

## 1. Options for Calculations

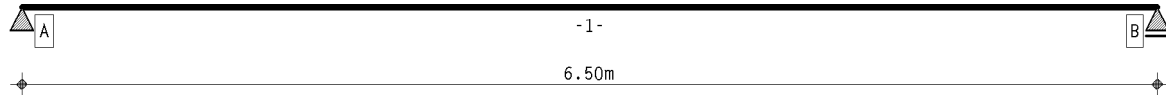
calculation DIN EN 1995:2010, Germany

service class 2

coefficient of thermal expansion for timber  $\alpha_t = 0.500 \cdot 10^{-5}/^{\circ}\text{K}$

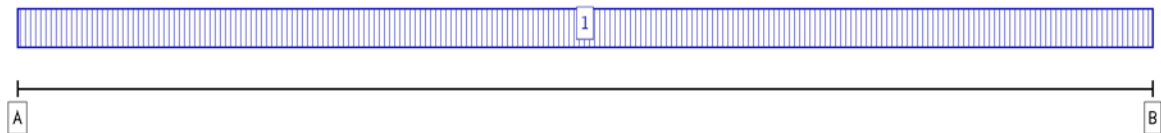
$\psi_2 = 0.60$  (factor acc. to DIN EN 1995-1-1 2.3.2.2 (2))

## 2. Structural system

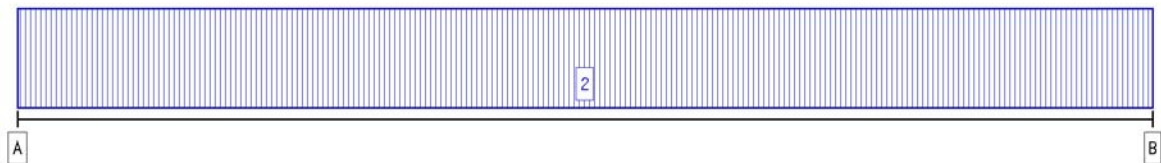


main beam

## 3. Loading



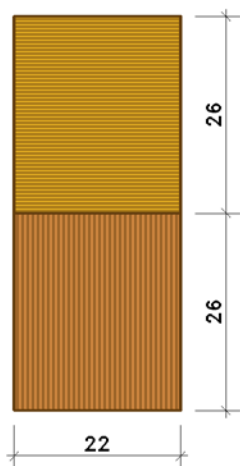
action effect 1: permanent loads (permanent, 1 load cases)



action effect 2: live loads (1) (transient, 1 load cases)

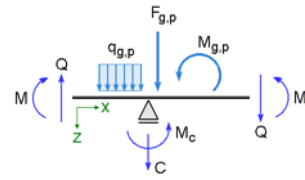
## 4. main beam

section scale 1:10



|                                    |                                           |
|------------------------------------|-------------------------------------------|
| <b>timber grade top flange</b>     | <b>solid coniferous timber, C24 (S10)</b> |
| char. bend. strength $f_{m,k}$     | : 24.0 N/mm <sup>2</sup>                  |
| char. shear strength $f_{v,k}$     | : 4.0 N/mm <sup>2</sup>                   |
| char. ten. strength $f_{t,k}$      | : 14.5 N/mm <sup>2</sup>                  |
| char. compr. strength $f_{c,0,k}$  | : 21.0 N/mm <sup>2</sup>                  |
| char. compr. strength $f_{c,90,k}$ | : 2.5 N/mm <sup>2</sup>                   |
| modulus of elasticity $E_{0,mean}$ | : 11000 N/mm <sup>2</sup>                 |
| Dichte $\rho_k/\rho_m$             | : 350 / 420 kg/m <sup>3</sup>             |
| deformation factor $k_{def}$       | : 0.60 -                                  |
| area $A_{flange}$                  | : 572.000 cm <sup>2</sup>                 |
| moment of inertia $I_{flange}$     | : 32222.667 cm <sup>4</sup>               |
| <b>timber grade web</b>            | <b>solid coniferous timber, C24 (S10)</b> |
| char. bend. strength $f_{m,k}$     | : 24.0 N/mm <sup>2</sup>                  |
| char. shear strength $f_{v,k}$     | : 4.0 N/mm <sup>2</sup>                   |
| char. ten. strength $f_{t,k}$      | : 14.5 N/mm <sup>2</sup>                  |
| char. compr. strength $f_{c,0,k}$  | : 21.0 N/mm <sup>2</sup>                  |
| char. compr. strength $f_{c,90,k}$ | : 2.5 N/mm <sup>2</sup>                   |
| $k_{cr}$                           | : 0.50 mm <sup>2</sup> /N                 |
| modulus of elasticity $E_{0,mean}$ | : 11000 N/mm <sup>2</sup>                 |
| Dichte $\rho_k/\rho_m$             | : 350 / 420 kg/m <sup>3</sup>             |
| deformation factor $k_{def}$       | : 0.60 -                                  |
| area $A_{flange}$                  | : 572.000 cm <sup>2</sup>                 |
| moment of inertia $I_{flange}$     | : 32222.667 cm <sup>4</sup>               |

