# GOOD TO KNOW

Design of post-installed rebar connections with PROFIS Engineering

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

Anchor theory covers both single anchor fixed points and anchor groups in steel anchor plate fixtures while rebar theory is the discipline used for concrete member connections through post-installed reinforcement bars and adhesive.

## THE NECESSITY OF POST-INSTALLED CONNECTORS

Today, most construction projects require the installation of concrete-to-concrete or steel-to-concrete fixtures, which are often secured by post-installed injection mortars. These are specified during the design stage or are needed during the execution phase to improve jobsite efficiency or to correct installation errors.

### The difference between anchor and rebar theory

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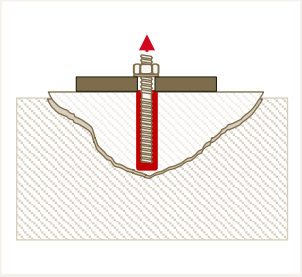


**Abb. 1:** Connection with post-installed anchors

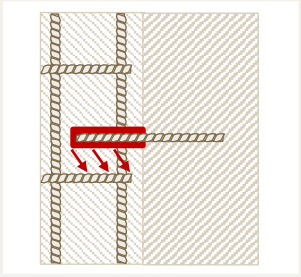


**Abb. 2:** Connection with post-installed rebar

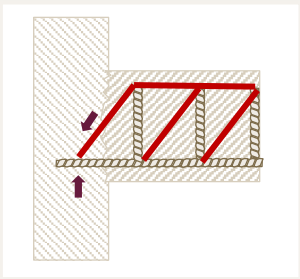


**Abb. 3:** Strut and tie model

The regulatory framework covering anchor and rebar is based on different theoretical principles, design approaches and qualification processes. For anchors you can follow the EN 1992-4 whereas for post-installed rebar you either have the option of designing acc. to EN 1992-1 or TR 069.
Just calculating the embedment depth of the rebar as an anchor (possible to a certain extent, since rebars can be qualified as a steel element for anchoring applications) might not be in line with the code utilized in the concrete design.

### Anchor Theory

Using anchor theory, the load from a steel member is transferred to the concrete structure – through an anchor plate that is fixed to the concrete – using an anchor bolt fixing. The steel elements of the fixing transfer the load to the existing concrete element through either tensile load or shear load, or a combination of both. Leveraging the concrete's inherent tensile strength is essential for the fixing to resist the load. It means that the brittle concrete cone failure is accepted and accounted for in the design.

### Rebar Theory

According to the rebar theory the load is transferred to the concrete in the same way as with a cast-in reinforcement bar. Connections are designed through strut-and-tie modeling. In the case of a splice (or overlap) connection, the load is transferred through a local strut-tie mechanism in the same way as with a cast-in non-contact reinforcement bar splice. The brittle concrete failure mode is prevented by means of global or local compressive struts; therefore, international reinforced concrete code design rules do not consider the concrete's tensile capacity and expect all tensile forces to be resisted by rebars.

### The main differences of anchor and rebar theory can be differentiated in the qualification process and the design approach

- Qualification procedure

Whether you design a post-installed steel-to-concrete or concrete-to-concrete connection, in both cases you should rely on qualified systems that are consistent with the regulatory framework adopted for the project (i.e. ETA document). Both design theories are supported by different qualification procedures in line with the application conditions covered in the approval (e.g. static, seismic).

- The design approach

When designing a post-installed anchor group, the design capacity of the selected layout is calculated and then compared with the design load, in an approach such as normal structural design according to limit state principles. For post-installed rebar connections, the outcome of the calculation is the anchorage length for simply supported and moment connections, or lap length for splice connections, which follow similar rules to cast-in reinforcement.

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

With the Rebar Revolution of EOTA TR 069 you can design your post-installed rebars with beyond cast-in bond strength for mortars tested according to EAD 332402-00-0601.

## What is EOTA TR 069 and why do we talk about a Rebar Revolution?

2

Post-installed rebar is used both in new and in existing buildings. Typical connections are new to existing concrete walls, anchoring stair landings, connecting of stair landings, connections of ceilings to wall panels or wall panels or anchoring columns in existing foundations. The basic prerequisite for the transmission of planned tensile forces or to design a moment bearing connection was till recently the construction as an overlapping joint. This means in accordance to EAD 330087 and DIN EN 1992-1-1 with concreted-in, straight concrete steels.

Rebar Revolution refers to the 2019 launched technical Report EOTA TR069 «Design method for anchorages of post-installed reinforcing bars (rebars) with improved bond-splitting behaviour as compared to EN 1992-1-1» that allows the design of post-installed moment resisting reinforced concrete connections on a European level, which do not have to be executed as overlap joints.

