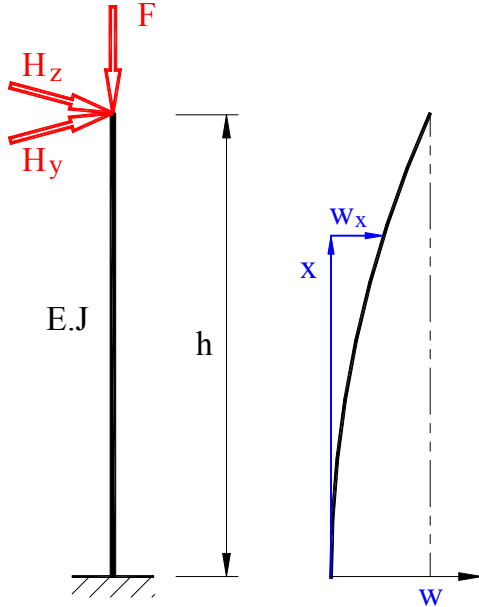


Zorlama: Aksel kuvvet ve iki eksenli eğilme momenti.

Bilinen değerler:

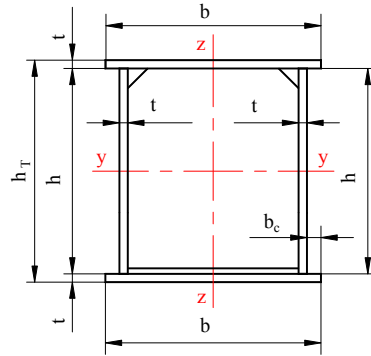


Resim 1

Kabul: Eğrinin şekli parabol

$$y := 0.5 \cdot (b + t) - b_c \quad y = 235 \cdot \text{mm}$$

Resim 2



$$h_T := h + 2 \cdot t \quad h_T = 500 \cdot \text{mm} \quad z := 0.5 \cdot (h + t) \quad z = 245 \cdot \text{mm}$$

$$J_y := 2 \cdot \frac{b \cdot t^3}{12} + 2 \cdot \frac{t \cdot h^3}{12} + 2 \cdot t \cdot b \cdot z^2$$

$$J_y = 760.6 \cdot 10^6 \cdot \text{mm}^4$$

$$W_y := \frac{2 \cdot J_y}{h_T}$$

$$W_y = 3042.6 \cdot 10^3 \cdot \text{mm}^3$$

$$EJ_y := E \cdot J_y$$

$$EJ_y = 159.7 \cdot \text{MN} \cdot \text{m}^2$$

$$J_z := 2 \cdot \frac{b^3 \cdot t}{12} + 2 \cdot \frac{t \cdot h^3}{12} + 2 \cdot t \cdot h \cdot y^2$$

$$J_z = 714.6 \cdot 10^6 \cdot \text{mm}^4$$

$$W_z := \frac{2 \cdot J_z}{b}$$

$$W_z = 2977.3 \cdot 10^3 \cdot \text{mm}^3$$

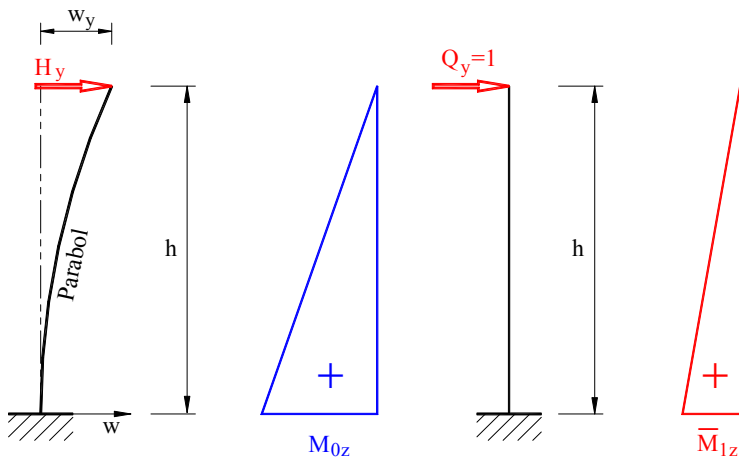
$$A_{\text{tot}} := 2 \cdot t \cdot (b + h)$$

