

1. Przemieszczenie δ_{11}

$$\delta_{11} = \int_b^a \frac{M_y^{01} * M_y^{01}}{E * J_y} + \int_c^b \frac{M_y^{01} * M_y^{01}}{E * J_y} + \int_e^d \frac{M_y^{01} * M_y^{01}}{E * J_y} + \int_c^b \frac{M_z^{01} * M_z^{01}}{E * J_z} + \int_d^c \frac{M_z^{01} * M_z^{01}}{E * J_z} + \int_b^a \frac{M_s^{01} * M_s^{01}}{E * J_s} + \int_d^c \frac{M_s^{01} * M_s^{01}}{E * J_s}$$

$$\begin{aligned} \delta_{11} &= \frac{1}{200 * 10^6 * 18h^4} \\ &* \left[\int_b^a [(6.4 * 6 * 6.4) + (6.4 * 6 * \frac{1}{2} * 6) + (6 * 6 * \frac{1}{2} * 6.4) + (6 * 6 * \frac{1}{2} * \frac{2}{3} * 6)] + \frac{1}{200 * 10^6 * 18h^4} \right. \\ &* \int_c^b [(6.4 * 6 * 6.4)] + \frac{1}{200 * 10^6 * 18h^4} * \int_e^d [(6.4 * 6.4 * \frac{1}{2} * \frac{2}{3} * 6.4)] + \frac{1}{200 * 10^6 * 0.5h^4} \\ &* \int_c^b [(10 * 6 * 10)] + \frac{1}{200 * 10^6 * 0.5h^4} * \int_d^c [(10 * 10 * \frac{1}{2} * \frac{2}{3} * 10)] + \frac{1}{76.92 * 10^6 * 1.794h^4} \\ &* \int_b^a [(6.4 * 10 * 6.4)] + \frac{1}{76.92 * 10^6 * 1.128h^4} * \int_d^c [(10 * 6 * 10)] \left. \right] \\ \delta_{11} &= \frac{548.16}{200 * 10^6 * 18h^4} + \frac{245.76}{200 * 10^6 * 18h^4} + \frac{87.381}{200 * 10^6 * 18h^4} + \frac{600}{200 * 10^6 * 0.5h^4} \\ &+ \frac{333.33}{200 * 10^6 * 0.5h^4} + \frac{409.6}{76.92 * 10^6 * 1.794h^4} + \frac{600}{76.92 * 10^6 * 1.794h^4} \\ \delta_{11} &= \frac{0.152}{10^6 * h^4} + \frac{0.0683}{10^6 * h^4} + \frac{0.0243}{10^6 * h^4} + \frac{6}{10^6 * h^4} + \frac{3.333}{10^6 * h^4} + \frac{2.968}{10^6 * h^4} + \frac{4.348}{10^6 * h^4} \\ \delta_{11} &= \frac{16.894}{10^6 * h^4} \end{aligned}$$

2. Przemieszczenie $\delta_{12} = \delta_{21}$

$$\begin{aligned} \delta_{12} &= \int_b^a \frac{M_y^{01} * M_y^{02}}{E * J_y} + \int_c^b \frac{M_y^{01} * M_y^{02}}{E * J_y} \\ &= \frac{1}{200 * 10^6 * 18h^4} \\ &* \left[\int_b^a [(6.4 * 6 * 6) + (6 * 6 * \frac{1}{2} * 6)] + \frac{1}{200 * 10^6 * 18h^4} * \int_c^b [6.4 * 6 * \frac{1}{2} * 6] \right] \\ \delta_{12} &= \frac{338.4}{200 * 10^6 * 18h^4} + \frac{115.2}{200 * 10^6 * 18h^4} = \frac{0.094}{10^6 * h^4} + \frac{0.032}{10^6 * h^4} \\ \delta_{12} &= \frac{0.126}{10^6 * h^4} \end{aligned}$$

3. Przemieszczenie δ_{22}

$$\begin{aligned} \delta_{22} &= \int_b^a \frac{M_y^{02} * M_y^{02}}{E * J_y} + \int_c^b \frac{M_y^{02} * M_y^{02}}{E * J_y} = \\ &= \frac{1}{200 * 10^6 * 18h^4} * \int_b^a [6 * 6 * 6] + \frac{1}{200 * 10^6 * 18h^4} * \int_c^b [6 * 6 * \frac{1}{2} * \frac{2}{3} * 6] \\ \delta_{12} &= \frac{216}{200 * 10^6 * 18h^4} + \frac{72}{200 * 10^6 * 18h^4} = \frac{0.06}{10^6 * h^4} + \frac{0.02}{10^6 * h^4} \\ \delta_{22} &= \frac{0.08}{10^6 * h^4} \end{aligned}$$

