# BRIDGE EDGE BEAM ANCHORING



Version 1.0
March 2023

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# 1. TERMINOLOGY AND TYPES OF EDGE BEAMS

## 1.1 Definition of edge beam

Bridge edge beam is structural member whose main function is to support additional structures on bridge edges and transfer their loads into bridge deck such as:

- Railing
- Crash barriers
- Sound barrier
- Pavement

Apart from structural requirements for edge beam and its connections there are also requirements for:

- Lifespan minimum 25 years
- Easy to repair, replace both the structures on edge beam and edge beam itself
- Not compromise the waterproof protection of bridge deck
- Flexibility in dimensions of edge beam to accommodate various structures, combinations, bridge shapes
- Thermal expansion and dilatation
- Architectural requirements

## 1.2 Terminology

Below is basic scheme of edge beam with naming used throughout this document.

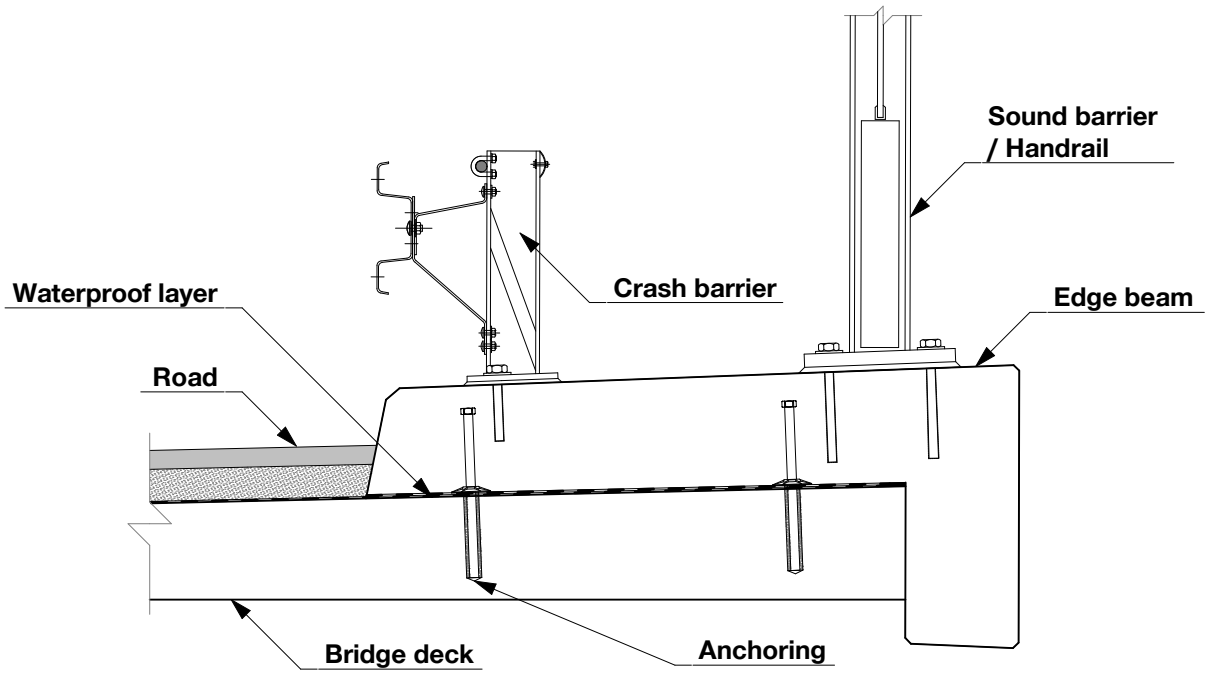



**Figure 1-1 Edge beam with naming.**

In this document we will focus on the connection between bridge deck and edge beam. Based on how this connection is solved we can divide edge beams into several types.

## 1.3 Integrated edge beam

Part of entire bridge deck as one monolithic structure.

**Advantages:**

- No connection problem to solve.
- No penetration of waterproof layer.

**Disadvantages:**

- Repair or renovation requires very costly diamond cutting.
- Next renovation after cutting will most likely be non-integrated edge beam.
- Bridge deck lifespan could be negatively impacted and thus, longevity of whole bridge.

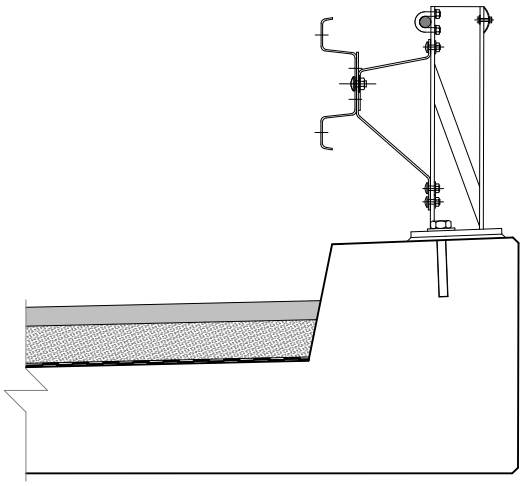


**Figure 1-2 Integrated edge beam**

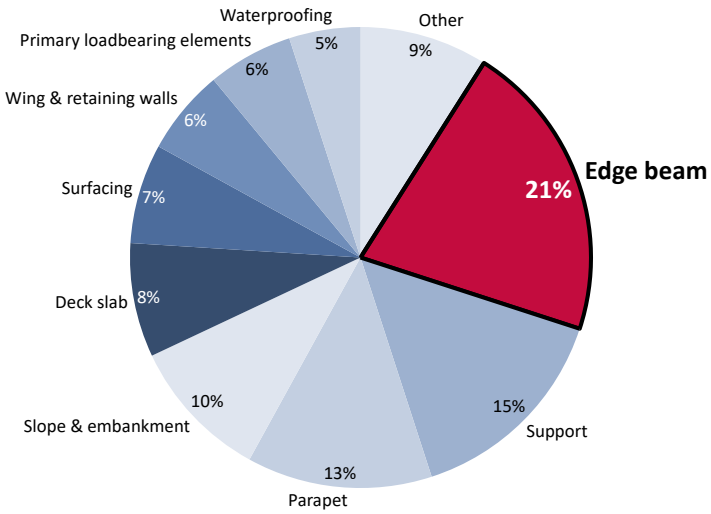



**Figure 1-3 Percentage distribution of damage remarks from sample made of 353 bridges in different parts of Sweden. according to Racutanu, 2001 [2].**

## 1.4 Non-integrated edge beams

Typical bridge service life when designed is 100 years. By separating edge beam and bridge deck we can repair and renovate edge beam independently. Below we will describe most common approaches to the connection of edge beam to bridge deck.

### 1.4.1 Steel hooks “V shaped” or “butterfly”

**Advantages:**

- Based on design experience its generally assumed that load resistance in edge beam part is very high.

**Disadvantages:**

- Challenging waterproofing without proof or certification it works.
- Postproduction of HDG steel parts needed.
- Currently unclear how to design and be compliant with Eurocode.
- High material costs

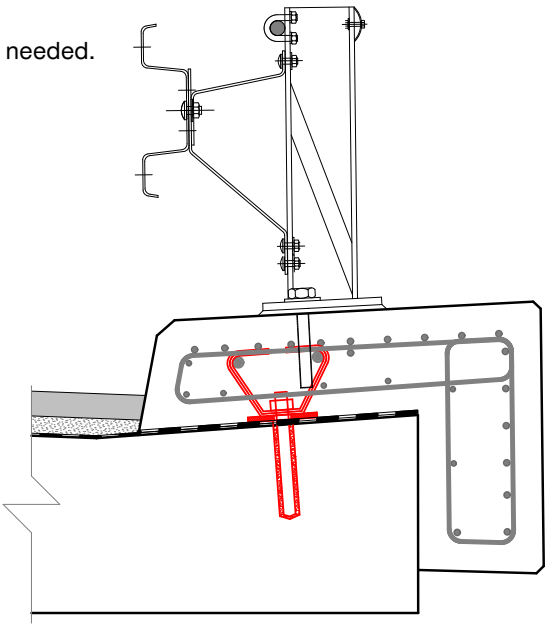


**Figure 1-4 Steel V shaped hooks for fixing edge beams**



**Figure 1-5 The so called "Butterfly" traditional solution used in Czechia. Acceptance is based on experience.**

## 1.4.2 Rebar hooks

**Advantages:**

• Simple to design according to Eurocode.

**Disadvantages:**

• Impossible to waterproof and seal water-tight rebar penetration.
• Corrosion resistance requires HDG or stainless-steel rebar.

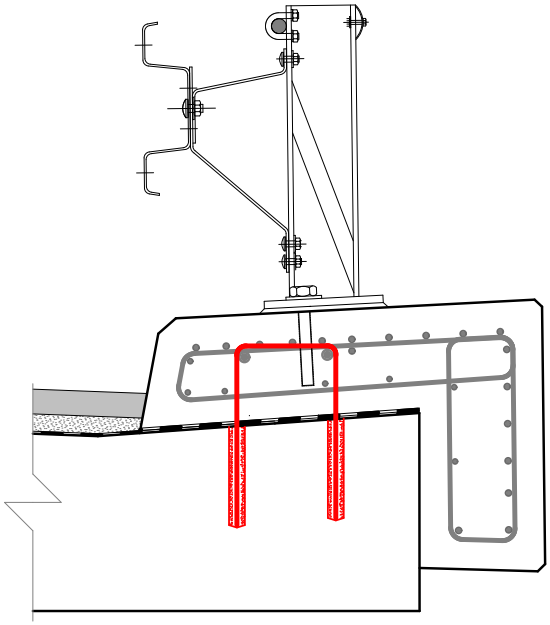


**Figure 1-6 Rebar fixing edge beam**



**Figure 1-7 Rebar hooks provide good resistance, but mean lots of drilling and have no proof of watertightness. It's also not possible to screw HIW-SD sealing cap on rebar.**

## 1.4.3 Prefabricated concrete beam front faced anchors trough steel cantilevers

**Advantages:**

- Steel to steel connection inside concrete is perceived as safe and easier to design.
- Waterproofing of threaded rod can be secured with Hilti RE500V3/V4 + sealing disc HIW-SD.

**Disadvantages:**

- Complexity of steel-to-steel connection.
- High accuracy during installation needed.
- Economical aspect due price of steel.

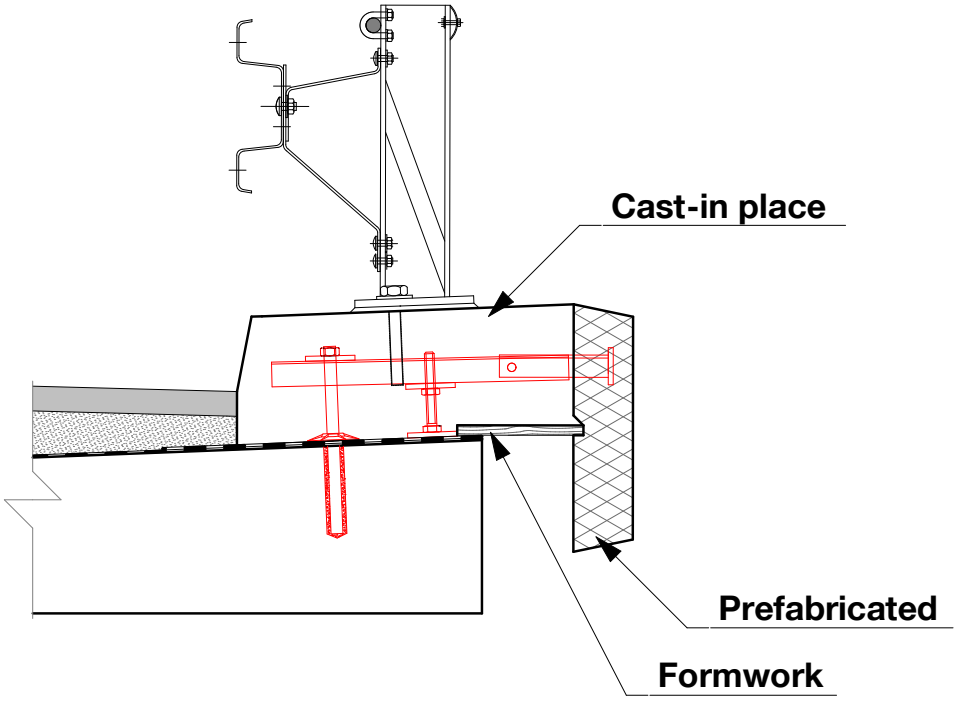



**Figure 1-8 Example of steel-to-steel connection embedded inside concrete.**



**Figure 1-9 Prefabricated concrete has embedded wooden board to serve as formwork for pouring of edge beam.**

## 1.4.4 Prefabricated concrete beam with holes and steel plates for bolts

**Advantages:**

- Simple steel to steel connection.
- Waterproofing of threaded rod can be secured with Hilti RE500V3/V4 + sealing disc HIW-SD.

