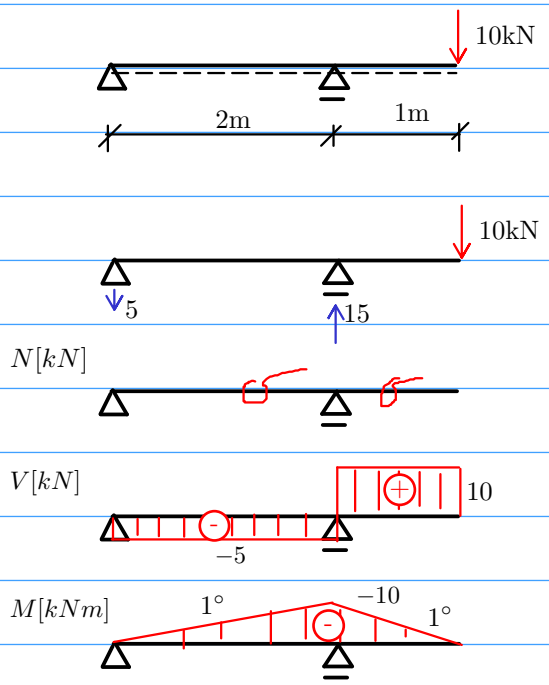
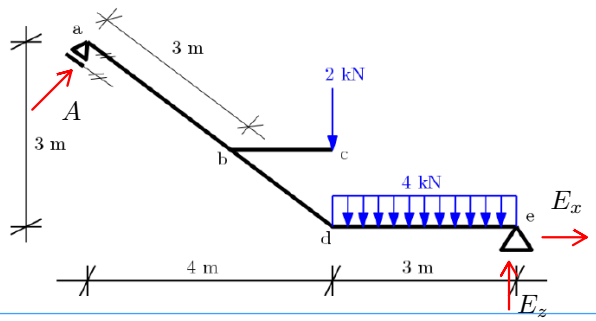
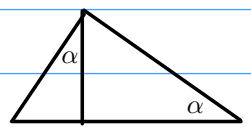
Vykreslete průběh vnitřních sil



Příklad IV.1 Vykreslete průběhy vnitřních sil po konstrukci. Na intervalu d-e vyjádřete průběhy vnitřních sil analyticky.





$cos\alpha = 0.8$

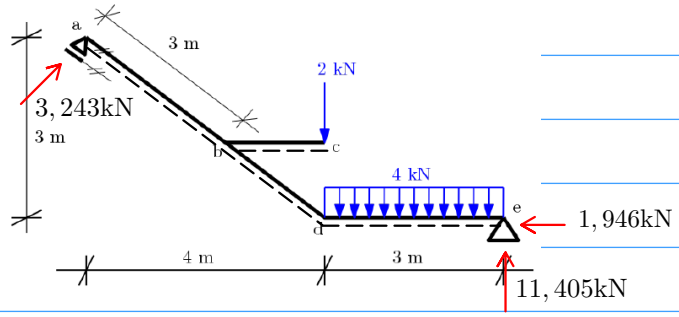
$\sin\alpha = 0.6$

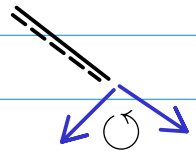
$\circlearrowleft_E$: $4 \cdot 3 \cdot 1,5 + 2 \cdot 3 - A \cdot \cos\alpha \cdot 7 - A \cdot \sin\alpha \cdot 3 = 0 \implies A = 3,243\text{kN}$

$\rightarrow$: $A \cdot \sin\alpha + E_x = 0 \implies E_x = -1,946\text{kN}$

$\uparrow$: $A \cdot \cos\alpha - 2 + E_z - 4 \cdot 3 = 0 \implies E_z = 11,405\text{kN}$

kontrola: $\circlearrowleft_D$: $-A \cdot 5 - 4 \cdot 3 \cdot 1,5 + 3 \cdot E_z = 0$ ✓

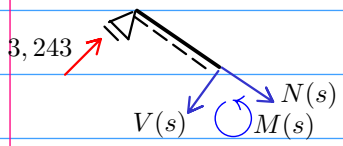




Doporučení:

- Začněte řešením a vykreslováním průběhů vnitřních sil nejprve od styčníku a ke styčníku b, pak od c k b.
- Určete hodnoty vnitřních sil v řezu bd z rovnováhy vnitřních sil ve styčníku b a dále stanovte průběh vnitřních na intervalu b-d.
- Pokračujte vyšetřením vnitřních sil od styčníku e ke styčníku d.
- Průběhy si zkontrolute kontrolou rovnováhy ve styčníku d.

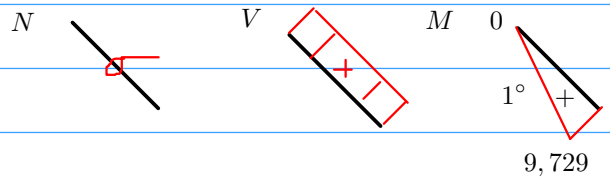
$A - B$



$N(s) = 0\text{kN}$

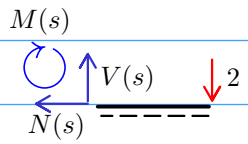
$V(s) = 3,243\text{kN}$

$M(s) = 3,243s$ [kNm]



$M(0) = 0\text{kNm}$ $\quad M(3) = M_{ba} = 9,729\text{kNm}$

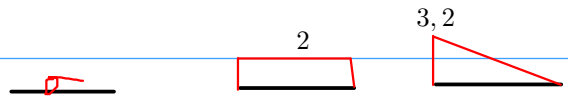
$C - B$



$N(s) = 0\text{kN}$

$V(s) = 2\text{kN}$

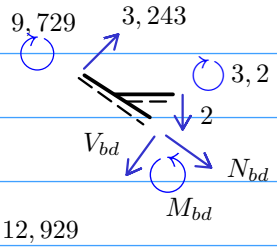
$M(s) = -2s$ [kNm]



