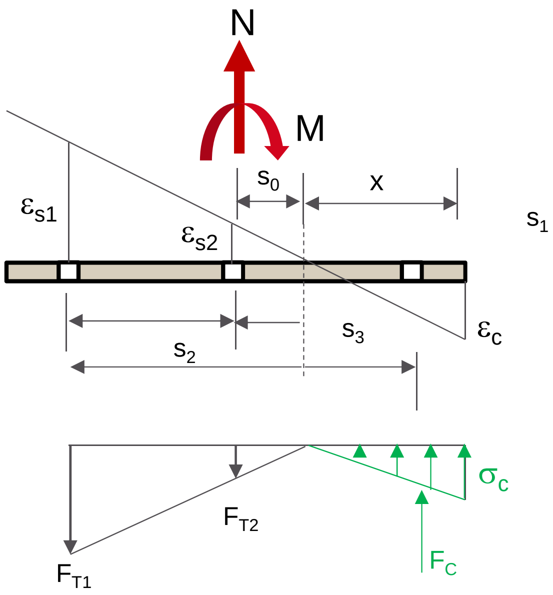
# PROFIS ANCHOR 2

**Explanation anchor forces**

# LOAD DETERMINATION : BASICS

**Under loading, it is assumed that plane surfaces remain plane (rigid base plate assumption)**

Here are the stress/strain relationship and equilibrium conditions for a connection subject to axial force and bending moment.




Equilibrium conditions

$$\sum F = 0 \qquad N + F_{T1} + F_{T2} + F_c = 0$$

$$\sum M = 0 \qquad M + N \cdot s_0 + F_{T1} \cdot s_1 + F_{T2} \cdot s_2 + F_c \cdot s_3 = 0$$

Force calculations

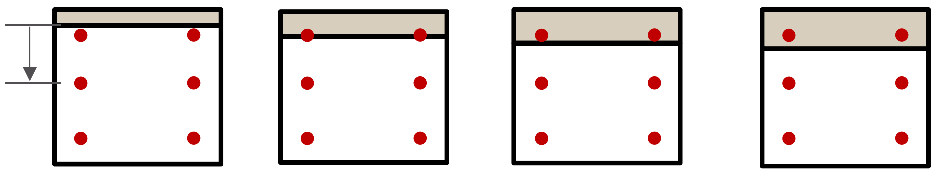
$$F_{T1} = \sigma_{s1} \cdot A_{s1} = \varepsilon_{s1} \cdot E_s \cdot A_{s1} = \frac{\varepsilon_c \cdot (d - x)}{x} \cdot \alpha_E \cdot E_c \cdot A_s$$

$$F_{T2} = \sigma_{s2} \cdot A_{s2} = \varepsilon_{s2} \cdot E_s \cdot A_{s2} = \frac{\varepsilon_c \cdot (d - s - x)}{x} \cdot \alpha_E \cdot E_c \cdot A_s$$

$$F_C = \frac{\sigma_c \cdot x}{2} \cdot b$$

*This may all be correct…..but how do we get there (concrete might not be at the limit of 0.35%)*

# LOAD DETERMINATION : METHOD



- Increase the compression zone iteratively..
  and for each step do the following…..

**Steel** + **Concrete**

$$I_y = \sum\left[I_{y,s,i} + \alpha_E \cdot A_{s,i} \cdot {s_i}^2\right] + \frac{b \cdot x^3}{12} + \frac{b \cdot x^2}{2}$$

- Calculate the 2nd Moment of Area

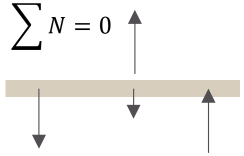
$$\sigma_s = \alpha_E * \left[\frac{M^*}{I_y} * s_i\right] \qquad \sigma_{c.max} = \left[\frac{M^*}{I_{y,}} * x\right]$$

- Determine the stresses in the concrete and anchors.

