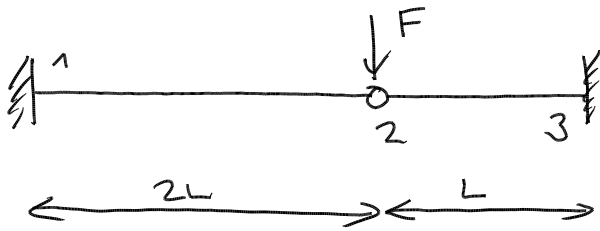


Pr



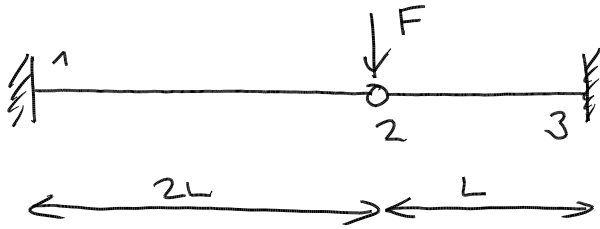
$$EI = 20 \text{ MN/m}^2$$

$$M_0 = 100 \text{ kNm}$$

$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

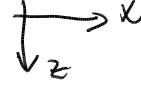
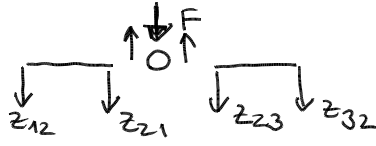
Pr



$$EI = 20 \text{ MNm}^2$$
$$M_0 = 100 \text{ kNm}$$
$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

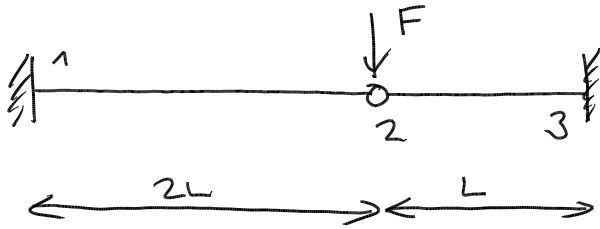
→ řešení pomocí \mathcal{Z}



$$z_{21} = z_{21}^l$$
$$z_{23} = z_{23}^l$$

$$z_{21} + z_{23} = F$$

Pr



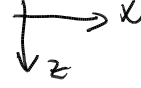
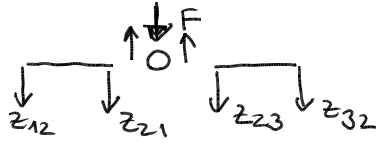
$$EI = 20 \text{ MNm}^2$$

$$M_0 = 100 \text{ kNm}$$

$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

→ řešení pomocí \mathcal{M}



$$z_{21} = z_{21}^L$$

$$z_{23} = z_{23}^L$$

$$z_{21} + z_{23} = F$$

$$z_{21} = \frac{3k_{12}}{2(2L)} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} \cdot \frac{w_2}{2L} = \frac{3EI}{8L^3} w_2$$

$\rightarrow k_{12} = \frac{2EI}{2L}$

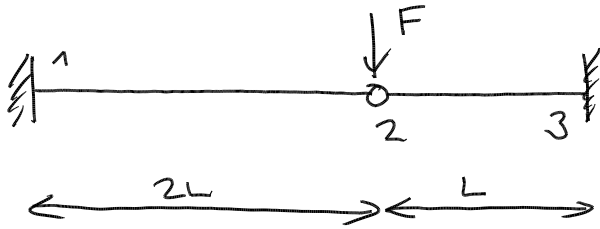
$$z_{23} = \frac{3EI}{L^2} \cdot \frac{w_2}{L} = \frac{3EI}{L^3} \cdot w_2$$

$$w_2 \left[\frac{3EI}{8L^3} + \frac{3EI}{L^3} \right] = F$$

$$w_2 \frac{3EI + 24EI}{8L^3} = F$$

$$\rightarrow w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

Pr



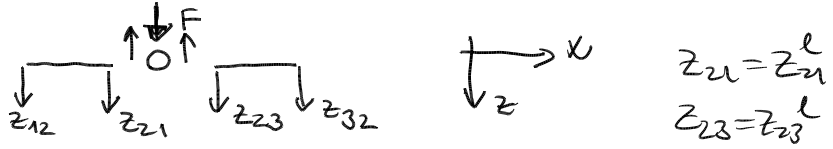
$$EI = 20 \text{ MNm}^2$$

$$M_0 = 100 \text{ kNm}$$

$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

→ řešení pomocí Φ



$$z_{21} = z_{21}^L$$

$$z_{23} = z_{23}^L$$

$$z_{21} + z_{23} = F$$

$$z_{21} = \frac{3k_{12}}{2(2L)} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} \cdot \frac{w_2}{2L} = \frac{3EI}{8L^3} w_2$$

$\rightarrow k_{12} = \frac{2EI}{2L}$

$$w_2 \left[\frac{3EI}{8L^3} + \frac{3EI}{L^3} \right] = F$$

$$z_{23} = \frac{3EI}{L^2} \cdot \frac{w_2}{L} = \frac{3EI}{L^3} \cdot w_2$$

$$w_2 \frac{3EI + 24EI}{8L^3} = F$$

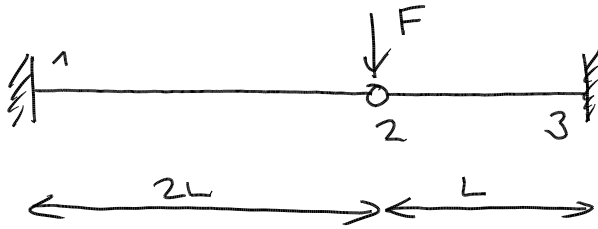
$$\rightarrow w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

→ kritické průřezy 1, 3

$$M_{12} = \frac{3k_{12}}{2} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} w_2 = \frac{3EI}{4L^2} \cdot \frac{8}{27} \frac{FL^3}{EI} = \frac{2}{9} FL$$

$$M_{32} = -\frac{3EI}{L^2} w_2 = -\frac{8}{9} FL$$

Pr



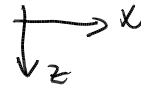
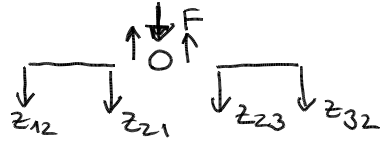
$$EI = 20 \text{ MNm}^2$$

$$M_0 = 100 \text{ kNm}$$

$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

→ řešení pomocí ΦM



$$z_{21} = z_{21}^L$$

$$z_{23} = z_{23}^L$$

$$z_{21} + z_{23} = F$$

$$z_{21} = \frac{3k_{12}}{2(2L)} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} \cdot \frac{w_2}{2L} = \frac{3EI}{8L^3} w_2$$

$\rightarrow k_{12} = \frac{2EI}{2L}$

$$w_2 \left[\frac{3EI}{8L^3} + \frac{3EI}{L^3} \right] = F$$

$$z_{23} = \frac{3EI}{L^2} \cdot \frac{w_2}{L} = \frac{3EI}{L^3} \cdot w_2$$

$$w_2 \frac{3EI + 24EI}{8L^3} = F$$

$$\rightarrow w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

→ kritická průřez 1,3

$$M_{12} = \frac{3k_{12}}{2} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} w_2 = \frac{3EI}{4L^2} \cdot \frac{8}{27} \frac{FL^3}{EI} = \frac{2}{9} FL$$

$$M_{32} = -\frac{3EI}{L^2} w_2 = -\frac{8}{9} FL$$

$|M_{32}| > |M_{12}| \rightarrow$ 1. plastický kloub v průřezu "3"

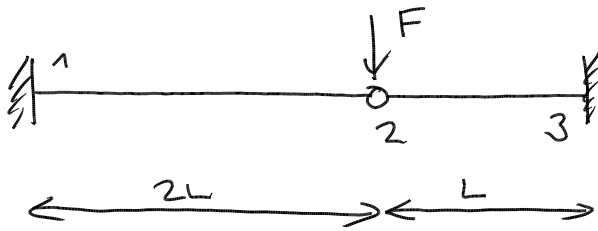
→ dopótká odpovídající síly $F^{(1)}$ $|M_{32}| = M_0 \rightarrow F^{(1)} = \frac{9}{8} \frac{M_0}{L} = \frac{9 \cdot 100}{8 \cdot 2} = 56,25 \text{ kN}$

→ pro další analýzu $M_{12} = \frac{2}{9} \cdot \frac{9}{8} \frac{M_0}{L} \cdot L = \frac{M_0}{4} = 25 \text{ kNm}$

Vykreslení pro sílu $F^{(1)}$



Pr



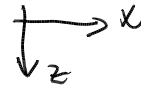
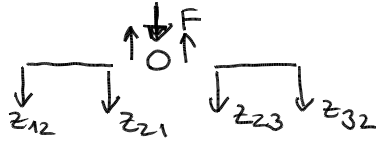
$$EI = 20 \text{ MNm}^2$$

$$M_0 = 100 \text{ kNm}$$

$$L = 2 \text{ m}$$

přirůstková analýza, $F^{(1)}$, F_{\max} , průběhy $M+V$ pro oba stavy, reakce pro F_{\max}

→ řešení pomocí ΣM



$$z_{21} = z_{21}^L$$

$$z_{23} = z_{23}^L$$

$$Z_{21} + Z_{23} = F$$

$$Z_{21} = \frac{3k_{12}}{2(2L)} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} \cdot \frac{w_2}{2L} = \frac{3EI}{8L^3} w_2$$

$\rightarrow k_{12} = \frac{2EI}{2L}$

$$w_2 \left[\frac{3EI}{8L^3} + \frac{3EI}{L^3} \right] = F$$

$$Z_{23} = \frac{3EI}{L^2} \cdot \frac{w_2}{L} = \frac{3EI}{L^3} \cdot w_2$$

$$w_2 \frac{3EI + 24EI}{8L^3} = F$$

$$\rightarrow w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

→ kritické průřezy 1,3

$$M_{12} = \frac{3k_{12}}{2} \left(\varphi_1 + \frac{w_2 - w_1}{2L} \right) = \frac{3EI}{(2L)^2} w_2 = \frac{3EI}{4L^2} \cdot \frac{8}{27} \frac{FL^3}{EI} = \frac{2}{9} FL$$

