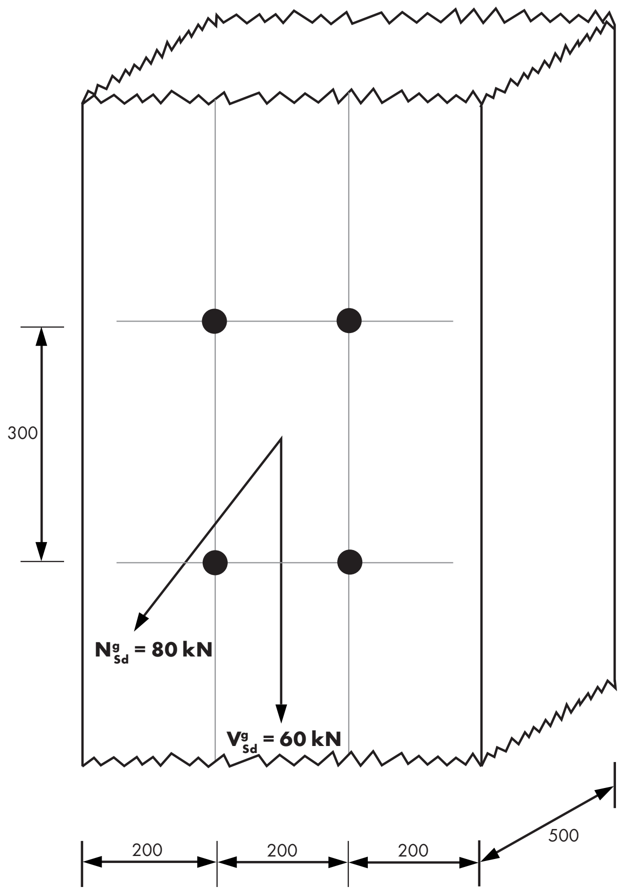
DESIGN EXAMPLE – BONDED ANCHORS

Design Example

Anchor design according to Würth Simplified Anchor Design Method

Given Data:

- Concrete C40/50
- Non-cracked concrete
- Dry concrete
- Service temperature max. 24°C
- Thickness of concrete component h = 500mm



Selected anchor: WIT-PE 500 with stud M16 strength class 5.8, h_{ef} = 150mm

Actions			
Design value of tensile load	$N^g_{Sd} =$	80.0	kN
Number of anchors in the group loaded with tension	n =	4	
Design value of tensile load acting on a single anchor	$N^h_{Sd} = \frac{N^g_{Sd}}{n} =$	20.0	kN
Design value of shear load	$V^g_{Sd} =$	60.0	kN
Number of anchors in the group loaded with shear	n =	4	
Design value of shear load acting on a single anchor	$V^h_{Sd} = \frac{V^g_{Sd}}{n} =$	15.0	kN
Anchor data			
Anchor type		WIT-PE 500	
Anchor diameter	M	16	
Anchorage depth	$h_{ef} =$	150	mm
Base material			
Compressive strength class of concrete			
Characteristic compressive cube strength of concrete at 28days	$f_{ck,cube} =$	50	N/mm²
Characteristic compressive cylinder strength of concrete at 28days	$f_{ck,cyl} =$	40	N/mm²
Cracked concrete	**Non-cracked concrete**	✔	
Structural verification			
	$\beta_N = \max(\beta_{N,s}; \beta_{N,p}; \beta_{N,c}; \beta_{N,sp}) =$	0.577	
	$\beta_N \leq 1$	✔	
	$\beta_V = \max(\beta_{V,s}; \beta_{V,cp}; \beta_{V,c}) =$	0.628	
	$\beta_V \leq 1$	✔	
	$\beta_N + \beta_V = 0.577 + 0.628 =$	1.2	
	$\beta_N + \beta_V \leq 1.2$	✔	

