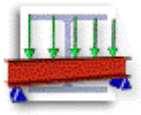


Zorlama: Eksenel kuvvet ve iki eksenli eğilme momenti.

Bilinen değerler:

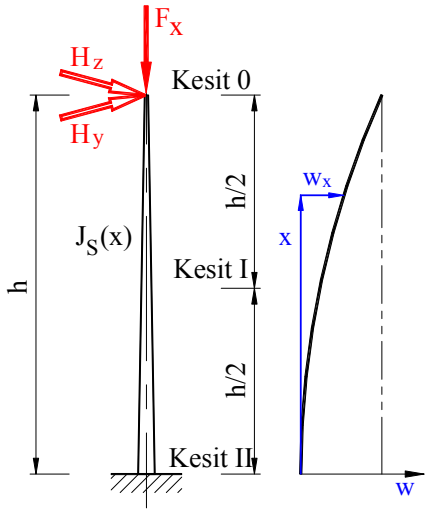
Malzeme := "S235" $f_y := 235\cdot MPa$ $E := 210000\cdot MPa$

$\gamma_M := 1.1$ $h_S := 4\cdot m$

Emniyetli akma mukavemeti $f_{EM} := \frac{f_y}{\gamma_M}$ $f_{EM} = 213.6\cdot MPa$

$F_x := 700\cdot kN$

Kabul: Eğrinin şekli parabol $H_y := 60\cdot kN$ $H_z := 40\cdot kN$



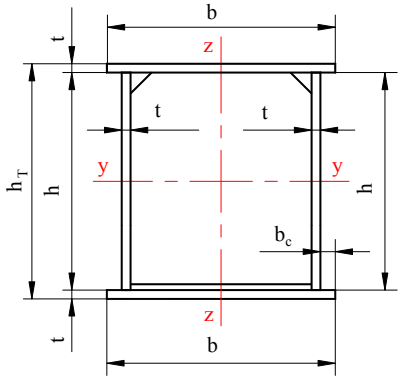
Resim 1

Kesit 0, üst 0 m:

$b_0 := 420\cdot mm$ $h_0 := 380\cdot mm$ $t := 10\cdot mm$ $b_ç := 10\cdot mm$

$h_{T0} := h_0 + 2\cdot t$ $h_{T0} = 400\cdot mm$ $z_0 := 0.5\cdot(h_0 + t)$ $z_0 = 195\cdot mm$

$$J_{y0} := 2\cdot\frac{b_0\cdot t^3}{12} + 2\cdot\frac{t\cdot h_0^3}{12} + 2\cdot t\cdot b_0\cdot z_0^2 \qquad J_{y0} = 410.9\cdot 10^6\cdot mm^4$$



Resim 2

$$W_{y0} := \frac{2\cdot J_{y0}}{h_{T0}} \qquad W_{y0} = 2054.7\cdot 10^3\cdot mm^3$$

$EJ_{y0} := E\cdot J_{y0}$ $EJ_{y0} = 86.3\cdot MN\cdot m^2$

$A_0 := 2\cdot t\cdot(b_0 + h_0)$ $A_0 = 16000\cdot mm^2$

$y_0 := 0.5\cdot(b_0 + t) - b_ç$ $y_0 = 205\cdot mm$

$$J_{z0} := 2\cdot\frac{b_0^3\cdot t}{12} + 2\cdot\frac{t^3\cdot h_0}{12} + 2\cdot t\cdot h_0\cdot y_0^2 \qquad J_{z0} = 442.9\cdot 10^6\cdot mm^4$$

$$W_{z0} := \frac{2\cdot J_{z0}}{b_0} \qquad W_{z0} = 2109.2\cdot 10^3\cdot mm^3$$

$EJ_{z0} := E\cdot J_{z0}$ $EJ_{z0} = 93\cdot MN\cdot m^2$

Kesit II, alt 4 m:

Faktörler

$x := 4\cdot m$

$k_{II} := 1.5$ $b_2 := k_{II}\cdot b_0$ $b_2 = 630\cdot mm$ $h_2 := k_{II}\cdot h_0$ $h_2 = 570\cdot mm$

$k_{IIb} := \frac{b_2}{b_0}$ $k_{IIb} = 1.500$ $k_b := \frac{k_{IIb} - 1}{h_S}$ $k_b = 0.125\,m^{-1}$ $k_{bx} = 1 + k_b\cdot x$

$k_{IIh} := \frac{h_2}{h_0}$ $k_{IIh} = 1.500$ $k_h := \frac{k_{IIh} - 1}{h_S}$ $k_h = 0.125\,m^{-1}$ $k_{hx} = 1 + k_h\cdot x$

$h_{Tx} := h_0\cdot(1 + k_h\cdot x) + 2\cdot t$ $h_{Tx} = 590\cdot mm$ $z_x := 0.5\cdot\left[h_0\cdot((1 + k_h\cdot x)) + t\right]$ $z_x = 290\cdot mm$

$$J_{y2} := 2\cdot\left[\frac{b_0\cdot(1 + k_b\cdot x)\cdot t^3}{12} + \frac{t\cdot\left[h_0\cdot(1 + k_h\cdot x)\right]^3}{12} + t\cdot b_0\cdot(1 + k_b\cdot x)\cdot z_x^2\right] \qquad J_{y2} = 1368.4\cdot 10^6\cdot mm^4$$

$$W_{y2} := \frac{2 \cdot J_{y2}}{h_{Tx}} \qquad W_{y2} = 4638.7 \cdot 10^3 \cdot mm^3$$

$$EJ_{y2} := E \cdot J_{y2} \qquad EJ_{y2} = 287.4 \cdot MN \cdot m^2$$

$$y_{II} := 0.5 \cdot (b_0 + t) - b_ç \qquad y_0 = 205 \cdot mm$$

$$J_{z2} := 2 \cdot \frac{b_2^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h_2}{12} + 2 \cdot t \cdot h_2 \cdot \left[0.5 \cdot (b_2 + t) - b_ç\right]^2 \qquad J_{z2} = 1512.4 \cdot 10^6 \cdot mm^4$$

$$W_{z2} := \frac{2 \cdot J_{z2}}{b_2} \qquad W_{z2} = 4801.2 \cdot 10^3 \cdot mm^3$$

$$A_2 := 2 \cdot t \cdot (b_2 + h_2) \qquad A_2 = 24000 \cdot mm^2$$

$$EJ_{z2} := E \cdot J_{z2} \qquad EJ_{z2} = 317.6 \cdot MN \cdot m^2$$

x e bağlı Eylemsizlik ve karşı koyma momentleri ile alan formülü:

$$J_{yx} = 2 \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot \left[h_0 \cdot (1 + k_h \cdot x)\right]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot \left[0.5 \cdot \left[h_0 \cdot \left((1 + k_h \cdot x)\right) + t\right]\right]^2 \right]$$

