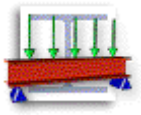
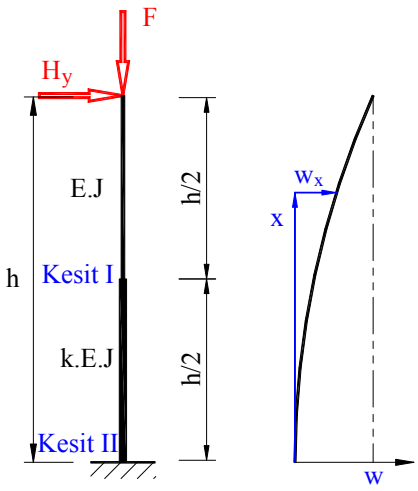
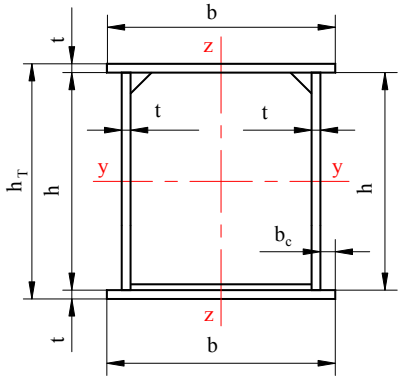


# Zorlama: Eksenel kuvvet ve yatay tek kuvvet

## Bilinen değerler:




Resim 1




Resim 2

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 $H_y := 60\cdot kN$

***Yatay tek kuvvet y yönünde olduğundan hesaplar z eksenine göre yapılır.***

### 1. Kısım

$b1 := 320\cdot mm$ $h1 := 320\cdot mm$ $t := 10\cdot mm$ $b_ç := 10\cdot mm$

$y1 := 0.5\cdot(b1 + t) - b_ç$ $y1 = 155\cdot mm$

$J_{z1} := 2\cdot\frac{b1^3\cdot t}{12} + 2\cdot\frac{t^3\cdot h1}{12} + 2\cdot t\cdot h1\cdot y1^2$ $J_{z1} = 208.4\cdot 10^6\cdot mm^4$

$W_{z1} := \frac{2\cdot J_{z1}}{b1}$ $W_{z1} = 1302.7\cdot 10^3\cdot mm^3$

$EJ_{z1} := E\cdot J_{z1}$ $EJ_{z1} = 43.8\cdot MN\cdot m^2$

$A_{tot1} := 2\cdot t\cdot(b1 + h1)$ $A_{tot1} = 12800\cdot mm^2$

### 2. Kısım:

$k := 1.5$ $b2 := k\cdot b1$ $b2 = 480\cdot mm$

$h2 := k\cdot h1$ $h2 = 480\cdot mm$

$h_{2T} := h2 + 2\cdot t$ $h_{2T} = 500\cdot mm$

$y2 := 0.5\cdot(b2 + t) - b_ç$ $y2 = 235\cdot mm$

$J_{z2} := 2\cdot\frac{b2^3\cdot t}{12} + 2\cdot\frac{t^3\cdot h2}{12} + 2\cdot t\cdot h2\cdot y2^2$ $J_{z2} = 714.6\cdot 10^6\cdot mm^4$

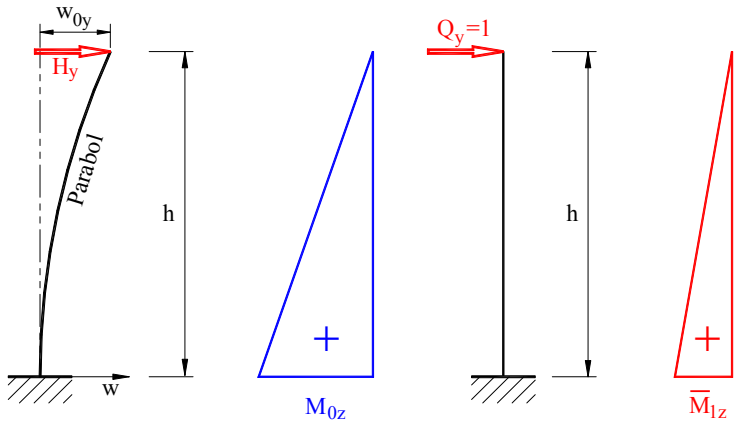
$W_{z2} := \frac{2\cdot J_{z2}}{b2}$ $W_{z2} = 2977.3\cdot 10^3\cdot mm^3$

