HILTI

FASTENING TECHNOLOGY MANUAL

Post-Installed Punching Reinforcement Hilti HZA-P

Foreword

A significant number of existing flat slabs requires currently to be strengthened against punching shear for safety reasons (increase of applied loads, deficiencies during design or construction) or to comply with more stringent code requirements. Available strengthening methods are however not completely satisfactory or they cannot be applied in many cases (depending on the possibilities to enlarge column sizes or to intervene on the upper face of slabs). In this document, an innovative system developed by Hilti for strengthening slabs against punching shear and overcoming most of difficulties of existing methods is described. It consists of inclined shear reinforcement installed within existing slabs by drilling holes only from the soffit of the slab and by bonding it with high-performance epoxy adhesive.

Design of the punching shear reinforcement is also treated in the document based on the critical shear crack theory. This theory was developed in Switzerland in the 1980's and is currently the theoretical basis of the Swiss Code for Concrete Structures SIA 262 (2003) with reference to members without shear reinforcement. The theory is based on a physical model allowing to calculate the strength and deformation capacity of members failing in shear or punching shear. An extension of this theory to the shear reinforcing system described in this document was performed at the Swiss Federal Institute of Technology of Lausanne (Switzerland) in cooperation with the scientific consultants of Hilti. This effort resulted into a rather simple and clear design concept accounting for the influence of the many mechanical and geometric parameters of the slabs and shear reinforcement.

The results of the application of the design concept were verified with the experimental results of a test campaign performed by Hilti on 12 full-size slabs. The specimens (3.0 × 3.0 × 0.25m) presented different amounts of flexural and shear reinforcement, corresponding to usual cases found in practice. The theory performed very well for predicting both the experimental strength and deformation capacity at failure and with sufficient safety margin. In addition, 6 tests on slabs reproducing real flat slabs with unusual reinforcing or geometric details (steel shear heads, bent-up bars and rectangular columns) were performed. The comparison of such tests to the design model showed again very good results allowing also to reproduce the actual failure modes observed.

The document is finally giving a series of detailing rules to ensure correct performance of the system. Such rules, derived from theoretical considerations, were validated through the test series and avoid developing undesirable failure modes.

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Content

1 Post-installed punching shear reinforcement

1.1 Application range

The safety against punching shear of existing concrete slabs is basically determined on the basis of the geometry and the reinforcement of the slab and the column. Such data can be taken from construction drawings if available or they are evaluated in situ by taking out concrete cores and seeking the existing reinforcement.

Post-installed punching shear reinforcement can be applied in two ways: if both the lower and the upper side of the slab are accessible for work simultaneously, then holes can be drilled through the slab. Steel bars can then be introduced through the holes and be prestressed against the slab by tightening nuts on both sides (fig. 1). An appropriate mortar is then injected into the annular gap through an injection washer, e.g. the Hilti Dynamic set. Thus, the steel rods cannot move under shear load and water cannot penetrate into the annular gap.

Such methods which include working from the upper side of the slab also have certain drawbacks: The cover of the slab has to be removed (earth, tiles, etc.). Moreover, the waterproofing system is penetrated and has to be repaired properly after installation of the reinforcement.

As often the upper side is not accessible for work or is accessible only with a high effort, a method has been developed to apply punching shear reinforcement only from the lower side of the slab. Hilti tension anchors HZA-P are bonded into drill holes inclined towards the column by means of an appropriate adhesive mortar (fig. 2). The drilled holes should protrude until at least the level just below the lowest layer of the upper (tensile) reinforcement, but preferably to the center of the tensile reinforcement. As the effectiveness of punching shear reinforcement strongly depends on the quality of its anchorage, a reliable adhesive mortar is required and the lower anchorage is carried out with the Hilti Dynamic set.

As penetrating reinforcement according to fig. 1 can be designed like cast-in-place punching shear reinforcement on the safe side, this brochure will in the following present details of the post-installed punching shear reinforcement applied only from the lower side of the slab according to figure 2.

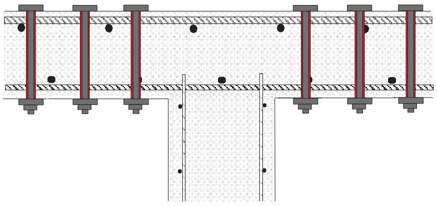


Fig. 1 Penetrating post-installed puching shear reinforcement

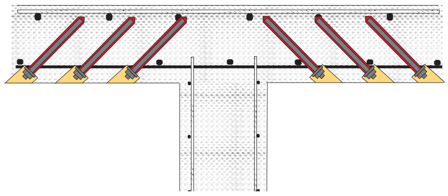


Fig. 2 Post-installed punching shear reinforcement applied only from bottom side of the slab

Fig. 3 Ceiling reinforcement

Fig. 4 Column foundation

Fig. 5 Bridge deck

1.2 Advantages of the method

- Cost effective reinforcement against punching shear loads
- Design according to applicable structural concrete code
- Proof of safety level required by structural code
- Can be combined with cast-in-place punching shear reinforcement
- Simple and fast design with software EXBAR-Punching
- Fire protection by covered anchorage
- Concrete surface remains smooth

2 System description

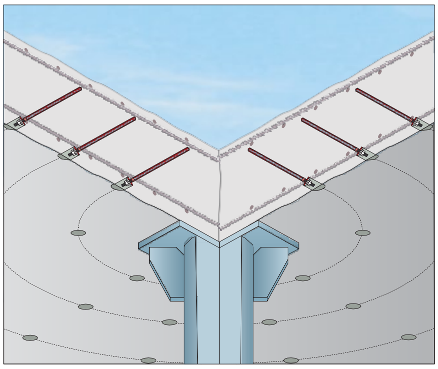


Fig. 6 Post-installed punching shear reinforcement

Fig. 7 Hilti tension anchor HZA-P

Fig. 8 Anchor head

Fig. 9 External anchor head

Fig. 10 Hilti filling set

Hilti Tension Anchors HZA-P in combination with Hilti adhesive mortars are used to install punching shear reinforcement into already hardened concrete slabs.

Inclined holes are hammer drilled into the concrete slab under an angle of 45° and in the direction towards the column. The length of the drilled holes should be such that they reach at least the lowest level of the upper (tensile) reinforcement, but preferably, the holes should end at the level between the tensile reinforcements in the two directions.

Adhesive mortar Hilti HIT-RE 500 V3 is injected into the drilled holes and the Hilti Tension Anchors HZA-P are set into the mortar filled holes. The Hilti tension anchor consists of a reinforcement bar of diameter 16mmor 20mm in the upper part. The lower part is a smooth shaft with a thread M16 or M20 at the end. For the design, the reinforcement bar is decisive since the smooth shaft and thread are made of steel with higher yield strength than that of the reinforcement bar.

After curing of the mortar, the lower anchor head is installed. The Hilti Dynamic Set consists of an injection washer (diameter 52 mm for M16 / 60 mm for M20), a spherical washer to eliminate bending of the bar and a nut. In order to create a slip-free anchorage the annular gaps are filled through the injection washer with Hilti HIT-RE 500V3.

The anchor head can be installed on the concrete surface with washers inclined at 45° or be embedded in an enlarged part of the drilled hole. The embedded anchorage has the advantage that it can be covered with a fire protection mortar and is not visible after the installation.

The design method presented in section 3 of this report refers to correctly installed punching shear reinforcement with Hilti Tension Anchors HZA. The appropriate installation equipment and procedure are described in section 8.

3 Design

3.1 Principles

The basis of the design is the punching shear resistance of the existing slab without shear reinforcement, $V_{Rd,c,c}$, which is calculated according to the applicable structural code.

Even if shear reinforcement is provided, the codes usually define a maximum possible punching shear strength ($V_{Rd,max,code}$) accounting for failure of the compression zone of the slab near the column. On the other hand, the specific design concept for reinforcement with Hilti HZA-P also defines a maximum resistance that can be achieved with this method ($V_{Rd,max,HZA-P}$). This value should not be exceeded even if $V_{Rd,max,code}$ is higher.

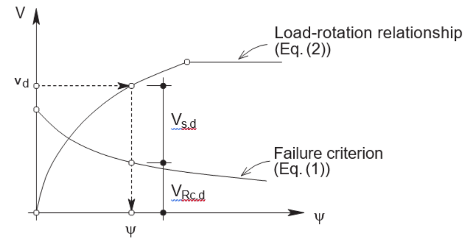


Fig. 11 Load on slab and concrete shear resistance

If the column load V_d is higher than the punching shear resistance of the slab without shear reiforcement, $V_{Rd,c,c}$, then the slab should be strengthened. The design method is based on punching shear tests carried out at the research laboratory of the Hilti Corporation which have been evaluated scientifically at the Federal Institute of Technology in Lausanne, Switzerland (EPFL).

The design model for strengthening with Hilti HZA-P is based on the critical shear crack theory with the following assumptions:

- The punching shear strength of the strengthened slab is the sum of a contribution by the cracked concrete and another contribution by the steel reinforcement:
  $V_{Rd} = V_{Rd,c} + V_{Rd,s}$.
- In order to activate the reinforcement, the opening of the shear crack is initiated.
- The opening of the punching shear crack and the maximum aggregate size of the concrete influence the remaining shear resistance of the concrete slab.

In figure 11 the opening of the punching shear crack is represented by the rotation of the slab. The line “Failure Criterion” shows how the punching shear resistance decreases with increasing rotation of the slab, i.e. with increasing opening of the shear crack.

