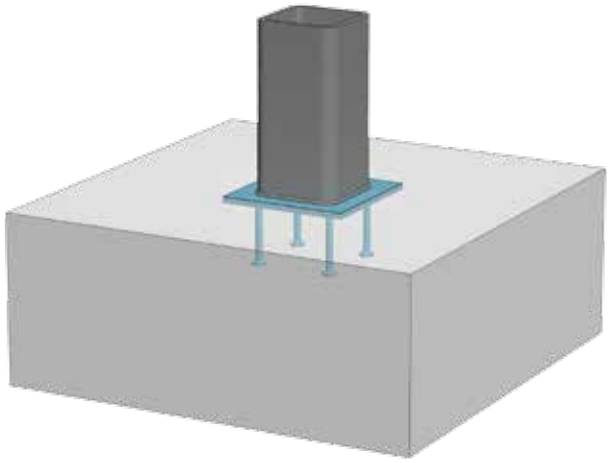

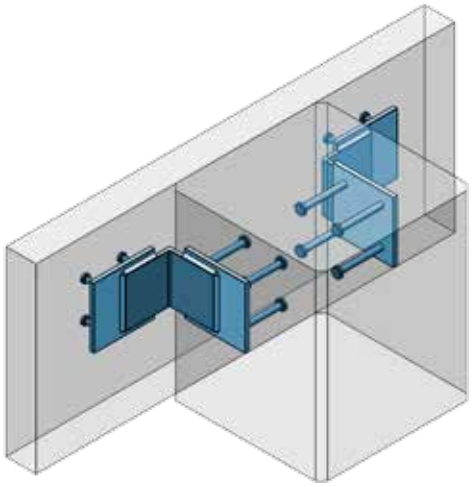

WELDA® FASTENING PLATES

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1. INTRODUCTION

Peikko Group has launched a new family of WELDA® Fastening Plate products with resistances calculated on the basis of technical specifications CEN/TS 1992-4-1..2, as published by the European Committee for Standardization (CEN). WELDA® Fastening Plates can be dimensioned for structures based on Eurocodes. They replace Peikko's previous line of SBKL Fastening Plates, which corresponded to Finnish national norms (RakMk) and were standardized by the Finnish Concrete Association.

The transition to WELDA® Fastening Plates provided Peikko with an opportunity to improve its product range and to update the technical details of its products to ensure that they fulfill the needs of designers today. WELDA® Fastening Plates provide designers with products that are optimized for Eurocode design and a more extensive range of standard products, particularly for thin structures.

Peikko is setting its sights on European markets with the new WELDA® Fastening Plates. They have been approved for the Finnish market, where they have been in use for several months already. WELDA® Fastening Plates can also be used in other countries providing that the design is based on Eurocode standards and national annexes.

WELDA® Fastening Plates enable connections to be formed between steel and concrete structures. They also enable concrete elements to be joined together. Fastening plates do not protrude from the cast surface. Therefore, they enable connections to be less conspicuous than with post-anchoring and bolt connections.

This article details the structural behavior of WELDA® Fastening Plates, the inspections that must be made during dimensioning (Peikko Designer®) with regard to the tensile and shear forces that can act on anchors, and the potential for modifying WELDA® Fastening Plates.

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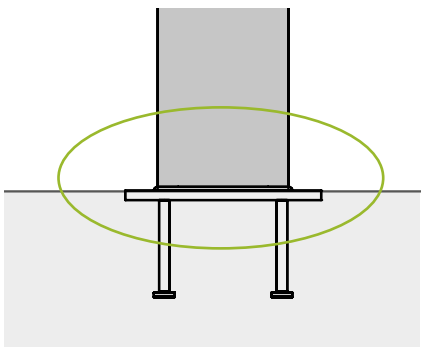
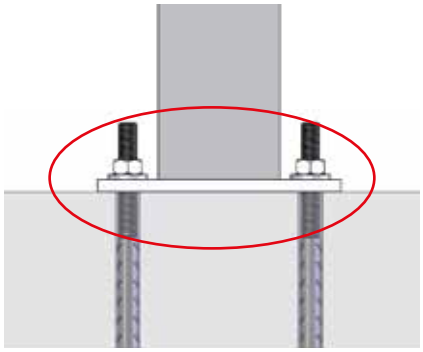
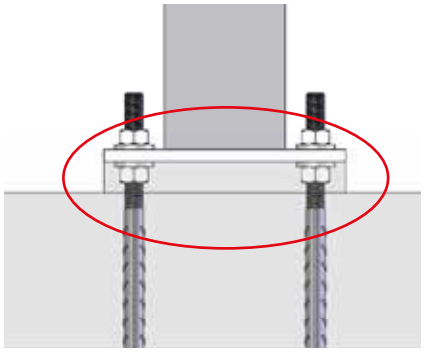






