

# 1. Options for Calculations

calculation acc. to DIN 1052:2008

service class 1

coefficients of thermal expansion: timber  $\alpha_t = 0.500 \cdot 10^{-5}/^{\circ}\text{K}$ , steel  $\alpha_t = 1.200 \cdot 10^{-5}/^{\circ}\text{K}$

## 2. Structural system



reinforcement left side

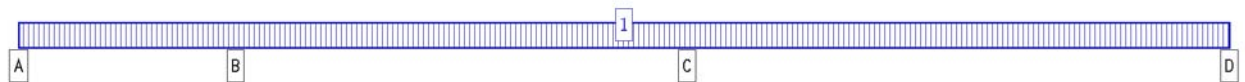


main beam



reinforcement right side

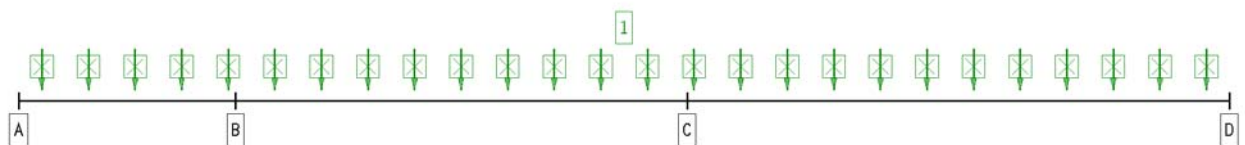
## 3. Loading



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



D



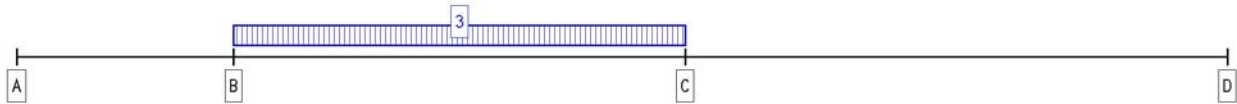
D



D



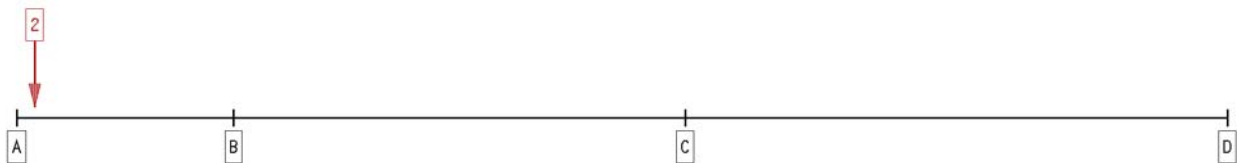
action effect 2: live loads (transient, 3 load cases)



D



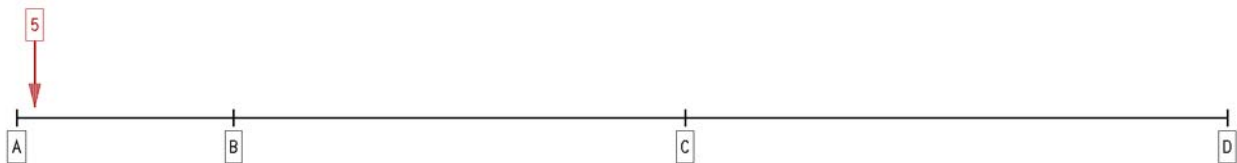
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D



action effect 3: snow (transient, 1 load cases)



D

## 4. material parameters

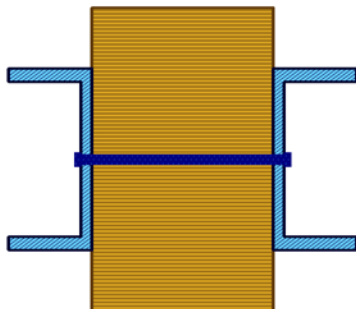
|                                |                                        |
|--------------------------------|----------------------------------------|
| timber grade main beam         | solid coniferous timber, C24 (S10)     |
| service class                  | 1                                      |
| beam width                     | $b = 120 \text{ mm}$                   |
| coeff. therm.expan. timber:    | $0.500 \cdot 10^{-5} / ^\circ\text{K}$ |
| coeff. thermal expan. steel:   | $1.200 \cdot 10^{-5} / ^\circ\text{K}$ |
| char. bend. strength $f_{m,k}$ | $24.0 \text{ N/mm}^2$                  |
| char. shear strength $f_{v,k}$ | $2.0 \text{ N/mm}^2$                   |
| modulus of elast. $E_{0,mean}$ | $11000 \text{ N/mm}^2$                 |

definition of internal forces and moments:

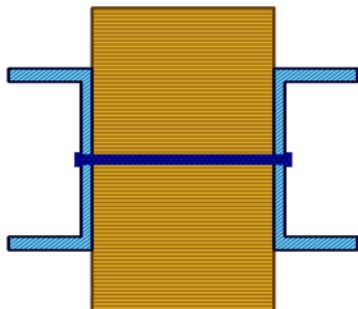


## 5. Beam sections

section beam section 1, scale 1: 5



section beam section 2, scale 1: 5



### main beam sections

| section | $x_A$<br>m | $x_E$<br>m | $l$<br>m | $l_{ef}$<br>m | $k_m$<br>- | $l_v$<br>m | cantil. | $h_{main\ beam}$<br>mm |
|---------|------------|------------|----------|---------------|------------|------------|---------|------------------------|
| 1       | 0.00       | 1.20       | 1.20     | 2.00          | 1.0000     | 1.20       | x       | 200                    |
| 2       | 1.20       | 3.70       | 2.50     | 2.00          | 1.0000     | 2.50       | x       | 200                    |
| 3       | 3.70       | 6.70       | 3.00     | 4.00          | 1.0000     | 3.00       | -       | 200                    |

### sections with reinforcements

| section | reinforcement left side      | reinforcement right side     |
|---------|------------------------------|------------------------------|
| 1       | steel plate S235 (St37) U120 | steel plate S235 (St37) U120 |
| 2       | steel plate S235 (St37) U120 | steel plate S235 (St37) U120 |
| 3       | -                            | -                            |

## 6. Fastener data

section 1 from  $x_A = 0.00$  m to  $x_E = 1.20$

bolt 10 mm, FK 4.6

1 - row, simplified verification acc. to DIN 1052:2008, 12.5.4(2)

$f_{uk} = 400$  N/mm<sup>2</sup>,  $M_{yk} = 47773$  Nmm

$K_{ser} = 6548$  N/mm,  $\gamma_M = 1.10$ ,  $R_k = 4728.3$  N, all values per shear plane

#### coordinates of connectors section 1

| Nr. | $x_{Abs}$<br>m | $x_D$<br>m |
|-----|----------------|------------|
| 1   | 0.200          | 0.200      |
| 2   | 0.600          | 0.600      |
| 3   | 1.000          | 1.000      |

section 2 from  $x_A = 1.20$  m to  $x_E = 3.70$

bolt 10 mm, FK 4.6

1 - row, simplified verification acc. to DIN 1052:2008, 12.5.4(2)

$f_{uk} = 400$  N/mm<sup>2</sup>,  $M_{yk} = 47773$  Nmm

$K_{ser} = 6548$  N/mm,  $\gamma_M = 1.10$ ,  $R_k = 4728.3$  N, all values per shear plane

#### coordinates of connectors section 2

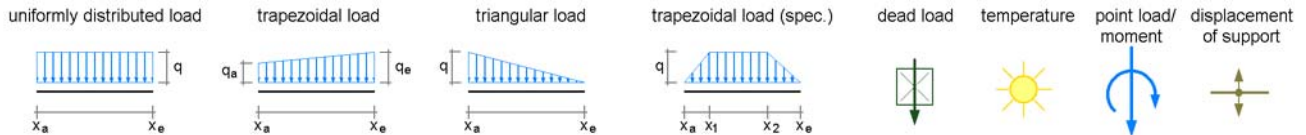
| Nr. | $x_{Abs}$<br>m | $x_D$<br>m | Nr. | $x_{Abs}$<br>m | $x_D$<br>m |
|-----|----------------|------------|-----|----------------|------------|
| 1   | 0.200          | 1.400      | 4   | 1.400          | 2.600      |
| 2   | 0.600          | 1.800      | 5   | 1.800          | 3.000      |
| 3   | 1.000          | 2.200      | 6   | 2.200          | 3.400      |