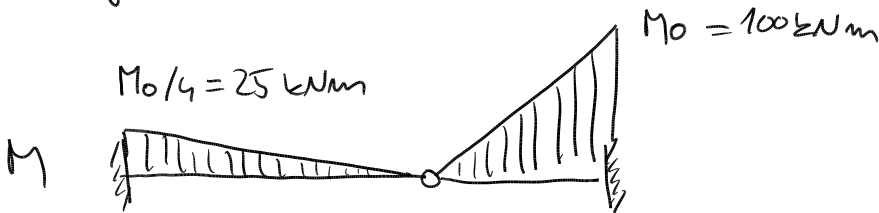
$$M_{32} = -\frac{3EI}{L^2} w_2 = -\frac{8}{9} FL$$

$|M_{32}| > |M_{12}| \rightarrow$ 1. plastický kloub v průřezu "3"

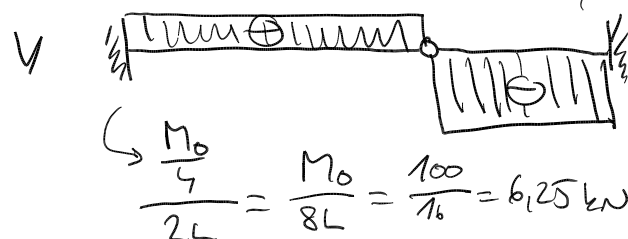
→ dopótkem odpovídající síly $F^{(1)}$ $|M_{32}| = M_0 \rightarrow F^{(1)} = \frac{9}{8} \frac{M_0}{L} = \frac{9 \cdot 100}{8 \cdot 2} = 56,25 \text{ kN}$

→ pro další analýzu $M_{12} = \frac{2}{9} \cdot \frac{9}{8} \frac{M_0}{L} \cdot L = \frac{M_0}{4} = 25 \text{ kNm}$

Vykreslení pro sílu $F^{(1)}$

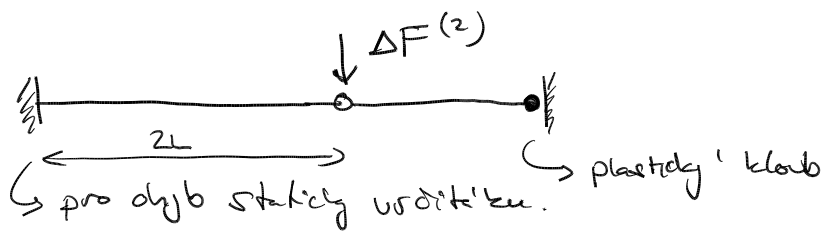


$$\frac{M_0}{L} = \frac{100}{2} = 50 \text{ kN}$$

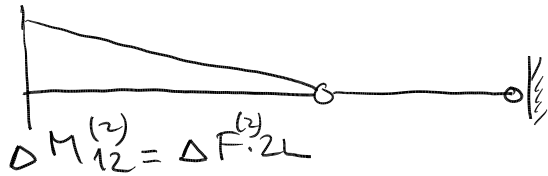
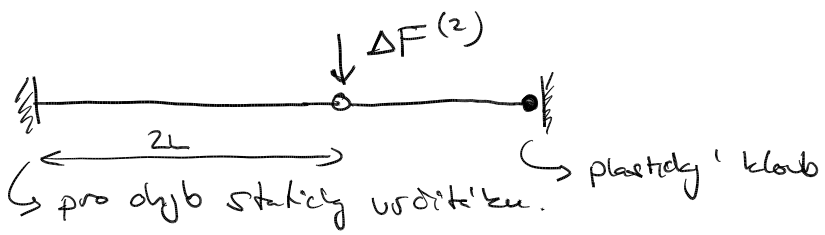


Kontrola: $50 + 6,25 = 56,25 \text{ kN}$

→ Modifikované statické schéma

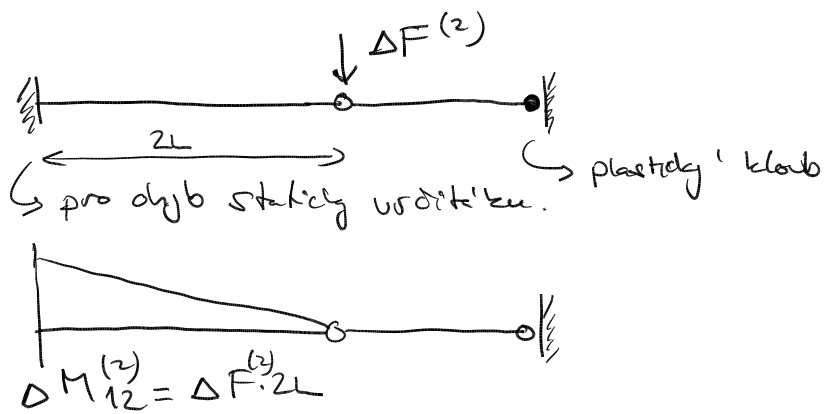


→ Modifikované statické schéma



→ vznik 2. plast. kloubu v průřezu 1

→ Modifikované statické schéma



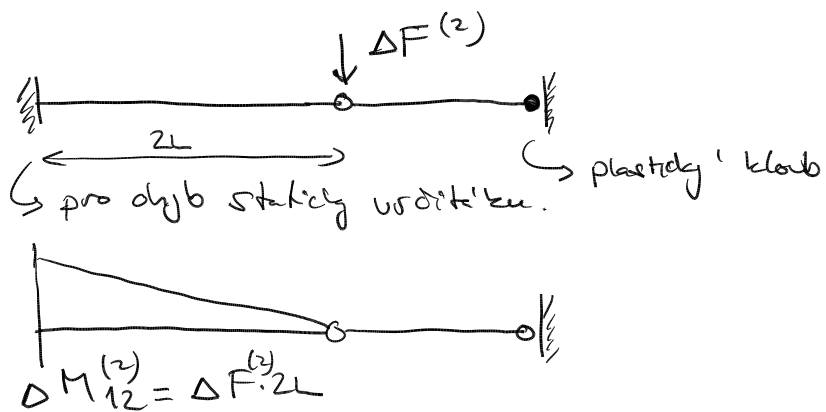
→ vznik 2. plast. kloubu v průřezu 1

$$|M_{12}^{(1)} + \Delta M_{12}^{(2)}| = M_0$$

$$\frac{M_0}{4} + \Delta F^{(2)} \cdot 2L = M_0$$

$$\Delta F^{(2)} = \frac{3}{4} M_0 / 2L = \frac{3}{8} \frac{M_0}{L} = \frac{3}{8} \cdot \frac{100}{2} = 18,75 \text{ kN}$$

→ Modifikované statické schéma



→ vznik 2. plast. kloubu v průřezu 1

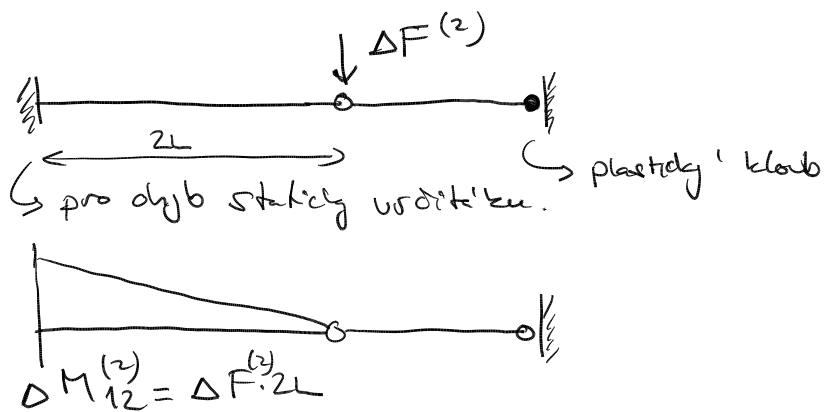
$$|M_{12}^{(1)} + \Delta M_{12}^{(2)}| = M_0$$

$$\frac{M_0}{4} + \Delta F^{(2)} \cdot 2L = M_0$$

$$\Delta F^{(2)} = \frac{3}{4} M_0 / 2L = \frac{3}{8} \frac{M_0}{L} = \frac{3}{8} \cdot \frac{100}{2} = 18,75 \text{ kN}$$

$$\begin{aligned} F_{\max} &= F^{(1)} + \Delta F^{(2)} = \frac{9}{8} \frac{M_0}{L} + \frac{3}{8} \frac{M_0}{L} = \frac{12}{8} \frac{M_0}{L} = \frac{3}{2} \frac{M_0}{L} \\ &= 56,25 + 18,75 = \underline{\underline{75 \text{ kN}}} \end{aligned}$$

→ Modifikované statické schéma



→ vznik 2. plast. kloubu v průřezu 1

$$|M_{12}^{(1)} + \Delta M_{12}^{(2)}| = M_0$$

$$\frac{M_0}{4} + \Delta F^{(2)} \cdot 2L = M_0$$

$$\Delta F^{(2)} = \frac{3}{4} M_0 / 2L = \frac{3}{8} \frac{M_0}{L} = \frac{3}{8} \cdot \frac{100}{2} = 18,75 \text{ kN}$$

$$F_{max} = F^{(1)} + \Delta F^{(2)} = \frac{9}{8} \frac{M_0}{L} + \frac{3}{8} \frac{M_0}{L} = \frac{12}{8} \frac{M_0}{L} = \frac{3}{2} \frac{M_0}{L}$$

$$= 56,25 + 18,75 = \underline{\underline{75 \text{ kN}}}$$

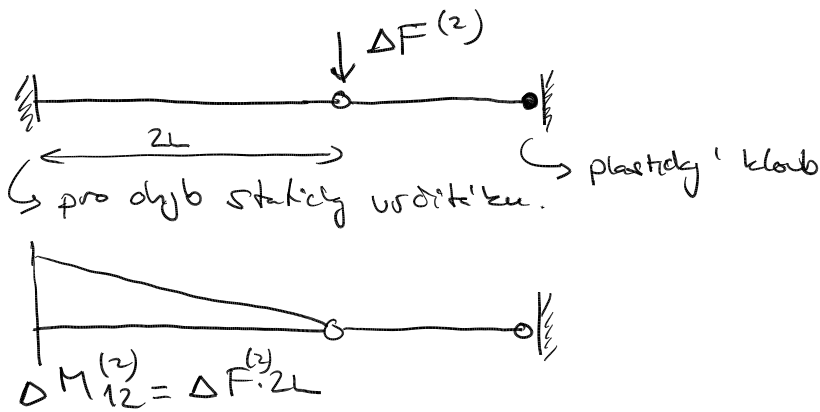
→ Vykreslení pro sílu F_{max}



Reakce:



→ Modifikované statické schéma



→ vznik 2. plast. kloubu v průřezu 1

$$|M_{12}^{(1)} + \Delta M_{12}^{(2)}| = M_0$$

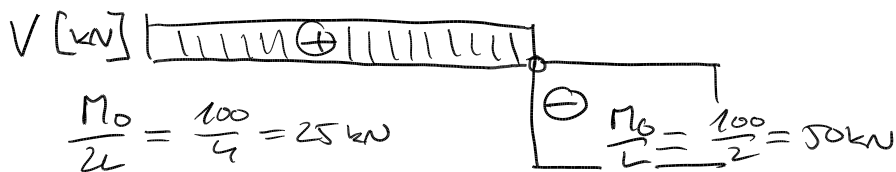
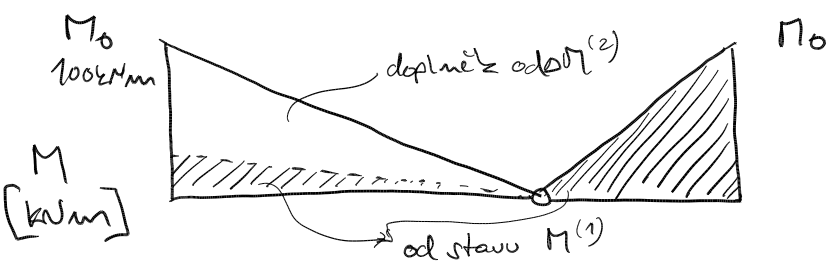
$$\frac{M_0}{4} + \Delta F^{(2)} \cdot 2L = M_0$$

$$\Delta F^{(2)} = \frac{3}{4} M_0 / 2L = \frac{3}{8} \frac{M_0}{L} = \frac{3}{8} \cdot \frac{100}{2} = 18,75 \text{ kN}$$

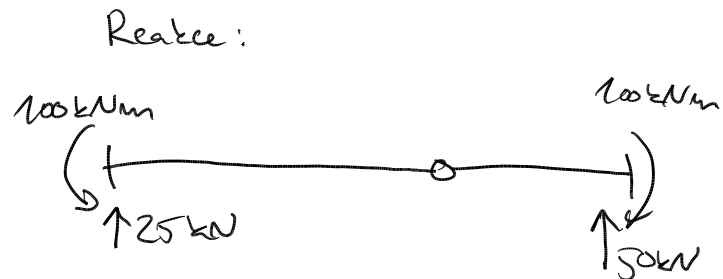
$$F_{max} = F^{(1)} + \Delta F^{(2)} = \frac{9}{8} \frac{M_0}{L} + \frac{3}{8} \frac{M_0}{L} = \frac{12}{8} \frac{M_0}{L} = \frac{3}{2} \frac{M_0}{L}$$

$$= 56,25 + 18,75 = \underline{\underline{75 \text{ kN}}}$$

→ Vykreslení pro sílu F_{max}



kontrola $25 + 50 = 75 \checkmark$



Vývoj posunu svistého posunu sfčínku 2 v závislosti na zatížení

1) "Průžin" chování konstrukce

$$F \in (0; F^{(1)})$$

$$w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

$$w_2^{(1)} = \frac{8}{27} \cdot \frac{9}{8} \frac{M_0}{L} \frac{L^3}{EI} = \frac{1}{3} \frac{M_0 L^2}{EI}$$

Vývoj posunu svistého posunu sféricku 2 v závislosti na zatížení

1) "Průběh" chování konstrukce

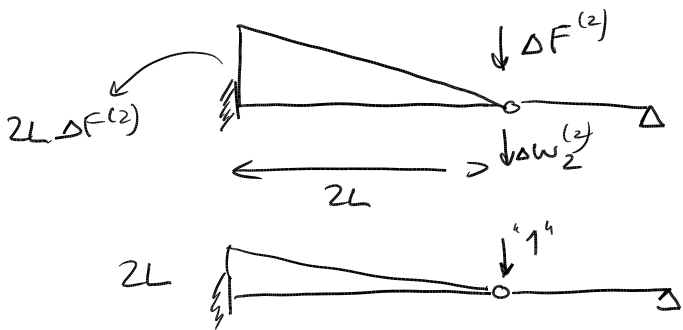
$$F \in (0; F^{(1)})$$

$$w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

$$w_2^{(1)} = \frac{8}{27} \cdot \frac{9}{8} \frac{M_0}{L} \frac{L^3}{EI} = \frac{1}{3} \frac{M_0 L^2}{EI}$$

2) Chování ke po vzniku 1. plastického kloubu do dosažení F_{max}

→ přírůstek průhybu $\Delta w_2^{(2)}$



Vývoj posunu svislého posunu sféricku 2 v závislosti na zatížení

1) "Průběh" chování konstrukce

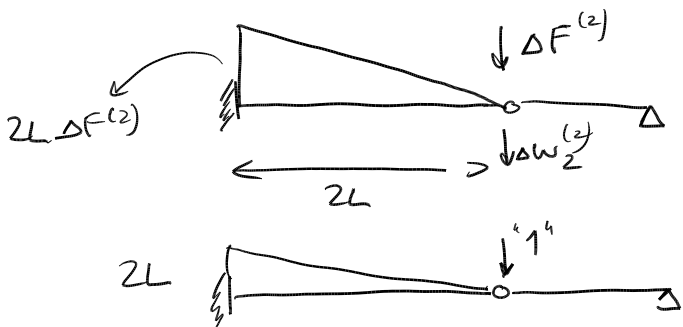
$$F \in (0; F^{(1)})$$

$$w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

$$w_2^{(1)} = \frac{8}{27} \cdot \frac{9}{8} \frac{M_0}{L} \frac{L^3}{EI} = \frac{1}{3} \frac{M_0 L^2}{EI}$$

2) Chování ke po vzniku 1. plastického kloubu do dosažení F_{max}

→ přírůstek průhybu $\Delta w_2^{(2)}$



$$\begin{aligned} \Delta w_2^{(2)} &= \int \frac{M(x) M^*(x)}{EI} dx = \\ &= \frac{1}{3} \frac{\Delta F^{(2)} (2L)^3}{EI} = \frac{1}{3} \frac{3 M_0}{8 L} \frac{8L^3}{EI} = \\ &= \frac{M_0 L^2}{EI} \end{aligned}$$

Vývoj posunu svistého posunu sfčínku 2 v závislosti na zatížení

1) "Průběh" chování konstrukce

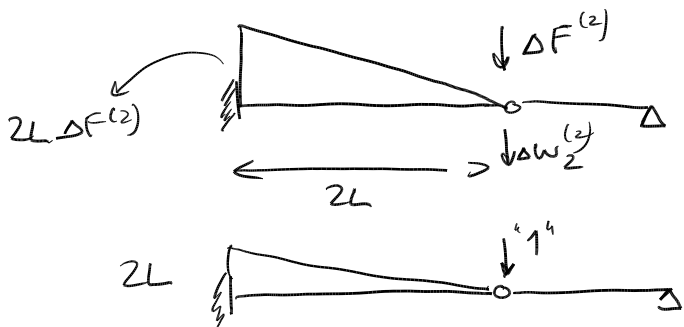
$$F \in (0; F^{(1)})$$

$$w_2 = \frac{8}{27} \frac{FL^3}{EI}$$

$$w_2^{(1)} = \frac{8}{27} \cdot \frac{9}{8} \frac{M_0}{L} \frac{L^3}{EI} = \frac{1}{3} \frac{M_0 L^2}{EI}$$

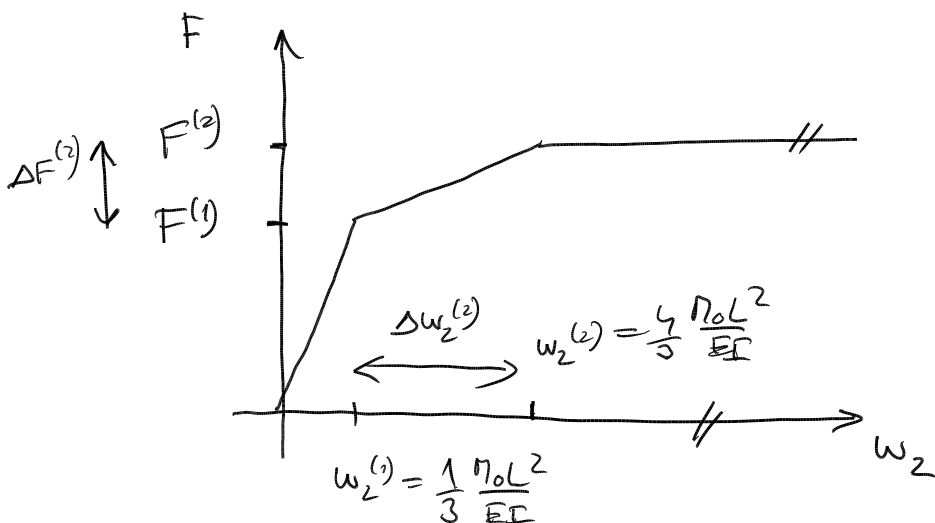
2) Chování ke po vzniku 1. plastického kloubu do dosažení F_{max}

→ přírůstek průhybu $\Delta w_2^{(2)}$

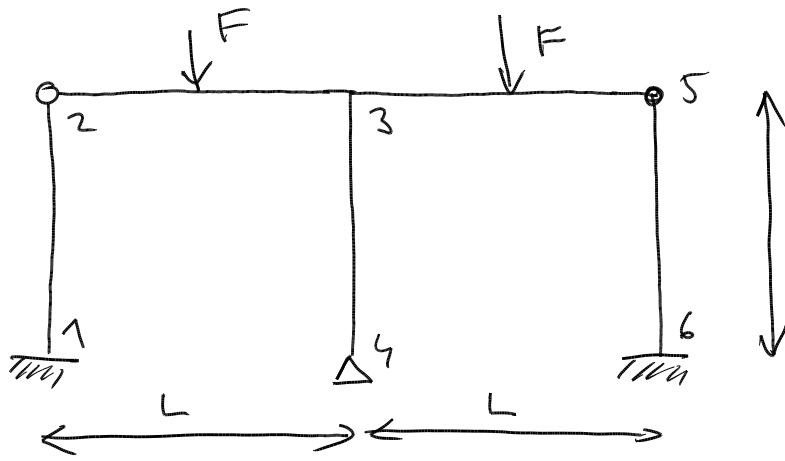


$$\begin{aligned} \Delta w_2^{(2)} &= \int \frac{M(x) M^*(x)}{EI} dx = \\ &= \frac{1}{3} \frac{\Delta F^{(2)} (2L)^3}{EI} = \frac{1}{3} \frac{3 M_0}{8 L} \frac{8 L^3}{EI} = \\ &= \frac{M_0 L^2}{EI} \end{aligned}$$

$$w_2^{(2)} = w_2^{(1)} + \Delta w_2^{(2)} = \frac{1}{3} \frac{M_0 L^2}{EI} + \frac{M_0 L^2}{EI} = \frac{4}{3} \frac{M_0 L^2}{EI}$$