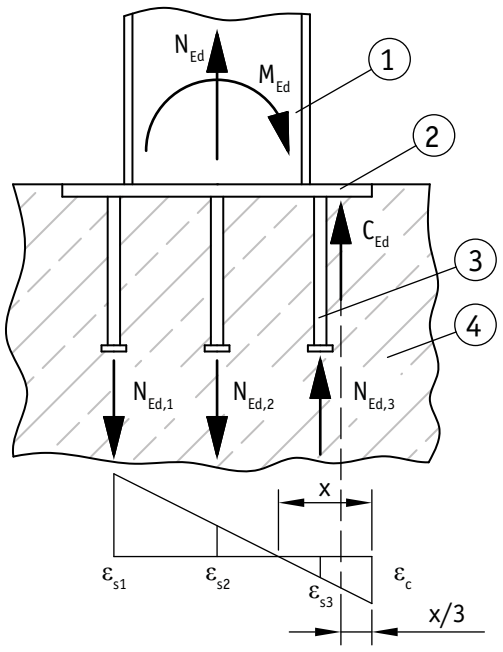
Benefits of WELDA® Fastening Plates for various parties in the construction process	
Architect	A visually less conspicuous solution with no parts protruding from the concrete surface that would otherwise be distracting or would need to be hidden
Structural Designer	The expanded range of standard products offers approved connection solutions to replace solutions that previously needed to be made using modified special steel parts
	A diverse selection of materials enables solutions to be found, even for highly challenging sites such as industrial buildings or maritime climates
	WELDA® Fastening Plates offer almost unlimited scope for modification, enabling optimal solutions to be created in terms of dimensions and resistance for challenging sites such as structures with large amounts of reinforcement
	Technical manuals, approval documentation, the Peikko Designer® software, 2D and 3D components speed up planning and product selection, making the process more efficient
Precast factory / construction site	Smaller and lighter than earlier products while being easier to install – even into dense reinforcement – ensuring that less time is consumed by manual work phases
	WELDA® Fastening Plates can be fastened into place without breaking molds
	An expanded range of products in stock enables faster delivery
Construction site	Extensive plate-axis installation tolerances: connecting structures can be installed and welded in exactly the right location

2. STRUCTURAL BEHAVIOR

WELDA® Fastening Plates include a steel plate to which headed anchors are welded and embedded into the concrete in the casting phase. WELDA® Fastening Plates are designed to transfer the loads caused by bending moments, normal forces, and shear forces into the concrete. The calculations presume that the steel plate is completely rigid and remains a plane in the loading. The steel plate transfers forces from the profile, which is welded on, to anchors in the concrete.

The presumption of a rigid plate in the event of normal forces and moments requires the fastening area to be sufficiently large in relation to the surface of the plate. Special attention must be paid to this when calculations are made for long fastening plates. For long fastening plates, the calculating model should be a plate that is large enough to enable the steel profile to be connected within the relevant tolerances and that has no unnecessary rows of anchors with regard to the calculation. If necessary, additional supports can be used between the fastening plate and the steel profile to increase the fastening area. In such cases, the steel profile can be modeled in accordance with the external dimensions of the additional supports for the purpose of calculation.

Figure 1. Model of the distribution of forces when fastening plates are subject to moments and normal forces.



