

## Anchor design

### Safety concept

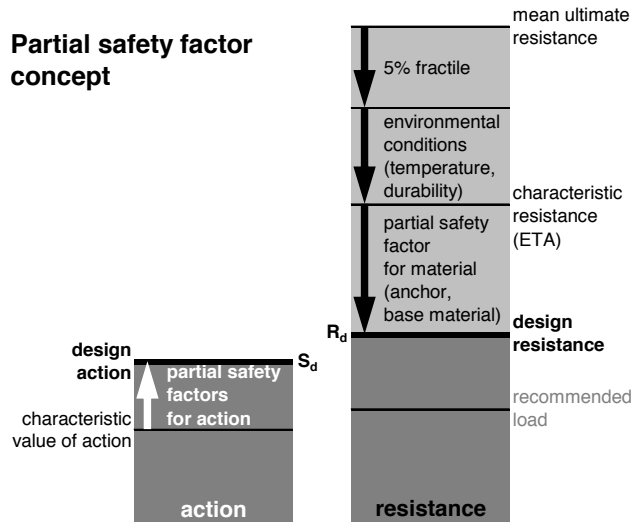
Depending on the application and the anchor type one of the following two concepts can be applied:

For anchors for use in concrete having an European Technical Approval (ETA) the partial safety factor concept according to the European Technical Approval Guidelines ETAG 001 or ETAG 020 shall be applied. It has to be shown, that the value of design actions does not exceed the value of the design resistance:  $S_d \leq R_d$ .

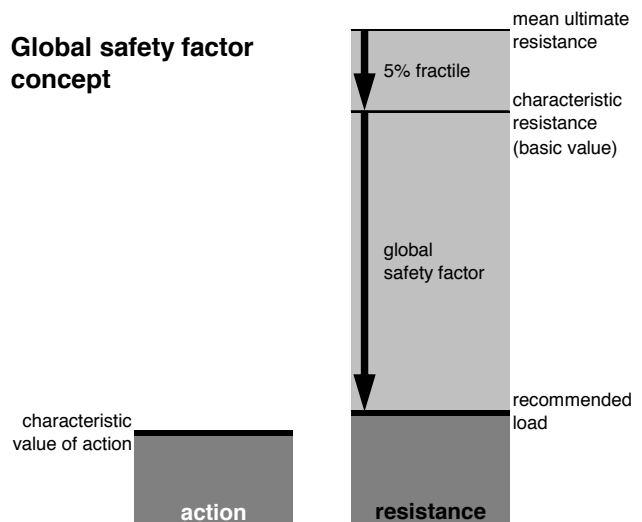
For the characteristic resistance given in the respective ETA, reduction factors due to e.g. freeze/thaw, service temperature, durability, creep behaviour and other environmental or application conditions are already considered.

According ETAG 001, Annex C, the partial safety factor is  $\gamma_G = 1,35$  for permanent actions and  $\gamma_Q = 1,5$  for variable actions. In addition to the design resistance, in this manual recommended loads are given, using an overall partial safety factor for action  $\gamma = 1,4$ .

#### Partial safety factor concept



#### Global safety factor concept



For the global safety factor concept it has to be shown, that the characteristic value of action does not exceed the recommended load value.

The characteristic resistance given in the tables is the 5% fractile value obtained from test results under standard test conditions. With a global safety factor all environmental and application conditions for action and resistance are considered, leading to a recommended load.

## Design methods

### Metal anchors for use in concrete according ETAG 001

The design methods for metal anchors for use in concrete are described in detail in Annex C of the European Technical Approval guideline ETAG 001 and for bonded anchors with variable embedment depth in EOTA Technical Report TR 029. Additional design rules for redundant fastenings are given in Part 6 of ETAG 001.

The design method given in this Anchor Fastening Technology Manual is based on these guidelines. The calculations according to this manual are simplified and lead to conservative results, i.e. the results are on the safe side. Tables with basic load values and influencing factors and the calculation method are given for each anchor in the respective section.

### Anchors for use in other base materials and for special applications

If no special calculation method is given, the basic load values given in this manual are valid, as long as the application conditions (e.g. base material, geometry, environmental conditions) are observed.

### Redundant fastenings with plastic anchors

Design rules for redundant fastenings with plastic anchors for use in concrete and masonry for non-structural applications are given in Annex C of ETAG 020. The additional design rules for redundant fastenings are considered in this manual.

### Resistance to fire

When resistance to fire has to be considered, the load values given in the section "resistance to fire" should be observed. The values are valid for a single anchor.

### Hilti design software PROFIS Anchor

For a more complex and accurate design according to international and national guidelines and for applications beyond the guidelines, e.g. group of anchors with more than four anchors close to the edge or more than eight anchors far away from the edge, the Hilti design software PROFIS anchor yields customised fastening solutions. The results can be different from the calculations according to this manual.

## Simplified design method

Simplified version of the design method according ETAG 001, Annex C or EOTA Technical Report TR 029. Design resistance according data given in the relevant European Technical Approval (ETA)

- Influence of concrete strength
- Influence of edge distance
- Influence of spacing
- Valid for a group of two anchors. (The method may also be applied for anchor groups with more than two anchors or more than one edge. The influencing factors must then be considered for each edge distance and spacing. The calculated design loads are then on the safe side: They will be lower than the exact values according ETAG 001, Annex C. To avoid this, it is recommended to use the anchor design software PROFIS anchor)

The design method is based on the following simplification:

- No different loads are acting on individual anchors (no eccentricity)

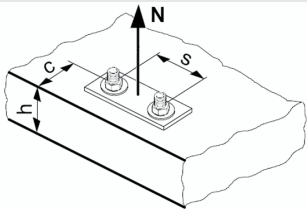
The differences to the design method given in the guideline are shown in the following.

**Anchors with fixed embedment depth**

**Design tensile resistance**

The design tensile resistance is the lower value of

- Design steel resistance  $N_{Rd,s}$
- Design pull-out resistance  $N_{Rd,p}$
- Design concrete cone resistance  $N_{Rd,c}$
- Design splitting resistance  $N_{Rd,sp}$



**Design steel resistance  $N_{Rd,s}$**

**Annex C of ETAG 001 and relevant ETA**

$$N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$$

- \*  $N_{Rk,s}$ : characteristic steel resistance
- \*  $\gamma_{Ms}$ : partial safety factor for steel failure

\* Values given in the relevant ETA

**Simplified design method**

$$N_{Rd,s}$$
  
\*\* Value given in the respective tables in this manual

**Design pull-out resistance  $N_{Rd,p}$**

**Annex C of ETAG 001 and relevant ETA**

$$N_{Rd,p} = (N_{Rk,p} / \gamma_{Mp}) \cdot \psi_c$$

- \*  $N_{Rk,p}$ : characteristic pull-out resistance
- \*  $\gamma_{Mp}$ : partial safety factor for pull-out failure
- \*  $\psi_c$ : influence of concrete strength

\* Values given in the relevant ETA

**Simplified design method**

$$N_{Rd,p} = N_{Rd,p}^0 \cdot f_B$$

- \*\*  $N_{Rd,p}^0$ : Basic design pull-out resistance
- \*\*  $f_B$ : influence of concrete strength