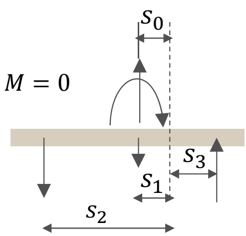
$$N_{s,i} = \sigma_{s,i} * A_{s,i} \qquad F_c = \sigma_{c.max} \cdot \frac{b \cdot x}{2}$$

- Determine the resultant forces

$$\sum N = 0$$

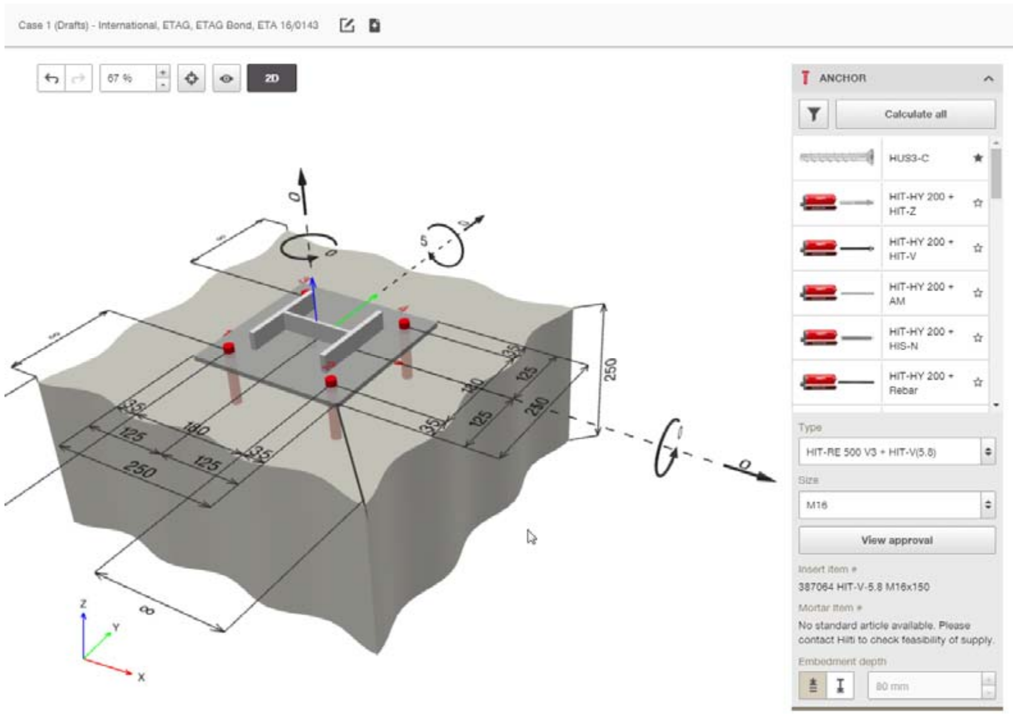


$$\sum M = 0$$




- Compare loads to resistance

# EXAMPLE 1 – SQUARE PLATE WITH 4 ANCHORS, BENDING AROUND 1 AXIS

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| Design: | Case 1 | Date: | 10/20/2017 |
| Fastening point: | | | |

## 2 Load case/Resulting anchor forces

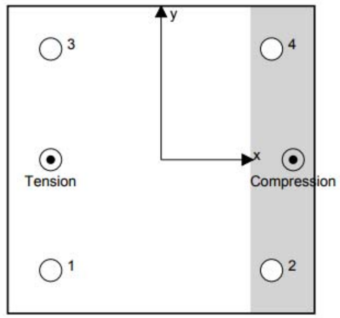
Load case: Design loads

**Anchor reactions [kN]**

Tension force: (+Tension, -Compression)

| Anchor | Tension force | Shear force | Shear force x | Shear force y |
|---|---|---|---|---|
| 1 | 12.652 | 0.000 | 0.000 | 0.000 |
| 2 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 12.652 | 0.000 | 0.000 | 0.000 |
| 4 | 0.000 | 0.000 | 0.000 | 0.000 |

max. concrete compressive strain: 0.13 [‰]
max. concrete compressive stress: 3.88 [N/mm$^2$]
resulting tension force in (x/y)=(-90.0/0.0): 25.304 [kN]
resulting compression force in (x/y)=(107.6/0.0): 25.304 [kN]



# RESULTS OF THE INDEPENDENT CALCULATION

**<u>Under loading, it is assumed that plane surfaces remain plane (rigid base plate assumption)</u>**

Here are the stress/strain relationship and equilibrium conditions for a connection subject to axial force and bending moment.

