WALL SHOES AND FIELD OF APPLICATION

Fig. 1: Wall shoes of different size

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INTRODUCTION

Wall shoes were developed to provide connection between precast concrete wall elements. In principle the connection is designed to carry only tensile forces. Such a situation exists in stiffening walls subjected to bending moments while vertical load is negligible. No doubt wall shoes can provide a reasonable strength also in shear when shear acts in the plane of walls.

Precasters appreciate, in particular, the following:

- Fast and easy installation of wall shoes and anchor bolts together with element reinforcement inside a formwork;
- Surface quality of a formwork is not influenced by wall shoes installations.

Construction companies take the advantage of:

- Comfortable and fast bolt connection without welding on site;
- Easy assembly of elements provided by anchor bolts and wall shoes;
- Fully functioning connections that are able to transfer forces during execution once an element is assembled.

Designers can profit from:

- Strong tensile connection of precast shear walls (stiffening walls);
- Jointing that is invisible after completion of the job.

All three precasters, construction companies and designers together enjoy practical standard range of size and consequently capacity range.

DESCRIPTION OF WALL SHOES

Wall shoe (see Fig. 1) consists of massive bottom plate, side plates, a back plate and top plate. 2 or 4 anchoring bars are welded to side plates. Number of anchoring bars depends on the size of a wall shoe. Bottom plates are provided by an opening that accommodates an anchor bar. The shape of the opening enables certain tolerance in both installation of a wall shoe in a wall element and assembly of a wall element on site. Thick washer distributes forces from an anchor bar nut to a bottom plate. Forces from a bottom plate are transferred to side plates and anchoring bars and, finally, to reinforcement elements of a wall. There is a recommendation how to arrange reinforcement of a wall element with regard to transfer of forces by splicing.

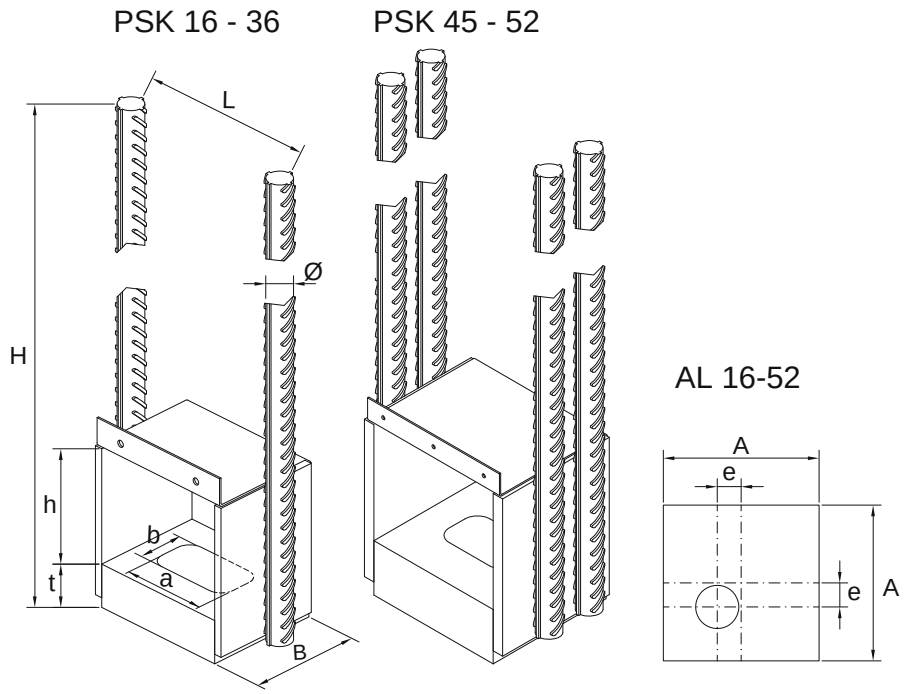
RANGE OF PRODUCTS

Overview of standard products is shown in Table 1.

CAPACITIES IN TENSION AND SHEAR

Wall shoes were initially designed only to transfer tensile forces. Load bearing capacity of anchor bolts are decisive for the strength calculation of a composite system consisting of steel elements of a wall shoe and concrete of a precast wall. The detailed calculation has been done according to Eurocodes (namely EN 1990, EN 1992-1-1, EN 1993-1-1, EN 1993-1-8) and other European standards and Technical specifications. Calculations have been performed for concrete grade C30/37. The calculation takes into account material properties and all detailed arrangement concerning welding and geometry. Decisive parameters including capacities in tension can be taken from Table 2.

Table 1: Dimensions [mm], weights [kg] and painting marks of the wall shoes.