**definition of internal forces and moments:**



## 5. Beam sections

beam sections

| section | $x_A$<br>m | $x_E$<br>m | $l$<br>m | $l_v$<br>m | cantile. | $s_{ef}$<br>mm |
|---------|------------|------------|----------|------------|----------|----------------|
| 1       | 0.00       | 6.50       | 6.50     | 6.50       | -        | 50.0           |

stiffness values serviceability initial state

| section | $\gamma_2$<br>- | $a_2$<br>mm | $K_1$<br>N/mm | $\gamma_{1r}$<br>- | $a_1$<br>mm | $E I_{ef,inst}$<br>Nmm <sup>2</sup> | $\phi$ $K_{def}$<br>- |
|---------|-----------------|-------------|---------------|--------------------|-------------|-------------------------------------|-----------------------|
| 1       | 1.0000          | -87.2       | 7485          | 0.5046             | -172.8      | 2.1353E13                           | 0.4529                |

stiffness values load-carrying capacity initial state

| section | $\gamma_2$<br>- | $a_2$<br>mm | $K_1$<br>N/mm | $\gamma_1$<br>- | $a_1$<br>mm | $E I_{ef,inst}$<br>Nmm <sup>2</sup> | $I_{ef,inst}$<br>mm <sup>2</sup> | $h_{q,inst}$<br>mm | $A_{q,inst}$<br>mm |
|---------|-----------------|-------------|---------------|-----------------|-------------|-------------------------------------|----------------------------------|--------------------|--------------------|
| 1       | 1.0000          | -74.9       | 4990          | 0.4044          | -185.1      | 1.9337E13                           | 1757880064.                      | 20.49              | 837.67             |

stiffness values load-carrying capacity final state

| section | $\gamma_2$<br>- | $a_2$<br>mm | $K_1$<br>N/mm | $\gamma_1$<br>- | $a_1$<br>mm | $E I_{ef,inf}$<br>Nmm <sup>2</sup> | $I_{ef,inf}$<br>mm <sup>2</sup> | $h_{q,inf}$<br>mm | $A_{q,inf}$<br>mm |
|---------|-----------------|-------------|---------------|-----------------|-------------|------------------------------------|---------------------------------|-------------------|-------------------|
| 1       | 1.0000          | -67.3       | 2901          | 0.3493          | -192.7      | 1.3309E13                          | 1645501184.                     | 19.73             | 845.33            |

net section properties

| section | $A_{n,2}$<br>cm <sup>2</sup> | $W_{n,2}$<br>cm <sup>3</sup> | $I_{n,2}$<br>cm <sup>4</sup> | $A_{n,1}$<br>cm <sup>2</sup> | $W_{n,1}$<br>cm <sup>3</sup> | $I_{n,1}$<br>cm <sup>4</sup> |
|---------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| 1       | 468.00                       | 2478.67                      | 32222.67                     | 468.00                       | 2478.67                      | 32222.67                     |

## 6. Fasteners

section 1 from  $x_A = 0.00$  m to  $x_E = 6.50$

bolt 20 mm, FK 4.6 as fitted bolt

2-row with  $a_1 = 100.0$  mm

2 - row with  $a_2 = 65.0$  mm, simplified verification acc. to NA.8.2.4

$f_{uk} = 400$  N/mm<sup>2</sup>,  $M_{yk} = 289640$  Nmm

$K_{ser} = 7485$  N/mm,  $\gamma_M = 1.10$ ,  $R_k = 16309.7$  N, all values per shear plane

