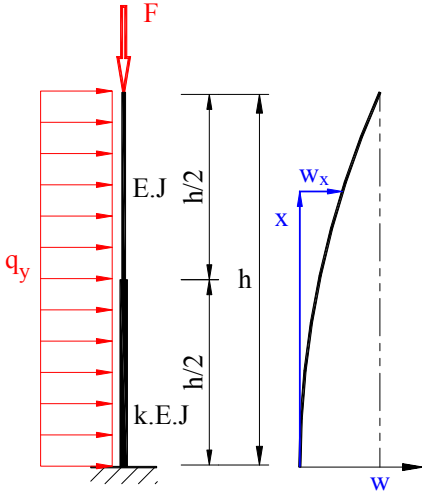


## Zorlama: Eksenel kuvvet ve yayılı yatay yük

### Bilinen değerler:



Malzeme := "S235"

$$f_y := 235 \cdot \text{MPa}$$

$$E := 210000 \cdot \text{MPa}$$

$$\gamma_M := 1.1$$

$$h_S := 4 \cdot \text{m}$$

Emniyetli akma mukavemeti

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

$$f_{EM} = 213.6 \cdot \text{MPa}$$

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

Kabul: Eğrinin şekli parabol

$$q_y := 30 \cdot \text{kN} \cdot \text{m}^{-1}$$

**Yayılı yatay yük y yönünde olduğundan hesaplar z eksenine göre yapılır.**

### 1. Kısım

$$b1 := 320 \cdot \text{mm}$$

$$h1 := 320 \cdot \text{mm}$$

$$t := 10 \cdot \text{mm}$$

$$b_c := 10 \cdot \text{mm}$$

$$y1 := 0.5 \cdot (b1 + t) - b_c$$

$$y1 = 155 \cdot \text{mm}$$

$$J_{z1} := 2 \cdot \frac{b1^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h1}{12} + 2 \cdot t \cdot h1 \cdot y1^2$$

$$J_{z1} = 208.4 \cdot 10^6 \cdot \text{mm}^4$$

$$W_{z1} := \frac{2 \cdot J_{z1}}{b1}$$

$$W_{z1} = 1302.7 \cdot 10^3 \cdot \text{mm}^3$$

$$EJ_{z1} := E \cdot J_{z1}$$

$$EJ_{z1} = 43.8 \cdot \text{MN} \cdot \text{m}^2$$

$$A_{\text{tot}1} := 2 \cdot t \cdot (b1 + h1)$$

$$A_{\text{tot}1} = 12800 \cdot \text{mm}^2$$

### 2. Kısım: $k := 1.5$

$$b2 := k \cdot b1$$

$$b2 = 480 \cdot \text{mm}$$

$$h2 := k \cdot h1$$

$$h2 = 480 \cdot \text{mm}$$

$$h_{2T} := h2 + 2 \cdot t$$

$$h_{2T} = 500 \cdot \text{mm}$$

$$y2 := 0.5 \cdot (b2 + t) - b_c$$

$$y2 = 235 \cdot \text{mm}$$

$$J_{z2} := 2 \cdot \frac{b2^3 \cdot t}{12} + 2 \cdot \frac{t^3 \cdot h2}{12} + 2 \cdot t \cdot h2 \cdot y2^2$$

