

## 1. input data

### 1.1. general information

verifications of stability acc. to EN 1993-1-1

c/t-verification (classification of cross-section)

lateral torsional buckling with the method of fictitious bars for  $M_y$

### 1.2. safety factor of material

resistance of cross-sections  $\gamma_{M0} = 1.00$

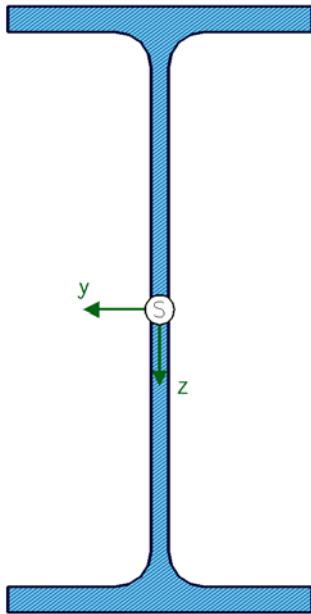
resistance of members in stability failure  $\gamma_{M1} = 1.10$

### 1.3. cross-section

material: S235 (St37) ( $E = 210000 \text{ N/mm}^2$ ,  $G = 80769 \text{ N/mm}^2$ ,  $f_{y,k} = 235 \text{ N/mm}^2$ )

section: IPE200

section scale 1:2.5



### 1.4. cross-section values (related to the centre of gravity S)

$I_y = 1940.0 \text{ cm}^4$ ,  $I_z = 142.0 \text{ cm}^4$ ,  $I_{yz} = 1940.0 \text{ cm}^4$ ,  $I_{\eta} = 142.0 \text{ cm}^4$ ,  $\alpha = 0.0^\circ$

$I_{\omega} = 12990.0 \text{ cm}^6$ ,  $I_T = 7.0 \text{ cm}^4$

$W_y = 194.0 \text{ cm}^3$ ,  $W_z = 28.5 \text{ cm}^3$ ,  $W_{pl,y} = 221.0 \text{ cm}^3$ ,  $W_{pl,z} = 44.7 \text{ cm}^3$

$z_{m,y} = 0.0 \text{ mm}$ ,  $z_{m,z} = -0.0 \text{ mm}$ ,  $A = 28.5 \text{ cm}^2$

### 1.5. load application point (related to the center of the surrounding rectangle)

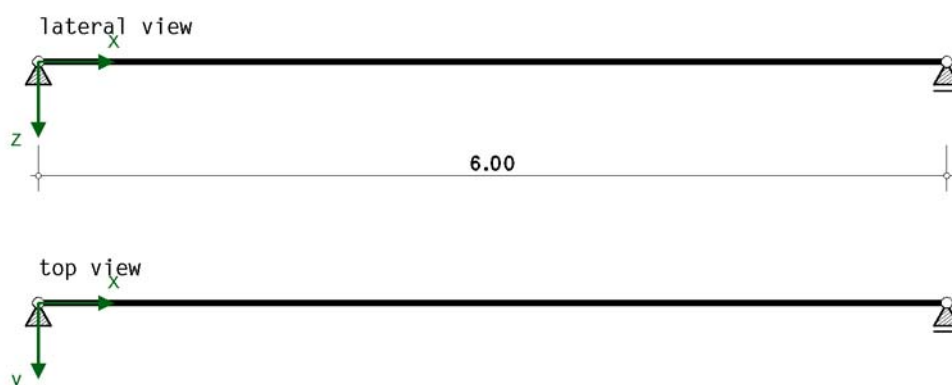
$y_{load} = 0.0 \text{ mm}$  (centroid)

$z_{load} = -100.0 \text{ mm}$  (upper edge of cross-section)

### 1.6. static system

all bearings with fork restraint, bar length 6.000 [m]

no intermediate bearing in z-direction, no intermediate bearing in y-direction



## 1.7. buckling coefficients

⊥ y-axis:  $\beta_y = 1.000$ , ⊥ z-axis:  $\beta_z = 1.000$

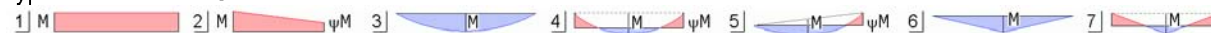
warping restraint intensity  $\beta_0 = 1.000$