$$W_{yx} = \frac{2 \cdot J_{yx}}{h_0 \cdot (1 + k_h \cdot x) + 2 \cdot t}$$

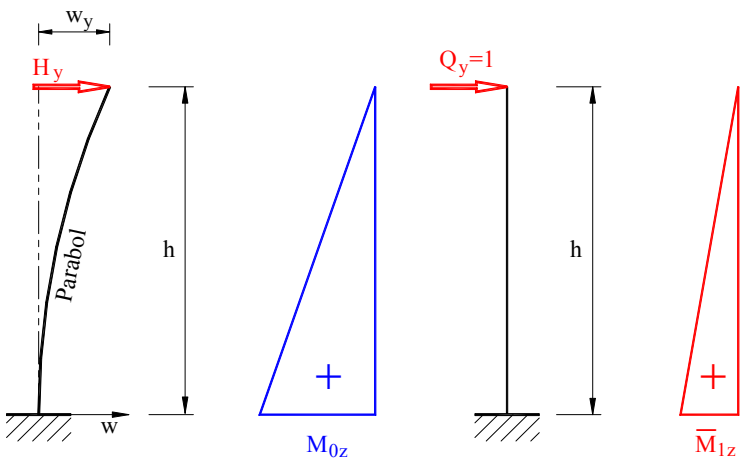
$$J_{zx} = 2 \cdot \left[\frac{b_0^3 \cdot (1 + k_b \cdot x)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x) - t\right] - b_ç\right]^2 \right]$$

$$W_{zx} = \frac{2 \cdot J_{zx}}{b_0 \cdot (1 + k_b \cdot x)}$$

$$A_x = 2 \cdot t \cdot \left[b_0 \cdot (1 + k_b \cdot x) + h_0 \cdot (1 + k_h \cdot x)\right]$$

Çözüm: 1. dereceli hesaplama kuralına göre

Resim 3



$$M_{0z} := H_y \cdot h_S$$

$$M_{0z} = 240 \cdot kN \cdot m$$

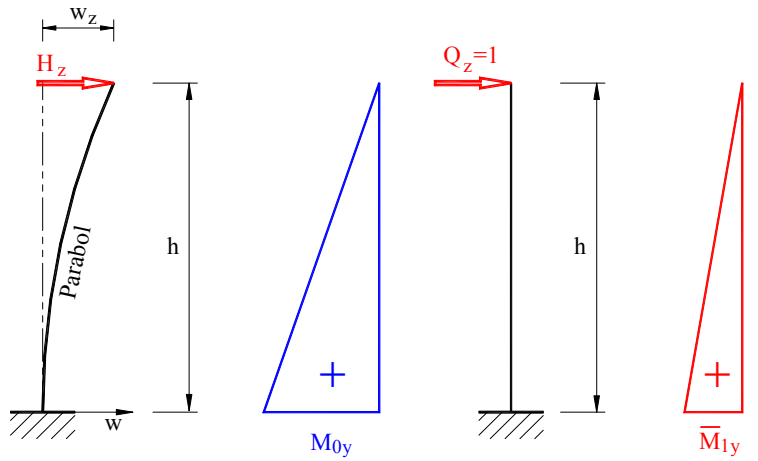
$$M_{1z} = h_S$$

$$w_{0y} = \int_0^{h_S} M_{0z} \cdot M_{1z} \cdot \frac{1}{E \cdot J_{zx}}\, dx$$

$$w_{0y} = \int_0^{h_S} \frac{H_y \cdot h_S^2}{E \cdot J_{zx}}\, dx$$

$$w_{0yx} := \int_0^{h_S} \frac{H_y \cdot h_S^{\,2}}{2 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot \left[h_0 \cdot (1 + k_h \cdot x) \right]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot \left[0.5 \cdot \left[h_0 \cdot \left((1 + k_h \cdot x) \right) + t \right] \right]^2 \right]} dx$$

$w_{0yx} = 24.876 \cdot mm$



$M_{0y} := H_z \cdot h_S$

$M_{0y} = 160 \cdot kN \cdot m$

$M_{1y} = h_S$

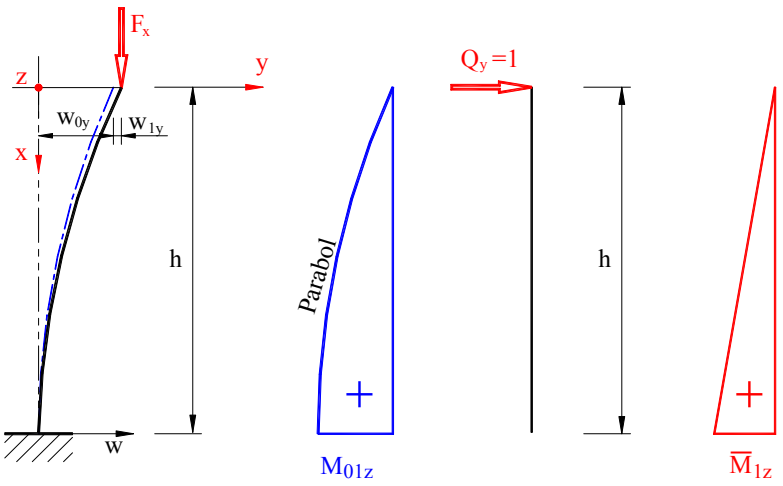
$$w_{0z} = \int_0^{h_S} M_{0y} \cdot M_{1y} \cdot \frac{1}{EJ_{yx}} dx$$

$$w_{0y} = \int_0^{h_S} \frac{H_z \cdot h_S^{\,2}}{E \cdot J_{yx}} dx$$

$$w_{0zx} := \int_0^{h_S} \frac{H_z \cdot h_S^{\,2}}{2 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot \left[h_0 \cdot (1 + k_h \cdot x) \right]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot \left[0.5 \cdot \left[h_0 \cdot \left((1 + k_h \cdot x) \right) + t \right] \right]^2 \right]} dx$$

$w_{0zx} = 16.584 \cdot mm$

Vianelloya göre



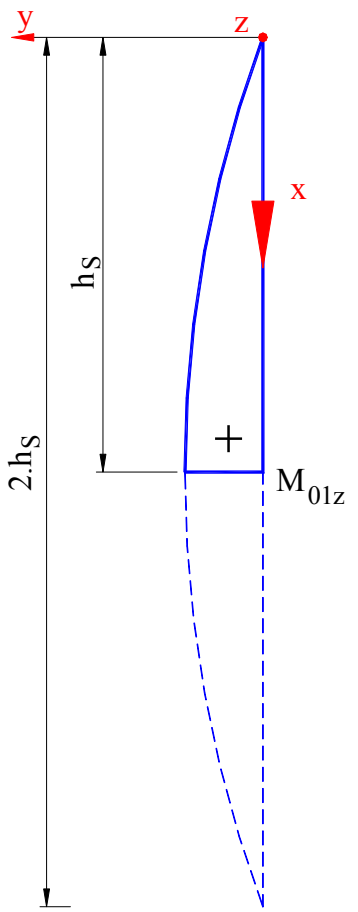
Resim 5

$M_{01zx} = f(x) \cdot F_x$

$M_{1z} = x$

EJ lineer değil

$$w_{1yx} = \int_0^{h_S} M_{01zx} \cdot M_{1zx} \cdot \frac{1}{E \cdot J_{zx}} dx$$



