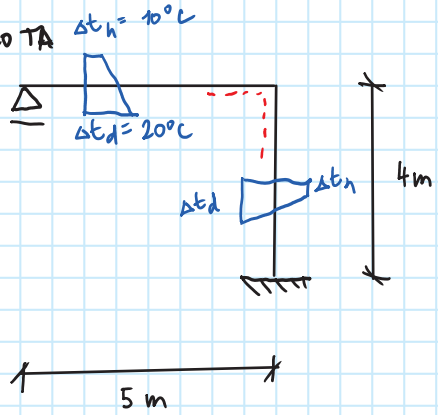
Cv.07 - Staticky neurčitý rám s deformačním zatížením

čtvrtek 25. března 2021

A) TEPLOTA

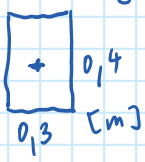


$\Delta t_h = 10°C$

$\Delta t_d = 20°C$

$\alpha_T = 10^{-5}\ K^{-1}$

$E = 30\ GPa$



$A = 0{,}3 \cdot 0{,}4 = 0{,}12\ m^2$

$I = \frac{1}{12} b h^3 = \frac{1}{12} 0{,}3 \cdot 0{,}4^3 = 1{,}6 \cdot 10^{-3}\ m^4$

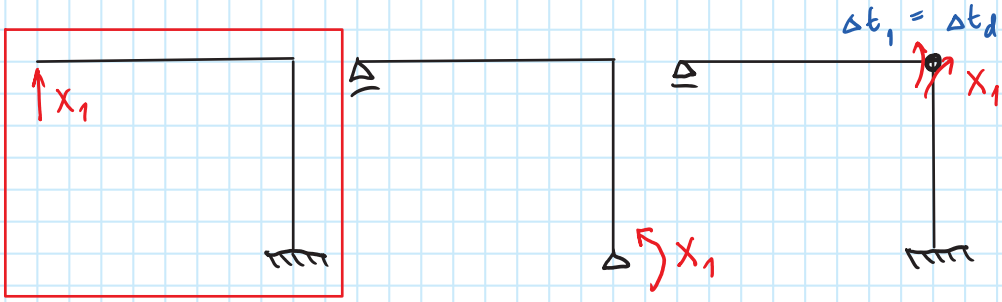
$EA = 3600\,000\ kPa \cdot m^2$

$EI = 48\,000\ kPa \cdot m^4$

$\Delta t_0 = \frac{\Delta t_h + \Delta t_d}{2} = \frac{10+20}{2} = 15°C$

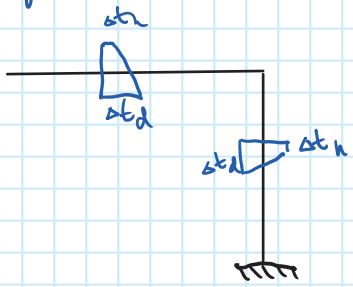
$\Delta t_1 = \Delta t_d - \Delta t_h = 20 - 10 = 10°C$

1) $n_s = 3$, zsus $\quad n_s = 1$



2) vykreslení vnitřních sil od jednotlivých zat. stavů

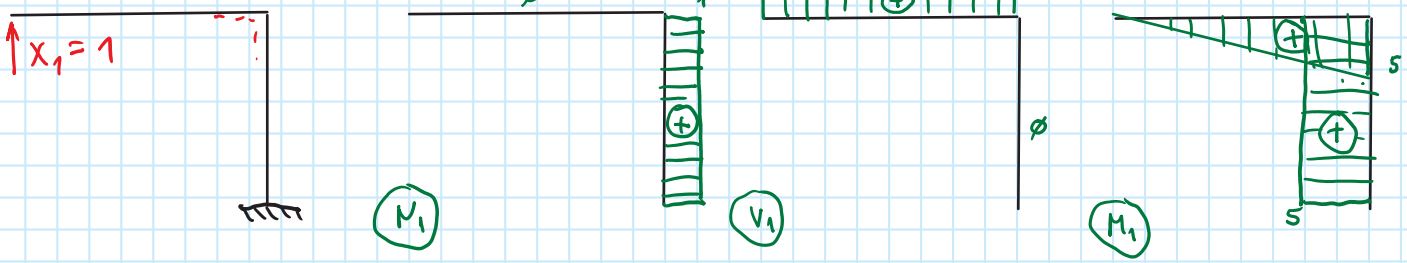
0.25:



- na sg hl od def. zatížení nevznikají vnitřní síly

$\Rightarrow N_0, V_0, M_0 = \emptyset$

1.25:



3) sestavení přetvárných rovnic + výpočet δ

$\delta_{1,1} X_1 + {}^T\delta_{1,0} = 0$

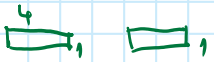
$$ {}^M\delta_{1,1} = \int \frac{M_1 M_1}{EI} dx = \frac{1}{EI}\left\{ \left(\tfrac{1}{2}\cdot 5 \cdot 5\right) \cdot \left[\tfrac{2}{3}\cdot 5\right] + \left(4 \cdot 5\right) \cdot \left[5\right] \right\} = \frac{141{,}\overline{6}}{EI} = 2{,}95138\overline{8} \cdot 10^{-3} $$

$$ {}^M\delta_{1,0} = \int \bar{N} \alpha_T \Delta t_0\, dx + \int \bar{M} \alpha_T \frac{\Delta t_1}{h} dx = \left[\left(0 + 4 \cdot 1 \cdot 10^{-5} \cdot 15\right) + \left(\tfrac{1}{2} \cdot 5 \cdot 5 \cdot 10^{-5} \cdot \tfrac{10}{9{,}4} + 4 \cdot 5 \cdot 10^{-5} \cdot \tfrac{10}{9{,}4} \right) \right] = $$

$$ = 8{,}725 \cdot 10^{-3} $$

$$ 2{,}95138\overline{8} \cdot X_1 + 8{,}725 \cdot 10^{-3} = 0 \Rightarrow \underline{X_1 = -2{,}956\ kN} $$

4) zohlednění vlivu norm. síly



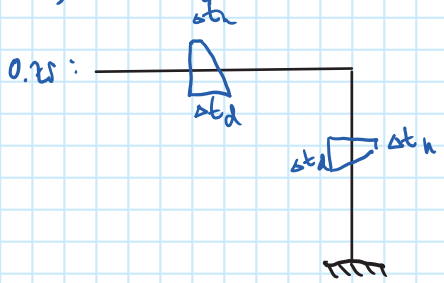
$$^{N}\delta_{1,1} = \int \frac{N_1 N_1}{EA}\,dx = \frac{1}{EA}\left\{4 \cdot 1 \cdot [1]\right\} = \frac{4}{EA} = 1{,}1 \cdot 10^{-6}$$

$$\delta_{1,1} = {}^{M}\delta_{1,1} + {}^{N}\delta_{1,1} = 2{,}9525 \cdot 10^{-3}$$

$$2{,}9525 \cdot 10^{-3} X_1 + 8{,}725 \cdot 10^{-3} = 0 \Rightarrow \underline{X_1 = -2{,}955\ \text{kN}}$$

5) průběhy vnitřních sil

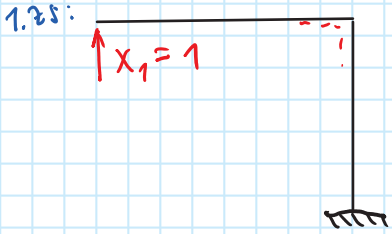
0.25:

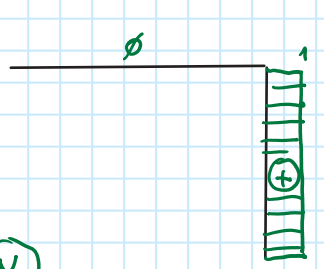


– na SÚ bez od def. zatížení nevznikají vnitřní síly

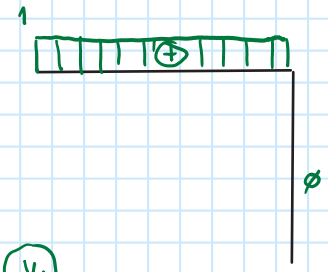
$\Rightarrow N_0, V_0, M_0 = \emptyset$

1.25:

