**Content** **Typ Eurotruss FT50**

## 1. Description

The structure is a modular truss beam. Elements with different length can be mount to a straight beam.

The profile is a foldable trapezoid with 4 maintubes.

The truss is a welded structure of tubes. A drawing has to be attached to this calculation to complete it.

In the calculation the resistance and design cutting forces are determined and a table with permissible user loads is created.

The calculated values are based on the framework theory - so all loads are applied on the knotpoints.

This static calculation is applicable on all straight elements with a bracing of minimum 54° to the horizontal axis on the whole length of the element. For lower angles or missing bracing the calculation is not applicable.

The folling standards have been considered:

DIN EN 1999-1-1 and DIN EN 1999-1-1/A2

This standards are binding according european building authorities.

The necessary manufacturer qualificatin is:
DIN EN 1090 - with EXC 2, or EXC 3 for temporary structures

Note:
The standard uses "eff" for different values - the calculation separates 2eff,buck" for buckling and "eff" for HAZ reasons.

## 2. Materials

| | |
|---|---|
| Aluminium | |
| Welding process | WIG |
| Correction factor | 0,8 für nachfolgende Werte $f_{haz}$, $\rho$ |
| Welding material | 4043A |

| EN AW | main tube | bracing | connector | |
|---|---|---|---|---|
| alloy | 6082 | 6082 | 6082 | |
| temper | T6 | T6 | T6 | |
| **Strength according Table 3.2b** | | | | |
| t - thickness | t ≤ 5 | t ≤ 5 | 5 < t ≤ 15 | mm |
| $f_o$ = | 250 | 250 | 260 | N / mm$^2$ |
| $f_u$ = | 290 | 290 | 310 | N / mm$^2$ |
| $f_{o,haz}$ = | 125 | 125 | 125 | N / mm$^2$ |
| $f_{u,haz}$ = | 185 | 185 | 185 | N / mm$^2$ |
| **HAZ factor according table 3.2b - proper calculated** | | | | |
| $\rho_{o,haz}$ = | 0,500 | 0,500 | 0,481 | |
| $\rho_{u,haz}$ = | 0,638 | 0,638 | 0,597 | |
| **Values including factor of footnote 4) table 3.2b** | | | | |
| $f_{o,haz}$ = | 100 | 100 | 100 | N / mm$^2$ |
| $f_{u,haz}$ = | 148 | 148 | 148 | N / mm$^2$ |
| $\rho_{o,haz}$ = | 0,400 | 0,400 | 0,385 | N / mm$^2$ |
| $\rho_{u,haz}$ = | 0,510 | 0,510 | 0,477 | N / mm$^2$ |

E = 70000 N / mm$^2$

## 3. Partial factors

| | | |
|---|---|---|
| Selfweight of truss | $\gamma_{f1}$ = 1,35 | |
| User Load | $\gamma_{f2}$ = 1,5 | |
| Resistance | $\gamma_{M0}$ = 1,00 | |
| | $\gamma_{M1}$ = 1,10 | buckling |
| | $\gamma_{M2}$ = 1,25 | breaking caused by tension |
| | $\gamma_{MP}$ = 1,25 | |
| | $\gamma_{Mw}$ = 1,25 | |

## 4. Profile main tube and bracing

Main tube

| | | | | | |
|---|---|---|---|---|---|
| d = | 50 | mm | $\beta$ = | 10,607 | |
| t = | 4 | mm | $\varepsilon$ = | 1,000 | |
| A = | 578,05 | $mm^2$ | Material class | A | |
| I = | 154051,14 | $mm^4$ | $\beta / \varepsilon$ = | 10,607 | |
| W = | 6162,05 | $mm^3$ | CS class | 2 | |
| i = | 16,32 | mm | Proof | EL-EL | |
| $L_{cr}$ = | 689,90 | mm | $A_{eff,buck}$ = | 578,05 | |
| $\lambda$ = | 42,261 | | $N_{cr}$ = | 223609,58 | N |