Resim 6

Genelde parabol denklemi

$$M_{01zx} = a\cdot x^2 + b\cdot x + c$$

$M_{01zx}(x=0) = 0$ $\quad c = 0$

$M_{01zx}(x=h_S) = F_x.\ w_{0max}$

$M_{01zx}(x=2.h_S) = 0$

Eğer $x=2.h_S$ yerleştirilirse:

$$0 = (2\cdot L_S)^2 a + 2\cdot L_S\cdot b$$

$0 = 2\cdot L_S\, a + b$ $\quad b = -2\cdot a\cdot L_S$

b yi yerleştirelim $\quad x = h_S^2$

$M_{01zx} = a\cdot x^2 + b\cdot x + c$ $\quad F_x\cdot w_0 = a\cdot h_S^2 + b\cdot h_S + 0$

$F_x\cdot w_0 = a\cdot h_S^2 - 2\cdot a\cdot h_S^2$

$F_x\cdot w_0 = -a\cdot h_S^2$ $\quad a = -\dfrac{F_x\cdot w_0}{h_S^2}$

$b = -2\cdot a\cdot h_S$ $\quad b = -\dfrac{2\cdot F_x\cdot w_0}{h_S}$

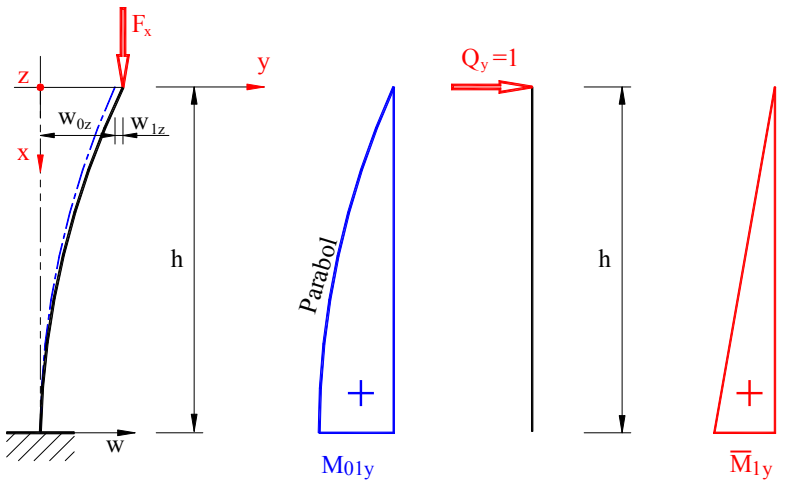
x e bağlı moment dağılımı $\quad M_{01zx} = -\dfrac{F_x\cdot w_{0y}}{h_S^2}\cdot x^2 - \dfrac{2\cdot F_x\cdot w_{0y}}{h_S}\cdot x$

$$M_{01zx} = F_x\cdot w_{0y}\cdot\left(\frac{x^2}{h_S^2} + \frac{2\cdot x}{h_S}\right)$$

$$w_{1yx} = \int_0^{h_S} \frac{F_x\cdot w_{0y}\cdot\left(\dfrac{x^2}{h_S^2} + \dfrac{2\cdot x}{h_S}\right)\cdot x}{2\cdot E\cdot\left[\dfrac{b_0^3\cdot(1+k_b\cdot x)^3\cdot t}{12} + \dfrac{t^3\cdot h_0\cdot(1+k_b\cdot x)}{12} + t\cdot h_0\cdot(1+k_h\cdot x)\cdot\left[0.5\cdot\left[b_0\cdot(1+k_b\cdot x) - t\right] - b_ç\right]^2\right]}\,dx$$

$$w_{1yx} := \int_0^{h_S} \frac{\dfrac{x^3}{h_S^2} + \dfrac{2\cdot x^2}{h_S}}{2\cdot E\cdot\left[\dfrac{b_0^3\cdot(1+k_b\cdot x)^3\cdot t}{12} + \dfrac{t^3\cdot h_0\cdot(1+k_b\cdot x)}{12} + t\cdot h_0\cdot(1+k_h\cdot x)\cdot\left[0.5\cdot\left[b_0\cdot(1+k_b\cdot x) - t\right] - b_ç\right]^2\right]}\,dx$$

$F_x\cdot w_{0y}$ = sabit $\quad$ İntegralin dışına alalım ve integralin değeri: $\quad w_{1yx} = 64.4\cdot\dfrac{10^{-9}}{N}$



Resim 7

$M_{01yx} = f(x) \cdot F_x$

$M_{1y} = x$

EJ lineer değil

$$w_{1zx} = \int_0^{h_S} M_{01yx} \cdot M_{1yx} \cdot \frac{1}{E \cdot J_{yx}}\, dx$$

$$M_{01yx} = F_x \cdot w_{0z} \cdot \left(\frac{x^2}{h_S^{\,2}} + \frac{2 \cdot x}{h_S} \right)$$

$$w_{1zx} = \int_0^{h_S} \frac{F_x \cdot w_{0z} \cdot \left(\frac{x^2}{h_S^{\,2}} + \frac{2 \cdot x}{h_S} \right) \cdot x}{2 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot [h_0 \cdot (1 + k_h \cdot x)]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot [0.5 \cdot [h_0 \cdot ((1 + k_h \cdot x)) + t]]^2 \right]}\, dx$$

$$w_{1zx} := \int_0^{h_S} \frac{\frac{x^3}{h_S^{\,2}} + \frac{2 \cdot x^2}{h_S}}{2 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot [h_0 \cdot (1 + k_h \cdot x)]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot [0.5 \cdot [h_0 \cdot ((1 + k_h \cdot x)) + t]]^2 \right]}\, dx$$

$F_x \cdot w_{0z}$ = sabit İntegralin dışına alalım ve integralin değeri:

$$w_{1zx} = 67.2 \cdot \frac{10^{-9}}{N}$$

Kritik burkulma kuvveti

$w_{yx} := w_{0yx} + w_{1yx} \cdot F_x \cdot w_{0yx}$ $w_{yx} = 26 \cdot mm$

$w_{zx} := w_{0zx} + w_{1zx} \cdot F_x \cdot w_{0zx}$ $w_{zx} = 17.4 \cdot mm$

Eğer $F_x = F_{kr}$; $w_{ymax} = w_{0yx}$ ve $w_{zmax} = w_{0zx}$ ise:

$w_{ymax} = F_x \cdot w_{0yx} \cdot w_{1yx}$ $1 = F_{kry} \cdot w_{yx}$ $F_{kry} := \frac{1}{w_{1yx}}$ $F_{kry} = 15531.5 \cdot kN$

$w_{zmax} = F_x \cdot w_{0zx} \cdot w_{1zx}$ $1 = F_{krz} \cdot w_{zx}$ $F_{krz} := \frac{1}{w_{1zx}}$ $F_{krz} = 14890 \cdot kN$

$F_{kr} := F_{kry}$ $F_{kr} = 15532 \cdot kN$ $F_x = 700 \cdot kN$

Sonuç: Çubukta burkulma tehlikesi yoktur.