## 7. Supports

### coordinates of supports

| supp.name | $x$<br>m | $c_F$<br>kN/m | $c_M$<br>kNm/- | left reinf.<br>(F) (M) |   | main beam<br>(F) (M) |   | right reinf.<br>(F) (M) |   |
|-----------|----------|---------------|----------------|------------------------|---|----------------------|---|-------------------------|---|
| B         | 1.20     | fix           | ----           | -                      | - | X                    | - | -                       | - |
| C         | 3.70     | fix           | ----           | -                      | - | X                    | - | -                       | - |
| D         | 6.70     | fix           | ----           | -                      | - | X                    | - | -                       | - |

## 8. Action effects



### Permanent action effect: permanent loads

#### 1. additive load case: dead load (1)

- unif.distr.load (main beam):  $q = 2.00 \text{ kN/m}$  from  $x_a = 0.00 \text{ m}$  to  $x_e = 6.70 \text{ m}$
- point load (main beam):  $F = 3.00 \text{ kN}$  at  $x = 0.10 \text{ m}$
- unif.distr.load (main beam):  $q = 1.50 \text{ kN/m}$  from  $x_a = 3.20 \text{ m}$  to  $x_e = 4.20 \text{ m}$
- dead load (main beam):  $\gamma = 6.00 \text{ kN/m}^3$  from  $x_a = 0.00 \text{ m}$  to  $x_e = 6.70 \text{ m}$

#### 2. Transient action effect: live loads

##### 2. additive load case: span 1

- unif.distr.load (main beam):  $q = 1.20 \text{ kN/m}$  from  $x_a = 0.00 \text{ m}$  to  $x_e = 1.20 \text{ m}$
- point load (main beam):  $F = 2.00 \text{ kN}$  at  $x = 0.10 \text{ m}$

##### 3. additive load case: span 2

- unif.distr.load (main beam):  $q = 1.20 \text{ kN/m}$  from  $x_a = 1.20 \text{ m}$  to  $x_e = 3.70 \text{ m}$

##### 4. additive load case: span 3

- unif.distr.load (main beam):  $q = 1.20 \text{ kN/m}$  from  $x_a = 3.70 \text{ m}$  to  $x_e = 6.70 \text{ m}$

#### 3. Transient action effect: snow

##### 5. additive load case: snow

- unif.distr.load (main beam):  $q = 1.00 \text{ kN/m}$  from  $x_a = 3.20 \text{ m}$  to  $x_e = 4.20 \text{ m}$
- point load (main beam):  $F = 2.00 \text{ kN}$  at  $x = 0.10 \text{ m}$

## 9. verifications

### 1: DIN 1052:2008 load-carrying capacity

safety against overturning will be executed

Extreme rule 1

### 2: DIN 1052:2008 deformations (rarely)

Extreme rule 1

### 3: DIN 1052:2008 deformations (quasicontinuous)

Extreme rule 1

### 4: DIN 4102-22:2004-11 fire protection

fire resistance duration  $t_f = 30 \text{ min}$

combustion depth  $d_f = 2.40 \text{ cm}$

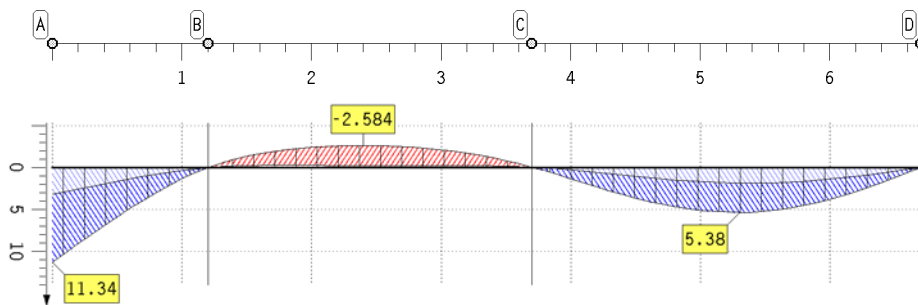
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Extreme rule 1

## 10. Results of verification of ultimate limit state

### 10.1. Verification of ultimate limit state

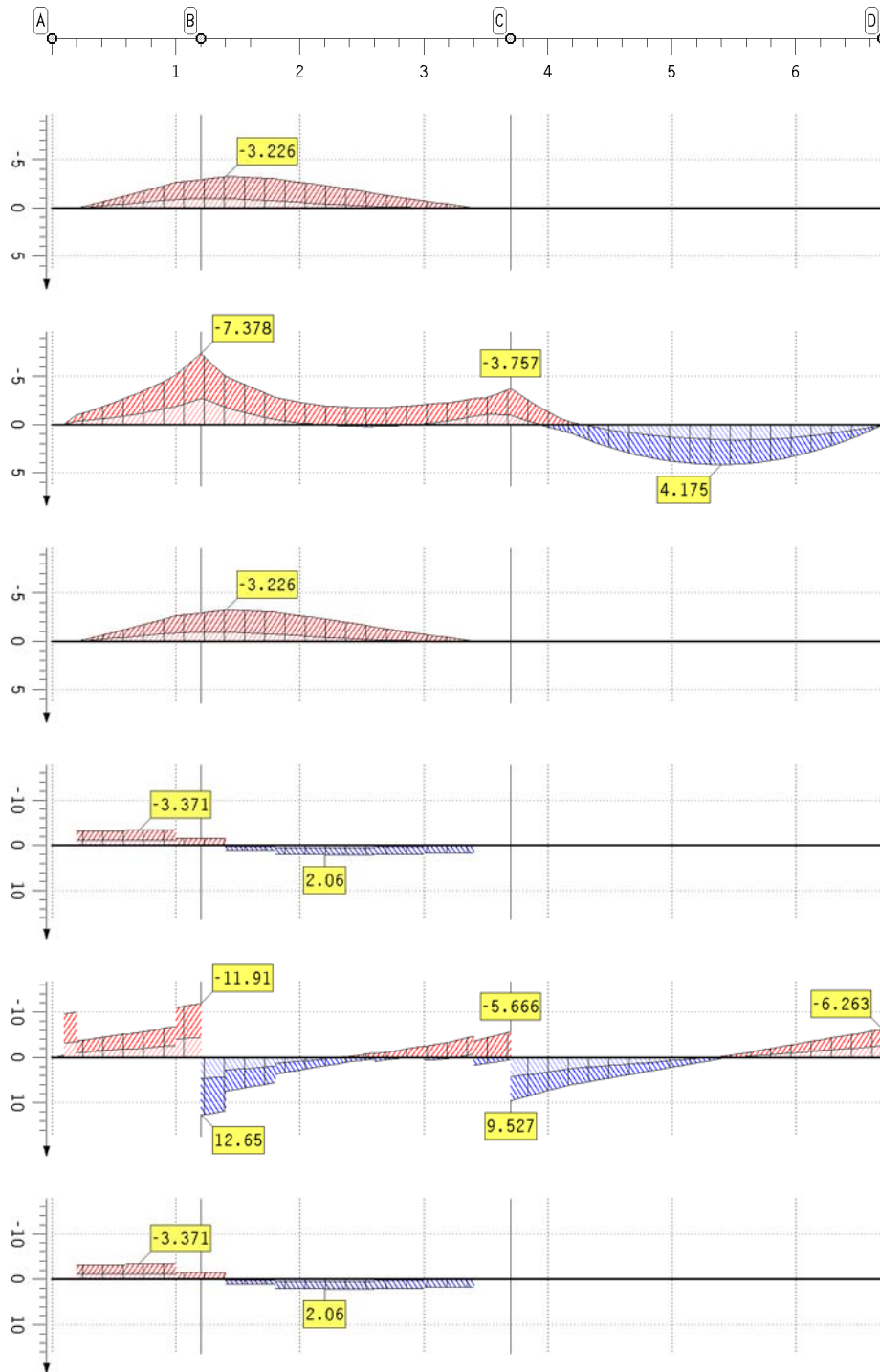
extremal deflections of main beam (incl.  $\gamma_F$ )