PSK	wall shoe								AL washer			weight	colour
	H	B	L	t	h	Ø	a	b	A	e	s		
PSK 16	580	80	141	30	82	16	76	36	65	5	12	4,4	yellow
PSK 20	850	90	146	35	90	16	80	40	70	5	15	6,1	blue
PSK 24	960	120	166	35	100	20	84	44	80	10	20	10,1	grey
PSK 30	1170	120	185	45	120	25	90	50	95	10	20	16,8	green
PSK 36	1755	150	212	60	130	32	96	56	110	10	30	36,2	red
PSK 45	1940	180	252	80	160	32	105	65	130	10	35	75,8	violet
PSK 52	2520	200	288	80	185	32	112	72	160	10	40	102,3	white

Table 2: Capacity grades according to ETA anchor bolts approval

PSK	Connecting bolt + washer	According to ETA approval N_{Rd} [kN]
PSK 16	HPM 16 + AL 16	61,7
PSK 20	HPM 20 + AL 20	96,3
PSK 24	HPM 24 + AL 24	138,7
PSK 30	HPM 30 + AL 30	220,4
PSK 36	PPM 36 + AL 36	435,7
PSK 45	PPM 45 + AL 45	696,5
PSK 52	PPM 52 + AL 52	937,6

Wall shoes could be a useful tool used also as a shear reinforcement of joints of prefabricated elements. Contribution of wall shoes (and anchor bolts) to shear resistance of joints can be derived from the Eq. 6.25 of Eurocode 2 (EN 1992-1-1), par. 6.2.5 Shear at the interface between concrete cast in different times.

Design shear resistance stress v_{Rdi} at the interface is given by

$$v_{Rdi} = c\, f_{ctd} + \mu\, \sigma_n + \rho\, f_{yd}\, (\mu \sin \alpha + \cos \alpha) \leq 0{,}5\, \upsilon\, f_{cd} \qquad (1)$$

where:

c and μ are factors which depend on the roughness of the interface.

f_{ctd} is the design tensile strength of the concrete with the lowest strength with $f_{ctd} = f_{ctk,0,05}/\gamma_c$, where $f_{ctk,0,05}$ follows from Table 3.1 of [1].

σ_n stress per unit area caused by the minimum external normal force across the interface that can act simultaneously with the shear force, positive for compression, such that $\sigma_n < 0{,}6\, f_{cd}$, and negative for tension. When σ_n is tensile $c\, f_{ctd}$ should be taken as 0.

ρ $= A_s / A_i$

A_s is the area of reinforcement (anchor bolts) crossing the interface, including ordinary shear reinforcement (if any), with adequate anchorage at both sides of the interface.

A_i is the area of the joint.

α is defined in Fig. 2 and should be limited by $45° \leq \alpha \leq 90°$ we can assume in our case $\alpha = 90°$.

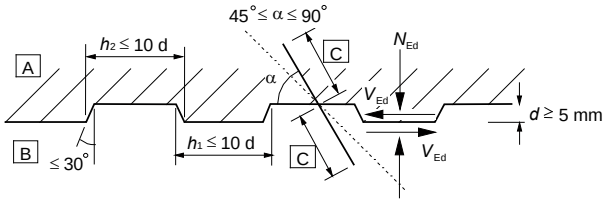
υ is a strength reduction factor for concrete cracked in shear. The value υ for use in a Country may be found in its national Annex. The recommended value follows from

$\upsilon = 0{,}6\, [1 - f_{ck} / 250\,]$ f_{ck} in N/mm^2

In the absence of more detailed information surfaces may be classified as very smooth, smooth, rough or indented, with the following examples:

- Very smooth: a surface cast against steel, plastic or specially prepared wooden moulds:
  $c = 0{,}25$ and $\mu = 0{,}5$
- Smooth: a slipformed or extruded surface, or a free surface left without further treatment after vibration:
  $c = 0{,}35$ and $\mu = 0{,}6$
- Rough: a surface with at least 3 mm roughness at about 40 mm spacing, achieved by raking, exposing of aggregate or other methods giving an equivalent behaviour:
  $c = 0{,}45$ and $\mu = 0{,}7$
- Indented: a surface with indentations complying with Fig. 2:
  $c = 0{,}50$ and $\mu = 0{,}9$

Fig. 2: Indented construction joint



V is a strength reduction factor

A - new concrete, B - old concrete, C - anchorage

Shear capacity of a joint reinforced by anchor bars and anchored by means of wall shoes can be calculated from

$$V_{Rdi} = A_j\, (c\, f_{ctd} + \mu\, \sigma_n) + \mu\, A_s\, f_{yd} \qquad (2)$$