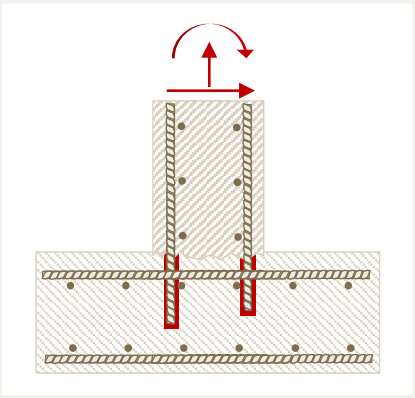


**Abb. 4: Design acc. to EOTA TR069**

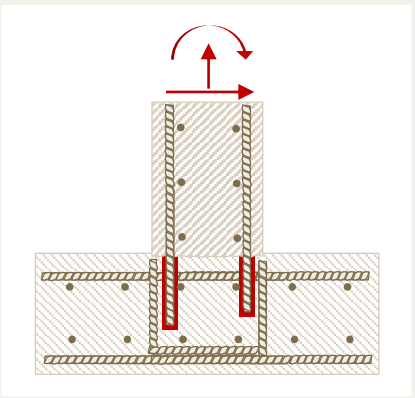


**Abb. 5: Design acc. to EC 2-1**

## WHICH MORTARS DO APPLY AND HOW DO THEY NEED TO BE TESTED

EAD 332402-00-0601 is the testing basis for injection mortars that can withstand moment or tension bearing applications without overlap joints. Test criteria include the assessment for the real bond/gap behaviour of post-installed reinforcing bars, which, depending on the injection mortar system, can be significantly more favourable than for reinforcement bars set in concrete.
Currently you can only design acc. to EOTA TR 069 with the Hilti Mortars RE 500 V4 as well as HY 200-R V3.

## EOTA TR 069 – ANCHOR DESIGN MEETS REBAR DESIGN

EOTA TR 069 forms a bridge between the standards and regulations of DIN EN 1992-4 (anchor design) and DIN EN 1992-1-1 (the design of reinforced concrete structures) based on the EAD 332402-00-0601. With EOTA TR 069 the corresponding anchorage length is determined by the smallest resistance of either the anchorage and the concrete based on either Steel failure, Concrete failure or bond/split failure.
Additionally, you can check for yielding, concrete breakout and rebar pull-out or splitting of the concrete. Furthermore, the determined anchorage length needs to be higher or equal with the min. anchorage length acc. to EN 1992-1-1

EOTA TR 069 purpose is to determine and verify the anchorage length of the post-installed reinforcement in the existing component. The transfer of the forces into the concrete component or the entire construction must be verified separately according to DIN EN 1992-1-1 (e.g., shear transfer in the connection joint as well as bending and shear force resistance)

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

Easily design post-installed rebar connections such as Lap splices and End anchorages with all different applications and possible design methods.

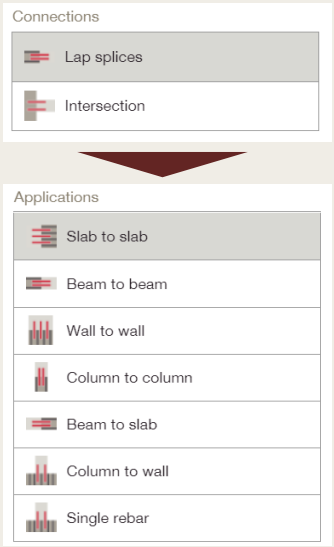
## ENTRIES IN PROFIS ENGINEERING

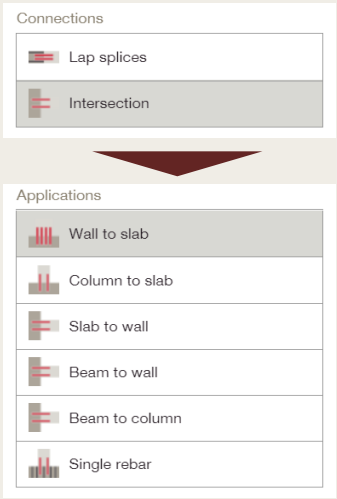
Start by selecting the right connection and following the application.

3

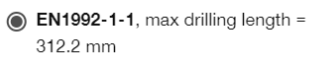
Start your post-installed rebar design by selecting the right connection and application type . The list of options will change whether you select lap spliced or end orages.

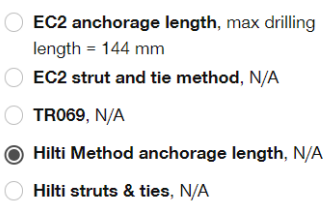
To start go to the tab „Application“

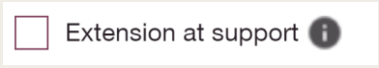


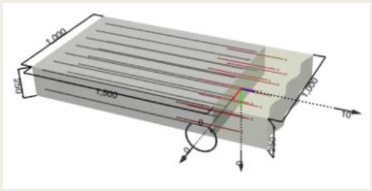

The possible design method is depending on the connection type and load type.

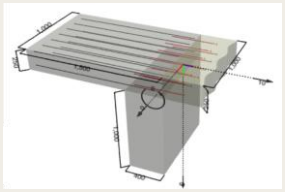


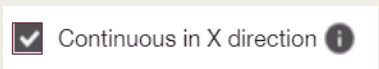




Lap spliced can be designed as an extension at support if the post-installed rebars are overlapping in the region of the support.