**Disadvantages:**

- Very high precision needed during installation.
- Costly to fix if prefabricated part doesn't match the installed anchors.
- Large cranes and machinery needed to move the prefabricated sections & access.
- Curing time of grout is typically 20+ days.

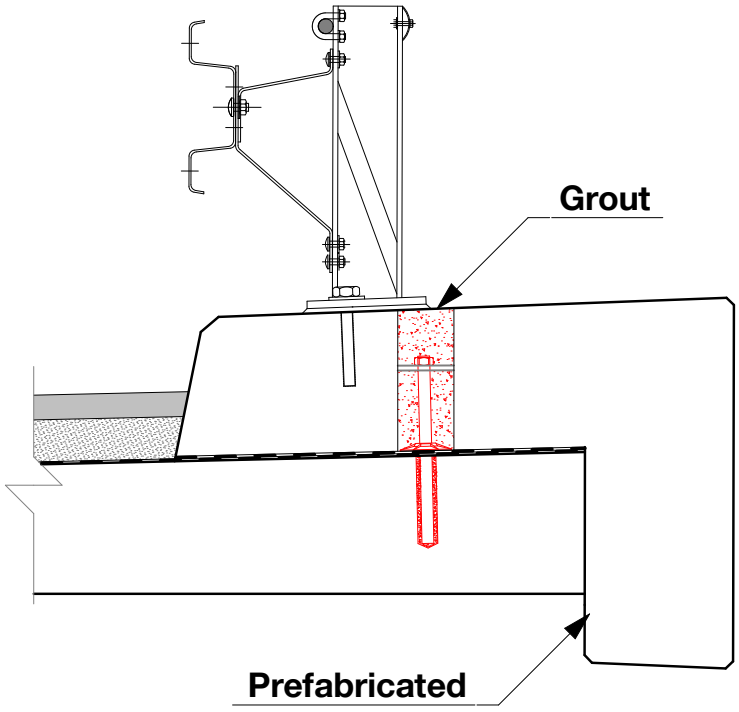



**Figure 1-10 Entire edge beam is prefabricated off-site with holes prepared for anchor rods.**

## 1.4.5 Hilti HPA solution

**Advantages:**
- Structural design fully complaint with Eurocode.
- Flexible design allowing optimalization.
- Easy installation and high productivity on jobsite.
- Certified, tested and approved.
- Solved waterproofing
- Only solution allowing reinforcement of already installed edge beams. See figure 1-13.

**Disadvantages:**
- Actual structural calculation must be done.

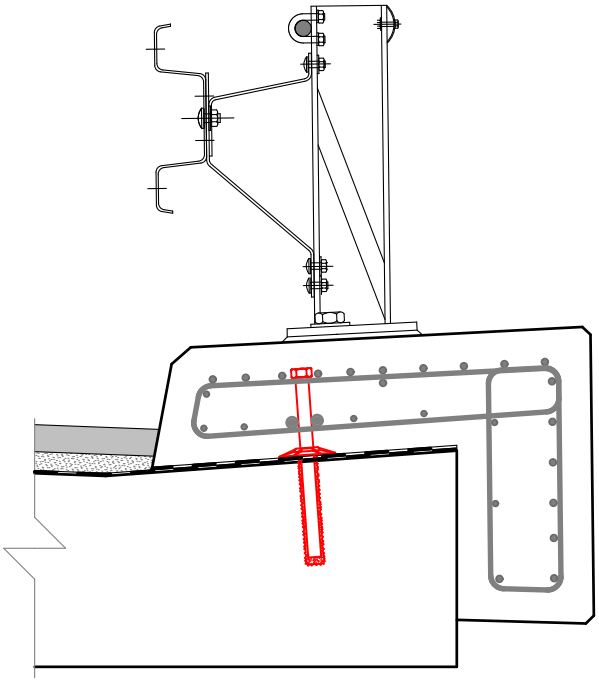


**Figure 1-11 Hilti solution for fixing edge beams - HPA**



**Figure 1-12 Nut at the top acts as headed anchor, sealing cap ensures correct overflow and spread of RE500. Later covered by concrete cast in place.**

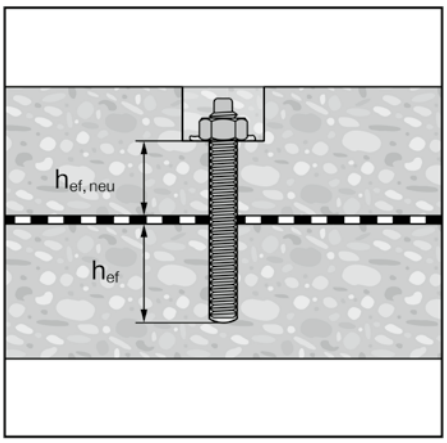



**Figure 1-13 HPA is only solution allowing additional reinforcement of existing edge beam.**

# 2. TYPES OF ACTING LOADS

## 2.1 General requirements

Forces on edge beam depend on the structures fixed to edge beam. Below we list only few most common combinations. Final design forces on edge beam must be confirmed and calculated by general designer of bridge.

## 2.2 Crash barrier

Often most challenging for design as edge beam is small to just accommodate the anchoring of crash barrier. Loads on edge beam come usually from technical data of crash barrier supplier.

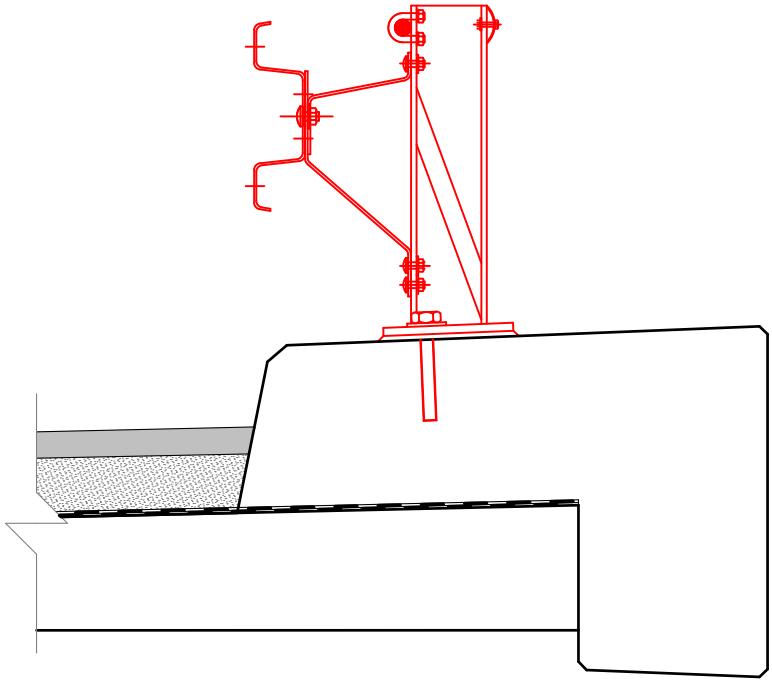


**Figure 2-1 Crash barrier on edge beam**

## 2.3 Crash barrier and sound barrier

In urban areas sound barrier is often added. Most critical load combination on edge beam must be used in calculation.

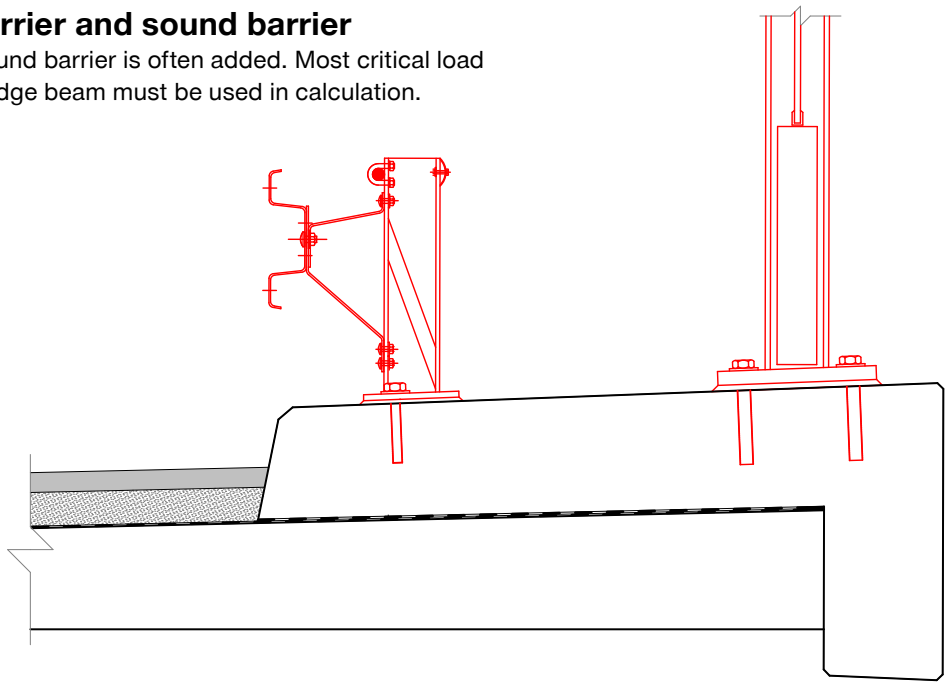


**Figure 2-2 Crash barrier together with sound barrier on edge beam**

## 2.4 Handrail only

In pedestrian areas where is low speed limit for cars we can see no crash barrier at all. We must calculate forces coming from handrail according to Eurocode, but for any edge beam without crash barrier there is also requirement to take loads from car hitting exposed curb with wheel. This is explained in Eurocode EN 1991-2 Section 4.7.3.2 - Collision forces on curbs.

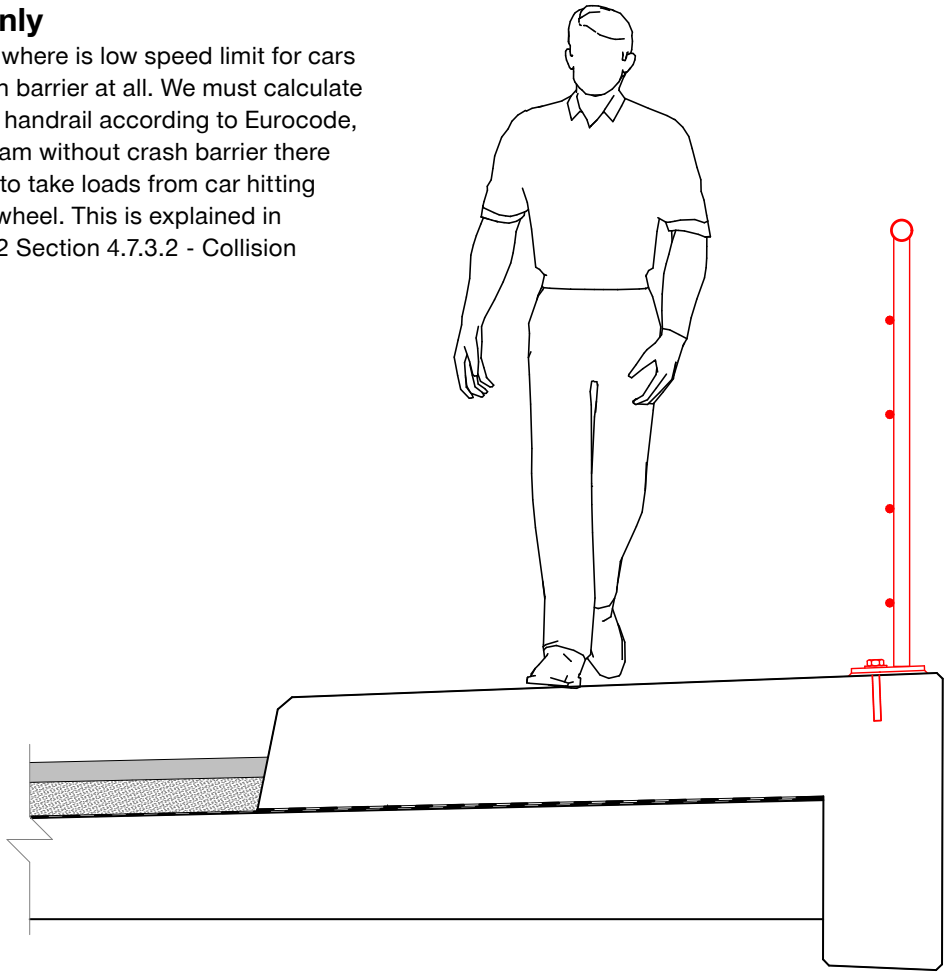


**Figure 2-3 Edge beam with pedestrian pavement and handrail.**

# 3. HILTI SOLUTION

## 3.1 General description

Hilti offers the concrete connector HPA for anchoring edge beams in bridge construction.
This solution consists of Hilti HAS-U / HIT-C threaded rod in either carbon steel 8.8 HDG or stainless steel A4 grade. Rod is equipped with nut at the top acting as headed anchor. Middle of rod has screwed on plastic sealing disc HIW-SD that ensures even spread of epoxy mortar RE500V3/V4 over waterproof layer making the connection watertight. Typical diameter is M12-M24 depending on geometry and loads. Recommended injection mortar is Hilti RE500V4 or Hilti RE500V3.