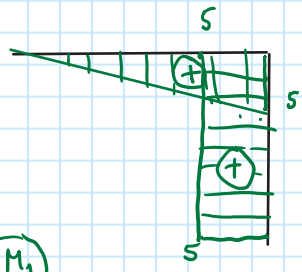




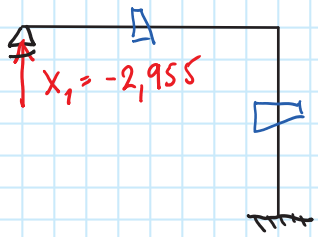
N_1

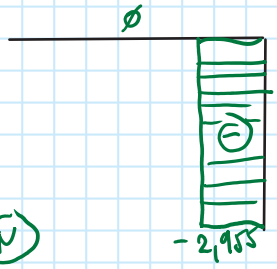


V_1

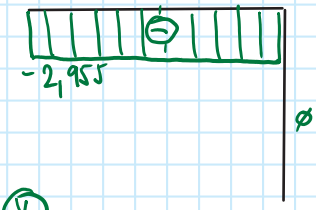


M_1

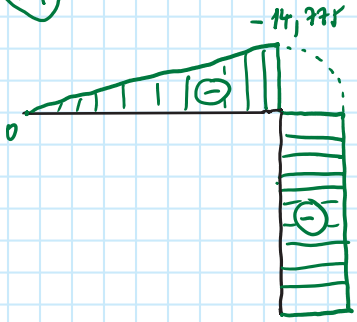




N



V



$N = N_1 \cdot X_1 + N_0$ $\quad V = V_1 X_1 + V_0$ $\quad M = M_1 X_1 + M_0$

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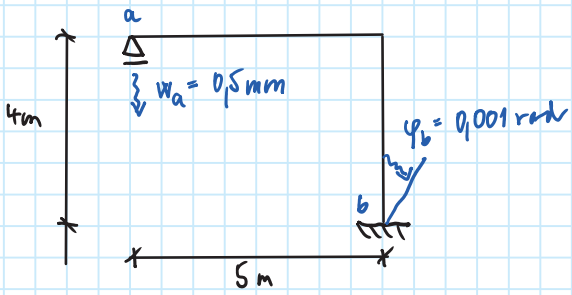
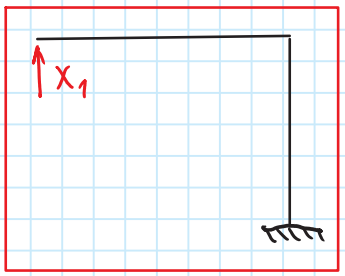
B) POPUŠTĚNÍ PODPOR

1) $n_s = ?$, zsus $n_s = 1$

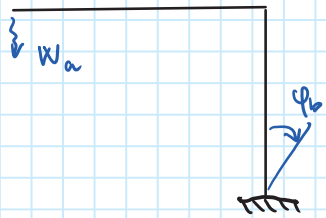




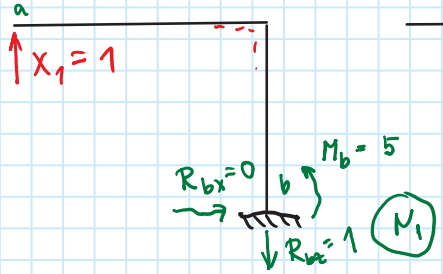
2) vykreslení vnitřních sil od jednotlivých zat. stavů + výpočet reakcí

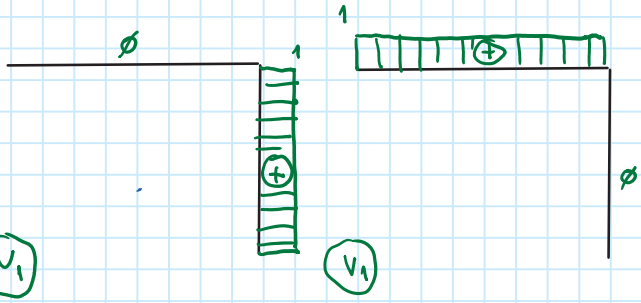
0.zs: – na sc bez od def. zatížení nevznikají vnitřní síly