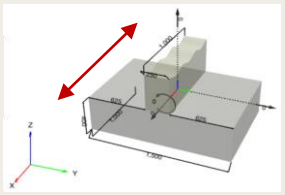




If a support is defined, the tension on the rebars resulting from shear load ΔFtd is considered to act only in the bottom layer of slabs and beams.
If a support is not defined, the tension on the rebars resulting from shear load ΔFtd is considered to act in both layers of reinforcement of slabs and beams.




By activating „Continous in X direction“ the User definies that the concrete element is not limited in x direction but goes on.



# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

With PROFIS Engineering Concrete to Concrete rebar module you can easily define and check loads from different directions.

## Enter your acting Loads

You can either enter your loads in the 3D-Model or in the table below the 3D Model. Based on the application and connection selection you can enter different loads.

| N° | Name | Type | Forces [kN] | | | Moments [kNm] | |
|---|---|---|---|---|---|---|---|
| | | | Vx | Vy | N | Mx | My |
| 1 | Combination 1 | | 0 | 0 | 0 | 0 | |

## Splices

| | Vx | Vy | N | Mx | My |
|---|---|---|---|---|---|
| Slab to slab | x | x | x | x | |
| Beam to beam | | x | x | x | |
| Wall to wall | x | x | x | x | |
| Column to colum | x | x | x | x | x |
| Beam to slab | | x | x | x | |
| Column to wall | x | x | x | x | x |
| Single rebar | | | x | | |

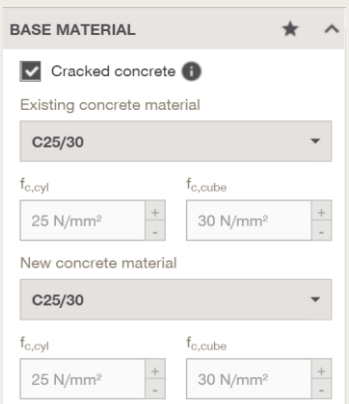
## End anchorage

| | Vx | Vy | N | Mx | My |
|---|---|---|---|---|---|
| Wall to slab | x | x | x | x | |
| Column to slab | x | x | x | x | x |
| Slab to wall | x | x | x | x | |
| Beam to wall | | x | x | x | |
| Beam to column | | x | x | x | |
| Single rebar | | | x | | |

## Continue by defining the base material

Continue your design by entering the base material parameters for the existing and the new concrete member.

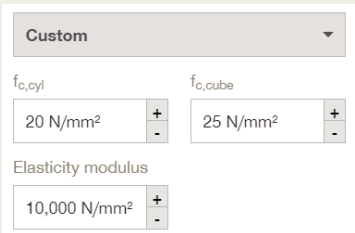
To start go to the tab „base material“

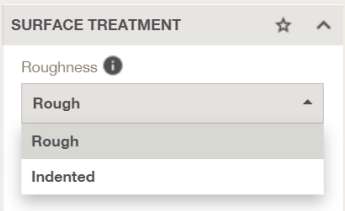



For Rebar design cracked concrete is a selected default. In case cracked concrete does not apply to your application please deselect the check mark. This has an effect on the resistance.

In the dropdowns existing concrete material and new concrete material the user can select the concrete strength in a range from C12/15 till C50/60 including the B15, B25 and B35.

If the you have higher or lower concrete strength you can adapt them by entering custom concrete.



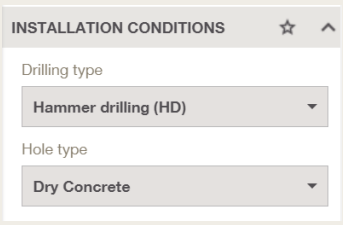

You can define the roughness between the new and the old concrete member. The grade of choosen and executed roughness effect the shear verification and the transfer of loads via the interface.

- rough (xxmm)
- indented (yymm)

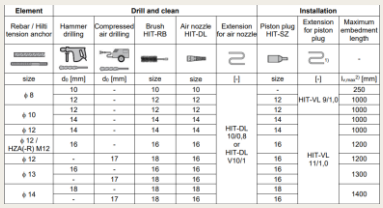
# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

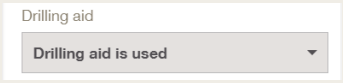
Did you know that using drilling aid will help you decrease your drilling in accuracy by 4-6%? Other wise you might need to increase your concrete cover to ensure a safe anchorage.




Depending on the existing concrete strength, the present reinforcement, the diameter or also embedment depths there are different drilling methods supporting the different out sets. The Software will indicate if you have chosen the wrong drilling type for your application.



