## Исходные данные

$F := 192\ kN$

$N_x := 19.2\ kN$

$T_{sk} := 38.4\ kN$

$M_y := 345.6\ kN \cdot m$

$Q_z := 115.2\ kN$

$Q_{z.sup} := 245.8\ kN$

$M_z := 0\ kN \cdot m$

$Q_y := 23\ kN$

$Q_{y.sup} := 49.2\ kN$

$l_b := 6000\ mm$

$h_w := 590\ mm$

$t_w := 16\ mm$

$b_{tf} := 320\ mm$

$t_{tf} := 20\ mm$

$b_{bf} := 200\ mm$

$t_{bf} := 20\ mm$

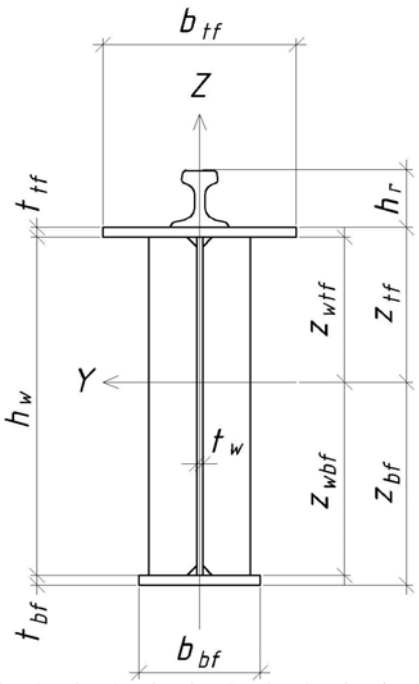
$MAT_b := \text{“С345”}$

$\gamma_n := 1.1$

$ST := \text{“ГИБКИЙ”}$

$OC := \text{“5К”}$

$RT := \text{“КР70”}$



## Характеристики материалов

$R_{y.w} = 320\ MPa$ $R_{s.w} = 185.6\ MPa$ $R_{u.w} = 460\ MPa$

$R_{y.tf} = 320\ MPa$ $R_{s.tf} = 185.6\ MPa$ $R_{u.tf} = 460\ MPa$

$R_{y.bf} = 320\ MPa$ $R_{s.bf} = 185.6\ MPa$ $R_{u.bf} = 460\ MPa$

$E = 206000\ MPa$

## Расчетные коэффициенты

$\gamma_{dyn} := 1.2$

$\gamma_{dyn.loc} = 1.2$

## Характеристики сечения балки и рельса

$h = 630\ mm$ $A_{tf} = 64\ cm^2$ $I_y = 121463.808\ cm^4$ $I_r = 1040.18\ cm^4$

$h_f = 610\ mm$ $A_{bf} = 40\ cm^2$ $I_z = 6814.805\ cm^4$ $J_r = 253\ cm^4$

$z_{bf} = 351.895\ mm$ $A_w = 94.4\ cm^2$ $I_{ytf} = 46024.664\ cm^4$ $b_r = 120\ mm$

$z_{tf} = 278.105\ mm$ $A = 19840\ mm^2$ $I_{ybf} = 46770.254\ cm^4$ $h_r = 120\ mm$

$z_{wtf} = 258.105\ mm$ $S_y = 2248.816\ cm^3$ $I_{ytf.s} = 21.333\ cm^4$

$z_{wbf} = 331.895\ mm$ $S_{tf} = 1715.871\ cm^3$ $I_{ztf} = 5461.333\ cm^4$

$z_{ctf} = 288.105\ mm$ $S_{bf} = 1367.581\ cm^3$ $I_{zbf} = 1333.333\ cm^4$

$z_{cbf} = 361.895\ mm$ $W_{ytf} = 4367.555\ cm^3$

$W_{ybf} = 3451.704\ cm^3$

$W_{ztf} = 341.333\ cm^3$

$J_t = 219.221\ cm^4$

$J_{tf} = 85.333\ cm^4$

*Разрезная сварная балка без тормозных конструкций при креплении рельса планками*