3.2 Evaluation of the load to be taken up by the reinforcement

The remaining shear strength considering a rotation ψ_d of the slab is:

$$V_{Rd,c} = k_\psi \frac{\eta_t \sqrt{f_{ck}}}{\gamma_c} b_0 \cdot d_v \quad (1)$$

$$k_\psi = \frac{1}{1.5 + 0.9 k_{dg} \psi d} \leq 0.6 \quad (2)$$

With:

$V_{Rd,c}$	concrete contribution to the punching shear resistance [N]
η_t	factor for long term effects
f_{ck}	characteristic compressive strength of concrete cone cylinder 150 / 300 [N/mm²]
d	effective depth [mm]
d_v	shear-resisting effective depth [mm]
b_0	control perimeter [mm]
ψ	rotation of the slab
k_{dg}	coefficient for the type of concrete and aggregate size properties

The rotation of the slab under load V_d [kN] is evaluated by:

$$\psi = 1.5 \cdot \frac{r_s}{d} \cdot \frac{f_{yd}}{E_s} \cdot \left(\frac{m_{Ed}}{m_{Rd}}\right)^{3/2} \quad (3)$$

With:
- r_s — distance from column edge to line of contraflexure for bending Moments [mm], for regular slabs: r_s=0.22 ℓ
- f_{yd} — design yield strength of horizontal slab reinforcement [N/mm²]
- E_s — Young's modulus of steel (=205,000 N/mm²)
- m_{Ed} — average bending moment in the support strip
- m_{Rd} — average flexural strength in the support strip

Parameter m_{Ed} has to be calculated consistently with the method used for determining the flexural reinforcement and is to be determined at the edge of the supported area maximizing m_{Ed}.

The average bending moment acting in the support strip (m_{Ed}) can be approximated for each reinforcement direction and support type as:

- For inner columns (top reinforcement in each direction):

$$m_{Ed} = V_{Ed} \cdot \left(\frac{1}{8} + \frac{|e|}{2b_s}\right) \quad (4)$$

- For edge columns:

when calculations are made considering the tension reinforcement parallel to the edge:

$$m_{Ed} = V_{Ed} \cdot \left(\frac{1}{8} + \frac{|e|}{2b_s}\right) \geq \frac{V_{Ed}}{4} \quad (5)$$

when calculations are made considering the tension reinforcement perpendicular to the edge:

$$m_{Ed} = V_{Ed} \cdot \left(\frac{1}{8} + \frac{|e|}{b_s}\right) \quad (6)$$

- For corner columns (tension reinforcement in each direction):

$$m_{Ed} = V_{Ed} \cdot \left(\frac{1}{8} + \frac{|e|}{b_s}\right) \geq \frac{V_{Ed}}{2} \quad (7)$$

In these equations, term *e* refers to the eccentricity of the resultant of shear forces with respect to the centroid of the basic control perimeter in the direction investigated (*i* = *x* and *y* for *x* and *y* directions respectively).

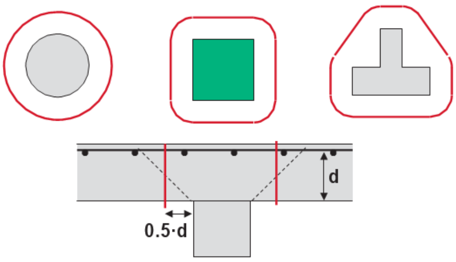


Fig. 12 Shear perimeter u_0 for typical column shapes

The design model uses a critical shear perimeter at a distance of 0.5 times the effective depth of the slab d. For standard column shapes, the critical shear perimeter is given in fig. 12. If the slab thickness varies in the vicinity of the column, the shear perimeter resulting in the smallest resistance is critical. The shear perimeter u' will be multiplied by k_e which is a reduction factor taking into account for irregular distribution of the shear force around the column.

$$u' = u_o \cdot k_e \,;\, k_e = \frac{1}{1+\frac{e}{b}} \quad (8)$$

If the column connection takes up a bending moment M_d, then the irregular distribution of the shear force is taken into account by $k_e = 1/(1+e/b)$ where e is $|M_d/V_d|$ and b is the diameter of a circle with the same area as is inside the critical shear perimeter at 0.5 times the effective depth of the slab.

In cases where the lateral stability does not depend on frame action of slabs and columns and where the adjacent spans do not differ in length by more than 25%, the following approximated values may be adopted for the coefficient k_e:

- 0.90 for inner columns;
- 0.70 for edge columns; for inner columns in the vicinity of large openings (SIA 262)
- 0.65 for corner columns;
- 0.75 for corners of walls (horizontal shear resisting members where the rules of Figure 7.3-22 apply).

Strengthening with Hilti HZA-P is possible if the column load V_d is not higher than the maximum possible resistance of the strengthened slab; $V_{Rd,max,HZA-P}$ is calculated from equation (3) by iterations:

$$V_{Ed} \leq V_{Rd,max} = 2.6 \cdot k_{\psi} \frac{\eta\sqrt{f_{ck}}}{\gamma_c} b_0 d_v \qquad (9)$$

The shear force which has to be taken up by the strengthening anchors is then:

$$V_{Rd,s,req} = V_d - V_{Rd,c} \geq 0.2V_d \qquad (10)$$

$V_{Rd,c}$ is calculated using the rotation ψ according to formula (3) with parameter V_d.

3.3 Design of the reinforcement with HZA-P

The shear reinforcement is designed to satisfy the following condition:

$$V_{s,d} \leq \sum_{i=1}^{n} N_{si,d} \cdot \sin\beta_i \qquad (11)$$

Where $N_{si,d}$ is the factored strength of the shear reinforcement and βi is the angle of the shear reinforcement.

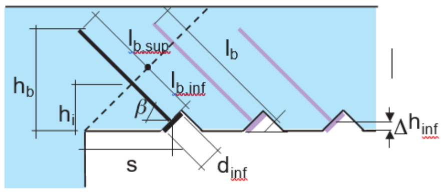


Fig. 13 geometry of reinforcement

The design strength of the Hilti Tension Anchor HZA-P ($N_{si,d}$) is equal to the minimum of the following values:

$$N_{si,d} = \min\left(N_{si,el,d}\,; N_{si,pl,d}\,; N_{si,p,d}\right) \qquad (12)$$

Where $N_{si,el,d}$ is the is the force in the shear reinforcement that can be activated assuming an elastic behavior of the bar. This value, accounting for the rotation of the slab at SLS (see fig. 14) results:

$$N_{si,el,d} = K_{ai} \cdot \sqrt{\Delta\psi_d \cdot h_i \cdot \sin(\alpha + \beta_i)} \quad [MN];[m] \qquad (13)$$

Where α is the angle of the critical shear crack (normally set to 45°). In the standard case of reinforcements set under βi=40-50° the value of sin(α+βi)≈1.00. hi is the height at which the reinforcement is crossed by the critical shear crack (Fig. 13). Δψd is the decisive rotation of the structure to be reinforced: Δψd= ψd – ψSLS.

V_{SLS} is the column load acting while the strengthening work is carried out.

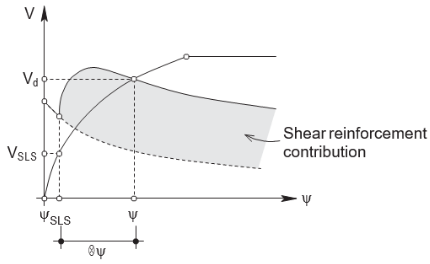


Fig. 14 Definition of $\Delta\psi_d$

K_a is a coefficient depending on the anchorage and is given in the following table 1:

d_b [mm]	K_{ai} [MN/$\sqrt{m}$]
12	2.02
16	3.10
20	4.33

Table 1 Values of coefficient Kai as a function of bar diameter for adhesive epoxy Hilti HIT-RE 500 V3

$N_{si,pl,d}$ is the plastic strength of the bar, equal to:

$$N_{si,pl,d} = A_{si} \cdot f_{yd} \qquad (14)$$

$N_{si,b,d}$ is the upper limit of the resistance due to the bond strength. It is assumed that the bar is bonded between the point where it cuts the shear crack and its upper end ($l_{b,sup,i}$ see Fig. 13).

$$N_{si,b,d} = \tau_{bd} \cdot d_b \cdot \pi \cdot l_{b,sup,i} \tag{15}$$

The design value of the bond strength is evaluated as $\tau_{bd} = \tau_{bd}^0 \cdot f_{B,N}$, where τ_{bd}^0 is the design strength in a concrete of class C20/25 and $f_{B,N}$ takes into account the effective concrete strength. The values are given in the following table 2. $f_{cc,k}$ should not be considered higher than 60 N/mm^2.

		Hilti HIT-RE 500 V3
Bond strength:	$\tau_{bd} =$	$\frac{\tau_{Rk}}{\gamma_c} = \frac{14}{1.5} = 9.3\ MPA$

Table 2 bond strength

$N_{si,p,d}$ is the resistance against pullout (by concrete cone failure) of the lower anchorage (Fig. 13):

$$N_{si,p,d} = A_{si} \cdot \frac{0.360}{\gamma_c} \cdot \sqrt{f_{ck}} \cdot \frac{l_{b,inf,i}^{1.5}}{d_{bi}^2}\left(1 + \frac{d_{inf,i}}{l_{b,inf,i}}\right)\ [\mathrm{MN}], [\mathrm{m}] \tag{16}$$

$l_{b,inf,i}$ is the distance between the point where the reinforcement bar intersects the critical shear crack and its lower anchorage plate; $d_{inf,i}$ is the diameter of the lower anchorage plate. It should be noted that this formula is dimension dependent and SI units should be introduced [MN,m].

