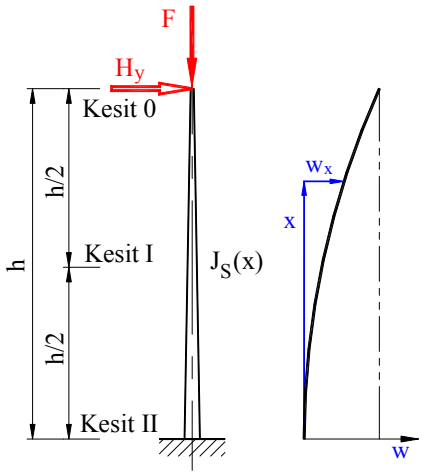
Zorlama: Eksenel kuvvet ve yatay tek kuvvet

Bilinen değerler:



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

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

$F_x := 700\cdot kN$

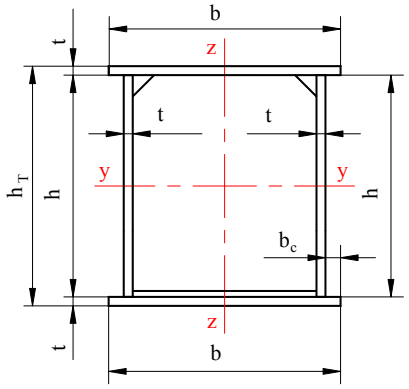
Emniyetli akma mukavemeti $f_{EM} := \frac{f_y}{\gamma_M}$ $f_{EM} = 213.6\cdot MPa$

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

Yatay yük y yönünde olduğundan hesaplar z eksenine göre yapılır.

Kesit 0, üst 0 m:

$b_0 := 320\cdot mm$ $h_0 := 320\cdot mm$ $t := 10\cdot mm$ $b_ç := 10\cdot mm$



$y_0 := 0.5\cdot(b_0 + t) - b_ç$ $y_0 = 155\cdot mm$

$J_{z0} := 2\cdot\frac{b_0^3\cdot t}{12} + 2\cdot\frac{t^3\cdot h_0}{12} + 2\cdot t\cdot h_0\cdot y_0^2$ $J_{z0} = 208.4\cdot 10^6\cdot mm^4$

$W_{z0} := \frac{2\cdot J_{z0}}{b_0}$ $W_{z0} = 1302.7\cdot 10^3\cdot mm^3$

$A_0 := 2\cdot t\cdot(b_0 + h_0)$ $A_0 = 12800\cdot mm^2$

$EJ_{z0} := E\cdot J_{z0}$ $EJ_{z0} = 43.8\cdot MN\cdot m^2$

Kesit II

$k_{II} := 1.5$ $b_{II} := k_{II}\cdot b_0$ $b_{II} = 480\cdot mm$ $h_{II} := k_{II}\cdot h_0$ $h_{II} = 480\cdot mm$

Faktörler

$k_{IIb} := \frac{b_{II}}{b_0}$ $k_{IIb} = 1.50000$ $k_b := \frac{k_{IIb} - 1}{h_S}$ $k_b = 0.125\,m^{-1}$ $k_{bx} = 1 + k_b\cdot x$

$k_{IIh} := \frac{h_{II}}{h_0}$ $k_{IIh} = 1.50000$ $k_h := \frac{k_{IIh} - 1}{h_S}$ $k_h = 0.125\,m^{-1}$ $k_{hx} = 1 + k_h\cdot x$

$y_{II} := 0.5\cdot(b_0 + t) - b_ç$ $y_0 = 155\cdot mm$

$J_{zII} := 2\cdot\frac{b_{II}^3\cdot t}{12} + 2\cdot\frac{t^3\cdot h_{II}}{12} + 2\cdot t\cdot h_{II}\cdot\left[0.5\cdot(b_{II} + t) - b_ç\right]^2$ $J_{zII} = 714.6\cdot 10^6\cdot mm^4$

$W_{zII} := \frac{2\cdot J_{zII}}{b_{II}}$ $W_{zII} = 2977.3\cdot 10^3\cdot mm^3$

