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PUNCHING SHEAR REINFORCEMENT **DE+DKD**

A QUICK SOLUTION TO COVER SHEAR FORCES IN SLABS
WITH PUNCHING SHEAR ELEMENTS AND DOUBLE-HEADED STUDS

PATENTED

A PUNCHING SHEAR REINFORCEMENT FOR THE SUPPORT AREA OF FLAT SLABS

DESCRIPTION

Punching shear elements[DE] are V-shaped mesh-like (or ladder-like) reinforcing elements, which are produced industrially by electric resistance welding similar to the production of reinforcing wire fabrics. The wire used for both the chords and the vertical bars is reinforcing steel B500A according to ÖNORM B 4707.

These elements are manufactured in various heights and leg lengths and can be used generally as punching shear reinforcement in all types of reinforced concrete slabs.

If higher punching shear resistance is required, punching shear elements[DE] will be combined with double-headed studs[DKD]. These studs with forged heads on both ends are made of ribbed reinforcing steel B500. The stud diameter is 10 mm for all heights and the stud head diameter is 30 mm.

The new punching shear reinforcement[DE+DKD] – punching shear elements[DE] or the combination of punching shear elements[DE] und double-headed studs[DKD] – is especially suited as punching shear reinforcement in the support area of slabs resting directly on columns (flat slabs).

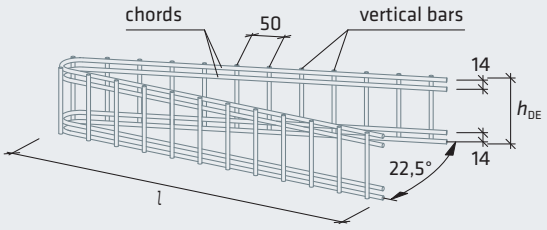


Fig. 1: Punching shear element[DE] and its dimensions

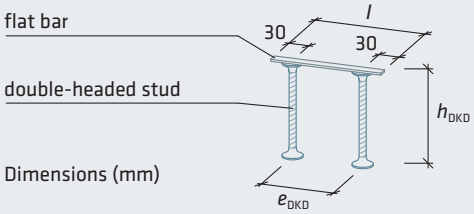


Fig. 2: Pair of double-headed studs[DKD] and its dimensions

SYSTEM AND LOAD-BEARING BEHAVIOUR

The vertical bars of punching shear elements DE are arranged at a small distance and provide some sort of "close stitches" to the slab section subject to punching. As a result, high shear forces in the loading area can be distributed to a very high number of thin vertical bars and, at the same time, the area subject to punching will be increased. The vertical bars are anchored in the tension and compression zone of the slab by two welding points at the double chords on top and at bottom. Transfer of forces to the flexural reinforcement is ensured by the double chords, as well. If required, double-headed studs provide strengthening in the area subject to the highest punching shear stress (approx. up to 1.5 × d from the edge of support). Due to their forged heads they are anchored very well at the level of the flexural reinforcement layers.

Design of punching shear reinforcement DE+DKD is based on the standards EN 1992-1-1 and ÖNORM B 1992-1-1. Slight deviations of the design concept from these standards can be found in the Technical Guidelines.

Punching shear resistance of DE with $K \leq 1.65$

If it is sufficient to increase the punching shear resistance $V_{Rd,c}$ of an unreinforced flat slab by up to 65% ($K_{max} = 1.65$), only punching shear elements DE are used as reinforcement. In this case, the calculation of the inner reinforcement perimeters (approx. 1.5 × d from the edge of support) is decisive for determining the required cross-sectional area $a_{sw,req}$. According to ÖNORM B 1992-1-1, the cross-sectional area $a_{sw,req}$ in this portion of the slab has to be increased by 60%.