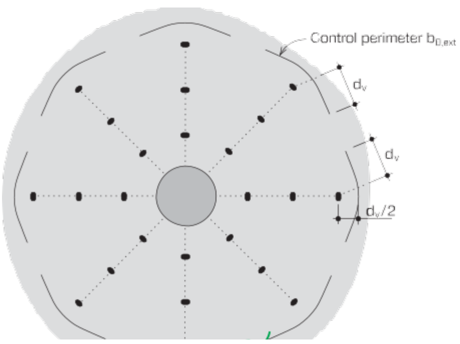


Fig. 15 External perimeter

The size of the reinforced area must be sufficient, so that the punching shear resistance outside the reinforced zone is inferior to the acting shear force on the column minus those forces acting inside the reinforced area. The punching shear resistance outside of the reinforced area is evaluated according to the applicable structural concrete code. It should be noted that the statical height d_V is reduced if the lower anchorage is inside the plate for fire protection or esthetic reasons (see fig. 13). The critical perimeteris defined by the diameter of the strengthened area. From the anchorage of a strengthening anchor a perimeter of not more than two times the effective depth can be taken into account (fig. 15). The external perimeter can be increased by adding intermediate anchors between those with a tangential distance of more than 2d (see green parts in fig. 15).

3.4 Rules for good detailing

In order to obtain a good detailing, the following constructive rules should be followed when designing punching shear reinforcement with Hilti Tension Anchors HZA-P:

3.4.1 Number of radii

The Hilti Tension Anchors HZA-P are placed along a series of radials where the angle between them has to be lower than or equal to 45°:

$\alpha_h \leq 45°$

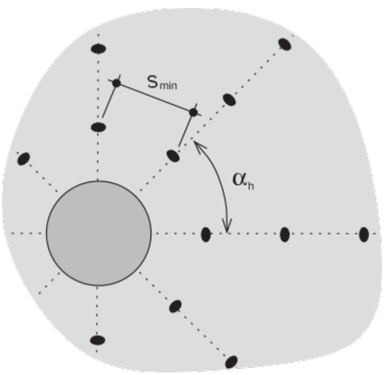
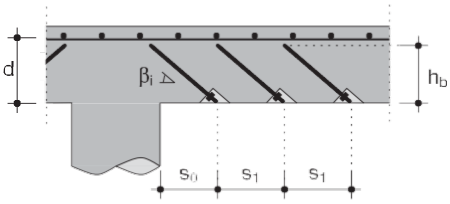


Fig. 16 Angle between radials

3.4.2 Number of reinforcements in a radial

At least two Hilti Tension Anchors HZA-P should be placed at each radial.

3.4.3 Distance between reinforcements and column



The distance of the first anchorage to the border of the column should be lower than or equal than the following value:

$$s_O \leq h_b \cot\beta - 10 \text{ mm}$$

Where *d* refers to the average effective depth of the member $d=(d_x+d_y)/2$.

The distance s_0, in combination with the HZA angles defined ensures that the first intersection of the failure surface (45° punching cone) and the shear reinforcement remains at a distance below 0.75*d* from the edge of the supported area. It shall be noted that low values of s_0 may seriously limit the performance of the Hilti Tension Anchors.

3.4.4 Radial distance between reinforcements

The distance between two anchorages in a radial should be lower than or equal to 0.75d:

$$s_1 \leq 0.75d$$

3.4.5 Axial distance

The minimum distance between axes of HZA-P bars (s_{min}, see figure 16) has to be greater than 3 times the diameter of the bore hole. In absence of other data:

- for HZA M16: smin = 170 mm
- for HZA M20: smin = 200 mm

3.4.6 Direction of the drilled holes

The angle of a Hilti Tension Anchor HZA with respect to the plane of the slab has to be in between 40° and 50°. Other values of this angle shall be justified in special cases:

$$40° \leq \beta_i \leq 50°$$

3.4.7 Length of the drilled holes

The height at which a Hilti Tension Anchor HZA-P should be bonded (h_b) is equal to d:

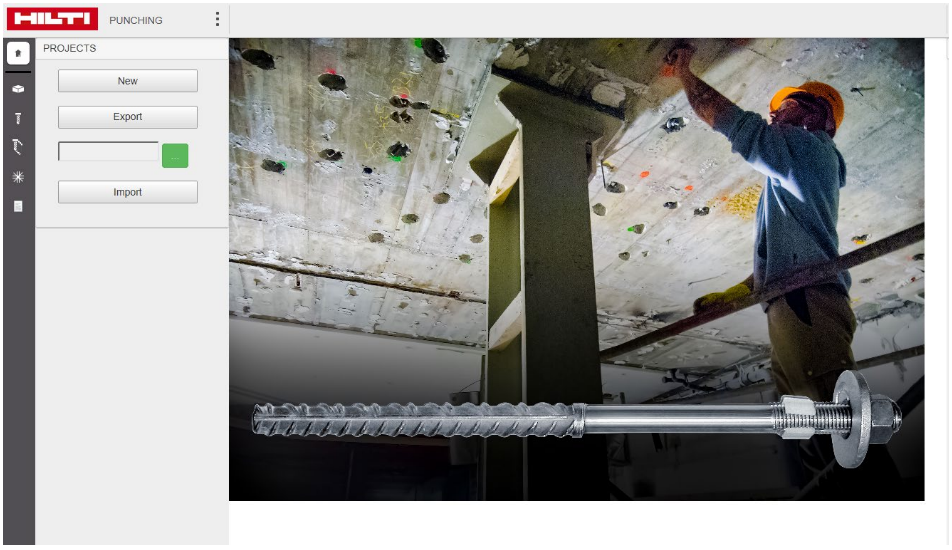
$$h_b = d$$

In cases where tensile reinforcement is intersected when the hole is being drilled, the bonded height (h_b) can be reduced in order not to cut the tensile reinforcement. The estimate of the strength of the system should be performed with a value of h_b that accounts for this possibility.

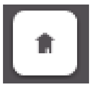
4 Hilti Design Tool Punching

The Hilti Design Tool Punching is the online design software for the strengthening of structural parts against punching shear with Hilti Tension Anchors HZA-P. It carries out the design according to section 3.

The resistance of the non-reinforced structural part, the maximum possible punching resistance (failure of compressed concrete at limit of column) and the punching shear resistance outside of the reinforced area are calculated by section 3. They should also be checked by the designer according to the applicable structural concrete code. The user enters all necessary data on the entry screen. If the concrete contribution should not exceed that given by the applicable structural code, this value can be entered as “concrete contribution according to code”.

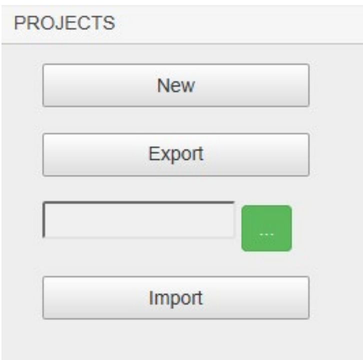


Based on the evaluation of the punching shear resistance of the non-reinforced slab and on the maximum possible punching shear resistance of the reinforced part, the user is informed, whether reinforcing with Hilti HZA-P is possible.



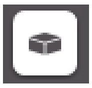
4.1 Start Menu

After Login the user can start a new project or import an existing project file from his computer. During design, the user can also use the export function to save a project on his computer.

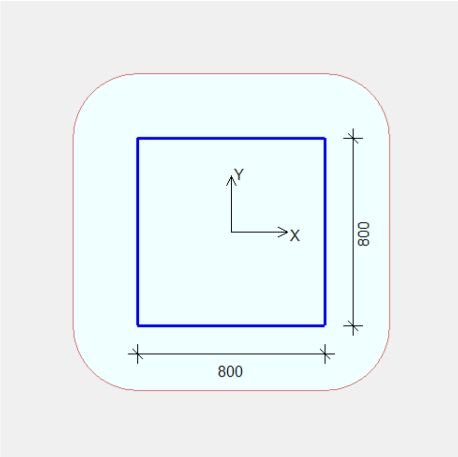


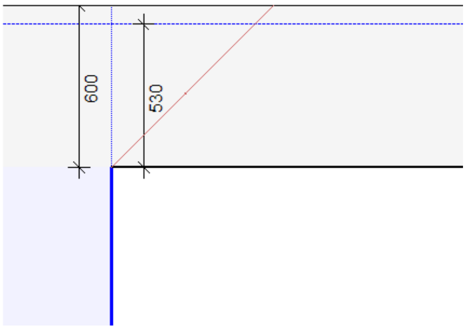
Please note that the user will be automatically logged out after being inactive for a while. For receiving your personal user account, please contact your local Hilti Engineering Support representative.

4.2 Geometry and Design Values

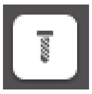


Gives user the possibility to enter existing geometry, design values, material properties and loading. Loading should always be entered as value covering all loads including dead loads.





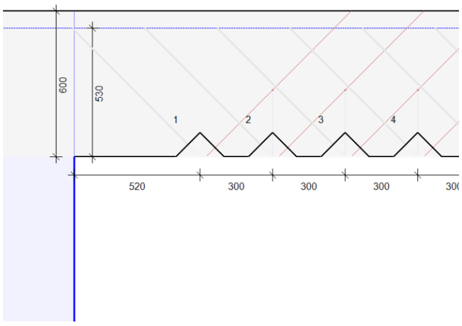
4.3 Reinforcement Anchor

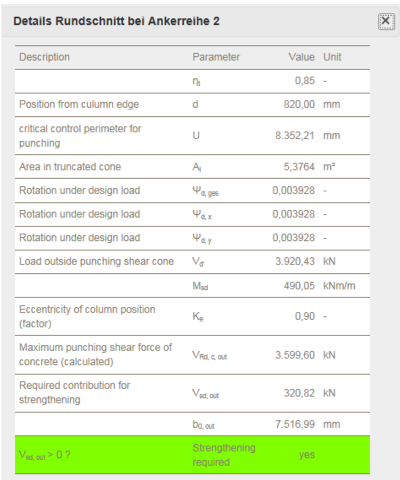


The user can enter data concerning the diameter of reinforcing bars, the distance between the first anchorage and the column edge and the radial distance between two reinforcements.

