



AKADEMIA EDUKACYJNO - INŻYNIERSKA

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MATURA STUDIA PRAKTYKA STAŻ PRACA BIZNES PRZEMYSŁ STEAM

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MECHANIKA III

"ZASADA PRAC PRZYGOTOWANYCH – RAMA"

PROJEKT

Oblicz:

– reakcje podporowe

dla układu ramowego ustroju nośnego.

DANE:

$F_1, F_2, M, q, \alpha = OK$

SZUKAM:

$R = ?$

M3

1) $F_1 = 20 \text{ [kN]}$

$M_L = 16 \text{ [kNm]}$

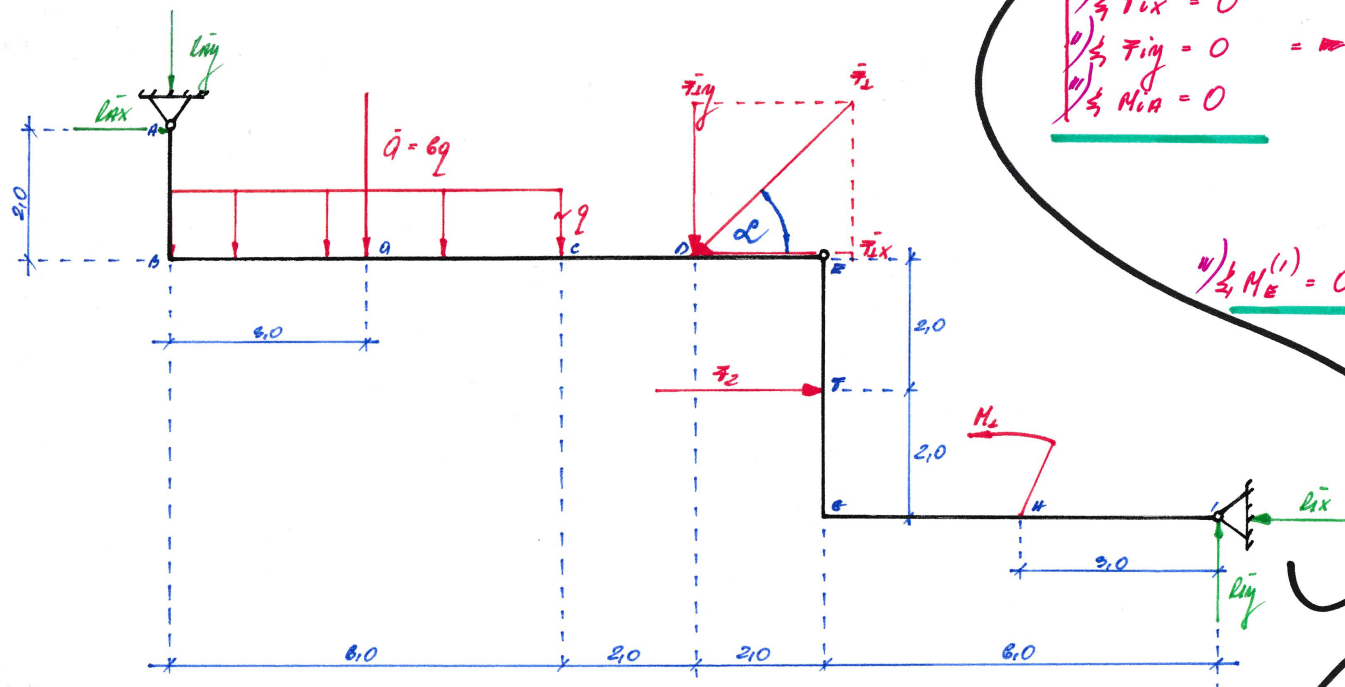
$\alpha = 45^\circ$

$F_2 = 15$

$q = 2 \text{ [kN/m]}$

52: $\bar{E} = ?$

1) СЧЕТЫ СЛОВОУСЛОВИЙ УПРУГОСТИ.



2) ОБЩЕАНГА.

1) $\sum T_{ix} = 0$

2) $\sum T_{iy} = 0$

3) $\sum M_{iA} = 0$

1) $R_{Ax} - F_{1x} + F_2 - R_{ix} = 0$
 2) $R_{Ay} - q - F_{1y} + R_{iy} = 0$
 3) $3q + 8F_{1y} + 2F_{1x} - 4F_2 - M_L + 6R_{ix} - 16R_{iy} = 0$

4) $\sum M_E^{(1)} = 0 \Rightarrow 2F_2 - M_L + 4R_{ix} - 6R_{iy} = 0$

$\frac{F_{1x}}{F_1} = \cos \alpha \Rightarrow F_{1x} = F_1 \cos \alpha$

$\frac{F_{1y}}{F_1} = \sin \alpha \Rightarrow F_{1y} = F_1 \sin \alpha$

3) $3 \cdot 6q + 8F_1 \sin \alpha + 2F_1 \cos \alpha - 4F_2 - M_L + 6R_{ix} - 16R_{iy} = 0$
 4) $2F_2 - M_L + 4R_{ix} - 6R_{iy} = 0$

1) $R_{ix} = \frac{2F_2 + M_L + 6R_{iy}}{4}$

1) $18q + 8F_1 \sin \alpha + 2F_1 \cos \alpha - 4F_2 - M_L + 6 \cdot \left(\frac{2F_2 + M_L + 6R_{iy}}{4} \right) - 16R_{iy} = 0$

11)

$$18Q + 8\bar{T}\sin\alpha + 2\bar{T}\cos\alpha - 4\bar{T}_2 - M_L + 3\bar{T}_2 + 1,5M_L + 9R_{xy} - 16R_{yx} = 0$$

$$18Q + 2\bar{T}_L(4\sin\alpha + \cos\alpha) - 4\bar{T}_2 - M_L + 3\bar{T}_2 + 1,5M_L - 4R_{yx} = 0$$

$$18Q + 2\bar{T}_L(4\sin\alpha + \cos\alpha) - \bar{T}_2 + 0,5M_L - 4R_{yx} = 0$$

$$R_{yx} = \frac{18Q + 2\bar{T}_L(4\sin\alpha + \cos\alpha) - \bar{T}_2 + 0,5M_L}{4}$$

$$R_{yx} = \frac{18 \cdot 2 + 2 \cdot 20 \cdot (4\sin 45^\circ + \cos 45^\circ) - 15 + 0,5 \cdot 16}{4}$$

$$= \frac{36 + 40 \cdot (2,828 + 0,707) - 15 + 8}{4}$$

$$= \frac{36 + 40 \cdot 3,535 - 15 + 8}{4} = \frac{36 + 141,4 - 15 + 8}{4}$$

$$= \frac{170,4}{4} = 42,6 \text{ [kN]}$$

12)

$$R_{ix} = \frac{2\bar{T}_2 + M_L + 6R_{yx}}{4}$$

$$R_{ix} = \frac{2 \cdot 15 + 16 + 6 \cdot 42,6}{4}$$

$$= \frac{30 + 16 + 255,6}{4} = \frac{291,6}{4} = 72,9 \text{ [kN]}$$

13)

$$R_{ax} - \bar{T}_{Lx} + \bar{T}_2 - R_{ix} = 0$$

$$R_{ax} = \bar{T}_{Lx} - \bar{T}_2 + R_{ix}$$

$$R_{ax} = 20 \cos 45^\circ - 15 + 48,01$$

$$R_{ax} = 14,14 - 15 + 48,01 = 47,15 \text{ [kN]}$$

14)

$$-R_{ay} - Q - \bar{T}_{Ly} + R_{iy} = 0$$

$$-R_{ay} - Q - \bar{T}_{Ly} + R_{iy} = 0$$

$$R_{ay} = -Q - \bar{T}_{Ly} + R_{iy}$$

$$R_{ay} = -6 \cdot 2 - 20 \sin 45^\circ + 24,34 =$$

$$= -12 - 14,14 + 24,34 = -1,80 \text{ [kN]}$$

$$\begin{aligned} &1) R_{ax} = 47,15 \text{ [kN]} \\ &2) R_{ay} = -1,80 \\ &3) R_{ix} = 48,01 \\ &4) R_{iy} = 24,34 \end{aligned}$$

3PE

$$\sum M_G = 0$$

- m

$$6R_{AX} - 10R_{AY} - 4Q - 2\bar{T}_1 - 4\bar{T}_1x + 2\bar{T}_2 - M_L - 6R_{AY} = 0$$

$$6R_{AX} - 10R_{AY} - 4 \cdot 69 - 2\bar{T}_1 \sin \alpha - 4\bar{T}_1 \cos \alpha + 2\bar{T}_2 - M_L - 6R_{AY} = 0$$

$$6R_{AX} - 10R_{AY} - 429 - 2\bar{T}_1 (\sin \alpha + 2 \cos \alpha) + 2\bar{T}_2 - M_L - 6R_{AY} = 0$$

$$6 \cdot (44,15) - 10 \cdot (-1,80) - 42 \cdot 2 - 2 \cdot 20 \cdot (\sin 45^\circ + 2 \cdot \cos 45^\circ) + 2 \cdot 15 - 16 \cdot 6 \cdot (24,34) = 0$$

$$282,9 + 18 - 84 - 40 \cdot (0,404 + 1,414) + 30 - 16 - 146,04 = 0$$

$$282,9 + 18 - 84 - 40 \cdot 2,121 + 30 - 16 - 146,04 = 0$$

$$216,9 - 84,34 - 132,04 = 0$$

$$132,06 - 132,04 = 0$$

$$L = P$$

$$\begin{aligned} \text{I) } R_{AX} &= 44,15 & (\text{kN}) \\ \text{II) } R_{AY} &= -1,80 \\ \text{III) } R_{AX} &= 48,01 \\ \text{IV) } R_{AY} &= 24,34 \end{aligned}$$

max

$$dW = \bar{F} \cdot ds + M \cdot d\varphi = 0$$

$$-M_L \cdot d\varphi_L + \bar{F}_2 \cdot ds_F - \bar{F}_{1x} \cdot ds_{Dx} - \bar{F}_{1y} \cdot ds_{Dy} - Q \cdot ds_Q + P_{AX} \cdot d\varphi_A = 0$$

$$q = d\varphi_L$$

$$ds_F = d\varphi_L \cdot 2 = 2 d\varphi_L$$

$$ds_{Dx} = d\varphi_L \cdot \sqrt{(6)^2 + (4)^2} = 7.21 d\varphi_L$$

$$ds_{Dy} = d\varphi_L \cdot |O_2E| = \sqrt{(10)^2 + (6.64)^2} d\varphi_L = 12 d\varphi_L$$