Kesit II de mukavemet hesabı:

Eylemsizlik radyusu $i_{y2} := \sqrt{\frac{J_{y2}}{A_2}}$ $i_{y2} = 238.8 \cdot mm$

Euler burkulma boyu $L_{By2} := \sqrt{\frac{EJ_{z2} \cdot \pi^2}{F_{kry}}}$ $L_{By2} = 14.206\,m$

Akma narinliği $\lambda_E := \pi \cdot \sqrt{\frac{E}{f_y}}$ $\lambda_E = 93.9$

Narinlik $\lambda_{y2} := \frac{L_{By2}}{i_{y2}}$ $\lambda_{y2} = 59.5$

Bağıntılı narinlik $\lambda_{By2} := \frac{\lambda_{y2}}{\lambda_E}$ $\lambda_{By2} = 0.634$

Merkez noktası mesafesi $k_{ely2} := \frac{W_{y2}}{A_2}$ $k_{ely2} = 193.3 \cdot mm$

Akma kuvveti $F_{pl2} := A_2 \cdot f_{EM}$ $F_{pl2} = 5127.3 \cdot kN$

Burkulma parametresi $\alpha_B := 0.34$ Kaynaklı kutular her eksende.

Max burkulma sehimi $w_{ymax2} := k_{ely2} \cdot \alpha_B \cdot (\lambda_{By2} - 0.2)$ $w_{ymax2} = 28.5 \cdot mm$

Burkulma yardımcı faktörü $\varphi_{By2} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{By2} - 0.2) + \lambda_{By2}^2\right]$ $\varphi_{By2} = 0.77$

Azaltma faktörü $\chi_{By2} := \frac{1}{\varphi_{By2} + \sqrt{\varphi_{By2}^2 - \lambda_{By2}^2}}$ $\chi_{By2} = 0.820$

Kuvvetin mukavemet emniyeti $S_{Fy2} := \frac{F_x}{\chi_{By2} \cdot F_{pl2}}$ $S_{Fy2} = 0.167$

Eylemsizlik radyusu $i_{z2} := \sqrt{\frac{J_{z2}}{A_2}}$ $i_{z2} = 251 \cdot mm$

Euler burkulma boyu $L_{Bz2} := \sqrt{\frac{EJ_{z2} \cdot \pi^2}{F_{kr}}}$ $L_{Bz2} = 14.206\,m$

Narinlik $\lambda_{z2} := \frac{L_{Bz2}}{i_{z2}}$ $\lambda_{z2} = 56.6$

Bağıntılı narinlik $\lambda_{Bz2} := \frac{\lambda_{z2}}{\lambda_E}$ $\lambda_{Bz2} = 0.603$

Merkez noktası mesafesi $k_{elz2} := \frac{W_{z2}}{A_2}$ $k_{elz2} = 200.1 \cdot mm$

Max burkulma sehimi $w_{zmax2} := k_{elz2} \cdot \alpha_B \cdot (\lambda_{Bz2} - 0.2)$ $w_{zmax2} = 27.4 \cdot mm$

Burkulma yardımcı faktörü $\varphi_{Bz2} := 0.5\cdot\left[1 + \alpha_B\cdot\left(\lambda_{Bz2} - 0.2\right) + \lambda_{Bz2}^{2}\right]$ $\varphi_{Bz2} = 0.75$

Azaltma faktörü $\chi_{Bz2} := \dfrac{1}{\varphi_{Bz2} + \sqrt{\varphi_{Bz2}^{2} - \lambda_{Bz2}^{2}}}$ $\chi_{Bz2} = 0.836$

Kuvvetin mukavemet emniyeti $S_{Fz2} := \dfrac{F_x}{\chi_{Bz2}\cdot F_{pl2}}$ $S_{Fz2} = 0.163$

Moment kontrolü:

Kesit 2 de toplam Moment $M_{y2} := H_z\cdot h_S + F_x\cdot w_{zx}$ $M_{y2} = 172.15\cdot kN\cdot m$

$M_{z2} := H_y\cdot h_S + F_x\cdot w_{yx}$ $M_{z2} = 258.2\cdot kN\cdot m$

$M_{ply2} := W_{y2}\cdot f_{EM}$ $M_{ply2} = 991\cdot kN\cdot m$

$M_{plz2} := W_{z2}\cdot f_{EM}$ $M_{plz2} = 1025.7\cdot kN\cdot m$

$M_{yF2} := F_x\cdot w_{zx}$ $M_{yF2} = 12.2\cdot kN\cdot m$

$M_{zF2} := F_x\cdot w_{yx}$ $M_{zF2} = 18.2\cdot kN\cdot m$

$\Delta M < 1$ $\Delta M2y := \dfrac{M_{yF2}}{M_{y2}}$ $\Delta M2y = 0.071$

$\Delta M2z := \dfrac{M_{zF2}}{M_{z2}}$ $\Delta M2z = 0.070$

$\beta_{My2} := 1.8 - 0.7\cdot\Delta M2y$ $\beta_{My2} = 1.8$

$\alpha_{pl} > 1$ $\alpha_{ply2} := \dfrac{M_{ply2}}{M_{y2}}$ $\alpha_{ply2} = 5.756$

$a_y \le 0.8$ $a_{y2x} := \lambda_{By2}\cdot\left(2\cdot\beta_{My2} - 4\right) + \left(\alpha_{ply2} - 1\right)$ $a_{y2x} = 4.44$

$a_{y2} := \begin{cases} a_{y2x} & \text{if } a_{y2x} \le 0.8 \\ 0.8 & \text{otherwise} \end{cases}$ $a_{y2} = 0.8$

$k_y \le 1,5$ $k_{y2x} := 1 - \dfrac{F_x}{\chi_{By2}\cdot F_{pl2}}\cdot a_{y2}$ $k_{y2x} = 0.867$

$k_{y2} := \begin{cases} k_{y2x} & \text{if } k_{y2x} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases}$ $k_{y2} = 0.867$