$EJ_{z2} := E\cdot J_{z2}$ $EJ_{z2} = 150.1\cdot MN\cdot m^2$

$k_{Jz} := \frac{J_{z2}}{J_{z1}}$ $k_{Jz} = 3.428$

$A_{tot2} := 2\cdot t\cdot(b2 + h2)$ $A_{tot2} = 19200\cdot mm^2$

## Çözüm: 1. dereceli hesaplama kuralına göre




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

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

$M_{1z} := h_S$

$$w_{0y1} = \int_0^{\frac{h_S}{2}} M_{0z} \cdot M_{1z} \cdot \frac{1}{EJ_{z1}}\, dx$$

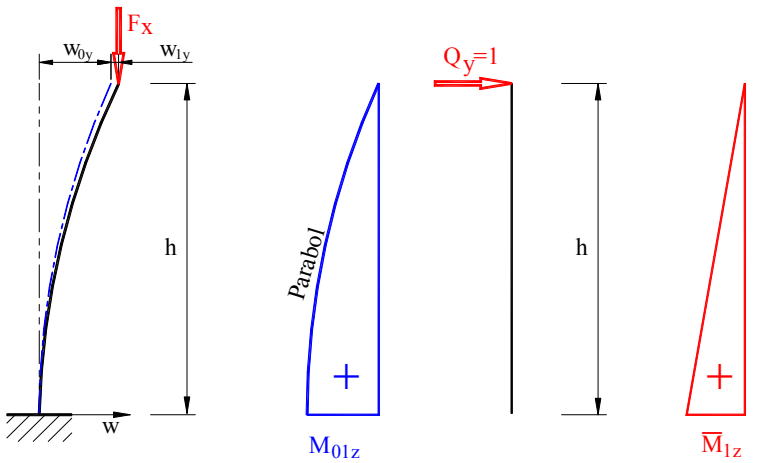
$$w_{0y2} = \int_0^{\frac{h_S}{2}} M_{0z} \cdot M_{1z} \cdot \frac{1}{k \cdot EJ_{z1}}\, dx$$

$$w_{0y} = w_{01} + w_{02} = \frac{1}{3} \cdot M_{0z} \cdot M_{1z} \cdot \frac{h_S}{2 \cdot EJ_{z1}} + \frac{1}{3} \cdot M_{0z} \cdot M_{1z} \cdot \frac{h_S}{2 \cdot k \cdot EJ_{z1}} \qquad w_{0y} = \frac{1}{3} \cdot M_{0z} \cdot M_{1z} \cdot \frac{h_S}{EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

$$w_{0y} = \frac{1}{3} \cdot H_y \cdot h_S \cdot h_S \cdot \frac{h_S}{2 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right) \qquad w_{0y} := \frac{H_y \cdot h_S^{\,3}}{6 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right)$$

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

## Vianelloya göre çözüm:




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

$M_{1z} = h_S$

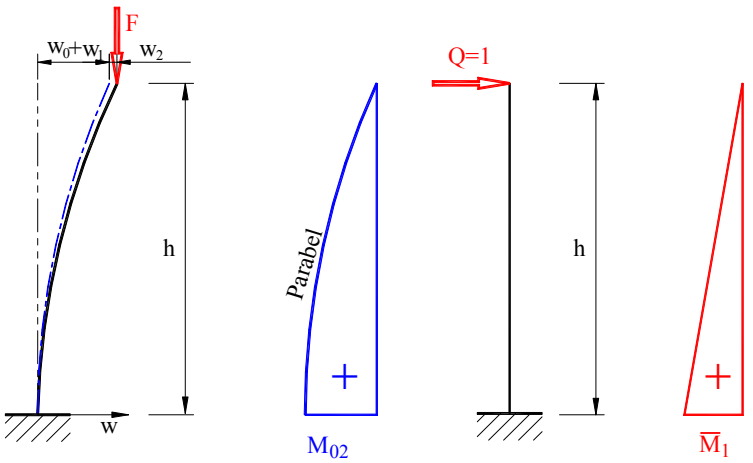
$$w_{11y} = \int_0^{\frac{h_S}{2}} M_{01z} \cdot M_{1z} \cdot \frac{1}{EJ_{z1}}\, dx$$