**Plate and anchor arrangement**

| | | |
|---|---|---|
| h | 250 | mm |
| b | 250 | mm |
| s1 | 180 | mm |
| s2 | 180 | mm |
| c1 | 35 | mm |
| $d_{nom}$ | 16 | mm |
| Asp | 157 | mm² |
| dsp | 14.14 | mm |
| Es | 210000 | N/mm² |
| Ec | 30000 | N/mm² |

**Concrete data**

Druckzonenhöhe

| | | | |
|---|---|---|---|
| x | 53.40 | mm | 534 |
| Ac | 13350 | mm² | |
| Ic | 12689442 | $mm^4$ | |

Max. Beton Spannung

| | | |
|---|---|---|
| $\sigma_{c,max}$ | 3.81 | N/mm² |
| $\varepsilon_c$ | 0.13 | $^0/_{00}$ |
| Fc | 25418 | N |
| Fc * zi | 904880 | Nmm |
| z' | 107.20 | mm |

**Anchor data**

$$\alpha_E = \frac{E_s}{E_c}$$

$$x' = \max\{x_i - x\,;0\}$$

$$I_{y,s} = I_{y,i} + \alpha_E \cdot A_{s,i} \cdot x'^2$$

$$\sigma_s = \alpha_E * \left[\frac{M^*}{I_{y,c+s}} * x_i'\right]$$

$$N_{s,i} = \sigma_{s,i} * A_{s,i}$$

$$\varepsilon_{s,i} = \frac{\sigma_{s,i}}{E_s}$$

| # | $x_i$ | ds | Es | Ec | $\alpha_E$ | As | $\alpha_E$*As | Iy,s,i | $\alpha_E$*Iy,i | x' | $I_{y,s}$ | $\sigma_s$ | Ns,i | $N_s$*$x_i$ | $\varepsilon_s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 35 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 2 | 35 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 3 | 215 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 161.6 | 28713638 | 80.67 | 12664 | 2046581 | 0.384 |
| 4 | 215 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 161.6 | 28713638 | 80.67 | 12664 | 2046581 | 0.384 |

$$\sigma_{c,max} = \left[\frac{M^*}{I_{y,c+s}} * x\right]$$

$$\varepsilon_c = \frac{\sigma_c}{E_c}$$

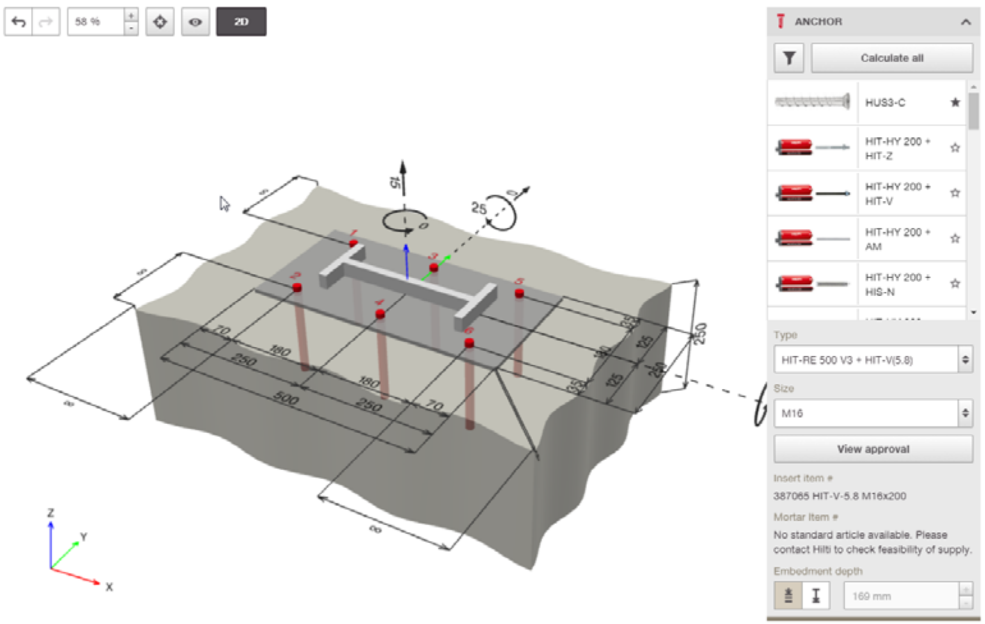
$$F_c = \sigma_{c.max} \cdot \frac{b \cdot x}{2}$$

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stahl | $\Sigma I_{y,s}$ | 57427275 | | $\Sigma N_{s,i}$ | 25329 N | | $\Sigma N_{s,i} * x_i'$ | 4093161 |
| Beton | Ic | 12689442 | | | | | | |
| | Iy, c+s | 70116717 | $mm^4$ | Total stiffness | | | | |

**Belastung**

| | | |
|---|---|---|
| N | 0 | kN |
| M | 5 | kNm |
| *M** | *5000000* | *Nmm* (Moment around zero - axis)) |