Explanation:

1. Connected steel profile or part
2. Steel plate
3. Headed anchor
4. Concrete structure

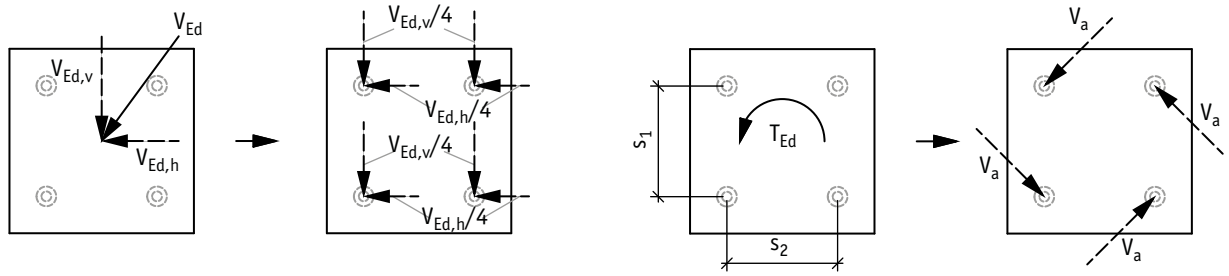
Parts 2 and 3 constitute the WELDA® Fastening Plate

The forces in the anchors (N) and concrete (C) are:

$$N_{Ed,i} = A_s \cdot \varepsilon_{s,i} \cdot E_s$$

$$C_{Ed} = 0.5 \cdot b \cdot x \cdot \varepsilon_c \cdot E_c$$

Figure 2. Defining shear forces for individual anchors when four anchors are subject to an inclinedshear force of V_{Ed} and a torque of T_{Ed}.

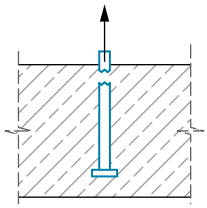
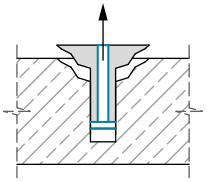
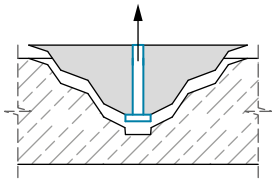
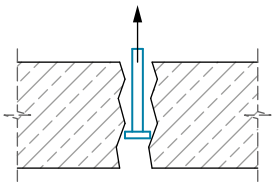
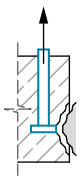


$$V_a = \frac{T_{Ed}}{I_p}\left[\left(\frac{s_1}{2}\right)^2 + \left(\frac{s_1}{2}\right)^2\right]^{0.5} \text{ and } I_p = {s_1}^2 + {s_2}^2$$

2.1 REQUIRED VERIFICATIONS FOR WELDA® HEADED ANCHORS LOADED IN TENSION

The verifications described below can be made using Peikko's own Peikko Designer® software.

Table 1. Required verifications for headed anchors loaded in tension.

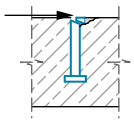
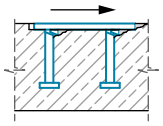
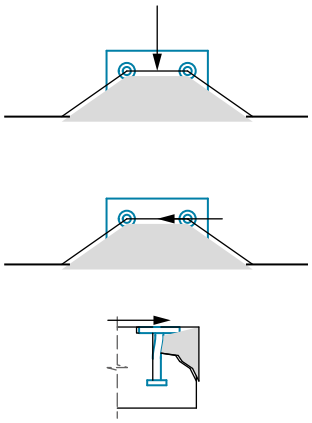
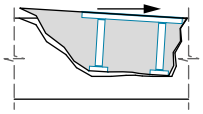
Failure mode	Example	Most loaded anchor	Anchor group
Steel strength of anchor		$N_{Ed}^h \le N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	
Pull-out strength of anchor		$N_{Ed}^h \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	
Concrete cone strength [1)]			$N_{Ed}^g \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$
Splitting strength [2)]			$N_{Ed}^g \le N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$
Blow-out strength [3)]			$N_{Ed}^g \le N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$

[1)] Not required if supplementary reinforcement is provided according to Appendix A1
[2)] Not required if the edge distance in all directions $c \ge 1{,}5\ h_{ef}$ for groups with one anchor and $c \ge 1{,}8\ h_{ef}$ for groups with more than one anchor or if supplementary reinforcement provided according to Appendix A2
[3)] Not required if the edge distance in all directions $c \ge 0{,}5\ h_{ef}$

2.2 REQUIRED VERIFICATION FOR WELDA® HEADED ANCHORS LOADED IN SHEAR

The verifications described below can be made using Peikko's own Peikko Designer® software.

Table 2. Required verifications for headed anchors loaded in shear.