extremal deflections of main beam (incl.  $\gamma_F$ )

| point | x     | min w | max w | point | x     | min w | max w | point   | x     | min w | max w |
|-------|-------|-------|-------|-------|-------|-------|-------|---------|-------|-------|-------|
| -     | m     | mm    | mm    | -     | m     | mm    | mm    | -       | m     | mm    | mm    |
| A     | 0.000 | 3.22  | 11.34 |       | 2.900 | -2.21 | -0.19 |         | 5.300 | 1.87  | 5.38  |
| B     | 1.200 | 0.00  | 0.00  |       | 3.300 | -1.40 | -0.17 |         | 5.900 | 1.51  | 4.19  |
| B     | 1.200 | 0.00  | 0.00  |       | 3.500 | -0.78 | -0.12 | D       | 6.700 | -0.00 | 0.00  |
|       | 1.400 | -0.98 | -0.18 | C     | 3.700 | -0.00 | -0.00 | minimum |       | -2.58 | -0.26 |
|       | 1.700 | -1.91 | -0.26 | C     | 3.700 | 0.00  | 0.00  | maximum |       | 3.22  | 11.34 |
|       | 2.400 | -2.58 | -0.20 |       | 4.700 | 1.43  | 4.43  |         |       |       |       |

## extremal internal forces



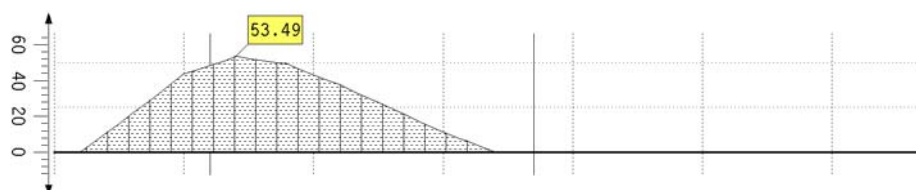
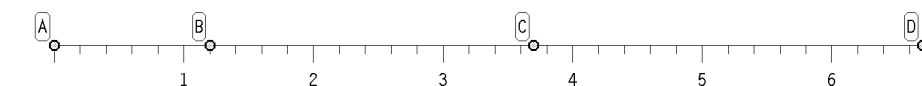
## extremal internal forces

| point | x     | type | main beam |        | reinf. left    |                | reinf. right   |                |
|-------|-------|------|-----------|--------|----------------|----------------|----------------|----------------|
|       |       |      | M         | V      | M <sub>l</sub> | V <sub>l</sub> | M <sub>r</sub> | V <sub>r</sub> |
|       | m     |      | kNm       | kN     | kNm            | kN             | kNm            | kN             |
| A     | 0.000 | Min  | 0.00      | -0.00  | -0.00          | -0.00          | -0.00          | -0.00          |
|       |       | Max  | 0.00      | -0.00  | 0.00           | 0.00           | 0.00           | 0.00           |
|       | 0.100 | Min  | -0.02     | -0.47  | -0.00          | -0.00          | -0.00          | -0.00          |
|       |       | Max  | -0.01     | -0.21  | 0.00           | 0.00           | 0.00           | 0.00           |
|       | 0.100 | Min  | -0.02     | -9.57  | 0.00           | -0.00          | -0.00          | -0.00          |
|       |       | Max  | -0.01     | -3.21  | 0.00           | -0.00          | 0.00           | 0.00           |
|       | 0.200 | Min  | -1.00     | -9.98  | -0.00          | -0.00          | -0.00          | -0.00          |
|       |       | Max  | -0.34     | -3.43  | -0.00          | -0.00          | 0.00           | 0.00           |
|       | 0.200 | Min  | -1.00     | -3.57  | -0.00          | -3.22          | -0.00          | -3.22          |
|       |       | Max  | -0.34     | -1.11  | -0.00          | -1.14          | -0.00          | -1.14          |
|       | 0.600 | Min  | -2.76     | -5.10  | -1.29          | -3.37          | -1.29          | -3.37          |
|       |       | Max  | -0.96     | -1.84  | -0.46          | -1.08          | -0.46          | -1.08          |
|       | 1.000 | Min  | -5.13     | -6.92  | -2.64          | -3.37          | -2.64          | -3.37          |
|       |       | Max  | -1.87     | -2.70  | -0.89          | -1.08          | -0.89          | -1.08          |
| 1.000 | Min   |      | -5.13     | -10.97 | -2.64          | -1.48          | -2.64          | -1.48          |