4.4 Reinforcement Anchor Series

Shows an overview of anchors and gives detailed data in case an anchor is selected.

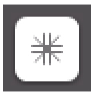




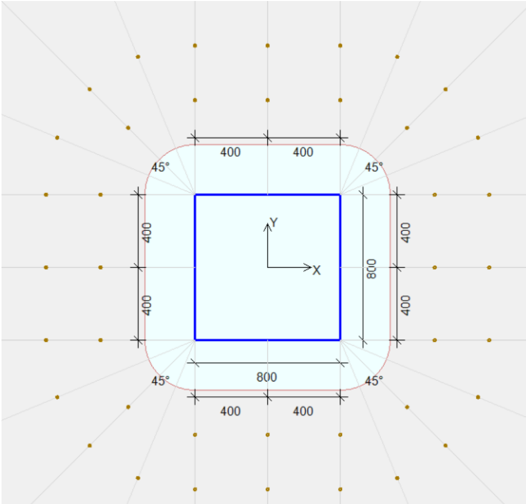
Details Rundschnitt bei Ankerreihe 2

Description	Parameter	Value	Unit
	η_t	0,85	-
Position from culumn edge	d	820,00	mm
critical control perimeter for punching	U	8.352,21	mm
Area in truncated cone	A_i	5,3764	m²
Rotation under design load	$\Psi_{d, ges}$	0,003928	-
Rotation under design load	$\Psi_{d, x}$	0,003928	-
Rotation under design load	$\Psi_{d, y}$	0,003928	-
Load outside punching shear cone	$V_{d'}$	3.920,43	kN
	M_{sd}	490,05	kNm/m
Eccentricity of column position (factor)	K_e	0,90	-
Maximum punching shear force of concrete (calculated)	$V_{Rd, c, out}$	3.599,60	kN
Required contribution for strengthening	$V_{sd, out}$	320,82	kN
	$b_{0, out}$	7.516,99	mm
$V_{sd, out} > 0$?	Strengthening required	yes	

4.5 Reinforcement Layout



This section allows the user to define the layout and optimize the layout by using the Automatic Layout function. The selected view will be transferred into the report. The number of reinforcements in one radial is automatically selected in such a way that proof of the punching shear resistance outside of the reinforced area can be performed with the model of section 3.



4.6 Report

Creates a report with comprehensive information and calculation details. Furthermore, the user data can be entered to be included in the report. By clicking the “Generate Report” function, the Hilti Design Tool will open the report as PDF document in a new tab of the browser. Afterwards the user can save the PDF on his computer.

4.7 General Information

When using the Hilti Design Tool Punching, the user will receive notifications and design results in the corresponding areas on the right side of the program.

NOTIFICATIONS

× Anker Winkel max 50 °

× **Anker s0 max 435 mm**

RESULTS

Required strengthening in the anchor series position

Anchor		Position [mm]	$V_{Rd, c, out}$ [kN]	$V_{Sd, out}$ [kN]
2	(i)	735	3.369,43	586,73
3	(i)	1.035	4.181,80	0,00

Results total system

Parameter	Value	Unit
Anchor series constructive	2	
Anchor series activated	2	
Anchor series strengthening	2	
Anchor series total	2	
Anchor series check	fullfilled	

When entering the above data, the user is constantly informed whether the selected reinforcing arrangement is sufficient or not.

Once the user has selected a satisfying reinforcement arrangement, he finds all the necessary design proofs in the report, which can be printed and added to a structural design document.

4.8 Additional Information

Input of data
In case the user wants to change values in the design tool, they will only be effective ones they are confirmed by pressing the enter button or by changing the tabulator into another field.

Time-Out
The design tool will automatically logout the user after a certain period of inactivity. Please be aware that afterwards the tool has to be restarted and data is not saved automatically. We suggest to save your projects during design or before taking breaks by exporting them to your computer.

Foundations
The design tool can also be used to cover punching shear reinforcement for foundations. The fib Model Code 2010 does not distinguish between both applications and therefor the basic control perimeter is in both cases at a distance of 0.5d from the column, as implemented in the design tool.

Cracked/Uncracked Concrete
The Hilti Design Method for punching shear reinforcement takes into account the bond strength design value of Hilti HIT-RE 500V3 mortar $\tau_{bd} = \frac{14}{1.5}$ = 9.3 N/mm² according to ETA-16/0143 (table C3). The design method goes beyond existing theory of uncracked/cracked concrete for anchoring. For the HZA-P system it is decisive, that the bond has to be active in ULS and even in case of failure of the base material, not only during SLS with crack limitation to 0.3mm. Therefor the parameter “bond strength” was validated during our research on large scale tests and the design method was calibrated accordingly.

Delta (h_{inf})
By adjusting the delta value in the design tool, the user can decide how to place the HZA-P system (e.g. countersunk or flush to the surface). The following recommendation is given for the standard HZA-P system, leading to a cover of approximately 20 mm:

M16: Δh_{inf} = 40 mm

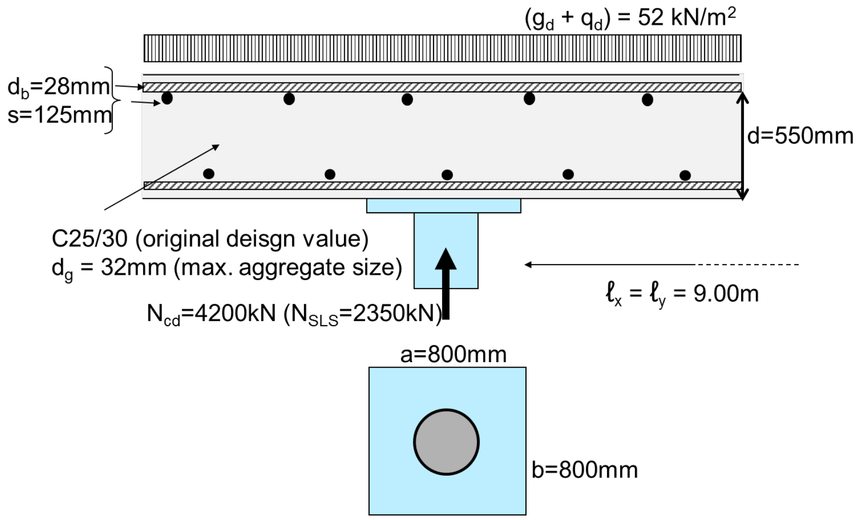
M20: Δh_{inf} = 50 mm

Please be aware, that in case of flush setting, external anchor heads have to be used to distribute the forces to the concrete surface.

5 Example

Strengthening of a ceiling

Given



Material parameters

Long-term influence — value for f_{ck} is current value: $\eta_t = 0.85$

Concrete — f_{ck} = 25 N/mm²

$$f_{cd} = \frac{\eta_t \cdot f_{ck}}{\gamma_C} = \frac{0.85 \cdot 25}{1.5} = 14.2 \text{ N/mm}^2 = 14200 \text{ kN/m}^2$$

Reinforcing steel — f_{yd} = 435 N/mm² = 435000 kN/m²

E_s = 200 GPa = $200 \cdot 10^6$ kN/m²

Bending resistance of slab

Reinforcement ratio

$$\rho = \frac{\phi^2 \pi / 4}{bd} = \frac{28^2 \pi / 4}{125 \cdot 550} = 0.90\ \%$$

Bending resistance

$$z \cong 0.9 \cdot d = 0.9 \cdot 0.55 = 0.495$$

$$m_{Rd} = \rho \cdot d \cdot f_{yd} \cdot z = 0.9\% \cdot 0.55 \cdot 435000 \cdot 0.495 = 1066 \text{ kNm/m}$$

Punching shear resistance of slab as is

Shear resistance

$$V_{Rd,c} = k_\psi \cdot \frac{\eta_t \cdot \sqrt{f_{ck}}}{\gamma_C} \cdot b_0 \cdot d = 0.338 \cdot \frac{0.85 \cdot \sqrt{25}}{1.5} \cdot 4.44 \cdot 550 = 2336 \text{ kN} \qquad (1)$$

Basic control perimeter

$$b_1 = 4 \cdot a + d \cdot \pi = 4 \cdot 0.80 + 0.55 \cdot \pi = 4.93 \text{ m}$$

Area inside basic c.p.

$$A_i = a^2 + 4 \cdot a \cdot \frac{d}{2} + \left(\frac{d}{2}\right)^2 \cdot \pi = 0.8^2 + 4 \cdot 0.8 \cdot 0.275 + 0.275^2 \cdot \pi = 1.76 \text{ m}^2$$

Influence eccentricity — inner column, regular spacing

$$k_e = 0.9 \qquad (8)$$

Shear resisting control perimeter $b_0 = k_e \cdot b_1 = 0.9 \cdot 4.93 = 4.44$ m (8)

Punching shear load

$V_d = N_{cd} - (g_d + q_d)A_i = 4200 - 52 \cdot 1.76 = 4109$ kN

Average bending moment inner column

$m_{sd} = \frac{V_d}{8} = \frac{4109}{8} = 514$ kNm/m (4)

Distance contraflexure

$r_s = 0.22\ell = 0.22 \cdot 9.0 = 1.98$m

Rotation at design load

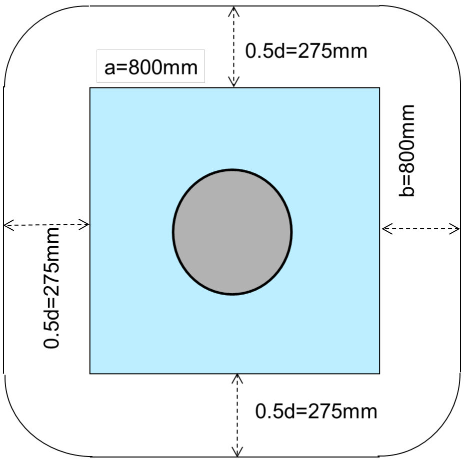
$\psi_d = 1.5 \cdot \frac{r_s}{d} \cdot \frac{f_{yd}}{E_s} \cdot \left(\frac{m_{sd}}{m_{Rd}}\right)^{\frac{3}{2}} = 1.5 \cdot \frac{1.98}{0.55} \cdot \frac{0.435}{200} \cdot \left(\frac{514}{1066}\right)^{\frac{3}{2}} = 0.003928$ (3)

Influence aggregate size

$k_{dg} = \left(\frac{32}{16+d_g} \geq 0.75\right) = \left(\frac{32}{16+32} \geq 0.75\right) = 0.75$

Influence of rotation

$k_\psi = \frac{1}{1.5 + 0.9 \cdot k_{dg} \cdot \psi_d \cdot d} = \frac{1}{1.5 + 0.9 \cdot 0.75 \cdot 0.003928 \cdot 550} = 0.338$ (1)



The punching shear resistance $V_{Rd,c}$ = 2366 kN is lower than the acting shear load V_d = 4109 kN. Therefore, the slab must be strengthened.