## 7. Supports

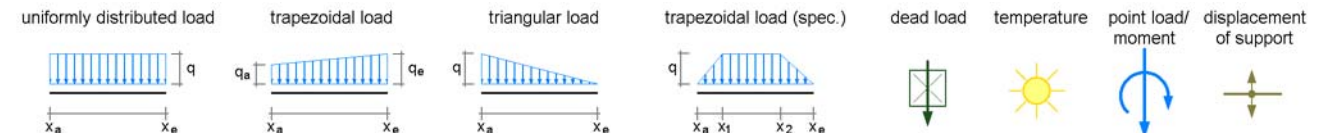
coordinates of supports

| supp.name | x<br>m | width<br>mm | depth<br>mm | CF<br>kN/m | CM<br>kNm/- | restraint<br>(F) (M) |
|-----------|--------|-------------|-------------|------------|-------------|----------------------|
| A         | 0.00   | 150         | 220         | fix        | ----        | X -                  |
| B         | 6.50   | 150         | 220         | fix        | ----        | X -                  |

## 8. Action effects

Attention! Acc. to DIN EN 1995-1-1, annex B.1

mechanically jointed cross-sections are only allowed to be loaded by line loads



**Permanent action effect: permanent loads**

1. additive load case: dead load (1)

→ unif.distr.load:  $q = 4.00$  kN/m from  $x_a = 0.00$  m to  $x_e = 6.50$  m

**2. Transient action effect: live loads (1)**

2. additive load case: live loads (1/1)

→ unif.distr.load:  $q = 8.00$  kN/m from  $x_a = 0.00$  m to  $x_e = 6.50$  m

## 9. verifications

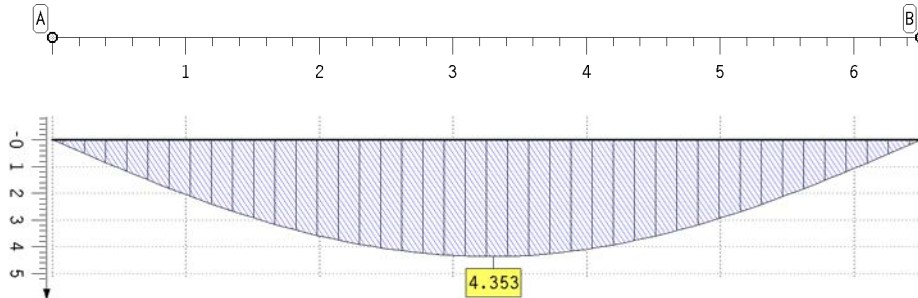
### 1: EC 5 load-carrying capacity

verification of bearing stress DIN EN 1995, 6.1.5 will be executed  
Extreme rule 1

## 10. Results of action effects

### 10.1. Action effect 1: permanent loads

extremal deflections of main beam (characteristic)

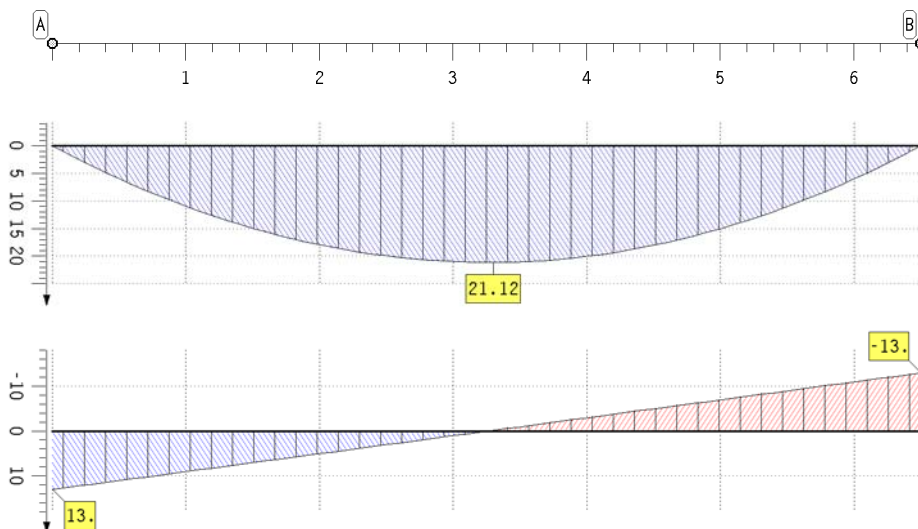


deflection  
main beam  
characteristic  
w in mm  
Min: -0.00  
Max: 4.35

extremal deflections of main beam (characteristic)