CALCULATION EXAMPLES

DESIGN EXAMPLE – BONDED ANCHORS

Resistances										
Calculation of Design values of resistance to **tension loads**										
In case of steel failure										
Desing value								$N_{Rd,s}$ =	52.2	kN
Ratio between design action and design resistance								$\beta_{N,s} = N^h_{Sd}/N_{Rd,s} = \frac{20}{52.2} =$	0.383	
In case of pull-out/pull-through failure										
Basic design value								$N^0_{Rd,p}$ =	48.9	kN
Influence of compressive strength of concrete								$f_{b,p}$ =	1.08	
Influence of anchorage depth										
h_{ef} =	150	mm	$h_{ef,typ}$ =	125	mm			$f_{hef} = h_{ef}/h_{ef,typ}$	1.20	
Influence of spacing										
s_x =	200	mm	$s_{cr,p}$ =	375	mm	$s_x/s_{cr,p}$ =	0.53	$f_{sx,p}$ =	0.77	
n_x =	2									
s_y =	300	mm				$s_y/s_{cr,p}$ =	0.80	$f_{sy,p}$ =	0.90	
n_y =	2									
Influence of edge distance										
c_x =	200	mm	$c_{cr,p}$ =	188	mm	$c_x/c_{cr,p}$ =	1.06	$f_{cx,1,p}$ =	1.00	
								$f_{cx,2,p}$ =	1.00	
c_y =	200	mm				$c_y/c_{cr,p}$ =	1.06	$f_{cy,p}$ =	1.00	
$N_{Rd,p} = N^0_{Rd,p} \cdot f_{b,N} \cdot f_{hef} \cdot f_{sx,p} \cdot f_{sy,p} \cdot f_{cx,1,p} \cdot f_{cx,2,p} \cdot f_{cy,p}$										
Design value								$N_{Rd,p}$ =	43.92	kN
Ratio between design action and design resistance								$\beta_{N,p} = N^h_{Sd}/N_{Rd,p} = \frac{20}{43.92} =$	0.455	
In case of concrete cone failure										
Basic design value								$N^0_{Rd,c}$ =	39.2	kN
Influence of compressive strength of concrete								$f_{b,N}$ =	1.41	
Influence of anchorage depth										
h_{ef} =	150	mm	$h_{ef,typ}$ =	125	mm			$f_{hef} = (h_{ef}/h_{ef,typ})^{1.5}$ =	1.31	
Influence of spacing										
s_x =	200	mm	$s_{cr,N}$ =	450	mm	$s_x/s_{cr,N}$ =	0.44	f_{sx} =	0.72	
n_x =	2									
s_y =	300	mm				$s_y/s_{cr,N}$ =	0.66	f_{sy} =	0.83	
n_y =	2									
Influence of edge distance										
c_x =	200	mm	$c_{cr,N}$ =	225	mm	$c_x/c_{cr,N}$ =	0.88	$f_{cx,1}$ =	0.96	
								$f_{cx,2}$ =	0.94	
c_y =	200	mm				$c_y/c_{cr,N}$ =	0.88	f_{cy} =	0.94	
$N_{Rd,c} = N^0_{Rd,c} \cdot f_{b,N} \cdot f_{sx} \cdot f_{sy} \cdot f_{cx,1} \cdot f_{cx,2} \cdot f_{cy}$										
Design value								$N_{Rd,c}$ =	36.70	kN
Ratio between design action and design restistance								$\beta_{N,c} = N^g_{Sd}/N_{Rd,c} = \frac{20}{36.70} =$	0.545	

CALCULATION EXAMPLES

In case of concrete splitting failure

No verification of splitting is required if at least one of the conditions is fulfilled:
a) The edge distance in all direction is $c \geq c_{cr,sp}$ for single fasteners and $c \geq 1.2\ c_{cr,sp}$ for fastener groups and the member depth is $h \geq h_{min}$ in both cases.
b) The characteristic resistance for concrete cone failure and pull-out failure is calculated for cracked concrete and reinforcement resists the splitting forces and limits the crack width to $w_k \leq 0.3$mm.