$\beta_{Mz2} := 1.8 - 0.7\cdot\Delta M2z$ $\beta_{Mz2} = 1.8$

$\alpha_{pl} > 1$ $\alpha_{plz2} := \dfrac{M_{plz2}}{M_{z2}}$ $\alpha_{plz2} = 3.973$

$a_{z2} := \lambda_{Bz2}\cdot\left(2\cdot\beta_{Mz2} - 4\right) + \left(\alpha_{plz2} - 1\right)$ $a_{z2} = 2.672$

$k_{z2} := 1 - \dfrac{F_x}{\chi_{Bz2}\cdot F_{pl2}}\cdot a_{z2}$ $k_{z2} = 0.564$

$$S_{2y} := \frac{F_x}{\chi_{By2} \cdot F_{pl2}} + \frac{M_{y2}}{M_{ply2}} \cdot k_{y2} + \frac{M_{z2}}{M_{plz2}} \cdot k_{z2} \qquad S_{2y} = 0.459$$

$$S_{2z} := \frac{F_x}{\chi_{Bz2} \cdot F_{pl2}} + \frac{M_{y2}}{M_{ply2}} \cdot k_{y2} + \frac{M_{z2}}{M_{plz2}} \cdot k_{z2} \qquad S_{2y} = 0.459$$

Sonuç: S_{2y} ve S_{2z} değerleri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.

Kesit I de mukavemet hesabı:

$x1 := 2 \cdot m$

$$y_1 := 0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_ç \qquad y_1 = 247.5 \cdot mm$$

$$J_{z1} := \left[2 \cdot \frac{{b_0}^3 \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + 2 \cdot t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot {y_1}^2 \right] \qquad J_{z1} = 823.2 \cdot 10^6 \cdot mm^4$$

$$W_{z1} := \frac{2 \cdot J_{z1}}{b_0 \cdot (1 + k_b \cdot x1)} \qquad W_{z1} = 3135.9 \cdot 10^3 \cdot mm^3$$

$$z_1 := 0.5 \cdot \left[h_0 \cdot ((1 + k_h \cdot x)) + t \right] \qquad z_1 = 290 \cdot mm$$

$$J_{y1} := 2 \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot \left[h_0 \cdot (1 + k_h \cdot x) \right]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x) \cdot {z_1}^2 \right] \qquad J_{y1} = 1368.4 \cdot 10^6 \cdot mm^4$$

$$W_{y1} := \frac{2 \cdot J_{y1}}{h_0 \cdot (1 + k_h \cdot x1) + 2 \cdot t} \qquad W_{y1} = 5529 \cdot 10^3 \cdot mm^3$$

$$A_1 := 2 \cdot t \cdot \left[b_0 \cdot (1 + k_b \cdot x1) + h_0 \cdot (1 + k_h \cdot x1) \right] \qquad A_1 = 20000 \cdot mm^2$$

Eylemsizlık radyusu $\quad i_{y1} := \sqrt{\frac{J_{y1}}{A_1}} \qquad i_{y1} = 261.6 \cdot mm$

Euler burkulma boyu $\quad L_{By1} := \sqrt{\frac{E \cdot J_{y1} \cdot \pi^2}{F_{kry}}} \qquad L_{By1} = 13.513\,m$

Akma narinliği $\quad \lambda_E = 93.9$

Narinlik $\quad \lambda_{y1} := \frac{L_{By1}}{i_{y1}} \qquad \lambda_{y1} = 51.7$

Bağıntılı narinlik $\quad \lambda_{By1} := \frac{\lambda_{y1}}{\lambda_E} \qquad \lambda_{By1} = 0.550$

Merkez noktası mesafesi $\quad k_{ely1} := \frac{W_{y1}}{A_1} \qquad k_{ely1} = 276.4 \cdot mm$

Akma kuvveti $\quad F_{pl1} := A_1 \cdot f_{EM} \qquad F_{pl1} = 4272.7 \cdot kN$

Burkulma yardımcı faktörü $\varphi_{By1} := 0.5\cdot\left[1 + \alpha_B\cdot\left(\lambda_{By1} - 0.2\right) + \lambda_{By1}^{2}\right]$ $\varphi_{By1} = 0.71$

Azaltma faktörü $\chi_{By1} := \dfrac{1}{\varphi_{By1} + \sqrt{\varphi_{By1}^{2} - \lambda_{By1}^{2}}}$ $\chi_{By1} = 0.861$

Kuvvetin mukavemet emniyeti $S_{Fy1} := \dfrac{F_x}{\chi_{By1}\cdot F_{pl1}}$ $S_{Fy1} = 0.190$

Eylemsizlık radyusu $i_{z1} := \sqrt{\dfrac{J_{z1}}{A_1}}$ $i_{z1} = 202.9\cdot mm$

Euler burkulma boyu $L_{Bz1} := \sqrt{\dfrac{E\cdot J_{z1}\cdot\pi^{2}}{F_{kr}}}$ $L_{Bz1} = 10.481\,m$

Narinlik $\lambda_{z1} := \dfrac{L_{Bz1}}{i_{z1}}$ $\lambda_{z1} = 51.7$

Bağıntılı narinlik $\lambda_{Bz1} := \dfrac{\lambda_{z1}}{\lambda_E}$ $\lambda_{Bz1} = 0.550$

Merkez noktası mesafesi $k_{elz1} := \dfrac{W_{z1}}{A_1}$ $k_{elz1} = 156.8\cdot mm$

Burkulma yardımcı faktörü $\varphi_{Bz1} := 0.5\cdot\left[1 + \alpha_B\cdot\left(\lambda_{Bz1} - 0.2\right) + \lambda_{Bz1}^{2}\right]$ $\varphi_{Bz1} = 0.71$

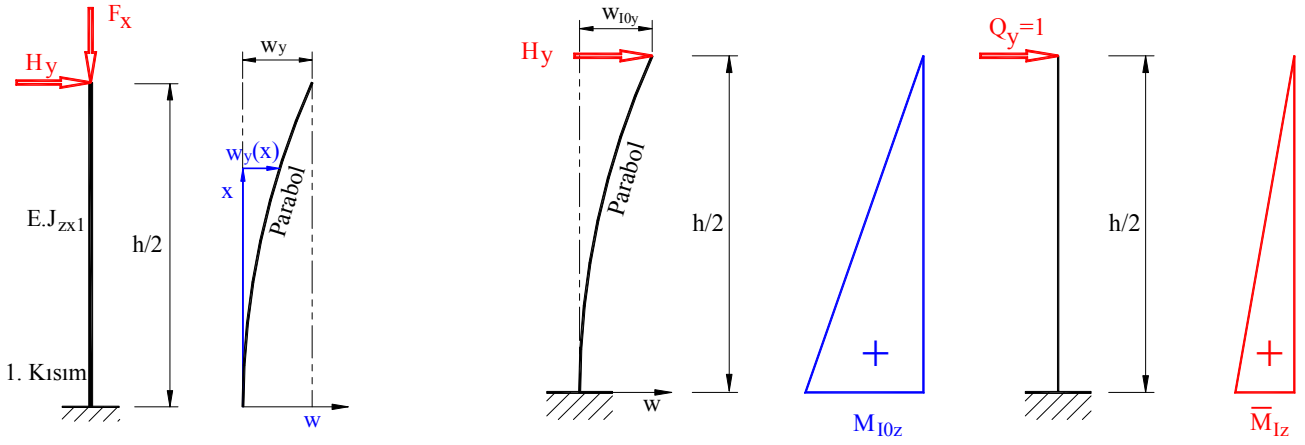
Azaltma faktörü $\chi_{Bz1} := \dfrac{1}{\varphi_{Bz1} + \sqrt{\varphi_{Bz1}^{2} - \lambda_{Bz1}^{2}}}$ $\chi_{Bz1} = 0.861$