| point | x<br>m | min w<br>mm | max w<br>mm | point   | x<br>m | min w<br>mm | max w<br>mm |
|-------|--------|-------------|-------------|---------|--------|-------------|-------------|
| A     | 0.000  | 0.00        | 0.00        | B       | 6.500  | -0.00       | -0.00       |
|       | 1.800  | 3.35        | 3.35        | minimum |        | -0.00       | -0.00       |
|       | 3.200  | 4.35        | 4.35        | maximum |        | 4.35        | 4.35        |
|       | 4.700  | 3.35        | 3.35        |         |        |             |             |

extremal internal forces



flexural moment  
main beam  
M in kNm  
Min: -0.00  
Max: 21.12

shear force  
main beam  
V in kN  
Min: -13.00  
Max: 13.00

extremal internal forces

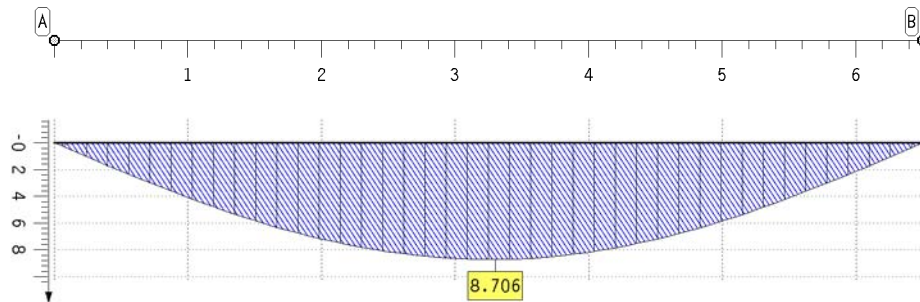
| point | x<br>m | min M<br>kNm | max M<br>kNm | min V<br>kN | max V<br>kN | point   | x<br>m | min M<br>kNm | max M<br>kNm | min V<br>kN | max V<br>kN |
|-------|--------|--------------|--------------|-------------|-------------|---------|--------|--------------|--------------|-------------|-------------|
| A     | 0.000  | -0.00        | -0.00        | 13.00       | 13.00       | B       | 6.500  | 0.00         | 0.00         | -13.00      | -13.00      |
|       | 1.600  | 15.68        | 15.68        | 6.60        | 6.60        | minimum |        | -0.00        | -0.00        | -13.00      | -13.00      |
|       | 3.200  | 21.12        | 21.12        | 0.20        | 0.20        | maximum |        | 21.12        | 21.12        | 13.00       | 13.00       |
|       | 4.900  | 15.68        | 15.68        | -6.60       | -6.60       |         |        |              |              |             |             |

extremal support forces

| point | x<br>m | min AP<br>kN | max AP<br>kN |
|-------|--------|--------------|--------------|
| A     | 0.000  | -13.00       | -13.00       |
| B     | 6.500  | -13.00       | -13.00       |

## 10.2. Action effect 2: live loads (1)

extremal deflections of main beam (characteristic)