$$J_{z2} = 714.6 \cdot 10^6 \cdot \text{mm}^4$$

$$W_{z2} := \frac{2 \cdot J_{z2}}{b2}$$

$$W_{z2} = 2977.3 \cdot 10^3 \cdot \text{mm}^3$$

$$EJ_{z2} := E \cdot J_{z2}$$

$$EJ_{z2} = 150.1 \cdot \text{MN} \cdot \text{m}^2$$

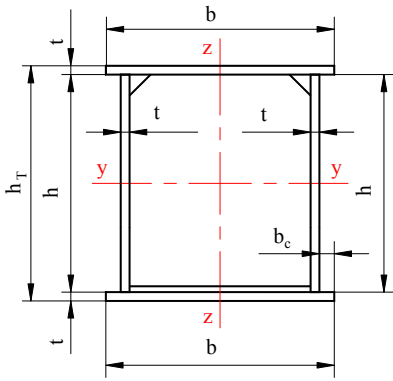
$$k_{Jz} := \frac{J_{z2}}{J_{z1}}$$

$$k_{Jz} = 3.428$$

$$A_{\text{tot}2} := 2 \cdot t \cdot (b2 + h2)$$

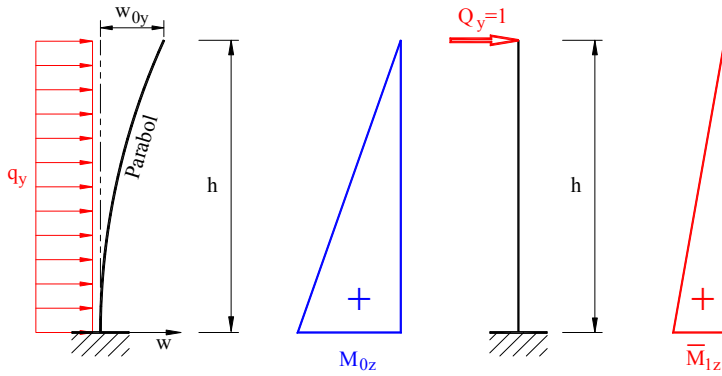
$$A_{\text{tot}2} = 19200 \cdot \text{mm}^2$$

Resim 1



Resim 2

### Çözüm: 1. dereceli hesaplama kuralına göre Resim 3



$$M_{0z} := 0.5 \cdot q_y \cdot h_S^2$$

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

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

$$w_{0y1} = \int_0^{h_S} M_{0z} \cdot M_{1z} \cdot \frac{1}{EJ_{z1}} dx$$

$$w_{0y2} = \int_0^{h_S} M_{0z} \cdot M_{1z} \cdot \frac{1}{k \cdot EJ_{z1}} dx$$

$$w_{0y} = w_{0y1} + w_{0y2} = \frac{1}{3} \cdot \frac{q_y \cdot h_S^2}{2} \cdot h_S \cdot \frac{h_S}{2 \cdot EJ_{z1}} + \frac{1}{3} \cdot \frac{q_y \cdot h_S^2}{2} \cdot h_S \cdot \frac{h_S}{2 \cdot k \cdot EJ_{z1}}$$

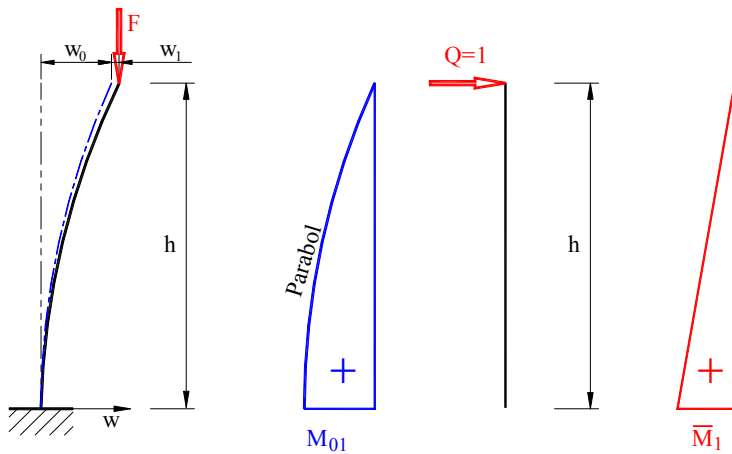
$$w_{0y} = \frac{1}{3} \cdot \frac{q_y \cdot h_S^2}{2} \cdot h_S \cdot \frac{h_S}{2 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_{0y} := \frac{q_y \cdot h_S^4}{12 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_{0y} = 24.370 \cdot \text{mm}$$