\*\* Values given in the respective tables in this manual

### Design concrete cone resistance $N_{Rd,c}$

#### Annex C of ETAG 001 and relevant ETA

$$N_{Rd,c} = (N_{Rk,c}^0 / \gamma_{Mc}) \cdot (A_{c,N} / A_{c,N}^0) \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{ucr,N}$$

where  $N_{Rk,c}^0 = k \cdot f_{ck,cube}^{0,5} \cdot h_{ef}^{1,5}$

**k:** = 7,2 (in general) variations therefrom are given in the relevant ETA

\*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure

+  $A_{c,N}^0$ : area of concrete cone of an individual anchor with large spacing and edge distance at the concrete surface (idealised)

+  $A_{c,N}$ : actual area of concrete cone of the anchorage at the concrete surface, limited by overlapping concrete cones of adjoining anchors and by edges of the concrete member

+  $\psi_{s,N}$ : influence of the disturbance of the distribution of stresses due to edges

+  $\psi_{re,N}$ : influence of dense reinforcement

+  $\psi_{ec,N}$ : influence of excentricity

$\psi_{ucr,N}$ : = 1,0 for anchorages in cracked concrete  
= 1,4 for anchorages in non-cracked concrete

$f_{ck,cube}$ : concrete compressive strength

\*  $h_{ef}$ : effective anchorage depth

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see Annex C of ETAG 001)

#### Simplified design method

$$N_{Rd,c} = N_{Rd,c}^0 \cdot f_B \cdot f_{1,N} \cdot f_{2,N} \cdot f_{3,N} \cdot f_{re,N}$$

\*\*  $N_{Rd,c}^0$ : Basic design concrete cone resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{1,N}, f_{2,N}$ : influence of edge distance

\*\*  $f_{3,N}$ : influence of anchor spacing

\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

## Design concrete splitting resistance $N_{Rd,sp}$

### Annex C of ETAG 001 and relevant ETA

$$N_{Rd,sp} = (N_{Rk,c}^0 / \gamma_{Mc}) \cdot (A_{c,N} / A_{c,N}^0) \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{ucr,N} \cdot \psi_{h,sp}$$

where  $N_{Rk,c}^0 = k \cdot f_{ck,cube}^{0,5} \cdot h_{ef}^{1,5}$

**k:** = 7,2 (in general) variations therefrom are given in the relevant ETA

\*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure

++  $A_{c,N}^0$ : area of concrete cone of an individual anchor with large spacing and edge distance at the concrete surface (idealised)

++  $A_{c,N}$ : actual area of concrete cone of the anchorage at the concrete surface, limited by overlapping concrete cones of adjoining anchors and by edges of the concrete member

+  $\psi_{s,N}$ : influence of the disturbance of the distribution of stresses due to edges

+  $\psi_{re,N}$ : influence of dense reinforcement

+  $\psi_{ec,N}$ : influence of excentricity

$\psi_{ucr,N}$ : = 1,0 for anchorages in cracked concrete  
= 1,4 for anchorages in non-cracked concrete

+  $\psi_{h,sp}$ : influence of the actual member depth

$f_{ck,cube}$ : concrete compressive strength

\*  $h_{ef}$ : effective anchorage depth

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see Annex C of ETAG 001)

++ Values of  $A_{c,N}^0$  and  $A_{c,N}$  for splitting failure may be different from those for concrete cone failure, due to different values for the critical edge distance and critical anchor spacing

### Simplified design method

$$N_{Rd,sp} = N_{Rd,c}^0 \cdot f_B \cdot f_{1,sp} \cdot f_{2,sp} \cdot f_{3,sp} \cdot f_{h,sp} \cdot f_{re,N}$$

\*\*  $N_{Rd,c}^0$ : Basic design concrete cone resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{1,sp}, f_{2,sp}$ : influence of edge distance

\*\*  $f_{3,sp}$ : influence of anchor spacing

\*\*  $f_{h,sp}$ : influence of base material thickness (concrete member depth)

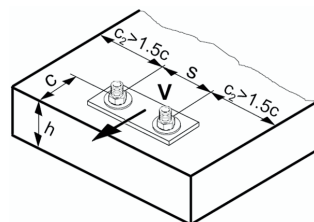
\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

### Design shear resistance

The design shear resistance is the lower value of

- Design steel resistance  $V_{Rd,s}$
- Design concrete pryout resistance  $V_{Rd,cp}$
- Design concrete edge resistance  $V_{Rd,c}$



### Design steel resistance $V_{Rd,s}$ (without lever arm)

#### Annex C of ETAG 001 and relevant ETA

$$V_{Rd,s} = V_{Rk,s} / \gamma_{Ms}$$

- \*  $V_{Rk,s}$ : characteristic steel resistance
- \*  $\gamma_{Ms}$ : partial safety factor for steel failure

\* Values given in the relevant ETA

For steel failure with lever arm see ETAG 001 Annex C

#### Simplified design method

$$** V_{Rd,s}$$

\*\* Value given in the respective tables in this manual

Steel failure with lever arm is not considered for the simplified design method

## Design concrete pryout resistance $V_{Rd,cp}$

### Annex C of ETAG 001 and relevant ETA

$$V_{Rd,cp} = (V_{Rk,cp} / \gamma_{Mp}) = k \cdot N_{Rd,c}$$

$$N_{Rd,c} = (N_{Rk,c}^0 / \gamma_{Mc}) \cdot (A_{c,N} / A_{c,N}^0) \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{ucr,N}$$

$$\text{where } N_{Rk,c}^0 = 7,2 \cdot f_{ck,cube}^{0,5} \cdot h_{ef}^{1,5}$$

\*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure

+  $A_{c,N}^0$ : area of concrete cone of an individual anchor with large spacing and edge distance at the concrete surface (idealised)

+  $A_{c,N}$ : actual area of concrete cone of the anchorage at the concrete surface, limited by overlapping concrete cones of adjoining anchors and by edges of the concrete member

+  $\psi_{s,N}$ : influence of the disturbance of the distribution of stresses due to edges

+  $\psi_{re,N}$ : influence of dense reinforcement

++  $\psi_{ec,N}$ : influence of excentricity

$\psi_{ucr,N}$ : = 1,0 for anchorages in cracked concrete  
= 1,4 for anchorages in non-cracked concrete

$f_{ck,cube}$ : concrete compressive strength

\*  $h_{ef}$ : effective anchorage depth

\*  $k$ : influence of embedment depth

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see Annex C of ETAG 001)

++ Details see Annex C of ETAG 001

### Simplified design method

$$V_{Rd,p} = V_{Rd,cp}^0 \cdot f_B \cdot f_{1,N} \cdot f_{2,N} \cdot f_{3,N} \cdot f_{re,N}$$

\*\*  $V_{Rd,cp}^0$ : Basic design concrete pryout resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{1,N}, f_{2,N}$ : influence of edge distance

\*\*  $f_{3,N}$ : influence of anchor spacing

\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

## Design concrete edge resistance $V_{Rd,c}$

### Annex C of ETAG 001 and relevant ETA

$$V_{Rd,c} = (V_{Rk,c}^0 / \gamma_{Mc}) \cdot (A_{c,V} / A_{c,V}^0) \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{ucr,V}$$

$$\text{where } V_{Rk,c}^0 = 0,45 \cdot d_{nom}^{0,5} \cdot (l_f/d_{nom})^{0,2} \cdot f_{ck,cube}^{0,5} \cdot c_1^{1,5}$$