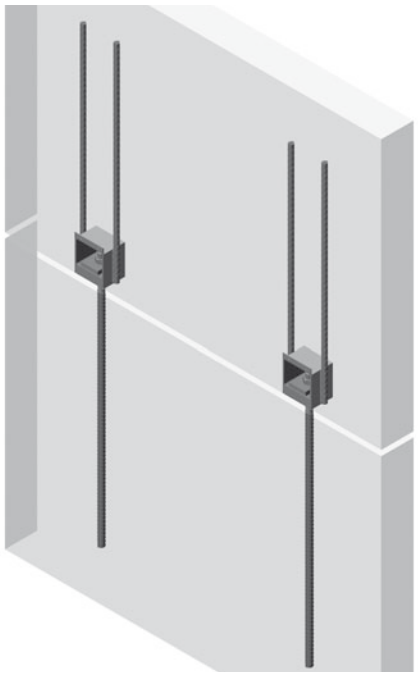
It can be seen from the Eq. (2) that each anchor bolt can contribute to shear capacity of a joint by 50 to 70% of anchor bolt capacity in tension with regard to surface roughness. The maximum amount of joint reinforcement is controlled by the right side of the Eq. (1)

WALL SHOES AND FIELD OF

BASIC APPLICATION

The basic application of PSK wall shoes is in the form of tensile reinforcement of horizontal joints of shear walls (see Fig. 3). It is assumed that the wall shoes transfer tensile forces only. Compression forces are transmitted by grouting of horizontal joints. Concrete cover of a wall shoe must be adequate to fire resistance requirements and required life span of a structure with regard to the environmental loading.

Fig. 3: Typical application of wall shoes with anchor bolts



Tension capacities in Tab. 2 are valid for static loading only. In the case of dynamic or fatigue loadings special provisions must be adopted. In application conditions when temperature might be bellow -20°C degrees special impact resistance of steel might be requested.

There are special rules concerning arrangement of a wall reinforcement to ensure transfer of forces from wall shoes anchor bars to the wall reinforcement.

APPLICATION

OTHER APPLICATIONS

a) Vertical joints between wall elements

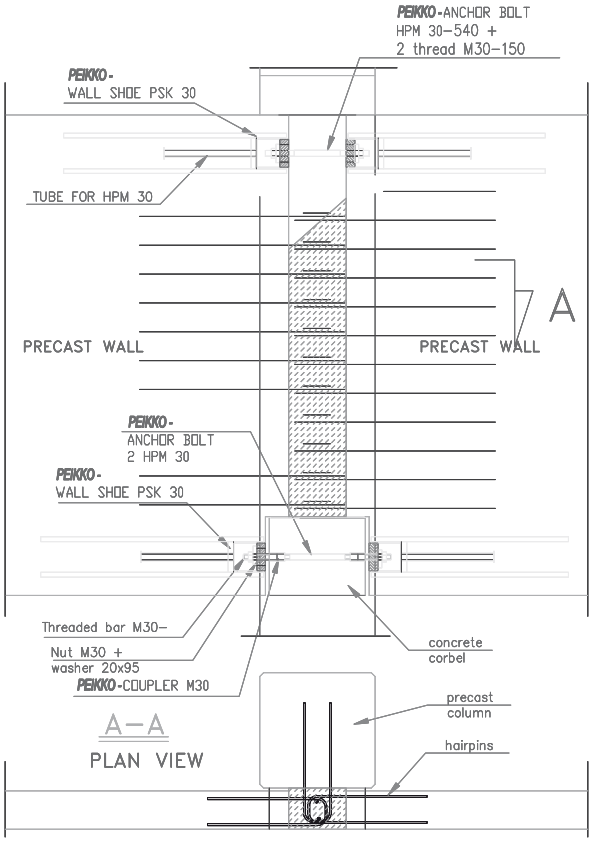
Prefabricated wall structures may require transfer of shear along the vertical joint between neighbouring walls. Special application is from the construction of heavy industrial hall Haindl Paper Mill project PM3 in Germany, in which horizontal elements are employed as units of stiffening walls (see Figs. 4, 5 and 6).

Fig. 4: Vertical joint of a stiffening wall

Fig. 5: Stiffening wall elements

In this case stiffening walls work as continuous beams thus wall shoes transfer tensile forces. Fig. 6 illustrates detailed arrangements of joints including sleeves for anchor bolts needed during the assembly.

Fig. 6: Vertical joint incorporating PSK Wall Shoes



b) Horizontal joints between staircase landings or floor slabs

The recent task to design an external emergency staircase for the air traffic control tower of Prague Airport required the production of staircase flights integrated with landings as one element. The staircase shaft had no stiffening in longitudinal direction in external face of the shaft. On the contrary, there is space available for accommodating a glass facade. Thus relatively large shear forces between adjacent parts of landings had to be transferred. Two wall shoes imbedded in landings were designed in compliance with Equation (2) to reach the required shear capacity of joints (see Figs 7 and 8).

Fig. 7: Assembly of staircase flight including landings

Fig. 8: View to staircase tower

CONCLUSION

Wall shoes are not useful just for vertical connection between prefabricated walls but generally very practical products for any joints of precast concrete units when tensile or shear forces must be transferred between adjacent prefabricated elements. The solution is particularly important when larger forces are in consideration because wall shoes provide perfect anchorage of reinforcing bars in joints.

REFERENCES

[1] PSK Wall Shoe. Peikko 11/2006
[2] EN 1992/1/1: 2006 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

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