SILOVÁ METODA

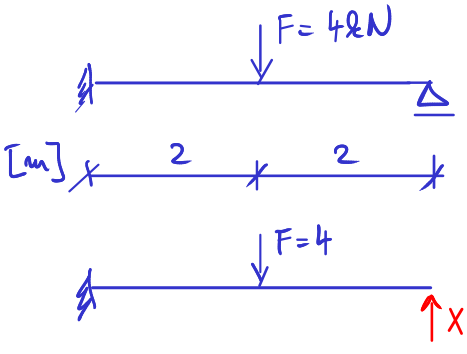
- kanonická rovnice

$$\sum_{k=1}^{n_s} \delta_{i,k} X_k + \delta_{i,0} = 0$$

$$i = 1, 2, \ldots n_s$$

$n_s = 2$

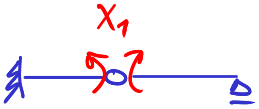
	$k=1$	$k=2$	
$i=1$	$\delta_{11} X_1$	$+ \delta_{12} X_2$	$+ \delta_{10} = 0$
$i=2$	$\delta_{21} X_1$	$+ \delta_{22} X_2$	$+ \delta_{20} = 0$



$EI = konst$

$n_s = 1$

ZSUS:



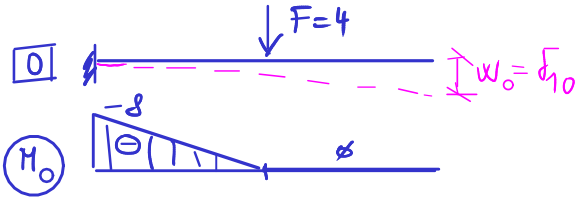
$w_1 = \delta_{11}$ = průhyb na konci konzoli od jednotkové síly umístěné na konci konzoli

$w_0 = \delta_{10}$ = průhy na konci konzoli od zadaného zatížení (F=4)

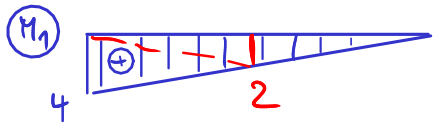
$$w_1 X_1 + w_0 = 0$$

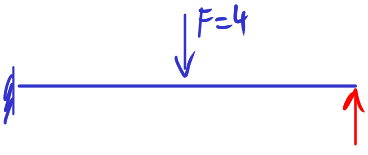
$$\delta_{11} X_1 + \delta_{10} = 0$$

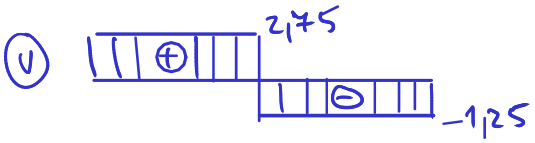
0. zatěžovací stav

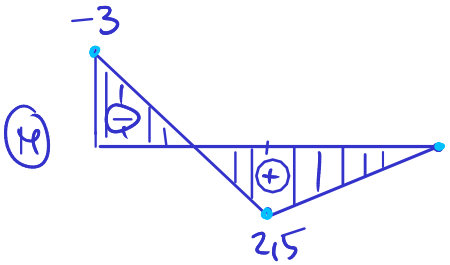


1. zatěžovací stav

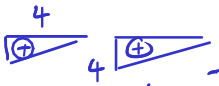








$$\delta_{11} = \int \frac{M_1 M_1}{EI} dx = \frac{1}{EI}\left[+\frac{1}{2} 4 \cdot 4 \cdot \left(\frac{2}{3} 4\right)\right] = \frac{64}{3EI}$$



$$\delta_{10} = \int \frac{M_0 M_1}{EI} dx = \frac{1}{EI}\left[-\frac{1}{2} 8 \cdot 2 \left(\frac{2}{3} 4\right) - \frac{1}{2} 8 \cdot 2 \left(\frac{1}{3} 2\right)\right] =$$

$$= -\frac{80}{3EI}$$

$$\frac{64}{3EI} X_1 - \frac{80}{3EI} = 0 \quad / 3EI$$

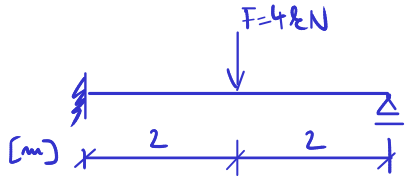
$$64 X_1 - 80 = 0$$

$$X_1 = \frac{80}{64} = 1{,}25 kN$$

(princip superpozice a linearnosti)