Failure mode	Example	Most loaded anchor	Anchor group
Steel strength of anchor		$V_{Ed}^{h} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	
Concrete edge strength [1)] • Shear perpendicular to the edge • Shear parallel to the edge • Inclined shear			$V_{Ed}^{g} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$
Concrete pry-out strength			$V_{Ed}^{g} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$

[1)] Not required if the edge distances in all directions $c \geq \min(10\, h_{ef}; 60Ø)$ or if supplementary reinforcement is provided according to Appendix B1

2.3 COMBINED TENSILE AND SHEAR FORCES

When an anchor is subject to simultaneous tensile and shear forces, the interaction must satisfy the following equations for the various failure modes. The interaction of tensile and shear forces is easy to check using the Peikko Designer® Fastening Plate software.

VERIFICATIONS TO BE CARRIED OUT FOR STEEL PARTS

Headed anchors

When simultaneous tensile and shear forces are acting, every anchor must satisfy the following condition:

$$|\beta_N|^2 + |\beta_V|^2 \leq 1 \qquad \text{CEN/TS 1992-4-2, Eq. (46)}$$

where

$$\beta_N = \frac{|N^1_{Ed}|}{N_{Rd}} \leq 1 \text{ and } \beta_V = \frac{|V^1_{Ed}|}{V_{Rd}} \leq 1$$

where

N^1_{Ed} = axial tensile force in the anchor subject to greatest force
V^1_{Ed} = shear force in the anchor subject to greatest force
N_{Rd} = the anchor's tensile resistance
V_{Rd} = the anchor's shear resistance

VERIFICATIONS TO BE CARRIED OUT FOR CONCRETE

Anchors without supplementary reinforcement

When simultaneous tensile and shear forces are acting, the following condition must be satisfied:

$$|\beta_N|^{1.5} + |\beta_V|^{1.5} \leq 1 \qquad \text{CEN/TS 1992-4-2, Eq. (48)}$$

Anchors with supplementary reinforcement

When simultaneous tensile and shear forces are acting, the following condition must be satisfied:

$$|\beta_N|^{2/3} + |\beta_V|^{2/3} \leq 1 \qquad \text{CEN/TS 1992-4-2, Eq. (49)}$$

where

β_N = the largest degree of utilization from concrete verifications under tensile force
β_V = the largest degree of utilization from concrete verifications under shear force

NOTE: Failure modes β_N and β_V are those not covered by supplementary reinforcement

3. USAGE CONDITIONS

The resistances of fastening plates have been calculated for static forces. For dynamic or fatigue forces, higher safety factors must be used on a case-by-case basis.

The pre-calculated resistances (table 5) presume that the fastening plates are sufficiently far from the edges. In practice, lower edge distances can limit the resistances of fastening plates and require supplementary reinforcement.

The eccentricity due to manufacturing and installation tolerances (10% of the side length, max. 20 mm) is taken into consideration in the resistances. The largest eccentricities must be taken into consideration when designing connections. This can be done using the Peikko Designer® software, which can be downloaded from Peikko's website for free.

3.1 TAKING ENVIRONMENTAL CONDITIONS INTO CONSIDERATION

WELDA® Fastening Plates are design for use indoors in dry conditions. The design life of WELDA® Fastening Plates in dry, indoor conditions (environmental classification X0) is 50 years. When fastening plates are used in other conditions, the environmental classification and design life must be taken into consideration when the surface treatment or raw material is selected. Fastening plates are also manufactured from stainless steel materials.

WELDA® Fastening Plates are also available in other materials. Such products are known as modified fastening plates. Contact Peikko's sales team for more information.

Surface treatments of standard WELDA® Fastening Plates: protection paint 40 µm. Epoxy painting and galvanization upon request. Stainless steel WELDA R/Rr/A/Ar Fastening Plates are not painted.

Table 3. Materials of standard fastening plates.