4. Przemieszczenie δ_{1p}

$$\delta_{1p} = \int_b^a \frac{M_y^{01} * M_y^{01}}{E * J_y} + \int_c^b \frac{M_y^{01} * M_y^{01}}{E * J_y} + \int_c^b \frac{M_z^{01} * M_z^{01}}{E * J_z} + \int_b^a \frac{M_s^{01} * M_s^{01}}{E * J_s}$$

$$\delta_{1p} = \frac{1}{200 * 10^6 * 18h^4} * \left[\int_b^a \left[(-36 * 6 * 6.4) + \left(-36 * 6 * \frac{1}{2} * 6 \right) + \left(-24 * 6 * \frac{1}{2} * 6.4 \right) + \left(-24 * 6 * \frac{1}{2} * \frac{2}{3} * 6 \right) \right] + \frac{1}{200 * 10^6 * 18h^4} * \int_c^b \left[\left(-36 * 6 * \frac{1}{2} * 6.4 \right) \right] + \frac{1}{200 * 10^6 * 0.5h^4} * \int_c^b \left[\left(-36 * 6 * \frac{1}{2} * 10 \right) \right] + \frac{1}{76.92 * 10^6 * 1.794h^4} * \int_b^a \left[\left(36 * 6 * (-10) \right) \right] \right]$$

$$\delta_{1p} = \frac{-2779.2}{200 * 10^6 * 18h^4} + \frac{-691.2}{200 * 10^6 * 18h^4} + \frac{-1080}{200 * 10^6 * 0.5h^4} + \frac{-2160}{76.92 * 10^6 * 1.794h^4}$$

$$\delta_{1p} = \frac{-0.772}{10^6 * h^4} + \frac{-0.192}{10^6 * h^4} + \frac{-10.8}{10^6 * h^4} + \frac{-15.653}{10^6 * h^4}$$

$$\delta_{1p} = \frac{-27.417}{10^6 * h^4}$$

5. Przemieszczenie δ_{2p}

$$\delta_{2p} = \int_b^a \frac{M_y^{0p} * M_y^{02}}{E * J_y} + \int_c^b \frac{M_y^{0p} * M_y^{02}}{E * J_y}$$

$$= \frac{1}{200 * 10^6 * 18h^4} * \left[\int_b^a \left[(-36 * 6 * 6) + \left(-24 * 6 * \frac{1}{2} * 6 \right) \right] + \frac{1}{200 * 10^6 * 18h^4} * \int_c^b \left[\left(-36 * 6 * \frac{1}{2} * \frac{2}{3} * 6 \right) \right] \right]$$

$$\delta_{2p} = \frac{-1728}{200 * 10^6 * 18h^4} + \frac{-432}{200 * 10^6 * 18h^4} = \frac{-0.48}{10^6 * h^4} + \frac{-0.12}{10^6 * h^4}$$

$$\delta_{2p} = \frac{-0.6}{10^6 * h^4}$$

6. Rozwiązanie układu równań

$$\begin{cases} 16.894 * X1 + 0.126 * X2 = 27.417 \\ 0.126 * X1 + 0.08 * X2 = 0.6 \end{cases}$$

$$\begin{cases} X1 = 1.53 \\ X2 = 5.58 \end{cases}$$

7. Obliczenie i narysowanie wykresów sił wewnętrznych

$$M_i^{rz} = M_i^{01} * X_1 + M_i^{02} * X_2 + M_i^{0p}; \quad i = x, y, z, s$$

My

$$M_{AB}^{rz} = -12.4 * 1.53 - 6 * (5.58) + 60 = 7.54 \text{ kNm}$$

$$M_{BA}^{rz} = -6.4 * 1.53 - 6 * (5.58) + 36 = -7.27 \text{ kNm}$$

$$M_{BC}^{rz} = -6.4 * 1.53 - 6 * (5.58) + 36 = -7.27 \text{ kNm}$$

$$M_{CB}^{rz} = -6.4 * 1.53 + 0 * (5.58) - 0 = -9.79 \text{ kNm}$$

$$M_{CD}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 \text{ kNm}$$

$$M_{DC}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 \text{ kNm}$$

$$M_{DE}^{rz} = -6.4 * 1.53 + 0 * (5.58) - 0 = -9.79 \text{ kNm}$$

$$M_{ED}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 \text{ kNm}$$

Mx

$$M_{AB}^{rz} = 0 * 1.53 + 0 * (5.58) - 74.4 = -74.4 kNm$$

$$M_{BA}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{BC}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{CB}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{CD}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{DC}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{DE}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{ED}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

Mz

$$M_{AB}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{BA}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{BC}^{rz} = -10 * 1.53 + 0 * (5.58) + 36 = 20.7 kNm$$

$$M_{CB}^{rz} = -10 * 1.53 + 0 * (5.58) - 0 = -15.3 kNm$$

$$M_{CD}^{rz} = -10 * 1.53 + 0 * (5.58) - 0 = -15.3 kNm$$

$$M_{DC}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{DE}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{ED}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

Ms

$$M_{AB}^{rz} = -10 * 1.53 + 0 * (5.58) + 36 = 20.7 kNm$$

$$M_{BA}^{rz} = -10 * 1.53 + 0 * (5.58) + 36 = 20.7 kNm$$

$$M_{BC}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{CB}^{rz} = 0 * 1.53 + 0 * (5.58) - 38.4 = -38.4 kNm$$

$$M_{CD}^{rz} = 6.4 * 1.53 + 0 * (5.58) - 0 = 9.79 kNm$$

$$M_{DC}^{rz} = 6.4 * 1.53 + 0 * (5.58) - 0 = 9.79 kNm$$

$$M_{DE}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

$$M_{ED}^{rz} = 0 * 1.53 + 0 * (5.58) - 0 = 0 kNm$$

Wykresy i sprawdzenia znowu na skanach.