$$A_{\text{tot}} = 19200 \cdot \text{mm}^2$$

$$EJ_z := E \cdot J_z$$

$$EJ_z = 150.1 \cdot \text{MN} \cdot \text{m}^2$$

Çözüm: 1. dereceli hesaplama kuralına göre



Resim 3

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

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

$$M_{1z} := h_s$$

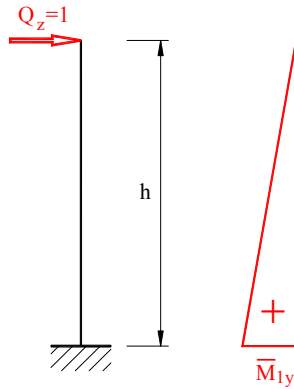
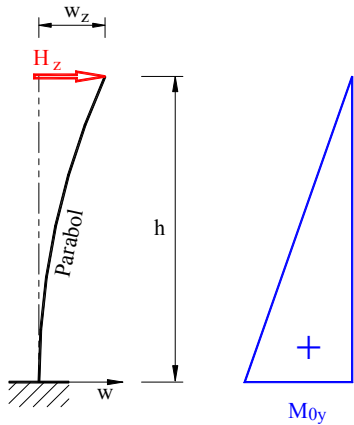
$$w_{0y} = \int_0^{h_s} M_{0z} \cdot M_{1z} \cdot \frac{1}{EJ_z} dx$$

$$w_{0y} = \frac{1}{3} \cdot M_{0z} \cdot M_{1z} \cdot \frac{h_s}{EJ_z}$$

$$w_{0y} = \frac{1}{3} \cdot H_y \cdot h_S \cdot h_S \cdot \frac{h_S}{EJ_z}$$

$$w_{0y} := \frac{H_y \cdot h_S^3}{3 \cdot EJ_z}$$

$$w_{0y} = 8.530 \cdot \text{mm}$$



Resim 4

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

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

$$M_{1y} := h_S$$

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

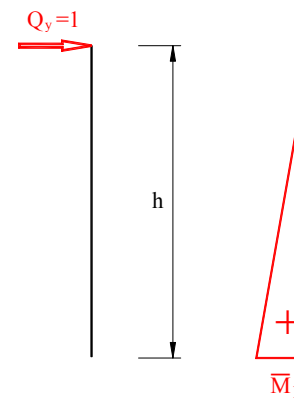
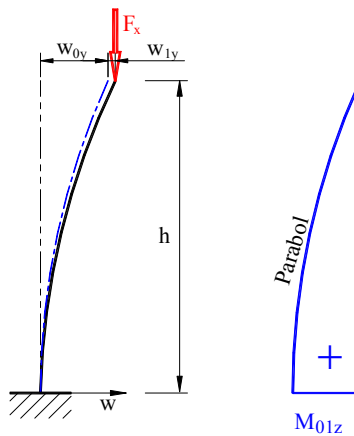
$$w_{0z} = \frac{1}{3} \cdot M_{0y} \cdot M_{1y} \cdot \frac{h_S}{EJ_y}$$

$$w_{0z} = \frac{1}{3} \cdot H_z \cdot h_S \cdot h_S \cdot \frac{h_S}{EJ_y}$$

$$w_{0z} := \frac{H_z \cdot h_S^3}{3 \cdot EJ_y}$$

$$w_{0z} = 5.342 \cdot \text{mm}$$

Vianelloya göre



Resim 5

$$M_{01z} := F_x \cdot w_{0z}$$

$$M_{01z} = 3.7 \cdot \text{kN} \cdot \text{m}$$

$$M_{1z} = h_S$$

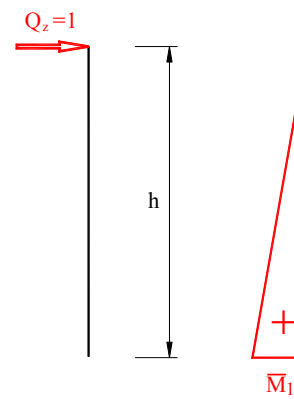
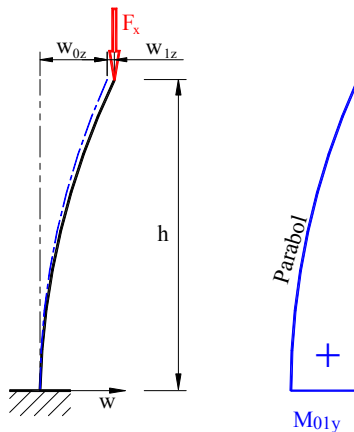
$$w_{1y} = \int_0^{h_S} M_{01z} \cdot M_{1z} \cdot \frac{1}{EJ_z} dx$$

$$w_{1y} = \frac{5}{12} \cdot M_{01z} \cdot M_{1z} \cdot \frac{h_S}{EJ_z}$$

$$w_{1y} = \frac{5}{12} \cdot F_x \cdot w_{0z} \cdot h_S \cdot \frac{h_S}{EJ_z}$$