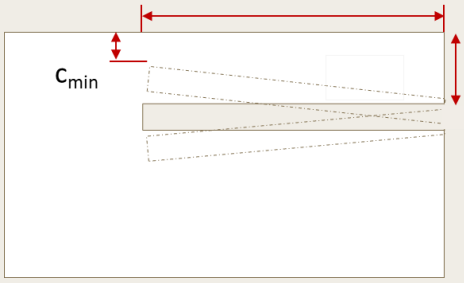
| Element | Drill and clean | | | | | Installation | | |
|---|---|---|---|---|---|---|---|---|
| Rebar / Hilti tension anchor | Hammer drilling | Compressed air drilling | Brush HIT-RB | Air nozzle HIT-DL | Extension for air nozzle | Piston plug HIT-SZ | Extension for piston plug | Maximum embedment length |
| size | $d_0$ [mm] | $d_0$ [mm] | size | size | [-] | size | [-] | $l_{s,max}$ [mm] |
| ϕ 8 | 10 | - | 10 | 10 | HIT-DL 10/0,8 or HIT-DL V10/1 | - | HIT-VL 9/1,0 | 250 |
| | 12 | - | 12 | 12 | | 12 | | 1000 |
| ϕ 10 | 12 | - | 12 | 12 | | 12 | | 1000 |
| | 14 | - | 14 | 14 | | 14 | | 1000 |
| ϕ 12 | 14 | - | 14 | 14 | | 14 | | 1000 |
| ϕ 12 / HZA(-R) M12 | 16 | - | 16 | 16 | | 16 | HIT-VL 11/1,0 | 1200 |
| ϕ 12 | - | 17 | 18 | 16 | | 16 | | 1200 |
| ϕ 13 | 16 | - | 16 | 16 | | 16 | | 1300 |
| | - | 17 | 18 | 16 | | 16 | | |
| ϕ 14 | 18 | - | 18 | 18 | | 18 | | 1400 |
| | - | 17 | 18 | 16 | | 16 | | |



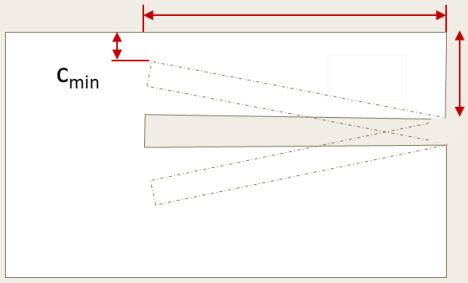

Without drilling aid, an inaccuracy is taken into account in the drilling process according to ETA.

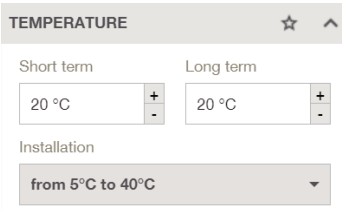
Test show that for hammer drilling you can assume a 6% deviation where as for compressed air drilling you even need to take into account a 8% difference. By using a drilling aid, this deviation from the theoretical borehole angle can be limited to 2%.
In certain cases e.g. overlap joints in thin slabs, even this reduction leads to impracticable results because of the borehole tolerances. In such cases, additional measures must be taken to guarantee the drilling direction.

Drilling aid is used




Drilling aid not used




Chemical mortars for post-installed rebars are impacted by temperature during their

- installation/ curing time as well as
- in the short and
- long term behavior

By entering these temperatures, the software will preselect possible mortars. For example, slow curing mortars for high installation temperatures etc.

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

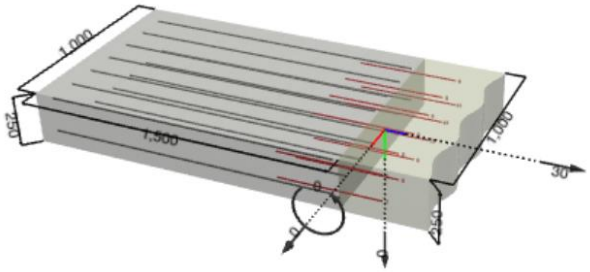
The more information PROFIS Engineering has about the existing reinforcement the better it can use it to transfer the loads from the post-installed rebar to the existing one.

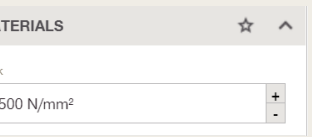
## Continue by defining the existing reinforcement

Continue your design by entering your information on the existing reinforcement in the existing concrete. The information needed varies by connection type.

To start go to the tab „existing reinforcement“

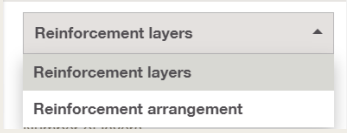
## For Splices you can define longitudinal and transverse reinforcement



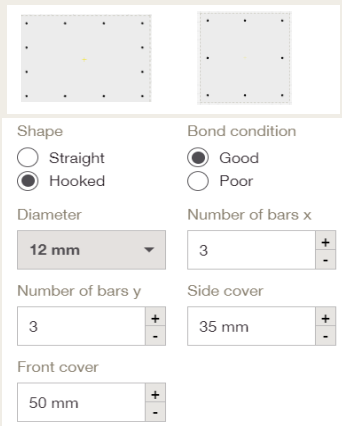

Define the characteristic yield stress of the existing rebar.