Suitability of Hilti HZA-P System

Concrete crushing

$V_{Rd,max} = 2.6 \cdot k_\psi \cdot \frac{\eta_t \cdot \sqrt{f_{ck}}}{\gamma_c} \cdot b_0 \cdot d = 2.6 \cdot 0.338 \cdot \frac{0,85 \cdot \sqrt{25}}{1.5} \cdot 4.44 \cdot 550 = 6075$ kN (9)

The maximum punching shear strength $V_{Rd,max}$ = 6075 kN is higher than the acting shear load V_d = 4109 kN. Therefore, the slab can be strengthened with Hilti HZA-P and Hilti HIT-RE 500V3. The force to be taken up by the post-installed punching shear reinforcement is:

Min. reinforcement strength

$V_{Rd,s,red} \geq V_d - V_{Rd,c} = 4109 - 2336 = 1772$ kN (10)

Parameters for design of post-installed shear reinforcement

Reinforcement type:

Hilti HZA-P M20 bonded in with Hilti HIT-RE 500v3

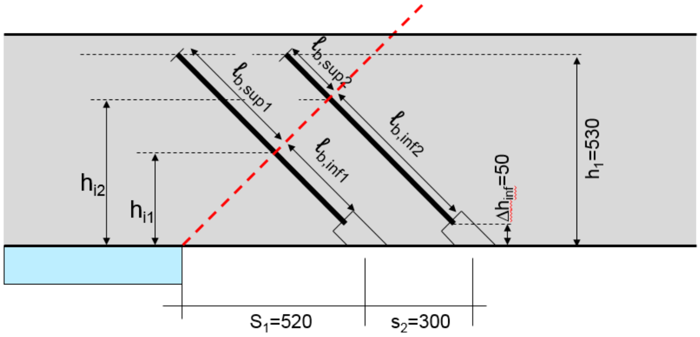
Steel area of bar ϕ20 $A_s = 314$ mm²

Bond strength: $\tau_{bd} = \frac{14}{1.5}$ = 9.3 N/mm²

Anchorage factor: $K_a = 4.33$ MNm$^{0.5}$

Diameter anchor plate $d_{inf} = 60$ mm

Selection of reinforcement layout



$h_{i1} = s_1/2$	$h_{i1} = 260$ mm	$h_{i2} = 410$ mm
$\ell_{b,inf1} = (h_{i1} - \Delta h_{inf}) \cdot \sqrt{2}$	$\ell_{b,inf1} = 297$ mm	$\ell_{b,inf2} = 509$ mm
$\ell_{b,sup1} = (h_b - h_{i1}) \cdot \sqrt{2}$	$\ell_{b,sup1} = 382$ mm	$\ell_{b,sup2} = 170$ mm

Design proof for selected layout

$$\Delta\psi = 1.5 \, \frac{r_s}{d} \cdot \frac{f_{yd}}{E_s} \left[\left(\frac{V_d}{8 m_{Rd}} \right)^{3/2} - \left(\frac{V_{SLS}}{8 m_{Rd}} \right)^{3/2} \right]$$

$$\Delta\psi = 1.5 \, \frac{0.22 \cdot 9}{0.55} \cdot \frac{0.435}{200} \left[\left(\frac{4200}{8 \cdot 1066} \right)^{3/2} - \left(\frac{2350}{8 \cdot 1066} \right)^{3/2} \right] = 0.002360$$

Enter into formulas below forces as [MN], stresses as [N/mm²] or [MN/m²], lengths as [m]:

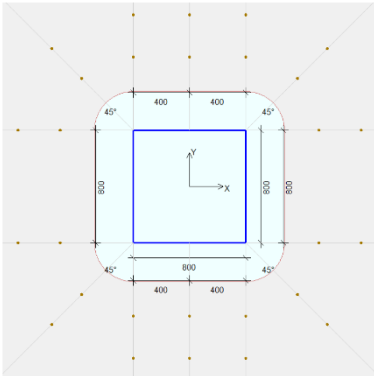
		Bar 1 [kN]	Bar 2 [kN]
Stress activation (X)	$N_{si,el,d} = K_a i \sqrt{\Delta\psi \cdot h_{ii} \cdot \sin(45° + 45°)}$ $N_{si,el,d} = 4.33 \cdot \sqrt{0.002360 \cdot 0.260 \cdot \sin 90°}$	106	133
Steel capacity (X)	$N_{si,pl,d} = A_s \cdot f_{yd}$ $N_{si,pl,d} = 314 \cdot 0.435$	137	137
Bond above crack (x)	$N_{si,b,d} = \tau_{bd} \cdot \phi \cdot \pi \cdot \ell_{b,sup,i}$ $N_{si,b,d} = 9.33 \cdot 20 \cdot \pi \cdot 382$	224	100
Cone below crack (X)	$N_{si,p,d} = A_s \cdot \frac{0.36}{1.5} \cdot \sqrt{f_{ck}} \cdot \frac{\ell_{b,inf,i}^{1.5}}{\phi^2} \cdot \left(1 + \frac{d_{inf,i}}{\ell_{b,inf,i}}\right)$ $N_{si,p,d} = 0.314 \cdot \frac{0.36}{1.5} \cdot \sqrt{25} \cdot \frac{0.297^{1,5}}{0.20^2} \cdot \left(1 + \frac{60}{297}\right)$	183	383
Minimum $N_{si,d}$		106	100

Design strength of one radial in the direction of the load

$$V_{Rd,r} = \sum N_{si,d} \cdot sin45° \cdot k_e = \frac{(106 + 100)}{\sqrt{2}} \cdot 0.9 = 131 \text{ kN}$$

Number of radials

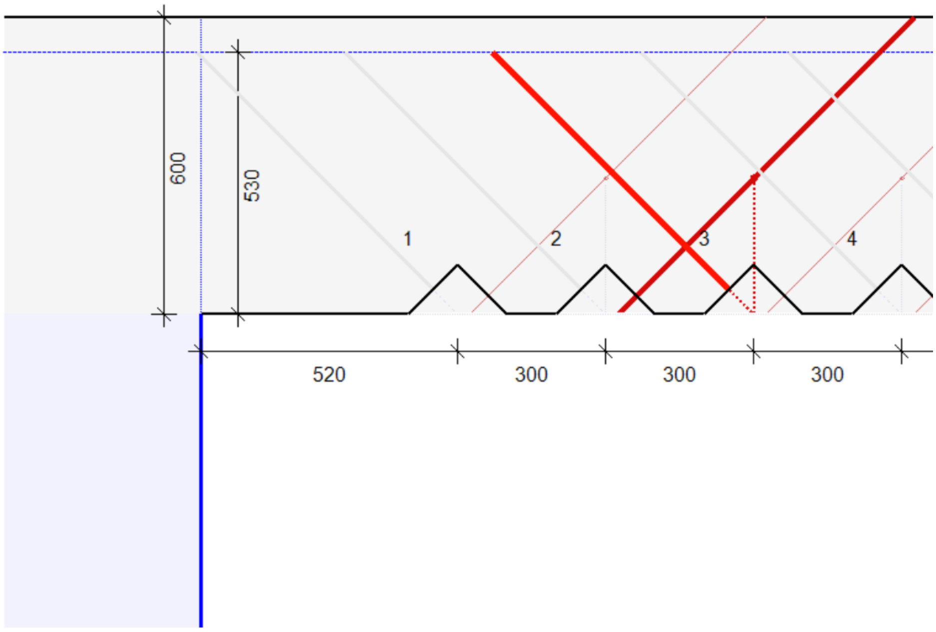
$n \geq \frac{V_{Rd,s,rqd}}{V_{Rd,r}} = \frac{1772.4}{131} = 13.5$ -> select (for symmetry) 14 radials



To strengthen the slab against the punching shear load of 4109 kN, 28 anchors HZA-P M20 are required in the layout shown on the side.

Punching shear resistance outside the reinforced area (Bar 3)

The punching shear resistance outside the reinforced area should now be calculated. If the punching shear resistance outside the reinforced area is not sufficient, then additional anchors Hilti HZA-P can be added to each radial until the external perimeter is large enough. If the lateral distance between anchors becomes larger than allowed, intermediate anchors should be added as described in section 3.4.



Shear resistance

$V_{Rd,c,out} = k_\psi \cdot \frac{\eta_t \cdot \sqrt{f_{ck}}}{\gamma_c} \cdot b_{0,out} \cdot d_V = 0.338 \cdot \frac{0.85 \cdot \sqrt{25}}{1.5} \cdot 9.213 \cdot 500 = 4413$ kN (1)

Effective depth w. reinf. $d_{V,out} = d_V - \Delta h_{inf}$ = 0.50 m

Basic control perimeter (at distance 1120 mm from column)

$b_1 = 4 \cdot a + 2 \cdot d \cdot \pi = 4 \cdot 0.80 + 2 \cdot 1.120 \cdot \pi = 10.24$ m

Area inside basic c.p.

