POLITECHNIKA POZNAŃSKA
WYDZIAŁ INŻYNIERII LĄDOWEJ I TRANSPORTU
INSTYTUT ANALIZY KONSTRUKCJI
ZAKŁAD MECHANIKI BUDOWLI

Nazwisko i imię studenta: **Jackowiak Sara**
Rok akademicki: **2023/24**
Grupa **1**
Grupa projektowa: **1**

ĆWICZENIE NR 2

METODA SIŁ

Termin oddania: 16.06.2024

Data	Uwagi sprawdzającego	Podpis

Dla zadanej **BELKI** (9) należy:

1. Korzystając z metody sił obliczyć siły przekrojowe (M, N, T) od zadanego obciążenia i wykonać kontrolę kinematyczną.
2. Zaprojektować przekrój z profilu dwuteowego (IN, IPE, HEB, HEA).
3. Obliczyć obrót przekroju w punkcie "B" korzystając z równania pracy wirtualnej i twierdzenia redukcyjnego.

Dla zadanej **RAMY** (3) należy:

1. Przyjąć wstępnie przekroje I_1 i I_2 (różne) z profili dwuteowych (IN, IPE, HEB, HEA).
2. Korzystając z metody sił obliczyć siły przekrojowe (M, N, T) od zadanego obciążenia i wykonać kontrolę kinematyczną.
3. Sprawdzić naprężenia w obu grupach przekrojów I_1 i I_2 oraz sformułować wnioski (w przypadku niespełnienia warunku nośności, obliczeń nie trzeba powtarzać).
4. Obliczyć przemieszczenie poziome punktu "C" korzystając z równania pracy wirtualnej i twierdzenia redukcyjnego.

We wszystkich obliczeniach przyjąć: E = 210 GPa, σ_{dop} = 235 MPa.

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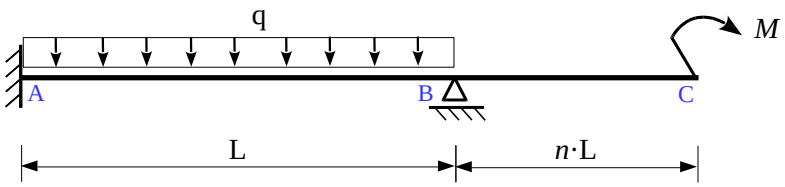
DANE DLA BELKI:

Nr schematu: **9**

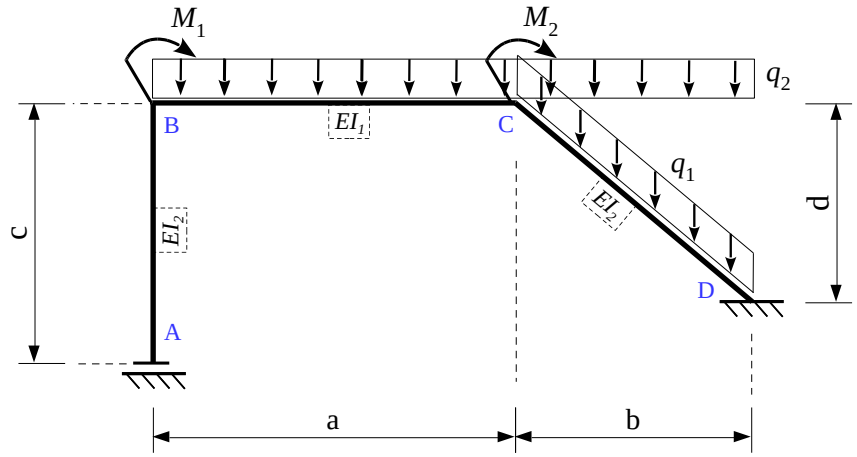


Dane:

L [m]	*n*	q [kN/m]	M [kNm]	P [kN]
6,5	0,6	7,0	16,0	-

DANE DLA RAMY:

Nr schematu: 3

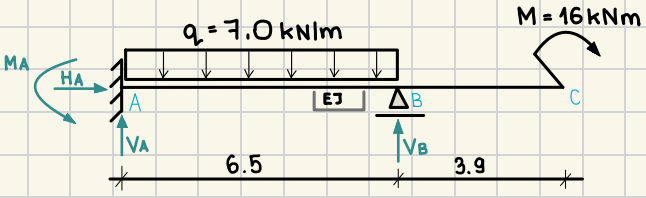


Dane:

a [m]	b [m]	c [m]	d [m]	q_1 [kN/m]	q_2 [kN/m]	M_1 [kNm]	M_2 [kNm]
4,5	4,5	4,8	4,8	13,5	-	14,0	-

Uwaga! Wartość dodatnia oznacza zwrot obciążenia zgodny z podanym na schemacie, ujemna – przeciwny.

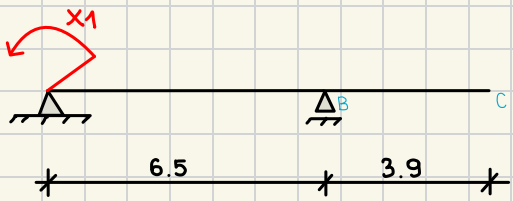
Sara Jackowiak, projekt nr 2



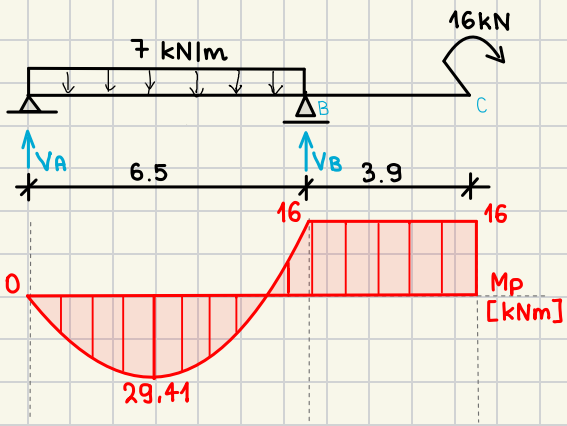
SSN = LR - LRR - LPW
4 - 3 - 0 = 1
SSN = 1

układ równań kanonicznych $\delta_{11} x_1 + \Delta_{1p} = 0$

układ zastępczy



Stan P, $x_1 = 0$

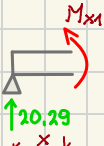


$\Sigma M_A = 0 \Rightarrow -6{,}5 V_B + 7 \cdot 6{,}5 \cdot \frac{1}{2} \cdot 6{,}5 + 16 = 0$