Kuvvetin mukavemet emniyeti $S_{Fz1} := \dfrac{F_x}{\chi_{Bz1}\cdot F_{pl1}}$ $S_{Fz1} = 0.190$

1. Kesitte burkulma tehlikesi yoktur.

1. Kesitte moment kontrolü:

$M_{I0z} := 0.5H_y\cdot h_S$ $M_{I0z} = 120\cdot kN\cdot m$ $M_{Iz} = 0.5\cdot h_S$

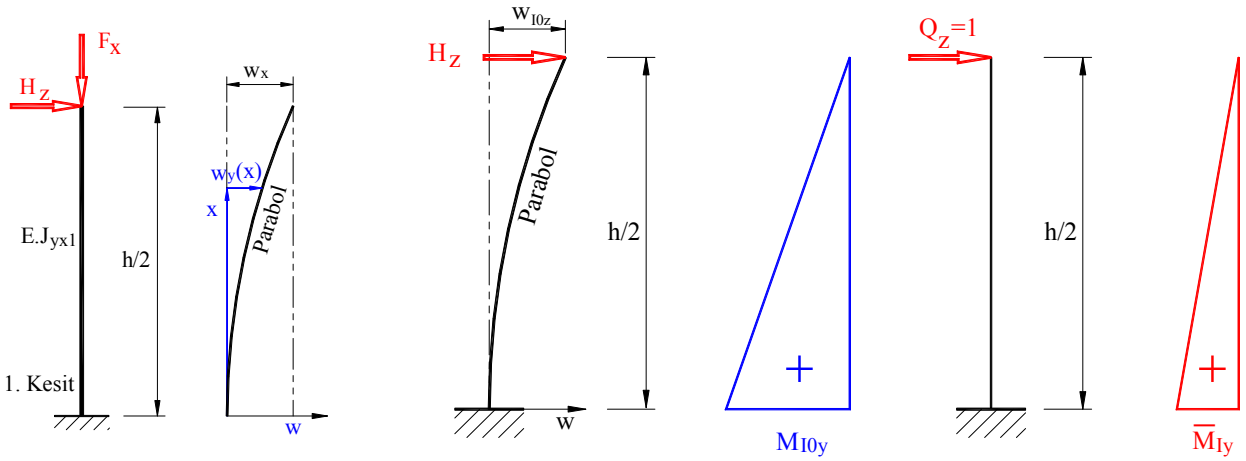


$$w_{10y} = \int_0^{\frac{h_S}{2}} M_{10z}\cdot M_{1z}\cdot\frac{1}{E\cdot J_{z1x}}\,dx \qquad w_{10y} = \int_0^{\frac{h_S}{2}} \frac{H_y\cdot h_S}{2}\cdot\frac{h_S}{2}\cdot\frac{1}{E\cdot J_{z1x}}\,dx \qquad w_{10y} = \int_0^{\frac{h_S}{2}} \frac{H_y\cdot h_S^{\,2}}{4\cdot E\cdot J_{z1x}}\,dx$$

$$w_{10yx} := \int_0^{\frac{h_S}{2}} \frac{H_y\cdot h_S^{\,2}}{8\cdot E\cdot\left[\frac{b_0^{\,3}\cdot(1+k_b\cdot x1)^3\cdot t}{12}+\frac{t^3\cdot h_0\cdot(1+k_b\cdot x1)}{12}+t\cdot h_0\cdot(1+k_h\cdot x1)\cdot\left[0.5\cdot\left[b_0\cdot(1+k_b\cdot x1)-t\right]-b_ç\right]^2\right]}\,dx1$$

$w_{10yx} = 3.948\cdot mm$

$M_{I0y} := 0.5H_z\cdot h_S \qquad M_{I0y} = 80\cdot kN\cdot m \qquad M_{Iy} = 0.5\cdot h_S$