Types	Plate material	Standard	Anchor material	Standard
WELDA	S355J2+N (carbon steel)	EN 10025-2	SD1 (carbon steel)	EN ISO 13918
WELDA R	1.4301 (rustproof)	EN 10088-2	SD1 (carbon steel)	EN ISO 13918
WELDA Rr	1.4301 (rustproof)	EN 10088-2	SD3 (stainless steel)	EN ISO 13918
WELDA A	1.4401 (acid-proof)	EN 10088-2	SD1 (carbon steel)	EN ISO 13918
WELDA Ar	1.4401 (acid-proof)	EN 10088-2	SD3 (stainless steel)	EN ISO 13918

SD1: $f_{yk} \geq 350$ N/mm2, $f_{uk} \geq 450$ N/mm^2, $A_5 \geq 15\%$; EN ISO 13918, carbon steel
SD3: $f_{p0.2} \geq 350$ N/mm2, $f_{uk} \geq 500$ N/mm^2, $A_5 \geq 25\%$; EN ISO 13918, stainless steel

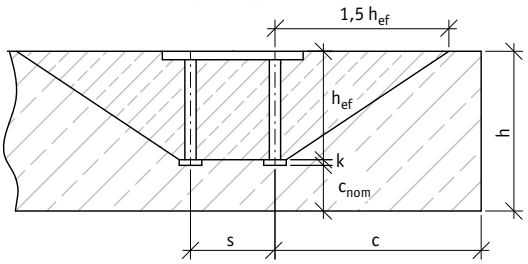
3.2 POSITIONING OF FASTENING PLATES

The precise position of fastening plates is shown on structural drawings. The plates must be fixed so that they are not able to move during casting. Fastening plates can be fixed to reinforcement or to the mold by nails, glue, double-sided tape, compression or magnets in steel molds. Upon request, holes can be made for nails to make the plate easier to fix in place.

Table 4. Installation parameters for headed anchors.

Nominal diameter [mm]		10	12	13	16	19	20
Minimum interval	s_{min} [mm]	50	70	70	80	100	100
Minimum edge distance	c_{min} [mm]	50	50	50	50	70	70
Minimum thickness of concrete structure	h_{min} [mm]	$h_{ef} + k + c_{nom} = H + c_{nom}$					
c_{nom} = Required thickness of concrete cover according to national regulations							

Figure 3. Parameters h_{ef}, k, c_{nom}, h, c, s.



3.3 MODIFIED WELDA® FASTENING PLATES

WELDA® Fastening Plates can be modified to ensure that they offer an optimal solution for different needs. The resistances of modified fastening plates can be verified using the Peikko Designer® software.

The properties that can be modified are as follows:
1) Plate dimensions:

- Thickness t: 8/10/12/15/20/25/30 mm
- Width B: 50–2000 mm
- Length L: 100–6000 mm

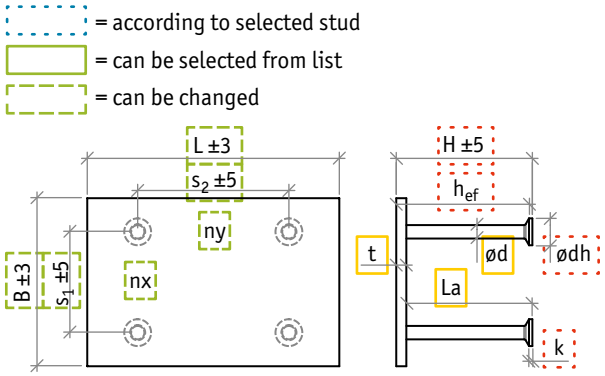
2) Headed anchors:

- Number and position of anchors
- Diameter Ød: 10/12/13/16/19/20(/22/25) mm
- Length La: 50–600 mm

3) Holes:

- Number and position of holes
- Diameter of holes

4) Steel quality (can be selected from steel qualities that are generally available)



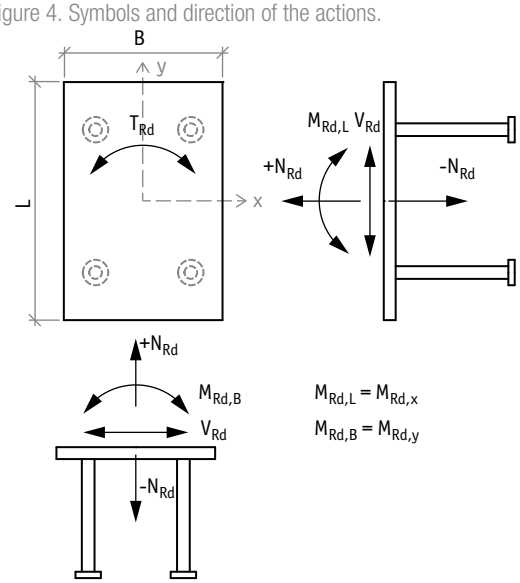
Modified WELDA® Fastening Plates must be named such that they cannot be confused with standard WELDA® Fastening Plates. Manufacturing drawings are required for production. The drawings must show the dimensions of the plate, the sizes and positions of the anchors, and the materials. Contact Peikko's sales team for more information about modifying WELDA® Fastening Plates.