⊕

$$\frac{4}{6} = \frac{|O_2B|}{10} \Rightarrow |O_2B| = \frac{4 \cdot 10}{6} = \frac{40}{6} = 6.64$$

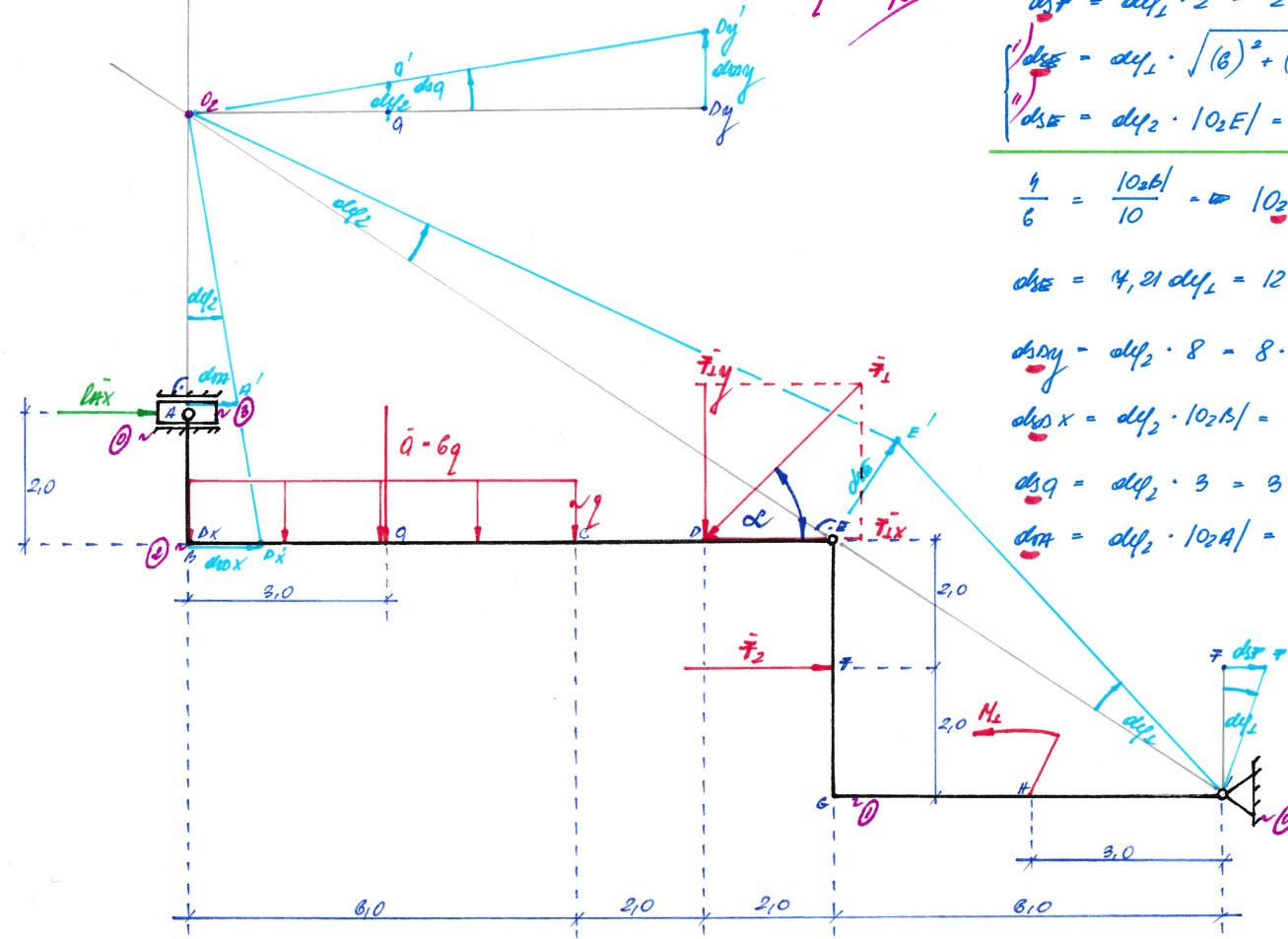
$$ds_E = 7.21 d\varphi_L = 12 d\varphi_2 \Rightarrow d\varphi_2 = \frac{7.21}{12} d\varphi_L = 0.6 d\varphi_L$$

$$ds_{Ay} = d\varphi_2 \cdot 8 = 8 \cdot 0.6 d\varphi_L = 4.8 d\varphi_L$$

$$ds_{Dx} = d\varphi_2 \cdot |O_2B| = 6.64 \cdot 0.6 d\varphi_L = 4 d\varphi_L$$

$$ds_Q = d\varphi_2 \cdot 3 = 3 \cdot 0.6 d\varphi_L = 1.8 d\varphi_L$$

$$d\varphi_A = d\varphi_2 \cdot |O_2A| = 4.64 \cdot 0.6 d\varphi_L = 2.8 d\varphi_L$$



$$P_{AX} = \frac{16 - 30 + 56.56 + 64.88 + 21.6}{2.8} = \frac{132.04}{2.8} = 47.15 \text{ [kN]}$$

$$-M_L d\varphi_L + \bar{F}_2 \cdot 2 d\varphi_L - \bar{F}_{1x} \cdot 4 d\varphi_L - \bar{F}_{1y} \cdot 4.8 d\varphi_L - 6q \cdot 1.8 d\varphi_L + P_{AX} \cdot 2.8 d\varphi_L = 0$$

$$P_{AX} = \frac{M_L - \bar{F}_2 + 4 \bar{F}_{1x} \cos 45^\circ + 4.8 \bar{F}_{1y} \sin 45^\circ + 10.8 q}{2.8} = \frac{16 - 2 \cdot 15 + 4 \cdot 20 \cos 45^\circ + 4.8 \cdot 20 \sin 45^\circ + 10.8 \cdot 2}{2.8}$$

-4-

lay

$$dW = F \cdot ds + H \cdot d\varphi = 0$$

=

$$- M_L \cdot d\varphi_L + F_2 \cdot ds_F - F_{Lx} \cdot d\varphi_{Lx} - F_{Ly} \cdot d\varphi_{Ly} + Q \cdot ds_Q + m_y \cdot d\varphi_m = 0$$

$q = d\varphi_L$

$$ds_F = d\varphi_L \cdot 2 = 2 d\varphi_L$$

$$ds_E = d\varphi_L \cdot \sqrt{(6)^2 + (4)^2} = 7,21 d\varphi_L$$

$$ds_E = d\varphi_L \cdot 10,3E = \sqrt{(3)^2 + (2)^2} = 3,61 d\varphi_L \quad (+)$$

$$\frac{4}{6} = \frac{|D_2 D_X|}{|E D_X|} = \frac{2}{|E D_X|} \Rightarrow |E D_X| = \frac{2 \cdot 6}{4} = 3$$

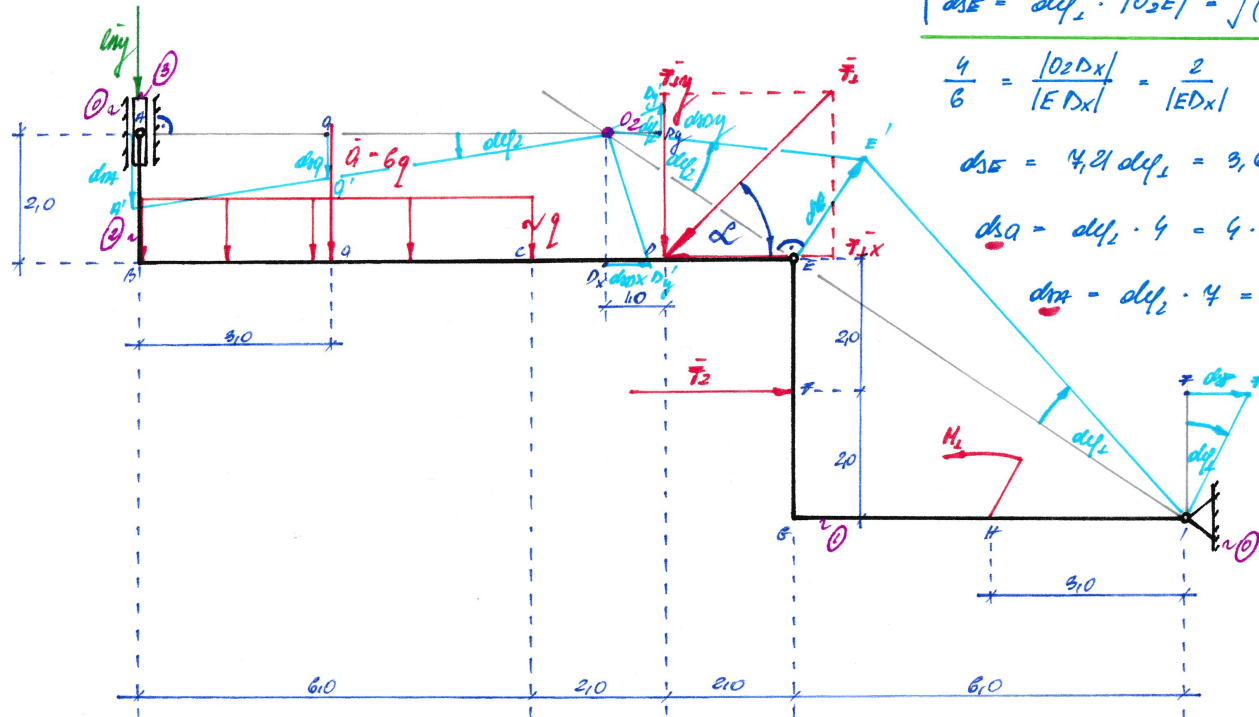
$$ds_E = 7,21 d\varphi_L = 3,61 d\varphi_2 \Rightarrow d\varphi_2 = \frac{7,21 d\varphi_L}{3,61} = 2 d\varphi_L$$