### Longitudinal reinforcement




For splices you can define whether your longitudinal reinforcement is placed in layers or an arrangement.

### Reinforcement arrangement



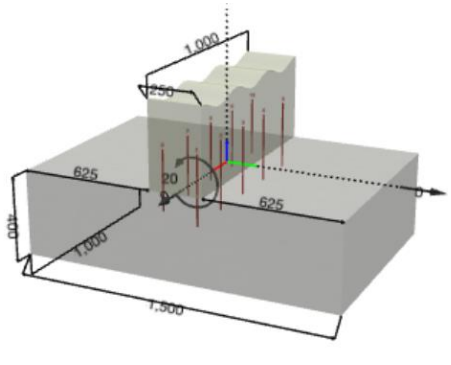

Define the rebar shape

Define the bond condition

Define the diameter and number of bars

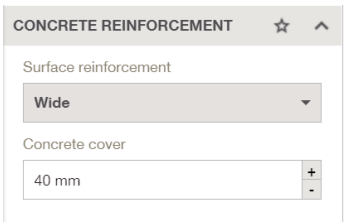
Define front and side cover of the concrete

## For End Anchorages you only need to define the material and the width of the surface reinforcment





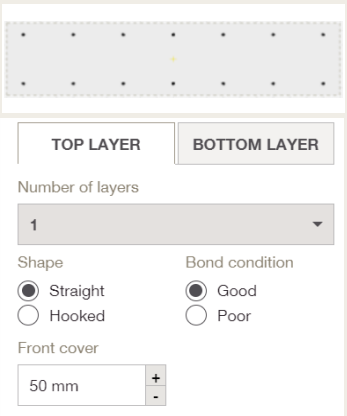
Define the characteristic yield stress of the existing rebar.




Define whether your surface reinforcement is installed in a wide or narrow pattern.

Define your existing concrete cover in z direction.

### Reinforcement Layers




You can define 0-2 layers as top and as Bottom layers.

Define the rebar shape

Define the bond condition

Define the front cover

# GOOD TO KNOW

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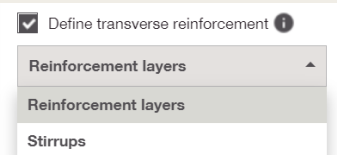
Design of post-installed rebar connections

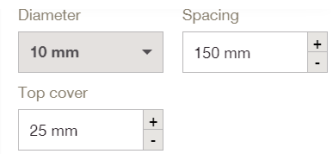
PROFIS Engineering Rebar Module gives you full flexibility in defining stirrups, reinforcement layers as well as the actual number of layers. You can from 1 to 4 Layers – really reflecting the situation on the jobsite.

## Transverse reinforcement



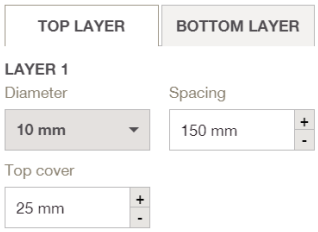

After activating the transverse reinforcement, define whether your application has reinforcement layers or stirrups.

### Stirrups

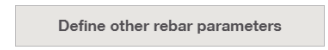



Define the diameter, the spacing and the top cover for the existing reinforcement.

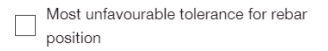
### Reinforcement Layers




Define the diameter in top and bottom layer, the spacing the and top cover for the existing reinforcement.



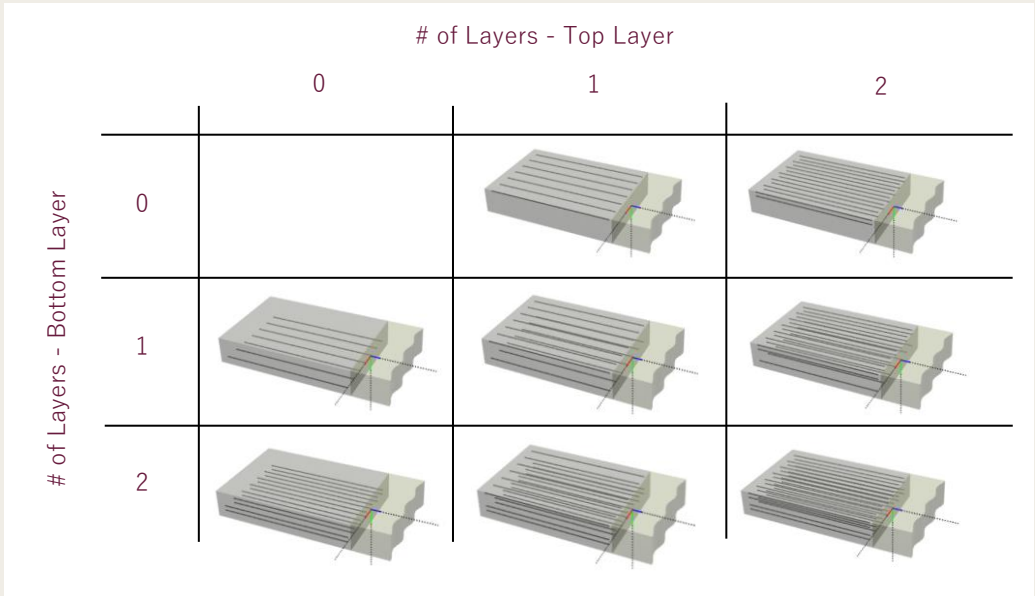

After activating the transverse reinforcement, define whether your application has reinforcement layers or stirrups.