<table>
<tr><td rowspan="2">$c_x =$</td><td rowspan="2">200</td><td rowspan="2">mm</td><td rowspan="2">$c_{cr,sp} =$</td><td rowspan="2">360</td><td rowspan="2">mm</td><td colspan="3">$c_x \geq c_{cr,sp}$</td><td>check required</td><td></td></tr>
<tr><td colspan="3">$c_x \geq 1.2 \cdot c_{cr,sp}$</td><td>check required</td><td></td></tr>
<tr><td rowspan="2">$c_y =$</td><td rowspan="2">200</td><td rowspan="2">mm</td><td rowspan="2">$1.2 \cdot c_{cr,sp} =$</td><td rowspan="2">432</td><td rowspan="2">mm</td><td colspan="3">$c_y \geq c_{cr,sp}$</td><td>check required</td><td></td></tr>
<tr><td colspan="3">$c_y \geq 1.2 \cdot c_{cr,sp}$</td><td>check required</td><td></td></tr>
<tr><td>$h =$</td><td>500</td><td>mm</td><td>$h_{min} =$</td><td>180</td><td>mm</td><td colspan="3">$h \geq h_{min}$</td><td>✔</td><td></td></tr>
<tr><td colspan="8">Basic design value</td><td>$N^0_{Rd,sp} =$</td><td>39.2</td><td>kN</td></tr>
<tr><td colspan="8">Influence of compressive strength of concrete</td><td>$f_{b,N} =$</td><td>1.41</td><td></td></tr>
<tr><td colspan="8">Influence of anchorage depth</td><td colspan="3"></td></tr>
<tr><td>$h_{ef} =$</td><td>150</td><td>mm</td><td>$h_{ef,typ} =$</td><td>125</td><td>mm</td><td colspan="2"></td><td>$f_{hef} = (h_{ef}/h_{ef,typ})^{1.5} =$</td><td>1.31</td><td></td></tr>
<tr><td colspan="8">Influence of spacing</td><td colspan="3"></td></tr>
<tr><td>$s_x =$</td><td>200</td><td>mm</td><td rowspan="4">$s_{cr,sp} =$</td><td rowspan="4">720</td><td rowspan="4">mm</td><td rowspan="2">$s_x/s_{cr,p} =$</td><td rowspan="2">0.27</td><td rowspan="2">$f_{sx,sp} =$</td><td rowspan="2">0.64</td><td rowspan="2"></td></tr>
<tr><td>$n_x =$</td><td>2</td><td></td></tr>
<tr><td>$s_y =$</td><td>300</td><td>mm</td><td rowspan="2">$s_y/s_{cr,sp} =$</td><td rowspan="2">0.42</td><td rowspan="2">$f_{sy,sp} =$</td><td rowspan="2">0.71</td><td rowspan="2"></td></tr>
<tr><td>$n_y =$</td><td>2</td><td></td></tr>
<tr><td colspan="8">Influence of edge distance</td><td colspan="3"></td></tr>
<tr><td rowspan="2">$c_x =$</td><td rowspan="2">200</td><td rowspan="2">mm</td><td rowspan="4">$c_{cr,sp} =$</td><td rowspan="4">360</td><td rowspan="4">mm</td><td rowspan="2">$c_x/c_{cr,sp} =$</td><td rowspan="2">0.55</td><td>$f_{cx,1,sp} =$</td><td>0.87</td><td></td></tr>
<tr><td>$f_{cx,2,sp} =$</td><td>0.78</td><td></td></tr>
<tr><td rowspan="2">$c_y =$</td><td rowspan="2">200</td><td rowspan="2">mm</td><td rowspan="2">$c_y/c_{cr,sp} =$</td><td rowspan="2">0.55</td><td rowspan="2">$f_{cy,sp} =$</td><td rowspan="2">0.78</td><td rowspan="2"></td></tr>
<tr></tr>
<tr><td>$h =$</td><td>500</td><td>mm</td><td>$h_{min} =$</td><td>180</td><td>mm</td><td>$h/h_{min} =$</td><td>2.78</td><td>$f_h =$</td><td>1.99</td><td></td></tr>
<tr><td colspan="9">$N_{Rd,sp} = N^0_{Rd,c(sp)} \cdot f_{b,N} \cdot f_{sx,sp} \cdot f_{sy,sp} \cdot f_{cx,1,sp} \cdot f_{cx,2,sp} \cdot f_{cy,sp} \cdot f_h$</td><td colspan="2"></td></tr>
<tr><td colspan="8">Design value</td><td>$N_{Rd,sp} =$</td><td>34.65</td><td>kN</td></tr>
<tr><td colspan="8">Ratio between design action and design restistance</td><td>$\beta_{N,sp} = N^h_{Sd}/N_{Rd,sp} = \frac{20}{34.65} =$</td><td>0.577</td><td></td></tr>
</table>