$A_i = a^2 + 4 \cdot a \cdot \frac{3d_v}{2} + \left(\frac{3d_v}{2}\right)^2 \cdot \pi = 0.8^2 + 4 \cdot 1.12 \cdot 0.8 + 1.12^2 \cdot \pi = 8.16$ m²

Influence eccentricity inner column, regular spacing

$k_e = 0.9$ (8)

Shear resisting control perimeter

$b_{0,out} = k_e \cdot b_1 = 0.9 \cdot 10.24 = 9.2$ m (8)

Punching shear load

$V_d = N_{cd} - (g_d + q_d) \cdot A_i = 4200 - 52 \cdot 8.16 = 3775$ kN

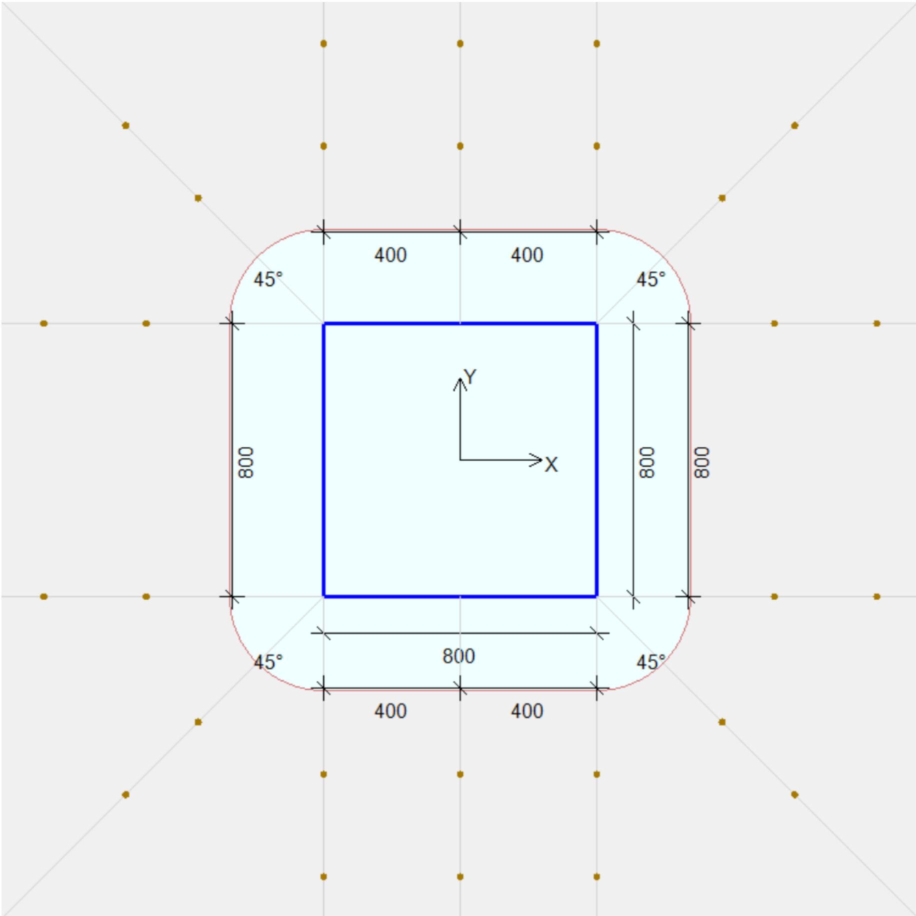
The punching shear resistance $V_{Rd,c}$ = 4413 kN is higher than the acting shear load V_d = 3775 kN. Therefore, further strengthening bars outside the reinforced area are not required.

Max. allowed radial distance between reinforcements: $s_1 \leq 2d$ = 1100 mm

Max. distance of anchors in straight areas: 800.0 mm < 1100 mm

Max. distance of anchor in curved areas: 627.6 mm < 1100 mm

No intermediate anchors are needed.



6 Test results

Hilti has performed tests where shear reinforcement HZA-P was bonded into drilled holes inclined towards the column. This is a continuation of a system that has been investigated at the Royal Institute of Technology KTH in Stockholm in 1995 [2].

It is important that the drilled holes proceed up to at least just below the tensile reinforcement of the slab. As the anchorage quality has a strong influence on the efficiency of shear reinforcement, the reinforcing bars were anchored at the bottom of the bar with an anchorage plate and a nut. In a first step beam tests have shown that the number of reinforcement bars and the characteristics of the used adhesive mortar have the strongest influence on the result.

Slab tests carried out subsequently have shown increases of resistance up to the theoretically possible maximum punching shear resistance. The results of these tests were incorporated into a consistent design concept by Professor A. Muttoni at the Swiss Federal Institute of Technology (ETH) in Lausanne.

In addition to the increase in resistance, slabs reinforced with Hilti Tension Anchors HZA-P also provide a significantly increased deformation capacity. The failure is definitely less brittle than that of non-reinforced slabs. Figure 19 shows the comparison of two tests with a relatively high tension reinforcement ratio. The non-reinforced slab failed at a load of about 1000 kN in a very brittle way. On the other hand, the reinforced slab failed outside of the reinforced area at about 1600 kN after a clear plastic deformation. This corresponds to an increase of the load capacity of 60% and to twice of the deformation capacity. Due to the increased deformation capacity, loads can be redistributed to neighboring columns in case of overloading, which increases the safety of the overall structure.

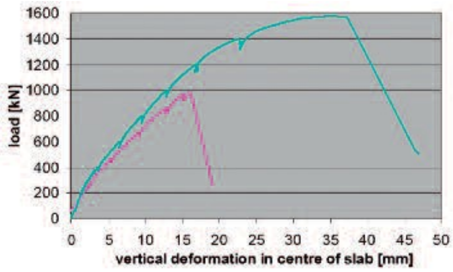


Fig. 19 Load vs. displacement curves

7 References

[1] Muttoni, A., Fernández Ruiz M.: Design of Hilti Tension Anchors HZA as Post-Installed Punching Shear Reinforcement. Lausanne, 2016.

[2] Hassanzadeh, G., “Förstärkning av brobaneplattormed häsyn till stansing“ („Strengthening of bridge slabs with respect to punching”),Master of Civil Engineering, Thesis, KTH, Stockholm, 1995 (in Swedish)

[3] Muttoni, Aurelio, Miguel Fernández Ruiz, and J. Kunz. "Nachträgliche Durchstanzbewehrung zur Verstärkung von Stahlbetonflachdecken." Bauingenieur, Springer VDI Verlag 83.EPFL-ARTICLE-134653 (2008): 503-511.

[4] Ruiz, Miguel Fernández, Aurelio Muttoni, and Jakob Kunz. "Strengthening of flat slabs against punching shear using post-installed shear reinforcement." ACI Structural Journal 107.4 (2010): 434.

8 Installation procedure

8.1 Detection and marking of the existing lower reinforcement

An area of at least 180 cm x 180 cm of the slab around the column is detected with the Ferroscan System PS 200 and the lower reinforcement is marked. Then, the pattern of the anchorages is marked.

Fig. 20 Location of reinforcement with Ferroscan PS 200

8.2 Drilling and borehole preparation

Hilti HIT-RE 500 V3
Installation guide for fastenings in concrete

The installation guide described here is a reduced version of the installation guide for fastenings in concrete.

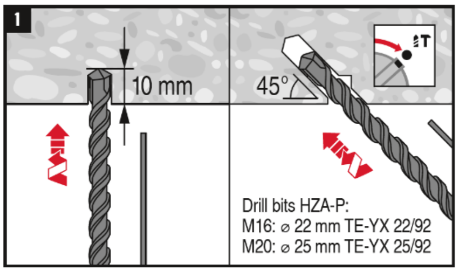
In this brochure the focus is on the installation procedure for Hilti Tension Anchors HZA-P which will be installed overhead. For the complete installation guide please refer to the Instruction for Use of Hilti HIT-RE 500V3 injection mortar.

- **Observe this guide for use and safety precautions before using Hilti HIT systems**
- **International and national approvals take precedence for approval governed applications**
- **Observe the Instructions for Use provided with each foil pack and the dispenser in use**
- **For updates of the present document, please refer to** www.hilti.group
- **For the availability of the Hilti products referenced in this document, please contact your local Hilti representative**

Safety Regulations:

- Review the Material Safety Data Sheet (MSDS) for use
- Wear well-fitting safety glasses, protective gloves and suitable protective clothing when working with Hilti HIT injection mortar
- Read the Installation guide

8.2.1 Borehole drilling (Hammer drilling)



- Drill about 10 mm vertically upward
- Rotate tool
- Drill the boreholes under an angle of 45° to the surface to the required embedment depth using a hammer-drill with an appropriately sized carbide drill bit set in rotation hammer mode.

Use the following drill bits:
- HZA-P M16: Ø 22 mm (e.g. TE-YD 22/89 or TE-YX 22/92)
- HZA-P M20: Ø 25 mm (e.g. TE-YD 25/89 or TE-YX 25/92)

A special drilling stand is available on request for guided drilling under 45° angle with higher precision and comfort.

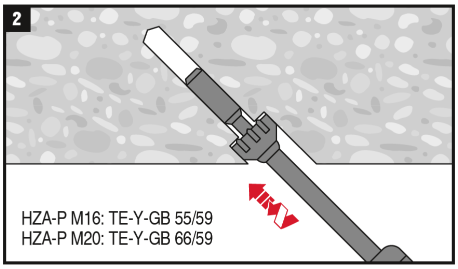
Please not that diamond coring is not permitted to avoid cutting of existing reinforcement.