No transverse welds - no brace connection

| | | |
|---|---|---|
| $\underline{\lambda}_0$ = | 0,1 | |
| $\alpha$ = | 0,2 | |
| $\underline{\lambda} = (A_{eff,buck} * f_0 / N_{cr})^{0,5}$ = | 0,804 | |
| $\phi = 0,5 * (1 + \alpha * (\underline{\lambda} - \underline{\lambda}_0) + \underline{\lambda}^2)$= | 0,894 | |
| $\chi = 1 / (\phi + (\phi^2 - \underline{\lambda}^2)^{0,5})$ = | 0,779 | |
| $\omega_x$ = | 1 | only axial force |

With transverse welds - brace connection in one plane

| | |
|---|---|
| $\underline{\lambda}_{haz} = (A_{u,eff} * f_u / N_{cr})^{0,5} = (A_g * \rho_{u,haz} * f_u / N_{cr})^{0,5}$ = | 0,619 |
| $\phi_{haz} = 0,5 * (1 + \alpha * (\underline{\lambda}_{haz} - \underline{\lambda}_0) + \underline{\lambda}_{haz}^2)$= | 0,743 |
| $\chi_{haz} = 1 / (\phi_{haz} + (\phi_{haz}^2 - \underline{\lambda}_{haz}^2)^{0,5})$ = | 0,866 |
| $\omega_{x,haz}$ = | 1 |

$\kappa$ = 1 - no longitudinal welds

Bracing vertical

| | | | | | |
|---|---|---|---|---|---|
| d = | 25 | mm | $\beta$ = | 8,660 | |
| t = | 3 | mm | $\varepsilon$ = | 1,000 | |
| A = | 207,35 | $mm^2$ | Material class | A | |
| I = | 12777,64 | $mm^4$ | $\beta / \varepsilon$ = | 8,660 | |
| W = | 1022,21 | $mm^3$ | CS class | 1 | |
| i = | 7,85 | mm | Proof | EL-EL | |
| $L_{cr}$ = | 583,90 | mm | $A_{eff,buck}$ = | 207,35 | |
| $\lambda$ = | 74,38 | | $N_{cr}$ = | 25892,36 | N |

| | | |
|---|---|---|
| $\underline{\lambda}_0$ = | 0,1 | |
| $\alpha$ = | 0,2 | |
| $\underline{\lambda} = (A_{eff,buck} * f_0 / N_{cr})^{0,5}$ = | 1,415 | |
| $\phi = 0,5 * (1 + \alpha * (\underline{\lambda} - \underline{\lambda}_0) + \underline{\lambda}^2)$ = | 1,632 | |
| $\chi = 1 / (\phi + (\phi^2 - \underline{\lambda}^2)^{0,5})$ = | 0,409 | |
| $\omega_x$ = | 1 | only axial force |
| $\kappa$ = | 1 | no longitudinal welds |

No horizontal stabilization - not usable for horizontal use!