Punching shear resistance of DE+DKD with $1.65 < K \leq 1.96$

A combination of punching shear elements DE and double-headed studs DKD will be used if the loads require a higher load-bearing capacity ($K > 1.65$). Punching shear elements DE usually are designed without increasing the cross section by 60% and, therefore, are designed only for the area outside the inner control perimeter at 1.5 × d from the edge of support. Double-headed studs DKD are used to cover the reinforcement $a_{sw,req}$ required by ÖNORM B 1992-1-1 at the inner reinforcement perimeters. Depending on the actual situation, however, a portion of this inner reinforcement could be provided by punching shear elements DE.

Fig. 3: Exemplary installation case of punching shear elements DE

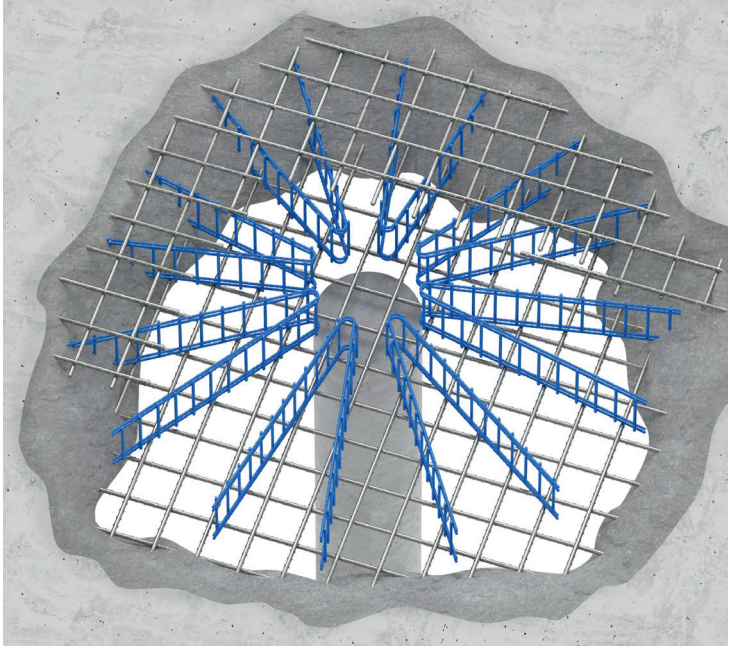
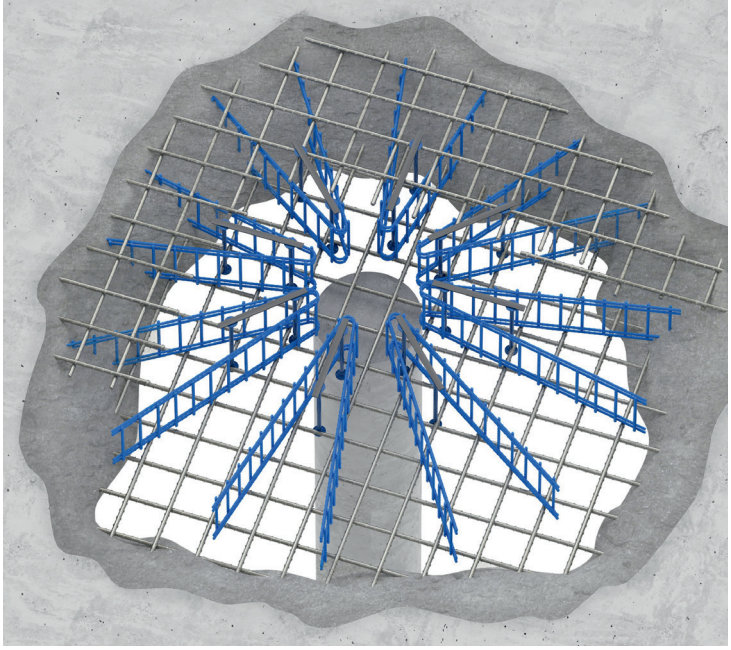


Fig. 4: Exemplary installation case of punching shear reinforcement DE+DKD



PLACING OF PUNCHING SHEAR ELEMENTS DE ($K \leq 1.65$)

Punching shear elements DE are placed between the lower and upper layers of flexural reinforcement and thus, they also serve as spacers. Usually, at least eight elements each with an opening angle of 22.5° are placed in the column head area in a rotationally symmetrical arrangement. The type of punching shear element DE depends on the slab thickness. With one row of elements, the outer diameter of the star-shaped shear reinforcement is defined by the leg length of the individual element.