By using Hilti TE-YD hollow drill bit with Hilti VC vacuum cleaners dust emissions can be reduced. Furthermore, by using Hilti hollow drill bits the borehole will be cleaned automatically to avoid the following necessary cleaning procedure described in section 8.2.3.

The suggested tool for drilling the holes is the rotary hammer Hilti TE 70.

Fig. 21 Drilling with special drilling stand and hollow drill bit for automatical borehole cleaning

8.2.2 Extension of drill holes for lower anchorage



In case of countersunk installation, the borehole has to be extended to fit the anchor head. The extension of the borehole should be done according to the given Δh_{inf}.

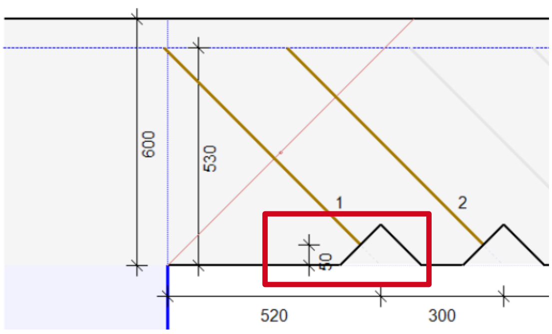
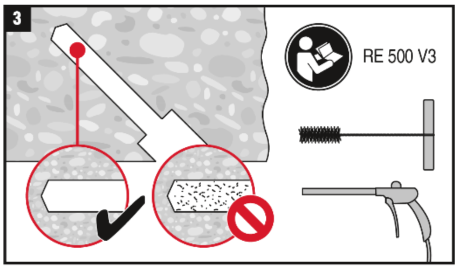


Fig. 22 Visualization of Δh_{inf} in Design report

Fig. 23 Widenin of borehole with special srill bit TE-Y-GB

For HZA-P M16: use special drill bit TE-Y-GB 55/59
For HZA-P M20: use special drill bit TE-Y-GB 66/59



8.2.3 Borehole cleaning

Load performances of chemical anchors are strongly influenced by the cleaning method. Inadequate borehole cleaning leads to poor load values. Design of HZA-P punching shear reinforcement is done with bond strength values for hammer drilling.

The borehole must be free of dust, debris, water when applicable, ice, oil, grease and other contaminants prior to mortar injection. Please refer to instructions for use of Hilti HIT-RE 500V3 injection mortar for applicable cleaning methods. The following instructions may give an overview but might not cover all conditions.

a) Compressed air
- at 6 m^3/ hour until return air stream is free of noticeable dust. Perform this step 2 times.
- For boreholes deeper than 250 mm, use the appropriate air nozzle Hilti HIT-DL (oil free compressed air ≥6 bar) – see Table II for the corresponding air nozzle / drill bit combination.
- Connect the selected air nozzle with the appropriate air cleaning extension: HIT-DL 20 or HIT-DL 25 with HIT-DL 16/0.8 or HIT-DL B and/or HIT-VL 16/0.7 and/ or HIT-VL 16.

Tips:
- Keep away from dust cloud, do not inhale concrete dust.
- Hilti recommends a dust collector or other equipment to collect the dust during the blowing operation.

b) Brushing
- Brush extensions HIT-RBS for machine brushing shall be used to accommodate cleaning of boreholes deeper than 250 mm.
- Select the corresponding brush extension HIT-RBS according to Table IV.
- Attach the round steel brush, HIT-RB, on one end of the brush extension(s) HIT-RBS, in order to reach the back of the borehole.
- Secure the other extension end into the TE-C/TE-Y (-T) holder.

Tips:

- Start machine brushing operation slowly.
- Start brushing operation once brush is inserted in borehole.

Cleaning set

Round steel brush	Extension	Holder
HIT-RB	HIT-RBS 10/0.7	TE-Y

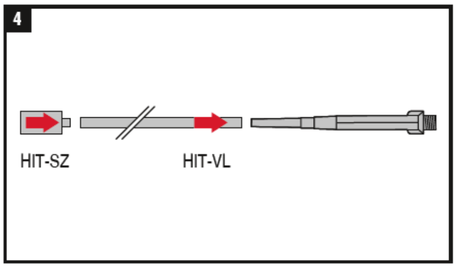
c) Compressed air

- Blow out the hole again from the back of the hole with compressed air until return air stream is free of noticeable dust. Perform this step 2 times.

8.3 Injection preparation

Prepare injection extension

- Use the static mixer that is delivered with the mortar
- Attach the injection extensions HIT-VL 16/0.7 or HIT-VL 16 to the static mixer
- Do not modify the static mixer
- Attach the piston-plug HIT-SZ to the extension



Determine anchor length

- Calculate the total length for HZA-P as shown in following example:

$$l_{e,ges} = \frac{(\mathrm{h} - \Delta \mathrm{h}_{inf})}{\sin\alpha} = \frac{(530-50)}{\sin 45°}$$

- Add 30 mm (M16) / 35 mm (M20) so that enough thread is outside the borehole to fasten the anchor head at a later stage
- Cut the HZA-P anchor at the rebar side to the correct length

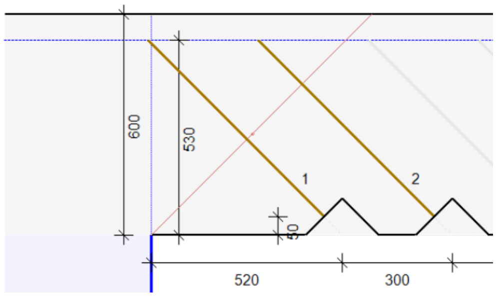


Fig. 24 Visualization of dimensions in Design report

Mark embedment depth and filling length

- Mark full embedment depth $l_{e,ges}$ on extension HIT-VL to be able to control full embedment when starting injection
- Mark filling length l_m at 1/3 of embedment depth $l_{e,ges}$ to inject approximately 2/3 of the borehole with mortar

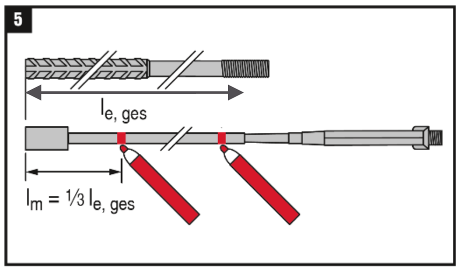
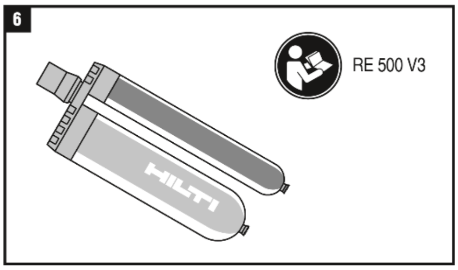


Fig. 25 Preparation of extension HIT-VL



Tightly attach mixer to foil pack manifold

- Attach the static mixer tightly on to the manifold before starting to dispense

Prepare foil pack and dispenser

Please refer to instructions for use of Hilti HIT-RE 500V3 injection mortar for necessary preparation of foil pack. The following instructions may give an overview but might not cover all conditions.

Insert foil pack in foil pack holder

- Observe the Instructions for Use of the dispenser
- When using Hilti HDE 500-A22 battery dispenser, make sure to use black cartridge holder HIT-CB 500
- Check cartridge holder for proper function
- Put foil pack into cartridge holder
- Do not use damaged foil packs / holders

Insert foil pack holder with foil pack into dispenser

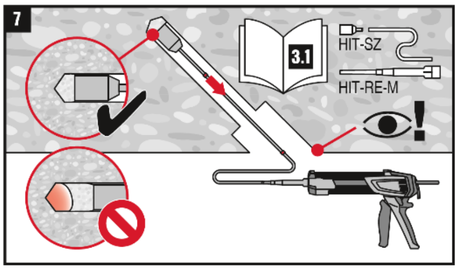
- Please refer to the Instructions for Use of the dispenser
- The efficient installation of the anchors is supported by the use of the large cartridges HIT-RE 500 V3, 1400 ml and the compressed air dispenser HIT P-8000-D.

Discard initial amount of mortar

- Observe the Instructions for Use of the mortar for the amount of mortar that has to be discarded
- The foil pack is self-opening when dispensing begins, do not pierce the foil pack manually (this can cause system failure)
- After changing a mixer, first trigger pulls must be discarded
- For each new foil pack a new static mixer must be used

Fig. 26 Discarding of initial amount of mortar

8.4 Injection of mortar

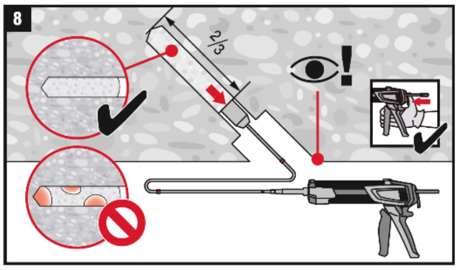


Inject mortar into borehole starting from the back of the borehole without forming air voids

- Verify if borehole conditions have changed after cleaning. If yes, repeat cleaning steps.
- The mixer extension with the piston plug should be inserted to the back of the bore-hole without resistance
- Inject the mortar from the back of the borehole after controlling that the depth of the borehole corresponds to the design value by checking the embedment mark on the extension

Fig. 27 Injection of mortar (Start position)

- During the injection the piston plug will be naturally pushed out of the borehole by the mortar pressure
- Attention: by pulling the mixer extension with piston plug, the piston plug may be rendered inactive and air voids may occur



- Fill holes approximately 2/3 full, or as required to ensure that the annular gap between the anchor/rebar and the concrete is completely filled with mortar over the entire embedment length

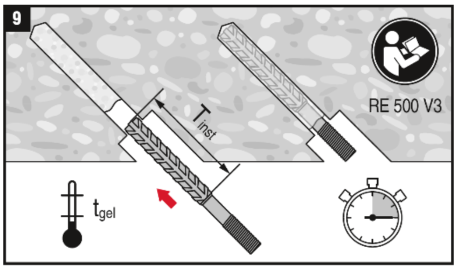
Fig. 28 Injection of mortar (End position)

Special Case: Injection overhead

Take care!
- Observe the Instructions for Use of the mortar for the use of piston plugs HIT-SZ in case of overhead applications.
- The flexible hose HIT-VL has to be used and connected to the static mixer.
- During the injection the elongations have to be secured in such a way that the pressure in the mortar during the injection is clearly noticeable.
- Attention: the connection between static mixer and foil pack may be disconnected. In the case of injection with the dispenser HIT-P 8000 D, secure the connection between the static mixer and the elongations e.g. with tape

Depressurize the dispenser
After injecting the mortar, depressurize the dispenser by pressing the release button. This will prevent further mortar from escaping out of the mixer.