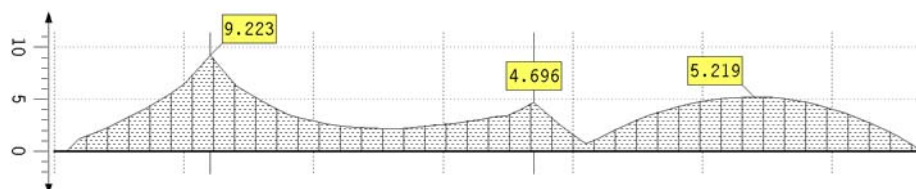
# extremal internal forces

| point   | x     | type  | main beam |        | reinf. left    |                | reinf. right   |                |       |       |
|---------|-------|-------|-----------|--------|----------------|----------------|----------------|----------------|-------|-------|
|         |       |       | M         | V      | M <sub>l</sub> | V <sub>l</sub> | M <sub>r</sub> | V <sub>r</sub> |       |       |
| -       | m     |       | kNm       | kN     | kNm            | kN             | kNm            | kN             |       |       |
| B       | 1.200 | Max   | -1.87     | -4.08  | -0.89          | -0.19          | -0.89          | -0.19          |       |       |
|         |       | Min   | -7.38     | -11.91 | -2.93          | -1.48          | -2.93          | -1.48          |       |       |
|         |       | Max   | -2.72     | -4.51  | -0.93          | -0.19          | -0.93          | -0.19          |       |       |
| B       | 1.200 | Min   | -7.38     | 4.64   | -2.93          | -1.48          | -2.93          | -1.48          |       |       |
|         |       | Max   | -2.72     | 12.65  | -0.93          | -0.19          | -0.93          | -0.19          |       |       |
|         |       | 1.400 | Min       | -5.05  | 4.22           | -3.23          | -1.48          | -3.23          | -1.48 |       |
|         | 1.400 | Max   | -1.76     | 11.71  | -0.97          | -0.19          | -0.97          | -0.19          |       |       |
|         |       | Min   | -5.05     | 2.71   | -3.23          | 0.22           | -3.23          | 0.22           |       |       |
|         |       | Max   | -1.76     | 7.36   | -0.97          | 1.04           | -0.97          | 1.04           |       |       |
|         | 1.800 | Min   | -2.81     | 1.85   | -2.96          | 0.22           | -2.96          | 0.22           |       |       |
|         |       | Max   | -0.46     | 5.48   | -0.70          | 1.04           | -0.70          | 1.04           |       |       |
|         |       | 1.800 | Min       | -2.81  | 1.19           | -2.96          | 0.55           | -2.96          | 0.55  |       |
|         |       | Max   | -0.46     | 3.64   | -0.70          | 1.96           | -0.70          | 1.96           |       |       |
|         |       | 2.200 | Min       | -1.91  | 0.16           | -2.26          | 0.54           | -2.26          | 0.54  |       |
|         |       | Max   | 0.06      | 1.84   | -0.36          | 2.06           | -0.36          | 2.06           |       |       |
|         | 2.500 | Min   | -1.75     | -0.59  | -1.67          | 0.54           | -1.67          | 0.54           |       |       |
|         |       | Max   | 0.19      | 0.56   | -0.18          | 2.06           | -0.18          | 2.06           |       |       |
|         |       | 3.400 | Min       | -2.69  | -4.73          | -0.00          | 0.07           | -0.00          | 0.07  |       |
|         |       | Max   | -0.89     | -0.74  | 0.00           | 1.69           | 0.00           | 1.69           |       |       |
|         |       | 3.400 | Min       | -2.69  | -3.65          | -0.00          | -0.00          | -0.00          | -0.00 |       |
|         |       | Max   | -0.89     | 1.70   | 0.00           | 0.00           | 0.00           | 0.00           |       |       |
| C       | 3.700 | Min   | -3.76     | -5.67  | 0.00           | -0.00          | 0.00           | -0.00          |       |       |
|         |       | Max   | -0.91     | 0.38   | 0.00           | 0.00           | 0.00           | 0.00           |       |       |
|         |       | C     | 3.700     | Min    | -3.76          | 4.25           | -----          | -----          | ----- | ----- |
| Max     | -0.91 |       |           | 9.53   | -----          | -----          | -----          | -----          |       |       |
| 4.200   | Min   |       |           | -0.16  | 2.34           | -----          | -----          | -----          | ----- |       |
|         |       | Max   | 1.00      | 5.86   | -----          | -----          | -----          | -----          |       |       |
|         |       | 4.800 | Min       | 1.10   | 1.05           | -----          | -----          | -----          | ----- |       |
|         |       | Max   | 3.43      | 3.05   | -----          | -----          | -----          | -----          |       |       |
|         | 5.400 | Min   | 1.59      | -0.24  | -----          | -----          | -----          | -----          |       |       |
|         |       | Max   | 4.17      | 0.23   | -----          | -----          | -----          | -----          |       |       |
|         |       | 6.000 | Min       | 1.31   | -2.98          | -----          | -----          | -----          | ----- |       |
|         |       | Max   | 3.23      | -1.12  | -----          | -----          | -----          | -----          |       |       |
|         |       | D     | 6.700     | Min    | 0.00           | -6.26          | -----          | -----          | ----- | ----- |
|         |       |       |           | Max    | 0.00           | -2.62          | -----          | -----          | ----- | ----- |
| minimum |       |       | -7.38     | -11.91 | -3.23          | -3.37          | -3.23          | -3.37          |       |       |
| maximum |       |       | 4.17      | 12.65  | 0.00           | 2.06           | 0.00           | 2.06           |       |       |

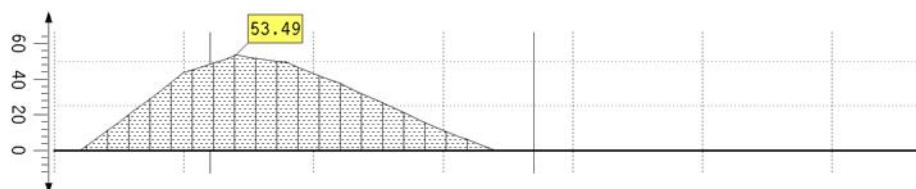
## results of verification of ultimate limit state



bending stress  
reinf. left  
 $\sigma_l$  in MN/m<sup>2</sup>  
Max: 53.49

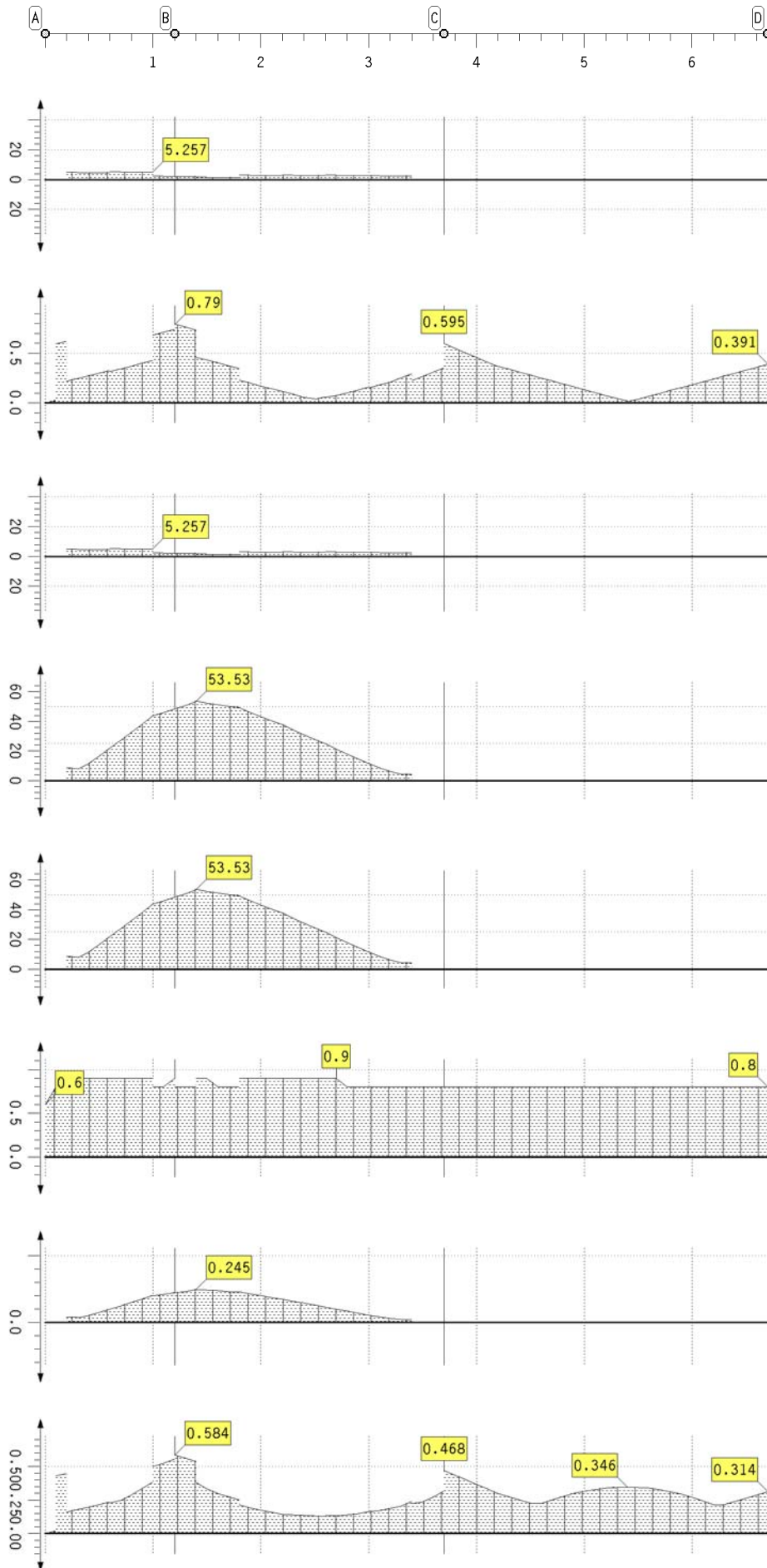


bending stress  
main beam  
 $\sigma_h$  in MN/m<sup>2</sup>  
Max: 9.22

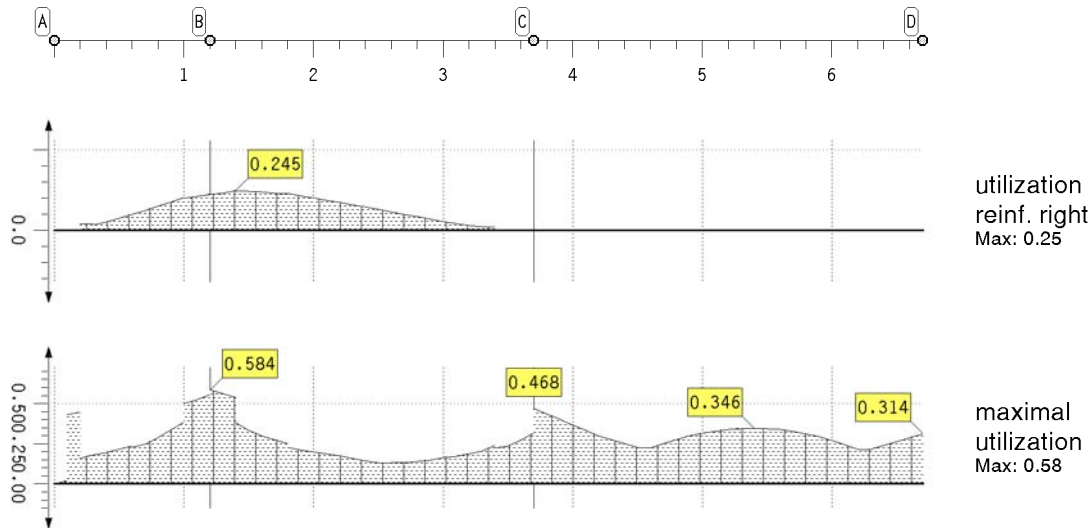


bending stress  
reinf. right  
 $\sigma_r$  in MN/m<sup>2</sup>  
Max: 53.49

# results of verification of ultimate limit state



# results of verification of ultimate limit state



## verification of ultimate limit state of left-sided steel reinforcement

| point | x     | $\sigma_l$        | $\tau_l$          | $\sigma_{v,l}$    | $U_l$ | point   | x     | $\sigma_l$        | $\tau_l$          | $\sigma_{v,l}$    | $U_l$ |
|-------|-------|-------------------|-------------------|-------------------|-------|---------|-------|-------------------|-------------------|-------------------|-------|
| -     | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     | -       | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     |
| A     | 0.000 | 0.00              | 0.00              | 0.00              | 0.000 |         | 1.800 | 49.10             | 1.62              | 49.12             | 0.225 |
|       | 0.200 | 0.00              | 0.00              | 0.00              | 0.000 |         | 1.800 | 49.10             | 3.05              | 49.17             | 0.225 |
|       | 0.200 | 0.00              | 5.02              | 8.70              | 0.040 |         | 2.100 | 40.19             | 2.79              | 40.28             | 0.185 |
|       | 0.500 | 15.92             | 4.60              | 16.51             | 0.076 |         | 2.200 | 37.55             | 3.21              | 37.66             | 0.173 |
|       | 0.600 | 21.36             | 5.26              | 21.86             | 0.100 |         | 3.000 | 11.20             | 3.13              | 11.54             | 0.053 |
|       | 1.000 | 43.71             | 5.26              | 43.96             | 0.201 |         | 3.000 | 11.20             | 2.63              | 11.44             | 0.052 |
| B     | 1.000 | 43.71             | 2.31              | 43.76             | 0.201 |         | 3.100 | 8.35              | 2.41              | 8.66              | 0.040 |
|       | 1.200 | 48.31             | 2.12              | 48.36             | 0.222 |         | 3.400 | 0.00              | 2.63              | 4.56              | 0.021 |
| B     | 1.200 | 48.31             | 2.12              | 48.36             | 0.222 |         | 3.400 | 0.00              | 0.00              | 0.00              | 0.000 |
|       | 1.400 | 53.49             | 2.31              | 53.53             | 0.245 | C       | 3.700 | 0.00              | 0.00              | 0.00              | 0.000 |
|       | 1.400 | 53.49             | 1.62              | 53.51             | 0.245 | minimum |       | 0.00              | 0.00              | 0.00              | 0.000 |
|       | 1.700 | 49.90             | 1.48              | 49.92             | 0.229 | maximum |       | 53.49             | 5.26              | 53.53             | 0.245 |

## verification of ultimate limit state of main beam

| point | x     | $k_{mod,h}$ | $\sigma_h$        | $\tau_h$          | $U_h$ | point   | x     | $k_{mod,h}$ | $\sigma_h$        | $\tau_h$          | $U_h$ |
|-------|-------|-------------|-------------------|-------------------|-------|---------|-------|-------------|-------------------|-------------------|-------|
| -     | m     | -           | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     | -       | m     | -           | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     |
| A     | 0.000 | 0.600       | 0.00              | 0.00              | 0.000 |         | 1.800 | 0.900       | 3.51              | 0.23              | 0.211 |
|       | 0.100 | 0.800       | 0.03              | 0.03              | 0.024 |         | 2.500 | 0.900       | 2.18              | 0.04              | 0.131 |
|       | 0.100 | 0.900       | 0.03              | 0.60              | 0.432 |         | 2.700 | 0.900       | 2.24              | 0.08              | 0.135 |
|       | 0.200 | 0.900       | 1.25              | 0.62              | 0.451 |         | 2.800 | 0.800       | 2.33              | 0.10              | 0.141 |
|       | 0.200 | 0.900       | 1.25              | 0.22              | 0.161 | C       | 3.700 | 0.800       | 4.70              | 0.35              | 0.318 |
|       | 1.000 | 0.900       | 6.41              | 0.43              | 0.386 | C       | 3.700 | 0.800       | 4.70              | 0.60              | 0.468 |
| B     | 1.000 | 0.800       | 6.41              | 0.69              | 0.501 |         | 4.100 | 0.800       | 0.76              | 0.41              | 0.332 |
|       | 1.100 | 0.800       | 7.79              | 0.71              | 0.525 |         | 4.600 | 0.800       | 3.50              | 0.25              | 0.225 |
| B     | 1.200 | 0.900       | 9.22              | 0.74              | 0.555 |         | 5.000 | 0.800       | 4.83              | 0.13              | 0.317 |
|       | 1.200 | 0.800       | 9.22              | 0.79              | 0.584 |         | 5.400 | 0.800       | 5.22              | 0.01              | 0.346 |
|       | 1.400 | 0.800       | 6.31              | 0.73              | 0.537 |         | 5.800 | 0.800       | 4.67              | 0.13              | 0.311 |
|       | 1.400 | 0.900       | 6.31              | 0.46              | 0.380 |         | 6.200 | 0.800       | 3.18              | 0.24              | 0.212 |
|       | 1.500 | 0.900       | 5.56              | 0.43              | 0.334 | D       | 6.700 | 0.800       | 0.00              | 0.39              | 0.314 |
|       | 1.600 | 0.800       | 4.84              | 0.40              | 0.296 | minimum |       | 0.600       | 0.00              | 0.00              | 0.000 |
|       | 1.800 | 0.800       | 3.51              | 0.34              | 0.248 | maximum |       | 0.900       | 9.22              | 0.79              | 0.584 |