Pr



$$EI = 4007 \text{ Nm}^2$$

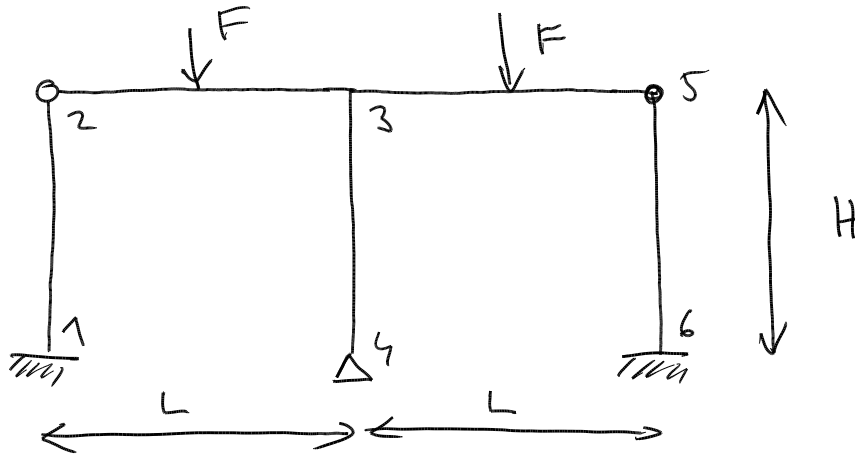
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

→ přímá metoda

→ zanedbatelná otláčivost
 $EA = \infty$

Pr



$$EI = 4007 \text{ Nm}^2$$

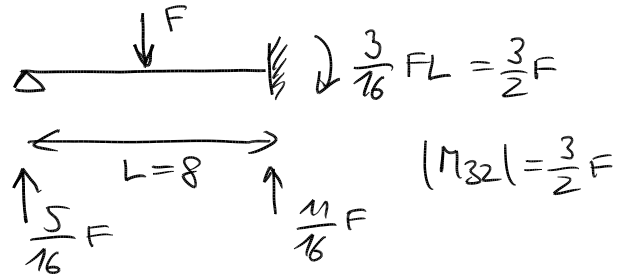
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

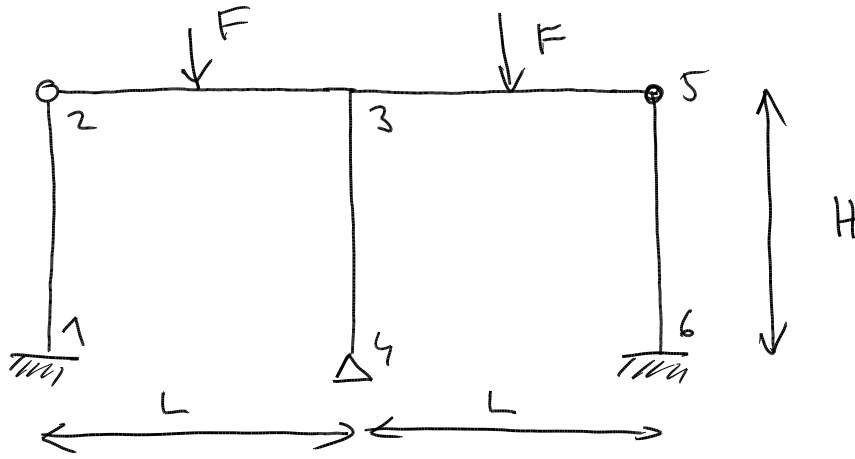
→ přímá metoda

→ zanedbání otláčivosti
 $EA = \infty$

→ zjednodušená konstrukce



Pr



$$EI = 4007 \text{ Nm}^2$$

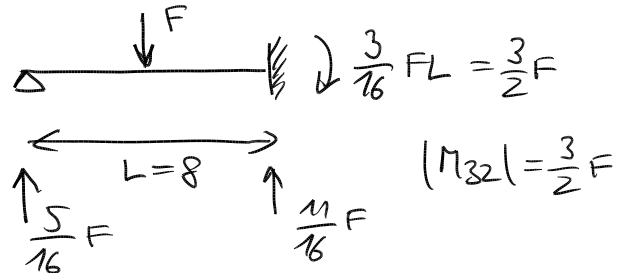
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

→ přímá metoda

→ zanedbatelná stlačitelnost
 $EA = \infty$

→ zjednodušená konstrukce



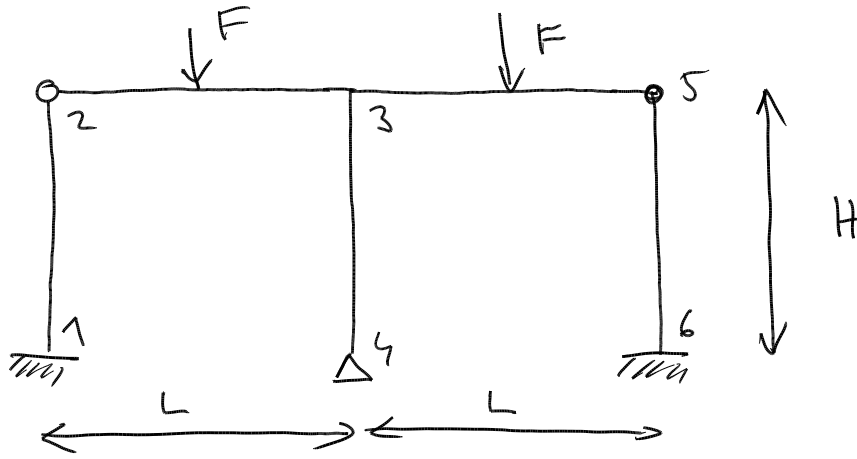
→ výpočet síly $F^{(1)}$

- moment pod silou = $M_F = \frac{5}{16} F \cdot \frac{L}{2} = \frac{5}{4} F$

$\frac{3}{2} F > \frac{5}{4} F \rightarrow$ 1. plastický kloub vznikne ve středě 3

$\frac{3}{2} F = M_0 = 200 \text{ kNm} \rightarrow F^{(1)} = \frac{2 \cdot 200}{3} = 133,33 \text{ kN}$

Pr



$$EI = 4007 \text{ Nm}^2$$

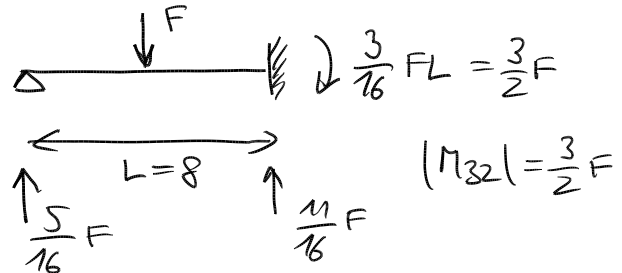
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

→ přibližná metoda

→ zanedbatelná tuhost $EA = \infty$

→ zjednodušená konstrukce



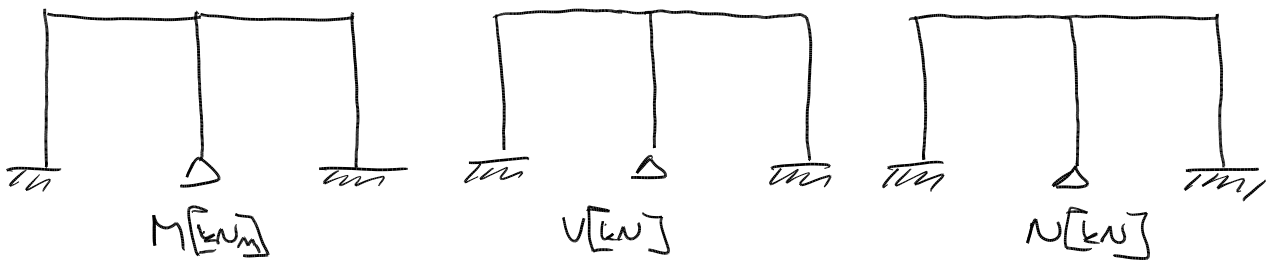
→ výpočet síly $F^{(1)}$

- moment pod silou $= M_F = \frac{5}{16} F \cdot \frac{L}{2} = \frac{5}{4} F$

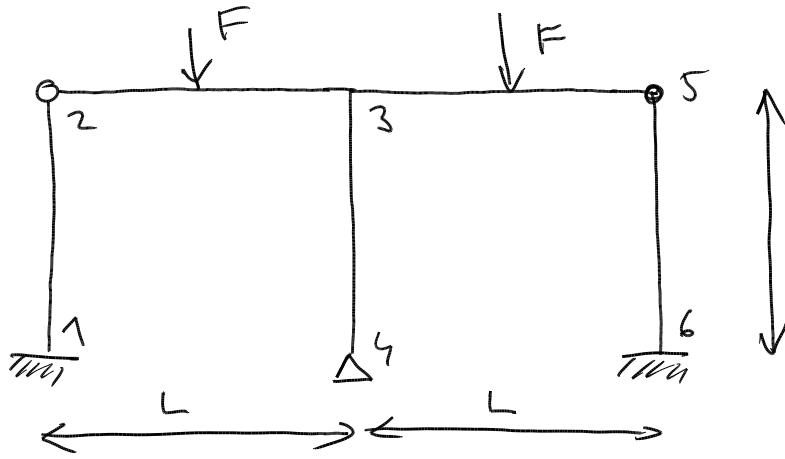
$\frac{3}{2} F > \frac{5}{4} F \rightarrow$ 1. plastický kloub vznikne ve středě

$\frac{3}{2} F = M_0 = 200 \text{ kNm} \rightarrow F^{(1)} = \frac{2 \cdot 200}{3} = 133,33 \text{ kN}$