$$ds_Q = d\varphi_2 \cdot 4 = 4 \cdot 2 d\varphi_L = 8 d\varphi_L$$

$$d\varphi_m = d\varphi_2 \cdot 4 = 4 \cdot 2 d\varphi_L = 8 d\varphi_L$$

$$d\varphi_{Lx} = d\varphi_2 \cdot 2 = 2 \cdot 2 d\varphi_L = 4 d\varphi_L$$

$$d\varphi_{Ly} = d\varphi_2 \cdot 1 = 1 \cdot 2 d\varphi_L = 2 d\varphi_L$$



$$- M_L d\varphi_L + F_2 \cdot 2 d\varphi_L - F_{Lx} \cos \alpha \cdot 4 d\varphi_L - F_{Ly} \sin \alpha \cdot 2 d\varphi_L + Q \cdot 8 d\varphi_L + m_y \cdot 14 d\varphi_L = 0$$

$$m_y = \frac{M_L - 2F_2 + 4F_{Lx} \cos \alpha + 2F_{Ly} \sin \alpha - 48Q}{14} = \frac{16 - 2 \cdot 15 + 4 \cdot 20 \cdot \cos 45^\circ + 2 \cdot 20 \cdot \sin 45^\circ - 48 \cdot 2}{14}$$

$$= \frac{16 - 30 + 56,56 + 28,28 - 96}{14} = \frac{-25,16}{14} = -1,80 \text{ [kN]}$$

l_{ix}

$$dW = \bar{F} \cdot ds + M \cdot d\varphi = 0 \quad \Rightarrow \quad -Q \cdot ds_Q - \bar{T}_{1y} \cdot ds_{Dy} - \bar{T}_{1x} \cdot ds_{DX} - \bar{T}_2 \cdot ds_F - M_L \cdot d\varphi_2 + R_{1x} \cdot ds_1 = 0$$

$q = d\varphi_1$

$$ds_Q = d\varphi_1 \cdot 3 = 3 d\varphi_1$$

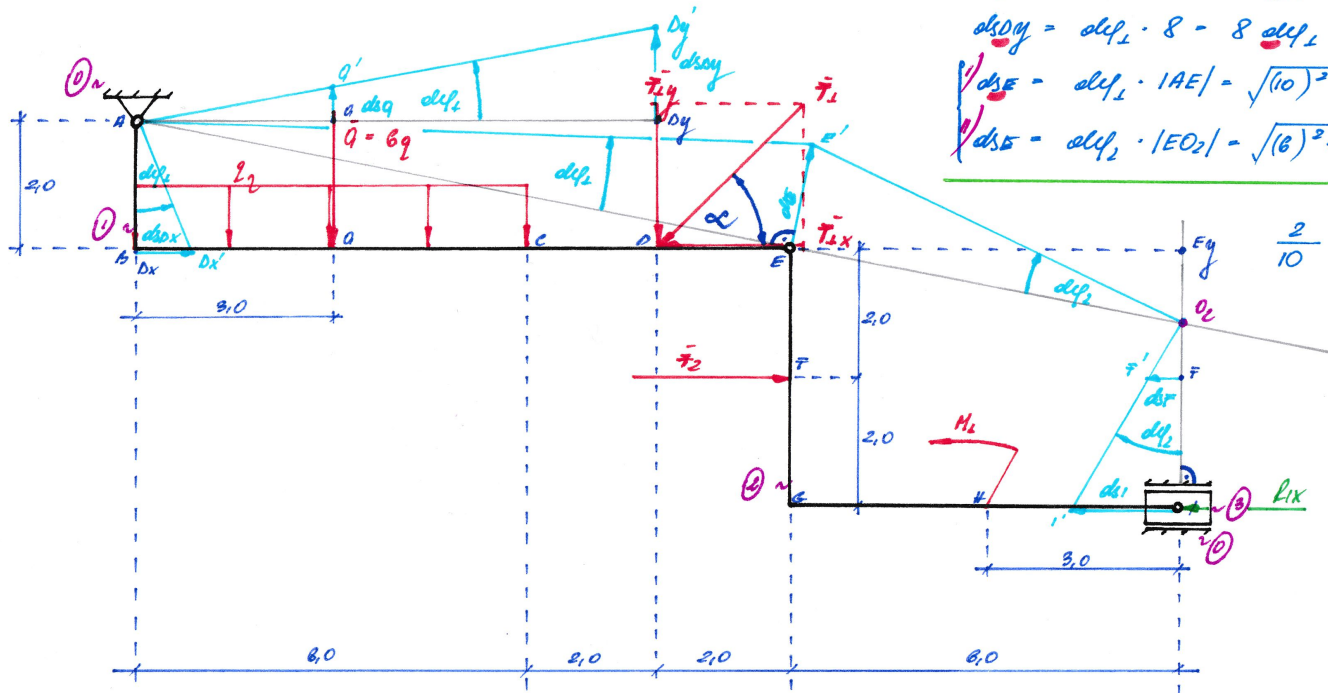
$$ds_{DX} = d\varphi_1 \cdot 2 = 2 d\varphi_1$$

$$ds_{Dy} = d\varphi_1 \cdot 8 = 8 d\varphi_1$$

$$ds_E = d\varphi_1 \cdot |AE| = \sqrt{(10)^2 + (2)^2} d\varphi_1 = 10,2 d\varphi_1$$

$$ds_E = d\varphi_2 \cdot |EO_2| = \sqrt{(6)^2 + (1,2)^2} d\varphi_2 = 6,12 d\varphi_2$$

⊕



$$\frac{2}{10} = \frac{10,2 E \varphi_1}{6} \Rightarrow |O_2 E \varphi_1| = \frac{2 \cdot 6}{10} = 1,2$$

$$ds_E = 10,2 d\varphi_1 = 6,12 d\varphi_2$$

$$\Rightarrow d\varphi_2 = \frac{10,2 d\varphi_1}{6,12} = 1,64 d\varphi_1$$

$$ds_F = d\varphi_2 |OF| = 0,8 \cdot 1,64 d\varphi_1 = 1,34 d\varphi_1$$

$$ds_1 = d\varphi_2 |O_2 I| = 2,8 \cdot 1,64 d\varphi_1 = 4,64 d\varphi_1$$

$$-6q \cdot 3 d\varphi_1 - \bar{T}_{1y} \sin \alpha \cdot 8 d\varphi_1 - \bar{T}_{1x} \cos \alpha \cdot 2 d\varphi_1 - \bar{T}_2 \cdot 1,34 d\varphi_1 - M_L \cdot 1,64 d\varphi_1 + R_{1x} \cdot 4,64 d\varphi_1 = 0$$

$$R_{1x} = \frac{18q + 8 \bar{T}_{1y} \sin \alpha + 2 \bar{T}_{1x} \cos \alpha + 1,34 \bar{T}_2 + 1,64 M_L}{4,64} = \frac{18 \cdot 2 + 8 \cdot 20 \cdot \sin 46^\circ + 2 \cdot 20 \cdot \cos 46^\circ + 1,34 \cdot 15 + 1,64 \cdot 16}{4,64}$$

$$= \frac{36 + 118,13 + 28,28 + 20,1 + 26,42}{4,64} = \frac{229,23}{4,64} = 48,01 \text{ [kN]}$$

diag

$$\delta W = T \cdot \delta s + M \cdot \delta \varphi = 0 \quad \rightarrow \quad -Q \cdot \delta s_Q - F_{Ly} \cdot \delta x_Q - F_{Lx} \cdot \delta s_{DX} + F_2 \cdot \delta s_F - M_1 \cdot \delta \varphi_1 + R_{Hy} \cdot \delta s_1 = 0$$

$q = \delta \varphi_1$

$$\delta s_Q = \delta \varphi_1 \cdot 3 = 3 \delta \varphi_1$$

$$\delta s_{DX} = \delta \varphi_1 \cdot 2 = 2 \delta \varphi_1$$

$$\delta s_{Dy} = \delta \varphi_1 \cdot 8 = 8 \delta \varphi_1$$

$$\delta s_E = \delta \varphi_1 \cdot |AE| = \sqrt{(10)^2 + (2)^2} \delta \varphi_1 = 10,2 \delta \varphi_1$$

$$\delta s_F = \delta \varphi_2 \cdot |OF| = \sqrt{(20)^2 + (4)^2} \delta \varphi_2 = 20,39 \delta \varphi_2$$