## verification of ultimate limit state of right-sided steel reinforcement

| point | x     | $\sigma_r$        | $\tau_r$          | $\sigma_{v,r}$    | $U_r$ | point | x     | $\sigma_r$        | $\tau_r$          | $\sigma_{v,r}$    | $U_r$ |
|-------|-------|-------------------|-------------------|-------------------|-------|-------|-------|-------------------|-------------------|-------------------|-------|
| -     | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     | -     | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     |
| A     | 0.000 | 0.00              | 0.00              | 0.00              | 0.000 |       | 1.400 | 53.49             | 2.31              | 53.53             | 0.245 |
|       | 0.200 | 0.00              | 0.00              | 0.00              | 0.000 |       | 1.400 | 53.49             | 1.62              | 53.51             | 0.245 |
|       | 0.200 | 0.00              | 5.02              | 8.70              | 0.040 |       | 1.700 | 49.90             | 1.48              | 49.92             | 0.229 |
|       | 0.500 | 15.92             | 4.60              | 16.51             | 0.076 |       | 1.800 | 49.10             | 1.62              | 49.12             | 0.225 |
|       | 0.600 | 21.36             | 5.26              | 21.86             | 0.100 |       | 1.800 | 49.10             | 3.05              | 49.17             | 0.225 |
|       | 1.000 | 43.71             | 5.26              | 43.96             | 0.201 |       | 2.100 | 40.19             | 2.79              | 40.28             | 0.185 |
| B     | 1.000 | 43.71             | 2.31              | 43.76             | 0.201 |       | 2.200 | 37.55             | 3.21              | 37.66             | 0.173 |
|       | 1.200 | 48.31             | 2.12              | 48.36             | 0.222 |       | 3.000 | 11.20             | 3.13              | 11.54             | 0.053 |
| B     | 1.200 | 48.31             | 2.12              | 48.36             | 0.222 |       | 3.000 | 11.20             | 2.63              | 11.44             | 0.052 |

## verification of ultimate limit state of right-sided steel reinforcement

| point | x     | $\sigma_r$        | $\tau_r$          | $\sigma_{v,r}$    | $U_r$ | point   | x     | $\sigma_r$        | $\tau_r$          | $\sigma_{v,r}$    | $U_r$ |
|-------|-------|-------------------|-------------------|-------------------|-------|---------|-------|-------------------|-------------------|-------------------|-------|
| -     | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     | -       | m     | MN/m <sup>2</sup> | MN/m <sup>2</sup> | MN/m <sup>2</sup> | -     |
|       | 3.100 | 8.35              | 2.41              | 8.66              | 0.040 | C       | 3.700 | 0.00              | 0.00              | 0.00              | 0.000 |
|       | 3.400 | 0.00              | 2.63              | 4.56              | 0.021 | minimum |       | 0.00              | 0.00              | 0.00              | 0.000 |
|       | 3.400 | 0.00              | 0.00              | 0.00              | 0.000 | maximum |       | 53.49             | 5.26              | 53.53             | 0.245 |

## maximal utilization

| point | x     | U     | point | x     | U     | point | x     | U     | point   | x     | U     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|-------|-------|
| -     | m     | -     | -     | m     | -     | -     | m     | -     | -       | m     | -     |
| A     | 0.000 | 0.000 |       | 1.000 | 0.386 |       | 1.800 | 0.225 |         | 5.400 | 0.346 |
|       | 0.100 | 0.024 |       | 1.000 | 0.501 |       | 2.500 | 0.131 |         | 5.800 | 0.311 |
|       | 0.100 | 0.432 | B     | 1.200 | 0.555 |       | 3.200 | 0.188 |         | 6.200 | 0.212 |
|       | 0.200 | 0.451 | B     | 1.200 | 0.584 | C     | 3.700 | 0.318 | D       | 6.700 | 0.314 |
|       | 0.200 | 0.161 |       | 1.400 | 0.537 | C     | 3.700 | 0.468 | minimum |       | 0.000 |
|       | 0.700 | 0.249 |       | 1.400 | 0.380 |       | 4.500 | 0.226 | maximum |       | 0.584 |

## extremal support forces

| point | x     | min AP | max AP | min AP <sub>I</sub> | max AP <sub>I</sub> | min AP <sub>r</sub> | max AP <sub>r</sub> | min ΣAP | max ΣAP |
|-------|-------|--------|--------|---------------------|---------------------|---------------------|---------------------|---------|---------|
| -     | m     | kN     | kN     | kN                  | kN                  | kN                  | kN                  | kN      | kN      |
| B     | 1.200 | -24.55 | -9.15  | 0.00                | 0.00                | -0.00               | -0.00               | -24.55  | -9.15   |
| C     | 3.700 | -14.89 | -4.17  | -----               | -----               | -----               | -----               | -14.89  | -4.17   |
| D     | 6.700 | -6.26  | -2.62  | -----               | -----               | -----               | -----               | -6.26   | -2.62   |

## extremal connector reactions

| x     | min CP <sub>I</sub> | max CP <sub>I</sub> | min CM <sub>I</sub> | max CM <sub>I</sub> | min CP <sub>r</sub> | max CP <sub>r</sub> | min CM <sub>r</sub> | max CM <sub>r</sub> |
|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| m     | kN                  | kN                  | kNm                 | kNm                 | kN                  | kN                  | kNm                 | kNm                 |
| 0.200 | 1.14                | 3.22                | 0.00                | 0.00                | 1.14                | 3.22                | 0.00                | 0.00                |
| 0.600 | -0.06               | 0.18                | 0.00                | 0.00                | -0.06               | 0.18                | 0.00                | 0.00                |
| 1.000 | -2.04               | -0.69               | 0.00                | 0.00                | -2.04               | -0.69               | 0.00                | 0.00                |
| 1.400 | -2.21               | -0.75               | 0.00                | 0.00                | -2.21               | -0.75               | 0.00                | 0.00                |
| 1.800 | -1.08               | -0.19               | 0.00                | 0.00                | -1.08               | -0.19               | 0.00                | 0.00                |
| 2.200 | -0.31               | 0.27                | 0.00                | 0.00                | -0.31               | 0.27                | 0.00                | 0.00                |
| 2.600 | -0.10               | 0.40                | 0.00                | 0.00                | -0.10               | 0.40                | 0.00                | 0.00                |
| 3.000 | -0.04               | 0.52                | 0.00                | 0.00                | -0.04               | 0.52                | 0.00                | 0.00                |
| 3.400 | 0.07                | 1.69                | 0.00                | 0.00                | 0.07                | 1.69                | 0.00                | 0.00                |

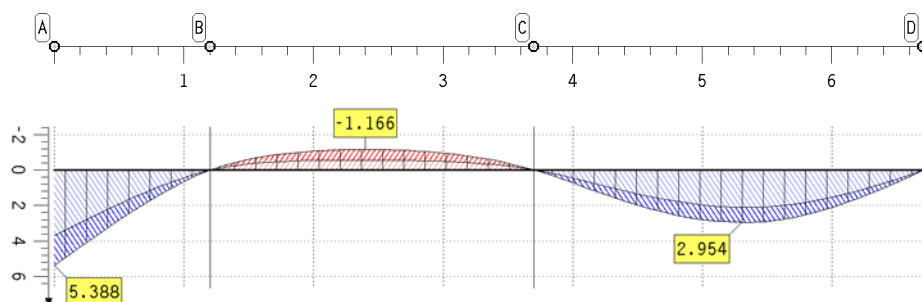
## verification of ultimate limit state for connectors

| x     | k <sub>mod,1</sub> | U <sub>I</sub> | k <sub>mod,r</sub> | U <sub>r</sub> | x     | k <sub>mod,1</sub> | U <sub>I</sub> | k <sub>mod,r</sub> | U <sub>r</sub> |
|-------|--------------------|----------------|--------------------|----------------|-------|--------------------|----------------|--------------------|----------------|
| m     | -                  | -              | -                  | -              | m     | -                  | -              | -                  | -              |
| 0.200 | 0.900              | 0.984          | 0.900              | 0.984          | 2.200 | 0.900              | 0.096          | 0.900              | 0.096          |
| 0.600 | 0.800              | 0.056          | 0.800              | 0.056          | 2.600 | 0.800              | 0.135          | 0.800              | 0.135          |
| 1.000 | 0.900              | 0.622          | 0.900              | 0.622          | 3.000 | 0.900              | 0.160          | 0.900              | 0.160          |
| 1.400 | 0.900              | 0.674          | 0.900              | 0.674          | 3.400 | 0.900              | 0.516          | 0.900              | 0.516          |
| 1.800 | 0.900              | 0.330          | 0.900              | 0.330          |       |                    |                |                    |                |

## 11. Results of verification of fire protection

### 11.1. Verification of fire protection

extremal deflections of main beam (incl.  $\gamma_F$ )