$$w_{12y} = \int_0^{\frac{h_S}{2}} M_{01z} \cdot M_{1z} \cdot \frac{1}{k \cdot EJ_{z1}}\, dx$$

$$w_{1y} = w_{11y} + w_{12y} = \frac{5}{12} \cdot F_x \cdot w_{0y} \cdot h_S \cdot \frac{h_S}{2 \cdot E \cdot J_{z1}} + \frac{5}{12} \cdot F_x \cdot w_{0y} \cdot h_S \cdot \frac{h_S}{2 \cdot k \cdot E \cdot J_{z1}}$$

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

$w_{1y} = 2.165 \cdot mm$




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

$M_{1z} = h_S$

$$w_{21y} = \int_0^{\frac{h_S}{2}} M_{02z} \cdot M_{1z} \cdot \frac{1}{EJ_{z1}}\, dx$$

$$w_{22} = \int_0^{\frac{h_S}{2}} M_{02z} \cdot M_{1z} \cdot \frac{1}{k \cdot EJ_{z1}}\, dx$$

$$w_{2y} = w_{21y} + w_{22y} = \frac{5}{12} \cdot M_{01z} \cdot M_{1z} \cdot \frac{h_S}{2 \cdot EJ_{z1}} + \frac{5}{12} \cdot M_{01z} \cdot M_{1z} \cdot \frac{h_S}{2 \cdot k \cdot EJ_{z1}} \qquad w_{2y} := \frac{5 \cdot F_x \cdot w_{1y} \cdot h_S^{\,2}}{24 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right) \qquad w_{2y} = 0.192 \cdot mm$$

Böylece devam edersek

$$w_{3y} := \frac{5 \cdot F_x \cdot w_{2y} \cdot h_S^{\,2}}{24 \cdot EJ_{z1}} \cdot \left(1 + \frac{1}{k}\right) \qquad w_{3y} = 0.017 \cdot mm$$

Toplam sehim $w_y := w_{0y} + w_{1y} + w_{2y} + w_{3y}$ $w_y = 26.745 \cdot mm$

Toplam Moment $M_{Tot} := H_y \cdot h_S + F_x \cdot w_y$ $M_{Tot} = 258.72 \cdot kN \cdot m$

## 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 $F_x = Fk_r$ ve $w_0 = w_1$ veya $\alpha_F = \frac{w_1}{w_0} = 1$ kabul edersek:

$$1 = \frac{5 \cdot F_{kr} \cdot h_S^{\,3}}{24 \cdot EJ_{z1}} \cdot \left(\frac{k+1}{k}\right) \qquad F_{kr} := \frac{24}{5} \cdot \frac{EJ_{z1}}{h_S^{\,2}} \cdot \frac{k}{k+1} \qquad F_{kr} = 7878.5 \cdot kN$$

$F_x = 700 \cdot kN$

***Sonuç: Çubukta burkulma tehlikesi yoktur.***

## Kesit II de mukavemet hesabı:

Eylemsizlık radyusu $i_{z2} := \sqrt{\frac{J_{z2}}{A_{tot2}}}$ $i_{z2} = 192.9 \cdot mm$

Euler burkulma boyu $L_{B2} := \sqrt{\frac{k \cdot EJ_{z1} \cdot \pi^2}{F_{kr}}}$ $L_{B2} = 9.069\,m$

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 $k_{el2} := \frac{W_{z2}}{A_{tot2}}$ $k_{el2} = 155.1 \cdot mm$

Akma kuvveti $F_{pl2} := A_{tot2} \cdot f_{EM}$ $F_{pl2} = 4101.8 \cdot kN$

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

Burkulma yardımcı faktörü $\varphi_{Bz2} := 0.5 \cdot \left[1 + \alpha_B \cdot \left(\lambda_{Bz2} - 0.2\right) + \lambda_{Bz2}^{2}\right]$ $\varphi_{Bz2} = 0.68$

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 $M_{plz2} := W_{z2} \cdot f_{EM}$ $M_{plz2} = 636.1 \cdot kN \cdot m$