### Vianelloya göre çözüm:

Resim 4



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

$$M_1 = h_S$$

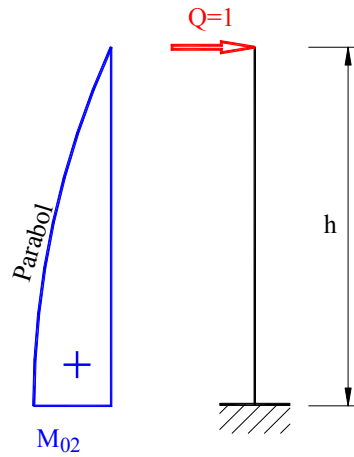
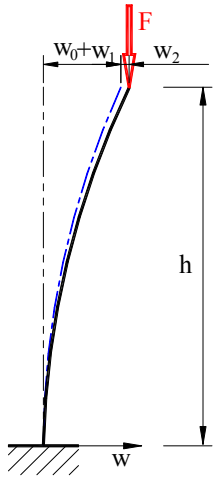
$$w_{11} = \int_0^{h_S} M_{01} \cdot M_1 \cdot \frac{1}{EJ} dx$$

$$w_{12} = \int_0^{h_S} M_{01} \cdot M_1 \cdot \frac{1}{k \cdot EJ} dx$$

$$w_1 = w_{11} + w_{12} = \frac{5}{12} \cdot F_x \cdot w_0 \cdot h_S \cdot \frac{h_S}{2 \cdot E \cdot J_{z1}} + \frac{5}{12} \cdot F_x \cdot w_0 \cdot h_S \cdot \frac{h_S}{2 \cdot k \cdot E \cdot J_{z1}}$$

$$w_1 := \frac{5 \cdot F_x \cdot w_{0y} \cdot h_S^2}{24 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_1 = 2.165 \cdot \text{mm}$$



$$M_{02} := F_x \cdot w_1$$

$$M_1 = h_S$$

$$w_{21} = \int_0^{h_S} M_{02} \cdot M_1 \cdot \frac{1}{EJ} dx$$

$$w_{22} = \int_0^{h_S} M_{02} \cdot M_1 \cdot \frac{1}{k \cdot EJ} dx$$

$$w_2 = w_{21} + w_{22} = \frac{5}{12} \cdot M_{01} \cdot M_1 \cdot \frac{h_S}{2 \cdot EJ} + \frac{5}{12} \cdot M_{01} \cdot M_1 \cdot \frac{h_S}{2 \cdot k \cdot EJ}$$

$$w_2 := \frac{5 \cdot F_x \cdot w_1 \cdot h_S^2}{24 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_2 = 0.192 \cdot \text{mm}$$

Böylece devam edersek

$$w_3 := \frac{5 \cdot F_x \cdot w_2 \cdot h_S^2}{24 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_3 = 0.017 \cdot \text{mm}$$

Toplam sehım

$$w_{\text{Tot}} := w_{0y} + w_1 + w_2 + w_3$$

$$w_{\text{Tot}} = 26.745 \cdot \text{mm}$$

Toplam Moment

$$M_{\text{Tot}} := 0.5 \cdot q_y \cdot h_S^2 + F_x \cdot w_{\text{Tot}}$$

$$M_{\text{Tot}} = 258.72 \cdot \text{kN} \cdot \text{m}$$

### Kritik burkulma kuvveti

$$w_1 = \frac{5 \cdot F_x \cdot w_0 \cdot h_S^2}{24 \cdot EJ} \cdot \left(1 + \frac{1}{k}\right)$$

eğer  $F_x = F_{kr}$  ve  $w_0 = w_1$  veya

$$\alpha_F = \frac{w_1}{w_0} = 1 \quad \text{kabul edersek:}$$

$$1 = \frac{5 \cdot F_{cr} \cdot h_S^3}{24 \cdot EJ} \cdot \left(\frac{k+1}{k}\right)$$