Hilti HPA is commonly used on bridges in Germany, Austria, Poland, Slovakia with many reference projects. To smaller extend it is also used in Czechia and Baltic countries.

For design of upper part Hilti holds German national approval Z-21.8.2118 issued by DIBt. Bottom part in bridge deck is designed according to Eurocode and ETA for chemical mortar (in case of RE500V4 ETA-20/0541). Additional suitability tests to proof the water tightness under static and fatigue relevant actions according to RVS 15.04.12 were performed by an accredited test lab in Austria.



**Figure 3-1 Installation of HPA on jobsite.**

Following Z-21.8.2118, the design of HPA needs to be done according EN 1992-4:2019-04, Section 7. This standard covers the connection of a steel element to a concrete member. For the connection of edge beams on bridges a new concrete member (edge beam) is fastened to the existing concrete bridge deck. Therefore, Z-21.8.2118 covers specific rules for the design and installation which supplement EN 1992-4.

## 3.2 Approvals overview

| Description | Product | Authority / Laboratory | No. / date of issue |
|---|---|---|---|
| European Technical Assessment | HIT-C (R), HAS-U (A4) + HIT-RE 500 V4 | CSTB France | ETA-20/0541 Issued 04.09.2021 |
| German approval | Hilti Betonverbinder HPA zur Verbindung von Betonbauteilen M12-M24 | DIBt Germany | Z-21.8-2118 Issued 03.09.2021 |
| Austrian testing of water tightness of anchor fastenings in concrete according to standard RVS 15.04.12 | Hilti Edge Beam anchoring M12, M16, M20, M24 | BAUTECHNISCHE VERSUCHSANTALT Austria | 160/21, 234/21, 189/21, 207/21a Issued 29.06.2021 |

# 4. EXAMPLE CALCULATION

## 4.1 Geometry

In this example we will show how to design edge beam anchoring using Hilti HPA solution.
Following geometry was picked as most challenging for design. Edge beam is fitted with crash barrier and at same time is very narrow giving small edge distances.

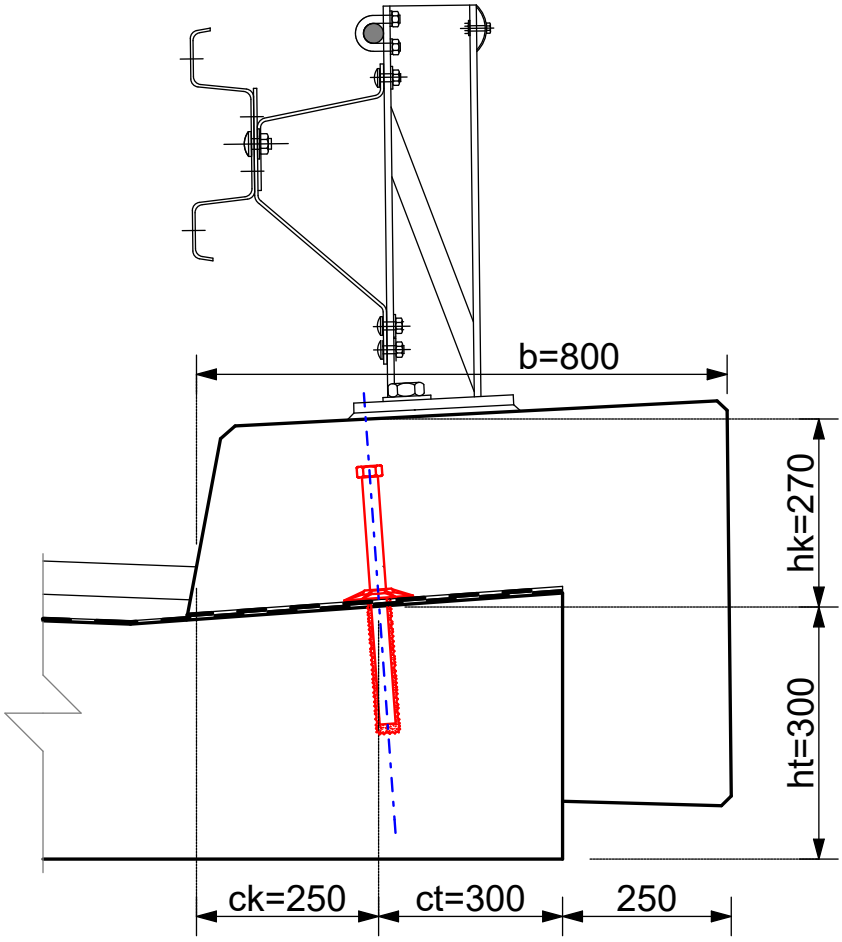



**Figure 4-1 Important dimensions of anchoring in relation to edge beam and bridge deck for structural design.**

Dimensions:
b = 800 mm
cT = 300 mm
cK = 250 mm
hK = 240 mm
hT = 300 mm
HPA anchor spacing = 1000 mm
Both bridge deck and edge beam cracked concrete C30/37
Water insulation layer thickness = 10 mm

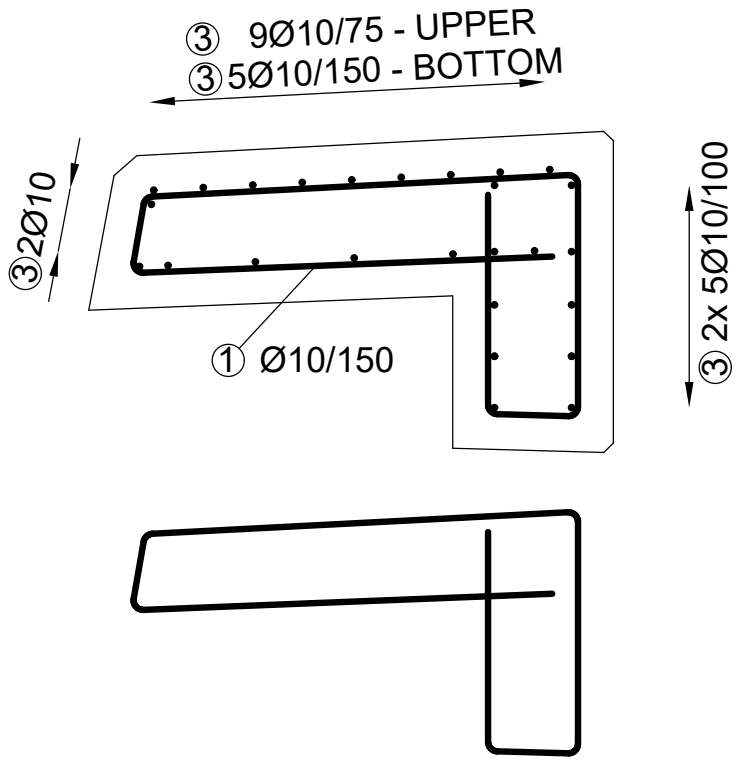



**Figure 4-2 Reinforcement of calculated edge beam**

## 4.2 Loads from crash barrier

As mentioned in chapter 2 if there are other structures present, we must evaluate each separately and find the most extreme one. They do not add up.

Acting loads for crash barrier are provided by crash barrier manufacturer and his testing. They come from the stiffness of the column. Anchoring then should provide higher resistance than steel column making sure the failure never occurs in anchors. Supplier of crash barrier should also specify exact forces on anchors and safety coefficients allowed for design. In our example we picked very common type of crash barrier used in Czechia.

Crash barrier type: JSMNH4/H2
Manufacturer technical data sheet: TP167_CZ_zari_2021 table.8 (September 2021)

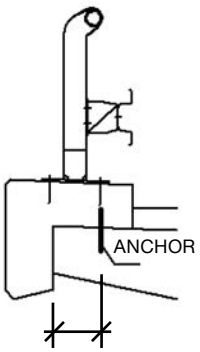
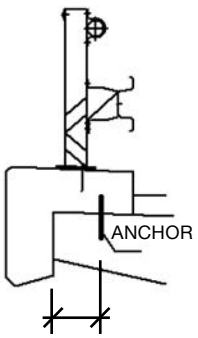
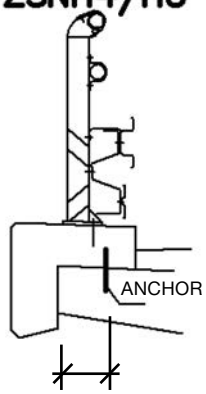
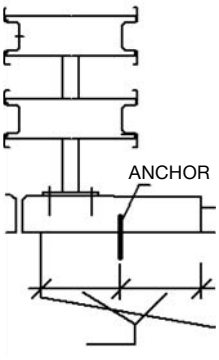
| **Anchoring of edge beam** | **Crash barrier type** | | | |
|---|---|---|---|---|
| **Anchoring in load bearing structure**<br>Distance of crash barrier columns is 2 m. Anchoring must be able to take loads in this table both for tension and shear. Position must meet the min. Distances in pictures. | ZSNH4/H2<br> | JSMNH4/H2<br> | ZSNH4/H3<br> | OSPNH4/H3<br> |
| Tension (kN) | 190 | 148 | 172 | 74 |
| Shear (kN) | 58 | 50 | 43 | 44 |

**Figure 4-3 Excerpt from manufacturers technical data sheet for crash barrier. All load values above are characteristic, and manufacturer explicitly allows comparison of characteristics load values.**

Spacing of colunms is 2m meaning that acting loads on anchors per 2m of edge beam are as follows:
N = 148 kN (tension)
V = 50 kN (shear)

**We choose spacing of 1m for HPA anchors effectively halving the load values:**

N = 74 kN (tension) (for 1 m distance)
V = 25 kN (shear) (for 1 m distance)

## 4.3 Anchor system

Fastener we choose **Hilti HIT-C M24 HDG 8.8.** carbon steel rod. Also defined in ETA-20/0541 certificate for RE500V4 as AM 8.8 rod.

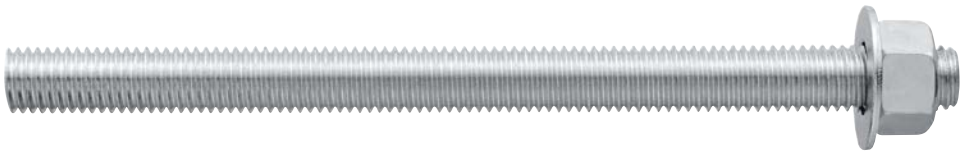


**Figure 4-4 To meet ETA requirements the rod should either be ETA defined with CE mark on box such as HAS-U or HIT-C rod where 3.1 certificate can be provided.**

In the edge beam the anchor acts like a headed anchor with the nut providing the pressure area.
For M24 the thickness of the nut is 19 mm.