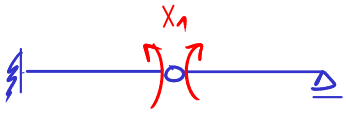
M_0 + $M_1 X_1$

ZÁKLADNÍ SUS v podobě gerberova nosníku

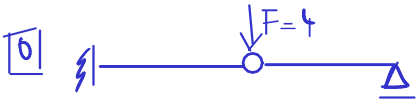


$EI = konst.$

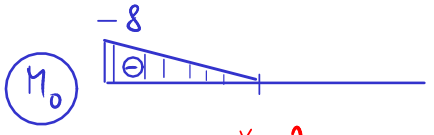
$n_s = 1$

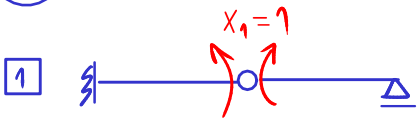


$$\delta_{11} X_1 + \delta_{10} = 0$$

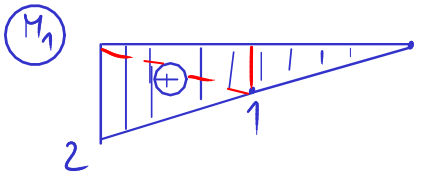


$$\delta_{11} = \frac{1}{EI}\left[+\frac{1}{2}\,4\cdot 2\cdot\left(\frac{2}{3}\,2\right)\right] = \frac{16}{3EI}$$



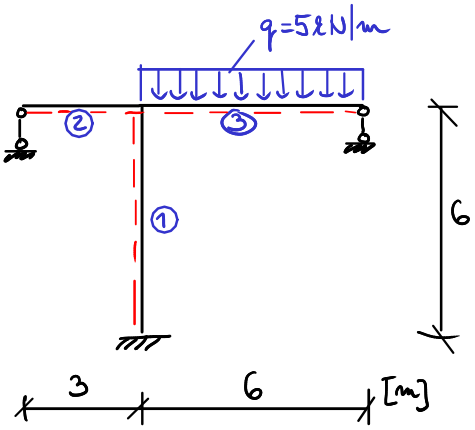


$$\delta_{10} = \frac{1}{EI}\left[-\frac{1}{2}\,8\cdot 2\cdot\left(\frac{2}{3}\,2\right) - \frac{1}{2}\,8\cdot 2\left(\frac{1}{3}\,1\right)\right] = -\frac{40}{3EI}$$



$$\frac{16}{3EI} X_1 - \frac{40}{3EI} = 0 \quad / \cdot 3EI$$

$$X_1 = \frac{40}{16} = \underline{2{,}5\ kNm}$$



$EI = konst.$ $E_1 = E_2 = E_3$ $I_1 = I_2 = I_3$

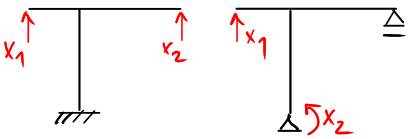
1) $n_s = ?$, z SUS

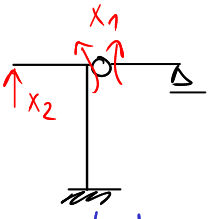
$n_s = 2x$

Kontrola: $n_s = 3u - p_R + (a-3)$

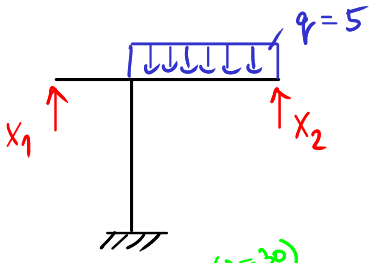
$n_s = 3 \cdot 0 - 0 + (5-3) = 2 \checkmark$