\*  $\gamma_{Mc}$ : partial safety factor for concrete edge failure

+  $A_{c,V}^0$ : area of concrete cone of an individual anchor at the lateral concrete surface not affected by edges (idealised)

+  $A_{c,V}$ : actual area of concrete cone of anchorage at the lateral concrete surface, limited by overlapping concrete cones of adjoining anchors, by edges of the concrete member and by member thickness

+  $\psi_{s,V}$ : influence of the disturbance of the distribution of stresses due to further edges

+  $\psi_{h,V}$ : takes account of the fact that the shear resistance does not decrease proportionally to the member thickness as assumed by the idealised ratio  $A_{c,V} / A_{c,V}^0$

++  $\psi_{\alpha,V}$ : Influence of angle between load applied and the direction perpendicular to the free edge

++  $\psi_{ec,V}$ : influence of excentricity

++  $\psi_{ucr,V}$ : = 1,0, 1,2 or 1,4

\*  $d_{nom}$ : nominal diameter of the anchor

\*  $l_f$ : effective length of anchor under shear loading

$f_{ck,cube}$ : concrete compressive strength

$c_1$ : edge distance

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see Annex C of ETAG 001)

++ Details see Annex C of ETAG 001

### Simplified design method

$$V_{Rd,c} = V_{Rd,c}^0 \cdot f_B \cdot f_h \cdot f_4$$

\*\*  $V_{Rd,c}^0$ : Basic design concrete edge resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_B$ : Influence of angle between load applied and the direction perpendicular to the free edge

\*\*  $f_h$ : Influence of base material thickness

\*\*  $f_4$ : Influence of anchor spacing and edge distance

\*\* Values given in the respective tables in this manual

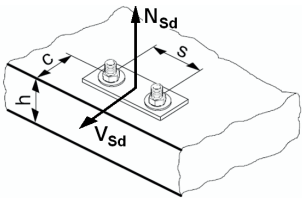


**Combined tension and shear loading**

The following equations must be satisfied

$\beta_N \leq 1$   
 $\beta_V \leq 1$   
 $\beta_N + \beta_V \leq 1,2 \text{ or } \beta_N^\alpha + \beta_V^\alpha \leq 1$

With  
 $\beta_N = N_{Sd} / N_{Rd}$  and  
 $\beta_V = V_{Sd} / V_{Rd}$   
 $N_{Sd} (V_{Sd}) = \text{tension (shear)}$   
                   design action  
 $N_{Rd} (V_{Rd}) = \text{tension (shear)}$   
                   design resistance



**Annex C of ETAG 001**

$\alpha = 2,0$  if  $N_{Rd}$  and  $V_{Rd}$  are governed by steel failure  
 $\alpha = 1,5$  for all other failure modes

**Simplified design method**

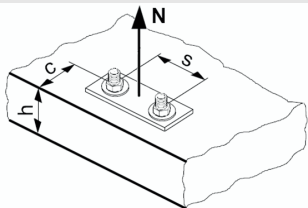
Failure mode is not considered for the simplified method  
 $\alpha = 1,5$  for all failure modes (leading to conservative results = being on the save side)

**Anchors with variable embedment depth according TR 029**

**Design tensile resistance**

The design tensile resistance is the lower value of

- Design steel resistance  $N_{Rd,s}$
- Design combined pull-out and concrete cone resistance  $N_{Rd,p}$
- Design concrete cone resistance  $N_{Rd,c}$
- Design splitting resistance  $N_{Rd,sp}$



**Design steel resistance  $N_{Rd,s}$**

**Technical Report TR 029 and relevant ETA**

$N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$   
 \*  $N_{Rk,s}$ : characteristic steel resistance  
 \*  $\gamma_{Ms}$ : partial safety factor for steel failure  
 \* Values given in the relevant ETA

**Simplified design method**

$N_{Rd,s}$   
 \*\* Value given in the respective tables in this manual

## Design combined pull-out and concrete cone resistance $N_{Rd,p}$

### Technical Report TR 029 and relevant ETA

$$N_{Rd,p} = (N_{Rk,p}^0 / \gamma_{Mp}) \cdot (A_{p,N} / A_{p,N}^0) \cdot \psi_{s,Np} \cdot \psi_{g,Np} \cdot \psi_{ec,Np} \cdot \psi_{re,Np} \cdot \psi_c$$

where  $N_{Rk,p}^0 = \pi \cdot d \cdot h_{ef} \cdot \tau_{Rk}$

$$\psi_{g,Np} = \psi_{g,Np}^0 - (s / s_{cr,Np})^{0.5} \cdot (\psi_{g,Np}^0 - 1) \geq 1$$

$$\psi_{g,Np}^0 = n^{0.5} - (n^{0.5} - 1) \cdot \{(d \cdot \tau_{Rk}) / [k \cdot (h_{ef} \cdot f_{ck,cube})^{0.5}]\}^{1.5} \geq 1$$

$$s_{cr,Np} = 20 \cdot d \cdot (\tau_{Rk,ucr} / 7.5)^{0.5} \leq 3 \cdot h_{ef}$$

- \*  $\gamma_{Mp}$ : partial safety factor for combined pull-out and concrete cone failure
- +  $A_{p,N}^0$ : influence area of an individual anchor with large spacing and edge distance at the concrete surface (idealised)
- +  $A_{p,N}$ : actual influence area of the anchorage at the concrete surface, limited by overlapping areas of adjoining anchors and by edges of the concrete member
- +  $\psi_{s,Np}$ : influence of the disturbance of the distribution of stresses due to edges
- +  $\psi_{ec,Np}$ : influence of excentricity
- +  $\psi_{re,Np}$ : influence of dense reinforcement
- \*  $\psi_c$ : influence of concrete strength
- \*  $d$ : anchor diameter
- \*  $h_{ef}$ : (variable) embedment depth
- \*  $\tau_{Rk}$ : characteristic bond resistance
- $s$ : anchor spacing
- $s_{cr,Np}$ : critical anchor spacing
- $n$ : number of anchors in a anchor group
- $k$ : = 2,3 in cracked concrete  
= 3,2 in non-cracked concrete
- $f_{ck,cube}$ : concrete compressive strength
- \*  $\tau_{Rk,ucr}$ : characteristic bond resistance for non-cracked concrete

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see TR 029. The basis of the calculations may depend on the critical anchor spacing).

### Simplified design method

$$N_{Rd,p} = N_{Rd,p}^0 \cdot f_{B,p} \cdot f_{1,N} \cdot f_{2,N} \cdot f_{3,N} \cdot f_{h,p} \cdot f_{re,N}$$

\*\*  $N_{Rd,p}^0$ : Basic design combined pull-out and concrete cone resistance

\*\*  $f_{B,p}$ : influence of concrete strength

\*\*  $f_{1,N}, f_{2,N}$ : influence of edge distance

\*\*  $f_{3,N}$ : influence of anchor spacing

\*\*  $f_{h,p}$ : influence of (variable) embedment depth

\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

For the simplified design method the factor  $\psi_{g,Np}$  (see TR 029) is assumed to be 1 and the critical anchor spacing is assumed to be  $s_{cr,Np} = 3 \cdot h_{ef}$ , both leading to conservative results = being on the save side.