8.5 Installation of the punching shear reinforcement



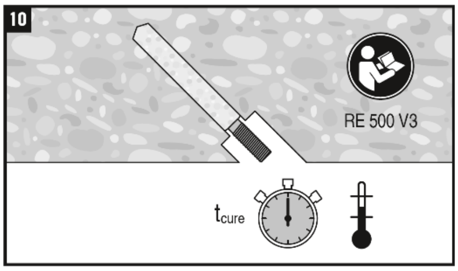
Insert element into the borehole
- Mark the element at the required embedment depth $l_{e,ges}$
- Place the center ring at the thread
- Set the element to the required embedment depth. **Embedment depth must be equal to the design specification.**
- Before use, verify that the element is dry and free of oil or other residue
- To ease installation, elements may be slowly twisted as they are inserted
- After installing an element, the annular gap must be completely filled with mortar and the center ring should be completely embeded in the borehole
- At least 30 mm (M16) / 35 mm (M20) of the thread should be outside the borehole to be able to fasten the anchor head at a later stage

Observe the gel time t_{gel}, which varies according to the temperature of base material. Please refer to the Instructions for Use of the mortar for details about t_{gel}. Minor adjustments to the element may be performed during the gel time. For the gel time see relevant information in the Instructions for Use of the mortars.

Fig. 29 Installtion of HZA-P anchor

Special Case: Installation overhead

- Take special care when inserting the element
- Excess mortar will be forced out of the borehole and might start dripping. Contact with dripping mortar has to be avoided absolutely.
- To ease installation, use the overhead dripping cup (HIT-OHC 2, item no. 387552) and push it to the mark $l_{e,ges}$
- Insert the element with the dripping cup into the borehole
- Remove and dispose the overhead dripping cup with the excess mortar safely. The overhead dripping cup is a throw-away item.
- The element is secured during the curing time t_{cure} with the center ring



Do not disturb the element

Once the gel time t_{gel} has elapsed, do not disturb the element until t_{cure} has passed. Please refer to the Instructions for Use of the mortar for details about t_{cure}.

8.6 Installation of anchor head

After curing of the injection mortar HIT-RE 500V3 the anchor head is installed.

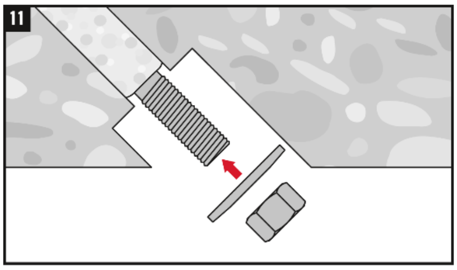
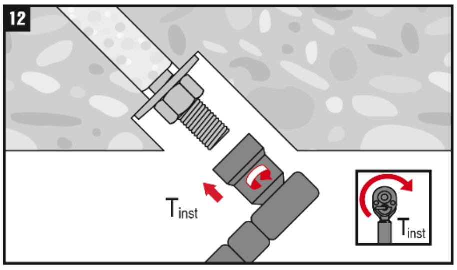


Fig. 30 Installation of anchor head



8.6.1 Installation of injection washer and nut

The injection washer HIT M16, spherical washer C17 und nut M16 or injection washer HIT M20, spherical washer C21 und nut M20 are fixed to the thread. The installation torque moment of 100 Nm (HZA-P M16) or 160 Nm (HZA-P M20) is applied afterwards by using a torque wrench.

Fig. 31 Application of torque moment

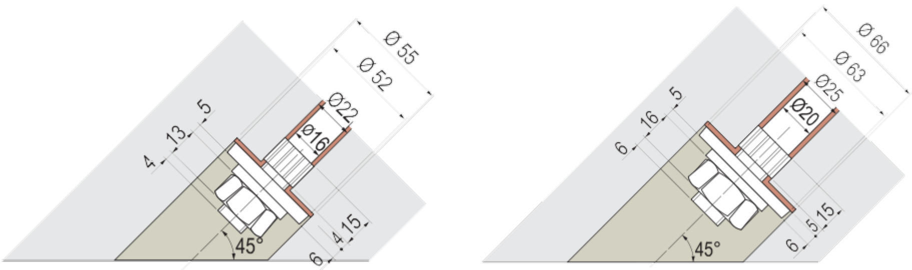
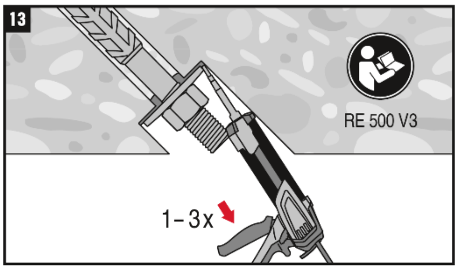


Fig. 32 Anchor head and hole extension HZA-P M16 (left) and M20 (right)

8.6.2 Injection of the washer with HIT-RE 500V3



After application of the torque moment, the washer of the anchor head is injected with adhesive mortar Hilti HIT-RE 500V3.

Fig. 33 Injection of mortar into washer

8.6.3 Filling of hole extension with fire protection mortar CP 636

The anchor head is covered with fire protection mortar CP 636.

Fig. 34 Final filling with fire protection mortar

9 Materials

Hollow drill bits

Ordering designation	for size	Item no.
TE-YD 22/59	M16	2018960
TE-YD 22/52 MP4	M16	2018971
TE-YD 22/89	M16	2078872
TE-YD 25/59	M20	2018962
TE-YD 25/59 MP4	M20	2018973
TE-YD 25/89	M20	2078876
TE-YD 25/119	M20	2078877

Drill bits

Ordering designation	for size	Item no.
TE-YX 22/32	M16	2122300
TE-YX 22/32 MP4	M16	2122301
TE-YX 22/52	M16	2122302
TE-YX 22/52 MP4	M16	2122303
TE-YX 22/92	M16	293177
TE-YX 25/32	M20	2122274
TE-YX 25/32 MP4	M20	2122275
TE-YX 25/52	M20	2122276
TE-YX 25/52 MP4	M20	2122277
TE-YX 25/72	M20	427848
TE-YX 25/92	M20	293229
TE-YX 25/130	M20	293230

Widening drill bits for embedment of the anchorage

Ordering designation	for size	Item no.
TE-Y GB 55/36	M16	261862
TE-Y GB 66/36	M20	261863

Material for borehole cleaning

Ordering designation	for size	Item no.
Round brush HIT RB 22	M16	370774
Round brush HIT RB 25	M20	336553
Extension RB 10/07	M16/M20	336645
Holder TE-C	M16/M20	263437
Holder TE-Y	M16/M20	263439
Pressurized air injector	M16/M20	381215
Air nozzle HIT DL 20	M16	371719
Air nozzle HIT DL 24	M20	371720
Extension Pressurized air injector	M20	336553

Hilti tension anchor HZA-P

Ordering designation	Package contains	Item no.
HZA-P M16x350	20 pieces incl. accessories	388729
HZA-P M16x700	20 pieces incl. accessories	2153239
HZA-P M16xlength		on request
HZA-P M20x700	10 pieces incl. accessories	388730
HZA-P M20x1000	10 pieces incl. accessories	2121078
HZA-P M20xlength		on request

The tension anchors HZA-P are delivered with accessories (1 injection washer, 1 spherical washer, 1 nut and 1 center ring per anchor). The shown lengths are total lengths of the anchor. Specific lengths must be shortened according to the requirements of the project or ordered as special.

Injection mortar

Ordering designation	Item no.
Hilti HIT-RE 500V3/1400	2123409
Hilti HIT-RE 500V3/1400 (32)	2203094
Hilti HIT-RE 500V3/1400 (64)	2199372
Hilti HIT-RE 500 V3/500	2123406
Hilti HIT-RE 500 V3/500 (20)	2144844
Hilti HIT-RE 500 V3/330	2123403
Hilti HIT-RE 500 V3/330 (25)	2144842

Dispensers

Ordering designation	For size	Item no.
Pneumatic dispenser P 8000 D	1400 ml	373959
Cartridge holder P 8000 D	1400 ml	373960
Battery dispenser HDE 500-A22	500/330 ml	2200644
Cartridge holder HIT-CB 500 (black)	500/330 ml	2007057

Injection accessories

Ordering designation	For size	Item no.
Mixer HIT-RE-M	330/500/1400 ml	337111
Extension tube HIT-VL-16/0.7 m (10)		336646
Extension tube HIT-VL-16/10 m		38249
Piston plug HIT-SZ 22	M16	2039312
Piston plug HIT-SZ 25	M20	2039315
Drip guard HIT-OHC2	M16/M20	387552

Fire protection mortar

Ordering designation	Item no.
Fire protection mortar Hilti CP 636	334897

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