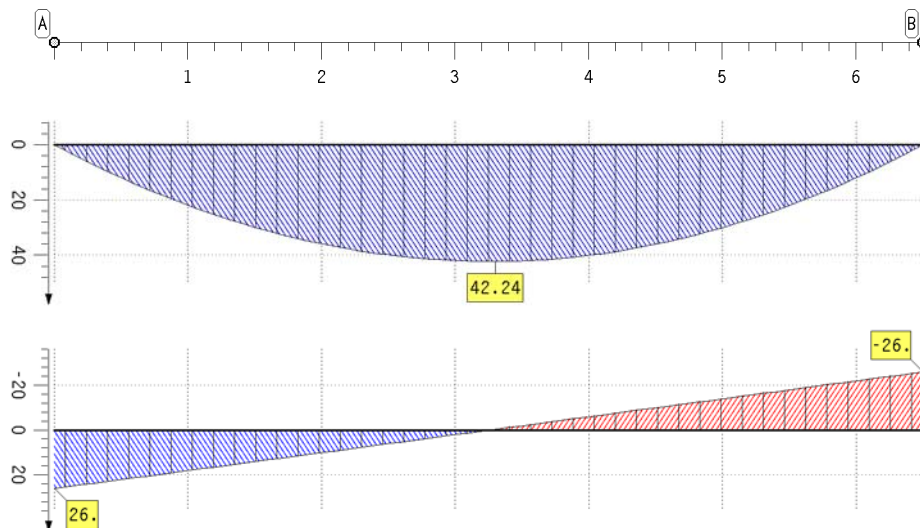


deflection  
main beam  
characteristic  
w in mm  
Min: -0.00  
Max: 8.71

extremal deflections of main beam (characteristic)

| point | x     | min w | max w | point   | x     | min w | max w |
|-------|-------|-------|-------|---------|-------|-------|-------|
| -     | m     | mm    | mm    | -       | m     | mm    | mm    |
| A     | 0.000 | 0.00  | 0.00  | B       | 6.500 | -0.00 | -0.00 |
|       | 1.800 | 0.00  | 6.70  | minimum |       | -0.00 | 0.00  |
|       | 3.200 | 0.00  | 8.71  | maximum |       | 0.00  | 8.71  |
|       | 4.700 | 0.00  | 6.70  |         |       |       |       |

extremal internal forces



flexural moment  
main beam  
M in kNm  
Min: -0.00  
Max: 42.24

shear force  
main beam  
V in kN  
Min: -26.00  
Max: 26.00

extremal internal forces

| point | x     | min M | max M | min V  | max V | point   | x     | min M | max M | min V  | max V |
|-------|-------|-------|-------|--------|-------|---------|-------|-------|-------|--------|-------|
| -     | m     | kNm   | kNm   | kN     | kN    | -       | m     | kNm   | kNm   | kN     | kN    |
| A     | 0.000 | -0.00 | -0.00 | 0.00   | 26.00 | B       | 6.500 | 0.00  | 0.00  | -26.00 | -0.00 |
|       | 1.600 | 0.00  | 31.36 | 0.00   | 13.20 | minimum |       | -0.00 | -0.00 | -26.00 | -0.00 |
|       | 3.200 | 0.00  | 42.24 | 0.00   | 0.40  | maximum |       | 0.00  | 42.24 | 0.00   | 26.00 |
|       | 4.900 | 0.00  | 31.36 | -13.20 | -0.00 |         |       |       |       |        |       |

