than the design of conventional types of reinforcement.

Within the past few years, PSB punching reinforcement has become increasingly popular for several reasons:

- **From the designers' point of view...**

the solution with PSB punching reinforcement is much more economical than traditional types of punching reinforcement. At the same time, technical approvals that cover the design and use of PSB in several European countries make it equivalent to traditional reinforcing products also from a legal point of view.

- **From the constructors' point of view...**

it is a simple solution that reduces on-site operations and enables for example the minimization of shuttering time, simplification of reinforcement work, ease of work under slabs. At the same time, by ordering PSB punching reinforcement, Peikko's customers are guaranteed quality, fast deliveries, and competitive prices.

- **From the building owners' point of view...**

it enables the saving of a lot of money by the entirety of all these advantages, including the minimization of storey heights.

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Examples of where PSB has been used

Siemens City in Vienna, Austria



Diamante Plaza in Cracow, Poland



Krisztina Palace in Budapest, Hungary



CONCON in Karlovy Vary, Czech Republic



Altra Sede Regione Lombardia, Milano, Italy



BBI Airport Berlin, Germany



References

[1] Guandalini S. (2005) „Poinçonnement symétrique des dalles en béton armé“, These N° 3380, EPFL, Lausanne.

[3] Z-15.1-231 : Allgemeine bauaufsichtliche Zulassung. Deutsches Institut für Bautechnik (DIBt) – 2.2.2005

[2] Beutel K. (2002) „Durchstanzen schubbewehrter Flachdecken im Bereich von Innenstützen“ Rheinisch-Westfälische Technische Hochschule Aachen, Fakultät für Bauingenieurwesen.



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