$A_{II} := 2\cdot t\cdot(b_{II} + h_{II})$ $A_{II} = 19200\cdot mm^2$

$EJ_{zII} := E\cdot J_{zII}$ $EJ_{zII} = 150.1\cdot MN\cdot m^2$

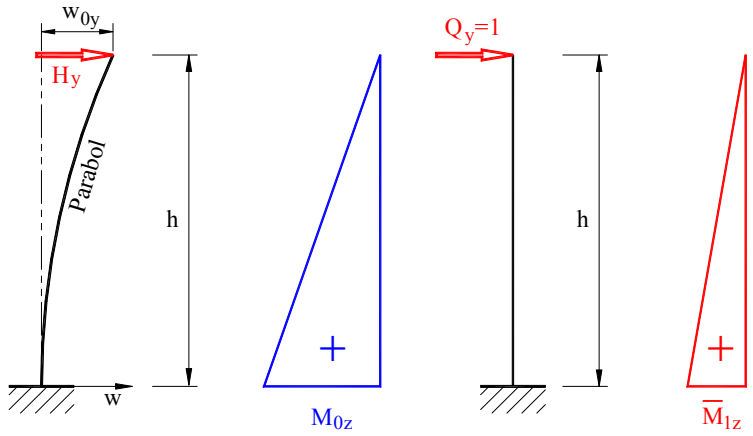
x e bağlı Eylemsizlik ve karşı koyma momentleri ile alan formülleri

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

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

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

Çözüm: 1. dereceli hesaplama kuralına göre



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

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

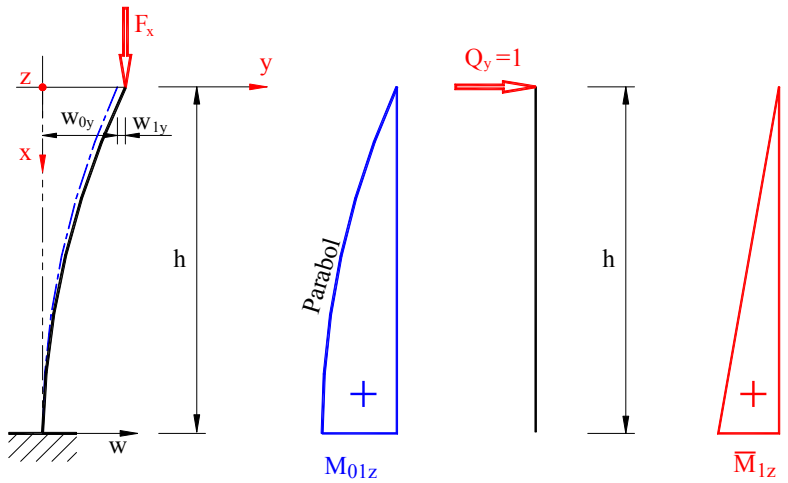
$M_{1z} = h_S$

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

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

$w_{0y} = 52.486\cdot mm$

Vianelloya göre



Resim 5

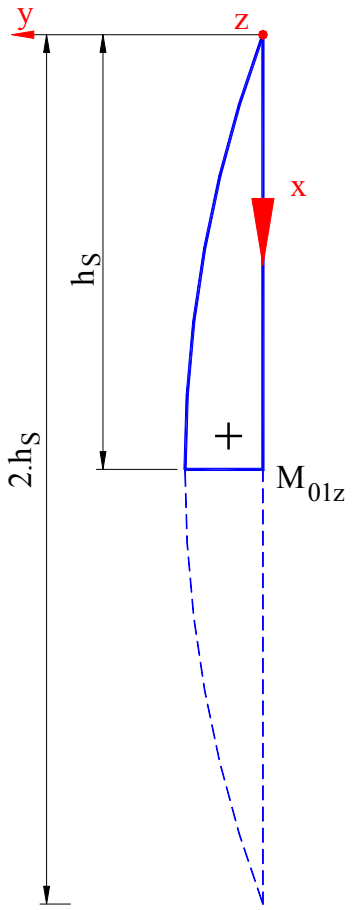
$M_{01zx} = f(x)\cdot F_x$

$M_{1z} = x$

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

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

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

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

$F_x\cdot w_{0yx}$ = sabit $\quad$ İntegralin dışına alalım ve integralin değeri: $\quad w_{1yx} = 139\cdot\dfrac{10^{-9}}{N}$

Kritik burkulma kuvveti

$w_{y0x} := w_{0y} + F_x \cdot w_{0y} \cdot w_{1yx}$ $w_{y0x} = 57.6 \cdot mm$

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

$w_{ymax} = F_x \cdot w_{0yx} \cdot w_{1yx}$ $1 = F_{kry} \cdot w_{yx}$ $F_{kr} := \frac{1}{w_{1yx}}$ $F_{kr} = 7196 \cdot kN$ $F_x = 700 \cdot kN$

Sonuç: Çubukta burkulma tehlikesi yoktur.