## 5. Profile Truss

Axis vertical

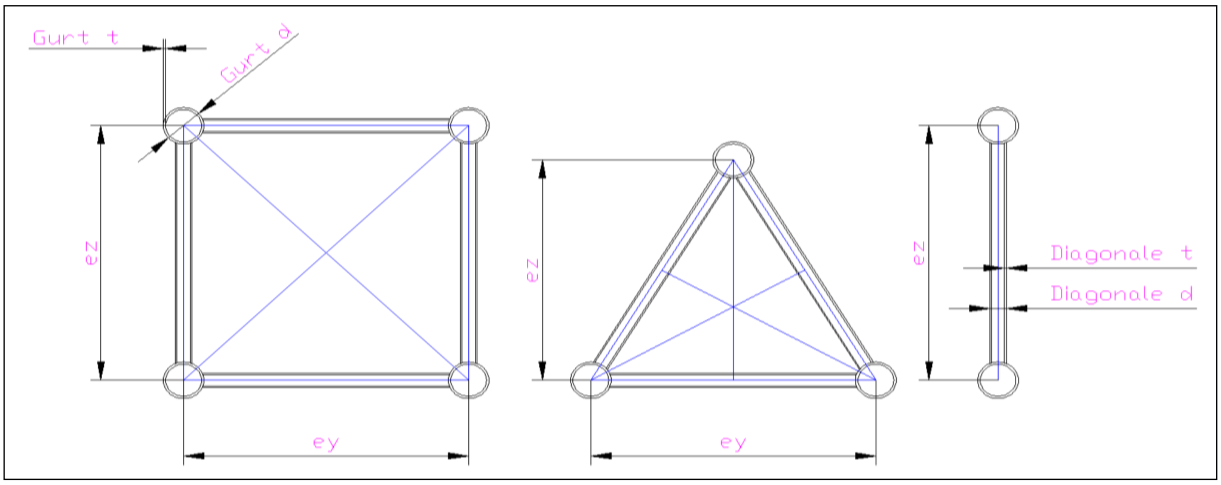
$e_z$ = 471,10 mm

Axis horizontal

$e_y$ = 520,00 mm

| | | |
|---|---|---|
| $A$ = | 2312 | $mm^2$ |
| $I_y$ = | 128906529 | $mm^4$ |
| $I_z$ = | 0 | $mm^4$ |
| $W_{y,el}$ = | 494748 | $mm^3$ |
| $W_{z,el}$ = | 0 | $mm^3$ |
| $i_y$ = | 236 | mm |
| $i_z$ = | 0 | mm |

Scheme of the cross section to calculate the profile values.
Mesasurements can be taken from manufacturers drawing.



## 6. Calculation of permissible force in main tube

### a. Tension in main tube (according 6.2.3)

General yielding along the member

$N_{o,Rd} = A_g * f_0 / \gamma_{M1} =$ 131375,693 N

Local failure at a section with holes

$N_{u,Rd} = 0{,}9 * A_{net} * f_u / \gamma_{M2} =$

- no holes in the tube

Local failure at a section with HAZ

$N_{u,Rd} = A_{u,eff} * f_u / \gamma_{M2} = A_g * \rho_{u,haz} * f_u / \gamma_{M2} =$ 68441,481 N

### b. Compression main tube (according 6.2.4 and 6.3.1.1)

Local failure at a section with transverse welds

$N_{u,Rd} = A_{u,eff} * f_u / \gamma_{M2} =$ 68441,481 N

$A_{u,eff}$ is smaler value of:

| | | |
|---|---|---|
| $A_g * \rho_{u,haz} =$ | 295,006 $mm^2$ | aufgrund Schweißnaht |
| $A_{eff,buck} =$ | 578,053 $mm^2$ | aufgrund örtlichen Beulens bei Q.- Kl.4 |

Permissible force in main tube due to buckling resistance

$N_{b,Rd} = \kappa * \chi * \omega_x * A_{eff,buck} * f_0 / \gamma_{M1} =$ 102353,188 N [1)]

Brace connection in one plane

| | | | |
|---|---|---|---|
| Arc length total | $L_{ges} =$ | 157,080 | mm |
| Arc length brace attachment | $L_{vB} =$ | 26,180 | mm |
| Extent of HAZ | | 30,000 | mm |
| Arc length HAZ | $L_{WEZ} =$ | 86,180 | mm |
| Reduced thickness | $t_{eff} = t_g * \rho_{u,haz} =$ | 2,041 | mm |
| | $A_{u,eff} =$ | 459,525 | $mm^2$ |

$N_{b,Rd} = \chi_{haz} * \omega_{x,haz} * A_{u,eff} * f_u / \gamma_{M2} =$ 92296,933 N [2)]

[1)] If there is no transverse bracing on the buckling length = no welding (6.49a)

[2)] Bracing from one plane = transversal weld (6.49b)