*Проверка прочности*

*Верхний пояс (8.2.1 [1])*

$$\sigma_{tf.My} := \frac{M_y \cdot \gamma_n \cdot \gamma_{dyn}}{W_{ytf}} = 104.45 \ MPa$$

$$\sigma_{tf.Mz} := \frac{M_z \cdot \gamma_n}{W_{ztf}} = 0 \ MPa$$

$$\sigma_{tf} := \sigma_{tf.My} + \sigma_{tf.Mz} = 104.45 \ MPa$$

$$U_{tf.str} := \frac{\sigma_{tf}}{R_{y.tf}} = 0.326$$

$\sigma_{tf} = 104.45 \ MPa$ $U_{tf.str} = 0.326$

*Нижний пояс (8.2.1 [1])*

$$\sigma_{bf} := \frac{M_y \cdot \gamma_n \cdot \gamma_{dyn}}{W_{ybf}} = 132.164 \ MPa$$

$$U_{bf.str} := \frac{\sigma_{bf}}{R_{y.bf}} = 0.413$$

$\sigma_{bf} = 132.164 \ MPa$ $U_{bf.str} = 0.413$

*Стенка (8.2.1; 8.2.2; 8.3.3 [1])*

$$\tau_{xz.w} := \begin{cases} \dfrac{Q_z \cdot S_{tf} \cdot \gamma_n \cdot \gamma_{dyn}}{I_y \cdot t_w} & \text{if } OC = \text{“1K”} \vee OC = \text{“2K”} \vee OC = \text{“3K”} \vee OC = \text{“4K”} \vee OC = \text{“5K”} \vee OC = \text{“6K”} \\ \dfrac{Q_z \cdot \gamma_n \cdot \gamma_{dyn}}{h_w \cdot t_w} & \text{else if } OC = \text{“7K”} \vee OC = \text{“8K”} \end{cases} = 13.426 \ MPa$$

$$\tau_{xz.w.max.sup} := \frac{Q_{z.sup} \cdot S_y \cdot \gamma_n \cdot \gamma_{dyn}}{I_y \cdot t_w} = 37.544 \ MPa$$

$$\sigma_{x.w} := \frac{M_y \cdot z_{wtf} \cdot \gamma_n \cdot \gamma_{dyn}}{I} = 96.939 \ MPa$$

$I_y$

$\psi := 3.25$

$I_{1f} := I_{ytf.s} + I_r = 1061.513\ cm^4$

$l_{ef.loc} := \psi \cdot \sqrt[3]{\frac{I_{1f}}{t_w}} = 283.456\ mm$

$\sigma_{z.w.loc} := \frac{F \cdot \gamma_n \cdot \gamma_{dyn.loc}}{l_{ef.loc} \cdot t_w} = 55.882\ MPa$

$\sigma_{x.w.loc} := \text{if } OC = \text{“1K”} \vee OC = \text{“2K”} \vee OC = \text{“3K”} \vee OC = \text{“4K”} \vee OC = \text{“5K”} \vee OC = \text{“6K”} \ = 0\ MPa$
$\quad \| \ 0\ MPa$
$\quad \text{else if } OC = \text{“7K”} \vee OC = \text{“8K”}$
$\quad \| \ 0.25 \cdot \sigma_{z.w.loc}$

$\tau_{xz.w.loc} := \text{if } OC = \text{“1K”} \vee OC = \text{“2K”} \vee OC = \text{“3K”} \vee OC = \text{“4K”} \vee OC = \text{“5K”} \vee OC = \text{“6K”} \ = 0\ MPa$
$\quad \| \ 0\ MPa$
$\quad \text{else if } OC = \text{“7K”} \vee OC = \text{“8K”}$
$\quad \| \ 0.3 \cdot \sigma_{z.w.loc}$

$e := 0.2 \cdot b_r = 24\ mm$

$M_t := F \cdot \gamma_n \cdot \gamma_{dyn.loc} \cdot e + 0.75 \cdot T_{sk} \cdot h_r \cdot \gamma_n = 9.884\ kN \cdot m$