By sliding punching shear elements DE into one another a rotationally symmetrical double-row arrangement can be achieved, which provides an increased cross-sectional area of punching shear reinforcement. By increasing the distance between the two rows, however, the outer control perimeter can be enlarged.

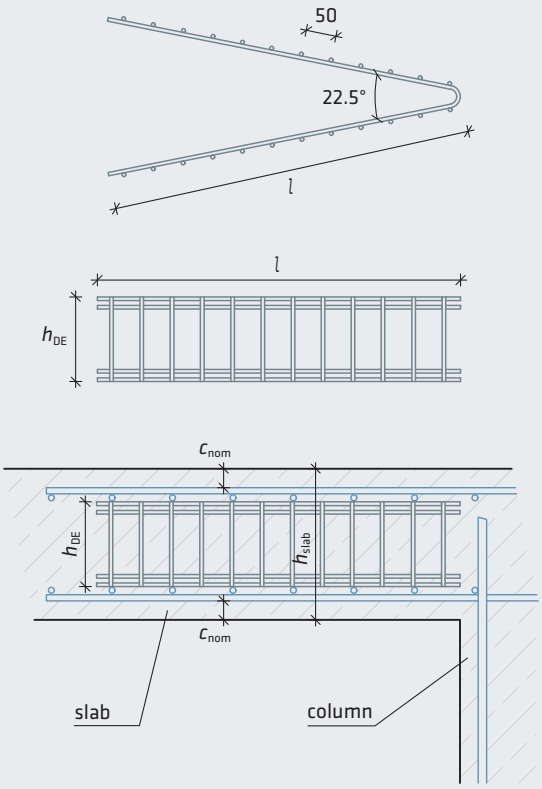


Fig. 5: Cross section of a slab with DE

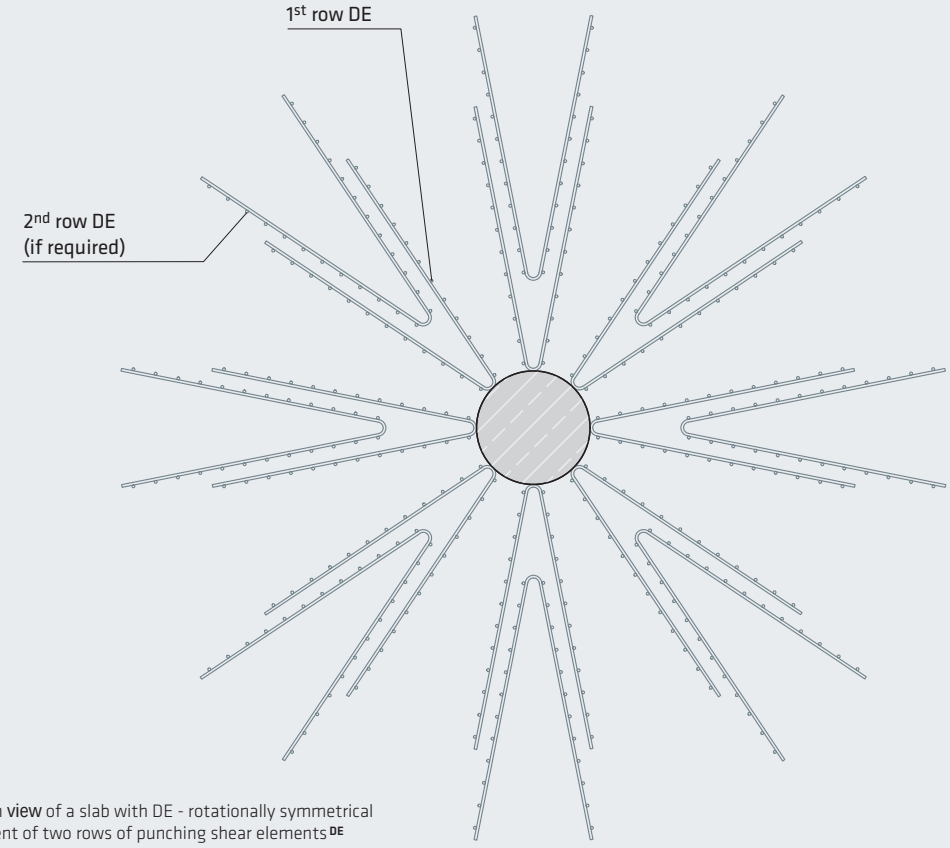


Fig. 6: Plan view of a slab with DE - rotationally symmetrical arrangement of two rows of punching shear elements DE

PLACING OF ADDITIONAL DOUBLE-HEADED STUDS (1.65 < *K* ≤ 1.96)

If 1.65 < K ≤ 1.96, double-headed studs DKD are required in addition to the punching shear elements DE. After placing of reinforcement has been completed, pairs of double-headed studs DKD (see fig. 7) are inserted from above. The top edge of the stud head is flush with the outer edge of the top reinforcement layer. The studs must be tied to the flexural reinforcement in order to ensure that they stay in place during concreting. Placement of double-headed studs DKD is independent of placement and number of punching shear elements DE.