At this design: min $N_{b,Rd} =$ 102353,188 N

## c. Connection main tube to fitting

$f_w$ = 190 N / mm² Schw.-Zusatz 4043A

Circular welding

$\sigma_{\perp,Rd} = fw / \gamma_{Mw} =$ 152 N / mm²

$\sigma_{haz,Rd} = f_{u,haz} / \gamma_{Mw} =$ 118,4 N / mm²

$t_e =$ 4 mm Einbrandtiefe

$A_w =$ 578,053 mm²

Permissible force in main tube due to circular weld

$N_{w,Rd} = A_w * \sigma_{\perp,Rd} =$ 87864,063 N

$N_{w,haz,Rd} = A_w * \sigma_{haz,Rd} =$ 68441,481 N

decisive 68441,481 N

Plug weld

$\tau_{\parallel,Rd} = \sigma_{\perp,Rd} / 1{,}732 =$ 87,760 N / mm²

$\tau_{haz,Rd} = f_{u,haz} / 1{,}732 / \gamma_{Mw} =$ 68,360 N / mm²

$L_w =$ 25 mm

$a_w =$ 2,828 mm

Amount 4

$A_w =$ 282,8 mm²

Permissible force in main tube due to plug weld

$N_{w,Rd} = A_w * \tau_{\parallel,Rd} =$ 24818,476 N

$N_{w,haz,Rd} = A_w * \tau_{haz,Rd} =$ 19332,286 N

decisive 19332,286 N

Permissible force in main tube in total due to welds

$N_{w,haz,Rd} =$ 87773,767 N

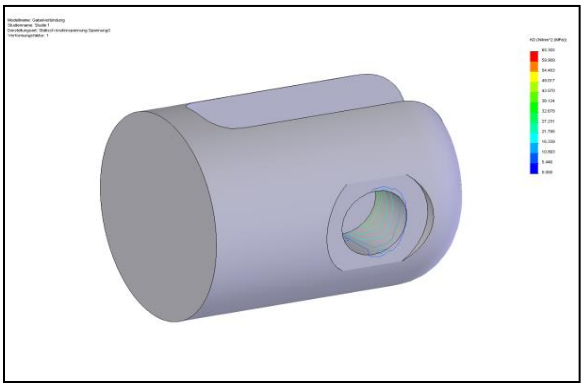
| | Plug in shaft | | Main tube | |
|---|---|---|---|---|
| E x A = | 70371675 | N | 40463713 | N |
| L = | 60,000 | mm | 60,000 | mm |
| ΔL = | 0,01648 | mm | 0,02867 | mm |

Elongation is not relevant

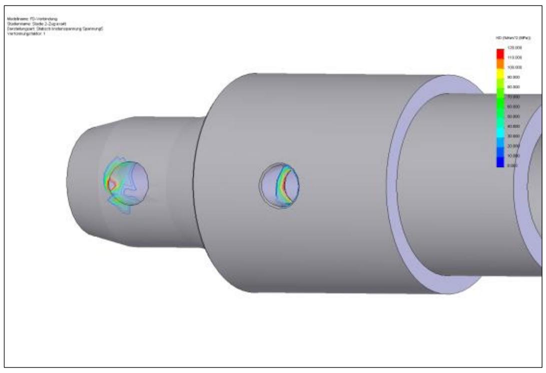
## d. Conical pin

| | | | | |
|---|---|---|---|---|
| $f_{yp}$ = | 900,000 N / mm$^2$ | | t1 = | 12,7 mm |
| $f_{up}$ = | 1000,000 N / mm$^2$ | | t2 = | 32,2 mm |
| d = | 14,500 mm | | s = | 1,2 mm |
| A = | 165,130 mm$^2$ | | | |
| W = | 299,298 mm$^3$ | | | |