Mortar used will be epoxy based **Hilti RE500V4** that holds certification for use in Edge beam anchoring.




| Description | Item number | Volume | Dispenser |
|---|---|---|---|
| HIT-RE 500 V4/500 | #2287557 | 500 ml | HDE 500-A22 battery |
| HIT-RE 500 V4/1400 | #2287552 | 1400 ml | P 8000 D pneumatic |

**Figure 4-5 Foil pack of RE500V4 epoxy mortar.**

To calculate exact volume of mortar needed and total consumption of packages per number of anchors please use our Hilti volume calculator app.

Volume calculator
App Store

Volume calculator
Google Play

Finally last piece that ensures proper waterproofing and spread of epoxy is Hilti HIW-SD sealing disc.
They come in sizes from M12-M24.

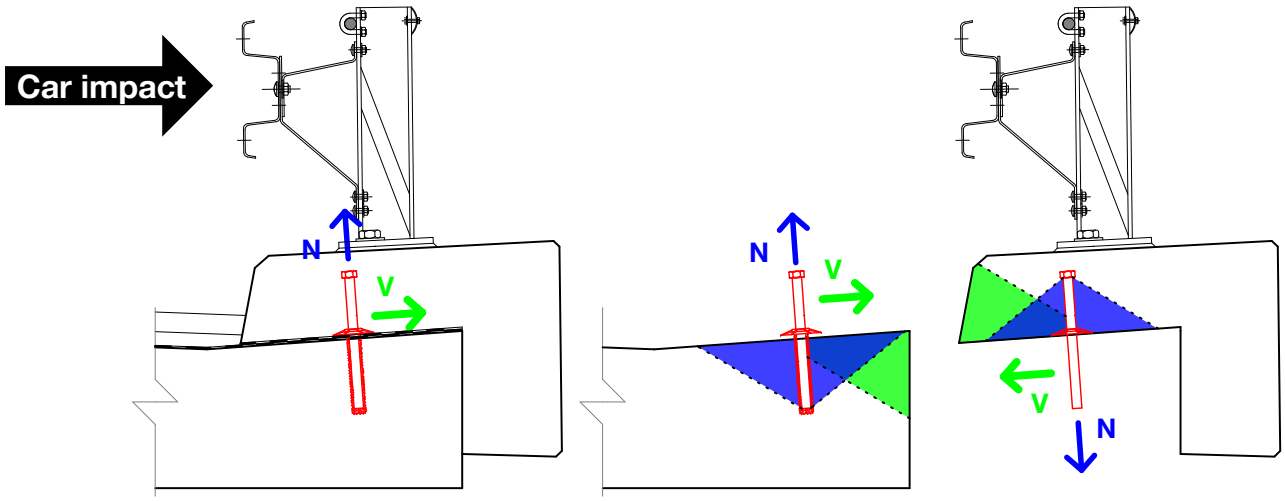



| Description | Item number | Package |
|---|---|---|
| HIW-SD M12 | #365251 | 20 pcs |
| HIW-SD M16 | #365252 | 20 pcs |
| HIW-SD M20 | #365253 | 20 pcs |
| HIW-SD M24 | #2178106 | 20 pcs |

**Figure 4-6 Sealing disc HIW-SD**

## 4.4 Calculation overview

For calculation we will input all the data into PROFIS engineering that is available for free at:
https://profisengineering.hilti.com/
There we will run two calculations, bottom part as typical anchor and upper part using new option for cast-in place headed fastener.




**Load values come from crash barrier manufacturer specification**

**4.5 Bridge deck bottom part PROFIS Engineering Post-installed anchor**

**4.6 Edge beam upper part PROFIS Engineering Cast-in-place Headed fastener**

**Figure 4-7 Calculation & forces overview.**

# 4.5 Calculation of bottom part in bridge deck

**www.hilti.cz**

| | | | |
|---|---|---|---|
| Company: | | Page: | 1 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | Concrete - 3 Dec 2022 | Date: | 03.12.2022 |
| Fastening Point: | | | |

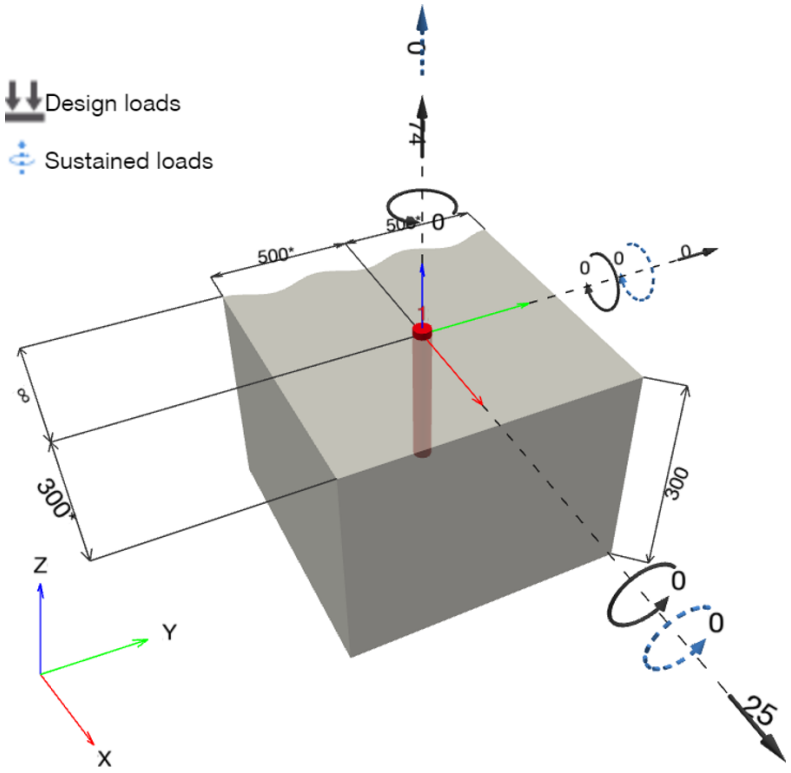
**Specifier's comments:**

## 1 Input data



| | |
|---|---|
| **Anchor type and size:** | **HIT-RE 500 V4 + AM (8.8) M24** |
| Return period (service life in years): | 50 |
| Item number: | 407501 AM 8.8 M24x1000 (insert) / 2287552 HIT-RE 500 V4 (mortar) |
| Effective embedment depth: | $h_{ef,opti}$ = 191.0 mm ($h_{ef,limit}$ = 244.0 mm) |
| Material: | 8.8 |
| Approval No.: | ETA 20/0541 |
| Issued I Valid: | 04.09.2021 \| - |
| Proof: | Design Method EN 1992-4, Chemical |
| Stand-off installation: | |
| Profile: | |
| Base material: | cracked concrete, C30/37, $f_{c,cyl}$ = 30.00 N/mm$^2$; h = 300.0 mm, Temp. short/long: 40/24 °C, User-defined partial material safety factor $\gamma_c$ = 1.200 |
| **Installation:** | **hammer drilled hole, Installation condition: Dry** |
| Reinforcement: | No reinforcement or Reinforcement spacing >= 150 mm (any Ø) or >= 100 mm (Ø <= 10 mm) |
| | no longitudinal edge reinforcement |

**Geometry [mm] & Loading [kN, kNm]**





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| | | | |
|---|---|---|---|
| Company: | | Page: | 2 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | Concrete - 3 Dec 2022 | Date: | 03.12.2022 |
| Fastening Point: | | | |

### 1.1 Load combination

| Case | Description | Forces [kN] / Moments [kNm] | Seismic | Fire | Max. Util. Anchor [%] |
|---|---|---|---|---|---|
| 1 | Combination 1 | N = 74.000; $V_x$ = 25.000; $V_y$ = 0.000; $M_x$ = 0.000; $M_y$ = 0.000; $M_z$ = 0.000; $N_{sus}$ = 0.000; $M_{x,sus}$ = 0.000; $M_{y,sus}$ = 0.000; | no | no | 100 |

## 2 Load case/Resulting anchor forces

**Anchor reactions [kN]**
Tension force: (+Tension, -Compression)

| Anchor | Tension force | Shear force | Shear force x | Shear force y |
|---|---|---|---|---|
| 1 | 74.000 | 25.000 | 25.000 | 0.000 |

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [N/mm$^2$]
resulting tension force in (x/y)=(0.0/0.0): 0.000 [kN]
resulting compression force in (x/y)=(0.0/0.0): 0.000 [kN]

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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# 3 Tension load (EN 1992-4, Section 7.2.1)

| | Load [kN] | Capacity [kN] | Utilization $\beta_N$ [%] | Status |
|---|---|---|---|---|
| Steel failure* | 74.000 | 188.267 | 40 | OK |
| Combined pullout-concrete cone failure** | 74.000 | 118.726 | 63 | OK |
| Concrete Breakout failure** | 74.000 | 92.773 | 80 | OK |
| Splitting failure** | 74.000 | 96.184 | 77 | OK |

* highest loaded anchor **anchor group (anchors in tension)

### 3.1 Steel failure

$$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{M,s}}$$ EN 1992-4, Table 7.1

| $N_{Rk,s}$ [kN] | $\gamma_{M,s}$ | $N_{Rd,s}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|
| 282.400 | 1.500 | 188.267 | 74.000 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 3.2 Combined pullout-concrete cone failure

$N_{Ed} \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{M,p}}$ EN 1992-4, Table 7.1

$N_{Rk,p} = N^0_{Rk,p} \cdot \frac{A_{p,N}}{A^0_{p,N}} \cdot \psi_{g,Np} \cdot \psi_{s,Np} \cdot \psi_{re,N} \cdot \psi_{ec1,Np} \cdot \psi_{ec2,Np}$ EN 1992-4, Eq. (7.13)

$N^0_{Rk,p} = \psi_{sus} \cdot \tau_{Rk} \cdot \pi \cdot d \cdot h_{ef}$ EN 1992-4, Eq. (7.14)

$\psi_{sus} = 1$ EN 1992-4, Eq. (7.14a)

$s_{cr,Np} = 7.3 \cdot d \cdot \sqrt{\psi_{sus} \cdot \tau_{Rk}} \le 3 \cdot h_{ef}$ EN 1992-4, Eq. (7.15)

$\psi_{g,Np} = \psi^0_{g,Np} - \left(\frac{s}{s_{cr,Np}}\right)^{0,5} \cdot \left(\psi^0_{g,Np} - 1\right) \ge 1.00$ EN 1992-4, Eq. (7.17)

$\psi^0_{g,Np} = \sqrt{n} - (\sqrt{n} - 1) \cdot \left(\frac{\tau_{Rk}}{\tau_{Rk,c}}\right)^{1,5} \ge 1.00$ EN 1992-4, Eq. (7.18)

$\tau_{Rk,c} = \frac{k_3}{\pi \cdot d} \cdot \sqrt{h_{ef} \cdot f_{ck}}$ EN 1992-4, Eq. (7.19)

$\psi_{s,Np} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,Np}} \le 1.00$ EN 1992-4, Eq. (7.20)

$\psi_{ec1,Np} = \frac{1}{1 + \left(\frac{2 \cdot e_{c1,N}}{s_{cr,Np}}\right)} \le 1.00$ EN 1992-4, Eq. (7.21)

$\psi_{ec2,Np} = \frac{1}{1 + \left(\frac{2 \cdot e_{c2,N}}{s_{cr,Np}}\right)} \le 1.00$ EN 1992-4, Eq. (7.21)

| $A_{p,N}$ [mm²] | $A^0_{p,N}$ [mm²] | $\tau_{Rk,ucr,20}$ [N/mm²] | $s_{cr,Np}$ [mm] | $c_{cr,Np}$ [mm] | $c_{min}$ [mm] | $f_{c,cyl}$ [N/mm²] |
|---|---|---|---|---|---|---|
| 328,329 | 328,329 | 15.00 | 573.0 | 286.5 | 300.0 | 30.00 |

| $\psi_c$ | $\tau_{Rk,cr}$ [N/mm²] | $k_3$ | $\tau_{Rk,c}$ [N/mm²] | $\psi^0_{g,Np}$ | $\psi_{g,Np}$ |
|---|---|---|---|---|---|
| 1.041 | 9.89 | 7.700 | 7.73 | 1.000 | 1.000 |

| $e_{c1,N}$ [mm] | $\psi_{ec1,Np}$ | $e_{c2,N}$ [mm] | $\psi_{ec2,Np}$ | $\psi_{s,Np}$ | $\psi_{re,Np}$ |
|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 1.000 | 1.000 |

| $\psi^0_{sus}$ | $\alpha_{sus}$ | $\psi_{sus}$ |
|---|---|---|
| 0.880 | 0.000 | 1.000 |

| $N^0_{Rk,p}$ [kN] | $N_{Rk,p}$ [kN] | $\gamma_{M,p}$ | $N_{Rd,p}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|---|
| 142.471 | 142.471 | 1.200 | 118.726 | 74.000 |

| Group anchor ID |
|---|
| 1 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 3.3 Concrete Breakout failure