# EXAMPLE 2 – RECTANGULAR PLATE WITH 6 ANCHORS, BENDING AROUND 1 AXIS

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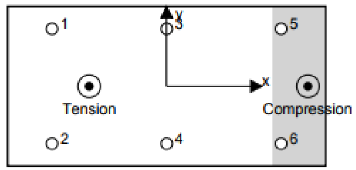
## 2 Load case/Resulting anchor forces

Load case: Design loads

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

| Anchor | Tension force | Shear force | Shear force x | Shear force y |
|---|---|---|---|---|
| 1 | 27.847 | 0.000 | 0.000 | 0.000 |
| 2 | 27.847 | 0.000 | 0.000 | 0.000 |
| 3 | 13.369 | 0.000 | 0.000 | 0.000 |
| 4 | 13.369 | 0.000 | 0.000 | 0.000 |
| 5 | 0.000 | 0.000 | 0.000 | 0.000 |
| 6 | 0.000 | 0.000 | 0.000 | 0.000 |




max. concrete compressive strain: 0.21 [‰]
max. concrete compressive stress: 6.44 [$N/mm^2$]
resulting tension force in (x/y)=(-121.6/0.0): 82.433 [kN]
resulting compression force in (x/y)=(222.1/0.0): 67.433 [kN]

# RESULTS OF THE INDEPENDENT CALCULATION

**<u>Under loading, it is assumed that plane surfaces remain plane (rigid base plate assumption)</u>**

Here are the stress/strain relationship and equilibrium conditions for a connection subject to axial force and bending moment.

**Plate and anchor arrangement**

| | | |
|---|---|---|
| h | 500 | mm |
| b | 250 | mm |
| s1 | 180 | mm |
| s2 | 180 | mm |
| c1 | 70 | mm |
| $d_{nom}$ | 16 | mm |
| Asp | 157 | mm² |
| dsp | 14.14 | mm |
| Es | 210000 | N/mm² |
| Ec | 30000 | N/mm² |

**Concrete data**

Druckzonenhöhe

| | | | |
|---|---|---|---|
| x | 85.60 | mm | 856 |
| Ac | 21400 | mm² | |
| Ic | 52268501 | $mm^4$ | |

Max. Beton Spannung

| | | |
|---|---|---|
| $\sigma_{c,max}$ | 6.31 | N/mm² |
| $\varepsilon_c$ | 0.21 | ‰ |
| Fc | 67546 | N |
| Fc * zi | 3854626 | Nmm |
| z* | 221.47 | mm |

**Anchor data**

$$\alpha_E = \frac{E_s}{E_c}$$

$$x' = \max\{x_i - x\,;0\}$$

$$I_{y,s} = I_{y,i} + \alpha_E \cdot A_{s,i} \cdot x'^2$$

$$\sigma_s = \alpha_E * \left[\frac{M^*}{I_{y,c+s}} * x_i'\right]$$

$$N_{s,i} = \sigma_{s,i} * A_{s,i}$$

$$\varepsilon_{s,i} = \frac{\sigma_{s,i}}{E_s}$$

| # | $x_i$ | ds | Es | Ec | $\alpha_E$ | As | $\alpha_E$*As | Iy,s,i | $\alpha_E$*Iy,i | x' | Iy,s | $\sigma_s$ | Ns,i | $N_s$*$x_i$ | $\varepsilon_s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 70 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 2 | 70 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 3 | 250 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 164.4 | 29716805 | 84.87 | 13324 | 2190501 | 0.404 |
| 4 | 250 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 164.4 | 29716805 | 84.87 | 13324 | 2190501 | 0.404 |
| 5 | 430 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 344.4 | 130367621 | 177.79 | 27913 | 9613160 | 0.847 |
| 6 | 430 | 14.14 | 2E+05 | 30000 | 7 | 157 | 1099 | 1962.31 | 13736 | 344.4 | 130367621 | 177.79 | 27913 | 9613160 | 0.847 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stahl | Σ Iy,s | 320168851 | | Σ $N_{s,i}$ | 82474 | N | Σ $N_{s,i}$ * $x_i$' | 23607322 |
| Beton | Ic | 52268501 | | | | | | |
| | Iy, c+s | 372437353 | $mm^4$ | Total stiffness | | | | |

$$\sigma_{c.max} = \left[\frac{M^*}{I_{y,c+s}} * x\right]$$

$$\varepsilon_c = \frac{\sigma_c}{E_c}$$

$$F_c = \sigma_{c.max} \cdot \frac{b \cdot x}{2}$$

**Belastung**

| | | | |
|---|---|---|---|
| N | 15 | kN | |
| M | 25 | kNm | |
| *M** | *27466000* | *Nmm* | (Moment around zero - axis) |