$$F_{kr} := \frac{24 \cdot EJ_{z1}}{5 \cdot h_S^2} \cdot \frac{k}{k+1}$$

$$F_{kr} = 7878.5 \cdot \text{kN}$$

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

**Sonuç: Çubukta burkulma tehlikesi yoktur.**

### Kesit II de mukavemet hesabı:

Eylemsizlik radyusu

$$i_{z2} := \sqrt{\frac{J_{z2}}{A_{\text{tot}2}}}$$

$$i_{z2} = 192.9 \cdot \text{mm}$$

Euler burkulma boyu

$$L_{B2} := \sqrt{\frac{k \cdot EJ_{z1} \cdot \pi^2}{F_{kr}}}$$

$$L_{B2} = 9.069 \cdot \text{m}$$

Akma narinliği

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

$$\lambda_E = 93.9$$

|                             |  |                                    |
|-----------------------------|--|------------------------------------|
| Narinlik                    | $\lambda_{z2} := \frac{L_{B2}}{i_{z2}}$  | $\lambda_{z2} = 47$                |
| Bağıntılı narinlik          | $\lambda_{Bz2} := \frac{\lambda_{z2}}{\lambda_E}$  | $\lambda_{Bz2} = 0.501$            |
| Merkez noktası mesafesi     | $k_{el2} := \frac{W_{z2}}{A_{tot2}}$   | $k_{el2} = 155.1 \cdot \text{mm}$  |
| Akma kuvveti                | $F_{pl2} := A_{tot2} \cdot f_{EM}$   | $F_{pl2} = 4101.8 \cdot \text{kN}$ |
| Burkulma parametresi        | $\alpha_B := 0.34$ Kaynaklı kutular her ekseninde.   |                                    |
| Burkulma yardımcı faktörü   | $\varphi_{Bz2} := 0.5 \cdot \left[ 1 + \alpha_B \cdot (\lambda_{Bz2} - 0.2) + \lambda_{Bz2}^2 \right]$ | $\varphi_{Bz2} = 0.68$             |
| Azaltma faktörü             | $\chi_{Bz2} := \frac{1}{\varphi_{Bz2} + \sqrt{\varphi_{Bz2}^2 - \lambda_{Bz2}^2}}$                     | $\chi_{Bz2} = 0.884$               |
| Kuvvetin mukavemet emniyeti | $S_{Fz2} := \frac{F_x}{\chi_{Bz2} \cdot F_{pl2}}$  | $S_{Fz2} = 0.193$                  |

### **Moment kontrolü:**

|                           |   |   |
|---------------------------|---|---|
| Kesit II de toplam Moment | $M_{II} := M_{Tot}$                                       | $M_{II} = 258.72 \cdot \text{kN} \cdot \text{m}$  |
|                           | $M_{plz2} := W_{z2} \cdot f_{EM}$                         | $M_{plz2} = 636.1 \cdot \text{kN} \cdot \text{m}$ |
|                           | $M_{bvor2} := F_x \cdot w_{Tot}$                          | $M_{bvor2} = 18.7 \cdot \text{kN} \cdot \text{m}$ |
|                           | $M_2 := F_x \cdot w_{Tot}$                                | $M_2 = 18.7 \cdot \text{kN} \cdot \text{m}$       |
|                           | $\Delta M2 := \frac{M_2}{M_{II}}$                         | $\Delta M2 = 0.072$                               |
|                           | $\beta_{mz2} := 0.66 + 0.44 \cdot \Delta M2$              | $\beta_{mz2} = 0.69$                              |
|                           | $S_{MII} := \frac{\beta_{mz2} \cdot M_{bvor2}}{M_{plz2}}$ | $S_{MII} = 0.020$                                 |
|                           |   | $\Delta n := 0.1$                                 |
|                           | $S_{II} := S_{Fz2} + S_{MII} + \Delta n$                  | $S_{II} = 0.313$                                  |

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

### **Kesit I de mukavemet hesabı:**

|                     |   |                                  |
|---------------------|---|----------------------------------|
| Eylemsizlik radyusu | $i_{z1} := \sqrt{\frac{J_{z1}}{A_{tot1}}}$            | $i_{z1} = 127.6 \cdot \text{mm}$ |
| Euler burkulma boyu | $L_{B1} := \sqrt{\frac{EJ_{z1} \cdot \pi^2}{F_{kr}}}$ | $L_{B1} = 7.405 \text{ m}$       |