By activating this box PROFIS Engineering assumes the most unfavourable position for the rebar in relation to each other. This automatically also increases the anchorage length .

## EXCURSE: NUMBER OF LAYERS

The combinations of the different layer numbers in the top and bottom reinforcement depend on the load direction. Missing Rebar Layers is only possible if that area is in the compression zone.



# GOOD TO KNOW

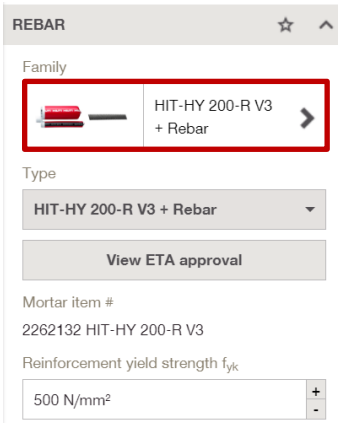
PROFIS Engineering Suite –
Design of post-installed rebar connections

PROFIS Engineering Rebar Module offers you to design your applications with 4 different mortars. HIT-CT1 is the ecological soultion, HY 200-R V3 the beyond cast-in mortar with fast curing time, RE 500 V4 is the solution for everything based on epoxy and FP 700 is the new fire design revolution.

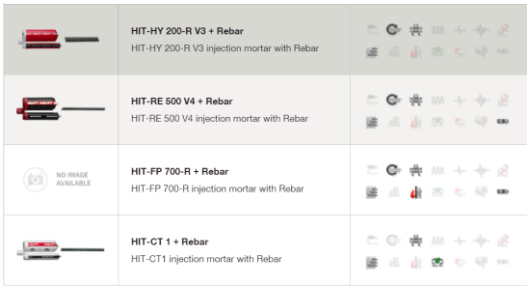
## Define the post-installed reinforcement

In this tab you can define the design type – either designmode or verification mode – as well as the mortar type and further relevant rebar types

To start go to the tab „post-installed rebar“



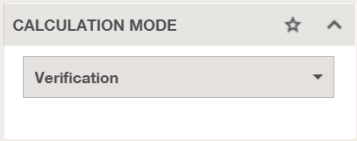

To select a mortar click on mortar family.



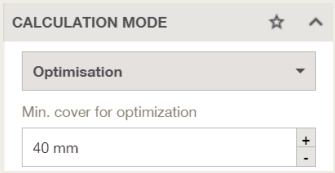

You can select either the ETA for TR069 and the Eurocode

Define the yield strength of the post-installed rebar

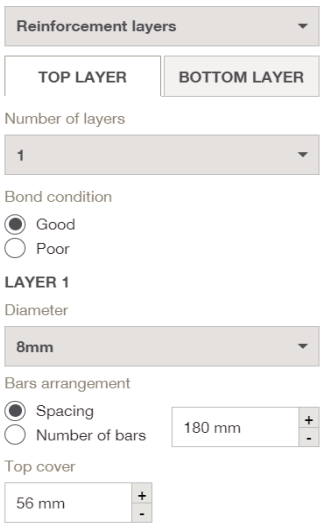
## There are two design modes – Verification und Optimization mode




In the verification mode you as the user define all post-installed rebar parameters and try to verify the check.

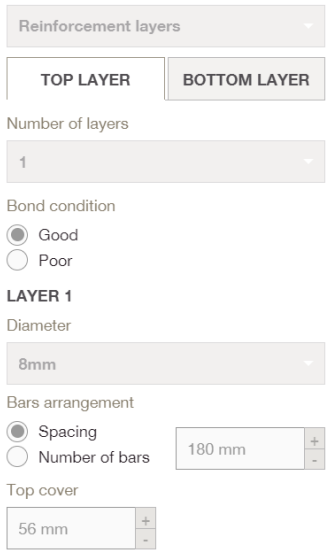



In the optimization mode the Software assumes the bond condition, diameter, spacing and cover.
You can decide to “optimize” based on min. anchorage length or min. number of bars.




You can define your exact application.

- Decide the post-installed rebar parameters by arranging them in reinforcement layers or arrangements like you did for the existing reinforcement.
- apply the relevant bond condition
- define the Diameter
- take up the top cover




In design mode the rebar definition fields are greyed out since the values are proposed by the software.