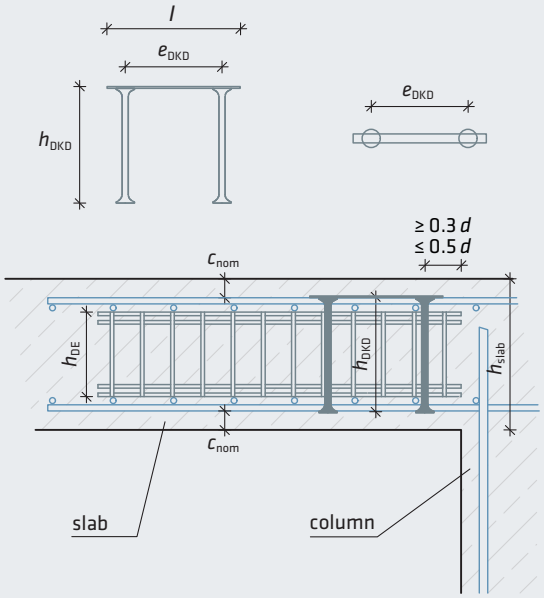


Fig. 7: Cross section of a slab with DE+DKD

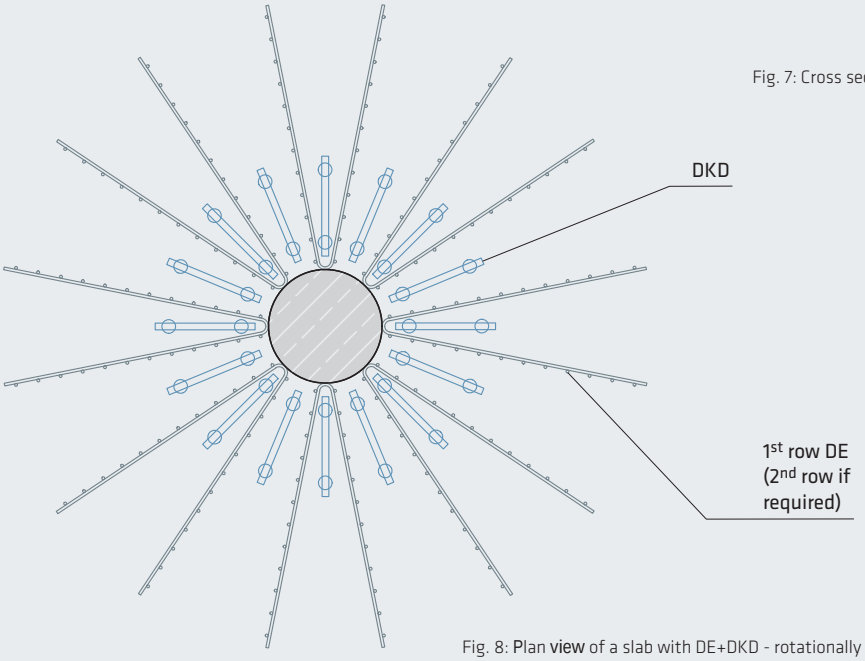


Fig. 8: Plan view of a slab with DE+DKD - rotationally symmetrical arrangement of punching shear elements DE and double-headed studs DKD

The optimal element heights result in:

$$h_{DE} = h_{slab} - \sum c_{nom} - \sum \varnothing_p \qquad h_{DKD} = h_{slab} - \sum c_{nom}$$

h_{DE}	height of punching shear element DE	$\sum c_{nom}$	sum of nominal concrete covers at the top and bottom
h_{DKD}	height of double-headed stud DKD	$\sum \varnothing_p$	sum of thickness of top and bottom reinforcement layers
h_{slab}	overall depth of slab		Please mind that ribbed bars usually require more space than their nominal diameter (see ÖNORM B 1992-1-1, 11.2.2).
c_{nom}	nominal concrete cover		

TYPES

Punching shear elements DE come in heights from 100 to 320 mm. They can be used to increase the bearing capacity of reinforced concrete members with an overall depth of 200 mm to maximum 450 mm.

Type	Height	Chords	Vertical Bars		Elements	
	h_{DE}	ø	ø	Distance	Leg Length l	Weight
	mm	mm	mm	mm	mm	kg
DE 100	100	6.0	6.0	50	600	1.60
DE 120	120	6.0	6.0	50	600	1.71
DE 140	140	6.0	6.0	50	600	1.81
DE 160	160	6.0	6.0	50	700	2.24
DE 180	180	6.0	6.0	50	700	2.36