(+)

$$\frac{10}{2} = \frac{|EO_2|}{4} = |EO_2| = \frac{4 \cdot 10}{2} = 20$$

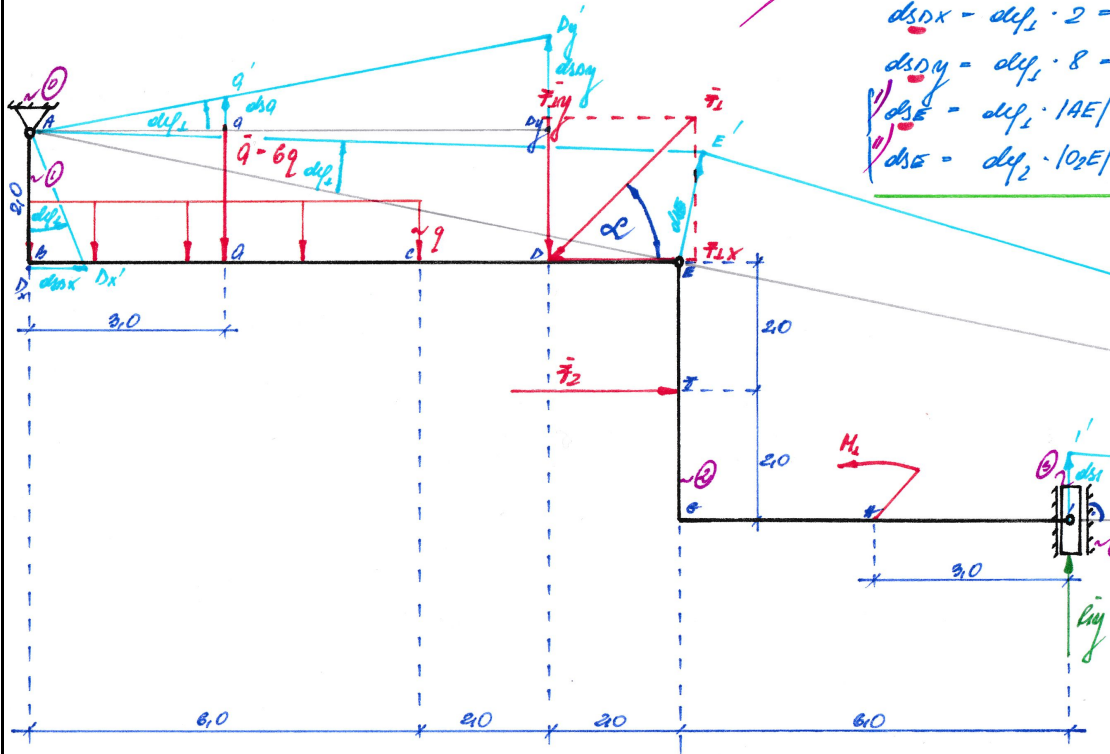
$$\delta s_E = 10,2 \delta \varphi_1 = 20,39 \delta \varphi_2$$

$$\Rightarrow \delta \varphi_1 = \frac{10,2 \delta \varphi_2}{20,39} = 0,5 \delta \varphi_2$$



$$\delta s_F = \delta \varphi_2 \cdot 2 = 2 \cdot 0,5 \delta \varphi_1 = \delta \varphi_1$$

$$\delta s_1 = \delta \varphi_2 \cdot |O_2F| = 14 \cdot 0,5 \delta \varphi_1 = 7 \delta \varphi_1$$



$$-6q \cdot 3 \delta \varphi_1 - F_{Lx} \sin \alpha \cdot 8 \delta \varphi_1 - F_{Ly} \cos \alpha \cdot 2 \delta \varphi_1 + F_2 \cdot \delta \varphi_1 - M_1 \cdot 0,5 \delta \varphi_1 + R_{Hy} \cdot 7 \delta \varphi_1 = 0$$

$$\text{diag} = \frac{18q + 8F_{Lx} \sin \alpha + 2F_{Ly} \cos \alpha - F_2 + 0,5 M_1}{14} = \frac{18 \cdot 2 + 8 \cdot 20 \cdot \sin 45^\circ + 2 \cdot 20 \cdot \cos 45^\circ - 15 + 0,5 \cdot 16}{14}$$

$$= \frac{36 + 113,13 + 28,28 - 15 + 8}{14} = \frac{140,41}{14} = 29,39 \text{ (kN)}$$

-4-

10/

$\triangleright: \bar{F}_L = 18 \text{ (kN)}$

$M = 8 \text{ (kNm)}$

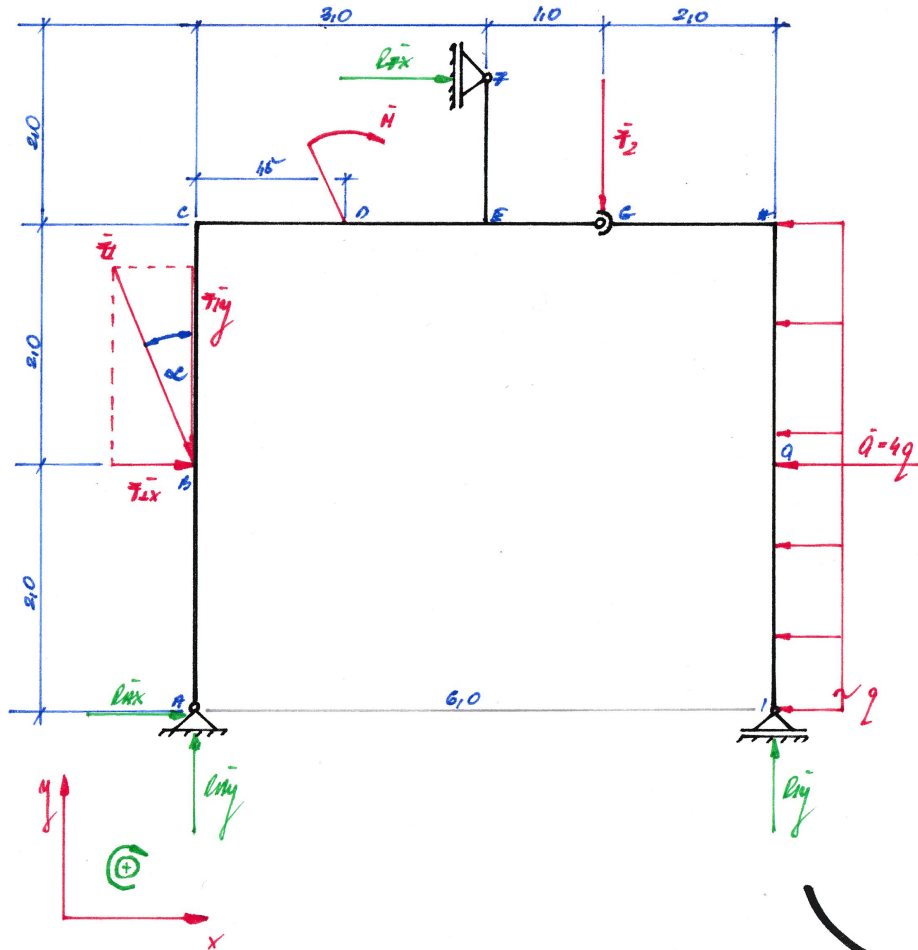
$\alpha = 30^\circ$

32: $\bar{L} = ?$

$\bar{F}_2 = 14$

$q = 2 \text{ (kN/m)}$

1) СЧЕТЫ РЕЗУЛЬТАНТОВ ВОЗРАСТОВ.



2) УРАВНЕНИЯ.

$\sum \bar{F}_{ix} = 0$
 $\sum \bar{F}_{iy} = 0$
 $\sum M_i = 0$
 $\sum M_G^{(i)} = 0$

$\sum \bar{F}_{ix} + \bar{F}_{Lx} + \bar{F}_{2x} - q = 0$
 $\sum \bar{F}_{iy} - \bar{F}_{Ly} - \bar{F}_2 + R_{iy} = 0$
 $\sum \bar{F}_{ix} \cdot 2 + M + \bar{F}_{Lx} \cdot 6 + \bar{F}_2 \cdot 4 - q \cdot 2 - R_{iy} \cdot 6 = 0$
 $\sum q \cdot 2 - R_{iy} \cdot 2 = 0$

$\frac{\bar{F}_{Lx}}{\bar{F}_L} = \sin \alpha \Rightarrow \bar{F}_{Lx} = \bar{F}_L \sin \alpha$
 $\frac{\bar{F}_{Ly}}{\bar{F}_L} = \cos \alpha \Rightarrow \bar{F}_{Ly} = \bar{F}_L \cos \alpha$