Naming products: **WELDA MODIFIED**
[unique project number or name]

Examples:
WELDA MODIFIED 1234
WELDA MODIFIED 25x600x2000+30d16-150

4. RESISTANCES

Figure 4. Symbols and direction of the actions.



Assumptions for the resistances presented in table 5:

- Concrete strength C25/30. Concrete cracked, without supplementary reinforcement.
- The eccentricity due to manufacturing and installation tolerances (10% of the side length, max. 20mm) is taken into consideration in the resistances.
- The plate is far enough away from the edges so the edge does not fail.
- The calculations have been made for static loads in accordance with the instructions in CEN/TS 1992-4-1...2.
- The minimum fastening areas have been calculated for plate material S355J2+N.

In all cases, the resistances of fastening plates can be verified using the Peikko Designer® software. This is particularly recommended in the following circumstances:

- There are interactions of forces (shear forces, moments and normal forces)
- Edge distances may limit resistances
- Installation tolerances are greater than 10% of the length of the edge, max. 20 mm
- The fastening plate has been modified

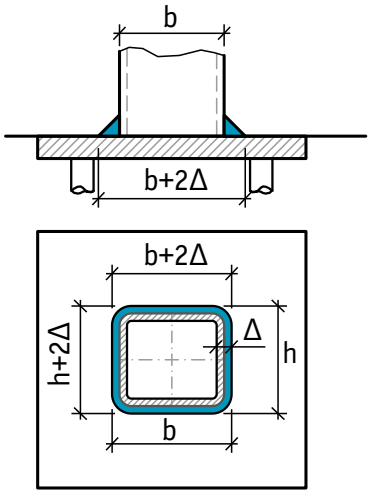
Table 5. Maximum tensile force N_{Rd}, shear force V_{Rd} [kN], bending moment M_{Rd} and torque resistance T_{Rd} [kNm] and minimum fastening area [mm^2] (kpa, calculated for moment M_{Rd}), when only one force applies.

WELDA® B x L – H	$+N_{Rd}$ [kN]	V_{Rd} [kN]	$M_{Rd,L}$ [kNm]	$M_{Rd,B}$ [kNm]	T_{Rd} [kNm]	Min kpa [mm x mm]
WELDA 50x100-68	7.8	19.0	0.8	0.3	0.9	5x67
WELDA 100x100-68	17.2	30.5	1.1	1.1	1.8	48x48
WELDA 100x150-70	20.3	37.2	1.8	1.3	2.7	34x84
WELDA 100x200-72	23.9	46.0	2.5	1.6	4.0	20x105
WELDA 100x200-162	79.2	89.0	6.4	5.4	7.7	50x160
WELDA 100x300-162	90.1	94.9	11.0	5.4	10.3	46x260
WELDA 150x150-70	22.7	44.4	2.0	2.0	3.5	55x55
WELDA 150x150-160	62.9	52.8	4.8	4.8	4.2	116x116
WELDA 150x150-162	77.9	90.6	7.5	7.5	7.1	115x115
WELDA 200x200-72	28.5	58.4	3.1	3.1	5.8	40x40
WELDA 200x200-162	86.6	143.2	10.4	10.4	14.3	157x157
WELDA 200x300-165	97.6	145.7	15.9	12.0	18.3	108x217
WELDA 250x250-165	104.2	150.2	15.7	15.7	20.3	169x169
WELDA 300x300-165	107.5	151.1	18.2	18.2	21.5	201x201

Note:

- When many actions are active at the same time, interaction have to take into account.
- The minimum fastening area depends on the directions and magnitudes of the forces.
- Welds can be taken into consideration when the required fastening areas are calculated.
- The compression resistances of fastening plates can be calculated using Peikko Designer®.

Figure 5. Welds can be taken into consideration when calculating the minimum fastening areas.