Kesit II de mukavemet hesabı:

Eylemsizlık radyusu $i_{zII} := \sqrt{\frac{J_{zII}}{A_{II}}}$ $i_{zII} = 192.9 \cdot mm$

Euler burkulma boyu $L_{BII} := \sqrt{\frac{E J_{zII} \cdot \pi^2}{F_{kr}}}$ $L_{BII} = 14.346\,m$

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

Narinlik $\lambda_{zII} := \frac{L_{BII}}{i_{zII}}$ $\lambda_{zII} = 74.4$

Bağıntılı narinlik $\lambda_{BzII} := \frac{\lambda_{zII}}{\lambda_E}$ $\lambda_{BzII} = 0.792$

Merkez noktası mesafesi $k_{elII} := \frac{W_{zII}}{A_{II}}$ $k_{elII} = 155.1 \cdot mm$

Akma kuvveti $F_{plII} := A_{II} \cdot f_{EM}$ $F_{plII} = 4101.8 \cdot kN$

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

Max burkulma sehimi $w_{max} := k_{elII} \cdot \alpha_B \cdot (\lambda_{BzII} - 0.2)$ $w_{max} = 31.2 \cdot mm$

Burkulma yardımcı faktörü $\varphi_{BzII} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{BzII} - 0.2) + \lambda_{BzII}^2\right]$ $\varphi_{BzII} = 0.91$

Azaltma faktörü $\chi_{BzII} := \frac{1}{\varphi_{BzII} + \sqrt{\varphi_{BzII}^2 - \lambda_{BzII}^2}}$ $\chi_{BzII} = 0.729$

Kuvvetin mukavemet emniyeti $S_{FzII} := \frac{F_x}{\chi_{BzII} \cdot F_{plII}}$ $S_{FzII} = 0.234$

Moment kontrolü:

Kesit II de toplam Moment $M_{II} := H_y \cdot h_S + F_x \cdot w_{max}$ $M_{II} = 261.84 \cdot kN \cdot m$

$M_{plzII} := W_{zII} \cdot f_{EM}$ $M_{plzII} = 636.1 \cdot kN \cdot m$

$M_{b0} := F_x \cdot w_{max}$ $M_{b0} = 21.8 \cdot kN \cdot m$

$\Delta M < 1$

$\Delta MII := \frac{M_{b0}}{M_{II}}$ $\Delta MII = 0.083$

$\beta_{mzII} := 0.66 + 0.44 \cdot \Delta MII$ $\beta_{mzII} = 0.70$

$S_{MII} := \frac{\beta_{mzII} \cdot M_{II}}{M_{plzII}}$ $S_{MII} = 0.287$

$\Delta n := 0.1$

$S_{II} := S_{FzII} + S_{MII} + \Delta n$ $S_{II} = 0.621$

Sonuç: S_{II} değeri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.

Kesit I de mukavemet hesabı:

$x1 := 2 \cdot m$

$$J_{z1x} := 2 \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_ç \right]^2 \right]$$

$J_{z1x} = 380.5 \cdot 10^6 \cdot mm^4$

$W_{z1x} := \frac{2 \cdot J_{z1x}}{b_0 \cdot (1 + k_b \cdot x1)}$ $W_{z1x} = 1902.7 \cdot 10^3 \cdot mm^3$

$A_I := 2 \cdot t \cdot \left[b_0 \cdot (1 + k_b \cdot x1) + h_0 \cdot (1 + k_h \cdot x1) \right]$ $A_I = 16000 \cdot mm^2$

Eylemsizlık radyusu $i_{zI} := \sqrt{\frac{J_{z1x}}{A_I}}$ $i_{zI} = 154.2 \cdot mm$

Euler burkulma boyu $L_{BI} := \sqrt{\frac{E \cdot J_{z1x} \cdot \pi^2}{F_{kr}}}$ $L_{BI} = 10.469\,m$