$\sum q \cdot 2 - R_{iy} \cdot 2 = 0$
 $R_{iy} = q$
 $R_{iy} = 4 \cdot 2 = 8 \text{ (kN)}$

$$4) \quad R_{ny} - F_1 \cos \alpha - F_2 + R_y = 0$$

$$R_{ny} = F_1 \cos \alpha + F_2 - R_y$$

$$R_{ny} = 18 \cos 30^\circ + 14 - 8 =$$

$$= 15,58 + 14 - 8 = 21,58 \text{ (kN)}$$

$$5) \quad 2F_1 \sin \alpha + M + 6R_{fx} + 4F_2 - 2 \cdot 49 - 6R_{ny} = 0$$

$$R_{fx} = \frac{-2F_1 \sin \alpha - M - 4F_2 + 89 + 6R_{ny}}{6}$$

$$R_{fx} = \frac{-2 \cdot 18 \cdot \sin 30^\circ - 8 - 4 \cdot 14 + 8 \cdot 2 + 6 \cdot 8}{6} =$$

$$= \frac{-18 - 8 - 56 + 16 + 48}{6} = \frac{-18}{6} = -3 \text{ (kN)}$$

$$6) \quad R_{ax} + F_1 \sin \alpha + R_{fx} - 49 = 0$$

$$R_{ax} = -F_1 \sin \alpha - R_{fx} + 49$$

$$R_{ax} = -18 \sin 30^\circ - (-3) + 4 \cdot 2 =$$

$$= -9 + 3 + 8 = 2 \text{ (kN)}$$

$$\sum M_i = 0 \quad \rightarrow \quad R_{ny} \cdot 6 + F_{1x} \cdot 2 - F_{1y} \cdot 6 + M + R_{ax} \cdot 6 - F_2 \cdot 2 - 9 \cdot 2 = 0$$

$$\rightarrow 6R_{ny} + 2F_1 \sin \alpha - 6F_1 \cos \alpha + M + 6R_{ax} - 2F_2 - 2 \cdot 49 = 0$$

$$6 \cdot 21,58 + 2 \cdot 18 \sin 30^\circ - 6 \cdot 18 \cos 30^\circ + 8 + 6 \cdot (-3) - 2 \cdot 14 - 8 \cdot 2 = 0$$

$$129,48 + 18 - 93,53 + 8 - 18 - 28 - 16 = 0$$

$$15,95 - 16 = 0$$

$$L = P \quad \checkmark$$

$$\rightarrow \begin{cases} R_{ax} = 2 \\ R_{ny} = 21,58 \\ R_{fx} = -3 \\ R_{fy} = 8 \end{cases} \text{ (kN)}$$

Box

$$dW = F \cdot ds + M \cdot d\phi = 0$$

$$-m \cdot \vec{r}_1 \cdot d\vec{r}_1 + M \cdot d\vec{r}_2 + m \cdot \vec{r}_2 \cdot d\vec{r}_2 + \vec{r}_2 \cdot d\vec{r}_2 - q \cdot d\vec{r}_q = 0$$

$$q = dy_+$$

$$\underline{dms} = 2 \underline{def}_\perp$$

$$\text{def} - \text{6 def} +$$

$$\begin{aligned} | & d\mathbf{r}_G = 1\text{MG} / d\varphi_1 \\ | & d\mathbf{r}_G = 102\text{G} / d\varphi_2 \end{aligned}$$

$$|AG| = \sqrt{|AC|^2 + |CE|^2} = \sqrt{4^2 + 4^2} = 4\sqrt{2}$$

$$|O_2 G| = \sqrt{|KH|^2 + |O_2 H|^2} = \sqrt{e^2 + e^2} = e\sqrt{2}$$

$$= \frac{1AC}{dy_1} - \frac{1026}{dy_2}$$

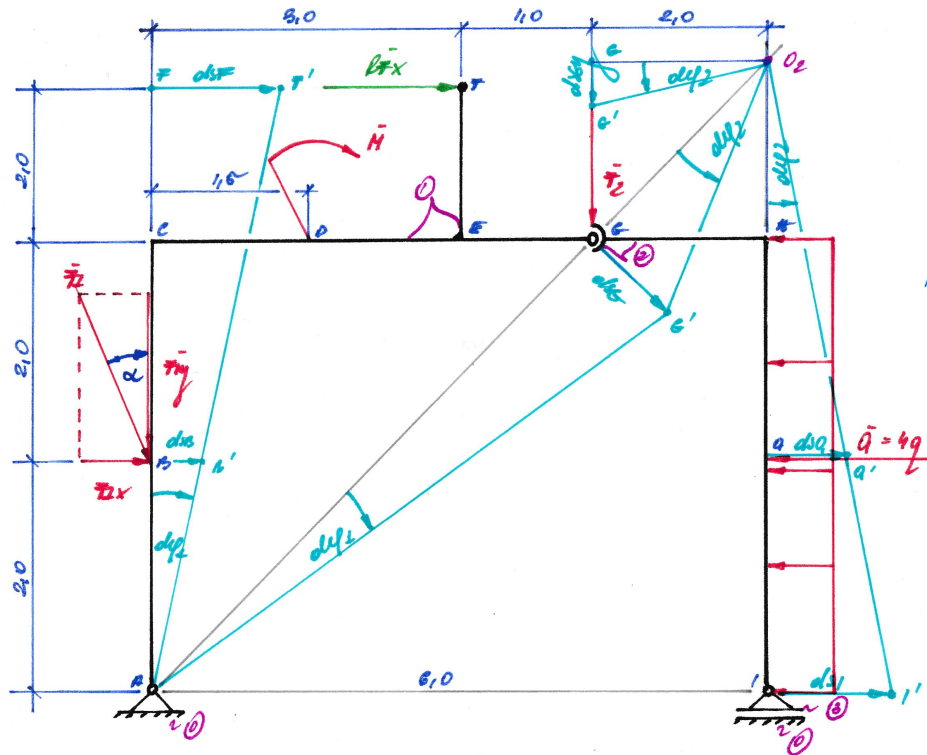
$$\text{def}_2 = \frac{1186/}{1026/} \text{def}_1$$

$$dq_2 = \frac{4R}{2R} dq_1 = 2 dq_1$$

$$dy = 2dy_2 = 2 \cdot 2dy_1 = 4dy_1$$

$$\underline{dof} = 4 \underline{dof}_2 = 4 \cdot 2 \underline{dof}_1 = 8 \underline{dof}_1$$

$$dn = 60df_2 = 6 \cdot 2 df_1 = 12 df_1$$



$$F_{\text{wind}} \cdot \sin \alpha + H \cdot \sin \beta + b \cdot x \cdot \cos \alpha + F_2 \cdot \sin \alpha - 49 \cdot \sin \alpha = 0$$

$$P_{ox} = \frac{-25 \text{ mmd} - M - 472 + 329}{6}$$

$$b_{px} = \frac{-2 \cdot 18 \sin 30^\circ - 8 - 4 \cdot 14 + 32 \cdot 2}{6} = \frac{-18 - 8 - 56 + 64}{6} = \frac{-18}{6} = -3 \text{ (kN)}$$

em

$$\delta W = \bar{F} \cdot \delta s + M \cdot \delta \phi = 0 \quad \Rightarrow$$

$$Q \cdot \delta s_Q - P_H \cdot \delta s_H = 0$$

$$Q = \delta \phi$$

$$\delta s_H = 2 \delta \phi$$

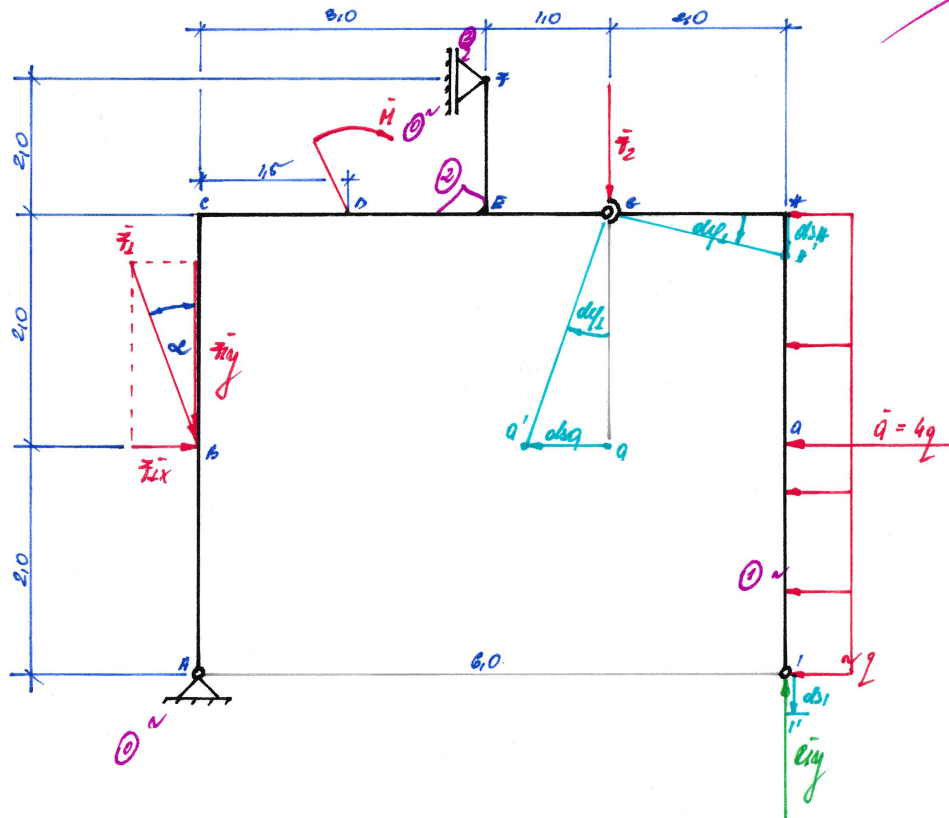
$$\delta s_H = \delta s_H = 2 \delta \phi$$

$$\delta s_Q = 2 \delta \phi$$

$$4Q \cdot 2 \delta \phi - P_H \cdot 2 \delta \phi = 0 \quad | : 2$$

$$P_H = 4Q$$

$$P_H = 4 \cdot 2 = 8 \text{ (kN)}$$



$$dW = \vec{F} \cdot d\vec{s} + M \cdot d\varphi = 0$$

$$- \rightarrow - P_{ax} \cdot d\alpha_1 - P_{bx} \cdot d\alpha_2 + M \cdot d\phi + F_D \cdot d\delta_y - Q \cdot d\delta_z = 0$$