→ vykreslení pro sílu $F^{(1)}$



Pr



$$EI = 4007 \text{ Nm}^2$$

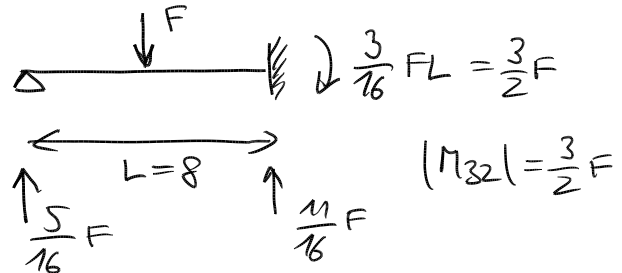
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

→ přímá metoda

→ zanedbatelná stlačitelnost $EA = \infty$

→ zjednodušená konstrukce



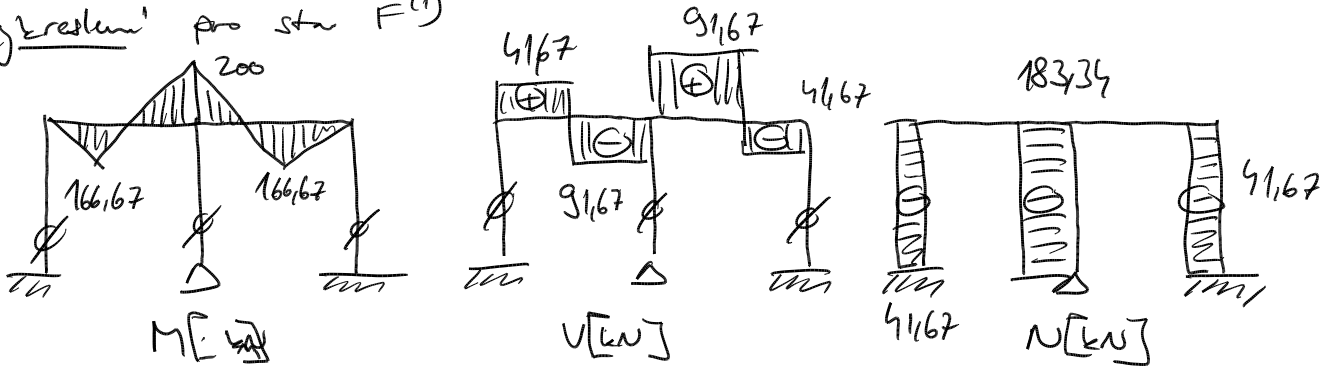
→ výpočet síly $F^{(1)}$

- moment pod silou $= M_F = \frac{5}{16} F \cdot \frac{L}{2} = \frac{5}{4} F$

$\frac{3}{2} F > \frac{5}{4} F \rightarrow$ 1. plastický kloub vznikne ve středě 3

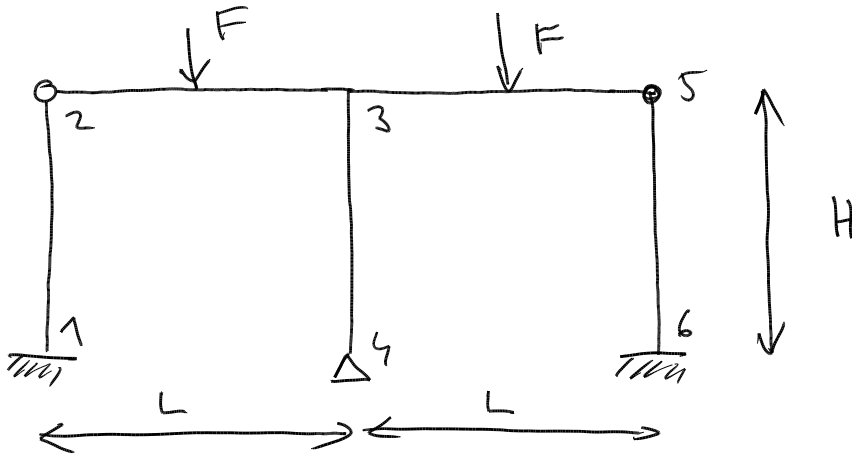
$\frac{3}{2} F = M_0 = 200 \text{ kNm} \rightarrow F^{(1)} = \frac{2 \cdot 200}{3} = 133,33 \text{ kN}$

→ výkreslení pro sílu $F^{(1)}$



$$M_F^{(1)} = \frac{5}{4} \cdot 133,33 = 166,67 \text{ kNm}$$

Pr



$$EI = 4007 \text{ Nm}^2$$

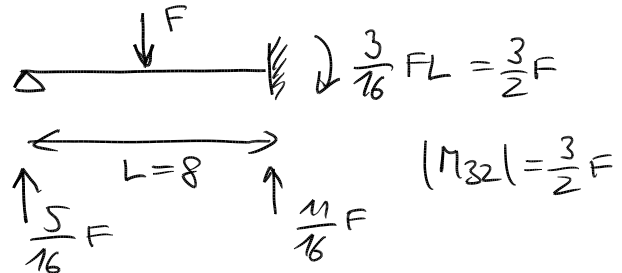
$$M_0 = 200 \text{ kNm}$$

$$L = H = 8 \text{ m}$$

→ přímá metoda

→ zanedbatelná tuhost $EA = \infty$

→ zjednodušená konstrukce



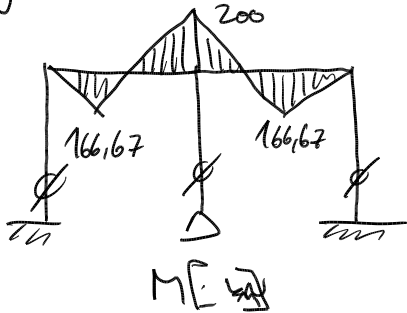
→ výpočet síly $F^{(1)}$

- moment pod silou $= M_F = \frac{5}{16} F \cdot \frac{L}{2} = \frac{5}{4} F$

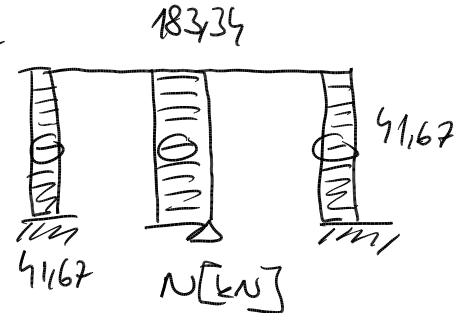
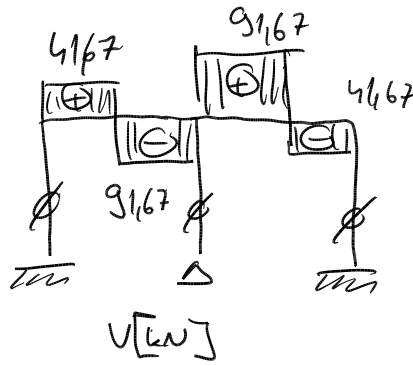
$\frac{3}{2} F > \frac{5}{4} F \rightarrow$ 1. plastický kloub vznikne ve středě 3

$\frac{3}{2} F = M_0 = 200 \text{ kNm} \rightarrow F^{(1)} = \frac{2 \cdot 200}{3} = 133,33 \text{ kN}$

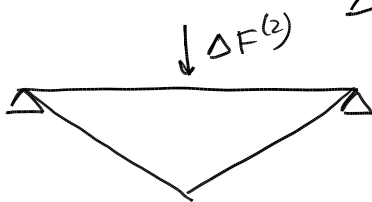
→ vykreslení pro sílu $F^{(1)}$



$$M_F^{(1)} = \frac{5}{4} \cdot 133,33 = 166,67 \text{ kNm}$$



→ výpočet $\Delta F^{(2)}$



$$\Delta M_F^{(2)} = M_0 - 166,67 = 33,33 \text{ kNm}$$

$$\Delta M_F^{(2)} = \frac{\Delta F^{(2)} \cdot L}{4} = 2 \Delta F^{(2)}$$

$$\Delta F^{(2)} = 16,67 \text{ kN}$$

$$\rightarrow F^{(2)} = F^{(1)} + \Delta F^{(2)} = 133,33 + 16,67 = 150 \text{ kN}$$

Vykreslení pro $\Delta F^{(2)}$



$M[kW]$



$V[kW]$

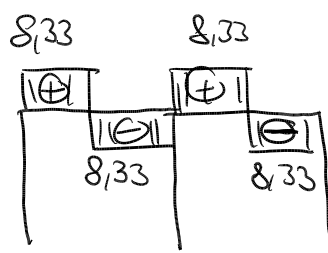


$N[kW]$

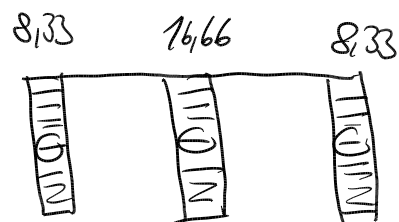
Vykreslení pro $\Delta F^{(2)}$



$M [kN\cdot m]$



$V [kN]$

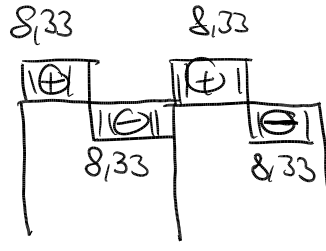


$N [kN]$

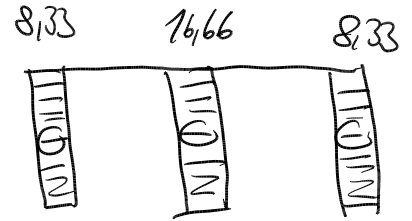
Vykreslení pro $\Delta F^{(2)}$



$M [kNm]$

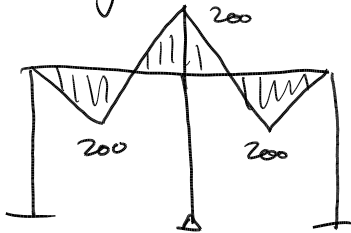


$V [kN]$

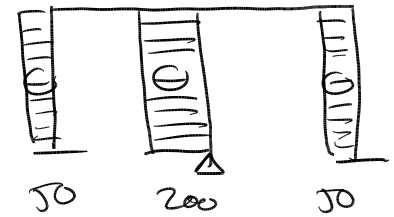
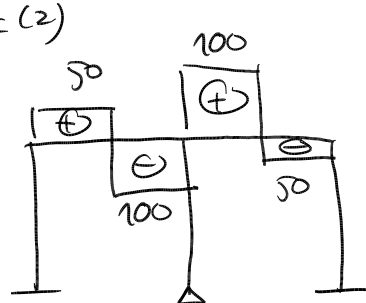