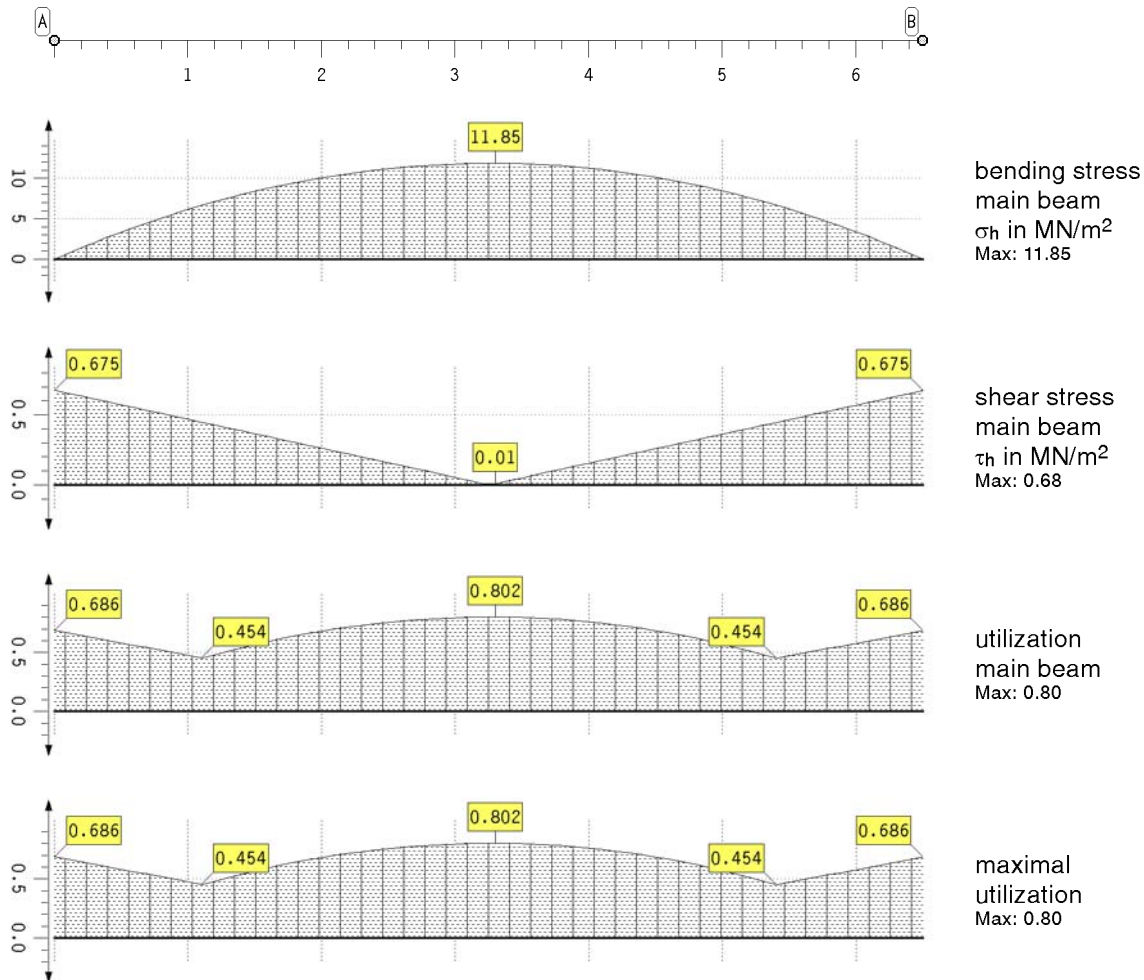
extremal support forces

| point | x     | min AP | max AP |
|-------|-------|--------|--------|
| -     | m     | kN     | kN     |
| A     | 0.000 | -26.00 | -0.00  |
| B     | 6.500 | -26.00 | -0.00  |

## 11. Results of verification of ultimate limit state

## 11.1. Verification of ultimate limit state

results of verification of ultimate limit state



maximal utilization

| point | x     | U     | point | x     | U     | point   | x     | U     |
|-------|-------|-------|-------|-------|-------|---------|-------|-------|
| -     | m     | -     | -     | m     | -     | -       | m     | -     |
| A     | 0.000 | 0.686 |       | 3.200 | 0.802 | B       | 6.500 | 0.686 |
|       | 1.100 | 0.454 |       | 4.300 | 0.719 | minimum |       | 0.454 |
|       | 2.200 | 0.719 |       | 5.400 | 0.454 | maximum |       | 0.802 |

extremal support forces

| point | x     | min AP | max AP |
|-------|-------|--------|--------|
| -     | m     | kN     | kN     |
| A     | 0.000 | -56.55 | -13.00 |
| B     | 6.500 | -56.55 | -13.00 |