You can define whether you want the software to propose you a solution based on:

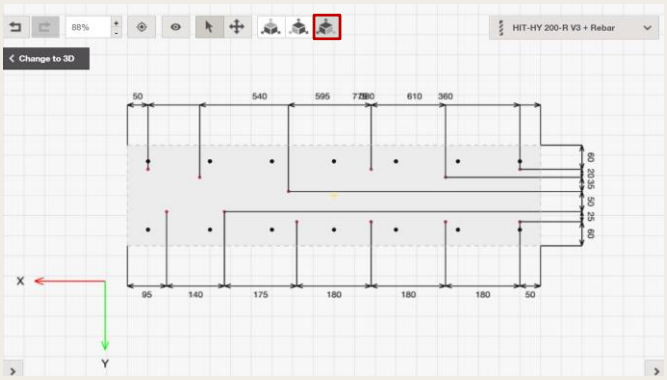
- the min. length of post-installed rebar
- min. number holes

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

Your jobsite situation is not the standard one? With the 2D Editor in the Rebar module you can check and calculate user defined existing or post-installed rebar layouts. You don´t have enough space to use typical layouts to transfer the loads? No Problem, the 2D Editor mirrors your needs.

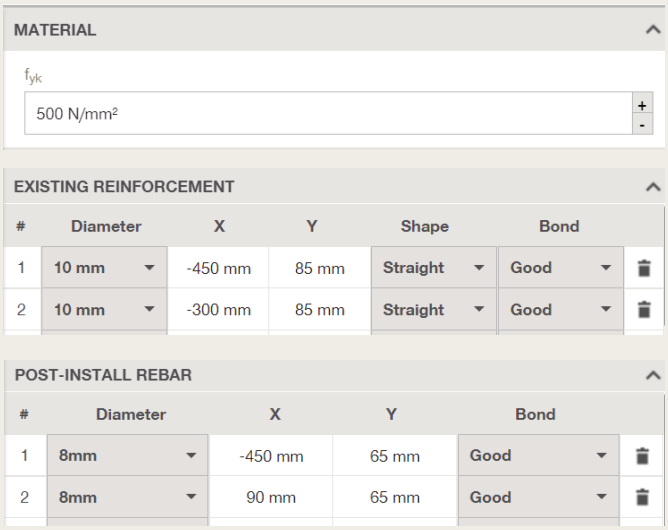
## Excurse 2D Editors




In verification mode you have the option to define your cast-in and post-installed rebar layout completely user-defined .

- Change to the “Front View” to see the post-installed rebar (red) and cast-in rebar (black).
- You can drag the post-installed rebar by dragging them with your mouse.
- The cast-in rebar position can only be adapted in the table on the left side.

To open the table, click on “modify coordinates” in the left menu.
You can change the Material.




**Define the cast-In/ existing Reinforcement:**

- Position
- Diameter
- Bond condition
- Shape

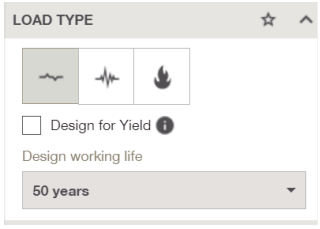
**Define the post-installed Reinforcement**:

- Position
- Diameter
- Bond condition

## Define the loads and design methods

In this tab you can define the Load type, load definition or shear design methods.

To start go to the tab „post-installed rebar“




You can distinguish between static, seismic and fire design. Please keep in mind that for fire relevant application you need to do a cold and a „hot“ design.

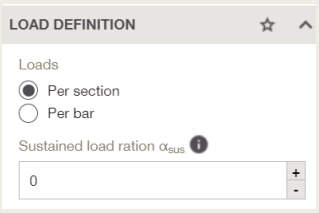
You can design static and seismic applications also under yield.

Define the livetime of your rebar application – 50 or 100 years.

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

For certain applications you might need to switch in between loads per section to loads per bar. Remember to




Define whether your loads apply per par or per section.

**Load per section** – Loads are entered for the entire section width according to the geometry input.

**Loads per bar** - Loads can be entered bar by bar. In this case, no section analysis is performed.

The relationship between permanent loads (consisting of permanent actions and the permanent component from variable actions) and the total value of loads is considered in the ultimate limit state.


If the checkbox min. reinforcement is activated PROFIS designs the area of reinforcement by the table below.

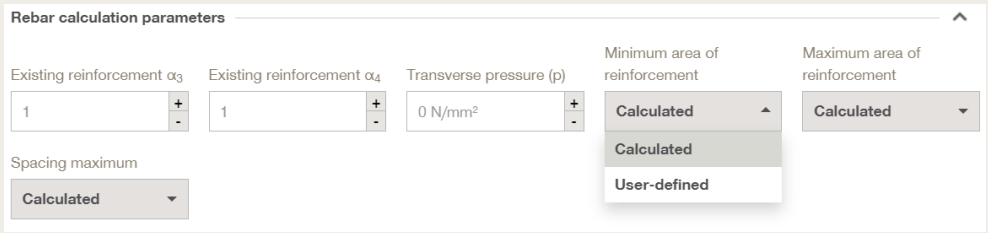
PROFIS Engineering automatically calculates the maximum area of reinforcement as $A_{s,max}=0{,}04 \cdot A_c$.