$N [kN]$

Četkové vykreslení pro $F^{(2)}$



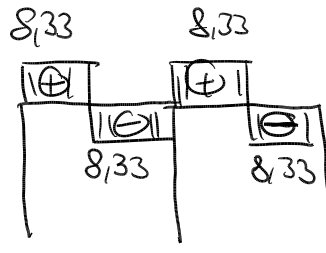
$M [kNm]$



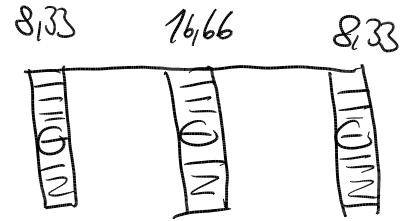
Vykreslení pro $\Delta F^{(2)}$



M [kNm]

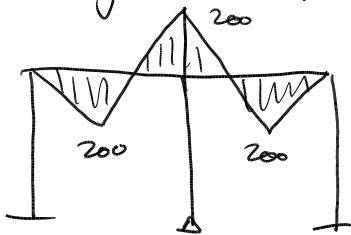


V [kN]

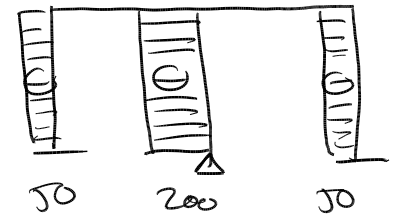
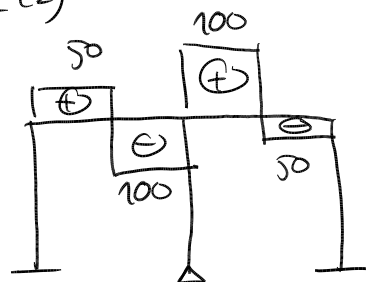


N [kN]

Celkové vykreslení pro $F^{(2)}$

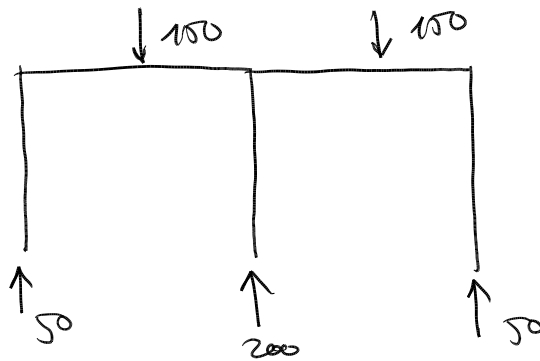


M [kNm]

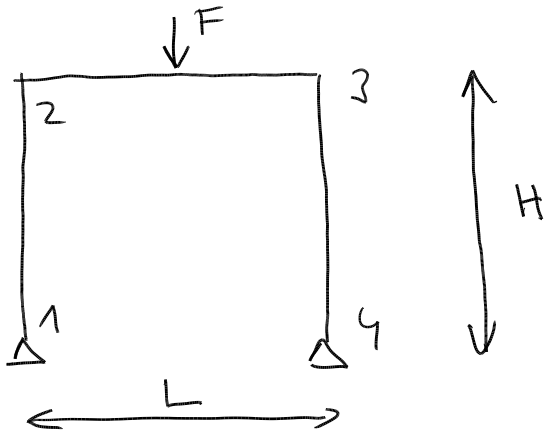


Reakce:

[kNm, kN]



Pr



$$EI = 20 \text{ MNm}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

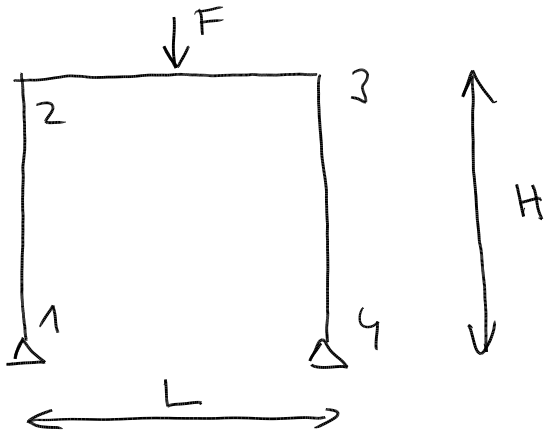
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu
+ mezni' stav konstrukce

→ reakce dle skutečni' orientace

Pr



$$EI = 207 \text{ N m}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

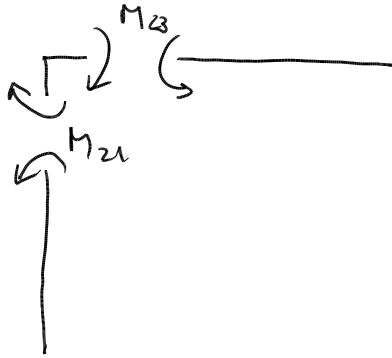
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu + mezni' stav konstrukce

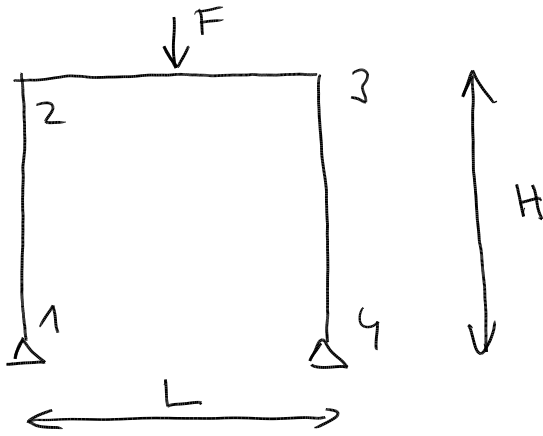
→ reakce dle skutečni' orientace

→ využiti' symetrie, 1 neznáma' deformační' metod, $\varphi_2 = -\varphi_3$



podmínka rovnováhy: $M_{21} + M_{23} = 0$

Pr



$$EI = 20 \text{ MNm}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

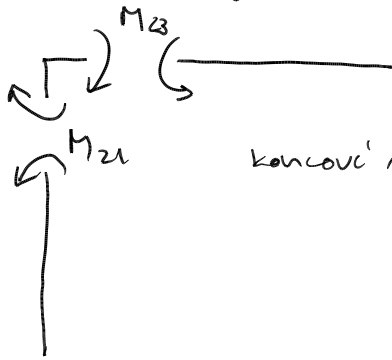
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu + mezni' stav konstrukce

→ reakce dle skutečni' orientace

→ využít' symetrie, 1 nezávislá' deformační' metod, $\varphi_2 = -\varphi_3$



$$\text{podmínka rovnováhy: } M_{21} + M_{23} = 0$$

$$\text{koncoví momenty: } M_{21} = \frac{3EI}{L} \varphi_2$$

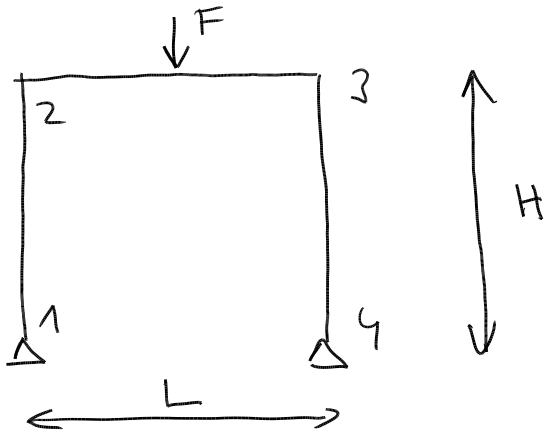
$$M_{23} = \frac{2EI}{L} (2\varphi_2 + \varphi_3) + \frac{FL}{8} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8}$$

\downarrow
 $-\varphi_2$

dosazení do podmínky rovnováhy:

$$\frac{3EI}{L} \varphi_2 + \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = 0 \quad \rightarrow \quad \varphi_2 = \frac{-\frac{FL^2}{8}}{5EI} = -\frac{FL^2}{40EI} = \frac{-4F}{40 \cdot 20} = -\frac{F}{200}$$

Pr



$$EI = 20 \text{ MNm}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

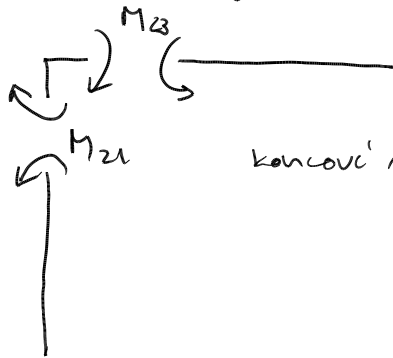
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu + mezni' stav konstrukce

→ reakce dle skutečni' orientace

→ využíti' symetrie, 1 neznáma' deformační' metod, $\varphi_2 = -\varphi_3$



podmínka rovnováhy: $M_{21} + M_{23} = 0$

koncoví momenty: $M_{21} = \frac{3EI}{L} \varphi_2$

$$M_{23} = \frac{2EI}{L} (2\varphi_2 + \varphi_3) + \frac{FL}{8} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8}$$

\downarrow
 $-\varphi_2$

dosazení do podmínky rovnováhy:

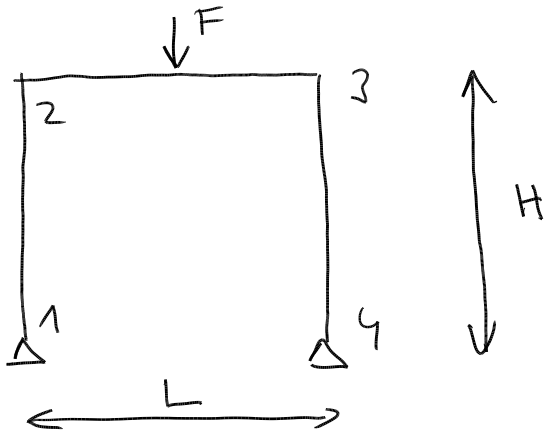
$$\frac{3EI}{L} \varphi_2 + \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = 0 \quad \rightarrow \quad \varphi_2 = \frac{-\frac{FL^2}{8}}{5EI} = -\frac{FL^2}{40EI} = \frac{-4F}{40 \cdot 20} = -\frac{F}{200}$$