$-6{,}5 V_B + 163{,}875 = 0$ $V_B = 25{,}21$ kN

$\Sigma Y = 0 \Rightarrow 6{,}5 \cdot V_A + 25{,}21 = 0$

$V_A = 20{,}29$ kN

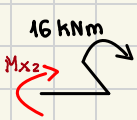


$M_{x1} = 20{,}29x - 7x \cdot \frac{x}{2} = 20{,}29x - 3{,}5x^2$

$M(0) = 0$ kNm $M(6{,}5) = -16$ kNm

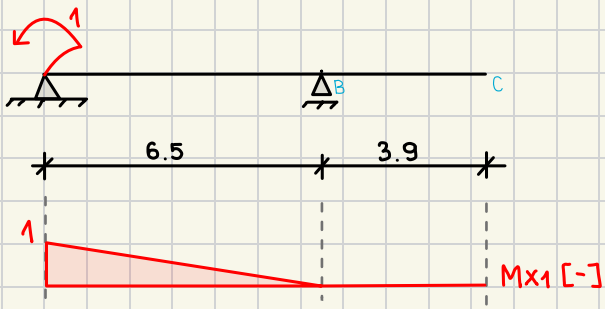
$20{,}29 - 7x = 0 \Rightarrow x = 2{,}8986$ m

$M(2{,}8986) = 29{,}41$ kNm

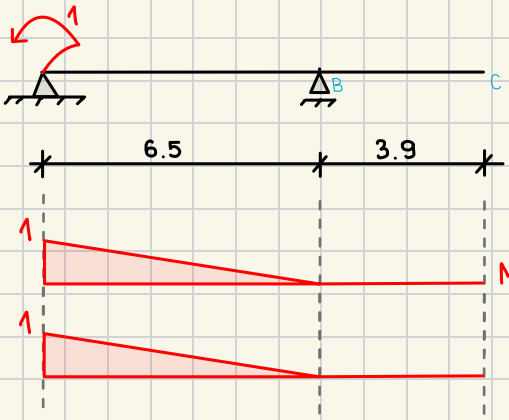


$M_{x2} = -16$ kNm

Stan P=0, x1 = 1

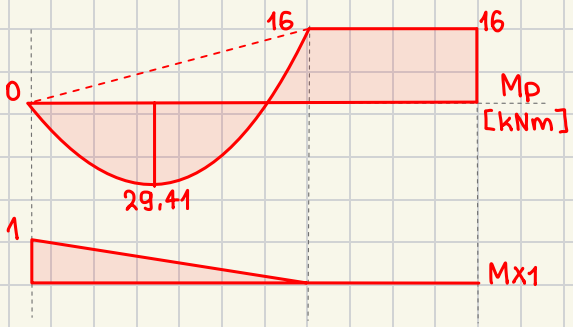


$$\delta_{11} = \int \frac{M_{x1} \cdot M_{x1}}{EJ} \, ds$$



$$\delta_{11} = \frac{1}{EJ}\left[\frac{1}{2} \cdot 1 \cdot 6{,}5 \cdot \frac{2}{3} \cdot 1\right] = \frac{2{,}1667}{EJ}$$

$$\Delta_{1P} = \int \frac{M_P \cdot M_{x1}}{EJ} \, ds$$

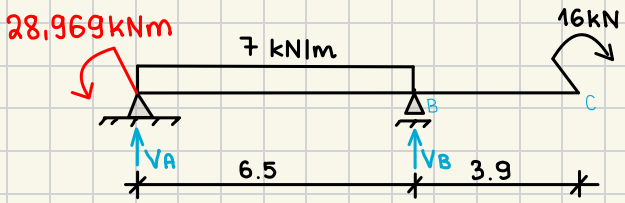


$$\Delta_{1P} = \frac{1}{EJ}\left[\frac{1}{2} \cdot 16 \cdot 6{,}5 \cdot \frac{1}{3} \cdot 1 - \frac{2}{3} \cdot \frac{7 \cdot 6{,}5^2}{8} \cdot 6{,}5 \cdot \frac{1}{2} \cdot 1\right] = -\frac{62{,}7656}{EJ}$$