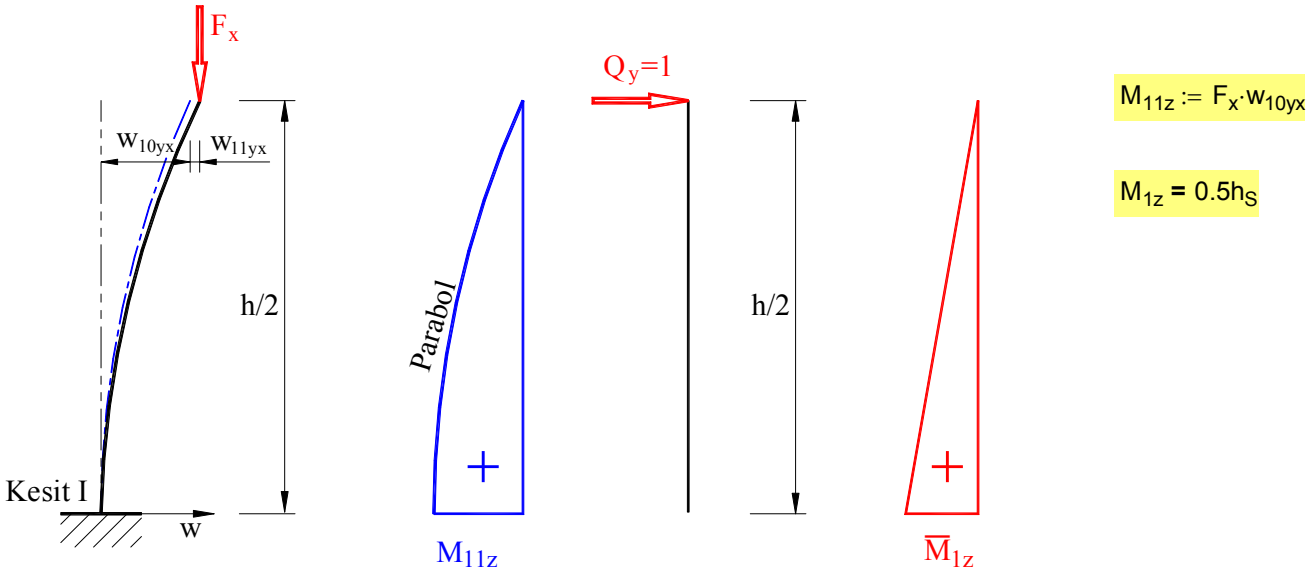


$$w_{10z} = \int_0^{\frac{h_S}{2}} M_{10y}\cdot M_{1z}\cdot\frac{1}{E\cdot J_{y1x}}\,dx \qquad w_{10z} = \int_0^{\frac{h_S}{2}} \frac{H_z\cdot h_S}{2}\cdot\frac{h_S}{2}\cdot\frac{1}{E\cdot J_{y1x}}\,dx \qquad w_{10z} = \int_0^{\frac{h_S}{2}} \frac{H_z\cdot h_S^{\,2}}{4\cdot E\cdot J_{y1x}}\,dx$$

$$w_{10zx} := \int_0^{\frac{h_S}{2}} \frac{H_z\cdot h_S^{\,2}}{8\cdot E\cdot\left[\frac{b_0\cdot(1+k_b\cdot x1)\cdot t^3}{12}+\frac{t\cdot\left[h_0\cdot(1+k_h\cdot x1)\right]^3}{12}+t\cdot b_0\cdot(1+k_b\cdot x1)\cdot\left[0.5\cdot\left[h_0\cdot\left((1+k_h\cdot x1)\right)+t\right]\right]^2\right]}\,dx1$$

$w_{10zx} = 2.680\cdot mm$

Vianelloya göre



$M_{11z} := F_x \cdot w_{10yx}$

$M_{1z} = 0.5 h_S$

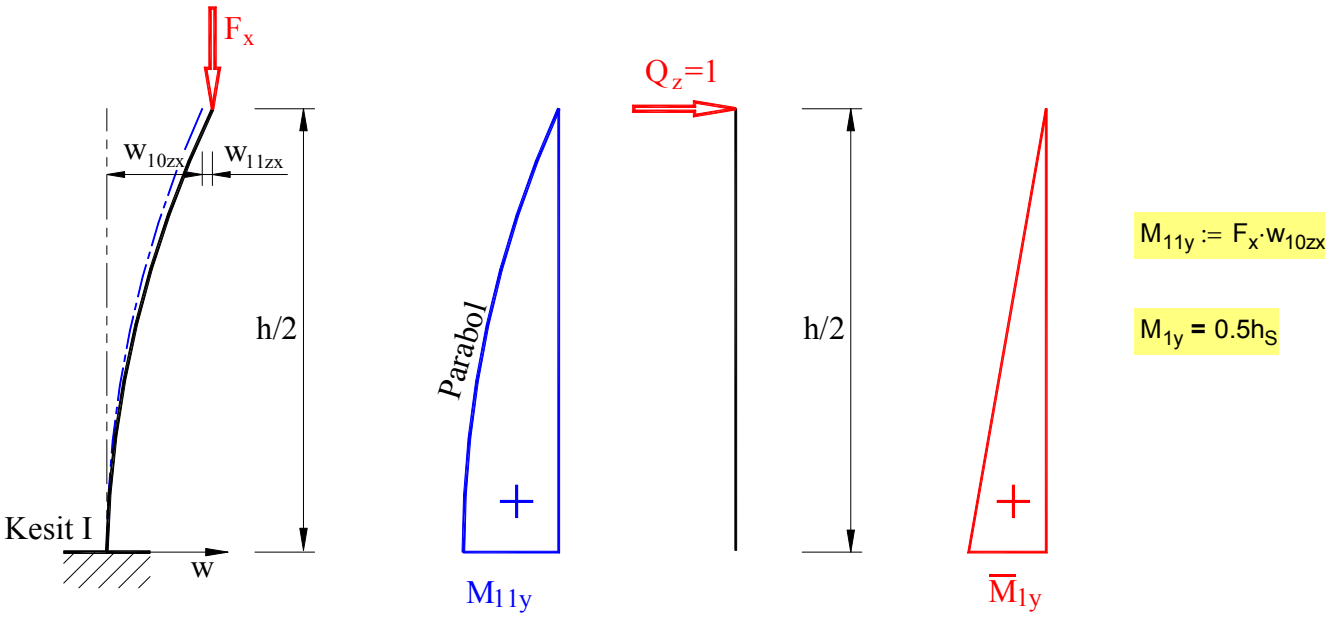
$$w_{11yx} = \int_0^{\frac{h_S}{2}} M_{11z} \cdot M_{1z} \cdot \frac{1}{EJ_{z1x}}\, dx \qquad w_{11yx} = \int_0^{\frac{h_S}{2}} F_x \cdot w_{10yx} \cdot \frac{h_S}{2} \cdot \frac{1}{EJ_{z1x}}\, dx \qquad w_{11yx} = \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{10yx} \cdot h_S}{2 \cdot EJ_{z1x}}\, dx$$

$$w_{11yx} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{10yx} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_{ç} \right]^2 \right]}\, dx1$$

$w_{11yx} = 0.091 \cdot mm$

$$w_{12yx} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{11yx} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_{ç} \right]^2 \right]}\, dx1$$

$w_{12yx} = 0.002 \cdot mm$



$M_{11y} := F_x \cdot w_{10zx}$

$M_{1y} = 0.5 h_S$

$$w_{11zx} = \int_0^{\frac{h_S}{2}} M_{11y} \cdot M_{1z} \cdot \frac{1}{EJ_{y1x}}\, dx \qquad w_{11zx} = \int_0^{\frac{h_S}{2}} F_x \cdot w_{10zx} \cdot \frac{h_S}{2} \cdot \frac{1}{EJ_{y1x}}\, dx \qquad w_{11yx} = \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{10zx} \cdot h_S}{2 \cdot EJ_{y1x}}\, dx$$

$$w_{11zx} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{10zx} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot [h_0 \cdot (1 + k_h \cdot x1)]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_0 \cdot ((1 + k_h \cdot x1)) + t \right] \right]^2 \right]}\, dx1$$

$w_{11zx} = 0.063 \cdot mm$

$$w_{12zx} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{11zx} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0 \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot [h_0 \cdot (1 + k_h \cdot x1)]^3}{12} + t \cdot b_0 \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_0 \cdot ((1 + k_h \cdot x1)) + t \right] \right]^2 \right]}\, dx1$$