In case different area of maximum post-installed reinforcement shall be considered, please select «User defined».

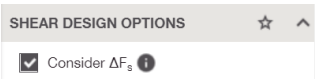
Min. Reinforcement

| Beam | Slab | Column | Wall | Single |
|---|---|---|---|---|
| $A_{s,min}= 0{,}26(\frac{fctm}{f_{yk}}bt*d) \geq 0{,}0013btd$<br>$S_{max,slab} = \min\{3h;400mm\}$ | | $A_{s,min}= \max(\frac{0{,}1*N_{Ed}}{f_{yd}}; 0{,}002 *A_c)$<br>and at least 4 bars | $A_{s,min}= 0{,}002\ A_c$ | no minimum is considered |

Definition of min and max reinforcement




## SHEAR DESIGN OPTIONS




The additional effect of shear in tension zone is considered by default in case of beams and slabs. This can be de-activated by the user. The design formular changes whether it is a direct or an indirect support (with or without shear-reinforcement). Please see the specs below.

| Direct support | Indirect support |
|---|---|
| $\Delta F_{td} = V_{Ed} a_l / z$ | |
| (See EN1992-1-1 section 9.2.1.3)<br>No shear reinforcement<br>$a_l = d$<br>Shear reinforcement<br>$a_l = z(\cot \theta - \cot \alpha)/2$ | (See EN1992-1-1 section 6.2.3)<br>No shear reinforcement<br>$\Delta F_{td} = V_{Ed} \cot \theta$<br>Shear reinforcement<br>$\Delta F_{td} = V_{Ed} (\cot \theta - \cot \alpha)$ |

# GOOD TO KNOW

PROFIS Engineering Suite –
Design of post-installed rebar connections

Shear design for post-installed rebar do not rely on the rebar diameter but rather on interface roughness. In PROFIS Engineering you can design your shear interface acc. to 3 formulars.

Post-installed rebars are not generally designed to resist direct shear loading in the same way as an anchor bolt.

The forces are defined through a strut-and-tie model, which presupposes that the rebar only resists axial loads to guarantee equilibrium with global concrete struts.

The connection interface needs to be properly roughened to ensure the shear load is transferred by friction.

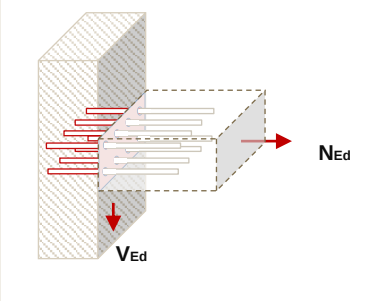
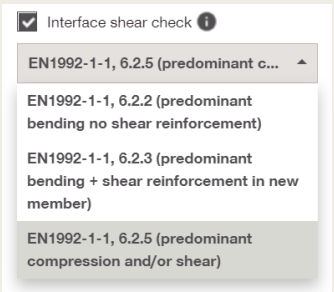



**Abb. 6:** Shear interface for post-installed rebar applications

## There are 3 shear design check formulas that can be applied for the shear design check for post-installed rebar




The shear check design is optional and can be activated via checkboc in the «loads tab»

- Predominant bending without shear reinforcement → EN 1992-1-1 6.2.2
- Predominant bending with shear reinforcement in new member → EN 1992-1-1 6.2.3
- Predominant compression with or without shear reinforcement → EN 1992-1-1 6.2.5

## When does what check apply? – Guidance to choose the correct shear check

Where,
ed - is the eccentricity of the bending moment to the center of the cross section and h - is the height of the concrete element

| if $e_d/h>=3.5$ | | if ed/h<3.5 |
|---|---|---|
| EN1992-1-1 6.2.2 | EN1992-1-1 6.2.3 | EN1992-1-1 6.2.5 |

$$V_{Rd,c} = [C_{R,dc}k(100^* \rho\, |f_{ck})^{1/3} + k_1\ \sigma_{cp}]b_w d$$

Members not requiring design shear reinforcement

$$V_{Rd,s} = (A_{sw}/s)\ z\ f_{ywd} \cot\theta$$

$$V_{Rd,max} = \alpha cw\ bw\ z\ \nu 1\ (A_{sw}/s)\ z\ f_{ywd} \cot\theta$$

Members requiring design shear reinforcement

$$V_{Rd,i} = c\ \underbrace{f_{ctd} + \mu\ \sigma_n}_{V_{Rd,c}} + \underbrace{\rho\ f_{yd}\ (\mu\ \sin\alpha + \cos\alpha)}_{V_{Rd,s}} \le 0{,}5\ \nu\ f_{cd}$$

If $V_{Rd,c} \ge V_{Ed}$ → No requirements on bars crossing the interface

$L_{0,min}$ / $l_{bd,min}$ in calculated in tension

If $V_{Rd,c} \le V_{Ed}$ → Bar crossing the interface are required for shear

Lbd,y required for the engaged bars