## Design concrete cone resistance $N_{Rd,c}$

### Technical Report TR 029 and relevant ETA

$$N_{Rd,c} = (N_{RK,c}^0 / \gamma_{Mc}) \cdot (A_{c,N} / A_{c,N}^0) \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N}$$

where  $N_{RK,c}^0 = k_1 \cdot f_{ck,cube}^{0.5} \cdot h_{ef}^{1.5}$

\*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure

+  $A_{c,N}^0$ : area of concrete cone of an individual anchor with large spacing and edge distance at the concrete surface (idealised)

+  $A_{c,N}$ : actual area of concrete cone of the anchorage at the concrete surface, limited by overlapping concrete cones of adjoining anchors and by edges of the concrete member

+  $\psi_{s,N}$ : influence of the disturbance of the distribution of stresses due to edges

+  $\psi_{re,N}$ : influence of dense reinforcement

+  $\psi_{ec,N}$ : influence of excentricity

$k_1$ : = 7,2 for anchorages in cracked concrete  
= 10,1 for anchorages in non-cracked concrete

$f_{ck,cube}$ : concrete compressive strength

\*  $h_{ef}$ : effective anchorage depth

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see TR 029)

### Simplified design method

$$N_{Rd,c} = N_{Rd,c}^0 \cdot f_B \cdot f_{1,N} \cdot f_{2,N} \cdot f_{3,N} \cdot f_{h,N} \cdot f_{re,N}$$

\*\*  $N_{Rd,c}^0$ : Basic design concrete cone resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{1,N}, f_{2,N}$ : influence of edge distance

\*\*  $f_{3,N}$ : influence of anchor spacing

\*\*  $f_{h,N}$ : influence of embedment depth

\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

## Design concrete splitting resistance $N_{Rd,sp}$

### Technical Report TR 029 and relevant ETA

$$N_{Rd,sp} = (N_{RK,c}^0 / \gamma_{Mc}) \cdot (A_{c,N} / A_{c,N}^0) \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{h,sp}$$

where  $N_{RK,c}^0 = k_1 \cdot f_{ck,cube}^{0.5} \cdot h_{ef}^{1.5}$

\*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure

++  $A_{c,N}^0$ : area of concrete cone of an individual anchor with large spacing and edge distance at the concrete surface (idealised)

++  $A_{c,N}$ : actual area of concrete cone of the anchorage at the concrete surface, limited by overlapping concrete cones of adjoining anchors and by edges of the concrete member

+  $\psi_{s,N}$ : influence of the disturbance of the distribution of stresses due to edges

+  $\psi_{re,N}$ : influence of dense reinforcement

+  $\psi_{ec,N}$ : influence of excentricity

$k_1$ : = 7,2 for anchorages in cracked concrete  
= 10,1 for anchorages in non-cracked concrete

+  $\psi_{h,sp}$ : influence of the actual member depth

$f_{ck,cube}$ : concrete compressive strength

\*  $h_{ef}$ : embedment depth

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see TR 029)

++ Values of  $A_{c,N}^0$  and  $A_{c,N}$  for splitting failure may be different from those for concrete cone failure, due to different values for the critical edge distance and critical anchor spacing

### Simplified design method

$$N_{Rd,sp} = N_{Rd,c}^0 \cdot f_B \cdot f_{1,sp} \cdot f_{2,sp} \cdot f_{3,sp} \cdot f_{h,N} \cdot f_{re,N}$$

\*\*  $N_{Rd,c}^0$ : Basic design concrete cone resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{1,sp}, f_{2,sp}$ : influence of edge distance

\*\*  $f_{3,sp}$ : influence of anchor spacing

\*\*  $f_{h,N}$ : influence of base material thickness (concrete member depth)

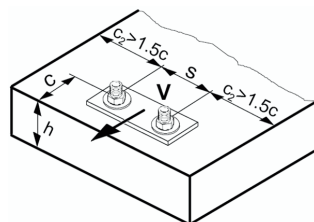
\*\*  $f_{re,N}$ : influence of dense reinforcement

\*\* Values given in the respective tables in this manual

## Design shear resistance

The design shear resistance is the lower value of

- Design steel resistance  $V_{Rd,s}$
- Design concrete pryout resistance  $V_{Rd,cp}$
- Design concrete edge resistance  $V_{Rd,c}$



### Design steel resistance $V_{Rd,s}$

#### Technical Report TR 029 and relevant ETA

$$V_{Rd,s} = V_{Rk,s} / \gamma_{Ms}$$

- \*  $V_{Rk,s}$ : characteristic steel resistance
- \*  $\gamma_{Ms}$ : partial safety factor for steel failure

\* Values given in the relevant ETA

For steel failure with lever arm see TR 029

#### Simplified design method

$$** V_{Rd,s}$$

\*\* Value given in the respective tables in this manual

Steel failure with lever arm is not considered for the simplified design method

### Design concrete pryout resistance $V_{Rd,cp}$

#### Technical Report TR 029 and relevant ETA

$$V_{Rd,cp} = (V_{Rk,cp} / \gamma_{Mp/Mc}) = k \cdot \text{lower value of } N_{Rd,p} \text{ and } N_{Rd,c}$$

$$N_{Rd,p} = N_{Rk,p} / \gamma_{Mp}$$

$$N_{Rd,c} = N_{Rk,c} / \gamma_{Mc}$$

$N_{Rd,p}$ : characteristic tension resistance for combined pull-out and concrete cone failure (see design combined pull-out and concrete cone failure)

$N_{Rk,c}$ : characteristic tension resistance for concrete cone failure (see design concrete cone failure)

- \*  $\gamma_{Mp}$ : partial safety factor for combined pull-out and concrete cone failure (see design combined pull-out and concrete cone failure)

- \*  $\gamma_{Mc}$ : partial safety factor for concrete cone failure (see design concrete cone failure)

- \*  $k$ : influence of embedment depth

\* Values given in the relevant ETA

#### Simplified design method

$$V_{Rd,cp} = k \cdot \text{lower value of } N_{Rd,p} \text{ and } N_{Rd,c}$$

$N_{Rd,p}$ : characteristic tension resistance for combined pull-out and concrete cone failure (see design combined pull-out and concrete cone failure)

$N_{Rk,c}$ : characteristic tension resistance for concrete cone failure (see design concrete cone failure)

- \*\*  $k$ : influence of embedment depth

\*\* Values given in the respective tables in this manual

## Design concrete edge resistance $V_{Rd,c}$

### Technical Report TR 029 and relevant ETA

$$V_{Rd,c} = (V_{Rk,c} / \gamma_{Mc}) \cdot (A_{c,V} / A_{c,V}^0) \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$$

where  $V_{Rk,c} = k_1 \cdot d^\alpha \cdot h_{ef}^\beta \cdot f_{ck,cube}^{0,5} \cdot c_1^{1,5}$

$$\alpha = 0,1 \cdot (h_{ef} / c_1)^{0,5}$$

$$\beta = 0,1 \cdot (d / c_1)^{0,2}$$

\*  $\gamma_{Mc}$ : partial safety factor for concrete edge failure

+  $A_{c,V}^0$ : area of concrete cone of an individual anchor at the lateral concrete surface not affected by edges (idealised)

+  $A_{c,V}$ : actual area of concrete cone of anchorage at the lateral concrete surface, limited by overlapping concrete cones of adjoining anchors, by edges of the concrete member and by member thickness

+  $\psi_{s,V}$ : influence of the disturbance of the distribution of stresses due to further edges