Akma narınlığı

$\lambda_E = 93.9$

Narinlik

$$\lambda_{z1} := \frac{L_{B1}}{i_{z1}}$$

$\lambda_{z1} = 58$

Bağıntılı narinlik

$$\lambda_{Bz1} := \frac{\lambda_{z1}}{\lambda_E}$$

$\lambda_{Bz1} = 0.618$

Merkez noktası mesafesi

$$k_{el1} := \frac{W_{z1}}{A_{tot1}}$$

$k_{el1} = 101.8 \cdot \text{mm}$

Akma kuvveti

$$F_{pl1} := A_{tot1} \cdot f_{EM}$$

$F_{pl1} = 2734.5 \cdot \text{kN}$

Burkulma parametresi

$\alpha_B = 0.34$  Kaynaklı kutular her ekseninde.

Burkulma yardımcı faktörü

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

$\varphi_{Bz1} = 0.76$

Azaltma faktörü

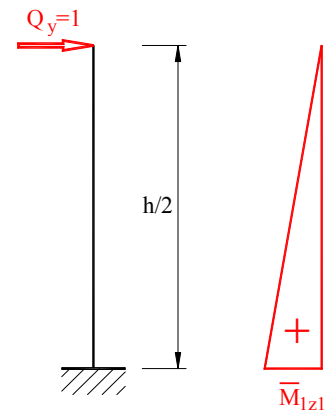
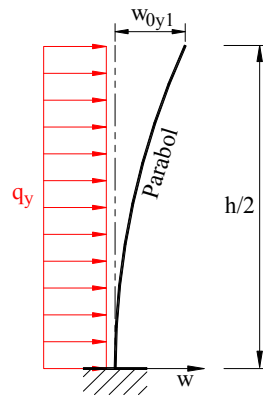
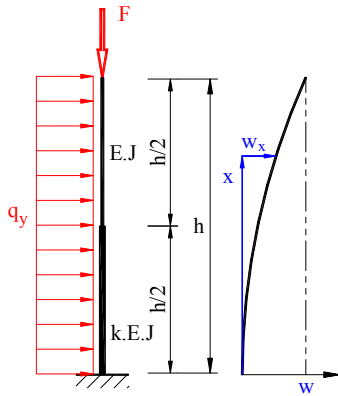
$$\chi_{Bz1} := \frac{1}{\varphi_{Bz1} + \sqrt{\varphi_{Bz1}^2 - \lambda_{Bz1}^2}}$$

$\chi_{Bz1} = 0.828$

Kuvvetin mukavemet emniyeti

$$S_{Fz1} := \frac{F_x}{\chi_{Bz1} \cdot F_{pl1}}$$

$S_{Fz1} = 0.309$

**Kesit I de moment kontrolü:**

$$w_{0y1} = \int_0^{h_s} M_{0z1} \cdot M_{1z1} \cdot \frac{1}{EJ_{z1}} dx$$

$$M_{0z1} := \frac{q_y \cdot h_s^2}{8}$$

$$M_1 = \frac{h_s}{2}$$

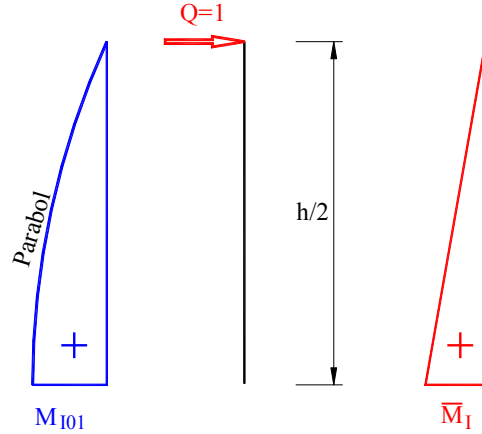
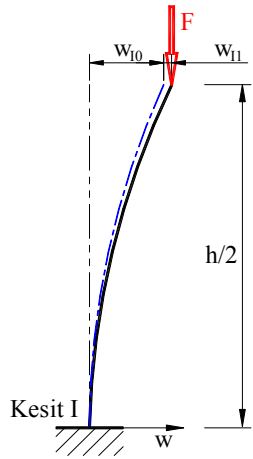
$$w_{10} = \frac{1}{3} \cdot M_{0z1} \cdot M_{1z1} \cdot \frac{h_s}{2 \cdot EJ_{z1}}$$