$N_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{M,c}}$ EN 1992-4, Table 7.1

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$ EN 1992-4, Eq. (7.1)

$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$ EN 1992-4, Eq. (7.2)

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \le 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,N}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,N}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{M,N} = 1$ EN 1992-4, Eq. (7.7)

| $A_{c,N}$ [mm²] | $A^0_{c,N}$ [mm²] | $c_{cr,N}$ [mm] | $s_{cr,N}$ [mm] | $f_{c,cyl}$ [N/mm²] | |
|---|---|---|---|---|---|
| 328,329 | 328,329 | 286.5 | 573.0 | 30.00 | |

| $e_{c1,N}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,N}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ |
|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 1.000 | 1.000 |

| z [mm] | $\psi_{M,N}$ | $k_1$ | $N^0_{Rk,c}$ [kN] | $\gamma_{M,c}$ | $N_{Rd,c}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|---|---|---|
| 0.0 | 1.000 | 7.700 | 111.327 | 1.200 | 92.773 | 74.000 |

| Group anchor ID |
|---|
| 1 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 3.4 Splitting failure

$N_{Ed} \le N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$ EN 1992-4, Table 7.1

$N_{Rk,sp} = N^0_{Rk,sp} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{h,sp}$ EN 1992-4, Eq. (7.23)

$N^0_{Rk,sp} = \min\left(N^0_{Rk,p}, N^0_{Rk,c}\right)$

$A^0_{c,N} = s_{cr,sp} \cdot s_{cr,sp}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,sp}} \le 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,sp}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,sp}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{h,sp} = \left(\frac{h}{h_{min}}\right)^{2/3} \le \max\left\{1; \left(\frac{h_{ef} + 1.5 \cdot c_1}{h_{min}}\right)^{2/3}\right\} \le 2.00$ EN 1992-4, Eq. (7.24)

| $A_{c,N}$ [mm²] | $A^0_{c,N}$ [mm²] | $c_{cr,sp}$ [mm] | $s_{cr,sp}$ [mm] | $\psi_{h,sp}$ | $f_{c,cyl}$ [N/mm²] | |
|---|---|---|---|---|---|---|
| 432,460 | 458,600 | 338.6 | 677.2 | 1.138 | 30.00 | |

| $e_{c1,N}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,N}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ | $k_1$ |
|---|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 0.966 | 1.000 | 7.700 |

| $N^0_{Rk,sp}$ [kN] | $\gamma_{M,sp}$ | $N_{Rd,sp}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|
| 111.327 | 1.200 | 96.184 | 74.000 |

| Group anchor ID |
|---|
| 1 |

# 4 Shear load (EN 1992-4, Section 7.2.2)

| | Load [kN] | Capacity [kN] | Utilization $\beta_V$ [%] | Status |
|---|---|---|---|---|
| Steel failure (without lever arm)* | 25.000 | 112.960 | 23 | OK |
| Steel failure (with lever arm)* | N/A | N/A | N/A | N/A |
| Pryout failure** | 25.000 | 185.545 | 14 | OK |
| Concrete edge failure in direction x+** | 25.000 | 58.242 | 43 | OK |

* highest loaded anchor **anchor group (relevant anchors)

### 4.1 Steel failure (without lever arm)

$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{M,s}}$ EN 1992-4, Table 7.2

$V_{Rk,s} = k_7 \cdot V^0_{Rk,s}$ EN 1992-4, Eq. (7.35)

| $V^0_{Rk,s}$ [kN] | $k_7$ | $V_{Rk,s}$ [kN] | $\gamma_{M,s}$ | $V_{Rd,s}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|---|
| 141.200 | 1.000 | 141.200 | 1.250 | 112.960 | 25.000 |

### 4.2 Pryout failure (concrete cone relevant)

$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{M,c,p}}$ EN 1992-4, Table 7.2

$V_{Rk,cp} = k_8 \cdot \min \{N_{Rk,c}; N_{Rk,p}\}$ EN 1992-4, Eq. (7.39c)

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$ EN 1992-4, Eq. (7.1)

$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$ EN 1992-4, Eq. (7.2)

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,1}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,2}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{M,N} = 1$ EN 1992-4, Eq. (7.7)

| $A_{c,N}$ [mm²] | $A^0_{c,N}$ [mm²] | $c_{cr,N}$ [mm] | $s_{cr,N}$ [mm] | $k_8$ | $f_{c,cyl}$ [N/mm²] |
|---|---|---|---|---|---|
| 328,329 | 328,329 | 286.5 | 573.0 | 2.000 | 30.00 |

| $e_{c1,V}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,V}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ | $\psi_{M,N}$ |
|---|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 1.000 | 1.000 | 1.000 |

| $k_1$ | $N^0_{Rk,c}$ [kN] | $\gamma_{M,c,p}$ | $V_{Rd,cp}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|
| 7.700 | 111.327 | 1.200 | 185.545 | 25.000 |

| Group anchor ID |
|---|
| 1 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 4.3 Concrete edge failure in direction x+

$$V_{Ed} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{M,c}}$$ EN 1992-4, Table 7.2

$$V_{Rk,c} = k_T \cdot V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$$ EN 1992-4, Eq. (7.40)

$$V^0_{Rk,c} = k_9 \cdot d_{nom}^{\alpha} \cdot l_f^{\beta} \cdot \sqrt{f_{ck}} \cdot c_1^{1,5}$$ EN 1992-4, Eq. (7.41)

$$\alpha = 0.1 \cdot \left(\frac{l_f}{c_1}\right)^{0,5}$$ EN 1992-4, Eq. (7.42)

$$\beta = 0.1 \cdot \left(\frac{d_{nom}}{c_1}\right)^{0,2}$$ EN 1992-4, Eq. (7.43)

$$A^0_{c,V} = 4.5 \cdot c_1^2$$ EN 1992-4, Eq. (7.44)

$$\psi_{s,V} = 0.7 + 0.3 \cdot \frac{c_2}{1.5 \cdot c_1} \le 1.00$$ EN 1992-4, Eq. (7.45)

$$\psi_{h,V} = \left(\frac{1.5 \cdot c_1}{h}\right)^{0,5} \ge 1.00$$ EN 1992-4, Eq. (7.46)

$$\psi_{ec,V} = \frac{1}{1 + \left(\frac{2 \cdot e_V}{3 \cdot c_1}\right)} \le 1.00$$ EN 1992-4, Eq. (7.47)

$$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos \alpha_V)^2 + (0.5 \cdot \sin \alpha_V)^2}} \ge 1.00$$ EN 1992-4, Eq. (7.48)

| $l_f$ [mm] | $d_{nom}$ [mm] | $k_9$ | $\alpha$ | $\beta$ | $f_{c,cyl}$ [N/mm$^2$] |
|---|---|---|---|---|---|
| 191.0 | 24.00 | 1.700 | 0.080 | 0.060 | 30.00 |

| $c_1$ [mm] | $A_{c,V}$ [mm$^2$] | $A^0_{c,V}$ [mm$^2$] |
|---|---|---|
| 300.0 | 270,000 | 405,000 |

| $\psi_{s,V}$ | $\psi_{h,V}$ | $\psi_{\alpha,V}$ | $e_{c,V}$ [mm] | $\psi_{ec,V}$ | $\psi_{re,V}$ |
|---|---|---|---|---|---|
| 1.000 | 1.225 | 1.000 | 0.0 | 1.000 | 1.000 |

| $V^0_{Rk,c}$ [kN] | $k_T$ | $\gamma_{M,c}$ | $V_{Rd,c}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|
| 85.598 | 1.0 | 1.200 | 58.242 | 25.000 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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## 5 Combined tension and shear loads (EN 1992-4, Section 7.2.3)

Steel failure

| $\beta_N$ | $\beta_V$ | $\alpha$ | Utilization $\beta_{N,V}$ [%] | Status |
|---|---|---|---|---|
| 0.393 | 0.221 | 2.000 | 21 | OK |

$\beta_N^{\alpha} + \beta_V^{\alpha} \leq 1.0$

Concrete failure

| $\beta_N$ | $\beta_V$ | $\alpha$ | Utilization $\beta_{N,V}$ [%] | Status |
|---|---|---|---|---|
| 0.798 | 0.429 | 1.500 | 100 | OK |

$\beta_N^{\alpha} + \beta_V^{\alpha} \leq 1.0$

## 6 Displacements (highest loaded anchor)

Short term loading:

$N_{Sk}$ = 54.815 [kN] $\delta_N$ = 0.4948 [mm]

$V_{Sk}$ = 18.519 [kN] $\delta_V$ = 0.5556 [mm]

$\delta_{NV}$ = 0.7440 [mm]

Long term loading:

$N_{Sk}$ = 54.815 [kN] $\delta_N$ = 0.6090 [mm]

$V_{Sk}$ = 18.519 [kN] $\delta_V$ = 0.9259 [mm]

$\delta_{NV}$ = 1.1083 [mm]

Comments: Tension displacements are valid with half of the required installation torque moment for uncracked concrete! Shear displacements are valid without friction between the concrete and the baseplate! The gap due to the drilled hole and clearance hole tolerances are not included in this calculation!

The acceptable anchor displacements depend on the fastened construction and must be defined by the designer!

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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## 7 Warnings

- The anchor design methods in PROFIS Engineering require rigid baseplates per current regulations (AS 5216:2021, ETAG 001/Annex C, EOTA TR029 etc.). This means load re-distribution on the anchors due to elastic deformations of the baseplate are not considered - the baseplate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the design loading. PROFIS Engineering calculates the minimum required baseplate thickness with CBFEM to limit the stress of the baseplate based on the assumptions explained above. The proof if the rigid baseplate assumption is valid is not carried out by PROFIS Engineering. Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Checking the transfer of loads into the base material is required in accordance with EN 1992-4, Annex A!
- The design is only valid if the clearance hole in the fixture is not larger than the value given in Table 6.1 of EN 1992-4! For larger diameters of the clearance hole see section 6.2.2 of EN 1992-4!
- The accessory list in this report is for the information of the user only. In any case, the instructions for use provided with the product have to be followed to ensure a proper installation.
- For the determination of the $\psi_{re,v}$ (concrete edge failure) the minimum concrete cover defined in the design settings is used as the concrete cover of the edge reinforcement.
- Characteristic bond resistances depend on short- and long-term temperatures.
- Edge reinforcement is not required to avoid splitting failure
- The characteristic bond resistances depend on the return period (service life in years): 50

**Fastening meets the design criteria!**


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# 8 Installation data

Baseplate, steel: -

Profile: -

Hole diameter in the fixture: -

Plate thickness (input): -

Drilling method: Hammer drilled
Cleaning: Compressed air cleaning of the drilled hole according to instructions for use is required

Anchor type and size: HIT-RE 500 V4 + AM (8.8) M24
Item number: 407501 AM 8.8 M24x1000 (insert) / 2287552
HIT-RE 500 V4 (mortar)

Maximum installation torque: 200 Nm

Hole diameter in the base material: 28.0 mm

Hole depth in the base material: 191.0 mm

Minimum thickness of the base material: 247.0 mm

Hilti AM threaded rod with HIT-RE 500 V4 injection mortar with 191 mm embedment h_ef, M24, Steel galvanized, Hammer drilling installation per ETA 20/0541