$M_2 := F_x \cdot w_y$ $M_2 = 18.7 \cdot kN \cdot m$

$\Delta M2 := \frac{M_2}{M_{Tot}}$ $\Delta M2 = 0.072$

$\beta_{mz2} := 0.66 + 0.44 \cdot \Delta M2$ $\beta_{mz2} = 0.69$

$S_{M2} := \frac{\beta_{mz2} \cdot M_2}{M_{plz2}}$ $S_{M2} = 0.020$

$\Delta n := 0.1$

$S_2 := S_{Fz2} + S_{M2} + \Delta n$ $S_2 = 0.313$

## *Sonuç: $S_2$ değeri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.*

## Kesit I de mukavemet hesabı:

Eylemsizlık radyusu $i_{z1} := \sqrt{\frac{J_{z1}}{A_{tot1}}}$ $i_{z1} = 127.6 \cdot mm$

Euler burkulma boyu $L_{B1} := \sqrt{\frac{E J_{z1} \cdot \pi^2}{F_{kr}}}$ $L_{B1} = 7.405\,m$

Akma narinliği $\lambda_E = 93.9$

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 $k_{el1} := \frac{W_{z1}}{A_{tot1}}$ $k_{el1} = 101.8 \cdot mm$

Akma kuvveti $F_{pl1} := A_{tot1} \cdot f_{EM}$ $F_{pl1} = 2734.5 \cdot kN$

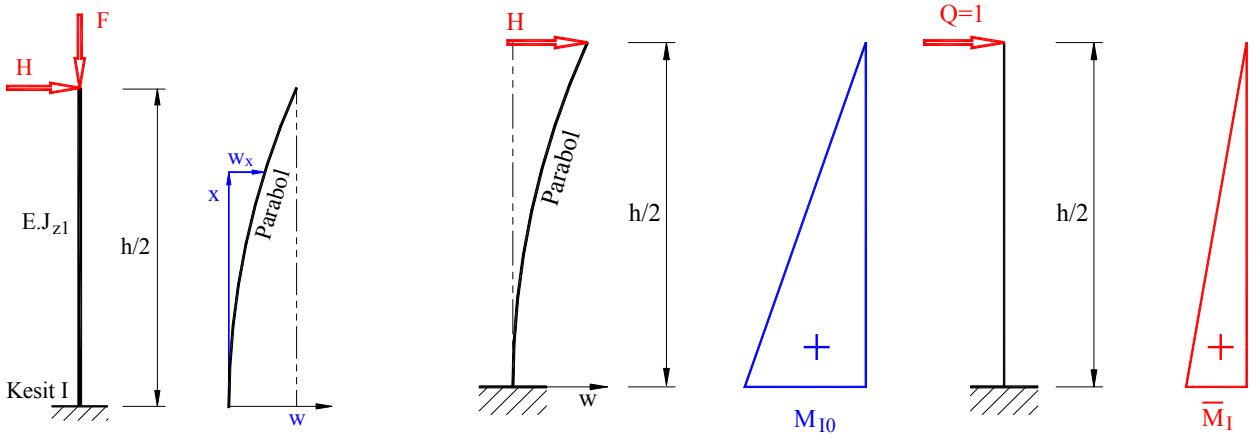
Burkulma parametresi $\alpha_B = 0.34$ Kaynaklı kutular her eksende.

Burkulma yardımcı faktörü $\varphi_{Bz1} := 0.5 \cdot \left[1 + \alpha_B \cdot \left(\lambda_{Bz1} - 0.2\right) + \lambda_{Bz1}^{2}\right]$ $\varphi_{Bz1} = 0.76$