$w_{12zx} = 0.001 \cdot mm$

Toplam sehim

$w_{1y} := w_{10yx} + w_{11yx} + w_{12yx}$ $\quad w_{1y} = 4.041 \cdot mm$

$w_{1z} := w_{10zx} + w_{11zx} + w_{12zx}$ $\quad w_{1z} = 2.745 \cdot mm$

Kritik burkulma kuvveti

eğer $F_x = F_{kr}$ ve $w_{10zx} = w_{11zx}$ veya $\alpha_F = \frac{w_{11zx}}{w_{10zx}} = 1$ kabul edersek:

$$1 = F_{kr1z}\cdot\int_0^{\frac{h_S}{2}} \frac{h_S}{4\cdot E\cdot\left[\frac{b_0\cdot(1+k_b\cdot x1)\cdot t^3}{12}+\frac{t\cdot[h_0\cdot(1+k_h\cdot x1)]^3}{12}+t\cdot b_0\cdot(1+k_b\cdot x1)\cdot[0.5\cdot[h_0\cdot((1+k_h\cdot x1))+t]]^2\right]}\,dx1$$

$$F_{kr1z} := \frac{1}{\int_0^{\frac{h_S}{2}} \frac{h_S}{4\cdot E\cdot\left[\frac{b_0\cdot(1+k_b\cdot x1)\cdot t^3}{12}+\frac{t\cdot[h_0\cdot(1+k_h\cdot x1)]^3}{12}+t\cdot b_0\cdot(1+k_b\cdot x1)\cdot[0.5\cdot[h_0\cdot((1+k_h\cdot x1))+t]]^2\right]}\,dx1}$$

$$F_{kr1z} = 29848\cdot kN$$

$$1 = F_{kr1y}\cdot\int_0^{\frac{h_S}{2}} \frac{h_S}{4\cdot E\cdot\left[\frac{b_0^{\,3}\cdot(1+k_b\cdot x1)^3\cdot t}{12}+\frac{t^3\cdot h_0\cdot(1+k_b\cdot x1)}{12}+t\cdot h_0\cdot(1+k_h\cdot x1)\cdot[0.5\cdot[b_0\cdot(1+k_b\cdot x1)-t]-b_ç]^2\right]}\,dx1$$

$$F_{kr1y} := \frac{1}{\int_0^{\frac{h_S}{2}} \frac{h_S}{4\cdot E\cdot\left[\frac{b_0^{\,3}\cdot(1+k_b\cdot x1)^3\cdot t}{12}+\frac{t^3\cdot h_0\cdot(1+k_b\cdot x1)}{12}+t\cdot h_0\cdot(1+k_h\cdot x1)\cdot[0.5\cdot[b_0\cdot(1+k_b\cdot x1)-t]-b_ç]^2\right]}\,dx1}$$

$$F_{kr1y} = 30392.3\cdot kN$$

$F_{kr1} := F_{kr1z}$ $F_{kr1} = 29848\cdot kN$ $F_x = 700\cdot kN$

Sonuç: Çubuğun 1. kesiti için burkulma tehlikesi yoktur.

1. Kesitte mukavemet hesabı

Moment:

$M_{ply1} := W_{y1}\cdot f_{EM}$ $M_{ply1} = 1181.2\cdot kN\cdot m$

$M_{plz1} := W_{z1}\cdot f_{EM}$ $M_{plz1} = 670\cdot kN\cdot m$

$M_{y1} := H_z\cdot h_S + F_x\cdot w_{1z}$ $M_{y1} = 161.9\cdot kN\cdot m$

$M_{z1} := H_y\cdot h_S + F_x\cdot w_{1y}$ $M_{z1} = 242.8\cdot kN\cdot m$

$M_{y1F} := F_x\cdot w_{1z}$ $M_{y1F} = 1.9\cdot kN\cdot m$

$M_{z1F} := F_x\cdot w_{1y}$ $M_{z1F} = 2.8\cdot kN\cdot m$

$\Delta M < 1$

$$\Delta My1 := \frac{M_{y1}}{M_{ply1}} \qquad \Delta My1 = 0.137$$

$$\Delta Mz1 := \frac{M_{z1}}{M_{plz1}} \qquad \Delta Mz1 = 0.362$$

$$\beta_{My1} := 1.8 - 0.7 \cdot \Delta My1 \qquad \beta_{My1} = 1.7$$

$\alpha_{pl} > 1$

$$\alpha_{ply1} := \frac{M_{ply1}}{M_{y1}} \qquad \alpha_{ply1} = 7.295$$

$$a_{y1x} := \lambda_{By1} \cdot \left(2 \cdot \beta_{My1} - 4\right) + \left(\alpha_{ply1} - 1\right) \qquad a_{y1x} = 5.969$$

$a_y \le 0.8$

$$a_{y1} := \begin{cases} a_{y1x} & \text{if } a_{y1x} \le 0.8 \\ 0.8 & \text{otherwise} \end{cases} \qquad a_{y1} = 0.8$$

$$k_{y1x} := 1 - \frac{F_x}{\chi_{By1} \cdot F_{pl1}} \cdot a_{y1} \qquad k_{y1x} = 0.848$$

$k_y \le 1,5$

$$k_{y1} := \begin{cases} k_{y1x} & \text{if } k_{y1x} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases} \qquad k_{y1} = 0.848$$

$$\beta_{Mz1} := 1.8 - 0.7 \cdot \Delta Mz1 \qquad \beta_{Mz1} = 1.5$$

$\alpha_{pl} > 1$

$$\alpha_{plz1} := \frac{M_{plz1}}{M_{z1}} \qquad \alpha_{plz1} = 2.759$$

$$a_{z1x} := \lambda_{Bz1} \cdot \left(2 \cdot \beta_{Mz1} - 4\right) + \left(\alpha_{plz1} - 1\right) \qquad a_{z1x} = 1.26$$

$a_z \le 0.8$

$$a_{z1} := \begin{cases} a_{z1x} & \text{if } a_{z1x} \le 0.8 \\ 0.8 & \text{otherwise} \end{cases} \qquad a_{z1} = 0.8$$

$$k_{z1x} := 1 - \frac{F_x}{\chi_{Bz1} \cdot F_{pl1}} \cdot a_{z1} \qquad k_{z1x} = 0.848$$

$k_z \le 1,5$

$$k_{z1} := \begin{cases} k_{z1x} & \text{if } k_{z1x} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases} \qquad k_{z1} = 0.848$$

$$S_{y1} := \frac{F_x}{\chi_{By1} \cdot F_{pl1}} + \frac{M_{y1}}{M_{ply1}} \cdot k_{y1} + \frac{M_{z1}}{M_{plz1}} \cdot k_{z1} \qquad S_{y1} = 0.614$$

$$S_{z1} := \frac{F_x}{\chi_{Bz1} \cdot F_{pl1}} + \frac{M_{y1}}{M_{ply1}} \cdot k_{y1} + \frac{M_{z1}}{M_{plz1}} \cdot k_{z1} \qquad S_{z1} = 0.614$$

Sonuç: S_{Iy} ve S_{Iz} değerleri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.

SON