verification of bearing stress

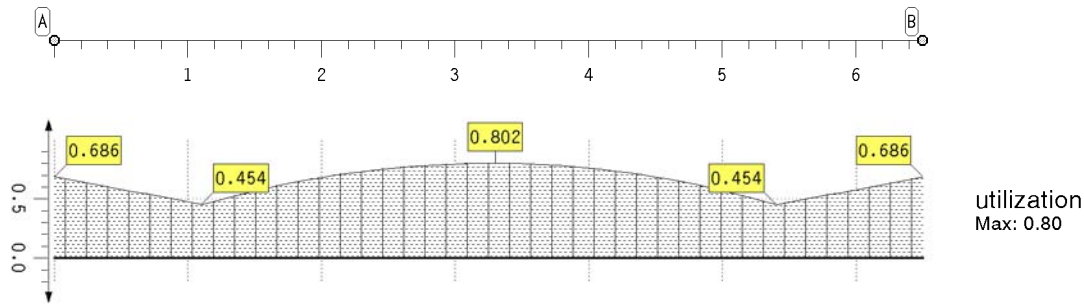
| support | $l_{ef}$ | $A_{ef}$        | $A_P$ | $k_{c90}$ | $k_{mod}$ | $f_{c90d}$        | $\sigma_{c90d}$   | u    |
|---------|----------|-----------------|-------|-----------|-----------|-------------------|-------------------|------|
|         | mm       | mm <sup>2</sup> | N     |           |           | N/mm <sup>2</sup> | N/mm <sup>2</sup> | -    |
| A       | 180      | 39600           | 56550 | 1.00      | 0.80      | 1.54              | 1.43              | 0.93 |
| B       | 180      | 39600           | 56550 | 1.00      | 0.80      | 1.54              | 1.43              | 0.93 |

verification of bearing stresses für den main beam(u = 0.928) successful!

## 12. Summary

### 12.1. Summary of all verifications

maximal utilization



maximal utilization

| point | x     | U     | point | x     | U       | point | x     | U |
|-------|-------|-------|-------|-------|---------|-------|-------|---|
| -     | m     | -     | -     | m     | -       | -     | m     | - |
| A     | 0.000 | 0.686 | 3.200 | 0.802 | B       | 6.500 | 0.686 |   |
|       | 1.100 | 0.454 | 4.300 | 0.719 | minimum |       | 0.454 |   |
|       | 2.200 | 0.719 | 5.400 | 0.454 | maximum |       | 0.802 |   |

verification of bearing stress

| support | $l_{ef}$ | $A_{ef}$        | $A_P$ | $k_{c90}$ | $k_{mod}$ | $f_{c90d}$        | $\sigma_{c90d}$   | u    |
|---------|----------|-----------------|-------|-----------|-----------|-------------------|-------------------|------|
|         | mm       | mm <sup>2</sup> | N     | -         | -         | N/mm <sup>2</sup> | N/mm <sup>2</sup> | -    |
| A       | 180      | 39600           | 56550 | 1.00      | 0.80      | 1.54              | 1.43              | 0.93 |
| B       | 180      | 39600           | 56550 | 1.00      | 0.80      | 1.54              | 1.43              | 0.93 |

verification of bearing stresses für den main beam(u = 0.928) successful!

### 13. Utilizations of all verifications

all verifications successful!

### 14. Detailed verification piont

#### 14.1. Verification of load-carrying capacity at x = 0.00 m

internal forces and moments

| state     | M     | V     |
|-----------|-------|-------|
|           | kNm   | kN    |
| start,min | -0.00 | 13.00 |
| start,max | -0.00 | 56.55 |
| end,min   | -0.00 | 13.00 |
| end,max   | -0.00 | 56.55 |

stresses and utilization

| state | $k_{mod,1}$ | $\sigma_{m,1}$    | $\sigma_{c,1}$    | $u_1$ | $k_{mod,2}$ | $\sigma_{m,2}$    | $\sigma_{c,2}$    | $u_{\sigma,2}$ | $\tau_2$          | $u_{\tau}$ | $u_2$ |
|-------|-------------|-------------------|-------------------|-------|-------------|-------------------|-------------------|----------------|-------------------|------------|-------|
|       | -           | N/mm <sup>2</sup> | N/mm <sup>2</sup> | -     | -           | N/mm <sup>2</sup> | N/mm <sup>2</sup> | -              | N/mm <sup>2</sup> | -          | -     |
| start | 0.8         | 0.00              | 0.00              | 0.00  | 0.8         | 0.00              | 0.00              | 0.00           | 0.68              | 0.27       | 0.27  |
| end   | 0.8         | 0.00              | 0.00              | 0.00  | 0.8         | 0.00              | 0.00              | 0.00           | 0.67              | 0.27       | 0.27  |

fastener

| state | $F_{1,d}$ | $u_{1,d}$ |
|-------|-----------|-----------|
|       | N         | -         |
| start | -6888     | 0.69      |
| end   | -6616     | 0.66      |

resulting utilization at verification point  $u_{res} = 0.274$