## 1.8. design member forces (load combinations)

| Lk | type<br>- y - | $M_{0y,d}$<br>kNm | $\psi_y$<br>- | $k_{c,y}$<br>- | $\zeta_y$<br>- |
|----|---------------|-------------------|---------------|----------------|----------------|
| 1  | 3             | 18.90             | 1.000         | 0.940          | 1.128          |

type (y): type of moment curves each direction;  $M_{0y,d}, \psi_y$ : reference values of moment curve;  $k_{c,y}, \zeta_y$ : coefficients for calculation

types of moment curves



## 2. verifications

### 2.1. classification of cross-section

#### 2.1.1. load combination 1 ⇒ section class 1

| no | c<br>mm | t<br>mm | c/t<br>- | $\epsilon$<br>- | $\sigma_1$<br>N/mm <sup>2</sup> | $\sigma_2$<br>N/mm <sup>2</sup> | tab 5.2    | $\alpha$<br>- | $\psi$<br>- | $k_\sigma$<br>- | class<br>- |
|----|---------|---------|----------|-----------------|---------------------------------|---------------------------------|------------|---------------|-------------|-----------------|------------|
| 1  | 35.2    | 8.5     | 4.14     | 1.000           | 93.28                           | 93.28                           | single 1/1 | ---           | ---         | ---             | 1          |
| 2  | 35.2    | 8.5     | 4.14     | 1.000           | 93.28                           | 93.28                           | single 1/1 | ---           | ---         | ---             | 1          |
| 3  | 159.0   | 5.6     | 28.39    | 1.000           | 77.45                           | -77.45                          | both 1/1   | ---           | ---         | ---             | 1          |
| 4  | 35.2    | 8.5     | 4.14     | 1.000           | -93.28                          | -93.28                          | -----      | ---           | ---         | ---             | ---        |
| 5  | 35.2    | 8.5     | 4.14     | 1.000           | -93.28                          | -93.28                          | -----      | ---           | ---         | ---             | ---        |

compressive stresses have a positive sign acc. to EC 3.

verifications are carried out in the **specified** cross-section class 2:  $U_{c/t} = 0.414 < 1$  **ok**

### 2.2. lateral torsional buckling for bending around y-axis

$c^2 = 78305 \text{ mm}^2$ , buckling curve b ⇒  $\alpha_{LT} = 0.34$ ,  $N_{cr} = 81.75 \text{ kN}$

#### 2.2.1. utilisations

| Lk | $M_{cr}$<br>kNm | $\lambda_{LT}$<br>- | f<br>- | $\Phi_{LT}$<br>- | $\chi_{LT}$<br>m | $\chi_{LT,mod}$<br>m | $M_{Ed}$<br>kNm | $M_{b,Rd}$<br>kNm | U<br>- |
|----|-----------------|---------------------|--------|------------------|------------------|----------------------|-----------------|-------------------|--------|
| 1  | 21.60           | 1.550               | 1.000  | 1.597            | 0.406            | 0.406                | 18.90           | 19.18             | 0.985  |

max U = 0.985 < 1 **ok**

## 3. final result

maximum utilisation U = 0.985 < 1 **ok**

c/t-utilisation U = 0.414 < 1 **ok**

**verification succeeded**

## 4. Selected Design Parameters of the National Annex

DIN EN 1993-1-1 (EC 3, Hochbau), NA Deutschland

| chapter    | value                                                                                                                                                                                                 | definition                                                                                                                                                                                                                                                     |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6.1(1)     | permanent/transient situation<br>$\gamma_{M0} = 1.00$<br>$\gamma_{M1} = 1.10$<br>$\gamma_{M2} = 1.25$<br>accidental situation<br>$\gamma_{M0} = 1.00$<br>$\gamma_{M1} = 1.00$<br>$\gamma_{M2} = 1.25$ | partial safety factors for structural steel<br>collapse of cross-section<br>instability<br>fracture cross-sections in tension<br>partial safety factors for structural steel<br>collapse of cross-section<br>instability<br>fracture cross-sections in tension |
| 6.3.2.2(2) | factor f to modify<br>$\chi_{LT}$                                                                                                                                                                     | lateral torsional buckling<br>general case                                                                                                                                                                                                                     |
| 6.3.2.3(1) | $\lambda_{LT,0} = 0.40$<br>$\beta = 0.75$                                                                                                                                                             | slenderness eqn. (6.75)<br>correction factor eqn. (6.75)                                                                                                                                                                                                       |
| 6.3.2.3(2) | coefficient $k_c$ from tab. 6.6                                                                                                                                                                       | calculation of the reduction factor $\chi_{LT}$                                                                                                                                                                                                                |

DIN EN 1993-1-2 (EC 3, Brandfall), NA Deutschland

| chapter | value                                   | definition                                      |
|---------|-----------------------------------------|-------------------------------------------------|
| 2.3(1)  | event of fire<br>$\gamma_{M,f1} = 1.00$ | partial safety factor for<br>mechanical failure |