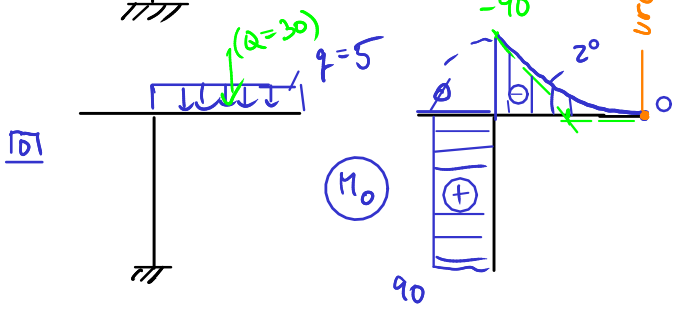
$n_s = 5 - 3 \cdot 1 = 2 \checkmark$





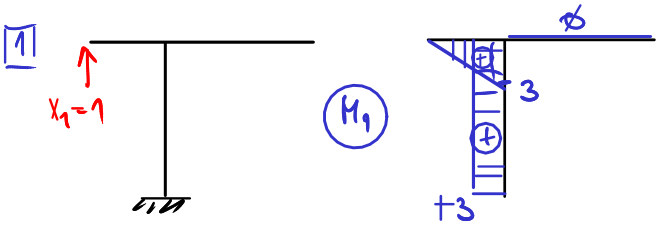
2) z SUS = lomená kon a
⊕ není nutné řešit reakce
(vykreslíme z volných konců)



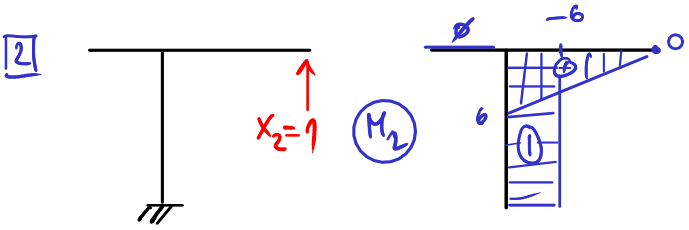


[0] M_0

3) vnitřní síly (zanedbáme N, V)



[1] M_1



[2] M_2

4) rovnice

$$\sum_{i=1}^{n_s} \delta_{i,i} X_i + \delta_{i,0} \qquad i = 1, 2 \dots n_s$$

$$\delta_{11} X_1 + \delta_{12} X_2 + \delta_{10} = 0$$

$$\delta_{21} X_1 + \delta_{22} X_2 + \delta_{20} = 0$$

$$\begin{bmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{bmatrix} \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} + \begin{Bmatrix} \delta_{10} \\ \delta_{20} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

5) vyčíslení δ

$$\delta = \int \frac{M\bar{M}}{EI}\,dx$$

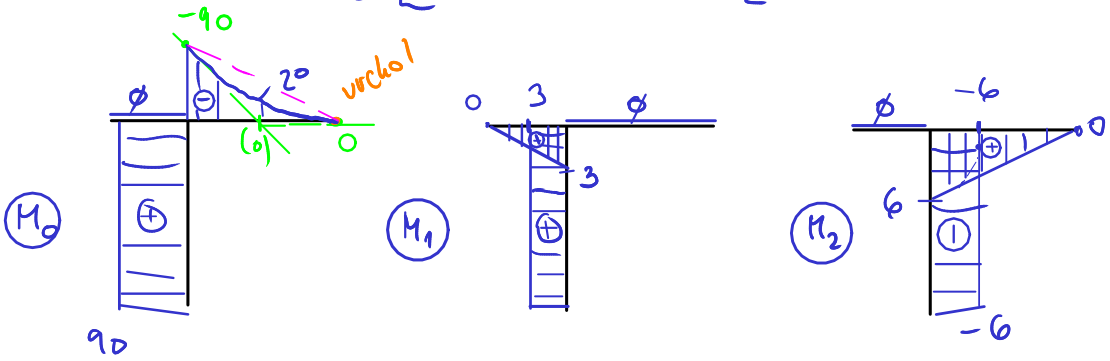
$$\delta_{11} = \frac{1}{EI}\int M_1 M_1\,dx = \frac{1}{EI}\left[\frac{1}{2}\,3\cdot 3\left(\frac{2}{3}3\right) + 3\cdot 6\cdot(3)\right] = \frac{63}{EI}$$

$$\delta_{22} = \frac{1}{EI}\int M_2 M_2\,dx = \frac{1}{EI}\left[+\frac{1}{2}\,6\cdot 6\left(\frac{2}{3}6\right) + 6\cdot 6\cdot 6\right] = \frac{288}{EI}$$

$$\delta_{12} = \delta_{21} = \frac{1}{EI}\int M_1 M_2\,dx = \frac{1}{EI}\left[-3\cdot 6\cdot 6\right] = -\frac{108}{EI}$$