$\sigma_{z.f} := \text{if } OC = \text{“1K”} \vee OC = \text{“2K”} \vee OC = \text{“3K”} \vee OC = \text{“4K”} \vee OC = \text{“5K”} \vee OC = \text{“6K”} \ = 0\ MPa$
$\quad \| \ 0\ MPa$
$\quad \text{else if } OC = \text{“7K”} \vee OC = \text{“8K”}$
$\quad \| \ \frac{2 \cdot M_t \cdot t_w}{J_{tf} + J_r}$

$\tau_{xz.f} := 0.25 \cdot \sigma_{z.f} = 0\ MPa$

$\sigma_{x.w.tot} := \sigma_{x.w} + \sigma_{x.w.loc} = 96.939\ MPa$

$\sigma_{z.w.tot} := \sigma_{z.w.loc} + \sigma_{z.f} = 55.882\ MPa$

$\tau_{xz.w.tot} := \tau_{xz.w} + \tau_{xz.w.loc} + \tau_{xz.f} = 13.426\ MPa$

$\sigma_{IV.w} := \text{if } OC = \text{“1K”} \vee OC = \text{“2K”} \vee OC = \text{“3K”} \vee OC = \text{“4K”} \vee OC = \text{“5K”} \vee OC = \text{“6K”} \ = 87.427\ MPa$
$\quad \| \ \sqrt{\sigma_{x.w}^2 - \sigma_{x.w} \cdot \sigma_{z.w.loc} + \sigma_{z.w.loc}^2 + 3 \cdot \tau_{xz.w}^2}$
$\quad \text{else if } OC = \text{“7K”} \vee OC = \text{“8K”}$
$\quad \| \ \sqrt{\left(\sigma_{x.w} + \sigma_{x.w.loc}\right)^2 - \left(\sigma_{x.w} + \sigma_{x.w.loc}\right) \cdot \sigma_{z.w.loc} + \sigma_{z.w.loc}^2 + 3 \cdot \left(\tau_{xz.w} + \tau_{xz.w.loc}\right)^2}$

$$U_{w.str.\tau} := \frac{\tau_{xz.w.tot}}{R_{s.w}} = 0.072$$

$$U_{w.str.\tau.max.sup} := \frac{\tau_{xz.w.max.sup}}{R_{s.w}} = 0.202$$

$$U_{w.str.\sigma.x} := \frac{\sigma_{x.w.tot}}{R_{y.w}} = 0.303$$

$$U_{w.str.\sigma.z} := \frac{\sigma_{z.w.tot}}{R_{y.w}} = 0.175$$

$$\beta_{str} := 0.87$$

$$U_{w.str.\sigma IV} := \frac{\beta_{str} \cdot \sigma_{IV.w}}{R_{y.w}} = 0.238$$

$\tau_{xz.w.tot} = 13.426\ MPa$ $U_{w.str.\tau} = 0.072$

$\tau_{xz.w.max.sup} = 37.544\ MPa$ $U_{w.str.\tau.max.sup} = 0.202$

$\sigma_{x.w.tot} = 96.939\ MPa$ $U_{w.str.\sigma.x} = 0.303$

$\sigma_{z.w.tot} = 55.882\ MPa$ $U_{w.str.\sigma.z} = 0.175$

$\sigma_{IV.w} = 87.427\ MPa$ $U_{w.str.\sigma IV} = 0.238$

*Проверка общей устойчивости (8.4.1 [1])*

*Двутавровое сечение с более развитым сжатым поясом*
*Нагрузка сосредоточенная в середине пролета и приложена к верхнему поясу*

$$l_{b.ef} := l_b = 6000\ mm$$

$$\lambda_{b.ef} := \frac{l_{b.ef}}{b_{tf}} \cdot \sqrt{\frac{R_{y.tf}}{E}} = 0.739$$