DE 200	200	6.0	6.0	50	700	2.49
DE 220	220	6.0	6.0	50	850	3.17
DE 240	240	6.0	6.0	50	850	3.32
DE 260	260	6.0	6.0	50	850	3.47
DE 280	280	6.0	6.0	50	1000	4.26
DE 300	300	6.0	6.0	50	1000	4.44
DE 320	320	6.0	6.0	50	1000	4.62

Weight and dimensional tolerances as per ÖNORM B 4707

Double-headed studs DKD come in heights from 140 to 360 mm. Like punching shear elements DE, they can be used to increase the bearing capacity of reinforced concrete members with an overall depth of 200 mm to maximum 450 mm.

Type	Height	Flat Bar	Double-headed Stud Pair		
	h_{DKD}	l	Shaft ø	Head ø	Distance e_{DKD}
	mm	mm	mm	mm	mm
DKD-P 140	140	165	10	30	105
DKD-P 160	160	180	10	30	120
DKD-P 180	180	195	10	30	135
DKD-P 200	200	210	10	30	150
DKD-P 220	220	225	10	30	165
DKD-P 240	240	240	10	30	180
DKD-P 260	260	255	10	30	195
DKD-P 280	280	270	10	30	210
DKD-P 300	300	285	10	30	225
DKD-P 320	320	300	10	30	240
DKD-P 340	340	315	10	30	255
DKD-P 360	360	330	10	30	270

STRUCTURAL DESIGN SOFTWARE

The design of punching shear reinforcement DE+DKD is accomplished by using a calculation software based on Excel, which can be downloaded from our website (www.avi.at). A summary of the results is shown directly on the input screen. Additionally, detailed results can be printed.