$$\delta_{11}x_1 + \Delta_{1p} = 0$$

$$\frac{2,1667}{EJ} \cdot x_1 + \left(-\frac{62,7656}{EJ}\right) = 0$$

$$x = 28,969\ kNm$$



$$\Sigma M_A = 7 \cdot 6,5 \cdot \frac{6,5}{2} - 6,5V_B + 16 - 28,969 = 0$$

$$147,875 - 6,5V_B + 16 - 28,969$$

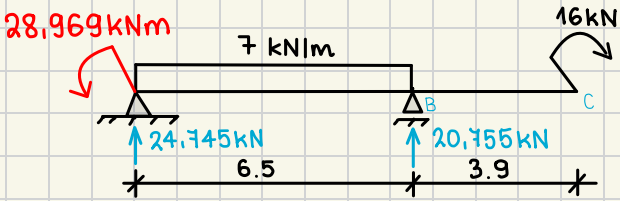
$$-6,5V_B + 134,906 = 0$$

$$V_B = 20,755\ kN$$

$$\Sigma Y = 0 \Rightarrow V_A - 7 \cdot 6,5 + 20,755 = 0$$

$$V_A - 45,5 + 20,755 = 0$$

$$V_A = 24,745\ kN$$



$M_{x1} = -28,969 + 24,745x - 3,5x^2$

$M(0) = -28,969\ kNm$

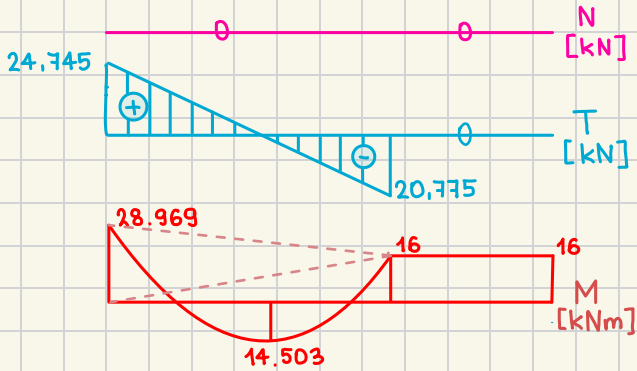
$M(6.5) = -16kNm$

$24,745 - 6,5x = 0$

$6,5x = 24,745 \quad x = 3,81m$

$M(3,81) = 14,503kNm$

$M_{x2} = -16kNm$



Zaprojektowanie przekroju

$E = 210GPa$

$\sigma_{dop} = 235\ MPa$

$\sigma_{max} \leq \sigma_{dop} = 235\ MPa$

$\frac{M_{max}}{W} \leq 235MPa$

$M_{max} = 28,969\ kNm$

$W \geq \frac{2896.9}{23,5} = 123,27\ cm^3$

Przyjęto IPE 180

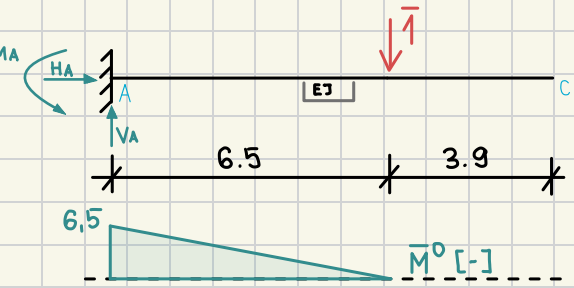
$W = 146,00cm^3$

$J = 1320.00cm^4$

$A = 23,90cm^2$

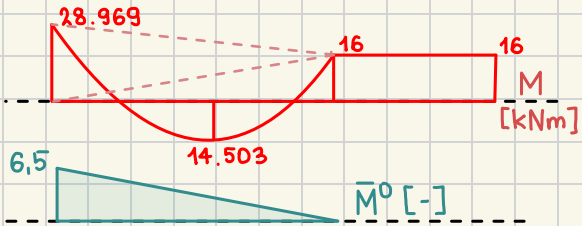
$EJ = 210 \cdot 10^6 \cdot 1320 \cdot 10^{-8} = 2772kNm^2$

Kontrola kinematyczna



$\Sigma Y = 0 \Rightarrow V_A - 1 = 0 \Rightarrow V_A = 2{,}1\,kN$

$\Sigma M_A = 0 \Rightarrow$



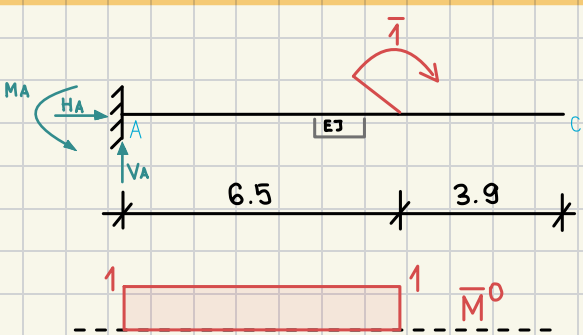
$$\delta_0^V = \Sigma \int \frac{M \cdot \bar{M}^0}{EJ}\, dx$$

$$\delta_0^V = \frac{1}{EJ}\left[\frac{1}{2}\cdot 28{,}969 \cdot 6{,}5 \cdot \frac{2}{3}\cdot 6{,}5 + \frac{1}{2}\cdot 16 \cdot 6{,}5 \cdot \frac{1}{3}\cdot 6{,}5 - \frac{2}{3}\cdot \frac{7\cdot 6{,}5^2}{8}\cdot 6{,}5 \cdot \frac{1}{2}\cdot 6{,}5\right] =$$

$$= \frac{0{,}003520}{EJ} \approx 0$$

Warunek spełniony

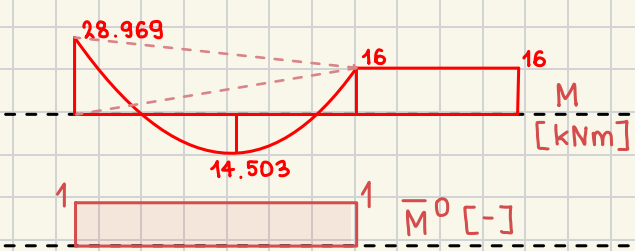
Obrót przekroju w punkcie B



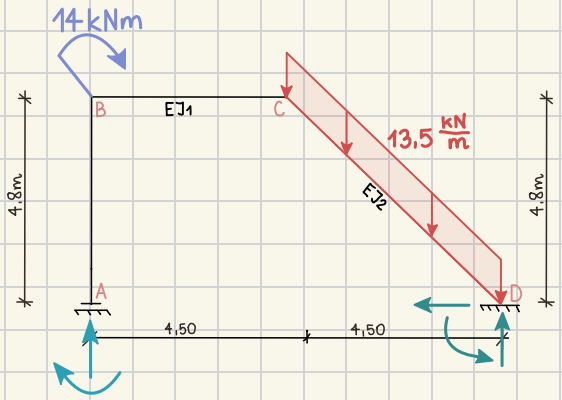
$$\varphi_B = \Sigma \int \frac{M \cdot \bar{M}^0}{EJ}\, dx$$

$$\varphi_B = \frac{1}{EJ}\left[\frac{1}{2}\cdot 28{,}969 \cdot 6{,}5 \cdot 1 + \frac{1}{2}\cdot 16 \cdot 6{,}5 \cdot 1 - \frac{2}{3}\cdot \frac{7\cdot 6{,}5^2}{8}\cdot 6{,}5 \cdot 1\right] =$$

$$= -0{,}005068\ rad = -26{,}49°$$



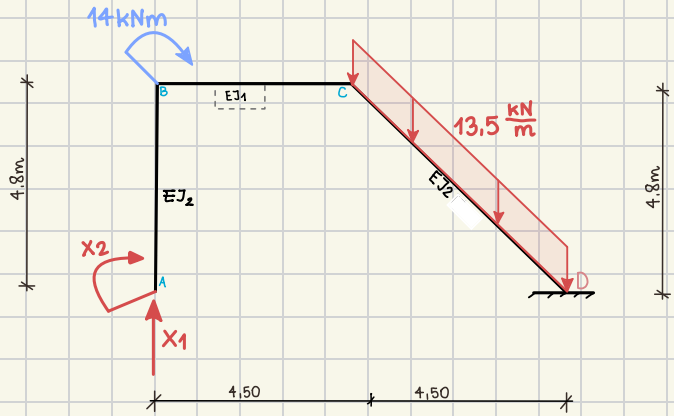
Rama, schemat 3



SSN = LR - LRR - LPW
5 - 3 - 0
SSN = 2

LR - liczba reakcji podporowych
LRR - liczba równań równowagi
LPW - liczba przegubów wewnętrznych

Układ zastępczy



1 Wstępne przyjęcie przekrojów

EJ1 : I 200
J = 2140 cm⁴
A = 33,5 cm²
W = 214 cm³

EJ2 : I 300
J = 9800 cm⁴
A = 69,1 cm²
W = 653 cm³

$EJ_1 = 10^6 \cdot 210 \cdot 10^{-8} \cdot 2140 = 4494\ kNm^2$

$EJ_2 = 10^6 \cdot 210 \cdot 10^{-8} \cdot 9800 = 20580\ kNm^2$

$J_2 = J_0$

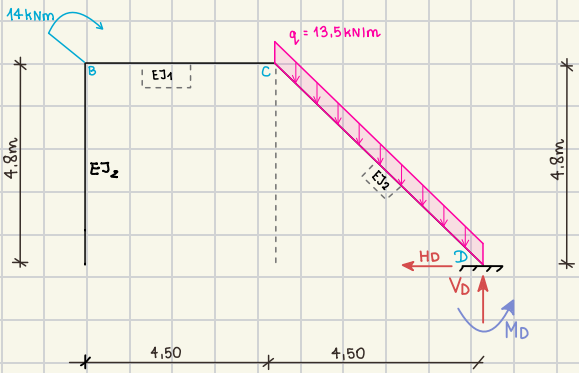
$\frac{J_1}{J_2} = \frac{2140}{9800}$

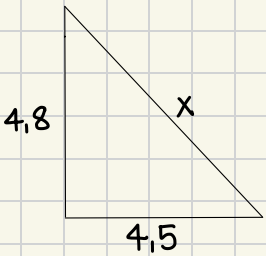
$\frac{J_1}{J_0} = \frac{2140}{9800}$

$J_1 \cdot 9800 = 2140 J_0 \ |:9800$

$J_1 = 0,2184\, J_0$

Stan P, $x_1 = 0$, $x_2 = 0$





$$x = \sqrt{(4,8)^2 + (4,5)^2} = 6,5795$$

$$\sin\alpha = \frac{4,8}{6,5795} = 0,7295$$

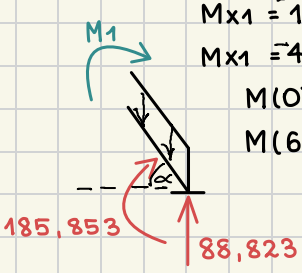
$$\cos\alpha = \frac{4,5}{6,5795} = 0,6839$$

$\Sigma Y = 0 \Rightarrow V_D - 13,5 \times 6,5795 = 0$

$V_D = 88,823\,kN$

$\Sigma M_D = 0 \Rightarrow -13,5 \cdot 6,5795 \cdot 2,25 + 14 - M_D = 0$

$M_D = -185,853\,kN$



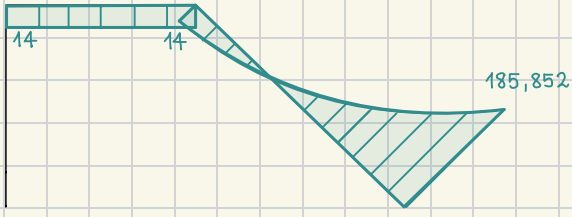
$$M_{x1} = -13,5 \cdot \cos\alpha \cdot x \cdot \frac{x}{2} - 185,853 + 88,823 \cdot x \cdot \cos\alpha$$

$$M_{x1} = -4,616x^2 - 185,852 + 60,75x$$

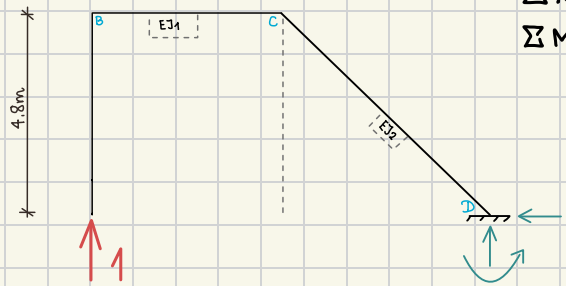
$M(0) = -185,852\,kNm$

$M(6,5795) = 14\,kNm$

$M_{x2} = 14\,kNm$



Stan x1 = 1



$\Sigma Y = 0 \Rightarrow 1 + V_D = 0 \Rightarrow V_D = -1\,kN$

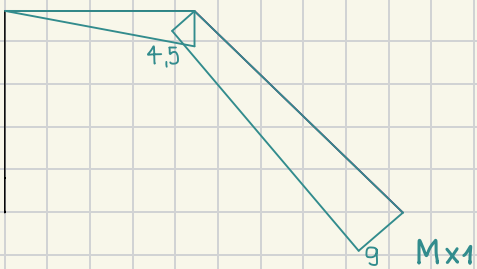
$\Sigma X = 0 \Rightarrow H_D = 0\,kN$

$\Sigma M_D = 0 \Rightarrow 9 - M_D = 0 \Rightarrow M_D = 9\,kNm$

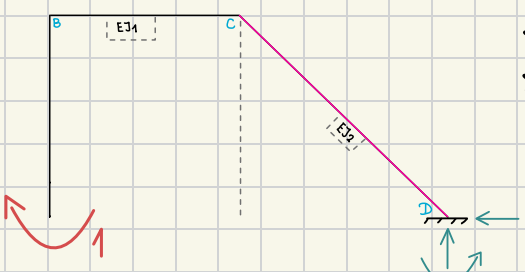
$M_{x1} = 0\,kNm$

$M_{x2} = 1x$ → $M(0) = 0\,kNm$, $M(4,5) = 4,5\,kNm$

$M_{x3} = 1\cos x + 9$ → $M(0) = 9\,kNm$, $M(6,5795) = 4,5\,kNm$



Stan x2 = 1



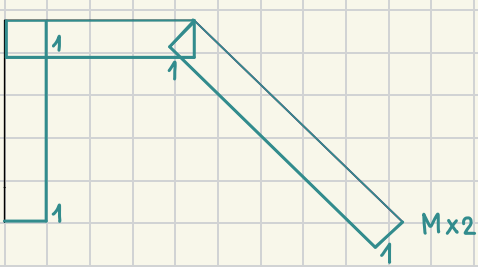
$\Sigma Y = 0 \Rightarrow V_D = 0\,kN$

$\Sigma X = 0 \Rightarrow H_D = 0\,kN$

$\Sigma M_D = 0 \Rightarrow 1 - M_D = 0 \Rightarrow M_D = 1\,kN$

$M_{x1} = 1\,kNm$

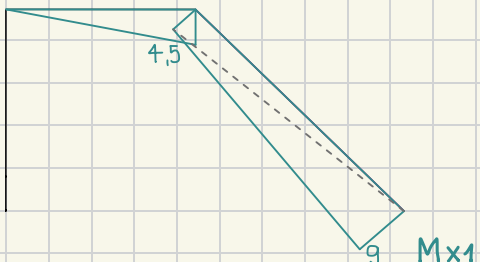
$M_{x1} = 1\,kNm$

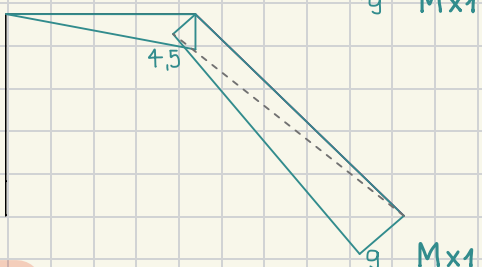


$$\delta_{11} = \sum \int \frac{\bar{M}_{x1} \cdot \bar{M}_{x1}}{EJ} dx$$

$$\delta_{11} = \frac{1}{EJ_1}\left[\frac{1}{2} \cdot 4{,}5 \cdot 4{,}5 \cdot \frac{2}{3} \cdot 4{,}5\right) + \frac{1}{EJ_2}\left(\frac{1}{2} \cdot 4{,}5 \cdot 6{,}5795 \cdot \left(\frac{2}{3} \cdot 4{,}5 + \frac{1}{3} \cdot 9\right) + \frac{1}{2} \cdot 9 \cdot 6{,}5795$$

$$\cdot \left(\frac{1}{3} \cdot 4{,}5 + \frac{2}{3} \cdot 9\right)\Big] = \frac{1}{0{,}2184\ EJ_0} \cdot 30{,}375 + \frac{1}{EJ_0} \cdot 310{,}881 = \frac{449{,}98}{EJ_0}$$

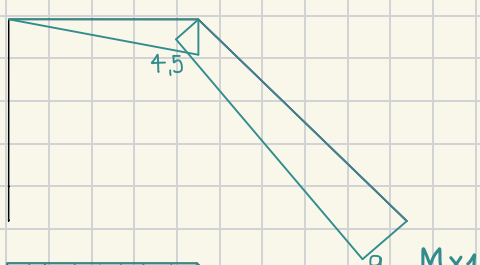


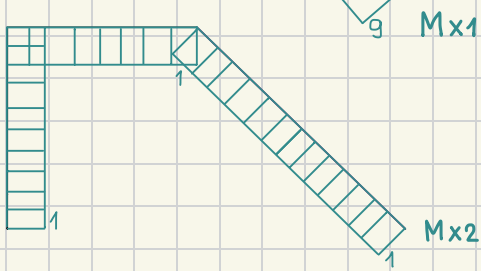


$$\delta_{12} = \sum \int \frac{\bar{M}_{x1} \cdot \bar{M}_{x2}}{EJ} dx$$

$$\delta_{12} = \frac{1}{EJ_1}\left[\frac{1}{2} \cdot 4{,}5 \cdot 4{,}5 \cdot 1\right] + \frac{1}{EJ_2}\left[\frac{1}{2} \cdot 4{,}5 \cdot 6{,}5795 \cdot 1 + \frac{1}{2} \cdot 9 \cdot 6{,}5795 \cdot 1\right] =$$

$$= \frac{1}{0{,}2184 EJ_0} \cdot 10{,}125 + \frac{1}{EJ_0} \cdot 44{,}4116 = \frac{90{,}778}{EJ_0}$$



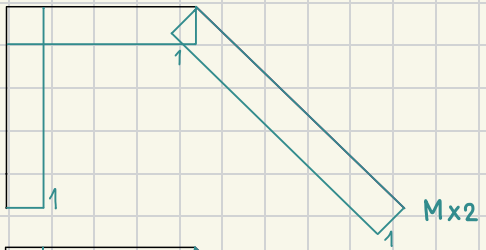


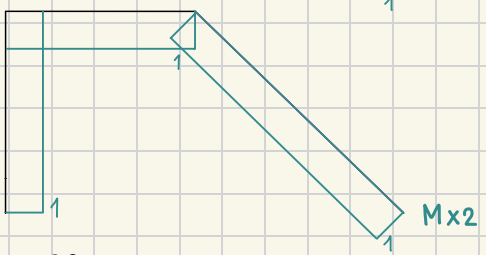
$$\delta_{21} = \delta_{12}$$

$$\delta_{22} = \sum \int \frac{\bar{M}_{x2} \cdot \bar{M}_{x2}}{EJ}$$

$$\delta_{22} = \frac{1}{EJ_1}\left[1 \cdot 4{,}5 \cdot 1\right] + \frac{1}{EJ_2}\left[1 \cdot 4{,}5 \cdot 1 + 1 \cdot 6{,}5795 \cdot 1\right] = \frac{1}{0{,}2184\ EJ_0} \cdot 4{,}5$$

$$+ \frac{1}{EJ_0} \cdot 11{,}3795 = \frac{31{,}99}{EJ_0}$$





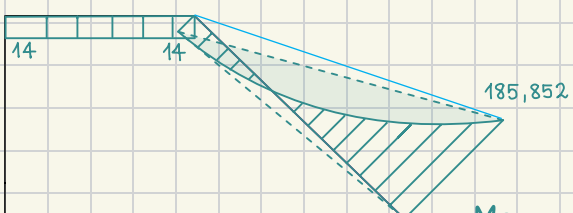
$$\delta_{1P} = \sum \int \frac{M_P \cdot \bar{M}_{x1}}{EJ}\, dx$$

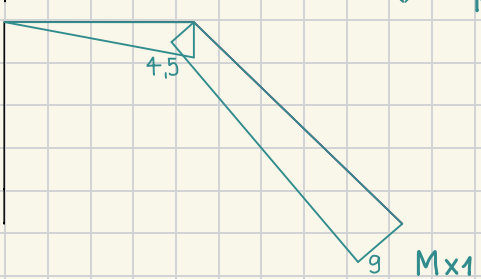
$$q_\perp = 13{,}5 \cdot 0{,}6839 = 9{,}2332$$

$$\delta_{1P} = \frac{1}{EJ_1}\left[14 \cdot 4{,}5 \cdot \frac{1}{2} \cdot 4{,}5\right] + \frac{1}{EJ_2}\left(-\frac{1}{2} \cdot 185{,}852 \cdot 6{,}5795 \cdot \left(\frac{2}{3} \cdot 9 + \frac{1}{3} \cdot 4{,}5\right) + \frac{1}{2} \cdot 14\right.$$

$$\left. \cdot 6{,}5795 \cdot \left(\frac{1}{3} \cdot 9 + \frac{2}{3} \cdot 4{,}5\right) + \frac{2}{3} \cdot \frac{9{,}2332 \cdot 6{,}5795^2}{8} \cdot 6{,}5795 \cdot \left(\frac{1}{2} \cdot 9 + \frac{1}{2} \cdot 4{,}5\right)\right] =$$

$$= \frac{1}{0{,}2184\ EJ_0} \cdot 141{,}75 - \frac{1}{EJ_0} \cdot 2830 = -\frac{2180{,}8}{EJ_0}$$

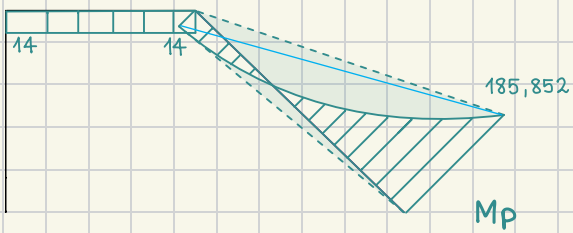


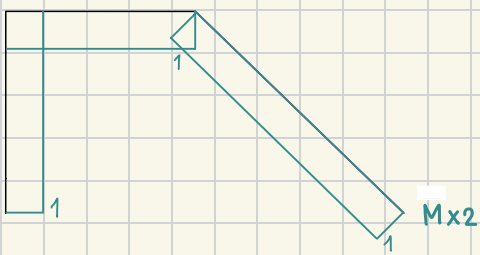


$$\delta_{2p} = \sum \int \frac{M_p \cdot \bar{M}_{x2}}{EJ}$$

$$\delta_{2p} = \frac{1}{EJ_1}\left[14 \cdot 4{,}5 \cdot 1\right] + \frac{1}{EJ_2}\left(-\frac{1}{2} \cdot 185{,}852 \cdot 6{,}5795 \cdot 1 + \frac{1}{2} \cdot 14 \cdot 6{,}5795 \cdot 1 + \frac{2}{3} \cdot \frac{9{,}2332 \cdot 6{,}5795^2}{8} \cdot 6{,}5795 \cdot 1\right] = \frac{1}{0{,}2184\, EJ_0} \cdot 63 - \frac{1}{EJ_0} \cdot 346{,}21 =$$

$$= -\frac{57{,}7}{EJ_0}$$





$$\begin{cases} \delta_{11} x_1 + \delta_{12} x_2 + \delta_{1p} = 0 \\ \delta_{21} x_1 + \delta_{22} x_2 + \delta_{2p} = 0 \end{cases}$$

$$\delta_{1p} = -\frac{2180{,}8}{EJ_0}$$

$$\delta_{2p} = -\frac{57{,}7}{EJ_0}$$

$$\delta_{11} = \frac{449{,}98}{EJ_0}$$

$$\delta_{12} = \frac{90{,}78}{EJ_0}$$

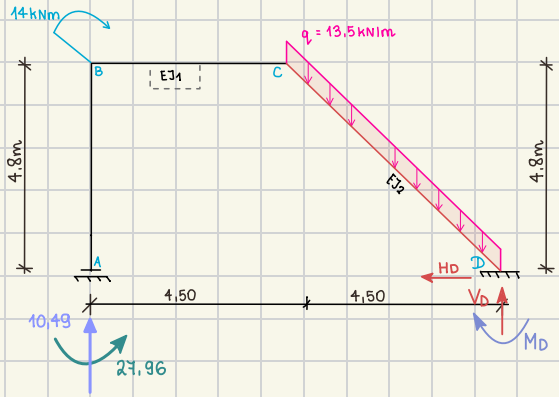
$$\delta_{21} = \frac{90{,}78}{EJ_0}$$

$$\delta_{22} = \frac{31{,}99}{EJ_0}$$

$$\begin{cases} \frac{449{,}98}{EJ_0} x_1 + \frac{90{,}78}{EJ_0} x_2 - \frac{2180{,}8}{EJ_0} = 0 \\ \frac{90{,}78}{EJ_0} x_1 + \frac{31{,}99}{EJ_0} x_2 - \frac{57{,}7}{EJ_0} = 0 \end{cases}$$

$x_1 = 10{,}49\ kN$

$x_2 = -27{,}96\ kNm$



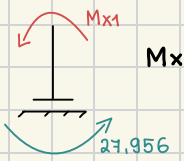
$\Sigma Y = 0 \Rightarrow 10{,}49 - 13{,}5 \cdot 6{,}5795 + V_D = 0$

$V_D = 78{,}34 \text{ kN}$

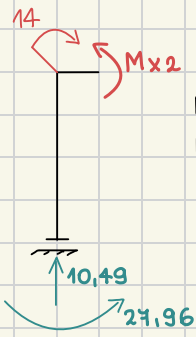
$\Sigma X = 0 \Rightarrow H_D = 0 \text{ kN}$

$\Sigma M_D = 0 \Rightarrow -27{,}96 + 14 + 10{,}49 \cdot 9 - 13{,}5 \cdot 6{,}5795 \cdot 2{,}25 + M_D = 0$

$M_D = 119{,}43 \text{ kNm}$



$M_{x1} = -27{,}96 \text{ kNm}$



$M_{x2} = 10{,}49 \; x - 27{,}96 + 14 = 0$

$M(0) = -13{,}96 \text{ kNm}$

$M(4{,}5) = 33{,}23 \text{ kNm}$

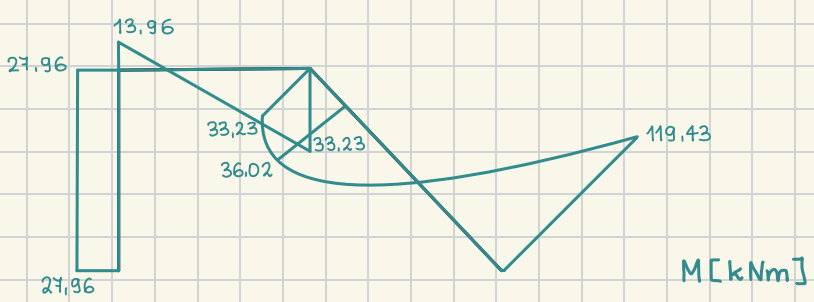
$M_{x3} = -119{,}43 + 78{,}34 \cdot \cos \cdot x - 13{,}5 \cdot \cos \; x \cdot \frac{x}{2}$