$$\alpha := 8 \cdot \left(\frac{l_{b.ef} \cdot t_{tf}}{h_f \cdot b_{tf}}\right)^2 \cdot \left(1 + \frac{0.5 \cdot h_f \cdot t_w^{\ 3}}{b_{tf} \cdot t_{tf}^{\ 3}}\right) = 4.499$$

$$\beta(n) := (2 \cdot n - 1) \cdot \left(0.47 - 0.035 \cdot \left(\frac{b_{tf}}{h_f}\right) \cdot \left(1 + \frac{b_{tf}}{h_f} - 0.072 \cdot \left(\frac{b_{tf}}{h_f}\right)^2\right)\right)$$

$$\eta(n) := (1-n)\cdot\left(9.87\cdot n + 0.385\cdot\frac{\cdot}{I_{zbf}}\cdot\left(\frac{\cdot}{h_f}\right)\right)$$

$$n := \frac{I_{ztf}}{I_{ztf}+I_{zbf}} = 0.804$$

$$\delta(n) := n + 0.734\cdot\beta(n)$$

$$\mu(n) := n + 1.145\cdot\beta(n)$$

$$B(n) := \delta(n) - 1$$

$$C(n) := \begin{array}{l}\text{if } n \le 0.9 \\ \quad 0.33\cdot\eta(n) \\ \text{else if } n = 1 \\ \quad 0.0826\cdot\alpha\end{array}$$

In Robot B=1

$$B(n) = 0.001$$

$$C(n) = 0.91$$

$$D := 3.265$$

$$N_1 := \begin{bmatrix} 0.9 \\ 1 \end{bmatrix}$$

$$\Psi_1 := \begin{bmatrix} \left(B(0.9) + \sqrt{B(0.9)^2 + C(0.9)}\right)\cdot D \\ \left(B(1) + \sqrt{B(1)^2 + C(1)}\right)\cdot D \end{bmatrix}$$

$$\psi_a := \begin{array}{l}\text{if } n \le 0.9 \vee n = 1 \\ \quad \left(B(n) + \sqrt{B(n)^2 + C(n)}\right)\cdot D \\ \text{else if } 0.9 < n < 1 \\ \quad \text{linterp}\left\langle N_1, \Psi_1, n\right\rangle\end{array} = 3.119$$

$$\varphi_1 := \psi_a\cdot\frac{I_z}{I_y}\cdot\frac{2\cdot h_f\cdot z_{ctf}}{l_{b.ef}^2}\cdot\frac{E}{R_{y.tf}} = 1.1$$

$$\varphi_2 := \psi_a\cdot\frac{I_z}{I_y}\cdot\frac{2\cdot h_f\cdot z_{cbf}}{l_{b.ef}^2}\cdot\frac{E}{R_{y.bf}} = 1.381$$

$$\varphi_b := \begin{array}{l}\text{if } \varphi_2 \le 0.85 \\ \quad \text{if } \varphi_1 \le 1 \\ \quad\quad \varphi_1 \\ \quad \text{else} \\ \quad\quad 1 \\ \text{else} \\ \quad \text{if } \varphi_1\cdot\left(0.21 + 0.68\cdot\left(\frac{n}{\varphi_1} + \frac{1-n}{\varphi_2}\right)\right) \le 1 \\ \quad\quad (\quad n \quad 1-n\ )\end{array} = 0.884$$

$$\begin{cases} \varphi_1 \cdot \left(0.21 + 0.68 \cdot \left(\frac{\eta}{\varphi_1} + \frac{1 - \eta}{\varphi_2}\right)\right) \\ \text{else} \\ 1 \end{cases}$$

$$\sigma_{ltb.My} := \frac{M_y \cdot \gamma_n \cdot \gamma_{dyn}}{W_{ytf} \cdot \varphi_b} = 118.192 \ MPa$$

$$\sigma_{ltb} := \sigma_{ltb.My} + \sigma_{tf.Mz} = 118.192 \ MPa$$

$$U_{ltb} := \frac{\sigma_{ltb}}{R_{y.tf}} = 0.369$$

$$\sigma_{ltb} = 118.192 \ MPa$$

$$U_{ltb} = 0.369$$