AVI PUNCHING SHEAR REINFORCEMENT DE+DKD based on EN 1992-1-1
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User name: | Project no.:
Project name: | Item:

Concrete grade: C35/45 | Steel grade: B550 | DE and DKD-P: DE 140 / DKD-P 200 | Height of DE and DKD

Dimensions of the slab
- Slab thickness: h= 250 mm
- Effective depth: d= 205 mm
- Penetration: h_E= 0 mm

Column: Circular column, interior
- Number= 1
- Column diameter: c= 300 mm
- - - mm

Overhangs (edge and corner columns)
- - - mm
- - - mm

Flexural reinforcement at the support
- X-direction (perpendicular to edge): $a_{s,x}$= 1828 mm²/m
- Y-direction (in parallel to edge): $a_{s,y}$= 1828 mm²/m

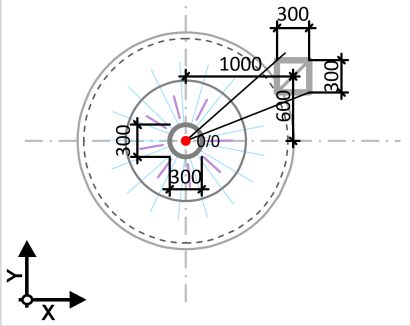
Adjust flexural reinforcement
- ☐ Increase flexural reinforcement to avoid additional rows of DE
- ☐ Increase flexural reinforcement to avoid DKD-P ($\beta V_{Ed} \le 1.65 V_{Rd,c}$)

Loading
- ☑ β automatically (acc. to ÖNORM B 1992-1-1, 9.4.6)
- Load increase factor: β_{chosen}= 1.15 ≥1.10
- Design value of load: V_{Ed}= 675.0 kN
- ☐ Design as column base: σ_{soil}= 0.0 kN/m²

Adjust punching shear reinforcement
- ☐ Minimise number of DKD-P (increase number of DE)
- ☑ Use DKD-P (k,max=1.96)
- ☐ Enter number of DE and DKD-P manually: $n_{DE,1st\ row}$= DE 140; n_{DKD-P}= DKD-P 200
- (structurally effective: Min,DE: 8 DE + 8 DKD-P; Max,DE: 8 DE + 8 DKD-P)

Opening
- Opening close to the support: rectangular opening
- Reduction of control perimeter: ○ mm ◉ percent ○ degree Δ_U= 22.5 %
- Location of the opening: ○ Edge of opening ◉ Centre of opening
- Distance in X-direction: e_x= 1000 mm
- Distance in Y-direction: e_y= 600 mm
- Dimensions of the opening
- Width in X-direction: b_x= 300 mm
- Width in Y-direction: b_y= 300 mm
- Angle due to the opening: Δφ= 20.1 °

Rotate the coordinate system according to the sketch



CALCULATION OF PUNCHING SHEAR RESISTANCE

Required flexural reinforcement:

Top reinforcement: $a_{s,x}$ = 1828 mm²/m $a_{s,y}$ = 1828 mm²/m
Collapse reinforcement: $A_{s,x} = A_{s,y}$ = 227 mm² (minimum 2 bars per direction)

Required punching reinforcement:

Punching shear elements: 8 elements DE 140
Double-headed stud pairs: 8 elements DKD-P 200

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Please direct technical inquiries to the Technical Service of AVI (support@avi.at).

Punching shear reinforcement DE-INO-03/23-E

ALPENLÄNDISCHE VEREDELUNGS-INDUSTRIE
GESELLSCHAFT M.B.H.
Gustinus-Ambrosi-Straße 1–3
8074 Raaba-Grambach/Austria
T +43 316 4005-0
F +43 316 4005-507
verkauf@avi.at
www.avi.at

You can also find us on: