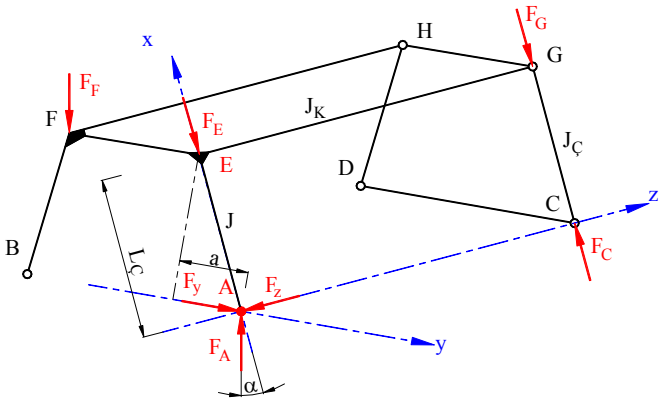
İki düzlemdeki çerçevelerin kesiti devamlı değişen ortak çubuğu

Sistem ve bilinen değerler:



Malzeme := "S235"

$f_y := 235 \cdot MPa$

$\gamma_M := 1.1$

Emniyetli akma mukavemeti

$f_{EM} := \frac{f_y}{\gamma_M}$

$f_{EM} = 214 \cdot MPa$

Elastiklik modülü

$E := 210000 \cdot MPa$

Kiriş

$L_K := 18 \cdot m$

$J_{yK} := 7447 \cdot 10^6 \cdot mm^4$

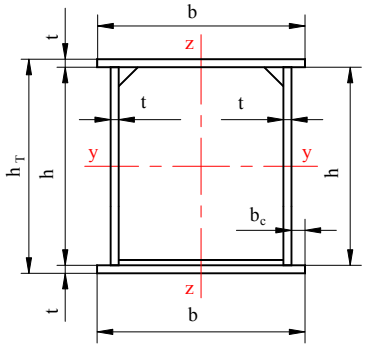
Uç bağlantı

$L_U := 2 \cdot m$

$J_{yU} := 703 \cdot 10^6 \cdot mm^4$

Kabul: Eğrinin şekli parabol

$L_H := 8 \cdot m$



$\alpha := 10 \cdot deg$

$F_A := 400 \cdot kN$

$F_G := 0.4 \cdot F_A$

$F_F := 0.9 \cdot F_A$

Kesit A:

$F_y := 60 \cdot kN$

$F_z := 40 \cdot kN$

$b_A := 420 \cdot mm$

$h_A := 380 \cdot mm$

$t := 10 \cdot mm$

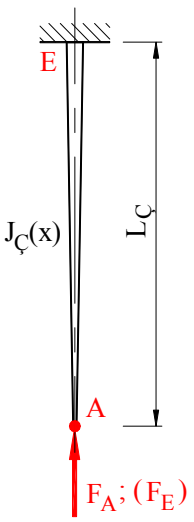
$b_ç := 10 \cdot mm$

$h_{TA} := h_A + 2 \cdot t$

$h_{TA} = 400 \cdot mm$

$z_A := 0.5 \cdot (h_A + t)$

$z_A = 195 \cdot mm$



$J_{yA} := 2 \cdot \frac{b_A \cdot t^3}{12} + 2 \cdot \frac{t \cdot h_A^3}{12} + 2 \cdot t \cdot b_A \cdot z_A^2$

$J_{yA} = 411 \cdot 10^6 \cdot mm^4$

$W_{yA} := \frac{2 \cdot J_{yA}}{h_{TA}}$

$W_{yA} = 2055 \cdot 10^3 \cdot mm^3$

$A_A := 2 \cdot t \cdot (b_A + h_A)$

$A_A = 16000 \cdot mm^2$

$L_Ç := L_H \cdot \cos(\alpha)^{-1}$

$L_Ç = 8.123\,m$

$y_A := 0.5 \cdot (b_A + t) - b_ç$

$y_A = 205 \cdot mm$

$J_{zA} := 2 \cdot \frac{b_A^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h_A}{12} + 2 \cdot t \cdot h_A \cdot y_A^2$

$J_{zA} = 442.9 \cdot 10^6 \cdot mm^4$

$W_{zA} := \frac{2 \cdot J_{zA}}{b_A}$

$W_{zA} = 2109.2 \cdot 10^3 \cdot mm^3$

$k_{xz} := \frac{L_K^2}{J_{yK}}$

$k_{xz} = 43507 \frac{1}{m^2}$

$k_{xy} := \frac{L_U^2}{J_{yU}}$

$k_{xy} = 5690 \frac{1}{m^2}$

$k_{xz} > k_{xy}$ olduğundan burkulma hesabı xz kesitinde yapılacaktır.

$F_E := F_A \cdot \cos(\alpha)^{-1}$ $F_E = 406.2 \cdot kN$

Kesit E:

$b_E := 900 \cdot mm$ $h_E := 880 \cdot mm$

Faktörler:

$k_{8b} := \frac{b_E}{b_A}$ $k_{8b} = 2.14286$ $k_b := \frac{k_{8b} - 1}{L_Ç}$ $k_b = 0.1407\,m^{-1}$

$k_{8h} := \frac{h_E}{h_A}$ $k_{8h} = 2.31579$ $k_h := \frac{k_{8h} - 1}{L_Ç}$ $k_h = 0.162\,m^{-1}$

$k_{bx} = 1 + k_b \cdot x$

$k_{hx} = 1 + k_h \cdot x$

$A_E := 2 \cdot t \cdot (b_E + h_E)$ $A_E = 35600 \cdot mm^2$

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

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

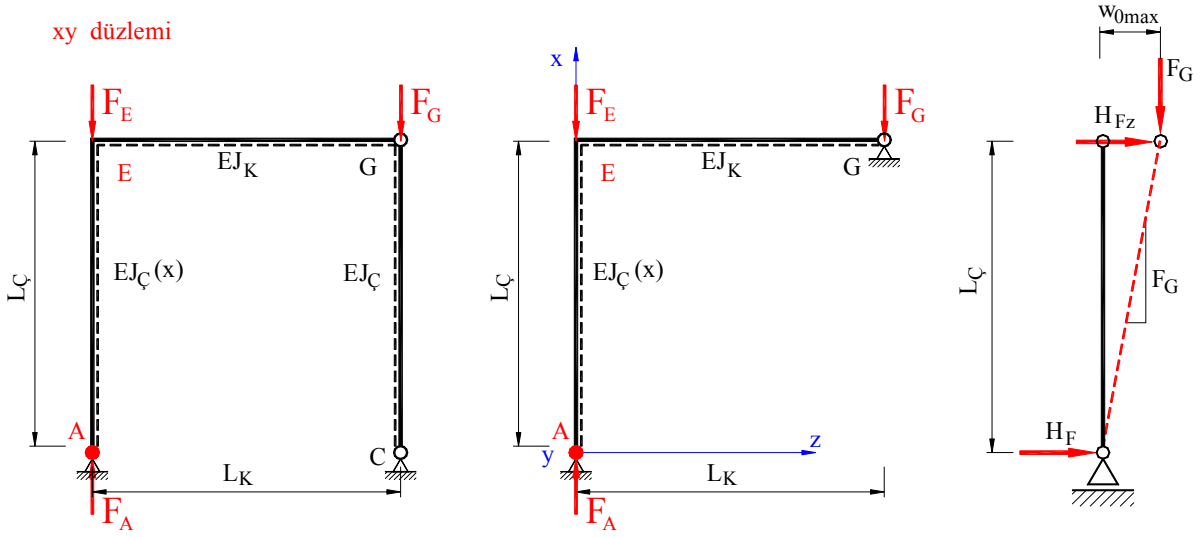
$$W_{yx} = \frac{2 \cdot J_{yx}}{h_A \cdot (1 + k_h \cdot x) + 2 \cdot t}$$

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

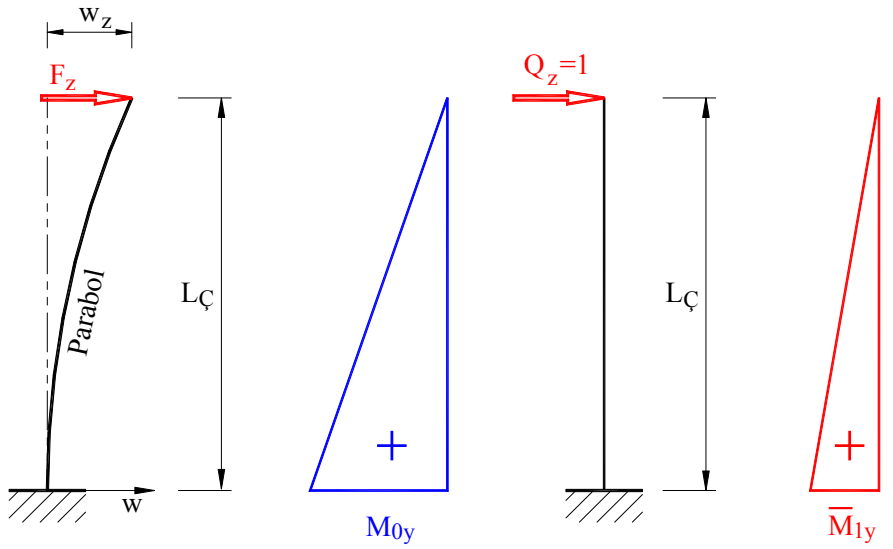
$$W_{zx} = \frac{2 \cdot J_{zx}}{b_A \cdot (1 + k_b \cdot x)}$$

$$A_x = 2 \cdot t \cdot [b_A \cdot (1 + k_b \cdot x) + h_A \cdot (1 + k_h \cdot x)]$$

Vianelloya göre çözüm:



Çözüm: 1. dereceli hesaplama kuralına göre

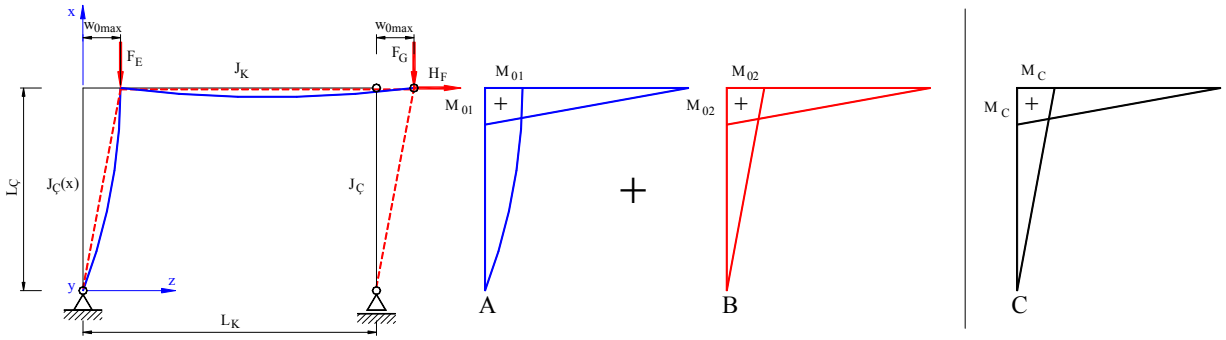


$$M_{0y} := F_z \cdot L_Ç \qquad M_{1y} = L_Ç \qquad w_{0z} = \int_0^{L_Ç} M_{0y} \cdot M_{1y} \cdot \frac{1}{E \cdot J_{yx}}\, dx \qquad w_{0z} = \int_0^{L_Ç} \frac{F_z \cdot L_Ç^{\,2}}{E \cdot J_{yx}}\, dx$$

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

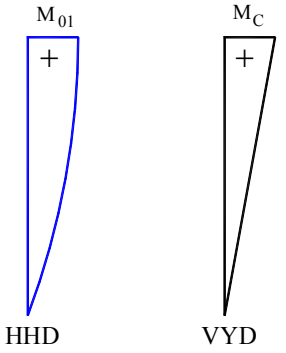
$$w_{0zx} = 79.609 \cdot mm$$

AE çubuğunun hesabı Vianello metodu ile xz düzlemine göre yapılır.



$$F_E \cdot w_{0max} = H_F \cdot L_Ç \qquad H_F = \frac{F_E \cdot w_{0max}}{L_Ç}$$

AE çubuğunda F_E etkili 1. sehim



$$w_{11} = \int_0^{L_Ç} \frac{M_{01x} \cdot M_{Cx}}{E \cdot J_{Çyx}}\, dx$$

x e bağlı momentler:

$$M_{Cx} = \frac{x}{L_Ç} \cdot L_Ç = x$$

$$M_{01} = F_E \cdot w_{0max}$$

M_{01} dağılımı parabol olursa parabolün genel formülü:

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

$$M_{0ASx}(x=0) = 0$$

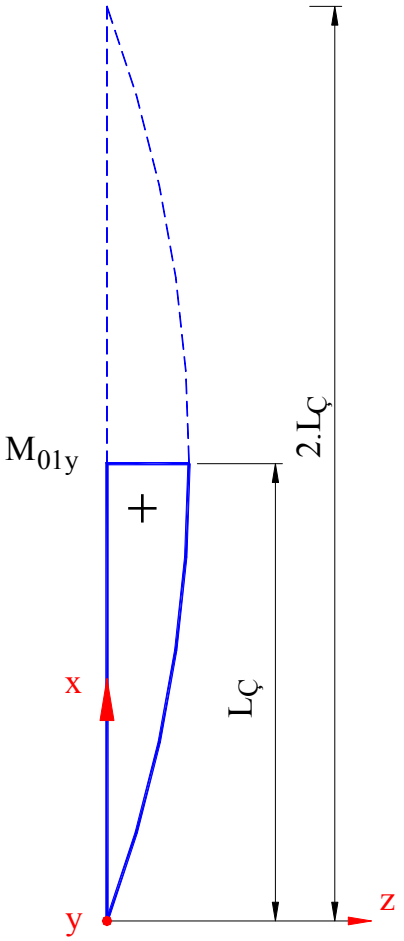
$$M_{0ASx}(x=L_Ç) = F_E \cdot w_{0max} \qquad c = 0$$

$$M_{0ASx}(x=2.L_Ç) = 0$$

Eğer $x=2.L_Ç$ yerleştirirsek:

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

$$0 = 2 \cdot L_Ç\, a + b \qquad b = -2 \cdot a \cdot L_Ç$$



$x = L_S$

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

$$F_E \cdot w_{0max} = a \cdot L_Ç^2 + b \cdot L_Ç + 0$$

$$F_E \cdot w_{0max} = a \cdot L_Ç^2 - 2 \cdot a \cdot L_Ç^2$$

$$F_E \cdot w_{0max} = -a \cdot L_Ç^2 \qquad a = -\frac{F_E \cdot w_{0max}}{L_Ç^2}$$

$$b = -2 \cdot a \cdot L_Ç \qquad b = -\frac{2 \cdot F_E \cdot w_{0max}}{L_Ç}$$

x e bağlı parabol olarak dağılımlı moment:

$$M_{01x} = -\frac{F_E \cdot w_{0max}}{L_Ç^2} \cdot x^2 - \frac{2 \cdot F_E \cdot w_{0max}}{L_Ç} \cdot x$$

Değerleri yerleştirirsek

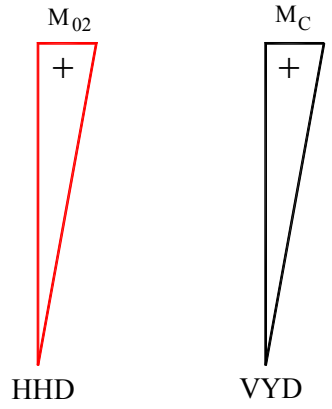
$$w_{11x} = \int_0^{L_Ç} \frac{\left(-\frac{F_E \cdot w_{0max}}{L_Ç^2} \cdot x^2 - \frac{2 \cdot F_E \cdot w_{0max}}{L_Ç} \cdot x\right) \cdot x}{2 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot h_A^3 \cdot (1 + k_b \cdot x)^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x) \cdot \left[0.5 \cdot \left[h_A \cdot (1 + k_h \cdot x) + t\right]\right]^2\right]} dx$$

$F_E \cdot w_{0max}$ = sabit olduğundan integralin dışına alalım.

$$w_{11x} := \int_0^{L_Ç} \frac{\frac{x^3}{L_Ç^2} + \frac{2\cdot x^2}{L_Ç}}{2\cdot E\cdot\left[\frac{b_A\cdot(1+k_b\cdot x)\cdot t^3}{12} + \frac{t\cdot h_A^3\cdot(1+k_b\cdot x)^3}{12} + t\cdot b_A\cdot(1+k_b\cdot x)\cdot\left[0.5\cdot\left[h_A\cdot(1+k_h\cdot x)+t\right]\right]^2\right]}\,dx$$

$$w_{11x} = 0.109\cdot\frac{10^{-6}}{N}$$

AE çubuğunda H_F etkili 2. sehim



$$w_{12x} = \int_0^{L_Ç} \frac{M_{02x}\cdot M_{Cx}}{E\cdot J_{Çyx}}\,dx$$

x e bağlı momentler:

$$M_C = \frac{x}{L_Ç}\cdot L_Ç = x$$

$$M_{02} = H_F\cdot L_Ç = F_E\cdot w_{0max}$$

$$M_{02x} = H_F\cdot x = \frac{x}{L_Ç}\cdot F_E\cdot w_{0max}$$

$$w_{12x} = \int_0^{L_Ç} \frac{\frac{x}{L_Ç}\cdot F_E\cdot w_{0max}\cdot x}{E\cdot J_{Çyx}}\,dx$$

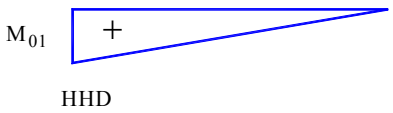
$$w_{12x} = \int_0^{L_Ç} \frac{\frac{x^2}{L_Ç}}{2\cdot E\cdot\left[\frac{b_A\cdot(1+k_b\cdot x)\cdot t^3}{12} + \frac{t\cdot h_A^3\cdot(1+k_b\cdot x)^3}{12} + t\cdot b_A\cdot(1+k_b\cdot x)\cdot\left[0.5\cdot\left[h_A\cdot(1+k_h\cdot x)+t\right]\right]^2\right]}\,dx$$

$F_E\cdot w_{0max}$ = sabit olduğundan integralin dışına alalım.

$$w_{12x} := \int_0^{L_Ç} \frac{6\cdot x^2}{E\cdot\left[b_A\cdot(1+k_b\cdot x)\cdot t^3 + t\cdot h_A^3\cdot(1+k_b\cdot x)^3 + 6\cdot t\cdot b_A\cdot(1+k_b\cdot x)\cdot\left[h_A\cdot(1+k_h\cdot x)+t\right]^2\right]\cdot L_Ç}\,dx$$

$$w_{12x} = 0.023\cdot\frac{10^{-6}}{N}$$

EG Kirişinde F_E etkili 3. sehim



$$M_{01} = F_E\cdot w_{0max}$$

$$M_C = L_K$$

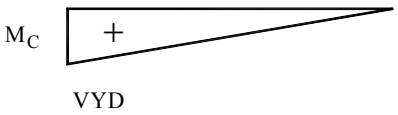
$$w_{13} = \int_0^{L_K} \frac{M_{01} \cdot M_C}{E \cdot J_{yK}}\, dx \qquad E \cdot J_{Ky} = \text{sabit}$$

İntegral tablosundan Üçgen + Üçgen $w_{13} = \frac{1}{3} \cdot \frac{F_E \cdot w_{0max} \cdot L_K^2}{E \cdot J_{yK}}$

$F_E \cdot w_{0max}$ = sabit olduğundan integralin dışına alalım. $w_{13} := \frac{1}{3} \cdot \frac{L_K^2}{E \cdot J_{yK}}$ $w_{13} = 0.069 \cdot \frac{10^{-6}}{N}$

EG Kirişinde H_F etkili 4. sehim

HHD



VYD

$M_{02} = F_E \cdot w_{0max}$

$M_C = L_K$

$$w_{14} = \int_0^{L_K} \frac{M_{02} \cdot M_C}{E \cdot J_{yK}}\, dx \qquad E \cdot J_{yK} = \text{sabit}$$

İntegral tablosundan Üçgen + Üçgen $w_{14} = \frac{1}{3} \cdot \frac{F_E \cdot w_{0max} \cdot L_K^2}{E \cdot J_{yK}}$

$F_E \cdot w_{0max}$ = sabit olduğundan integralin dışına alalım. $w_{14} := \frac{1}{3} \cdot \frac{L_K^2}{E \cdot J_{yK}}$ $w_{14} = 0.069 \cdot \frac{10^{-6}}{N}$

$w_{01} = F_E \cdot w_{0max} \cdot (w_{11x} + w_{12x} + w_{13} + w_{14})$ $F_E = F_{kr}$ $w_{01} = w_{0max}$ kabul edersek

$$F_{kr} := \frac{1}{w_{11x} + w_{12x} + w_{13} + w_{14}}$$

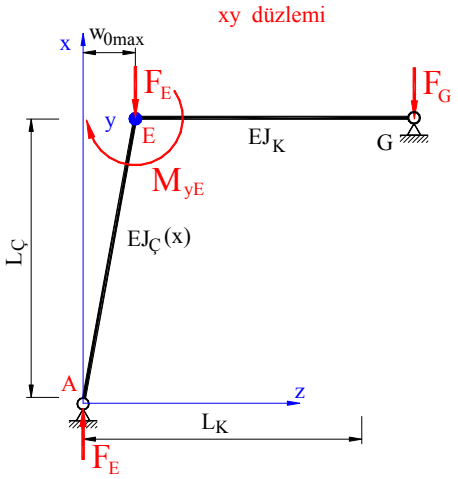
$F_{kr} = 3703 \cdot kN$ $F_A = 400 \cdot kN$

Sonuç: Çubukta burkulma tehlikesi yoktur.

E Kesitinde mukavemet hesabı:

Eğilme momenti M_{yE}

$x := 8 \cdot m$



$$J_{yE} := 2\cdot\left[\frac{b_A\cdot(1+k_b\cdot x)\cdot t^3}{12} + \frac{t\cdot h_A^{\,3}\cdot(1+k_b\cdot x)^3}{12} + t\cdot b_A\cdot(1+k_b\cdot x)\cdot\left[0.5\cdot\left[h_A\cdot(1+k_h\cdot x)+t\right]\right]^2\right]$$

$J_{yE} = 4354\cdot10^6\cdot mm^4$

$h_{TE} := h_E + 2\cdot t$

$W_{yE} := \frac{2\cdot J_{yE}}{h_{TE}}$

$W_{yE} = 9675\cdot10^3\cdot mm^3$

Eylemsizlık radyusu

$i_{yE} := \sqrt{\frac{J_{yE}}{A_E}}$

$i_{yE} = 349.7\cdot mm$

Euler burkulma boyu

$L_{ByE} := \sqrt{\frac{E\cdot J_{yE}\cdot\pi^2}{F_{kr}}}$

$L_{ByE} = 49.365\,m$

Akma narinliği

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

$\lambda_E = 93.913$

Narinlik

$\lambda_{yE} := \frac{L_{ByE}}{i_{yE}}$

$\lambda_{yE} = 141.159$

Bağıntılı narinlik

$\lambda_{ByE} := \frac{\lambda_{yE}}{\lambda_E}$

$\lambda_{ByE} = 1.503$

Merkez noktası mesafesi

$k_{elyE} := \frac{W_{yE}}{A_E}$

$k_{elyE} = 271.772\cdot mm$

Akma kuvveti

$F_{plE} := A_E\cdot f_{EM}$

$F_{plE} = 7605.5\cdot kN$

Burkulma parametresi

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

Max burkulma sehimi

$w_{ymaxE} := k_{elyE}\cdot\alpha_B\cdot(\lambda_{ByE} - 0.2)$

$w_{ymaxE} = 120.408\cdot mm$

Burkulma yardımcı faktörü

$\varphi_{ByE} := 0.5\cdot\left[1+\alpha_B\cdot(\lambda_{ByE}-0.2)+\lambda_{ByE}^{\,2}\right]$

$\varphi_{ByE} = 1.85$

Azaltma faktörü

$\chi_{ByE} := \frac{1}{\varphi_{ByE} + \sqrt{\varphi_{ByE}^{\,2} - \lambda_{ByE}^{\,2}}}$

$\chi_{ByE} = 0.341$

Kuvvetin mukavemet emniyeti

$S_{FyE} := \frac{F_E}{\chi_{ByE}\cdot F_{plE}}$

$S_{FyE} = 0.157$

Plastikliğin
en küçük momenti

$M_{plyE} := W_{yE}\cdot f_{EM}$

$M_{plyE} = 2067\cdot kN\cdot m$

$M_{0yE} := 0\cdot kN\cdot m$

$M_{EyE} := F_E\cdot w_{ymaxE}$

$M_{EyE} = 48.906\cdot kN\cdot m$

$-1 \le \psi_y \le 1$

$$\psi_{yE} := \frac{M_{0yE}}{M_{EyE}} \qquad \psi_{yE} = 0.000$$

$$\beta_{MyE} := 1.8 - 0.7 \cdot \psi_{yE} \qquad \beta_{MyE} = 1.8$$

$\alpha_{pl} \ge 1$

$$\alpha_{plyE} := \frac{M_{plyE}}{M_{EyE}} \qquad \alpha_{plyE} = 42.263$$

$a_y \le 0.8$

$$a_{yxE} := \lambda_{ByE} \cdot \left(2 \cdot \beta_{MyE} - 4\right) + \left(\alpha_{plyE} - 1\right) \qquad a_{yxE} = 40.662$$

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

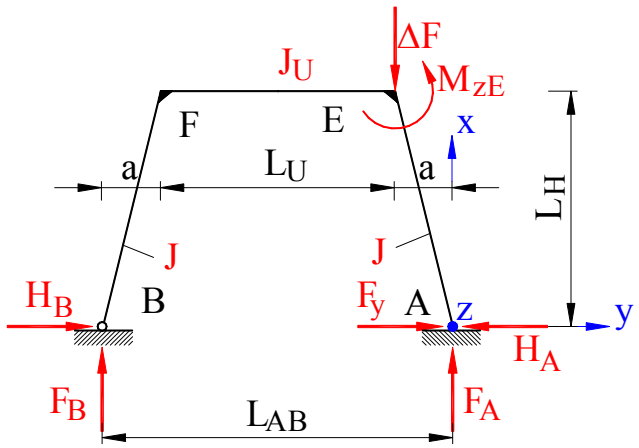
$k_y \le 1,5$

$$k_{yxE} := 1 - \frac{F_E}{\chi_{ByE} \cdot F_{plE}} \cdot a_{yE} \qquad k_{yxE} = 0.875$$

$$k_{yE} := \begin{cases} k_{yxE} & \text{if } k_{yxE} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases} \qquad k_{yE} = 0.875$$

$$S_{MyE} := \frac{M_{EyE}}{M_{plyE}} \cdot k_{yE} \qquad S_{MyE} = 0.021$$

Eğilme momenti M_z



$$\Delta F := F_A - F_F \qquad \Delta F = 40 \cdot kN$$

$$a := L_H \cdot \sin(\alpha) \qquad a = 1.389\,m$$

$$L_{AB} := L_U + 2 \cdot a \qquad L_{AB} = 4.778\,m$$

$$M_{zEA} := F_A \cdot a - 0.5 \cdot \Delta F \cdot a \cdot \frac{L_U}{L_{AB}} + F_y \cdot L_H$$

$$M_{zEB} := F_A \cdot w_{ymaxE} \qquad M_{zEB} = 48 \cdot kN \cdot m$$

$$M_{zE} := M_{zEA} + M_{zEB} \qquad M_{zE} = 1072 \cdot kN \cdot m$$

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

$J_{zE} = 4432 \cdot 10^6 \cdot mm^4$

$$W_{zE} := \frac{2 \cdot J_{zE}}{b_E} \qquad W_{zE} = 9850 \cdot 10^3 \cdot mm^3$$

Eylemsizlık radyusu

$$i_{zE} := \sqrt{\frac{J_{zE}}{A_E}} \qquad i_{zE} = 352.9 \cdot mm$$

Euler burkulma boyu

$$L_{BzE} := \sqrt{\frac{E \cdot J_{zE} \cdot \pi^2}{F_{kr}}} \qquad L_{BzE} = 49.808\,m$$

Narinlik

$$\lambda_{zE} := \frac{L_{BzE}}{i_{zE}} \qquad \lambda_{zE} = 141.159$$

Bağıntılı narinlik

$$\lambda_{BzE} := \frac{\lambda_{zE}}{\lambda_E} \qquad \lambda_{BzE} = 1.503$$

Merkez noktası mesafesi

$$k_{elzE} := \frac{W_{zE}}{A_E} \qquad k_{elzE} = 276.675 \cdot mm$$

Max burkulma sehimi

$$w_{zmaxE} := k_{elzE} \cdot \alpha_B \cdot \left(\lambda_{BzE} - 0.2\right) \qquad w_{zmaxE} = 122.58 \cdot mm$$

Burkulma yardımcı faktörü

$$\varphi_{BzE} := 0.5 \cdot \left[1 + \alpha_B \cdot \left(\lambda_{BzE} - 0.2\right) + \lambda_{BzE}^{2}\right] \qquad \varphi_{BzE} = 1.85$$

Azaltma faktörü

$$\chi_{BzE} := \frac{1}{\varphi_{BzE} + \sqrt{\varphi_{BzE}^{2} - \lambda_{BzE}^{2}}} \qquad \chi_{BzE} = 0.341$$

Kuvvetin mukavemet emniyeti

$$S_{FzE} := \frac{F_E}{\chi_{BzE} \cdot F_{plE}} \qquad S_{FzE} = 0.157$$

Plastikliğin
en küçük momenti

$$M_{plzE} := W_{zE} \cdot f_{EM} \qquad M_{plzE} = 2104.2 \cdot kN \cdot m$$

$$M_{0zE} := 0 \cdot kN \cdot m$$

$-1 \le \psi_z \le 1$

$$\psi_{zE} := \frac{M_{0zE}}{M_{zE}} \qquad \psi_{zE} = 0.000$$

$$\beta_{MzE} := 1.8 - 0.7 \cdot \psi_{zE} \qquad \beta_{MzE} = 1.8$$

$\alpha_{pl} > 1$

$$\alpha_{plzE} := \frac{M_{plzE}}{M_{zE}} \qquad \alpha_{plzE} = 1.963$$

$$a_{zEx} := \lambda_{BzE} \cdot \left(2 \cdot \beta_{MzE} - 4\right) + \left(\alpha_{plzE} - 1\right) \qquad a_{zEx} = 0.361$$

$$a_{zE} := \begin{cases} a_{zEx} & \text{if } a_{zEx} \le 0.8 \\ 0.8 & \text{otherwise} \end{cases} \qquad a_{zE} = 0.361$$

$$k_{zEx} := 1 - \frac{F_A}{\chi_{BzE} \cdot F_{plE}} \cdot a_{zE} \qquad k_{zEx} = 0.944$$

$$k_{zE} := \begin{cases} k_{zEx} & \text{if } k_{zEx} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases} \qquad k_{zE} = 0.944$$

$$S_{MzE} := \frac{M_{zE}}{M_{plzE}} \cdot k_{zE} \qquad S_{MzE} = 0.481$$

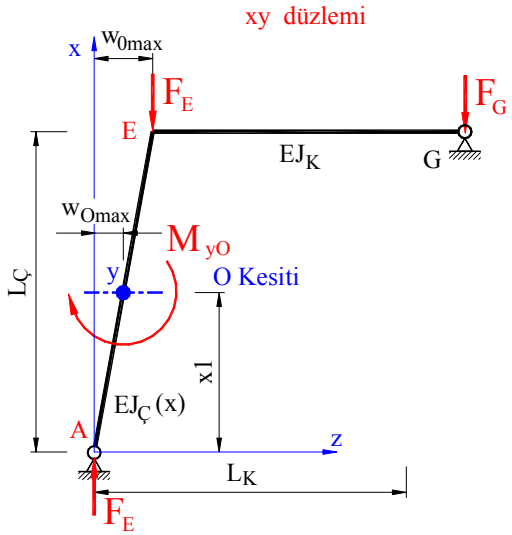
$$S_{Ey} := \frac{F_E}{\chi_{ByE} \cdot F_{plE}} + \frac{M_{EyE}}{M_{plyE}} \cdot k_{yE} + \frac{M_{zE}}{M_{plzE}} \cdot k_{zE} \qquad S_{Ey} = 0.658$$

$$S_{Ez} := \frac{F_E}{\chi_{BzE} \cdot F_{plE}} + \frac{M_{EyE}}{M_{plyE}} \cdot k_{yE} + \frac{M_{zE}}{M_{plzE}} \cdot k_{zE} \qquad S_{Ey} = 0.658$$

Sonuç: S_{Ey} ve S_{Ez} değerleri 1 den küçük olduğundan E kesitinin hesaplarına göre konstrüksiyon fonksiyonunu yapar.

O Kesitinde mukavemet hesabı:

$x1 = 0.5 \cdot L_Ç$ $x1 := 4 \cdot m$



$z_O := 0.5 \cdot \left[h_A \cdot \left(\left(1 + k_h \cdot x \right) \right) + t \right]$ $z_O = 441.2 \cdot mm$

$J_{yO} := 2 \cdot \left[\frac{b_A \cdot \left(1 + k_b \cdot x \right) \cdot t^3}{12} + \frac{t \cdot \left[h_A \cdot \left(1 + k_h \cdot x \right) \right]^3}{12} + t \cdot b_A \cdot \left(1 + k_b \cdot x \right) \cdot z_O^{\,2} \right]$ $J_{yO} = 4582 \cdot 10^6 \cdot mm^4$

$W_{yO} := \frac{2 \cdot J_{yO}}{h_A \cdot \left(1 + k_h \cdot x1 \right) + 2 \cdot t}$ $W_{yO} = 14182 \cdot 10^3 \cdot mm^3$

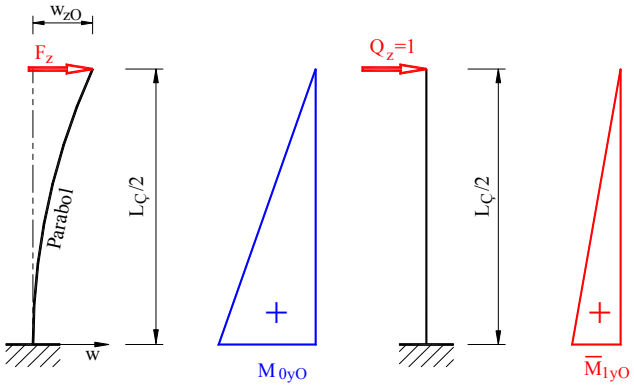
$A_O := 2 \cdot t \cdot \left[b_A \cdot \left(1 + k_b \cdot x1 \right) + h_A \cdot \left(1 + k_h \cdot x1 \right) \right]$ $A_O = 25651 \cdot mm^2$

$y_O := 0.5 \cdot \left[b_A \cdot \left(1 + k_b \cdot x1 \right) - t \right] - b_Ç$ $y_O = 313.177 \cdot mm$

$J_{zO} := \left[2 \cdot \frac{b_A^{\,3} \cdot \left(1 + k_b \cdot x1 \right)^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h_A \cdot \left(1 + k_b \cdot x1 \right)}{12} + 2 \cdot t \cdot h_A \cdot \left(1 + k_h \cdot x1 \right) \cdot y_O^{\,2} \right]$ $J_{zO} = 2 \times 10^3 \cdot 10^6 \cdot mm^4$

$W_{zO} := \frac{2 \cdot J_{zO}}{b_A \cdot \left(1 + k_b \cdot x1 \right)}$ $W_{zO} = 5179 \cdot 10^3 \cdot mm^3$

Çözüm: 1. dereceli hesaplama kuralına göre



$M_{0yO} := F_z \cdot \frac{L_Ç}{2}$ $M_{1yO} = \frac{L_Ç}{2}$

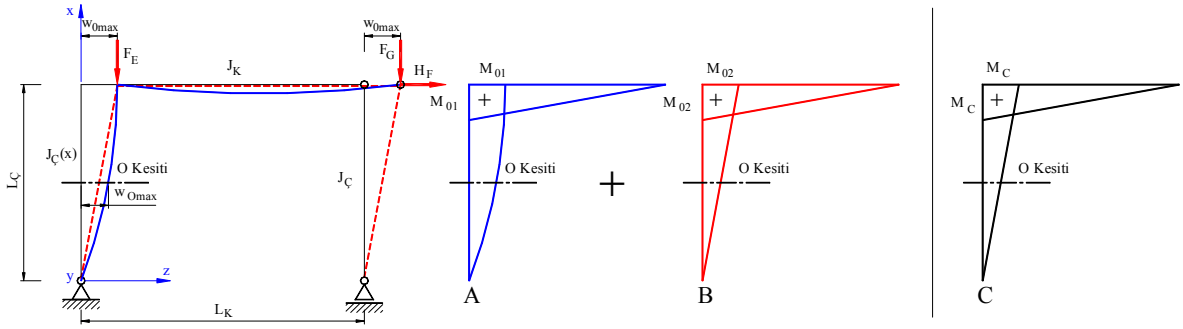
$w_{0zO} = \int_0^{\frac{L_Ç}{2}} M_{0yO} \cdot M_{1yO} \cdot \frac{1}{E \cdot J_{yx1}} \, dx1$

$$w_{zO} = \int_0^{\frac{L_Ç}{2}} F_z \cdot \frac{L_Ç}{2} \cdot \frac{L_Ç}{2} \cdot \frac{1}{E \cdot J_{yx1}}\, dx1 \qquad w_{zO} = \int_0^{\frac{L_Ç}{2}} \frac{F_z \cdot L_Ç^{\,2}}{8 \cdot E \cdot J_{yx1}}\, dx$$

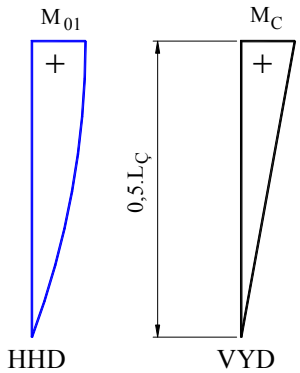
$$w_{zO} := \int_0^{\frac{L_Ç}{2}} \frac{F_z \cdot L_Ç^{\,2}}{16 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x) \cdot t^3}{12} + \frac{t \cdot \left[h_A \cdot (1 + k_h \cdot x) \right]^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x) \cdot \left[0.5 \cdot \left[h_A \cdot \left((1 + k_h \cdot x) \right) + t \right] \right]^2 \right]}\, dx$$

$w_{zO} = 7.708 \cdot mm$

O Kesitinde moment kontrolü:



O Kesitinde AE çubuğunda F_E etkili 1. sehim



$$w_{O1x} = \int_0^{\frac{L_Ç}{2}} \frac{M_{01x} \cdot M_{Cx}}{E \cdot J_{yO}}\, dx$$

x1 e bağlı momentler:

$$M_{Cx} = \frac{2 \cdot x1}{L_Ç} \cdot \frac{L_Ç}{2} = x1$$

$$M_{01x} = F_E \cdot w_{Omax} \cdot f(x1)$$

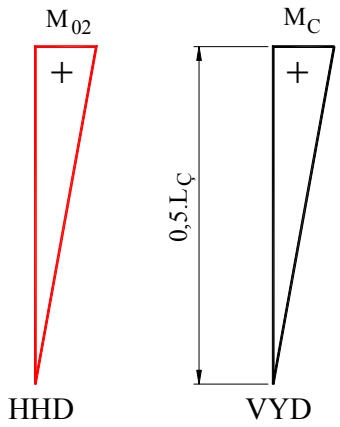
M_{01} dağılımı parabol olursa, parabolün genel formülünde değerleri yerleştirirsek:

$$w_{zO1x} = \int_0^{\frac{L_Ç}{2}} \frac{\left(-\frac{F_E \cdot w_{Omax}}{L_Ç^{\,2}} \cdot x1^2 - \frac{2 \cdot F_E \cdot w_{Omax}}{L_Ç} \cdot x1 \right) \cdot x1}{2 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot h_A^{\,3} \cdot (1 + k_b \cdot x1)^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_A \cdot (1 + k_h \cdot x1) + t \right] \right]^2 \right]}\, dx1$$

$$w_{zO1x} := \int_0^{\frac{L_Ç}{2}} \frac{\frac{x1^3}{L_Ç^2} + \frac{2 \cdot x1^2}{L_Ç}}{2 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot h_A^3 \cdot (1 + k_b \cdot x1)^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_A \cdot (1 + k_h \cdot x1) + t \right] \right]^2 \right]} dx1$$

$$w_{zO1x} = 0.025 \cdot \frac{10^{-6}}{N}$$

O Kesitinde AE çubuğunda H_F etkili 2. sehim



$$w_{zO2x} = \int_0^{\frac{L_Ç}{2}} \frac{M_{O2x} \cdot M_{Cx}}{E \cdot J_{yx}} dx$$

x1 e bağlı momentler:

$$M_C = \frac{2 \cdot x1}{L_Ç} \cdot \frac{L_Ç}{2} = x1$$

$$M_{02x} = H_F \cdot x1 = \frac{x1}{L_Ç} \cdot F_E \cdot w_{Omax}$$

$$w_{zO2x} = \int_0^{\frac{L_Ç}{2}} \frac{\frac{x1}{L_Ç} \cdot F_E \cdot w_{Omax} \cdot x1}{E \cdot J_{yx}} dx1$$

$$w_{zO2x} = \int_0^{\frac{L_Ç}{2}} \frac{F_E \cdot w_{Omax} \cdot \frac{x1^2}{L_Ç}}{2 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot h_A^3 \cdot (1 + k_b \cdot x1)^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_A \cdot (1 + k_h \cdot x1) + t \right] \right]^2 \right]} dx$$

$F_E \cdot w_{Omax}$ = sabit olduğundan integralin dışına alalım.

$$w_{zO2x} := \left[\int_0^{\frac{L_Ç}{2}} \frac{\frac{x1^2}{L_Ç}}{2 \cdot E \cdot \left[\frac{b_A \cdot (1 + k_b \cdot x1) \cdot t^3}{12} + \frac{t \cdot h_A^3 \cdot (1 + k_b \cdot x1)^3}{12} + t \cdot b_A \cdot (1 + k_b \cdot x1) \cdot \left[0.5 \cdot \left[h_A \cdot (1 + k_h \cdot x1) + t \right] \right]^2 \right]} dx \right]$$

$$w_{zO2x} = 0.023 \cdot \frac{10^{-6}}{N}$$

$w_{O1} = F_E \cdot w_{Omax} \cdot (w_{zO1x} + w_{zO2x})$ $F_E = F_{kr}$ $w_{O1} = w_{Omax}$ kabul edersek

$$F_{krO} := \frac{1}{w_{zO1x} + w_{zO2x}} \qquad F_{krO} = 20795 \cdot kN \qquad F_A = 400 \cdot kN$$

O Kesitinde burkulma tehlikesi yoktur.

O Kesitinde mukavemet hesabı

Eylemsizlik radyusu $i_{yO} := \sqrt{\frac{J_{yO}}{A_O}}$ $i_{yO} = 422.7 \cdot mm$

Euler burkulma boyu $L_{ByO} := \sqrt{\frac{E \cdot J_{yO} \cdot \pi^2}{F_{kr}}}$ $L_{ByO} = 50.643\,m$

Akma narinliği $\lambda_E = 93.913$

Narinlik $\lambda_{yO} := \frac{L_{ByO}}{i_{yO}}$ $\lambda_{yO} = 119.822$

Bağıntılı narinlik $\lambda_{ByO} := \frac{\lambda_{yO}}{\lambda_E}$ $\lambda_{ByO} = 1.276$

Merkez noktası mesafesi $k_{elyO} := \frac{W_{yO}}{A_O}$ $k_{elyO} = 552.884 \cdot mm$

Akma kuvveti $F_{plO} := A_O \cdot f_{EM}$ $F_{plO} = 5480 \cdot kN$

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

Max burkulma sehimi $w_{ymaxO} := k_{elyO} \cdot \alpha_B \cdot (\lambda_{ByO} - 0.2)$ $w_{ymaxO} = 202.245 \cdot mm$

Burkulma yardımcı faktörü $\varphi_{ByO} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{ByO} - 0.2) + \lambda_{ByO}^2\right]$ $\varphi_{ByO} = 1.50$

Azaltma faktörü $\chi_{ByO} := \frac{1}{\varphi_{ByO} + \sqrt{\varphi_{ByO}^2 - \lambda_{ByO}^2}}$ $\chi_{ByO} = 0.439$

Kuvvetin mukavemet emniyeti $S_{FyO} := \frac{F_E}{\chi_{ByO} \cdot F_{plO}}$ $S_{FyO} = 0.169$

Eylemsizlik radyusu $i_{zO} := \sqrt{\frac{J_{zO}}{A_O}}$ $i_{zO} = 257.4 \cdot mm$

Euler burkulma boyu $L_{BzO} := \sqrt{\frac{E \cdot J_{zO} \cdot \pi^2}{F_{kr}}}$ $L_{BzO} = 30.844\,m$

Narinlik $\lambda_{zO} := \frac{L_{BzO}}{i_{zO}}$ $\lambda_{zO} = 119.822$

Bağıntılı narinlik

$$\lambda_{BzO} := \frac{\lambda_{zO}}{\lambda_E}$$

$\lambda_{BzO} = 1.276$

Merkez noktası mesafesi

$$k_{elzO} := \frac{W_{zO}}{A_O}$$

$k_{elzO} = 201.912 \cdot mm$

Max burkulma sehimi

$$w_{zmaxO} := k_{elzO} \cdot \alpha_B \cdot \left(\lambda_{BzO} - 0.2\right)$$

$w_{zmaxO} = 73.86 \cdot mm$

Burkulma yardımcı faktörü

$$\varphi_{BzO} := 0.5 \cdot \left[1 + \alpha_B \cdot \left(\lambda_{BzO} - 0.2\right) + \lambda_{BzO}^{2}\right]$$

$\varphi_{BzO} = 1.50$

Azaltma faktörü

$$\chi_{BzO} := \frac{1}{\varphi_{BzO} + \sqrt{\varphi_{BzO}^{2} - \lambda_{BzO}^{2}}}$$

$\chi_{BzO} = 0.439$

Kuvvetin mukavemet emniyeti

$$S_{FzO} := \frac{F_E}{\chi_{BzO} \cdot F_{plO}}$$

$S_{FzO} = 0.169$

Plastikliğin
en küçük momenti

$$M_{plyO} := W_{yO} \cdot f_{EM}$$

$M_{plyO} = 3029.8 \cdot kN \cdot m$

$$M_{yO} := F_E \cdot w_{ymaxO}$$

$M_{yO} = 82.146 \cdot kN \cdot m$

$M_{yA} := 0 \cdot kN \cdot m$

$-1 \le \psi_y \le 1$

$$\psi_{yO} := \frac{M_{yA}}{M_{yO}}$$

$\psi_{yO} = 0.000$

$$\beta_{MyO} := 1.8 - 0.7 \cdot \psi_{yO}$$

$\beta_{MyO} = 1.8$

$\alpha_{pl} \ge 1$

$$\alpha_{plyO} := \frac{M_{plyO}}{M_{yO}}$$

$\alpha_{plyO} = 36.883$

$a_y \le 0.8$

$$a_{yxO} := \lambda_{ByO} \cdot \left(2 \cdot \beta_{MyO} - 4\right) + \left(\alpha_{plyO} - 1\right)$$

$a_{yxO} = 35.373$

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

$a_{yO} = 0.8$

$k_y \le 1,5$

$$k_{yxO} := 1 - \frac{F_E}{\chi_{ByO} \cdot F_{plO}} \cdot a_{yO}$$

$k_{yxO} = 0.865$

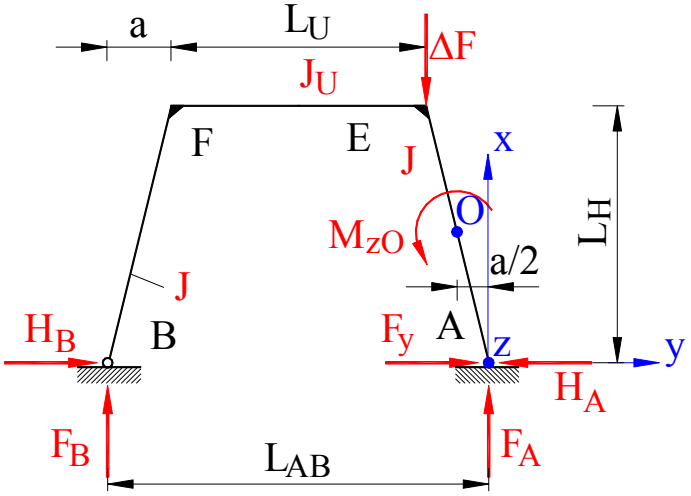
$$k_{yO} := \begin{cases} k_{yxO} & \text{if } k_{yxO} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases}$$

$k_{yO} = 0.865$

$$S_{MyO} := \frac{M_{yO}}{M_{plyO}} \cdot k_{yO}$$

$S_{MyO} = 0.023$

Eğilme momenti M_{zO}



$\Delta F = 40 \cdot kN$

$a = 1.389\,m$

$L_{AB} = 4.778\,m$

$M_{zOA} := 0.5 \cdot F_A \cdot a - 0.25 \cdot \Delta F \cdot a \cdot \frac{L_U}{L_{AB}}$

$M_{zOA} = 272.023 \cdot kN \cdot m$

Plastikliğin en küçük momenti

$M_{plzO} := W_{zO} \cdot f_{EM}$

$M_{plzO} = 1106.5 \cdot kN \cdot m$

$M_{zO1} := 0 \cdot kN \cdot m$

$M_{zOB} := F_A \cdot w_{zmaxO} + F_y \cdot L_H$

$M_{zOB} = 510 \cdot kN \cdot m$

$M_{zO} := M_{zOA} + M_{zOB}$

$M_{zO} = 782 \cdot kN \cdot m$

$-1 \le \psi_z \le 1$

$\psi_{zO} := \frac{M_{zO1}}{M_{zO}}$

$\psi_{zO} = 0.000$

$\beta_{MzO} := 1.8 - 0.7 \cdot \psi_{zO}$

$\beta_{MzO} = 1.8$

$\alpha_{pl} > 1$

$\alpha_{plzO} := \frac{M_{plzO}}{M_{zO}}$

$\alpha_{plzO} = 1.416$

$a_{zOx} := \lambda_{BzO} \cdot (2 \cdot \beta_{MzO} - 4) + (\alpha_{plzO} - 1)$

$a_{zOx} = -0.095$

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

$a_{zO} = -0.095$

$k_{zOx} := 1 - \frac{F_A}{\chi_{BzO} \cdot F_{plO}} \cdot a_{zO}$

$k_{zOx} = 1.016$

$k_{zO} := \begin{cases} k_{zOx} & \text{if } k_{zOx} \le 1.5 \\ 1.5 & \text{otherwise} \end{cases}$

$k_{zO} = 1.016$

$S_{MzO} := \frac{M_{zO}}{M_{plzO}} \cdot k_{zO}$

$S_{MzO} = 0.717$

$S_{yO} := \frac{F_E}{\chi_{ByO} \cdot F_{plO}} + \frac{M_{yO}}{M_{plyO}} \cdot k_{yO} + \frac{M_{zO}}{M_{plzO}} \cdot k_{zO}$

$S_{yO} = 0.910$

$S_{zO} := \frac{F_E}{\chi_{BzO} \cdot F_{plO}} + \frac{M_{yO}}{M_{plyO}} \cdot k_{yO} + \frac{M_{zO}}{M_{plzO}} \cdot k_{zO}$

$S_{zO} = 0.910$

Sonuç: S_{yO} ve S_{zO} değerleri 1 den küçük olduğundan x1 kesitinin hesaplarına göre konstrüksiyon fonksiyonunu yapar.

O kesitinin emniyetli mukavet değerine göre kontrolü:

$$\sigma_{heO} := \frac{F_E}{A_O} + \frac{M_{yO}}{W_{yO}} + \frac{M_{zO}}{W_{zO}}$$

$\sigma_{heO} = 173 \cdot MPa$

$f_{EM} = 214 \cdot MPa$

$$k_{EMO} := \frac{\sigma_{heO}}{f_{EM}}$$

$k_{EMO} = 0.81$

E kesitinin emniyetli mukavet değerine göre kontrolü:

$$\sigma_{heE} := \frac{F_E}{A_E} + \frac{M_{EyE}}{W_{yE}} + \frac{M_{zE}}{W_{zE}}$$

$\sigma_{heE} = 125 \cdot MPa$

$f_{EM} = 214 \cdot MPa$

$$k_{EME} := \frac{\sigma_{heE}}{f_{EM}}$$

$k_{EME} = 0.59$

Sonuç: Sistemin emniyetli mukavet değerine göre kontrolündede görüldüğü gibi konstrüksiyon fonksiyonunu yapar.

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