$q = dm$

$$dm = \rho dy_{\perp} \Rightarrow dy_{\perp} = \frac{1}{\rho} dm$$

$$dm_3 = \text{vol}_3 \cdot \frac{4}{6} dm_4 = \frac{2}{3} dm_4$$

$$\frac{dm}{dt} = \frac{2}{3} \frac{dM}{dt}$$

$$| \underline{dx} = \sqrt{4^2 + 2^2} \, dy_{\perp} = 2\sqrt{5} \, dy_{\perp} = \frac{1}{8} \sqrt{5} \, dm$$

$$| \underline{dx} = \sqrt{c^2 + 1^2} \, dq_2 = \sqrt{5} \, dq_2$$

$$dx_2 = \frac{15}{5} dx_1 = 3 dx_1 \Rightarrow dx_2 = 3 dx_1$$

$$ds_2 = 1 \text{ auf } 2 = \frac{1}{3} \text{ cm}$$

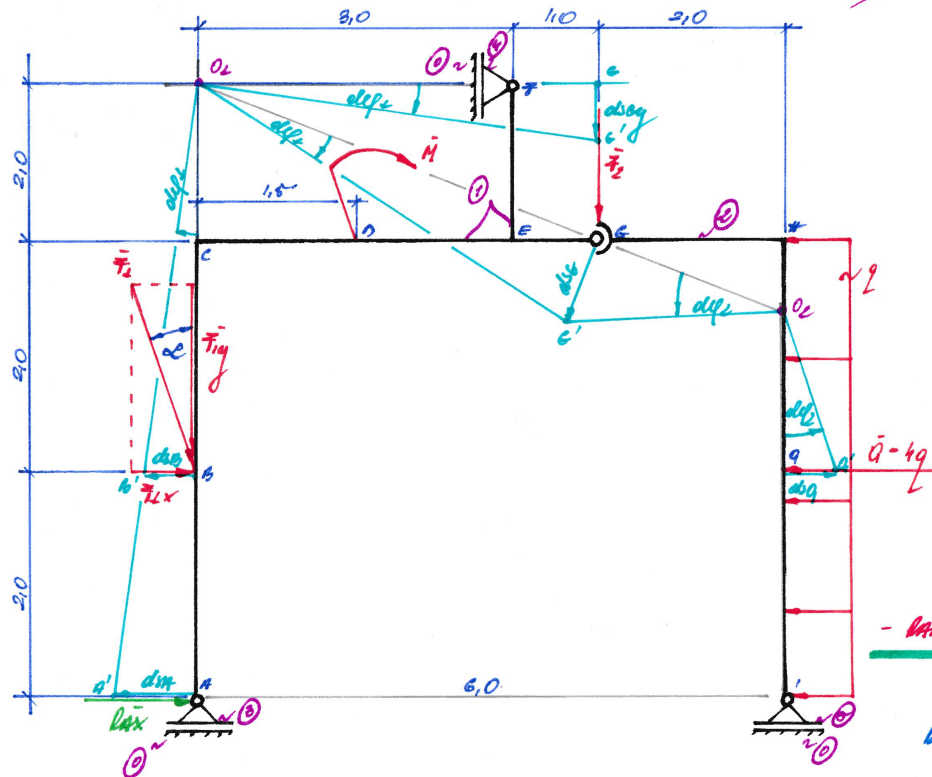
$$- \text{Max} \cdot dx_k - \pi_1 dx_1 \cdot \frac{2}{3} dx_k + M \cdot \frac{1}{6} dx_k + \pi_2 \cdot \frac{2}{3} dx_k - 49 \cdot \frac{1}{3} dx_k = 0$$

$$P_{Ax} = -\frac{2}{3} F_{\perp \text{ wire}} + \frac{1}{6} M + \frac{2}{3} F_2 = \frac{49}{3} \text{ lbf}$$

$$G_{4x} = -W_1 \sin \alpha + M + W_2 - 89$$

$$I_{ax} = \frac{-42 \text{ mm}^4 + 14 + 472 - 89}{6}$$

$$P_{\max} = \frac{-4 \cdot 18 \cdot \sin 30^\circ + 8 + 4 \cdot 14 - 8 \cdot 2}{6} = \frac{-36 + 8 + 56 - 16}{6} = \frac{12}{6} = 2 \text{ (kN)}$$



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$$F_1 = 24 \text{ [kN]}$$

$$M = 16 \text{ [kNm]}$$

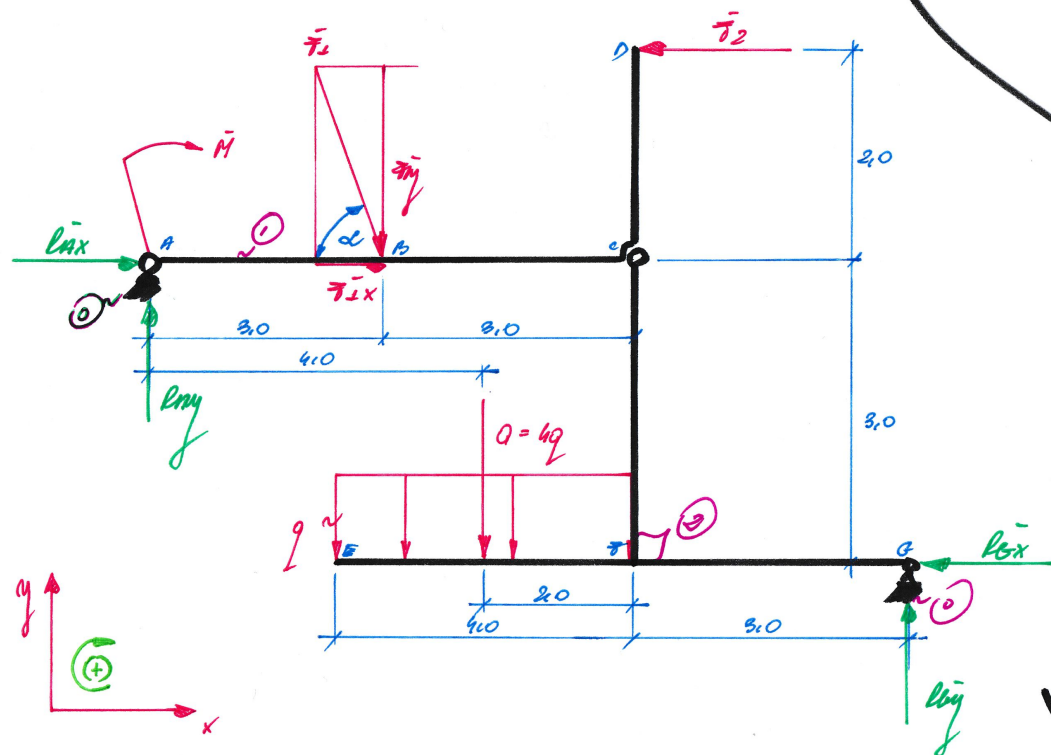
$$\alpha = 60^\circ$$

$$S2: \bar{E} = ?$$

$$F_2 = 14$$

$$q = 3 \text{ [kN/m]}$$

1) выбрать направление осей.



2) Решение.

$$\begin{aligned} &1) \sum F_{ix} = 0 \\ &2) \sum F_{iy} = 0 \\ &3) \sum M_i(A) = 0 \\ &4) \sum M_i(C) = 0 \end{aligned}$$

$$\begin{aligned} &1) R_{Ax} + F_{1x} - F_2 - R_{Bx} = 0 \\ &2) R_{Ay} - F_{1y} - Q + R_{By} = 0 \\ &3) M + F_{1y} \cdot 3 - F_2 \cdot 3 + Q \cdot 4 + R_{Bx} \cdot 3 - R_{By} \cdot 3 = 0 \\ &4) M + R_{Ay} \cdot 6 - F_{1y} \cdot 3 - F_2 \cdot 3 = 0 \end{aligned}$$

$$\frac{F_{1x}}{F_1} = \cos \alpha \Rightarrow F_{1x} = F_1 \cos \alpha$$

$$\frac{F_{1y}}{F_1} = \sin \alpha \Rightarrow F_{1y} = F_1 \sin \alpha$$

$$14) \quad M + 6k_y - 3T_2 \sin \alpha - 2F_2 = 0$$

$$k_y = \frac{-M + 3T_2 \sin \alpha + 2F_2}{6}$$

$$k_y = \frac{-16 + 3 \cdot 24 \cdot \sin 60^\circ + 2 \cdot 14}{6} = \frac{-16 + 62,35 + 28}{6} = \frac{74,35}{6} = 12,39 \text{ [kN]}$$

$$1) \quad k_y - T_2 \sin \alpha - 4q + k_y = 0$$

$$k_y = -k_y + T_2 \sin \alpha + 4q$$

$$k_y = -12,39 + 24 \sin 60^\circ + 4 \cdot 3 = -12,39 + 20,78 + 12 = 20,39 \text{ [kN]}$$

$$11) \quad M + 3T_2 \sin \alpha - 2F_2 + 4 \cdot 4q + 3k_x - 5k_y = 0$$

$$k_x = \frac{-M - 3T_2 \sin \alpha + 2F_2 - 16q + 5k_y}{3}$$

$$k_x = \frac{-16 - 3 \cdot 24 \cdot \sin 60^\circ + 2 \cdot 14 - 16 \cdot 3 + 5 \cdot 20,39}{3} = \frac{-16 - 62,35 + 28 - 48 + 101,95}{3} = \frac{85,16}{3} = 28,38 \text{ [kN]}$$

$$1) \quad k_{Ax} + T_2 \cos \alpha - F_2 - k_x = 0$$

$$k_{Ax} = -T_2 \cos \alpha + F_2 + k_x$$

$$k_{Ax} = -24 \cos 60^\circ + 14 + 28,38 = -12 + 14 + 28,38 = 30,38 \text{ [kN]}$$

$$\Rightarrow \begin{cases} k_{Ax} = 30,38 \\ k_y = 12,39 \\ k_x = 28,38 \\ k_y = 20,39 \end{cases} \text{ [kN]}$$

$$\sum M_G = 0 \Rightarrow -9 \cdot 6 - F_2 \cdot 5 - F_{2y} \cdot 6 + T_{2x} \cdot 3 + M + k_{Ax} \cdot 3 + k_y \cdot 5 = 0$$