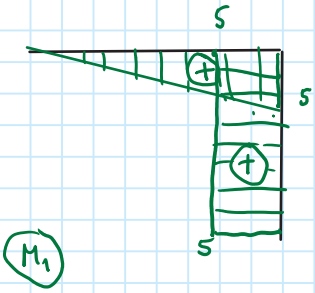
$\Rightarrow N_0, V_0, M_0 = \emptyset$



1.zs:







3) sestavení vyčíslení δ

$\delta_{1,1} \cdot X_1 + \delta_{1,0}^{PP} = -w_a$ (opačný směr $\uparrow X_1$ $\downarrow w_a$)

$\delta_{1,0}^{PP}$ – ostatní deformace ortatních podpor (φ_b)

posun/pootočení v místě odebrané vazby odpovídající typu odebrané vazby se objeví na pravé straně rovnice

(+) $w \rightarrow X_1$ mají stejný směr; $w \downarrow \downarrow X_1$; $\varphi \circlearrowright X_1$

$$\delta_{1,1} = \int \frac{N_1 N_1}{EA}\,dx + \int \frac{M_1 M_1}{EI} = 2{,}9525 \cdot 10^{-3} \quad \text{(viz dříve)}$$

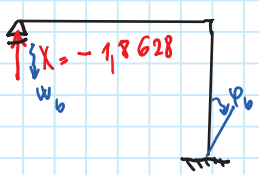
$\downarrow^5 \downarrow \varphi_b$

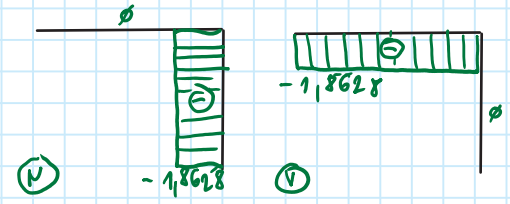
$$\delta_{1,0}^{PP} = -\sum_n \left(\bar{R}_{nx} u_n + \bar{R}_{nz} \cdot w_n + \bar{M}_n \cdot \varphi_n\right) = -\left[\bar{R}_{bx} \cdot u_b + \bar{R}_{bz} \cdot w_b + \bar{M}_b \cdot \varphi_b\right] =$$

$$= -(0 \cdot 0 + 1 \cdot 0 + (-5 \cdot 0{,}001)) = 0{,}005$$

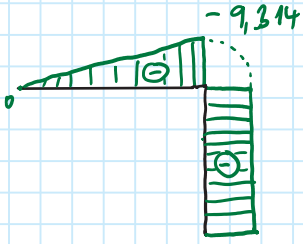
$$2{,}9525 \cdot 10^{-3} X_1 + 0{,}005 = -(0{,}5 \cdot 10^{-3}) \Rightarrow \underline{X_1 = -1{,}8628\ kN}$$

4) průběhy N, V, M





$N = N_1 \cdot X_1 + N_0$ $\quad V = V_1 X_1 + V_0$



$M = M_1 X_1 + M_0$

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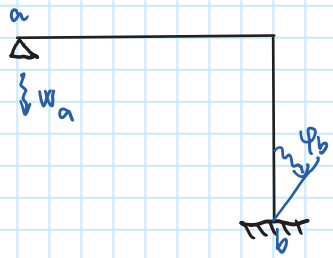
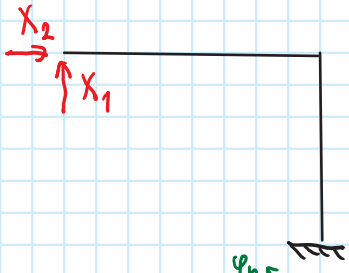
Sestavení přetvárných rovnic na různých zsus:



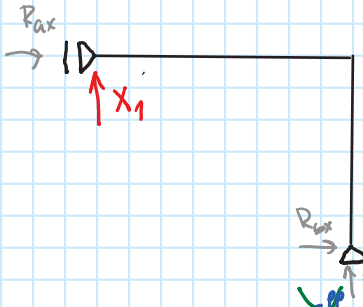


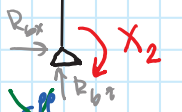
φ_b ↖ ↑ X_1 ↓ w_a

$$\delta_{1,1} X_1 + \delta_{1,2} X_2 + \delta^{pp}_{1,0} = -w_a$$

$$\delta_{2,1} X_1 + \delta_{2,2} X_2 + \delta^{pp}_{2,0} = 0$$

$\delta^{pp}_{2,0}$ ↙ φ_b





$$\delta_{1,1} X_1 + \delta_{1,2} X_2 + \cancel{\delta^{pp}_{1,0}} = -w_a$$

$$\delta_{2,1} X_1 + \delta_{2,2} X_2 + \cancel{\delta^{pp}_{2,0}} = +\varphi_b$$

↷ X_2 ↓ φ_b

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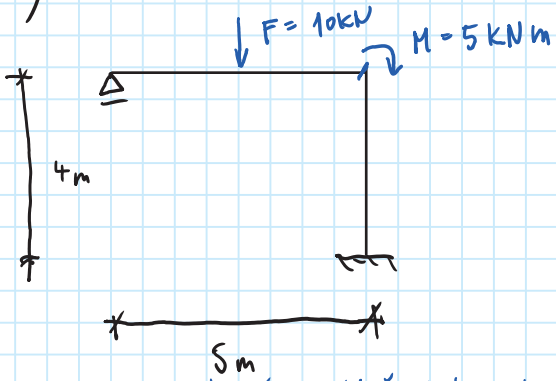
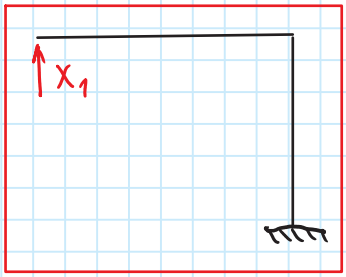
c) silové zatížení

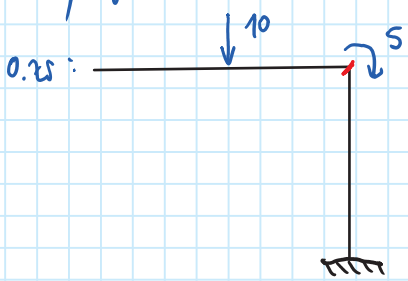


1) $m_S = ?$, zsus $n_S = 1$

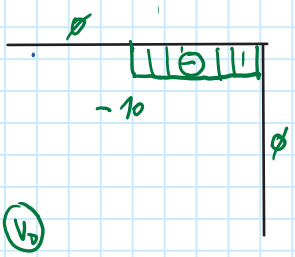


2) vykreslení vnitřních sil od jednotlivých zat. stavů

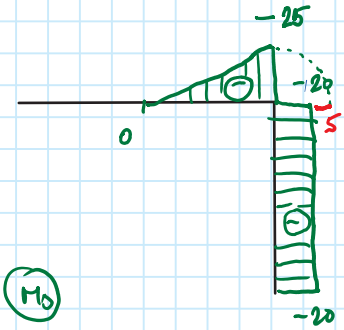
0.zs:



N_0

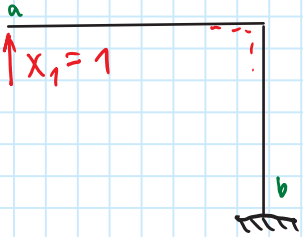


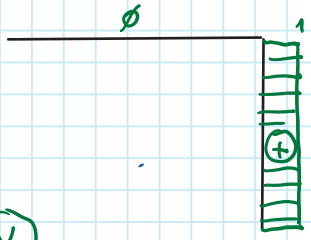
V_0



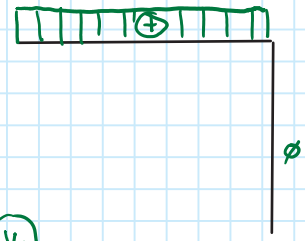
M_0

1.zs:

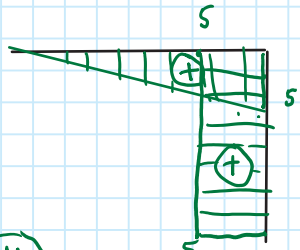




N_1



V_1



M_1

3) $\delta_{1,1} X_1 + \delta_{1,0} = 0$

$$\delta_{1,1} = \int \frac{N_1 N_1}{EA} dx + \int \frac{M_1 M_1}{EI} dx = 2,9525 \cdot 10^{-3}$$