+  $\psi_{h,V}$ : takes account of the fact that the shear resistance does not decrease proportionally to the member thickness as assumed by the idealised ratio  $A_{c,V} / A_{c,V}^0$

++  $\psi_{\alpha,V}$ : Influence of angle between load applied and the direction perpendicular to the free edge

++  $\psi_{ec,V}$ : influence of excentricity

++  $\psi_{re,V}$ : influence of reinforcement

$k_1$ : = 1,7 for anchorages in cracked concrete  
= 2,4 for anchorages in non-cracked concrete

\*  $d$ : anchor diameter

$f_{ck,cube}$ : concrete compressive strength

$c_1$ : edge distance

\* Values given in the relevant ETA

+ Values have to be calculated according data given in the relevant ETA (details of calculation see TR 029)

++ Details see TR 029

### Simplified design method

$$V_{Rd,c} = V_{Rd,c}^0 \cdot f_B \cdot f_{\beta} \cdot f_h \cdot f_4 \cdot f_{hef} \cdot f_c$$

\*\*  $V_{Rd,c}^0$ : Basic design concrete edge resistance

\*\*  $f_B$ : influence of concrete strength

\*\*  $f_{\beta}$ : Influence of angle between load applied and the direction perpendicular to the free edge

\*\*  $f_h$ : Influence of base material thickness

\*\*  $f_4$ : Influence of anchor spacing and edge distance

\*\*  $f_{hef}$ : influence of embedment depth

\*\*  $f_c$ : influence of edge distance

\*\* Values given in the respective tables in this manual

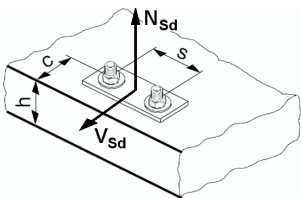
The factors  $f_{hef}$  and  $f_c$  replace the function  $d^\alpha \cdot h_{ef}^\beta$ , leading to conservative results = being on the safe side.

Combined tension and shear loading

The following equations must be satisfied

$\beta_N \leq 1$   
 $\beta_V \leq 1$   
 $\beta_N + \beta_V \leq 1,2$  or  $\beta_N^\alpha + \beta_V^\alpha \leq 1$

With  
 $\beta_N = N_{Sd} / N_{Rd}$  and  
 $\beta_V = V_{Sd} / V_{Rd}$   
 $N_{Sd} (V_{Sd}) =$  tension (shear) design action  
 $N_{Rd} (V_{Rd}) =$  tension (shear) design resistance



Annex C of ETAG 001

$\alpha = 2,0$  if  $N_{Rd}$  and  $V_{Rd}$  are governed by steel failure  
 $\alpha = 1,5$  for all other failure modes

Simplified design method

Failure mode is not considered for the simplified method  
 $\alpha = 1,5$  for all failure modes (leading to conservative results = beeing on the save side)



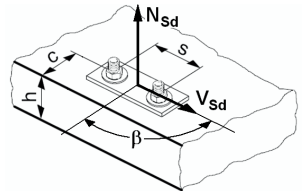


## Design examples

### Example 1: mechanical anchor in non-cracked concrete

#### Anchoring conditions

concrete	Non-cracked concrete C40/50	
number of anchors	Group of two anchors close to the edge	
base material thickness	$h$	250 mm
anchor spacing	$s$	300 mm
edge distance	$c$	120 mm
shear load direction perpendicular to free edge	$\beta$	90 °
TENSION design action (fixing point)	$N_{Sd}$	55,0 kN
SHEAR design action (fixing point)	$V_{Sd}$	20,0 kN
TENSION design action per anchor	$N_{Sd}^{(1)}$	27,5 kN
SHEAR design action per anchor	$V_{Sd}^{(1)}$	10,0 kN



The parameters are given in the anchor-section in the tables "setting details" and "setting parameters" (for HSL-3-G M16)

anchor	HSL-3-G M16	
effective anchorage depth	$h_{ef}$	100 mm
critical spacing for splitting failure	$s_{cr,sp}$	380 mm
critical spacing for concrete cone failure	$s_{cr,N}$	300 mm
critical edge distance for splitting failure	$c_{cr,sp}$	190 mm
critical edge distance for concrete cone failure	$c_{cr,N}$	150 mm
minimum edge distance	$s_{min}$	100 mm
for	$c \geq$	240 mm
minimum spacing	$c_{min}$	100 mm
for	$s \geq$	240 mm

#### General remarks

According ETAG 001, Annex C, concrete cone, splitting, pryout and concrete edge design resistance must be verified for the anchor group. Steel and pull-out design resistance must be verified for the most unfavourable anchor of the anchor group.

According to the simplified design method given in this Fastening Technology Manual all anchors of a group are loaded equally, the design resistance values given in the tables are valid for one anchor.

### Tension loading

#### Design steel resistance

$N_{Rd,s} =$	<b>83,7 kN</b>
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See “basic design tensile resistance”  
(for HSL-3-G M16)

#### Design concrete pull-out resistance

basic resistance	$N_{Rd,p}^0$	-
concrete	non-cracked concrete C40/50	$f_B$
$N_{Rd,p} = N_{Rd,p}^0$		-

See “basic design tensile resistance”  
(for HSL-3-G M16 pull-out failure is not decisive in non-cracked concrete)

#### Design concrete cone resistance

basic resistance	$N_{Rd,c}^0$	33,6 kN
concrete	non-cracked concrete C40/50	$f_B$
c = 120 mm	$c_{cr,N} = 150$ mm	$c/c_{cr,N} = 0,80 \rightarrow$
s = 300 mm	$s_{cr,N} = 300$ mm	$s/s_{cr,N} = 1,00 \rightarrow$
anchor	HSL-3-G M16	$f_{re,N}$
$N_{Rd,c} = N_{Rd,c}^0 f_B f_{1,N} f_{2,N} f_{3,N} f_{re,N}$		<b>40,1 kN</b>

See “basic design tensile resistance”  
(for HSL-3-G M16)  
and “influencing factors”  
(for HSL-3-G M16)

Influencing factors may be interpolated.

#### Design splitting resistance

basic resistance	$N_{Rd,c}^0$	33,6 kN
concrete	non-cracked concrete C40/50	$f_B$
c = 120 mm	$c_{cr,sp} = 190$ mm	$c/c_{cr,sp} = 0,63 \rightarrow$
s = 300 mm	$s_{cr,sp} = 380$ mm	$s/s_{cr,sp} = 0,79 \rightarrow$
h = 250 mm	$h_{ef} = 100$ mm	$[h/(2h_{ef})]^{2/3} = 2,5 \rightarrow$
anchor	HSL-3-G M16	$f_{re,N}$
$N_{Rd,sp} = N_{Rd,c}^0 f_B f_{1,sp} f_{2,sp} f_{3,sp} f_{h,sp} f_{re,N}$		<b>35,7 kN</b>

See “basic design tensile resistance”  
(for HSL-3-G M16)  
and “influencing factors”  
(for HSL-3-G M16)

Influencing factors may be interpolated.