$$\delta_{10} = \frac{1}{EI}\int M_0 M_1\,dx = \frac{1}{EI}\left[+90\cdot 6\cdot 3\right] = \frac{1620}{EI}$$

$$\delta_{20} = \frac{1}{EI}\int M_0 M_2\,dx = \frac{1}{EI}\left[-90\cdot 6\cdot 6 - \frac{1}{2}\,90\cdot 6\left(\frac{2}{3}6\right) + \frac{2}{3}\,6\cdot\frac{1}{8}\,5\cdot 6^2\cdot\left(\frac{1}{2}6\right)\right] = -\frac{4050}{EI}$$



6) soustava rovnic

$$\delta_{11}X_1 + \delta_{12}X_2 + \delta_{10} = 0$$

$$\delta_{21}X_1 + \delta_{22}X_2 + \delta_{20} = 0$$

$$\frac{63}{EI}X_1 - \frac{108}{EI}X_2 + \frac{1620}{EI} = 0 \quad /EI$$

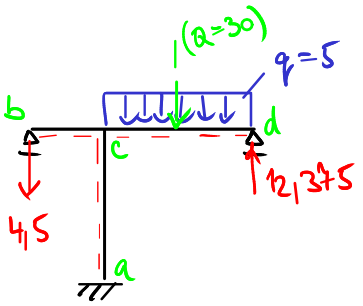
$$-\frac{108}{EI}X_1 + \frac{288}{EI}X_2 - \frac{4050}{EI} = 0 \quad /EI$$

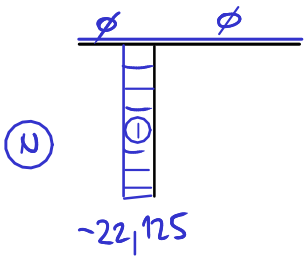
$$63X_1 - 108X_2 + 1620 = 0$$

$$-108X_1 + 288X_2 - 4050 = 0$$

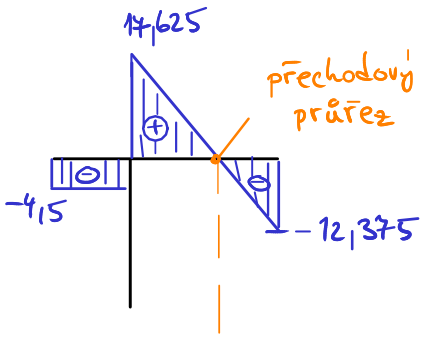
$$X_1 = -4{,}5\ kN \quad \text{(reakce levý kyvný prut)}$$