## 8.1 Recommended accessories

| Drilling | Cleaning | Setting |
|---|---|---|
| • Suitable Rotary Hammer<br>• Properly sized drill bit | • Compressed air with required accessories to blow from the bottom of the hole<br>• Proper diameter wire brush | • Dispenser including cassette and mixer<br>• Torque wrench |

**Coordinates Anchor [mm]**

| Anchor | x | y | $c_{-x}$ | $c_{+x}$ | $c_{-y}$ | $c_{+y}$ |
|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | - | 300.0 | 500.0 | 500.0 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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## 9 Remarks; Your Cooperation Duties

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# 4.6 Calculation of upper part in edge beam

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| | | | |
|---|---|---|---|
| Company: | | Page: | 1 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | HPA DOKUMENT_UPPER PART | Date: | 01.12.2022 |
| Fastening Point: | | | |

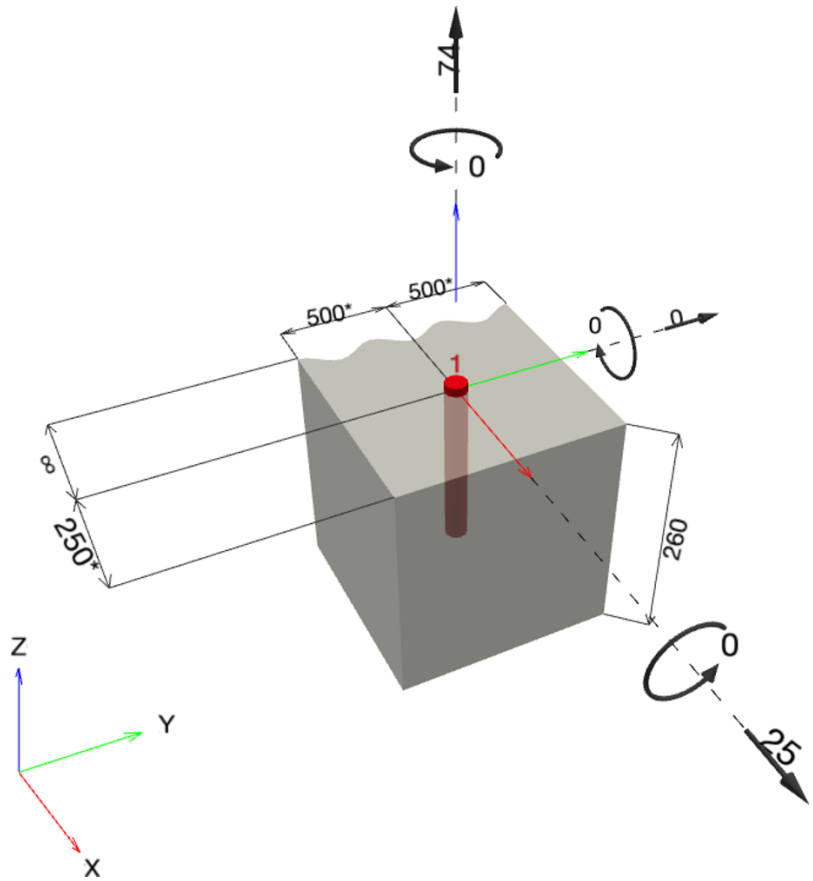
**Specifier's comments:**

## 1 Input data



| | |
|---|---|
| **Anchor type and size:** | **Headed fastener 8.8 M24** |
| Effective embedment depth: | $h_{ef}$ = 186.0 mm |
| Material: | 8.8 |
| Approval No.: | - |
| Issued I Valid: | - \| - |
| Proof: | Design Method EN 1992-4, CastInPlace |
| Stand-off installation: | |
| Profile: | |
| Base material: | cracked concrete, C30/37, $f_{c,cyl}$ = 30.00 N/mm$^2$; h = 260.0 mm, User-defined partial material safety factor $\gamma_c$ = 1.200 |
| Reinforcement: | Reinforcement spacing < 150 mm (any Ø) or < 100 mm (Ø <= 10 mm)<br>with longitudinal edge reinforcement d >= 12.0 [mm] + close mesh (stirrups, hangers) s <= 100.0 [mm] |

**Geometry [mm] & Loading [kN, kNm]**



| | | | |
|---|---|---|---|
| Company: | | Page: | 2 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | HPA DOKUMENT_UPPER PART | Date: | 01.12.2022 |
| Fastening Point: | | | |

### 1.1 Load combination

| Case | Description | Forces [kN] / Moments [kNm] | Seismic | Fire | Max. Util. Anchor [%] |
|---|---|---|---|---|---|
| 1 | Kombinace 1 | N = 74.000; $V_x$ = 25.000; $V_y$ = 0.000; $M_x$ = 0.000; $M_y$ = 0.000; $M_z$ = 0.000; | no | no | 93 |

## 2 Load case/Resulting anchor forces

**Anchor reactions [kN]**
Tension force: (+Tension, -Compression)

| Anchor | Tension force | Shear force | Shear force x | Shear force y |
|---|---|---|---|---|
| 1 | 74.000 | 25.000 | 25.000 | 0.000 |

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [N/mm$^2$]
resulting tension force in (x/y)=(0.0/0.0): 0.000 [kN]
resulting compression force in (x/y)=(0.0/0.0): 0.000 [kN]

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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| | | | |
|---|---|---|---|
| Company: | | Page: | 3 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | HPA DOKUMENT_UPPER PART | Date: | 01.12.2022 |
| Fastening Point: | | | |

## 3 Tension load EN 1992-4, Section 7.2.1

| | Load [kN] | Capacity [kN] | Utilization $\beta_N$ [%] | Status |
|---|---|---|---|---|
| Steel failure* | 74.000 | 241.274 | 31 | OK |
| Pull-out failure* | 74.000 | 106.029 | 70 | OK |
| Concrete Blowout Failure in direction ** | N/A | N/A | N/A | N/A |
| Concrete Breakout failure** | 74.000 | 94.646 | 79 | OK |
| Splitting failure** | 74.000 | 106.540 | 70 | OK |

* highest loaded anchor **anchor group (anchors in tension)

### 3.1 Steel failure

$$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{M,s}}$$ EN 1992-4, Table 7.1

| $N_{Rk,s}$ [kN] | $\gamma_{M,s}$ | $N_{Rd,s}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|
| 361.911 | 1.500 | 241.274 | 74.000 |

### 3.2 Pull-out failure

$$N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{M,p}}$$ EN 1992-4, Table7.1

$$N_{Rk,p} = k_2 \cdot A_h \cdot f_{ck}$$ EN 1992-4, Eq. (7.11)

| $k_2$ | $A_h$ [mm$^2$] | $f_{ck}$ [N/mm$^2$] |
|---|---|---|
| 7.500 | 565 | 30.00 |

| $N_{Rk,p}$ [kN] | $\gamma_{M,p}$ | $N_{Rd,p}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|
| 127.235 | 1.200 | 106.029 | 74.000 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 3.3 Concrete Breakout failure

$N_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{M,c}}$ EN 1992-4, Table 7.1

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$ EN 1992-4, Eq. (7.1)

$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$ EN 1992-4, Eq. (7.2)

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \le 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,N}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,N}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{M,N} = 1$ EN 1992-4, Eq. (7.7)

| $A_{c,N}$ [mm²] | $A^0_{c,N}$ [mm²] | $c_{cr,N}$ [mm] | $s_{cr,N}$ [mm] | $f_{c,cyl}$ [N/mm²] |
|---|---|---|---|---|
| 295,182 | 311,364 | 279.0 | 558.0 | 30.00 |

| $e_{c1,N}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,N}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ |
|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 0.969 | 1.000 |

| z [mm] | $\psi_{M,N}$ | $k_1$ | $N^0_{Rk,c}$ [kN] | $\gamma_{M,c}$ | $N_{Rd,c}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|---|---|---|
| 0.0 | 1.000 | 8.900 | 123.657 | 1.200 | 94.646 | 74.000 |

| Group anchor ID |
|---|
| 1 |

### 3.4 Splitting failure

$N_{Ed} \le N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$ EN 1992-4, Table 7.1

$N_{Rk,sp} = N^{0}_{Rk,sp} \cdot \frac{A_{c,N}}{A^{0}_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{h,sp}$ EN 1992-4, Eq. (7.23)

$N^{0}_{Rk,sp} = \min\left(N_{Rk,p}, N^{0}_{Rk,c}\right)$

$A^{0}_{c,N} = s_{cr,sp} \cdot s_{cr,sp}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,sp}} \le 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,1}}{s_{cr,sp}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{N,2}}{s_{cr,sp}}\right)} \le 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{h,sp} = \left(\frac{h}{h_{min}}\right)^{2/3} \le \max\left\{1; \left(\frac{h_{ef} + 1.5 \cdot c_1}{h_{min}}\right)^{2/3}\right\} \le 2.00$ EN 1992-4, Eq. (7.24)

| $A_{c,N}$ [mm²] | $A^{0}_{c,N}$ [mm²] | $c_{cr,sp}$ [mm] | $s_{cr,sp}$ [mm] | $\psi_{h,sp}$ | $f_{c,cyl}$ [N/mm²] |
|---|---|---|---|---|---|
| 295,182 | 311,364 | 279.0 | 558.0 | 1.126 | 30.00 |

| $e_{c1,N}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,N}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ |
|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 0.969 | 1.000 |

| $N^{0}_{Rk,sp}$ [kN] | $\gamma_{M,sp}$ | $N_{Rd,sp}$ [kN] | $N_{Ed}$ [kN] |
|---|---|---|---|
| 123.657 | 1.200 | 106.540 | 74.000 |

| Group anchor ID |
|---|
| 1 |


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# 4 Shear load EN 1992-4, Section 7.2.2

| | Load [kN] | Capacity [kN] | Utilization $\beta_V$ [%] | Status |
|---|---|---|---|---|
| Steel failure (without lever arm)* | 25.000 | 144.765 | 18 | OK |
| Steel failure (with lever arm)* | N/A | N/A | N/A | N/A |
| Pryout failure** | 25.000 | 189.292 | 14 | OK |
| Concrete edge failure in direction x+** | 25.000 | 65.226 | 39 | OK |

* highest loaded anchor **anchor group (relevant anchors)

### 4.1 Steel failure (without lever arm)

$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{M,s}}$ EN 1992-4, Table 7.2

$V_{Rk,s} = k_7 \cdot V^0_{Rk,s}$ EN 1992-4, Eq. (7.35)

| $V^0_{Rk,s}$ [kN] | $k_7$ | $V_{Rk,s}$ [kN] | $\gamma_{M,s}$ | $V_{Rd,s}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|---|
| 180.956 | 1.000 | 180.956 | 1.250 | 144.765 | 25.000 |

### 4.2 Pryout failure

$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{M,c,p}}$ EN 1992-4, Table 7.2

$V_{Rk,cp} = k_8 \cdot N_{Rk,c}$ EN 1992-4, Eq. (7.39a)

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{M,N}$ EN 1992-4, Eq. (7.1)

$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5}$ EN 1992-4, Eq. (7.2)

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$ EN 1992-4, Eq. (7.3)

$\psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} \leq 1.00$ EN 1992-4, Eq. (7.4)

$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,1}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{V,2}}{s_{cr,N}}\right)} \leq 1.00$ EN 1992-4, Eq. (7.6)