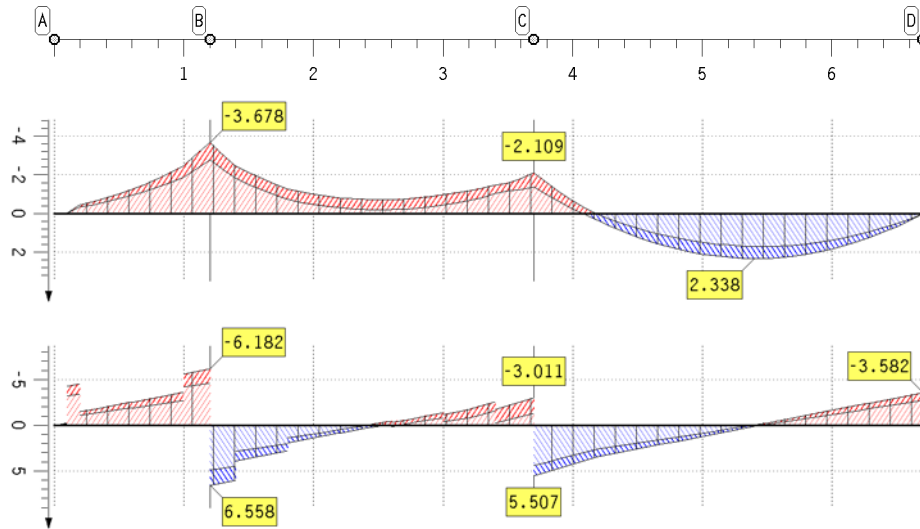


deflection  
main beam  
 $\gamma_F$ -fach  
w in mm  
Min: -1.17  
Max: 5.39

extremal deflections of main beam (incl.  $\gamma_F$ )

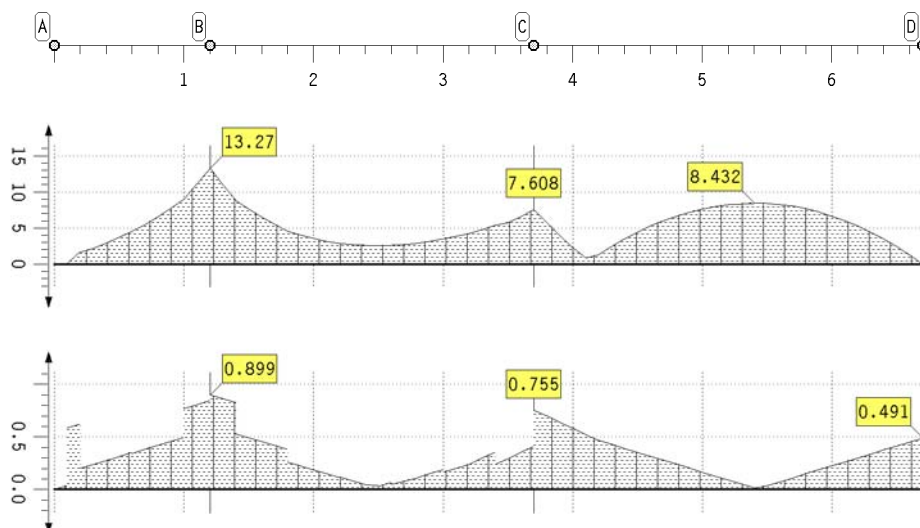
| point | x     | min w | max w | point | x     | min w | max w | point   | x     | min w | max w |
|-------|-------|-------|-------|-------|-------|-------|-------|---------|-------|-------|-------|
| -     | m     | mm    | mm    | -     | m     | mm    | mm    | -       | m     | mm    | mm    |
| A     | 0.000 | 3.68  | 5.39  |       | 2.400 | -1.17 | -0.56 |         | 5.300 | 2.10  | 2.95  |
| B     | 1.200 | 0.00  | 0.00  |       | 3.200 | -0.78 | -0.40 |         | 5.900 | 1.67  | 2.32  |
| B     | 1.200 | 0.00  | 0.00  | C     | 3.700 | -0.00 | -0.00 | D       | 6.700 | -0.00 | 0.00  |
|       | 1.600 | -0.76 | -0.42 | C     | 3.700 | 0.00  | 0.00  | minimum |       | -1.17 | -0.56 |
|       | 2.200 | -1.15 | -0.56 |       | 4.700 | 1.66  | 2.40  | maximum |       | 3.68  | 5.39  |

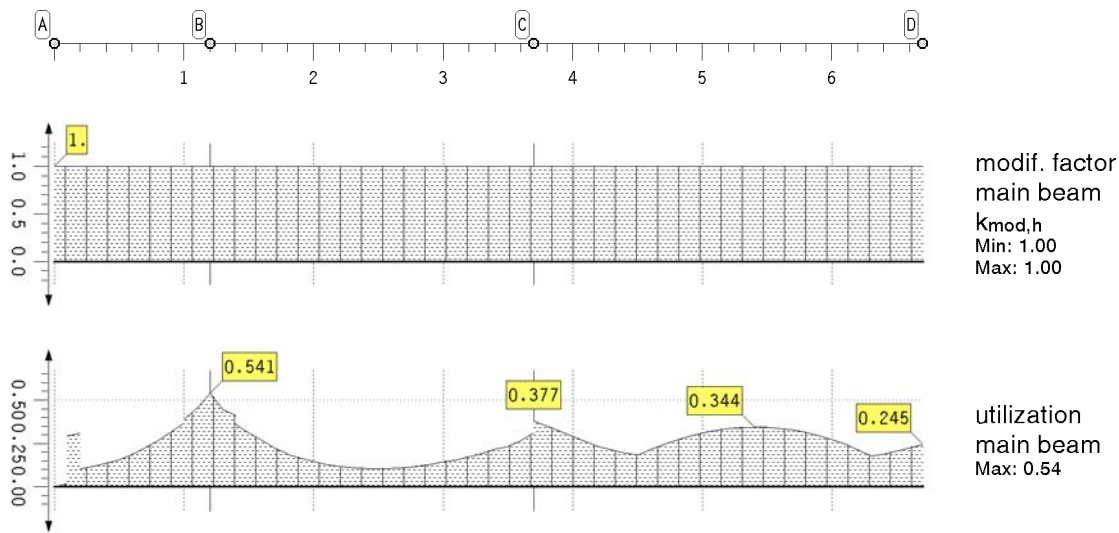
extremal internal forces



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 | -0.00 |         | 1.800 | -1.25 | -0.72 | 1.33  | 1.89  |
|       | 0.100 | -0.01 | -0.01 | -0.27 | -0.21 |         | 2.500 | -0.71 | -0.19 | -0.24 | 0.07  |
|       | 0.100 | -0.01 | -0.01 | -4.27 | -3.21 |         | 3.400 | -1.50 | -1.04 | -2.61 | -1.57 |
|       | 0.200 | -0.45 | -0.34 | -4.55 | -3.43 |         | 3.400 | -1.50 | -1.04 | -1.74 | -0.26 |
|       | 0.200 | -0.45 | -0.34 | -1.50 | -1.11 | C       | 3.700 | -2.11 | -1.38 | -3.01 | -1.36 |
|       | 1.000 | -2.50 | -1.88 | -3.62 | -2.74 | C       | 3.700 | -2.11 | -1.38 | 4.36  | 5.51  |
|       | 1.000 | -2.50 | -1.88 | -5.63 | -4.20 |         | 4.400 | 0.57  | 0.98  | 2.11  | 2.84  |
| B     | 1.200 | -3.68 | -2.77 | -6.18 | -4.63 |         | 5.400 | 1.71  | 2.34  | -0.03 | 0.09  |
| B     | 1.200 | -3.68 | -2.77 | 4.85  | 6.56  |         | 6.000 | 1.37  | 1.84  | -1.66 | -1.21 |
|       | 1.400 | -2.45 | -1.81 | 4.42  | 6.01  | D       | 6.700 | 0.00  | 0.00  | -3.58 | -2.71 |
|       | 1.400 | -2.45 | -1.81 | 2.85  | 3.86  | minimum |       | -3.68 | -2.77 | -6.18 | -4.63 |
|       | 1.800 | -1.25 | -0.72 | 1.99  | 2.76  | maximum |       | 1.71  | 2.34  | 4.85  | 6.56  |