$M_{x3} = -119{,}43 + 53{,}575x - 4{,}616x^2$

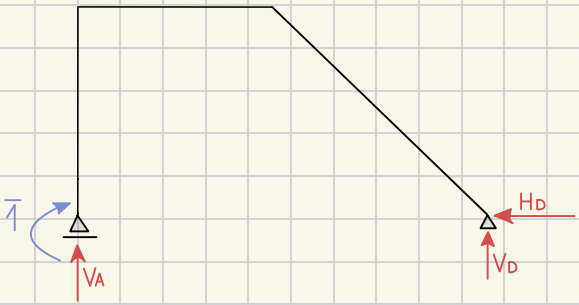
$M(0) = -119{,}43 \text{ kNm}$

$M(6{,}5795) = 33{,}23 \text{ kNm}$

$M(5{,}80) = 36{,}02 \text{ kNm}$



Kontrola kinematyczna - nowy układ podstawowy



$\Sigma M_A = 0 \Rightarrow 1 - V_D \cdot 9 = 0$

$9V_D = 1$

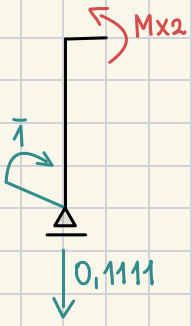
$V_D = 0{,}1111$

$\Sigma M_D = 0 \Rightarrow 1 + V_A \cdot 9 = 0$

$9V_A = -1$

$V_A = -0{,}1111$

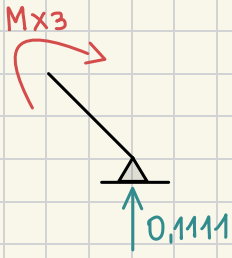
Spr. $\Sigma Y = 0 \Rightarrow -0{,}1111 + 0{,}1111 = 0 \Rightarrow 0 = 0$ □



$M_{x2} = -0{,}1111x + 1$

$M(0) = 1$

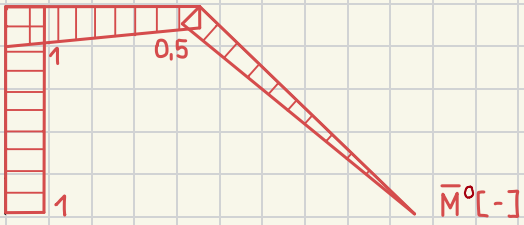
$M(4{,}5) = 0{,}5$



$M_{x3} = 0{,}1111 \cos \cdot x$

$M(0) = 0$

$M(6{,}5795) = 0{,}5$



$$\bar{1} \cdot H = \Sigma \int \frac{M \cdot \bar{M}^0}{EJ} dx = 0$$

$$\delta_0^H = \frac{1}{EJ_1}\left[-\frac{1}{2} \cdot 13,96 \cdot 4,5 \cdot \left(\frac{2}{3} \cdot 1 + \frac{1}{3} \cdot 0,5\right) + \frac{1}{2} \cdot 33,23 \cdot 4,5 \cdot \left(\frac{1}{3} \cdot 1 + \frac{2}{3} \cdot 0,5\right)\right.$$

$$+ \frac{1}{EJ_2}\left[-27,96 \cdot 4,8 \cdot 1 - \frac{1}{2} \cdot 119,43 \cdot 6,5795 \cdot \frac{1}{3} \cdot 0,5 + \frac{1}{2} \cdot 33,23 \cdot 6,5795\right.$$

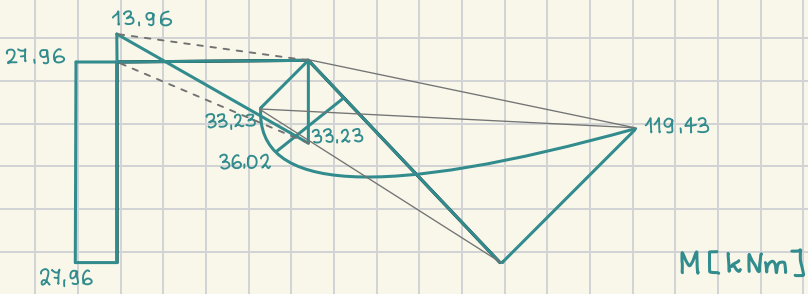
$$\left.\cdot \frac{2}{3} \cdot 0,5 + \frac{2}{3} \cdot \frac{9,2332 \cdot 6,5795^2}{8} \cdot 6,5795 \cdot \frac{1}{2} \cdot 0,5\right] =$$

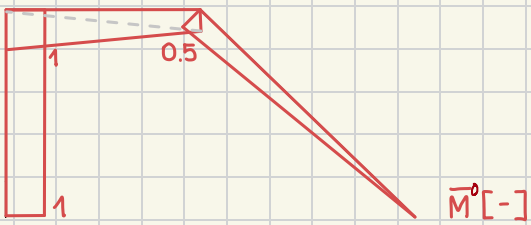
$$= \frac{1}{0,2184 EJ_0} \cdot 23,68 + \frac{1}{EJ_0} \cdot (-108,443) = -\frac{0,018}{EJ_0}$$