$\psi_{M,N} = 1$ EN 1992-4, Eq. (7.7)

| $A_{c,N}$ [mm²] | $A^0_{c,N}$ [mm²] | $c_{cr,N}$ [mm] | $s_{cr,N}$ [mm] | $k_8$ | $f_{c,cyl}$ [N/mm²] |
|---|---|---|---|---|---|
| 295,182 | 311,364 | 279.0 | 558.0 | 2.000 | 30.00 |

| $e_{c1,V}$ [mm] | $\psi_{ec1,N}$ | $e_{c2,V}$ [mm] | $\psi_{ec2,N}$ | $\psi_{s,N}$ | $\psi_{re,N}$ | $\psi_{M,N}$ |
|---|---|---|---|---|---|---|
| 0.0 | 1.000 | 0.0 | 1.000 | 0.969 | 1.000 | 1.000 |

| $k_1$ | $N^0_{Rk,c}$ [kN] | $\gamma_{M,c,p}$ | $V_{Rd,cp}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|
| 8.900 | 123.657 | 1.200 | 189.292 | 25.000 |

| Group anchor ID |
|---|
| 1 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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### 4.3 Concrete edge failure in direction x+

$$V_{Ed} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{M,c}}$$ EN 1992-4, Table 7.2

$$V_{Rk,c} = k_T \cdot V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$$ EN 1992-4, Eq. (7.40)

$$V^0_{Rk,c} = k_9 \cdot d_{nom}^{\alpha} \cdot l_f^{\beta} \cdot \sqrt{f_{ck}} \cdot c_1^{1,5}$$ EN 1992-4, Eq. (7.41)

$$\alpha = 0.1 \cdot \left(\frac{l_f}{c_1}\right)^{0,5}$$ EN 1992-4, Eq. (7.42)

$$\beta = 0.1 \cdot \left(\frac{d_{nom}}{c_1}\right)^{0,2}$$ EN 1992-4, Eq. (7.43)

$$A^0_{c,V} = 4.5 \cdot c_1^2$$ EN 1992-4, Eq. (7.44)

$$\psi_{s,V} = 0.7 + 0.3 \cdot \frac{c_2}{1.5 \cdot c_1} \le 1.00$$ EN 1992-4, Eq. (7.45)

$$\psi_{h,V} = \left(\frac{1.5 \cdot c_1}{h}\right)^{0,5} \ge 1.00$$ EN 1992-4, Eq. (7.46)

$$\psi_{ec,V} = \frac{1}{1 + \left(\frac{2 \cdot e_V}{3 \cdot c_1}\right)} \le 1.00$$ EN 1992-4, Eq. (7.47)

$$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos \alpha_V)^2 + (0.5 \cdot \sin \alpha_V)^2}} \ge 1.00$$ EN 1992-4, Eq. (7.48)

| $l_f$ [mm] | $d_{nom}$ [mm] | $k_9$ | $\alpha$ | $\beta$ | $f_{c,cyl}$ [N/mm$^2$] |
|---|---|---|---|---|---|
| 186.0 | 24.00 | 1.700 | 0.086 | 0.063 | 30.00 |

| $c_1$ [mm] | $A_{c,V}$ [mm$^2$] | $A^0_{c,V}$ [mm$^2$] |
|---|---|---|
| 250.0 | 195,000 | 281,250 |

| $\psi_{s,V}$ | $\psi_{h,V}$ | $\psi_{\alpha,V}$ | $e_{c,V}$ [mm] | $\psi_{ec,V}$ | $\psi_{re,V}$ |
|---|---|---|---|---|---|
| 1.000 | 1.201 | 1.000 | 0.0 | 1.000 | 1.400 |

| $V^0_{Rk,c}$ [kN] | $k_T$ | $\gamma_{M,c}$ | $V_{Rd,c}$ [kN] | $V_{Ed}$ [kN] |
|---|---|---|---|---|
| 67.143 | 1.0 | 1.200 | 65.226 | 25.000 |

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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| | | | |
|---|---|---|---|
| Company: | | Page: | 8 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | HPA DOKUMENT_UPPER PART | Date: | 01.12.2022 |
| Fastening Point: | | | |

## 5 Combined tension and shear loads (EN 1992-4, Section 7.2.3)

Steel failure

| $\beta_N$ | $\beta_V$ | $\alpha$ | Utilization $\beta_{N,V}$ [%] | Status |
|---|---|---|---|---|
| 0.307 | 0.173 | 2.000 | 13 | OK |

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

Concrete failure

| $\beta_N$ | $\beta_V$ | $\alpha$ | Utilization $\beta_{N,V}$ [%] | Status |
|---|---|---|---|---|
| 0.782 | 0.383 | 1.500 | 93 | OK |

$\beta_N^\alpha + \beta_V^\alpha \leq 1.0$

## 6 Displacements (highest loaded anchor)

Short term loading:

$N_{Sk}$ = 54.815 [kN]
$V_{Sk}$ = 18.519 [kN]

$\delta_N$ = - [mm]
$\delta_V$ = - [mm]
$\delta_{NV}$ = - [mm]

Long term loading:

$N_{Sk}$ = 54.815 [kN]
$V_{Sk}$ = 18.519 [kN]

$\delta_N$ = - [mm]
$\delta_V$ = - [mm]
$\delta_{NV}$ = - [mm]

Comments: Tension displacements are valid with half of the required installation torque moment for uncracked concrete! Shear displacements are valid without friction between the concrete and the baseplate! The gap due to the drilled hole and clearance hole tolerances are not included in this calculation!

The acceptable anchor displacements depend on the fastened construction and must be defined by the designer!

Input data and results must be checked for conformity with the existing conditions and for plausibility!
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| | | | |
|---|---|---|---|
| Company: | | Page: | 9 |
| Address: | | Specifier: | |
| Phone I Fax: | \| | E-Mail: | |
| Design: | HPA DOKUMENT_UPPER PART | Date: | 01.12.2022 |
| Fastening Point: | | | |

## 7 Warnings

- The anchor design methods in PROFIS Engineering require rigid baseplates per current regulations (AS 5216:2021, ETAG 001/Annex C, EOTA TR029 etc.). This means load re-distribution on the anchors due to elastic deformations of the baseplate are not considered - the baseplate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the design loading. PROFIS Engineering calculates the minimum required baseplate thickness with CBFEM to limit the stress of the baseplate based on the assumptions explained above. The proof if the rigid baseplate assumption is valid is not carried out by PROFIS Engineering. Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Checking the transfer of loads into the base material is required in accordance with EN 1992-4, Annex A!
- The design is only valid if the clearance hole in the fixture is not larger than the value given in Table 6.1 of EN 1992-4! For larger diameters of the clearance hole see section 6.2.2 of EN 1992-4!
- The accessory list in this report is for the information of the user only. In any case, the instructions for use provided with the product have to be followed to ensure a proper installation.
- For the determination of the $\psi_{re,v}$ (concrete edge failure) the minimum concrete cover defined in the design settings is used as the concrete cover of the edge reinforcement.
- The designed fasteners should respect the product design conditions and recommendations by the manufacturer and in EN 1992-4, section F.3, such as welding procedures, installation, max. size of fixing, etc.
- The characteristic bond resistances depend on the return period (service life in years): 50

**Fastening meets the design criteria!**


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# 8 Installation data

Baseplate, steel: -

Profile: -

Hole diameter in the fixture: -

Plate thickness (input): -

Anchor type and size: Headed fastener 8.8 M24

Item number: not available

Minimum thickness of the base material: 0.0 mm

Hilti Headed fastener headed stud anchor with 186 mm embedment, M24, Steel galvanized, installation per -

## 8.1 Recommended accessories

| Drilling | Cleaning | Setting |
|---|---|---|
| • - | • No accessory required | • - |

**Coordinates Anchor [mm]**

| Anchor | x | y | $c_{-x}$ | $c_{+x}$ | $c_{-y}$ | $c_{+y}$ |
|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | - | 250.0 | 500.0 | 500.0 |


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## 9 Remarks; Your Cooperation Duties

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Input data and results must be checked for conformity with the existing conditions and for plausibility!
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**Conclusion of both calculations**
Anchoring in bottom part of bridge deck - combined tension and shear loads resulted in **21%** utilization for steel and **98%** utilization in concrete (Calculation part 4.5).
Anchoring in upper edge beam - combined tension and shear loads resulted in **13%** utilization for steel and **93%** utilization in concrete (Calculation part 4.6).

**Connection is safe and meets requirements!**

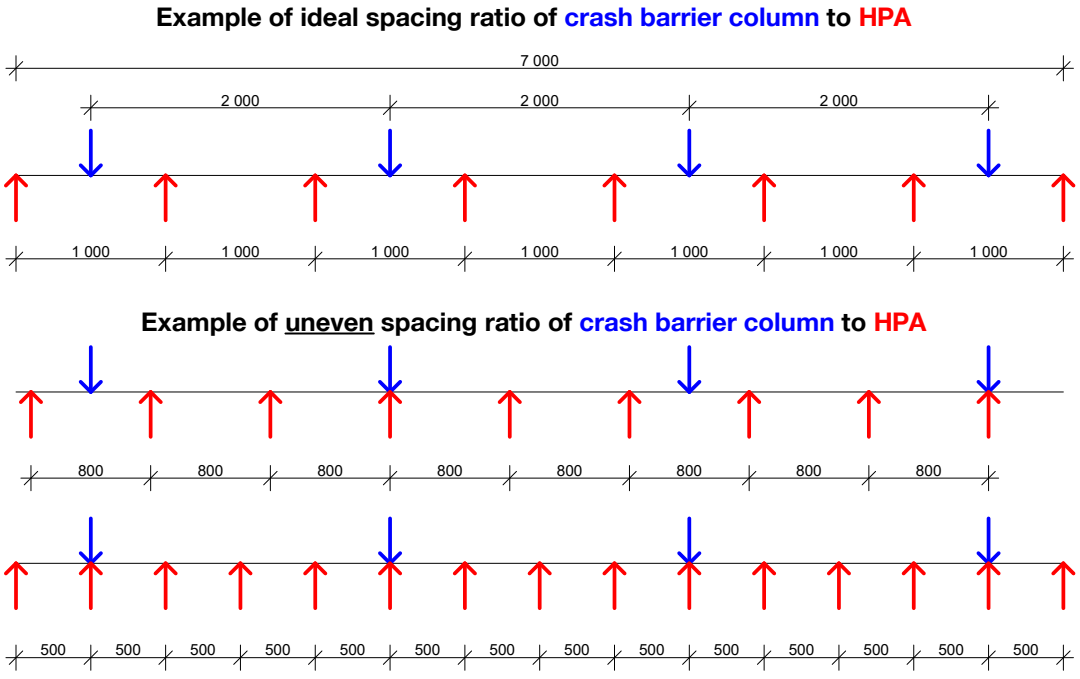
# 5. POSSIBLE FURTHER OPTIMIZATION

In our case we met the design criteria and utilization is safe, but in situations where the loads are extreme or geometry very unfavorable, we list below some further options that can be used to improve resistance. All those options should be consulted with Hilti and approved by structural engineer of the bridge.

## 5.1 Reduce the spacing between anchors

Smaller spacing distance seems like simplest option to reduce loads on 1 anchor however, some pre-cautions need to be considered and coordinated with structural engineer of the bridge:

- Distribution of design loads. If we have spaced of crash barrier columns of 2m and we place HPA anchors every 1m its safe to assume that load distribution is equal, but if we reduce the spacing there can be places where anchor is closer to crash barrier column – taking higher loads and opposite where anchor is further away from crash barrier column and taking lower loads. Final loads on 1 HPA is responsibility of structural engineer of the bridge and Hilti cannot decide the loads.



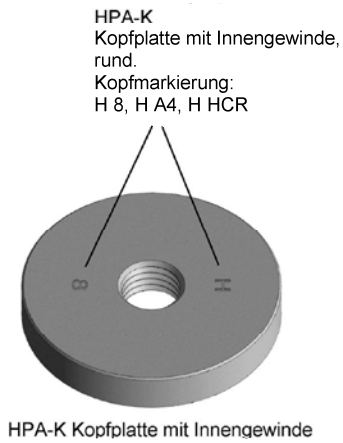

**Highest load forces on each HPA anchor point must be always specifed & confirmed by general designed of bridge!**

**Figure 5-1 Visual example of anchor spacing relation to column spacing of crash barrier.**

- Spacing can be also influenced by length of edge beam and its division into dilatation sections. Usually, HPA spacing is denser near the edge.
- Smaller spacing can cause concrete cone edge breakout to overlap and lower splitting resistance. Both of those must be recalculated and checked. For visual example see Figure 5-3.
- Collision with rebar layout, other anchors or structures inside edge beam or bridge deck.