Akma narinliği $\lambda_E = 93.9$

Narinlik $\lambda_{zI} := \frac{L_{BI}}{i_{zI}}$ $\lambda_{zI} = 67.9$

Bağıntılı narinlik $\lambda_{BzI} := \frac{\lambda_{zI}}{\lambda_E}$ $\lambda_{BzI} = 0.723$

Merkez noktası mesafesi $k_{eII} := \frac{W_{z1x}}{A_I}$ $k_{eII} = 118.9 \cdot mm$

Akma kuvveti $F_{pII} := A_I \cdot f_{EM}$ $F_{pII} = 3418.2 \cdot kN$

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

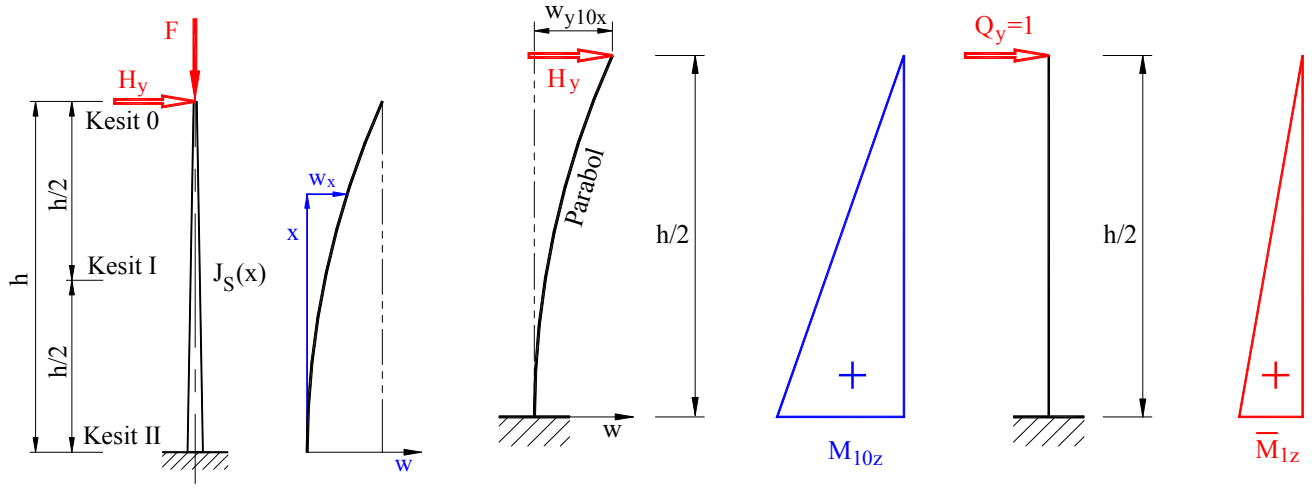
Burkulma yardımcı faktörü $\varphi_{BzI} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{BzI} - 0.2) + \lambda_{BzI}^2 \right]$ $\varphi_{BzI} = 0.85$

Azaltma faktörü $\chi_{BzI} := \frac{1}{\varphi_{BzI} + \sqrt{\varphi_{BzI}^2 - \lambda_{BzI}^2}}$ $\chi_{BzI} = 0.771$

Kuvvetin mukavemet emniyeti $S_{FzI} := \frac{F_x}{\chi_{BzI} \cdot F_{pII}}$ $S_{FzI} = 0.266$

Kesit I de burkulma tehlikesi yoktur.

Kesit I de moment kontrolü:



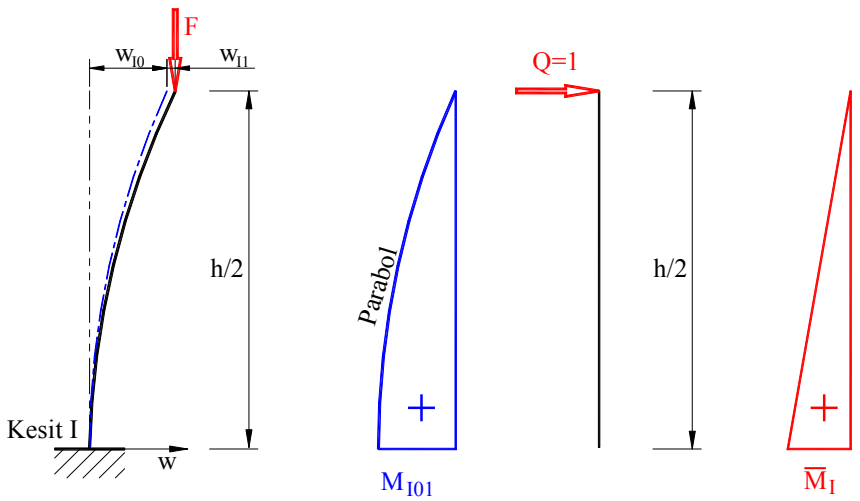
$x1 = 2\,m$ $M_{I0z} := 0.5H_y \cdot h_S$ $M_{I0z} = 120 \cdot kN \cdot m$ $M_{Iz} = 0.5 \cdot h_S$