The following factors must be taken into consideration in order to select the correct type of WELDA® Fastening Plate:

1. Type of loading and load cases: N_{Ed}, M_{xEd}, M_{yEd}, V_{xEd}, V_{yEd}, T_{Ed}. In the case of seismic, dynamic and fatigue loads, greater safety factors have to be used individually for each case.
2. Direction of loading
3. Dimensions of the steel profile
4. Eccentricity of the steel profile: ex, ey
5. Dimensions and edge distances of the concrete structure
6. Concrete grade
7. Cracked/uncracked concrete
8. Existing and supplementary reinforcement
9. Environmental conditions: dry internal/external atmospheric/other environment liable to corrosion

CONCLUSIONS

When structural design is based on Eurocodes and the CEN/TS 1992-4-1..2 specifications, ensuring the resistance of the selected fastening solution involves several different verifications with regard to different failure mechanisms. Often in such cases, it is not sufficient to ensure resistances on the basis of traditional resistance tables. To make the design of structural fastening details quick and reliable, it is recommended that the Peikko Designer® software be used to select WELDA® Fastening Plates. Peikko Designer® can be downloaded for free from Peikko's website.

The installation of WELDA® Fastening Plates into reinforced structures has been facilitated by updating the product's structural dimensions. The 2D and 3D design components can be used to check that the item will fit into the structure and openings in the reinforcement.

The optimal fastening solution is exactly the right size with regard to the surrounding structures and the structures to be fastened without giving rise to the need for supplementary localized reinforcement. The WELDA® product family has a larger range of standard products to help in identifying the optimal solution.

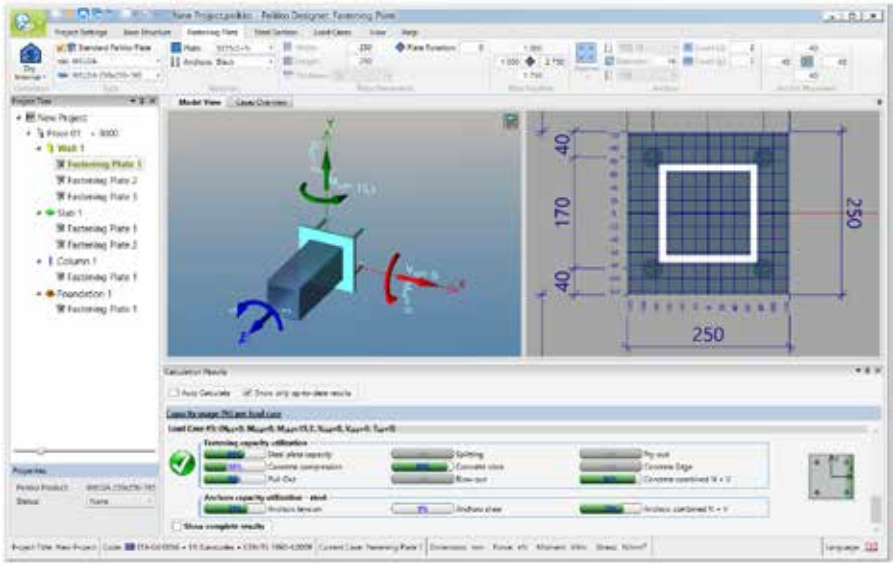
It should be noted that it is not always possible to find parts that are precisely suited for a particular purpose, even in such an extensive product range. As the size and dimensions of fastening plates are key factors, it is now also possible to design individual WELDA® MODIFIED Fastening Plates for specific purposes.

Peikko's transition to a new generation of fastening plates enables product development to correspond more closely to the requirements of different parties in the construction process. ■

REFERENCES

[1] WELDA® Fastening Plates, Technical Manual
[2] CEN/TS 1992-4-1:2009, Design of fastenings for use in concrete. Part 4-1: General
[3] CEN/TS 1992-4-2:2009, Design of fastenings for use in concrete. Part 4-2: Headed fasteners
[4] EN 1992-1-1:2004, Design of concrete structures: General rules and rules for buildings
[5] EN 1993-1-1:2005, Design of steel structures: General rules and rules for buildings
[6] EN 1993-1-8:2005, Design of steel structures. Part 1-8: Design of joints

Figure 6. Peikko Designer: Fastening Plate.



View WELDA® Fastening Plate animation on Youtube:

www.peikko.com/youtube