CALCULATION EXAMPLES

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Resistances

Calculation of Design values of resistance to **shear loads**

In case of steel failure

Desing value	$V_{Rd,s} =$	31.4	kN
Ratio between design action and design restistance	$\beta_{V,s} = V^h_{Sd}/V_{Rd,s} = \frac{15.0}{31.4} =$	0.478	

In case of pry-out failure

	$N_{Rd,c} =$	43.92	kN
	$N_{Rd,p} =$	36.70	kN
Influence of compressive strenght of concrete	$k =$	2	
$V_{Rd,cp} = k \cdot \min\{N_{Rd,p}; N_{Rd,c}\}$			
Design value	$V_{Rd,cp}$	73.40	kN
Ratio between design action and design resistance	$\beta_{V,cp} = V^h_{Sd}/V_{Rd,cp} = \frac{15.0}{73.4} =$	0.204	

In case of concrete edge failure

Verification of concrete edge failure may be omitted for single fasteners and groups with an edge distance in all directions $c > \max(10h_{ef}; 60d)$. For anchorages with more than one edge, the resistance for all edges shall be calculated. The smallest value should be used in verification.

Basic design value	$V^0_{Rd,c} =$	10.1	kN
Influence of compressive strength of concrete	$f_{b,V} =$	1.41	

Influence of anchorage depth

$h_{ef} =$	150	mm	$d =$	16	mm	$h_{ef}/d =$	9.375	$f_{hef,V} =$	1.03	

Influence of spacing

In groups loaded perpendicular to the edge only two adjacent anchors closest and parallel to the edge carry the load. The smallest spacing should be used for the verification.

$s =$	300	mm	$c_1 =$	200	mm	$s/c_1 =$	1.5	$f_{s,V} =$	1.5	

Influence of edge distance

$c_1 =$	200	mm	$d =$	16	mm	$c_1/d =$	12.5	$f_{c1,V} =$	2.05	
$c_2 =$	-	mm	$c_1 =$	-	mm	$c_2/c_1 =$		$f_{c2,V} =$	-	

Influence of load direction

In case of a > 90° it is assumed that only the component of the shear load parallel to the edge is acting on the anchor. The component acting away from the edge may be neglected for the proof of concrete edge failure.

$\alpha =$	90°	$f_\alpha =$	2.0	

Influence of concrete thickness

$h =$	500	mm	$c_1 =$	200	mm	$h/c_1 =$	2.5	$f_h =$	1.0	

$$V_{Rd,c} = V^0_{Rd,c} \cdot f_{b,V} \cdot f_{s,V} \cdot f_{c2,V} \cdot f_\alpha \cdot f_h$$

Design value	$V_{Rd,c} =$	90.21	kN
Ratio between design action and design resistance	$\beta_{V,c} = V^g_{Sd}/V_{Rd,c} = \frac{60.0}{90.21} =$	0.665	