→ dopčet koncových momentů a kontrola:

$$M_{21} = -\frac{3FL}{40} = -\frac{3F}{20}$$

$$M_{23} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = -\frac{FL}{20} + \frac{FL}{8} = \frac{3}{40} FL = \frac{3F}{20}$$

Pr



$$EI = 20 \text{ MNm}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

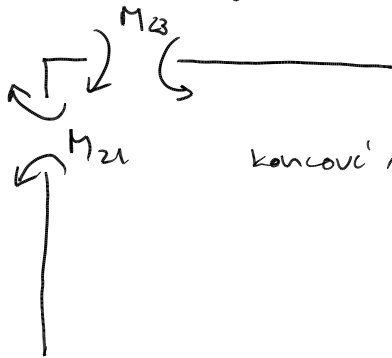
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu + mezní stav konstrukce

→ reakce dle skutečného ovláčení

→ využít symetrii, 1 nezávislá deformační metoda, $\varphi_2 = -\varphi_3$



podmínka rovnováhy: $M_{21} + M_{23} = 0$

koncoví momenty: $M_{21} = \frac{3EI}{L} \varphi_2$

$$M_{23} = \frac{2EI}{L} (2\varphi_2 + \varphi_3) + \frac{FL}{8} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8}$$

\downarrow
 $-\varphi_2$

dosazení do podmínky rovnováhy:

$$\frac{3EI}{L} \varphi_2 + \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = 0 \quad \rightarrow \quad \varphi_2 = \frac{-\frac{FL^2}{8}}{5EI} = -\frac{FL^2}{40EI} = \frac{-4F}{40 \cdot 20} = -\frac{F}{200}$$

→ dopčet koncových momentů a kontrola:

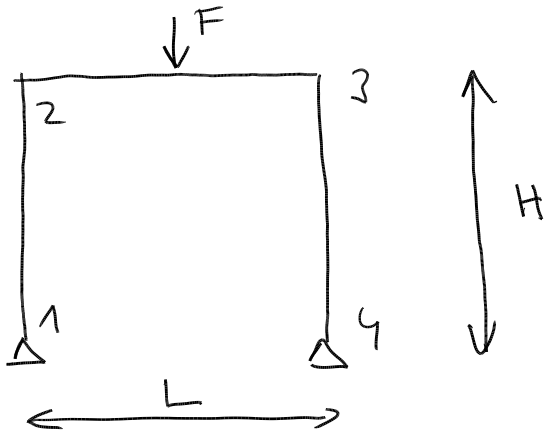
$$M_{21} = -\frac{3FL}{40} = -\frac{3F}{20}$$

$$M_{23} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = -\frac{FL}{20} + \frac{FL}{8} = \frac{3}{40} FL = \frac{3F}{20}$$

upřesnit momentu pod silou F, $M_F = \frac{-3FL}{40} + \frac{FL}{2} = \frac{7FL}{40} = \frac{7}{20} F$

$|M_F| > |M_{23}| \rightarrow$ 1. plastický kloub pod silou F

Pf



$$EI = 20 \text{ MNm}^2 \quad EA = \infty$$

$$M_0 = 100 \text{ kNm}$$

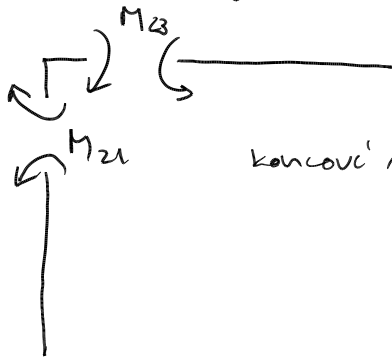
$$L = H = 2 \text{ m}$$

→ problémy M, V, N

→ F pro vznik 1. plast. kloubu + mezní stav konstrukce

→ reakce dle skutečného ovláčení

→ využít symetrii, 1 neznámá deformační měřítka, $\varphi_2 = -\varphi_3$



podmínka rovnováhy: $M_{21} + M_{23} = 0$

koncoví momenty: $M_{21} = \frac{3EI}{L} \varphi_2$

$$M_{23} = \frac{2EI}{L} (2\varphi_2 + \varphi_3) + \frac{FL}{8} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8}$$

\downarrow
 $-\varphi_2$

dosazení do podmínky rovnováhy:

$$\frac{3EI}{L} \varphi_2 + \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = 0 \quad \rightarrow \quad \varphi_2 = \frac{-\frac{FL^2}{8}}{5EI} = -\frac{FL^2}{40EI} = \frac{-4F}{40 \cdot 20} = -\frac{F}{200}$$

→ dopčet koncových momentů a kontrola:

$$M_{21} = -\frac{3FL}{40} = -\frac{3F}{20}$$

$$M_{23} = \frac{2EI}{L} \varphi_2 + \frac{FL}{8} = -\frac{FL}{20} + \frac{FL}{8} = \frac{3}{40} FL = \frac{3F}{20}$$

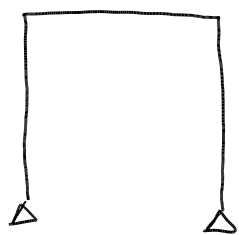
upřesnit momentu pod silou F, $M_F = \frac{-3FL}{40} + \frac{FL}{2} = \frac{7FL}{40} = \frac{7}{20} F$

$|M_F| > |M_{23}| \rightarrow$ 1. plastický kloub pod silou F

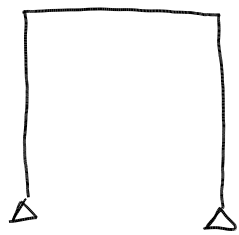
$$F^{(1)} = \frac{M_0 \cdot 20}{7} = \frac{100 \cdot 20}{7} = 285,71 \text{ kN}$$

dopčet $M_{21} = 42,856 \text{ kNm}$

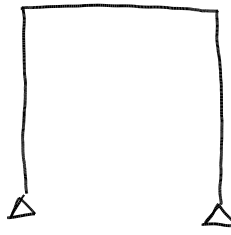
Vykreslení vnitřních sil pro $F = F^{(?)}$



M [Nm]

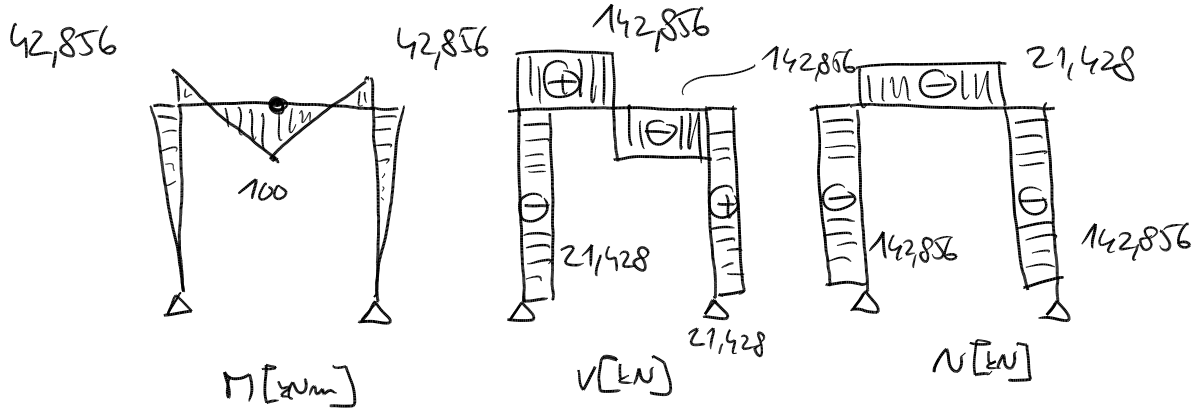


V [kN]

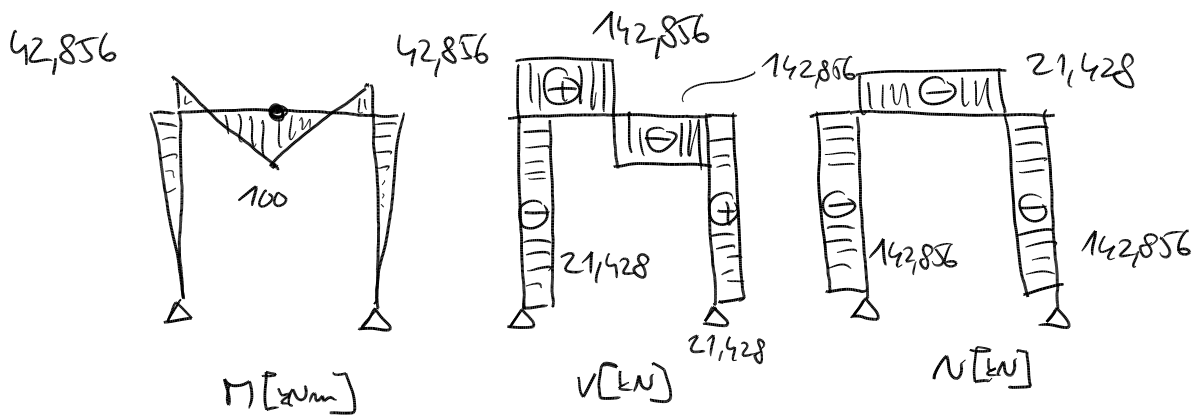


N [kN]

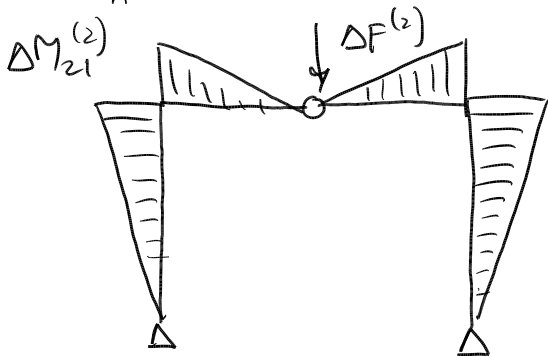
Vykreslení vnitřních sil pro $F = F^{(1)}$