502/

$$\frac{1}{2} M_0 = 0$$

-

$$-5.49 - 5F_2 - 6F_2 \sin 60^\circ + 3F_2 \cos 60^\circ + M + 3L_{ax} + 5L_{ay} = 0$$

$$-20.3 - 5.14 - 6.24 \cdot \sin 60^\circ + 3.24 \cdot \cos 60^\circ + 16 + 3 \cdot 30.38 + 3 \cdot 12.35 = 0$$

$$-60 - 40 - 124.40 + 36 + 16 + 91.14 + 111.81 = 0$$

$$-111.86 + 111.82 = 0$$

$$L = P$$

$$\Rightarrow \begin{cases} L_{ax} = 30.38 \\ L_{ay} = 12.35 \\ L_{bx} = 28.38 \\ L_{by} = 20.85 \end{cases} \quad [kN]$$

$$dW - F \cdot ds + M \cdot d\varphi = 0$$

$$-m \cdot H \cdot d_{f1} + T_{f1} \cdot d_{f1} - T_2 \cdot d_{f2} + q \cdot d_{f3} - R_{ex} \cdot d_{f4} = 0$$

$g = \text{def}_\perp$

$$dx_3 = 3 dy_+$$

$$\underline{d_{\text{ST}}} = \underline{2d_{\text{CF}_+}}$$

$$dsc = 6 dy_z$$

$$dsc = 3 dy_2 \Rightarrow dy_2 = \frac{dsc}{3} = \frac{60 \text{ dy}_2}{3} = 20 \text{ dy}_2$$

$$\underline{ds_2} = 5 \, dy_2 = 5 \cdot 2 \, dy_1 = \underline{10 \, dy_1}$$

$$\underline{ds} = 3 \deg_2 = 3 \cdot 2 \deg_1 = 6 \deg_1$$

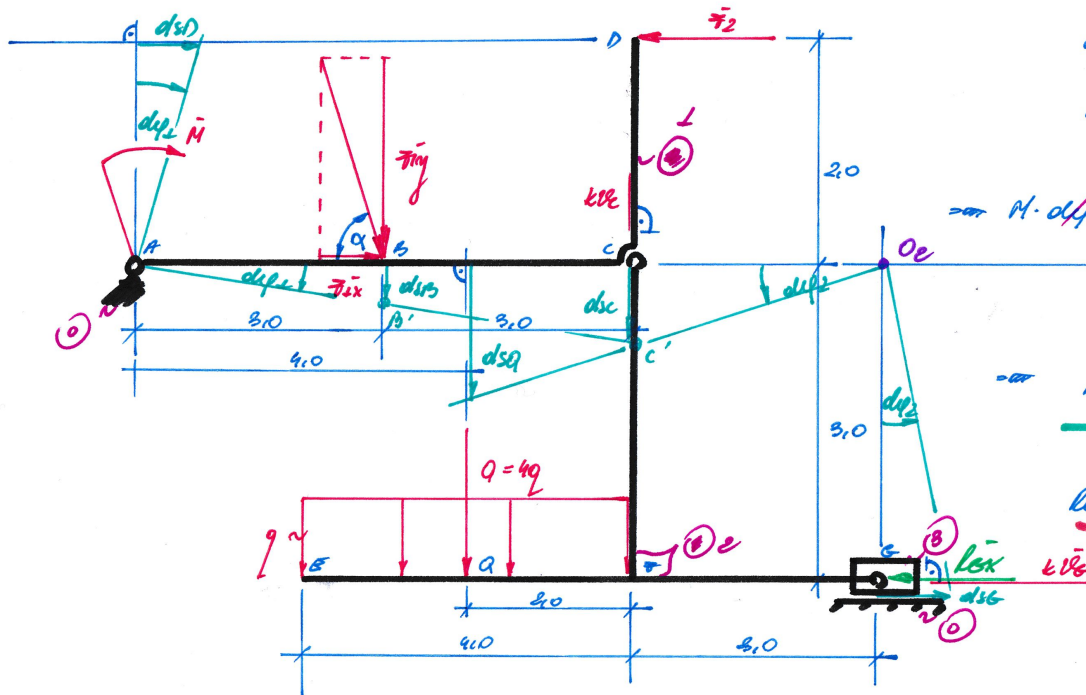
$$M \cdot d\varphi_z + T_{\text{winz}} \cdot 3d\varphi_z - F_2 \cdot 2d\varphi_z + 4q \cdot 10d\varphi_z - R_{0x} \cdot 6d\varphi_z = 0$$

$$R_{ex} = \frac{M + 3I \sin \alpha - E F_2 + 409}{6}$$

$$R_{EX} = \frac{16 + 3 \cdot 24 \cdot \sin 60^\circ - 2 \cdot 14 + 40 \cdot 3}{6} =$$

$$= \frac{16 + 62,35 - 28 + 10}{6} = \frac{14,35}{6} = 2,39$$

$$\Rightarrow R_{ex} = 28,35 \text{ (kN)}$$



Ray

$$\delta W = \bar{F} \cdot ds + M \cdot d\varphi = 0$$

$$\Rightarrow M \cdot d\varphi_{\perp} + \bar{F}_{1y} \cdot ds_B - \bar{F}_2 \cdot ds_D + Q \cdot ds_q - R_{ay} \cdot ds_G = 0$$

$\varphi = d\varphi_{\perp}$

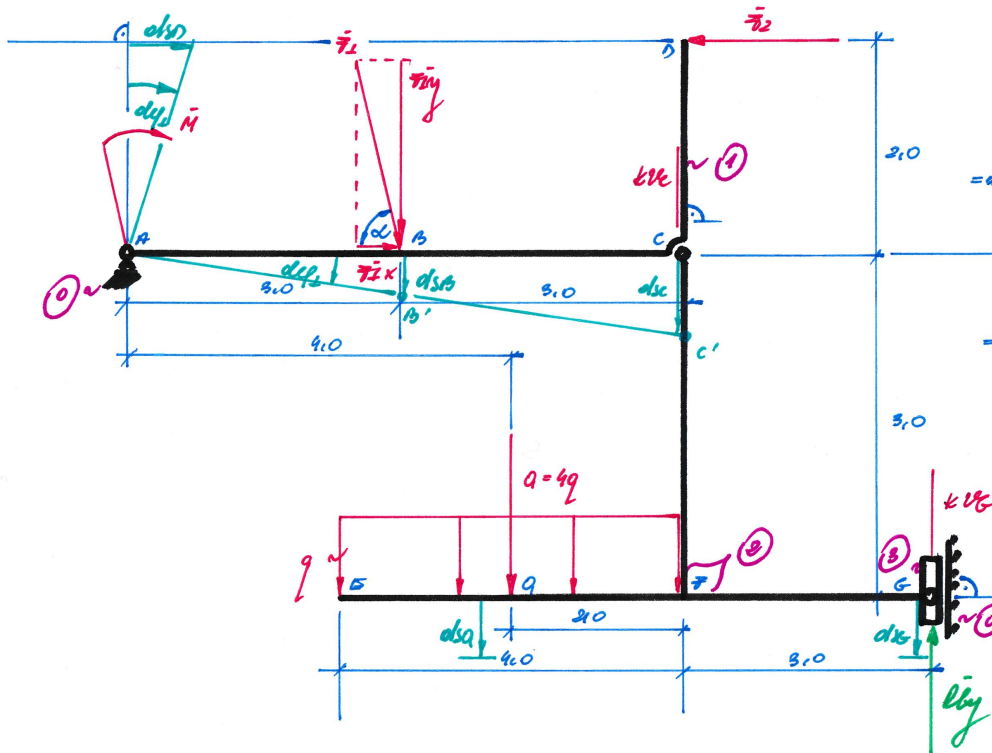
$$ds_B = 3 d\varphi_{\perp}$$

$$ds_D = 2 d\varphi_{\perp}$$

$$ds_C = 6 d\varphi_{\perp}$$

$$ds_q = ds_C = 6 d\varphi_{\perp}$$

$$ds_G = ds_C = 6 d\varphi_{\perp}$$



$$\Rightarrow M \cdot d\varphi_{\perp} + \bar{F}_{1y} \cdot 3 d\varphi_{\perp} - \bar{F}_2 \cdot 2 d\varphi_{\perp} + 4q \cdot 6 d\varphi_{\perp} - R_{ay} \cdot 6 d\varphi_{\perp} = 0$$

$$\Rightarrow R_{ay} = \frac{M + 3 \bar{F}_{1y} - 2 \bar{F}_2 + 24q}{6}$$

$$Q_2 = \infty$$

$$R_{ay} = \frac{16 + 3 \cdot 24 \cdot \sin 60^\circ - 2 \cdot 14 + 24 \cdot 3}{6} =$$

$$= \frac{16 + 62,35 - 28 + 72}{6} = \frac{122,35}{6} =$$

$$= 20,39$$

$$\Rightarrow R_{ay} = 20,39 \text{ (kN)}$$

max

$$\delta W = \bar{F} \cdot \delta s + M \cdot \delta \varphi = 0 \quad - \text{max}$$

$$M \cdot \delta \varphi_2 - R_{Ax} \cdot \delta s_A + \bar{F}_{1y} \cdot \delta m_y - \bar{F}_{1x} \cdot \delta m_x + \bar{F}_2 \cdot \delta m + Q \cdot \delta s_q = 0$$