$$|\delta| < \frac{1}{EJ}$$

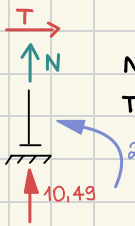
Warunek został spełniony

$$\frac{0,018}{EJ_0} < \frac{1}{EJ_0}$$



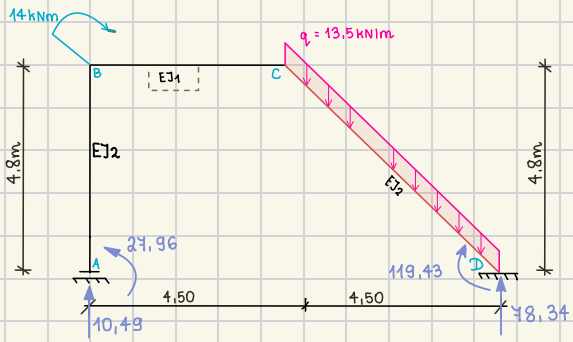


Siły przekrojowe (M, N, T) od zadanego obciążenia



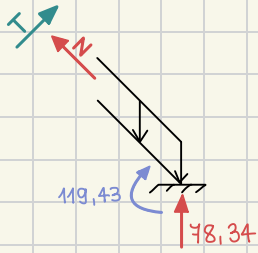
$N_{x1} = -10{,}49\,kN$

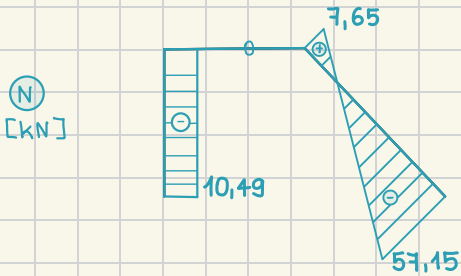
$T_{x1} = 0\,kN$

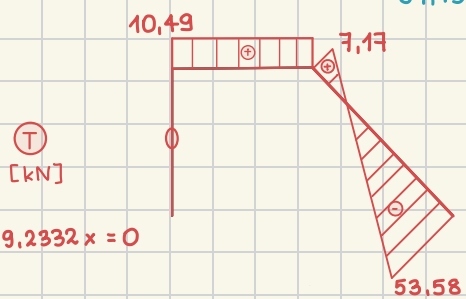


$N_{x2} = 0$

$T_{x2} = 10{,}49\,kN$







$T_{x3} = -78{,}34\cos + 9{,}2332\,x$

$T(0) = -53{,}58\,kN$

$T(6{,}5795) = 7{,}17\,kN$

$-78{,}34\cos + 9{,}2332\,x = 0$

$x = 5{,}80\,m$

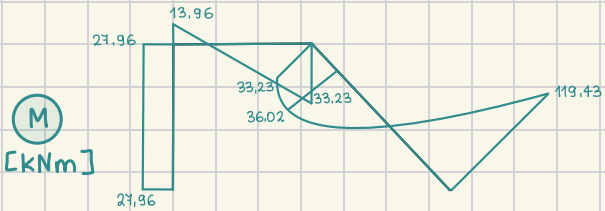
$N_{x3} = -78{,}34\sin + 9{,}8488\,x$

$N(0) = -57{,}15\,kN$

$N(6{,}5795) = 7{,}65\,kN$

$-78{,}34\sin + 9{,}8488\,x = 0$

$x = 5{,}80\,m$



Sprawdzenie naprężeń w obu przekrojów

$$\sigma_{dop} = 235\,MPa$$

I 200

$M_{max} = 36{,}02\,kNm$

$$\frac{M_{max}}{W} \leqslant 235\,MPa$$

$$\sigma_{max} = \frac{|M|}{W_y} + \frac{|N|}{A} = \frac{36{,}02}{214} + 0$$

$$\sigma_{max} = \frac{3602}{214} = 16{,}832\,kN/cm^2 \Rightarrow 168{,}32\,MPa$$

$168{,}32\,MPa < 235\,MPa \Rightarrow \sigma_{max} < \sigma_{dop}$

I 300

$M_{max} = 119{,}43\,kNm$

$$\frac{M_{max}}{W} \leqslant 235\,MPa$$

$$\sigma_{max} = \frac{|M|}{W_y} + \frac{|N|}{A} = \frac{119{,}43}{653} + \frac{57{,}15}{69{,}1} = \frac{11943}{653} + \frac{57{,}15}{69{,}1} = 19{,}117\,kN/cm^2$$

$\sigma_{max} = 19{,}117\,kN/cm^2 \Rightarrow 191{,}17\,MPa$

$191{,}17\,MPa < 235\,MPa \Rightarrow \sigma_{max} < \sigma_{dop}$

Wniosek:
W obydwu przypadkach warunek nośności został spełniony. Przekroje można by zoptymalizować i zmniejszyć, co wymagałoby ponownego obliczenia zadania dla zmienionych przekrojów.

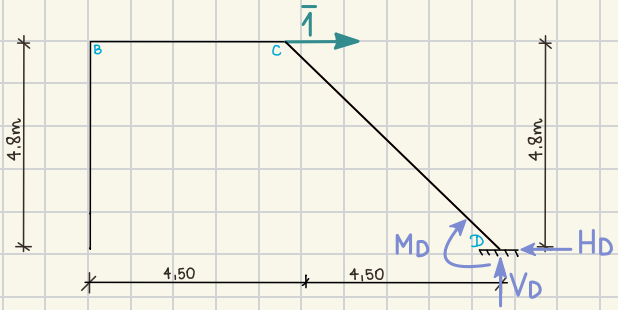
Przemieszczenie poziome w punkcie „C"

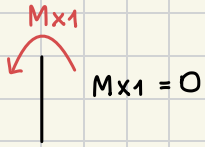
$\Sigma Y = 0 \Rightarrow V_D = 0kN$

$\Sigma X = 0 \Rightarrow H_D - 1kN$

$\Sigma M_D = 0 \Rightarrow 1 \times 4,8 + M_D = 0$

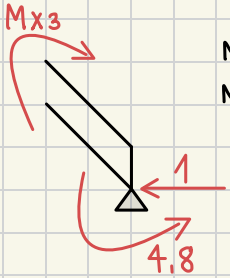
$M_D = -4,8kN$





$M_{x1} = 0$

$M_{x2} = 0$

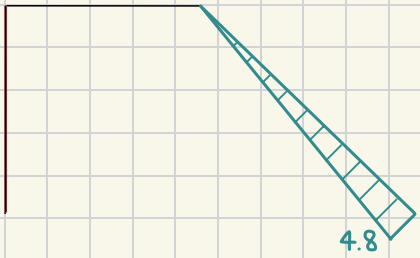


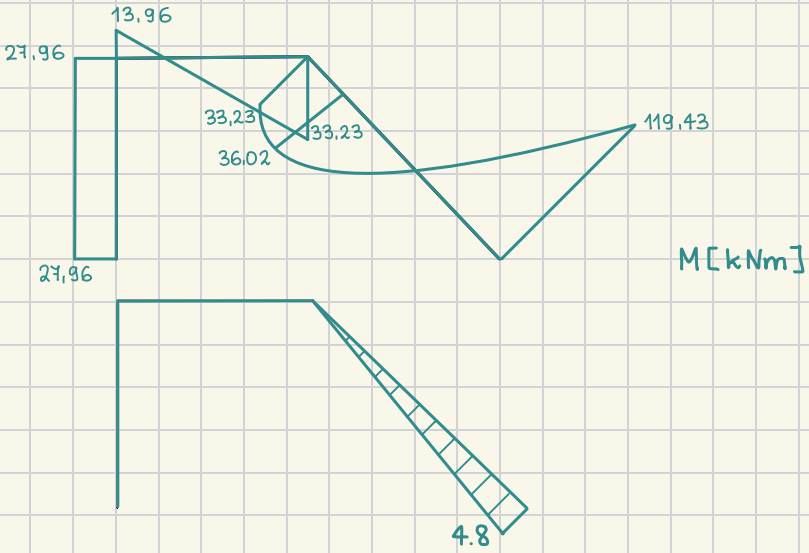
$M_{x3} = -1 \sin\alpha \cdot x + 4,8$

$M_{x3} = -0,7295x + 4,8$

$M(0) = 4,8kNm$

$M(6,5795) = 0kNm$





$$\delta_C^H = \frac{1}{EJ_2}\left[-\frac{1}{2}\cdot 119,43\cdot 6,5795\cdot\frac{2}{3}\cdot 4,8+\frac{1}{2}\cdot 33,23\cdot 6,5795\cdot\frac{1}{3}\cdot 4,8\right.$$

$$\left.+\frac{2}{3}\cdot\frac{9,2332\cdot 6,5795^2}{8}\cdot 6,5795\cdot\frac{1}{2}\cdot 4,8\right]=-\frac{556,38}{EJ_2}=-0,02704\,m$$