$$w_{1y} := \frac{5 \cdot F_x \cdot w_{0z} \cdot h_S^2}{12 \cdot EJ_z}$$

$$w_{1y} = 0.166 \cdot \text{mm}$$



Resim 6

$$M_{01y} := F_x \cdot w_{0z}$$

$$M_{01y} = 3.7 \cdot \text{kN} \cdot \text{m}$$

$$M_{1y} = h_S$$

$$w_{1z} = \int_0^{h_S} M_{01y} \cdot M_{1y} \cdot \frac{1}{EJ_y} dx$$

$$w_{1z} = \frac{5}{12} \cdot M_{01y} \cdot M_{1y} \cdot \frac{h_S}{EJ_y}$$

$$w_{1z} = \frac{5}{12} \cdot F_x \cdot w_{0z} \cdot h_S \cdot \frac{h_S}{EJ_y}$$

$$w_{1z} := \frac{5 \cdot F_x \cdot w_{0z} \cdot h_S^2}{12 \cdot EJ_y}$$

$$w_{1z} = 0.156 \cdot \text{mm}$$

Resim 7

$$M_{02z} := F_x \cdot w_{1y}$$

$$M_{02z} = 0.116 \cdot \text{kN} \cdot \text{m}$$

$$M_{1z} = h_S$$

$$w_{2y} = \int_0^{h_S} M_{02z} \cdot M_{1z} \cdot \frac{1}{EJ_z} dx$$

$$w_{2y} = \frac{5}{12} \cdot M_{02z} \cdot M_{1z} \cdot \frac{h_S}{EJ_z}$$

$$w_{2y} = 0.005 \cdot \text{mm}$$

Resim 8

$$M_{02y} := F_x \cdot w_{1z}$$

$$M_{02y} = 0.109 \cdot \text{kN} \cdot \text{m}$$

$$M_{1y} = h_S$$

$$w_{2z} = \int_0^{h_S} M_{02y} \cdot M_{1y} \cdot \frac{1}{EJ_z} dx$$

$$w_{2z} = \frac{5}{12} \cdot M_{02y} \cdot M_{1y} \cdot \frac{h_S}{EJ_z}$$

$$w_{2z} = 0.005 \cdot \text{mm}$$

$$w_{3y} = 0.000 \cdot \text{mm}$$

$$w_{3z} = 0.000 \cdot \text{mm}$$

Toplam sehım

$$w_y := w_{0y} + w_{1y} + w_{2y} + w_{3y}$$

$$w_y = 8.702 \cdot \text{mm}$$

$$w_z := w_{0z} + w_{1z} + w_{2z} + w_{3z}$$

$$w_z = 5.503 \cdot \text{mm}$$

Toplam Moment

$$M_y := H_z \cdot h_S + F_x \cdot w_z$$

$$M_y = 163.85 \cdot \text{kN} \cdot \text{m}$$

$$M_z := H_y \cdot h_S + F_x \cdot w_y$$

$$M_z = 246.09 \cdot \text{kN} \cdot \text{m}$$

Kritik burkulma kuvveti

$$w_{1y} = \frac{5 \cdot F_x \cdot w_{0y} \cdot h_S^3}{12 \cdot EJ_y}$$

$$\alpha_{Fy} = \frac{w_{1y}}{w_{0y}} = 1$$

$$1 = \frac{5 \cdot F_{kry} \cdot h_S^3}{12 \cdot EJ_y} \quad F_{kry} := \frac{12}{5} \cdot \frac{EJ_y}{h_S^2}$$

$$F_{kry} = 23960.2 \cdot \text{kN}$$

$$1 = \frac{5 \cdot F_{krz} \cdot h_S^3}{12 \cdot EJ_z} \quad F_{krz} := \frac{12}{5} \cdot \frac{EJ_z}{h_S^2}$$

$$F_{krz} = 22508.6 \cdot \text{kN}$$

$$F_{kr} := F_{kry}$$

$$F_{kr} = 23960 \cdot \text{kN}$$

$$F_x = 700 \cdot \text{kN}$$

Sonuç: Çubukta burkulma tehlikesi yoktur.