$q = \delta \varphi_2$

$$\delta s_q = 5 \delta \varphi_2$$

$$\delta s_c = 3\sqrt{2} \delta \varphi_2$$

$$\delta s_c = 3\sqrt{2} \delta \varphi_2 \Rightarrow \delta \varphi_2 = \frac{\delta s_c}{3\sqrt{2}} = \frac{3\sqrt{2} \delta \varphi_2}{6\sqrt{2}} = 0.5 \delta \varphi_2$$

$$\delta m = 6 \delta \varphi_2 = 6 \cdot 0.5 \delta \varphi_2 = 3 \delta \varphi_2$$

$$\delta m_x = \delta m = 3 \delta \varphi_2$$

$$\delta s_D = 4 \delta \varphi_2 = 4 \cdot 0.5 \delta \varphi_2 = 2 \delta \varphi_2$$

$$\delta m_y = 3 \delta \varphi_2 = 3 \cdot 0.5 \delta \varphi_2 = 1.5 \delta \varphi_2$$

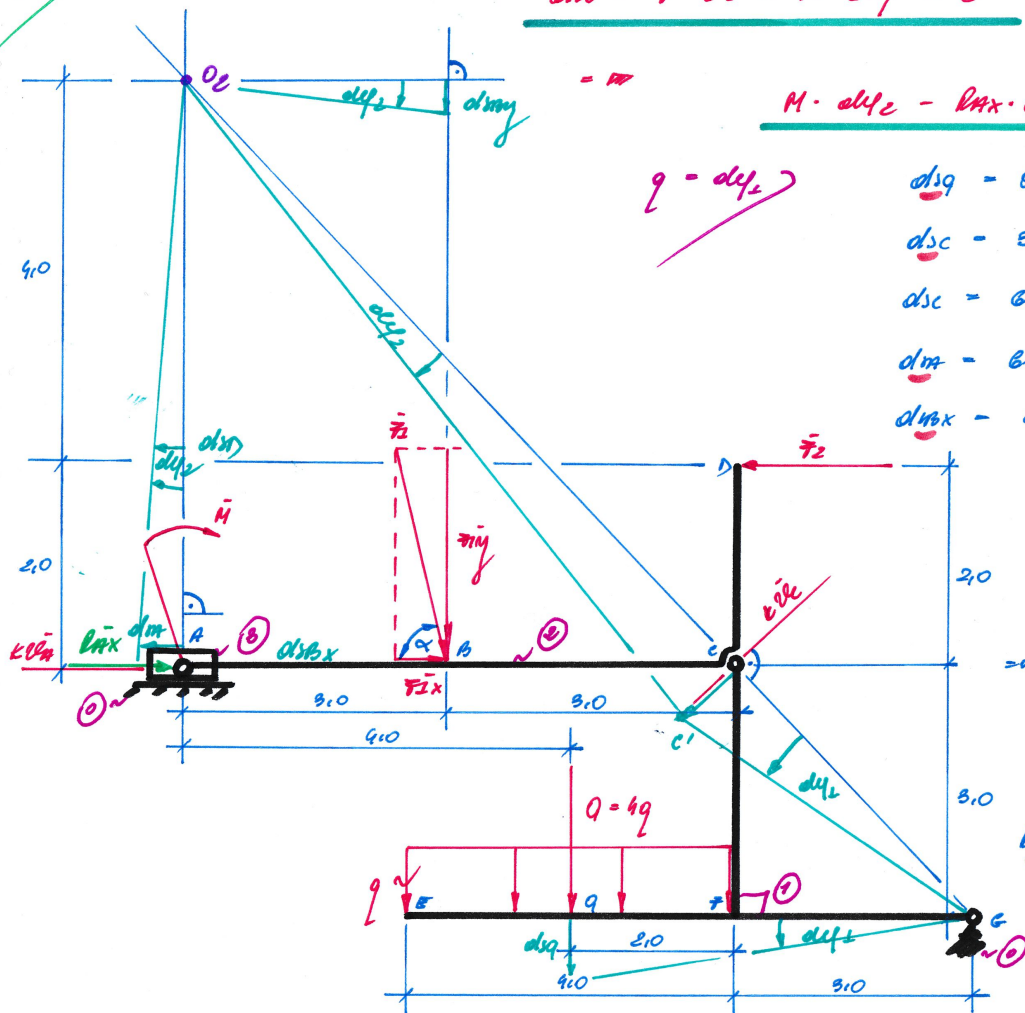
$$\Rightarrow M \cdot 0.5 \delta \varphi_2 - R_{Ax} \cdot 3 \delta \varphi_2 + \bar{F}_{1y} \sin \alpha \cdot 1.5 \delta \varphi_2 - \bar{F}_2 \cos \alpha \cdot 3 \delta \varphi_2 + \bar{F}_2 \cdot 2 \delta \varphi_2 + 4q \cdot 5 \delta \varphi_2 = 0$$

$$R_{Ax} = \frac{0.5M + 1.5 \bar{F}_1 \sin \alpha - 3 \bar{F}_2 \cos \alpha + 2 \bar{F}_2 + 20q}{3}$$

$$= \frac{0.5 \cdot 16 + 1.5 \cdot 24 \cdot \sin 60^\circ - 3 \cdot 24 \cdot \cos 60^\circ + 2 \cdot 19 + 20 \cdot 3}{3}$$

$$= \frac{8 + 31.14 - 36 + 28 + 60}{3} = \frac{31.14}{3}$$

$$= 30.38 \quad \Rightarrow R_{Ax} = 30.38 \text{ (kN)}$$



my

$$dW = T \cdot ds + M \cdot d\varphi = 0$$

$$- Q \cdot ds_q + \bar{T}_x \cdot ds_x + \bar{T}_y \cdot ds_y - M \cdot d\varphi_2 - m_y \cdot ds_{11} = 0$$

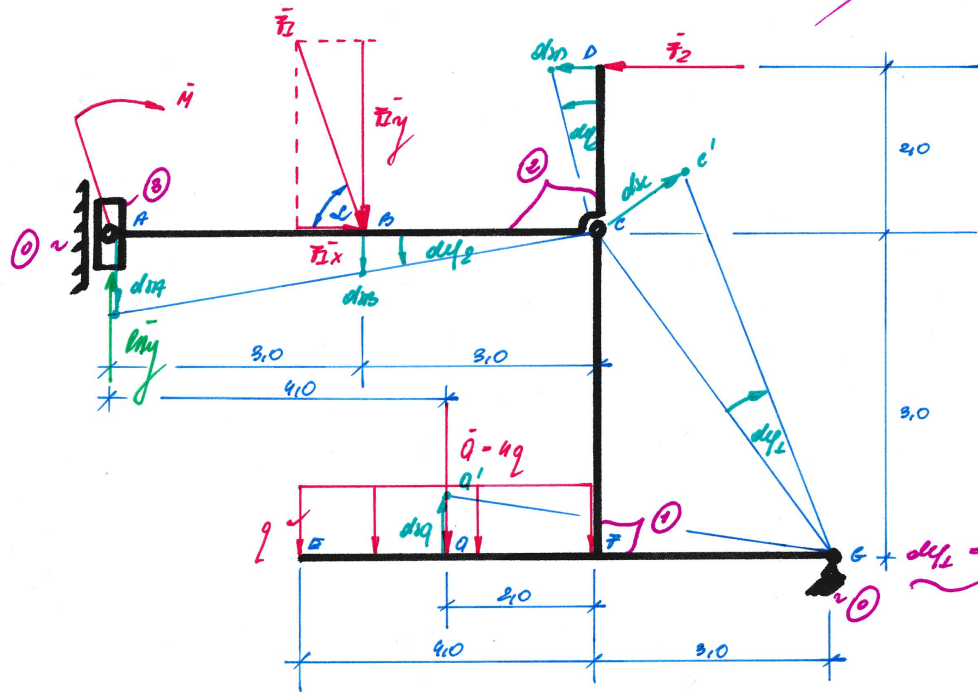
$$\varphi = d\varphi_2$$

$$ds_x = 3 d\varphi_2$$

$$ds_y = 5 d\varphi_2 = 0$$

$$ds_{11} = 6 d\varphi_2$$

$$ds = 20 d\varphi_2$$



$$- T_2 \sin \alpha \cdot 30 d\varphi_2 + T_2 \cdot 20 d\varphi_2 - M \cdot d\varphi_2 - m_y \cdot 60 d\varphi_2 = 0$$

$$m_y = \frac{3 T_2 \sin \alpha + 2 T_2 - M}{6}$$

$$m_y = \frac{3 \cdot 24 \cdot \sin 60^\circ + 2 \cdot 14 - 16}{6} = \frac{82.35 + 28 - 16}{6} = \frac{94.35}{6} = 15.725 \text{ [kN]}$$