$$w_{10} = \frac{1}{3} \cdot \frac{q_y \cdot h_s^2}{8} \cdot \frac{h_s}{2} \cdot \frac{h_s}{2 \cdot EJ_{z1}}$$

$$w_{0y1} := \frac{q_y \cdot h_s^4}{96 \cdot EJ_{z1}}$$

$w_{0y1} = 1.828 \cdot \text{mm}$

## Vianelloya göre



$$M_{I01} := F_x \cdot w_{0y1}$$

$$M_{I1} := \frac{h_S}{2}$$

$$w_{I1} = \int_0^{h_S} M_{I01} \cdot M_{I1} \cdot \frac{1}{EJ_{z1}} dx$$

$$w_{I1} = \frac{5}{12} \cdot M_{I01} \cdot M_{I1} \cdot \frac{h_S}{2 \cdot EJ_{z1}}$$

$$w_{I1} = \frac{5}{12} \cdot F_x \cdot w_{0y1} \cdot \frac{h_S}{2} \cdot \frac{h_S}{2 \cdot EJ_{z1}}$$

$$w_{I1} := \frac{5 \cdot F_x \cdot w_{0y1} \cdot h_S^2}{48 \cdot EJ_{z1}}$$

$$w_{I1} = 0.049 \cdot \text{mm}$$

Böylece devam ederseniz

$$w_{I2} := \frac{5 \cdot F_x \cdot w_{I1} \cdot h_S^2}{48 \cdot EJ_{z1}}$$

$$w_{I2} = 0.001 \cdot \text{mm}$$

$$w_{I3} := \frac{5 \cdot F_x \cdot w_{I2} \cdot h_S^2}{48 \cdot EJ_{z1}}$$

$$w_{I3} = 0.000 \cdot \text{mm}$$

Toplam sehım

$$w_I := w_{0y1} + w_{I1} + w_{I2} + w_{I3}$$

$$w_I = 1.878 \cdot \text{mm}$$

veya

$$\alpha_{FI} := \frac{w_{I2}}{w_{I1}}$$

$$\alpha_{FI} = 0.027$$

$$\mu_{FI} := \frac{1}{1 - \alpha_{FI}}$$

$$\mu_{FI} = 1.027$$

$$w_{I\max} := w_{0y1} \cdot \mu_{FI}$$

$$w_{I\max} = 1.878 \cdot \text{mm}$$

Toplam Moment

$$M_I := \frac{q_y \cdot h_S^2}{8} + F_x \cdot w_{I1}$$

$$M_I = 60.03 \cdot \text{kN} \cdot \text{m}$$

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

$$M_{plz1} = 278.3 \cdot \text{kN} \cdot \text{m}$$

$$M_{IF} := F_x \cdot w_I$$

$$M_{IF} = 1.3 \cdot \text{kN} \cdot \text{m}$$

 $\Delta M < 1$ 

$$\Delta M1 := \frac{M_{IF}}{M_I}$$

$$\Delta M1 = 0.022$$

$$\beta_{mz1} := 0.66 + 0.44 \cdot \Delta M1$$

$$\beta_{mz1} = 0.67$$

$$S_{IM} := \frac{\beta_{mz1} \cdot M_I}{M_{plz1}}$$

$$S_{IM} = 0.144$$

$$\Delta n = 0.1$$

$$S_I := S_{Fz1} + S_{IM} + \Delta n$$

$$S_I = 0.554$$

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

**SON**