## 5.2 Include head plate at the top of anchor

According to Z-21.8.2118 for an M24 anchor a head plate HPA-K with a diameter of 70 mm can be used. Today the provisions in EN 1992-4 do not allow to increase the concrete breakout strength when increasing the head size. However, there is research available providing guidance on the increase of the breakout strength for larger heads [(Nilforoush, 2017)]. The increase is represented by the factor $\psi_{AH}$ according to Equation (1). The critical maximum bearing pressure to ensure concrete cone breakout is $15^{fc}$.




$$A_b^0 = \frac{N_{cc-method}}{15 f_c} = \frac{16.8\sqrt{f_c}\,(h_{ef})^{1.5}}{15 f_c} \qquad \psi_H = \left(\frac{h}{2h_{ef}}\right)^{0.25}$$

$$\psi_{AH} = \left(\frac{A_b}{A_b^0}\right)^{0.1}$$

**Figure 5-2 "Kopfplatte" is large thick washer with internal thread available from Hilti on demand.**

## 5.3 Smaller distance of stirrups – denser reinforcement

If the spacing between the stirrups is reduced from 150 mm to 100 mm an increase factor ψre,V = 1.4 could be used. Minimal stirrup diameter should be ≥ 10 mm, minimal diameter of longitudinal reinforcement ≥12 mm. It is sufficient to reduce the spacing of the stirrups left and right next to the anchor in the breakout cone and not along the entire length of the edge beam.

Below excerpt from EN 1992-4 page 61:
(13) The factor Ψre,V takes account of the effect of the reinforcement located on the edge.
- Ψre,V=1,0 fastening in uncracked concrete and fastening in cracked concrete without edge reinforcement or stirrups
- Ψre,V=1,4 fastening in cracked concrete with edge reinforcement (see Figure 7.10) and closely spaced stirrups or wire mesh with spacing a ≤100 mm and a ≤2c1.

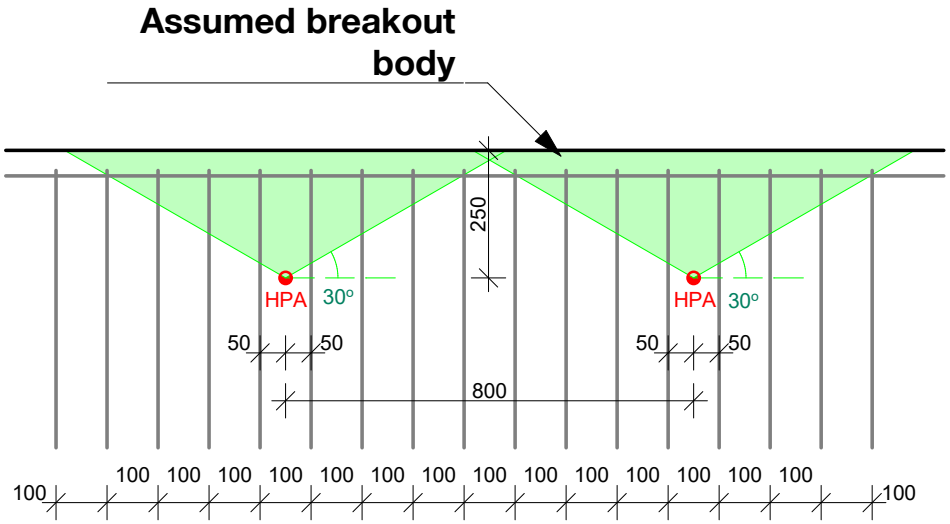



**Figure 5-3 Top-down view of edge beam and breakout cones of anchors.**

## 5.4 Rebar at the end of bridge deck to take shear loads

Rebar penetration is at the vertical front face of bridge deck, where waterproofing is not an issue. This helps us to take portion of shear loads. Final % of shear loads taken by rebar must be confirmed by general designer of bridge.

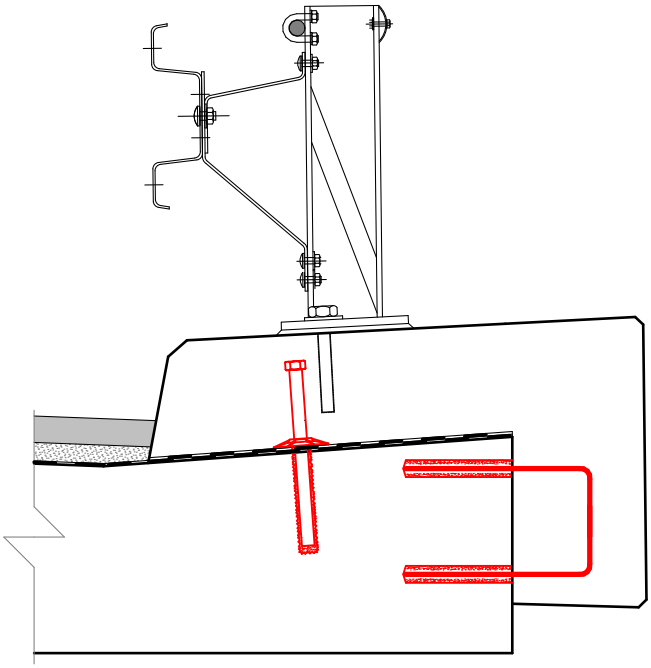


**Figure 5-4 This method is mandatory and used on bridges in Slovakia.**

## 5.5 Place two HPA anchors in a row

Only possible on wider edge beams, significant impact to costs.

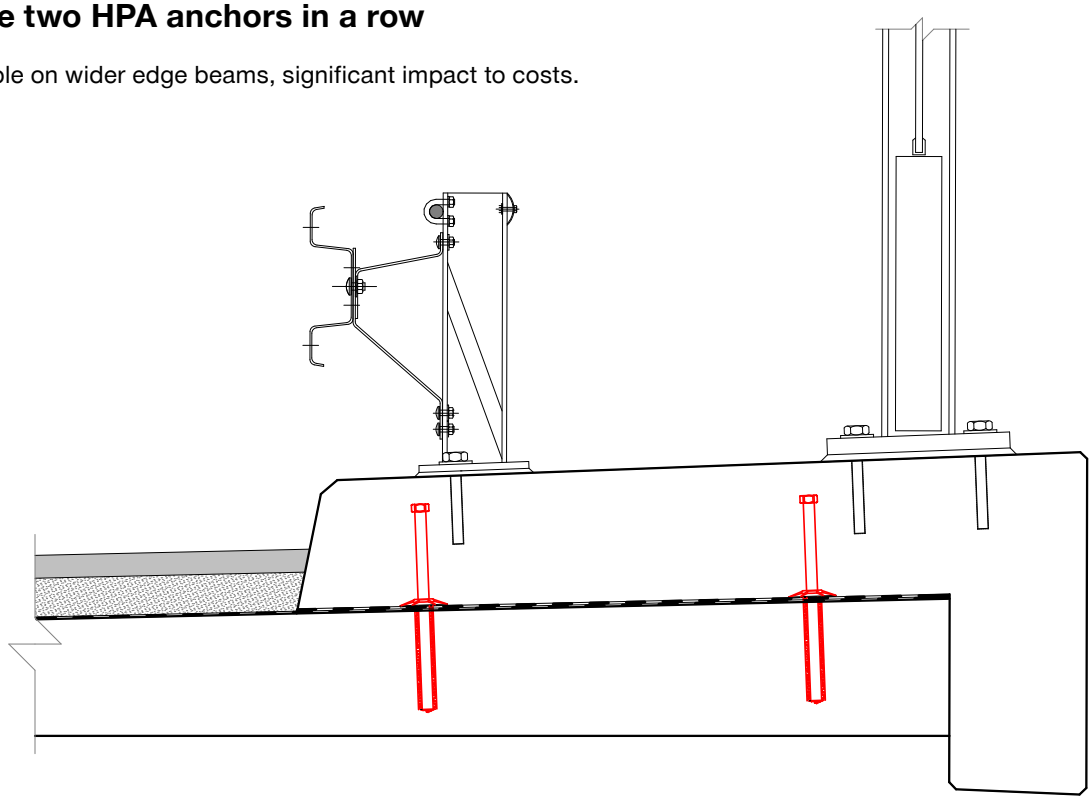
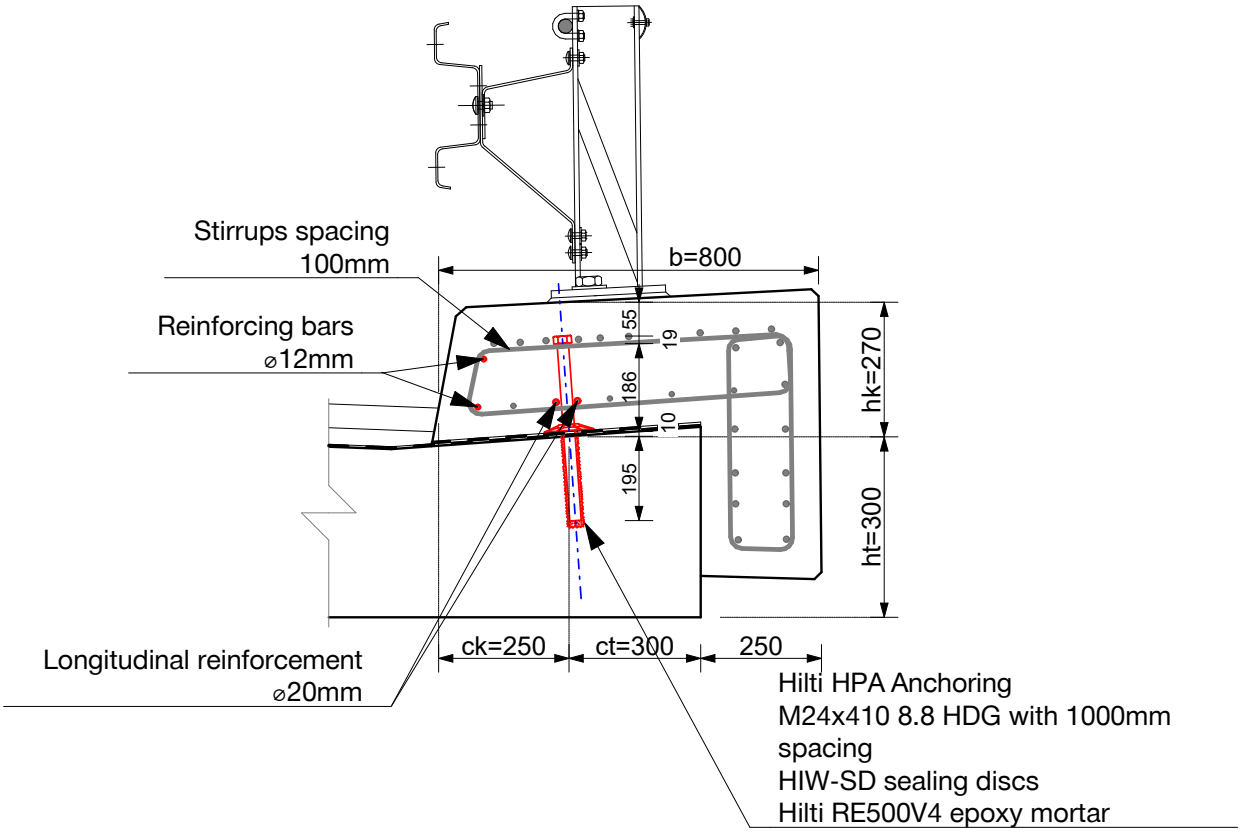


**Figure 5-5 Two HPA in a row on wider edge beams**

# 6. CONCLUSION

## 6.1 Final design



## 6.2 Summary

In this document we defined basic edge beam terminology, types of anchoring with their advantages and disadvantages. In detail we described Hilti solution and provided example how to calculate it using Hilti Profis Engineering safely and efficiently. Bridge edge beam connection is not typical type of connection and can be challenging to design at first. On top of it there are requirements for watertightness, productivity on jobsite and cost-effective solution.
All those criteria can be fulfilled with Hilti solution for edge beam anchoring.

## 6.3 Credits to

Dr. Ing. Philipp Grosser
Ing. Daniel Mikeš
Ing. Jan Jonáš
Ing. Martin Kolda
Ing. Jozef Kšiňan, PhD.

## 6.4 References

[1] EN 1992-4: Eurocode 2 – Design of concrete structures – Part 4: Design of fastenings for use in concrete

[2] Racutanu, George (2001): The real service life of Swedish road bridges, Doctoral thesis

[3] Nilforoush (2017): Anchorage in Concrete Structures, Numerical and Experimental Evaluations of Load-Carrying Capacity of Cast-in-Place Headed Anchors and Post-Installed Adhesive Anchors, Doctoral thesis, 2017

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**In Prague 28. 4. 2023**

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