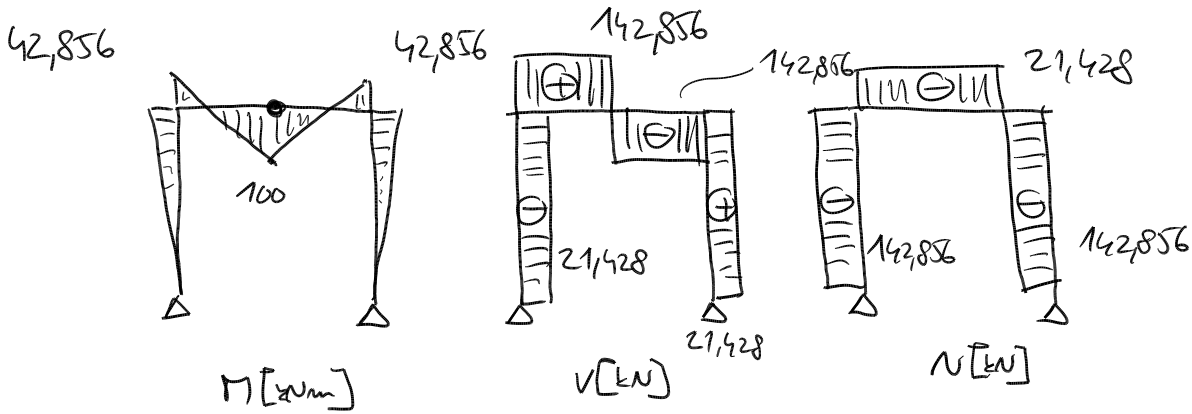
Vykreslení vnitřních sil pro $F = F^{(1)}$



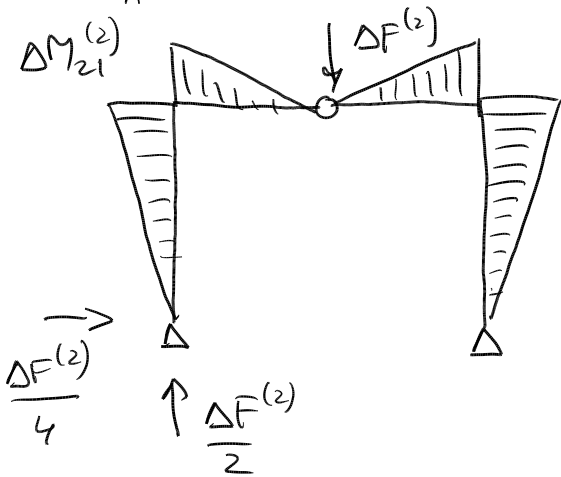
Výpočet $\Delta F^{(2)}$ \rightarrow vznik 2 plastického kloubu (a také 3.)



Vykreslení vnitřních sil pro $F = F^{(1)}$



Vypočet $\Delta F^{(2)}$ \rightarrow vznik 2 plastického kloubu (a také 3.)



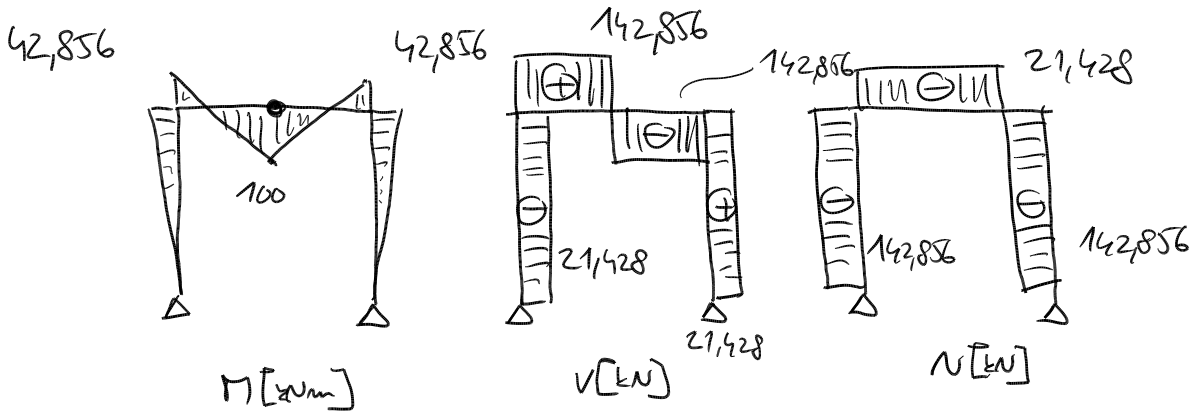
$$\Delta M_{21}^{(2)} = M_0 - M_{21}^{(1)} = 100 - 42,856 = 57,144 \text{ kNm}$$

$$\Delta M_{21}^{(2)} = \frac{\Delta F^{(2)}}{2} \cdot \frac{L}{2} = \frac{\Delta F^{(2)}}{2}$$

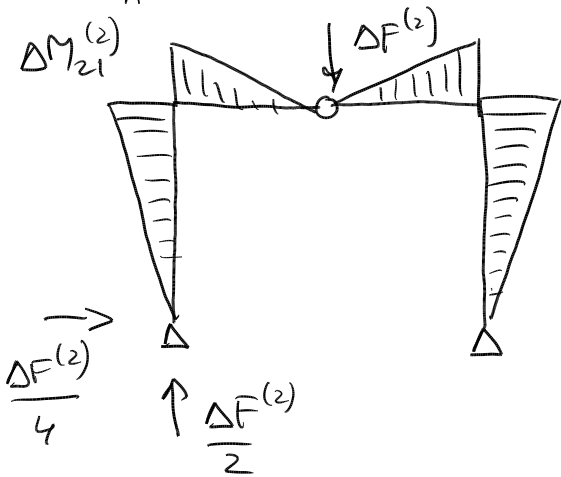
$$\rightarrow \Delta F^{(2)} = 2 \cdot 57,144 = 114,288 \text{ kN}$$

$$\text{Celková síla } F^{(2)} = F^{(1)} + \Delta F^{(2)} = 285,71 + 114,288 = 400 \text{ kN}$$

Vykreslení vnitřních sil pro $F = F^{(1)}$



Výpočet $\Delta F^{(2)}$ \rightarrow vznik 2 plastického kloubu (a také 3.)



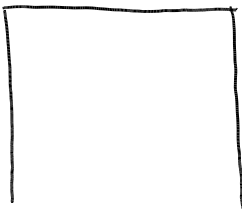
$$\Delta M_{21}^{(2)} = M_0 - M_{21}^{(1)} = 100 - 42,856 = 57,144 \text{ kNm}$$

$$\Delta M_{21}^{(2)} = \frac{\Delta F^{(2)}}{2} \cdot \frac{L}{2} = \frac{\Delta F^{(2)}}{2}$$

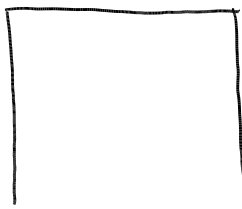
$$\rightarrow \Delta F^{(2)} = 2 \cdot 57,144 = 114,288 \text{ kN}$$

$$\text{Celková síla } F^{(2)} = F^{(1)} + \Delta F^{(2)} = 285,71 + 114,288 = 400 \text{ kN}$$

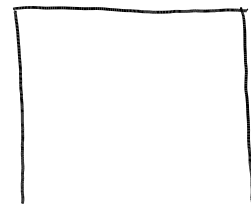
\rightarrow Vykreslení pro zatížení silou $F^{(2)}$



M [kNm]

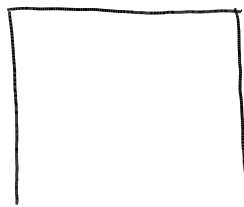


V [kN]

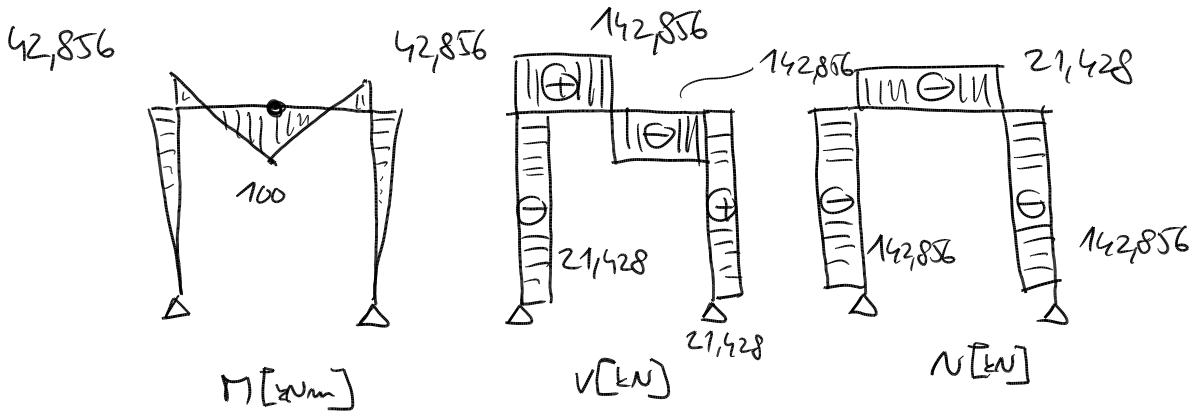


N [kN]

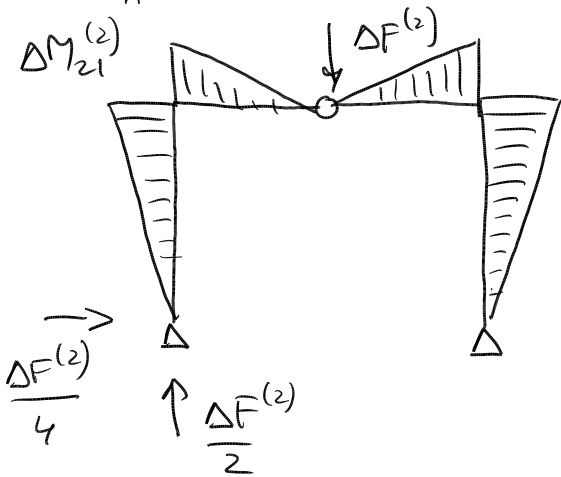
Reakce [kN]



Vykreslení vnitřních sil pro $F = F^{(1)}$



Vypočet $\Delta F^{(2)}$ \rightarrow vznik 2 plastického kloubu (a také 3.)



$$\Delta M_{21}^{(2)} = M_0 - M_{21}^{(1)} = 100 - 42,856 = 57,144 \text{ kNm}$$

$$\Delta M_{21}^{(2)} = \frac{\Delta F^{(2)}}{2} \cdot \frac{L}{2} = \frac{\Delta F^{(2)}}{2}$$

$$\rightarrow \Delta F^{(2)} = 2 \cdot 57,144 = 114,288 \text{ kN}$$

Cellková síla $F^{(2)} = F^{(1)} + \Delta F^{(2)} = 285,71 + 114,288 = 400 \text{ kN}$

\rightarrow Vykreslení pro zatížení silou $F^{(2)}$