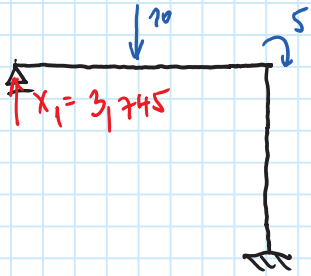
$$\delta_{1,0} = \int \frac{N_1 N_0}{EA} dx + \int \frac{M_1 M_0}{EI} dx = -1,1 \cdot 10^{-5} - 11,046 \cdot 10^{-3} = -11,057 \cdot 10^{-3}$$

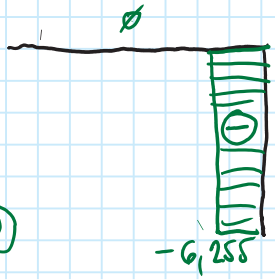
$$^N\delta_{1,0} = \frac{1}{EA}\left\{0 + \left(4 \cdot (-10)\right) \cdot [1]\right\} = \frac{-40}{EA} = -1,1 \cdot 10^{-5}$$

$$^M\delta_{1,0} = \frac{1}{EI}\left\{\left(\tfrac{1}{2} \cdot 2,5 \cdot (-25)\right)\left[2,5 + \tfrac{2}{3} 2,5\right] + (-20 \cdot 4) \cdot [5]\right\} = \frac{-530\,20\,83}{EI} = -11,046 \cdot 10^{-3}$$

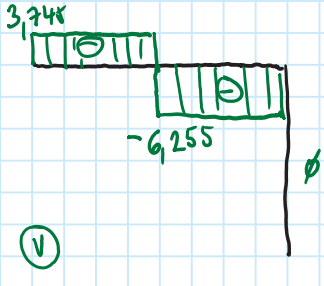
$$2,9525 \cdot 10^{-3} X_1 - 11,057 \cdot 10^{-3} = 0 \Rightarrow X_1 = 3,745 \text{ kN}$$

4) Průběhy N, V, M

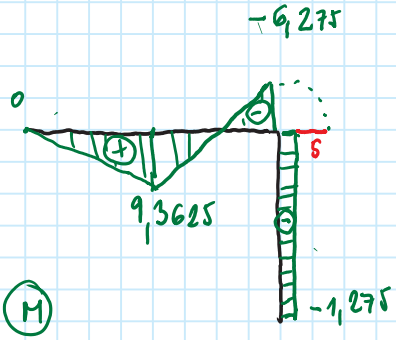




N



V



M

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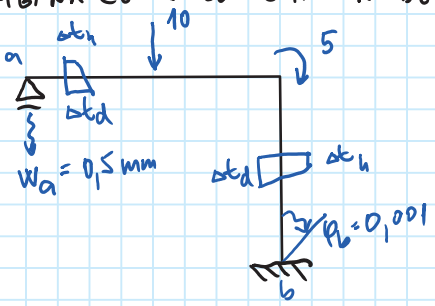
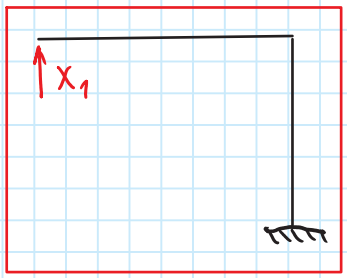
D) KOMBINACE SILOVÉHO A DEFORMAČNÍHO ~~[illegible]~~.



1) $n_s = n$, ZSUS $\quad n_s = 1$



2) ...

3) $\delta_{1,1} X_1 + \delta_{1,0}^{T} + \delta_{1,0}^{PP} + \delta_{1,0}^{silová} = -w_a \Rightarrow X_1 = -1,0728$

$$X_1 = X_1^T + X_1^{PP} + X_1^{silového} = -2,955 - 1,8628 + 3,745 = -1,0728\ kN$$

4) vykreslení N, V, M

$N = N^T + N^{PP} + N^{silové}$
$V = V^T + V^{PP} + V^{silové}$
$M = M^T + M^{PP} + M^{silové}$