<b>Tension design resistance: lowest value</b>	$N_{Rd} =$	<b>35,7 kN</b>
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## Shear loading

### Design steel resistance

$V_{Rd,s} =$	<b>68,6 kN</b>
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See “basic design shear resistance” (for HSL-3-G M16)

### Concrete pryout design resistance

basic resistance				$V_{Rd,cp}^0$	67,2 kN
concrete		non-cracked concrete C40/50		$f_B$	1,41
c = 120 mm	$c_{cr,N} = 150$ mm	$c/c_{cr,N} = 0,80 \rightarrow$		$f_{1,N}$	0,94
				$f_{2,N}$	0,90
s = 300 mm	$s_{cr,N} = 300$ mm	$s/s_{cr,N} = 1,00 \rightarrow$		$f_{3,N}$	1,00
anchor		HSL-3-G M16 $\rightarrow$		$f_{re,N}$	1,00
$V_{Rd,cp} = V_{Rd,cp}^0 f_B f_{1,N} f_{2,N} f_{3,N} f_{re,N} =$					80,2 kN

See “basic design shear resistance” (for HSL-3-G M16) and “influencing factors” (for HSL-3-G M16)

Influencing factors may be interpolated.

### Concrete edge design resistance

basic resistance				$V_{Rd,c}^0$	13,7 kN
concrete		non-cracked concrete C40/50		$f_B$	1,41
shear load direction perpendicular to free edge			$90^\circ \rightarrow$	$f_\beta$	2
$h = 250 \text{ mm}$	$c = 120 \text{ mm}$	$h/c = 2,08$	$\rightarrow$	$f_h$	1
$c = 120 \text{ mm}$	$h_{ef} = 100 \text{ mm}$	$c/h_{ef} = 1,20$	$\rightarrow$	$f_4$	1,20
$s = 300 \text{ mm}$	$h_{ef} = 100 \text{ mm}$	$s/h_{ef} = 3,00$	$\rightarrow$		
$V_{Rd,c} = V_{Rd,c}^0 f_B f_\beta f_h f_4 =$					<b>46,4 kN</b>

See “basic design shear resistance” (for HSL-3-G M16) and “influencing factors” (for HSL-3-G M16)

Influencing factors may be interpolated.

**Shear design resistance: lowest value**  $V_{Rd} =$  **46,4 kN**

## Combined tension and shear loading

The following equation must be satisfied for combined tension and shear loading:

$$(\text{Eq. 1}) \quad (\beta_N)^{1,5} + (\beta_V)^{1,5} \leq 1$$

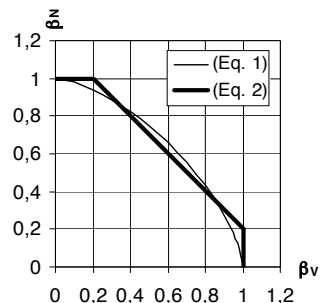
$\beta_N$  ( $\beta_V$ ) ratio between design action and design resistance for tension (shear) loading

According to ETAG 001, Annex C, the following simplified equation may be applied:

$$(\text{Eq. 2}) \quad \beta_N + \beta_V \leq 1,2 \quad \text{and} \quad \beta_N \leq 1, \beta_V \leq 1$$

### Example (load values are valid for one anchor)

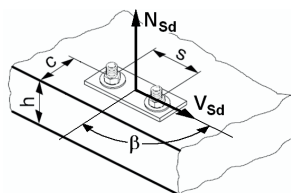
$N_{Sd}^{(1)} = 27,5 \text{ kN}$	$\beta_N = N_{Sd}^{(1)}/N_{Rd} = 0,770 \leq 1$	✓
$V_{Sd}^{(1)} = 10,0 \text{ kN}$	$\beta_V = V_{Sd}^{(1)}/V_{Rd} = 0,216 \leq 1$	✓
$N_{Rd} = 35,7 \text{ kN}$	$\beta_N + \beta_V = 0,986 \leq 1,2$	✓
$V_{Rd} = 46,4 \text{ kN}$	$(\beta_N)^{1,5} + (\beta_V)^{1,5} = 0,776 \leq 1$	✓



### Example 2: mechanical anchor in cracked concrete with dense reinforcement

#### Anchoring conditions

concrete	Cracked concrete C30/37		
number of anchors	Group of two anchors close to the edge		
base material thickness	h	150 mm	
anchor spacing	s	70 mm	
edge distance	c	120 mm	
shear load direction perpendicular to free edge	$\beta$	90 °	
TENSION design action (fixing point)	$N_{Sd}$	10,0 kN	
SHEAR design action (fixing point)	$V_{Sd}$	10,0 kN	
TENSION design action per anchor	$N_{Sd}^{(1)}$	5,0 kN	
SHEAR design action per anchor	$V_{Sd}^{(1)}$	5,0 kN	



The parameters are given in the anchor-section in the tables "setting details" and "setting parameters" (for HSL-3-SK M10)

anchor	HSL-3-SK M10		
effective anchorage depth	$h_{ef}$	70 mm	
critical spacing for splitting failure	$s_{cr,sp}$	270 mm	
critical spacing for concrete cone failure	$s_{cr,N}$	210 mm	
critical edge distance for splitting failure	$c_{cr,sp}$	135 mm	
critical edge distance for concrete cone failure	$c_{cr,N}$	105 mm	
minimum edge distance	$s_{min}$	70 mm	
for	$c \geq$	100 mm	
minimum spacing	$c_{min}$	70 mm	
for	$s \geq$	160 mm	

#### General remarks

According ETAG 001, Annex C, concrete cone, splitting, pryout and concrete edge design resistance must be verified for the anchor group. Steel and pull-out design resistance must be verified for the most unfavourable anchor of the anchor group.

According to the simplified design method given in this Fastening Technology Manual all anchors of a group are loaded equally, the design resistance values given in the tables are valid for one anchor.

## Tension loading

### Design steel resistance

$N_{Rd,s} =$	<b>30,9 kN</b>
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See "basic design tensile resistance"  
for HSL-3- SK M10

### Design concrete pull-out resistance

basic resistance	$N_{Rd,p}^0$	10,7
concrete	Cracked concrete C30/37 $f_B$	1,22
$N_{Rd,p} = N_{Rd,p}^0 f_B =$		<b>13,1 kN</b>

See "basic design tensile resistance"  
(for HSL-3- SK M10 pull-out failure is not decisive in non-cracked concrete)

### Design concrete cone resistance

basic resistance	$N_{Rd,c}^0$	14,1 kN
concrete	Cracked concrete C30/37 $f_B$	1,22
c = 120 mm	$c/c_{cr,N} = 1,14 \rightarrow$	$f_{1,N} = 1,00$
$c_{cr,N} = 105$ mm		$f_{2,N} = 1,00$
s = 70 mm	$s/s_{cr,N} = 0,33 \rightarrow$	$f_{3,N} = 0,67$
$s_{cr,N} = 210$ mm		
anchor	HSL-3-SK M10 $\rightarrow$	$f_{re,N} = 0,85$
$N_{Rd,c} = N_{Rd,c}^0 f_B f_{1,N} f_{2,N} f_{3,N} f_{re,N} =$		<b>9,8 kN</b>

See "basic design tensile resistance"  
(for HSL-3- SK M10) and "influencing factors"  
(for HSL-3- SK M10)

Influencing factors may be interpolated.