$$w_{y10x} = \int_0^{\frac{h_S}{2}} M_{I0z} \cdot M_{Iz} \cdot \frac{1}{EJ_{z1x}}\,dx \qquad w_{y10x} = \int_0^{\frac{h_S}{2}} \frac{H_y \cdot h_S}{2} \cdot \frac{h_S}{2} \cdot \frac{1}{EJ_{z1x}}\,dx$$

$$w_{y10x} := \int_0^{\frac{h_S}{2}} \frac{H_y \cdot h_S^{\,2}}{8 \cdot E \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t\right] - b_ç\right]^2\right]}\,dx1$$

$w_{y10x} = 8.576 \cdot mm$

Vianelloya göre



$M_{I01} := F_x \cdot w_{y10x}$

$$M_I = \frac{h_S}{2}$$

$$w_{I1} = \int_0^{\frac{h_S}{2}} M_{I01} \cdot M_1 \cdot \frac{1}{EJ_{z1x}}\,dx$$

$$w_{I1} = \int_0^{\frac{h_S}{2}} F_x \cdot w_{y10x} \cdot \frac{h_S}{2} \cdot \frac{1}{EJ_{z1x}}\, dx$$

$$w_{I1x} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{y10x} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_ç \right]^2 \right]} dx1$$

Devam edersek: $w_{I1x} = 0.429 \cdot mm$

$$w_{I2x} := \int_0^{\frac{h_S}{2}} \frac{F_x \cdot w_{I1x} \cdot h_S}{4 \cdot E \cdot \left[\frac{b_0^{\,3} \cdot (1 + k_b \cdot x1)^3 \cdot t}{12} + \frac{t^3 \cdot h_0 \cdot (1 + k_b \cdot x1)}{12} + t \cdot h_0 \cdot (1 + k_h \cdot x1) \cdot \left[0.5 \cdot \left[b_0 \cdot (1 + k_b \cdot x1) - t \right] - b_ç \right]^2 \right]} dx1$$

$w_{I2x} = 0.021 \cdot mm$

Toplam sehim $w_I := w_{y10x} + w_{I1x} + w_{I2x}$ $w_I = 9.026 \cdot mm$

eğer $F_x = F_{kr}$ ve $w_{y10x} = w_{I1x}$ veya $\alpha_F = \frac{w_{I1x}}{w_{y10x}} = 1$ kabul edersek:

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

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

$F_{kr} = 16616 \cdot kN$ $F_x = 700 \cdot kN$

Sonuç: Çubuğun 1. kesiti için burkulma tehlikesi yoktur.

Toplam Moment

$M_I := 0.5 \cdot H_y \cdot h_S + F_x \cdot w_I$ $M_I = 126.32 \cdot kN \cdot m$

$M_{plzI} := W_{z1x} \cdot f_{EM}$ $M_{plzI} = 406.5 \cdot kN \cdot m$

$M_{IF} := F_x \cdot w_I$ $M_{IF} = 6.3 \cdot kN \cdot m$

$\Delta M < 1$

$\Delta MI := \frac{M_{IF}}{M_I}$ $\Delta MI = 0.050$

$\beta_{mzI} := 0.66 + 0.44 \cdot \Delta MI$ $\beta_{mzI} = 0.68$

$S_{IM} := \frac{\beta_{mzI} \cdot M_I}{M_{plzI}}$ $S_{IM} = 0.212$

$\Delta n = 0.1$

$S_I := S_{FzI} + S_{IM} + \Delta n$ $S_I = 0.578$

Sonuç: S_I değeri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.

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