Cylindric Pin



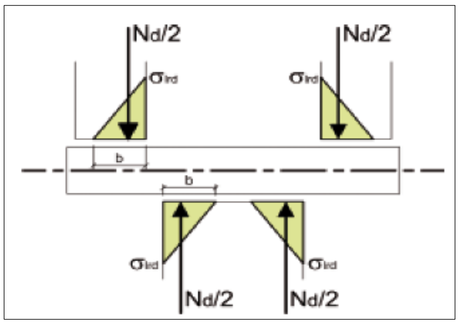
Conical pin



Spreading of the bearing width $a_p$ (Contact pressure FEM)

$a_p = t_1$ total width

$a_p$ <> $0,5 * t_1$ concentrated




Position of resultant force $x_h$

$x_h = 1/3 * t_1$

$x_h = 1/3 * 0,5 * t_1$

| | | |
|---|---|---|
| $h_M = x_h * 2 + s$ = | 5,433 mm | relevant lever |
| $a_p$ = | 6,350 mm | bearing width |
| maßgebend | right picture | for conical pin |

Existing stress

Highest stress of other componentsn:

| | | | |
|---|---|---|---|
| max $N_{Rd}$ = | 68441,481 | N | Tension main tube<br>Local failure at a section with transv. welds |
| $F_d$ = | 68500,000 | N | will be applied for proof |

| | | | |
|---|---|---|---|
| $M_d = F_d /2 * h_M$ = | 186091,7 | Nmm | max |
| $F_{v,d} = F_d / 2$ = | 34250,0 | N | max |
| $M_{Rd} = 1,5 * W_{el} * f_{yp} / \gamma_{M0}$ = | 404052,4 | Nmm | not move able |
| $F_{v,Rd} = \alpha * A * f_{up} / \gamma_{M2}$ = | 72657,2 | N | $\alpha$ = 0,55 |

| | | | |
|---|---|---|---|
| max | $M_d / M_{Rd}$ = | 0,461 | <1 |
| max | $F_{v,d} / F_{v,Rd}$ = | 0,471 | <1 |

Interaction

$M_{d1}$ at position of max $F_{v,d}$ - plane to inside fitting

| | | |
|---|---|---|
| $M_{d1} = 1/6 * a_p * F_d + F_d/2 * s$ = | 113595,83 | Nmm |
| $(M_{d1} / M_{Rd})^2 + (F_{v,d} / F_{v,Rd})^2$ = | 0,301 | <1 |
| max $\eta$ = | 0,471 | <1 |

Permissible force in main tube due to pin

$N_{Rd}$ > 68500,000 N

**e. Fitting**

| | | | |
|---|---|---|---|
| fu = | 310 | $N / mm^2$ | outer |
| fu = | 370 | $N / mm^2$ | inner |

| | Outer fitting | | Inner fitting | |
|---|---|---|---|---|
| Edge distance e1 = | 27 | mm | 21,3 | mm |
| $\alpha_d$ = e1 / (3 * $d_0$) = | 0,621 | | 0,490 | |
| $f_{up}$ / $f_u$ = | 3,226 | | 3,226 | |
| $\alpha_b$ = | 0,621 | | 0,490 | |
| $e_2$ = | 30 | mm | 16,1 | mm |
| $k_1$ = | 2,5 | | 1,408965517 | |

| | | | |
|---|---|---|---|
| $F_{b,Rd} = 2 * k_1 * \alpha b * f_u * d * t_1 / \gamma_{M2}$ = | 141732,0 | N | outer |
| $F_{b,Rd} = k_1 * \alpha b * f_u * d * t_2 / \gamma_{M2}$ = | 95346,8 | N | inner |
| $\sigma_{L,RD} = F_{b,Rd} / (d * t_1 * 2)$ = | 384,83 | $N / mm^2$ | outer |
| $\sigma_{L,RD} = F_{b,Rd} / (d * t_2 )$ = | 204,21 | $N / mm^2$ | inner |