### Design splitting resistance

basic resistance	$N_{Rd,sp}^0$	14,1 kN
concrete	Cracked concrete C30/37 $f_B$	1,22
c = 120 mm	$c/c_{cr,sp} = 0,89 \rightarrow$	$f_{1,sp} = 0,97$
$c_{cr,sp} = 135$ mm		$f_{2,sp} = 0,94$
s = 70 mm	$s/s_{cr,sp} = 0,26 \rightarrow$	$f_{3,sp} = 0,63$
$s_{cr,sp} = 270$ mm		
h = 150 mm	$h/(2h_{ef})^{2/3} = 2,14 \rightarrow$	$f_{h,sp} = 1,05$
$h_{ef} = 70$ mm		
anchor	HSL-3-SK M10 $\rightarrow$	$f_{re,N} = 0,85$
$N_{Rd,sp} = N_{Rd,c}^0 f_B f_{1,sp} f_{2,sp} f_{3,sp} f_{h,sp} f_{re,N} =$		<b>8,8 kN</b>

See "basic design tensile resistance"  
(for HSL-3- SK M10) and "influencing factors"  
(for HSL-3- SK M10)

Influencing factors may be interpolated.

<b>Tension design resistance: lowest value</b>	$N_{Rd} =$	<b>8,8 kN</b>
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### Shear loading

#### Design steel resistance

$V_{Rd,s} =$	<b>39,4 kN</b>
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See "basic design shear resistance"  
(for HSL-3- SK M10)

#### Concrete pryout design resistance

basic resistance			$V_{Rd,cp}^0$	28,1 kN
concrete		Cracked concrete C30/37	$f_B$	1,22
$c = 120 \text{ mm}$	$c_{cr,N} = 105 \text{ mm}$	$c/c_{cr,N} = 1,14 \rightarrow$	$f_{1,N}$	1,00
			$f_{2,N}$	1,00
$s = 70 \text{ mm}$	$s_{cr,N} = 210 \text{ mm}$	$s/s_{cr,N} = 0,33 \rightarrow$	$f_{3,N}$	0,67
anchor		HSL-3-SK M10 $\rightarrow$	$f_{re,N}$	0,85
$V_{Rd,cp} = V_{Rd,cp}^0 f_B f_{1,N} f_{2,N} f_{3,N} f_{re,N} =$				<b>19,5 kN</b>

See "basic design shear resistance"  
(for HSL-3- SK M10)  
and "influencing factors"  
(for HSL-3- SK M10)

Influencing factors may be  
interpolated.

#### Concrete edge design resistance

basic resistance			$V_{Rd,c}^0$	4,6 kN
concrete		Cracked concrete C30/37	$f_B$	1,22
shear load direction perpendicular to free edge		$90^\circ \rightarrow$	$f_\beta$	2
$h = 150 \text{ mm}$	$c = 120 \text{ mm}$	$h/c = 1,25 \rightarrow$	$f_h$	0,88
$c = 120 \text{ mm}$	$h_{ef} = 70 \text{ mm}$	$c/h_{ef} = 1,71 \rightarrow$	$f_4$	1,34
$s = 70 \text{ mm}$	$h_{ef} = 70 \text{ mm}$	$s/h_{ef} = 1,00$		
$V_{Rd,c} = V_{Rd,c}^0 f_B f_\beta f_h f_4 =$				<b>13,2 kN</b>

See "basic design shear resistance"  
(for HSL-3- SK M10)  
and "influencing factors"  
(for HSL-3- SK M10)

Influencing factors may be  
interpolated.

**Shear design resistance: lowest value**  $V_{Rd} =$  **13,2 kN**

### Combined tension and shear loading

The following equation must be satisfied for combined tension and shear loading:

$$(\text{Eq. 1}) \quad (\beta_N)^{1,5} + (\beta_V)^{1,5} \leq 1$$

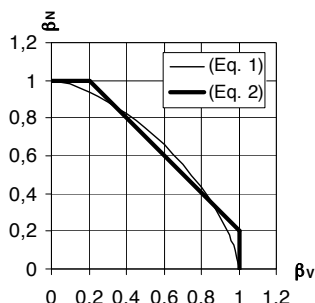
$\beta_N$  ( $\beta_V$ ) ratio between design action and design  
resistance for tension (shear) loading

According to ETAG 001, Annex C, the following simplified equation may  
be applied:

$$(\text{Eq. 2}) \quad \beta_N + \beta_V \leq 1,2 \quad \text{and} \quad \beta_N \leq 1, \beta_V \leq 1$$

#### Example (load values are valid for one anchor)

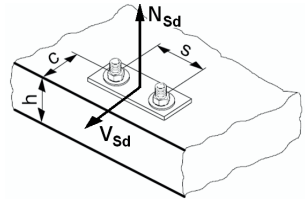
$N_{Sd}^{(1)} = 5,0 \text{ kN}$	$\beta_N = N_{Sd}^{(1)}/N_{Rd} = 0,567 \leq 1$	✓
$V_{Sd}^{(1)} = 5,0 \text{ kN}$	$\beta_V = V_{Sd}^{(1)}/V_{Rd} = 0,378 \leq 1$	✓
$N_{Rd} = 8,8 \text{ kN}$	$\beta_N + \beta_V = 0,945 \leq 1,2$	✓
$V_{Rd} = 13,2 \text{ kN}$	$(\beta_N)^{1,5} + (\beta_V)^{1,5} = 0,659 \leq 1$	✓



### Example 3: adhesive anchoring system with variable embedment depth in non-cracked concrete

#### Anchoring conditions

concrete	Non-cracked concrete C50/60		
service temperature	temperature range II		
range of base material			
number of anchors	Group of two anchors close to the edge		
base material thickness	h	100 mm	
anchor spacing	s	150 mm	
edge distance	c	100 mm	
shear load direction perpendicular to free edge	$\beta$	0 °	
TENSION design action (fixing point)	$N_{Sd}$	15,0 kN	
SHEAR design action (fixing point)	$V_{Sd}$	15,0 kN	
TENSION design action per anchor	$N_{Sd}^{(1)}$	7,5 kN	
SHEAR design action per anchor	$V_{Sd}^{(1)}$	7,5 kN	
effective anchorage depth	$h_{ef}$	70 mm	



The parameters are given in the anchor-section in the tables "setting details" and "setting parameters" (for HIT-RE 500-SD with HIT-V 5.8, size M12)

anchor	Hilti HIT-RE 500-SD with HIT-V 5.8, size M12		
external diameter	d	12 mm	
typical anchorage depth	$h_{ef,typ}$	110 mm	
minimum edge distance	$s_{min}$	60 mm	
minimum spacing	$c_{min}$	60 mm	

#### Critical spacings and edge distances

critical spacing for concrete cone failure $s_{cr,N}$ and critical spacing for combined pull-out and concrete cone failure $s_{cr,Np}$			
$h_{ef} =$	70 mm	$s_{cr,N} = s_{cr,Np} = 3 h_{ef} =$	210 mm

critical edge distance for concrete cone failure $c_{cr,N}$ and critical edge distance for combined pull-out and concrete cone failure $c_{cr,Np}$			
$h_{ef} =$	70 mm	$c_{cr,N} = c_{cr,Np} = 1,5 h_{ef} =$	105 mm

critical edge distance for splitting failure			
for $h \leq 1,3 h_{ef}$		$c_{cr,sp} = 2,26 h_{ef}$	
for $1,3 h_{ef} < h < 2 h_{ef}$		$c_{cr,sp} = 4,6 h_{ef} - 1,8 h$	
for $h \geq 2 h_{ef}$		$c_{cr,sp} = 1,0 h_{ef}$	
$h =$	100 mm	$h_{ef} =$	70 mm
		$h/h_{ef} =$	1,43 $\rightarrow$
		$c_{cr,sp} =$	142 mm

critical spacing for splitting failure			
$c_{cr,sp} =$	142 mm	$s_{cr,sp} = 2 c_{cr,sp} =$	284 mm

#### General remarks

According EOTA Technical Report TR 029, concrete cone, combined concrete cone and pull-out, splitting, pryout and concrete edge design resistance must be verified for the anchor group. Steel design resistance must be verified for the most unfavourable anchor of the anchor group.