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:*

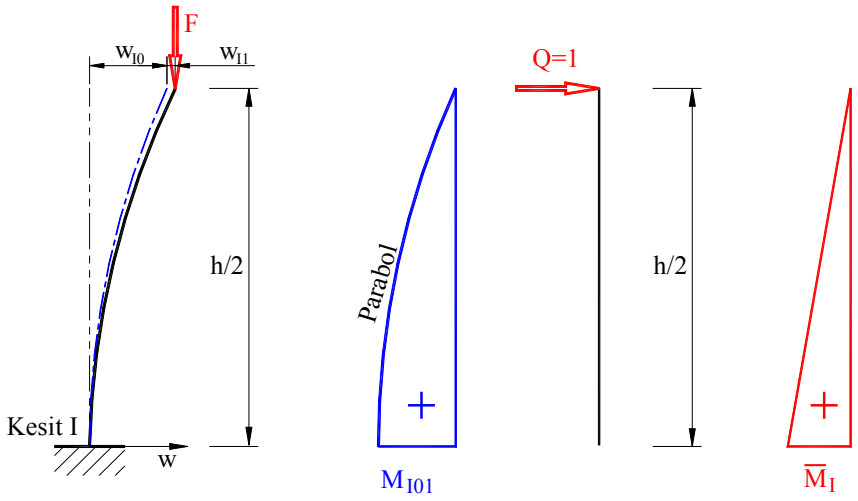



$M_{I0} := 0.5 H_y \cdot h_S$ $M_I = 0.5 \cdot h_S$

$w_{I0} = \int_0^{\frac{h_S}{2}} M_{I0} \cdot M_I \cdot \frac{1}{EJ_{z1}}\, dx$ $w_{I0} = \frac{1}{3} \cdot M_{I0} \cdot M_I \cdot \frac{h_S}{2 \cdot EJ_{z1}}$ $w_{I0} = \frac{1}{3} \cdot \frac{H_y \cdot h_S}{2} \cdot \frac{h_S}{2} \cdot \frac{h_S}{2 \cdot EJ_{z1}}$

$w_{I0} := \frac{H_y \cdot h_S^{3}}{24 \cdot EJ_{z1}}$ $w_{I0} = 3.656 \cdot mm$

## Vianelloya göre çözüm:




$M_{I01} := F_x \cdot w_{I0}$ $M_{I1} := \frac{h_S}{2}$

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

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

$$w_{I1} = \frac{5}{12} \cdot F_x \cdot w_{I0} \cdot \frac{h_S}{2} \cdot \frac{h_S}{2 \cdot EJ_{z1}}$$

$$w_{I1} := \frac{5 \cdot F_x \cdot w_{I0} \cdot h_S^2}{48 \cdot EJ_{z1}}$$

$w_{I1} = 0.097 \cdot mm$

$M_{I02} := F_x \cdot w_{I1}$ $w_{I2} = \int_0^{\frac{h_S}{2}} M_{02} \cdot M_{I1} \cdot \frac{1}{EJ}\, dx$ $w_{I2} = \frac{5}{12} \cdot M_{I02} \cdot M_{I1} \cdot \frac{h_S}{2EJ_{z1}}$ $w_{I2} := \frac{5 \cdot F_x \cdot w_{I1} \cdot h_S^2}{48 \cdot EJ_{z1}}$ $w_{I2} = 0.003 \cdot mm$

Böylece devam edersek $w_{I3} := \frac{5 \cdot F_x \cdot w_{I2} \cdot h_S^2}{48 \cdot EJ_{z1}}$ $w_{I3} = 0.000 \cdot mm$

Toplam sehim $w_I := w_{I0} + w_{I1} + w_{I2} + w_{I3}$ $w_I = 3.756 \cdot mm$

veya $\alpha_{FI} := \frac{w_{I2}}{w_{I1}}$ $\alpha_{FI} = 0.027$

$\mu_{FI} := \frac{1}{1 - \alpha_{FI}}$ $\mu_{FI} = 1.027$

$w_{Imax} := w_{I0} \cdot \mu_{FI}$ $w_{Imax} = 3.756 \cdot mm$

Toplam Moment $M_1 := 0.5 \cdot H_y \cdot h_S + F_x \cdot w_{I1}$ $M_1 = 120.07 \cdot kN \cdot m$

$M_{plz1} := W_{z1} \cdot f_{EM}$ $M_{plz1} = 278.3 \cdot kN \cdot m$

$M_{1F} := F_x \cdot w_I$ $M_{1F} = 2.6 \cdot kN \cdot m$

$\Delta M < 1$ $\Delta M1 := \frac{M_{1F}}{M_1}$ $\Delta M1 = 0.022$

$\beta_{mz1} := 0.66 + 0.44 \cdot \Delta M1$ $\beta_{mz1} = 0.67$

$S_{1M} := \frac{\beta_{mz1} \cdot M_1}{M_{plz1}}$ $S_{1M} = 0.289$

$\Delta n = 0.1$

$S_1 := S_{Fz1} + S_{1M} + \Delta n$ $S_1 = 0.698$

***Sonuç: $S_1$ değeri 1 den küçük olduğundan konstrüksiyon fonksiyonunu yapar.***

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