verification of ultimate limit state of main beam

| point | x<br>m | $k_{mod,h}$ | $\sigma_h$<br>MN/m <sup>2</sup> | $\tau_h$<br>MN/m <sup>2</sup> | $U_h$ | point   | x<br>m | $k_{mod,h}$ | $\sigma_h$<br>MN/m <sup>2</sup> | $\tau_h$<br>MN/m <sup>2</sup> | $U_h$ |
|-------|--------|-------------|---------------------------------|-------------------------------|-------|---------|--------|-------------|---------------------------------|-------------------------------|-------|
| A     | 0.000  | 1.000       | 0.00                            | 0.00                          | 0.000 |         | 2.500  | 1.000       | 2.57                            | 0.03                          | 0.105 |
|       | 0.100  | 1.000       | 0.05                            | 0.04                          | 0.019 |         | 3.200  | 1.000       | 4.27                            | 0.24                          | 0.174 |
|       | 0.100  | 1.000       | 0.05                            | 0.59                          | 0.293 | C       | 3.700  | 1.000       | 7.61                            | 0.41                          | 0.310 |
|       | 0.200  | 1.000       | 1.64                            | 0.62                          | 0.312 | C       | 3.700  | 1.000       | 7.61                            | 0.75                          | 0.377 |
|       | 0.200  | 1.000       | 1.64                            | 0.21                          | 0.103 |         | 4.100  | 1.000       | 0.89                            | 0.52                          | 0.261 |
|       | 1.000  | 1.000       | 9.01                            | 0.50                          | 0.367 |         | 4.500  | 1.000       | 4.47                            | 0.35                          | 0.182 |
|       | 1.000  | 1.000       | 9.01                            | 0.77                          | 0.386 |         | 5.000  | 1.000       | 7.66                            | 0.16                          | 0.312 |
| B     | 1.200  | 1.000       | 13.27                           | 0.85                          | 0.541 |         | 5.400  | 1.000       | 8.43                            | 0.01                          | 0.344 |
| B     | 1.200  | 1.000       | 13.27                           | 0.90                          | 0.541 |         | 5.800  | 1.000       | 7.62                            | 0.15                          | 0.310 |
|       | 1.400  | 1.000       | 8.83                            | 0.82                          | 0.412 |         | 6.300  | 1.000       | 4.38                            | 0.34                          | 0.178 |
|       | 1.400  | 1.000       | 8.83                            | 0.53                          | 0.360 | D       | 6.700  | 1.000       | 0.00                            | 0.49                          | 0.245 |
|       | 1.800  | 1.000       | 4.52                            | 0.38                          | 0.189 | minimum |        | 1.000       | 0.00                            | 0.00                          | 0.000 |
|       | 1.800  | 1.000       | 4.52                            | 0.26                          | 0.184 | maximum |        | 1.000       | 13.27                           | 0.90                          | 0.541 |

maximal utilization

| point | x<br>m | U     | point | x<br>m | U     | point | x<br>m | U     | point   | x<br>m | U     |
|-------|--------|-------|-------|--------|-------|-------|--------|-------|---------|--------|-------|
| A     | 0.000  | 0.000 | B     | 1.200  | 0.541 | C     | 3.700  | 0.310 |         | 6.300  | 0.178 |
|       | 0.100  | 0.019 | B     | 1.200  | 0.541 | C     | 3.700  | 0.377 | D       | 6.700  | 0.245 |
|       | 0.100  | 0.293 |       | 1.400  | 0.412 |       | 4.200  | 0.232 | minimum |        | 0.000 |
|       | 0.200  | 0.312 |       | 1.400  | 0.360 |       | 4.500  | 0.182 | maximum |        | 0.541 |
|       | 0.200  | 0.103 |       | 1.800  | 0.184 |       | 5.000  | 0.312 |         |        |       |
|       | 0.500  | 0.158 |       | 2.500  | 0.105 |       | 5.400  | 0.344 |         |        |       |
|       | 1.000  | 0.367 |       | 3.200  | 0.174 |       | 5.800  | 0.310 |         |        |       |

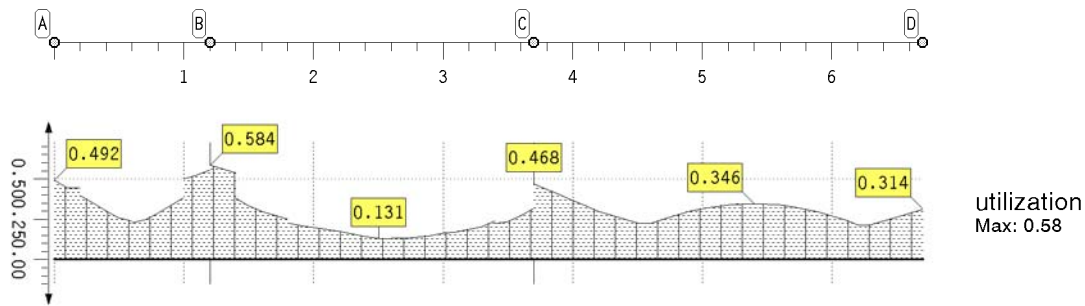
extremal support forces

| point | x<br>m | min AP<br>kN | max AP<br>kN | min AP <sub>l</sub><br>kN | max AP <sub>l</sub><br>kN | min AP <sub>r</sub><br>kN | max AP <sub>r</sub><br>kN | min ΣAP<br>kN | max ΣAP<br>kN |
|-------|--------|--------------|--------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------|---------------|
| B     | 1.200  | -12.74       | -9.48        | 0.00                      | 0.00                      | -0.00                     | -0.00                     | -12.74        | -9.48         |
| C     | 3.700  | -8.52        | -5.72        | -----                     | -----                     | -----                     | -----                     | -8.52         | -5.72         |
| D     | 6.700  | -3.58        | -2.71        | -----                     | -----                     | -----                     | -----                     | -3.58         | -2.71         |

## 12. Summary

### 12.1. Summary of all verifications

## maximal utilization



## maximal utilization

| point | x     | U     | point | x     | U     | point | x     | U     | point   | x     | U     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|-------|-------|
| -     | m     | -     | -     | m     | -     | -     | m     | -     | -       | m     | -     |
| A     | 0.000 | 0.492 | B     | 1.200 | 0.555 |       | 3.200 | 0.188 |         | 6.200 | 0.213 |
|       | 0.200 | 0.451 | B     | 1.200 | 0.584 | C     | 3.700 | 0.318 | D       | 6.700 | 0.314 |
|       | 0.200 | 0.396 |       | 1.400 | 0.537 | C     | 3.700 | 0.468 | minimum |       | 0.131 |
|       | 0.600 | 0.230 |       | 1.400 | 0.380 |       | 4.500 | 0.226 | maximum |       | 0.584 |
|       | 1.000 | 0.386 |       | 1.800 | 0.225 |       | 5.400 | 0.346 |         |       |       |
|       | 1.000 | 0.501 |       | 2.500 | 0.131 |       | 5.800 | 0.311 |         |       |       |

## maximal connector utilization

| x     | U    | x     | U    | x     | U    |
|-------|------|-------|------|-------|------|
| m     | -    | m     | -    | m     | -    |
| 0.200 | 0.98 | 1.400 | 0.67 | 2.600 | 0.14 |
| 0.600 | 0.06 | 1.800 | 0.33 | 3.000 | 0.16 |
| 1.000 | 0.62 | 2.200 | 0.10 | 3.400 | 0.52 |

## 13. Utilizations of all verifications

all verifications successful!