According to the simplified design method given in this Fastening Technology Manual all anchors of a group are loaded equally, the design resistance values given in the tables are valid for one anchor.

### Tension loading

#### Design steel resistance

$N_{Rd,s} =$	<b>28,0 kN</b>
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See "basic design tensile resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

#### Design combined pull-out and concrete cone resistance

basic resistance				$N_{Rd,p}^0$	29,9 kN
concrete		Non-cracked concrete C50/60		$f_{B,p}$	1,09
$h_{ef} = 70$ mm	$h_{ef,typ} = 110$ mm	$f_{h,p} = h_{ef}/h_{ef,typ} =$			0,64
$c = 100$ mm	$c_{cr,N} = 105$ mm	$c/c_{cr,N} = 0,95 \rightarrow$	$f_{1,N}$		0,99
			$f_{2,N}$		0,97
$s = 150$ mm	$s_{cr,N} = 210$ mm	$s/s_{cr,N} = 0,71 \rightarrow$	$f_{3,N}$		0,86
$h_{ef} = 70$ mm			$f_{re,N}$		1,00
$N_{Rd,p} = N_{Rd,p}^0 f_{B,p} f_{1,N} f_{2,N} f_{3,N} f_{h,p} f_{re,N} =$					<b>17,1 kN</b>

See "basic design tensile resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

#### Design concrete cone resistance

basic resistance				$N_{Rd,c}^0$	32,4 kN
concrete		Non-cracked concrete C50/60		$f_B$	1,55
$h_{ef} = 70$ mm	$h_{ef,typ} = 110$ mm	$f_{h,N} = (h_{ef}/h_{ef,typ})^{1,5} =$			0,51
$c = 100$ mm	$c_{cr,N} = 105$ mm	$c/c_{cr,N} = 0,95 \rightarrow$	$f_{1,N}$		0,99
			$f_{2,N}$		0,97
$s = 150$ mm	$s_{cr,N} = 210$ mm	$s/s_{cr,N} = 0,71 \rightarrow$	$f_{3,N}$		0,86
$h_{ef} = 70$ mm			$f_{re,N}$		1,00
$N_{Rd,c} = N_{Rd,c}^0 f_B f_{h,N} f_{1,N} f_{2,N} f_{3,N} f_{re,N} =$					<b>21,1 kN</b>

See "basic design tensile resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)  
and "influencing factors"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

Influencing factors may be interpolated.

#### Design splitting resistance

basic resistance				$N_{Rd,c}^0$	32,4 kN
concrete		Non-cracked concrete C50/60		$f_B$	1,55
$h_{ef} = 70$ mm	$h_{ef,typ} = 110$ mm	$f_{h,N} = (h_{ef}/h_{ef,typ})^{1,5} =$			0,51
$c = 100$ mm	$c_{cr,sp} = 142$ mm	$c/c_{cr,sp} = 0,70 \rightarrow$	$f_{1,sp}$		0,91
			$f_{2,sp}$		0,85
$s = 150$ mm	$s_{cr,sp} = 284$ mm	$s/s_{cr,sp} = 0,53 \rightarrow$	$f_{3,sp}$		0,76
$h_{ef} = 70$ mm			$f_{re,N}$		1,00
$N_{Rd,sp} = N_{Rd,c}^0 f_B f_{h,N} f_{1,sp} f_{2,sp} f_{3,sp} f_{re,N} =$					<b>15,0 kN</b>

See "basic design tensile resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)  
and "influencing factors"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

Influencing factors may be interpolated.

**Tension design resistance: lowest value**  $N_{Rd} =$  **15,0 kN**



## Shear loading

### Design steel resistance

$V_{Rd,s} =$	<b>16,8 kN</b>
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See "basic design shear resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

### Concrete pout design resistance

lower value of $N_{Rd,p}$ and $N_{Rd,c}$	$V^0 =$	17,1 kN
$h_{ef} = 70 \text{ mm}$	$\rightarrow k$	2
$V_{Rd,cp} = k V^0 =$		<b>34,3 kN</b>

See "basic design shear resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)  
and "influencing factors"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

### Concrete edge design resistance

basic resistance	$V^0_{Rd,c}$	11,6 kN
concrete	Non-cracked concrete C50/60 $f_B$	1,55
shear load direction perpendicular to free edge	$0^\circ \rightarrow f_{\beta}$	1,00
$h = 100 \text{ mm}$ $c = 100 \text{ mm}$ $h/c = 1,00 \rightarrow f_h$		0,82
$c = 100 \text{ mm}$ $h_{ef} = 70 \text{ mm}$ $c/h_{ef} = 1,43 \rightarrow f_4$		1,28
$s = 150 \text{ mm}$ $h_{ef} = 70 \text{ mm}$ $s/h_{ef} = 2,14 \rightarrow f_4$		
$h_{ef} = 70 \text{ mm}$ $d = 12 \text{ mm}$ $h_{ef}/d = 5,83 \rightarrow f_{hef}$		0,97
$c = 100 \text{ mm}$ $d = 12 \text{ mm}$ $c/d = 8,33 \rightarrow f_c$		0,67
$V_{Rd,c} = V^0_{Rd,c} f_B f_{\beta} f_h f_4 f_{hef} f_c =$		<b>12,3 kN</b>

See "basic design shear resistance"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)  
and "influencing factors"  
(for HIT-RE 500-SD with HIT-V 5.8, size M12)

Influencing factors may be interpolated.

**Shear design resistance: lowest value**  $V_{Rd} =$  **12,3 kN**

## Combined tension and shear loading

The following equation must be satisfied for combined tension and shear loads:

$$(\text{Eq. 1}) \quad (\beta_N)^{1,5} + (\beta_V)^{1,5} \leq 1$$

$\beta_N$  ( $\beta_V$ ) ratio between design action and design resistance for tension (shear) loading

According to ETAG 001, Annex C, the following simplified equation may be applied:

$$(\text{Eq. 2}) \quad \beta_N + \beta_V \leq 1,2 \quad \text{and} \quad \beta_N \leq 1, \beta_V \leq 1$$

### Example (load values are valid for one anchor)

$N_{Sd}^{(1)} =$	7,5 kN	$\beta_N = N_{Sd}^{(1)}/N_{Rd} =$	0,500	$\leq 1$	✓
$V_{Sd}^{(1)} =$	7,5 kN	$\beta_V = V_{Sd}^{(1)}/V_{Rd} =$	0,612	$\leq 1$	✓
$N_{Rd} =$	15,0 kN	$\beta_N + \beta_V =$	1,112	$\leq 1,2$	✓
$V_{Rd} =$	12,3 kN	$(\beta_N)^{1,5} + (\beta_V)^{1,5} =$	0,832	$\leq 1$	✓