Permissible force in main tube due to bearing in fitting

$F_{b,Rd}$ = 95346,838 N

**f. Spigot**

| | | | |
|---|---|---|---|
| $d_K$ = | 32,200 | mm | |
| $r_k$ = | 16,1 | mm | |
| $A_k$ = | 8,143 | $cm^2$ | without hole |
| $d_B$ = | 14,500 | mm | |
| $h_{Seg}$ = | 8,850 | mm | Thickness each segment |
| $A_{net}$ = | 363,730 | $mm^2$ | |
| $f_u$ = | 370 | $N / mm^2$ | |

Permissible force in main tube due to spigot failure

$N_{u,Rd} = 0,9 * A_{net} * f_u / \gamma_{M2}$ = 107664,221 N

## 7. Calculation of permissible force in main tube

### a. Buckling

**Vertical**

| | | |
|---|---|---|
| d = | 25,000 | mm |
| t = | 3,000 | mm |
| A = | 2,073 | $cm^2$ |

Permissible force in brace due to buckling

$N_{b,Rd} = \kappa * \chi * \omega_x * A_{eff,buck} * f_0 / \gamma_{M1} =$ 19259,787 N

<u>No horizontal stabilization - not usable for horizontal use!</u>

## b. Welding

### Vertical

$fw =$ 190 N / mm$^2$ Welding mat. 4043A

Circular weld

$\sigma_{\vdash,Rd} = fw / \gamma_{Mw} =$ 152 N / mm$^2$

$\sigma_{haz,Rd} = f_{u,haz} / \gamma_{Mw} =$ 118,4 N / mm$^2$

| | | | |
|---|---|---|---|
| $\alpha =$ | 53,8 | ° | to length axis |
| $\eta =$ | 0,9 | | circular around bracing |
| $L_w =$ | 79,14 | mm | |
| $a_w =$ | 3,00 | mm | |
| $A_w =$ | 237,42 | mm$^2$ | |

Permissible force in brace due to welding

$N_{w,Rd} = A_w * \sigma_{\vdash,Rd} =$ 36088,072 N

$N_{w,haz,Rd} = A_w * \sigma_{haz,Rd} =$ 28110,708 N

decisive 28110,708 N

<u>No horizontal stabilization - not usable for horizontal use!</u>

## c. HAZ

### Vertical

General yielding along the member
$N_{o,Rd} = A_{dia} * f_0 / \gamma_{M1} =$ 47123,890 N

Local failure at a section with HAZ
$N_{u,Rd} = A_{dia} * \rho_{u,haz} * f_u / \gamma_{M2} =$ 24549,662 N

decisive 24549,662 N

<u>No horizontal stabilization - not usable for horizontal use!</u>

## 8. Design cutting forces

Decisive main tube
$N_{Rd}$ = 68441,481 N

Tension main tube
aufgrund
Local failure at a section with transv. welds

Decisive brace vertical
$N_{Rd}$ = 19259,787 N

Decisive brace horizontal
$N_{Rd}$ = 0,000 N

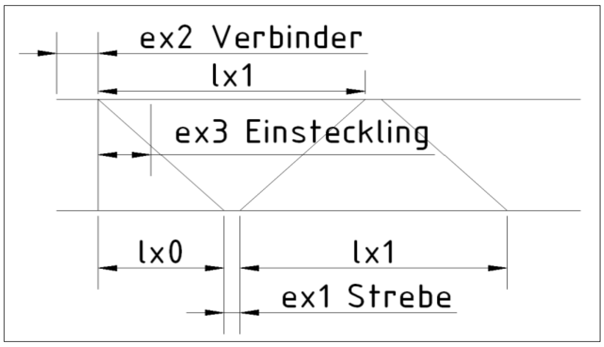
**Design values of resistance $M_{y,Rd}$ of truss**
(without interactition)
$M_{y,Rd}$ = 64,486 kNm