Mukavemet hesabı:

Eylemsizlik radyusu $i_z := \sqrt{\frac{J_z}{A_{\text{tot}}}}$ $i_z = 192.9 \cdot \text{mm}$

Euler burkulma boyu $L_{Bz} := \sqrt{\frac{E \cdot J_z \cdot \pi^2}{F_{krz}}}$ $L_{Bz} = 8.112 \cdot \text{m}$

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

Narinlik $\lambda_z := \frac{L_{Bz}}{i_z}$ $\lambda_z = 42$

Bağıntılı narinlik $\lambda_{Bz} := \frac{\lambda_z}{\lambda_E}$ $\lambda_{Bz} = 0.448$

Akma kuvveti $F_{pl} := A_{\text{tot}} \cdot f_{EM}$ $F_{pl} = 4101.8 \cdot \text{kN}$

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

Burkulma yardımcı faktörü $\varphi_{Bz} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{Bz} - 0.2) + \lambda_{Bz}^2 \right]$ $\varphi_{Bz} = 0.64$

Azaltma faktörü $\chi_{Bz} := \frac{1}{\varphi_{Bz} + \sqrt{\varphi_{Bz}^2 - \lambda_{Bz}^2}}$ $\chi_{Bz} = 0.907$

Kuvvetin mukavemet emniyeti $S_{Fz} := \frac{F_x}{\chi_{Bz} \cdot F_{pl}}$ $S_{Fz} = 0.188$

$i_y := \sqrt{\frac{J_y}{A_{\text{tot}}}}$ $i_y = 199 \cdot \text{mm}$

$L_{By} := \sqrt{\frac{E \cdot J_y \cdot \pi^2}{F_{kr}}}$ $L_{By} = 8.112 \cdot \text{m}$

$$\lambda_y := \frac{L_{By}}{i_y} \quad \lambda_y = 40.8$$

$$\lambda_{By} := \frac{\lambda_y}{\lambda_E} \quad \lambda_{By} = 0.434$$

$$\varphi_{By} := 0.5 \cdot \left[1 + \alpha_B \cdot (\lambda_{By} - 0.2) + \lambda_{By}^2 \right] \quad \varphi_{By} = 0.63$$

$$\chi_{By} := \frac{1}{\varphi_{By} + \sqrt{\varphi_{By}^2 - \lambda_{By}^2}} \quad \chi_{By} = 0.912$$

$$S_{Fy} := \frac{F_x}{\chi_{By} \cdot F_{pl}} \quad S_{Fy} = 0.187$$

$$\chi_B := \chi_{By} \quad \chi_B = 0.912$$

Moment:

$$M_{ply} := W_y \cdot f_{EM} \quad M_{ply} = 650 \cdot \text{kN} \cdot \text{m}$$

$$M_{plz} := W_z \cdot f_{EM} \quad M_{plz} = 636.1 \cdot \text{kN} \cdot \text{m}$$

$$M_{0Fy} := F_x \cdot w_z \quad M_{0Fy} = 3.9 \cdot \text{kN} \cdot \text{m}$$

$$M_{0Fz} := F_x \cdot w_y \quad M_{0Fz} = 6.1 \cdot \text{kN} \cdot \text{m}$$

$$\Delta M < 1$$

$$\Delta M_y := \frac{M_{0Fy}}{M_y} \quad \Delta M_y = 0.024$$

$$\Delta M_z := \frac{M_{0Fz}}{M_z} \quad \Delta M_z = 0.025$$

$$\beta_{My} := 1.8 - 0.7 \cdot \Delta M_y \quad \beta_{My} = 1.8$$

$$\alpha_{pl} > 1$$

$$\alpha_{ply} := \frac{M_{ply}}{M_y} \quad \alpha_{ply} = 3.967$$

$$a_y := \lambda_{By} \cdot (2 \cdot \beta_{My} - 4) + (\alpha_{ply} - 1)$$

$$k_y := 1 - \frac{F_x}{\chi_B \cdot F_{pl}} \cdot a_y \quad k_y = 0.5$$

$$\beta_{Mz} := 1.8 - 0.7 \cdot \Delta M_z \quad \beta_{Mz} = 1.8$$

$$\alpha_{pl} > 1$$

$$\alpha_{plz} := \frac{M_{plz}}{M_z} \quad \alpha_{plz} = 2.585$$

$$a_z := \lambda_{Bz} \cdot (2 \cdot \beta_{Mz} - 4) + (\alpha_{plz} - 1)$$

$$k_z := 1 - \frac{F_x}{\chi_B \cdot F_{pl}} \cdot a_z \quad k_z = 0.740$$

$$S_{He} := \frac{F_x}{\chi_B \cdot F_{pl}} + \frac{M_y}{M_{ply}} \cdot k_y + \frac{M_z}{M_{plz}} \cdot k_z \quad S_{He} = 0.594$$

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

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