$$X_2 = 12{,}375\ kN \quad \text{(reakce pravý kyvný prut)}$$





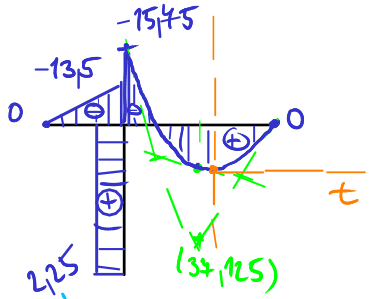
$(N = N_0 + N_1 X_1 + N_2 X_2)$



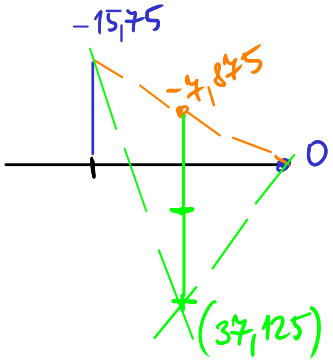
$$M = M_0 + M_1 X_1 + M_2 X_2$$

např. $M_{cd} = {}^0M_{cd} + {}^1M_{cd} X_1 + {}^2M_{cd} X_2 =$

$= -90 + 0 \cdot (-4,5) + 6 \cdot 12,375 = -15,75$ kNm

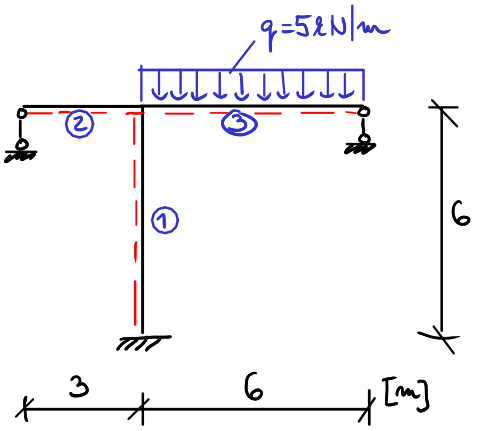


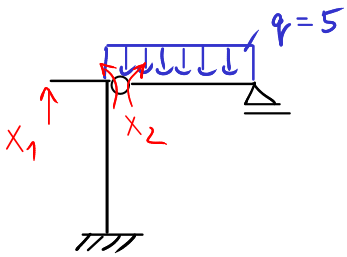
$90 + 3 \cdot (-4,5) + (-6) \cdot 12,375$



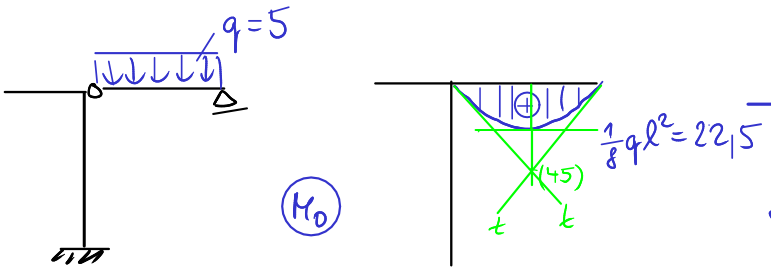
vzepětí $\frac{1}{8} q l^2 = \frac{1}{8} 5 \cdot 6^2 = 22,5$

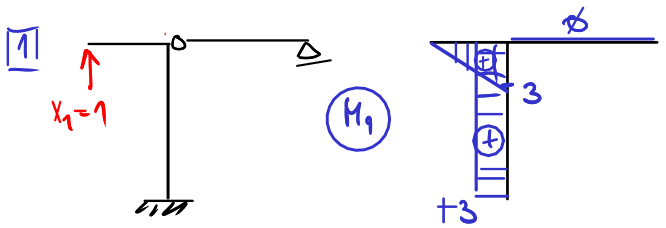
Alternativní ZSUS

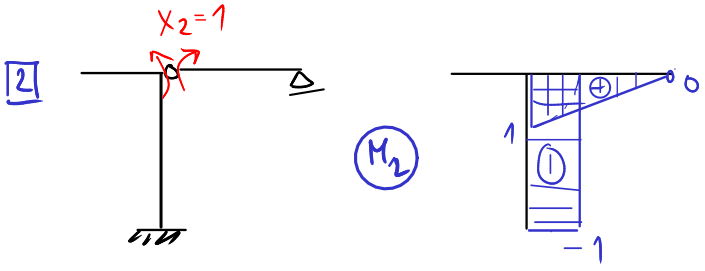




$$\delta_{11}X_1 + \delta_{12}X_2 + \delta_{10} = 0$$
$$\delta_{21}X_1 + \delta_{22}X_2 + \delta_{20} = 0$$







$$\delta_{11} = \frac{1}{EI}\left[+\frac{1}{2}3\cdot 3\cdot\left(\frac{2}{3}3\right) + 3\cdot 6\cdot 3\right] = \frac{63}{EI}$$

$$\delta_{22} = \frac{1}{EI}\left[+\frac{1}{2}6\cdot 1\cdot\left(\frac{2}{3}1\right) + 6\cdot 1\cdot 1\right] = \frac{8}{EI}$$

$$\delta_{12} = \delta_{21} = \frac{1}{EI}\left[-6\cdot 3\cdot 1\right] = -\frac{18}{EI}$$

$$\delta_{10} = 0$$

$$\delta_{20} = \frac{1}{EI}\left[\frac{2}{3}6\cdot 22{,}5\cdot\left(\frac{1}{2}1\right)\right] = \frac{45}{EI}$$

$$63X_1 - 18X_2 = 0 \quad /\cdot 18$$
$$-18X_1 + 8X_2 + 45 = 0 \quad /\cdot 63$$
$$1134X_1 - 324X_2 = 0$$
$$-1134X_1 + 504X_2 + 2835 = 0$$
$$180X_2 = -2835$$
$$X_2 = -15{,}75\,kNm$$

$\Rightarrow X_1 = -4{,}5\,kN$ (reakce v levém kyvném prutu)

(ohybový moment v místě vloženého kloubu)