**Design values of resistance $M_{z,Rd}$ of truss**
(without interactition)
$M_{z,Rd}$ = 0,000 kNm

**Design values of resistance $V_{z,Rd}$ of truss**
(without interactition)
$V_{z,Rd}$ = 28,148 kN

**Design values of resistance $V_{y,Rd}$ of truss**
(without interactition)
$V_{y,Rd}$ = 0,000 kN

## 9. Displacement in frame work




Without endbrace: $l_{x0} = l_{x1}$

<u>Displacement bracing</u> $e_{x1}$ = 20,70 mm

$l_{x1}$ = 689,9 mm

$l_{x0}$ = 365,6 mm

Local bending in main tube

$V_{z,Ebene}$ = $V_z$ x 0,5521392 for folding truss

$M_{lokal} = V_{z,Ebene} * e_{x1} / (e_{x1} + l_{x0} + l_{x1}) * l_{x1}$ = 0,733 x $V_z$ (cm * kN)

$\sigma_{(Mlokal)} = M_{lokal} / W$

Globale Spannung im Gurt aus N

$\sigma_{(Nglobal)} = N / A$

Gesamt

$\sigma d_{(gesamt)} = \sigma_{(Mlokal)} + \sigma_{(Nglobal)} < \sigma_{Rd}$

<u>Displacement at connection</u> $e_{x2}$ = 100,00 mm

$e_{x3}$ = 55 mm

Local bending in main tube

The truss is designed with end braces - load distribution on upper and lower chords

$V_{z,Gurt}$ = $V_{z,Ebene}$ x 0,5

$_{max} M_{lokal} = V_{z,Gurt} * e_{x2}$ = 2,761 x $V_z$ (cm * kN)

Influence of plugged connector

$M_{lokal(x)} = {}_{max} M_{lokal} * (l_{x1} - e_{x3}) / l_{x1}$ = 2,541 x Vz (cm * kN)

$\sigma_{(Mlokal(x))} = M_{lokal(x)} / W$

Displacement connection is decisive!

Reduced crossection at end brace
from CAD

| | | |
|---|---|---|
| $A_{u,eff}$ = | 351,80 | $mm^2$ |
| $I_{u,eff}$ = | 91279,40 | $mm^4$ |
| $W_{u,eff}$ = | 3319,25 | $mm^3$ |
| | | |
| $N_{u,Rd} = A_{u,eff} * f_u / \gamma_{M2}$ = | 81617,6 | N |
| $M_{u,Rd} = W_{u,eff} * f_u / \gamma_{M2}$ = | 770066,21 | Nmm |

Proof
((NEd / Nu,Rd)^1,3 + (MEd / Mu,Rd)^1,7)^0,6 < = 1

Due to the interaction the load chart is determined. The loads are determined manualy to reach not more than 100% utalization.

Reduced cross section at circular welding
with 100% HAS - only for information, because this area is reinforced by the plugged connector.

| | | | |
|---|---|---|---|
| $t_{eff} = t_g * \rho_{u,haz}$ = | 2,0413793 | mm | |
| $\Delta t = t_g - t_{eff}$ = | 1,9586207 | mm | |
| $d_{a,eff}$ = | 48,041379 | mm | |
| $d_{i,eff}$ = | 43,958621 | mm | |
| $A_{u,eff}$ = | 295,00638 | mm | $= A_g * \rho_{u,haz}$ |
| $I_{u,eff}$ = | 78182,858 | $mm^4$ | |
| $W_{u,eff}$ = | 3254,8132 | $mm^3$ | |
| | | | |
| $N_{u,Rd} = A_{u,eff} * f_u / \gamma_{M2}$ = | 68441,481 | N | |
| $M_{u,Rd} = W_{u,eff} * f_u / \gamma_{M2}$ = | 755116,67 | Nmm | |

## 10. Load chart for user loads

The user loads cause a 100% maximum to the design resistance values.
The interaction of local bending is considered.

The chart is useable for a simple beam with joint supports.
The loads are applied on the knot points.
Local bending caused by displaced loads is not considered.

Deflections are calculated with endless shear stifness between upper and lower chords. In reality smaler variance is possible (Bernoulli / Timoschenkow).

Considered selfweight:

g = 0,135 kN / m