$M(0) = 0\text{kNm}$ $\quad M(1,6) = M_{bc} = -3,2\text{kNm}$

$$M(s) = -\int V(s)ds = -2s + C \qquad M(0) = 0 \implies -2 \cdot 0 + C = 0 \implies C = 0 \implies M(s) = -2s$$

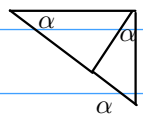
B



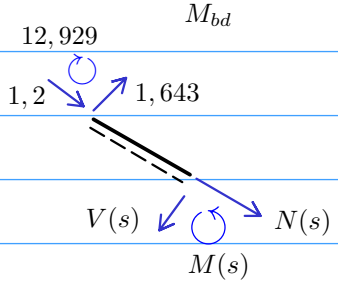
$\searrow: N_{bd} + 2 \cdot \sin\alpha = 0 \implies N_{bd} = -1,2\text{kN}$

$\swarrow: V_{bd} - 3,243 + 2 \cdot \cos\alpha = 0 \implies V_{bd} = 1,643\text{kN}$

$\circlearrowleft: M_{bd} - 3,2 - 9,729 = 0 \implies M_{bd} = 12,929\text{kNm}$



$B - D$



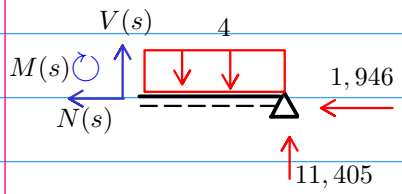
$\searrow: N(s) + 1,2 = 0 \implies N(s) = -1,2\text{kN}$

$\swarrow: V(s) - 1,643 = 0 \implies V(s) = 1,643\text{kN} \qquad M(s) = \int V(s)ds = 1,643s + 12,929$

$\circlearrowleft: M(s) - 12,929 - 1,643 \cdot s = 0 \implies M(s) = 1,643s + 12,929$ [kNm]

$M(0) = M_{bd} = 12,929\text{kNm} \qquad M(2) = M_{db} = 16,215\text{kNm}$

$E - D$



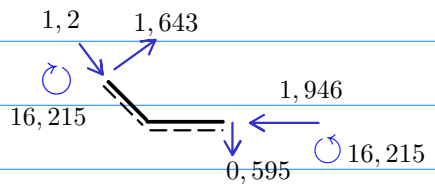
$\leftarrow: N(s) + 5,404 = 0 \implies N(s) = -1,946\text{kN}$

$V(s) = \int f_z(s)ds = 4s + C_1 \qquad V(0) = -11,405\text{kN} \implies C_1 = -11,405\text{kN}$

$M(s) = -\int V(s)ds = -2s^2 + 11,405s + C_2 \qquad M(0) = 0 \implies C_2 = 0$

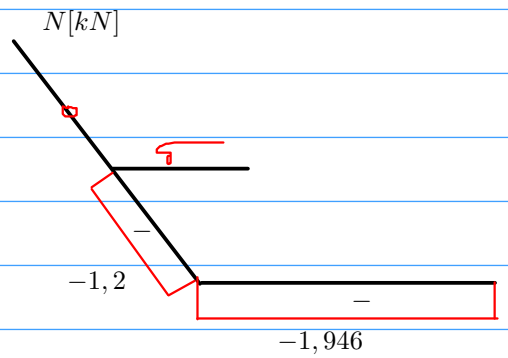
$V(s) = 0 = 4s - 11,405 \implies s_{\max} = 2,851\text{m}$ $\quad M_{\max} = 16,260\text{kNm}$ $\quad M(3) = 16,215\text{kNm}$

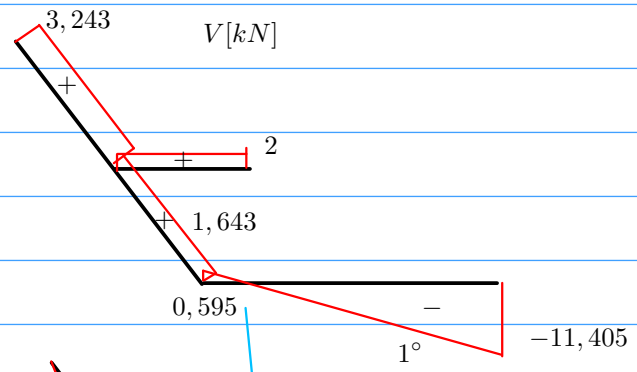
D

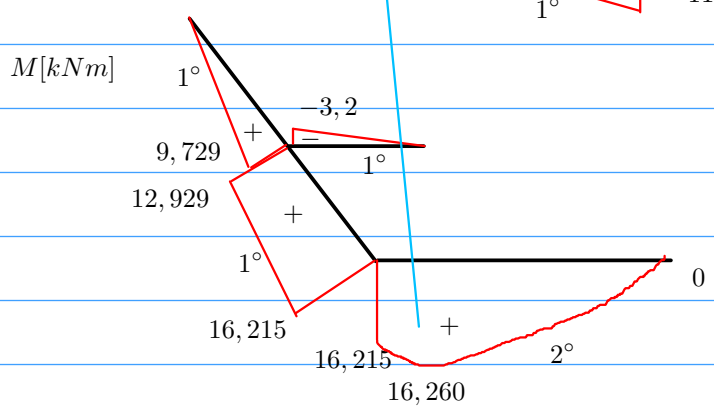


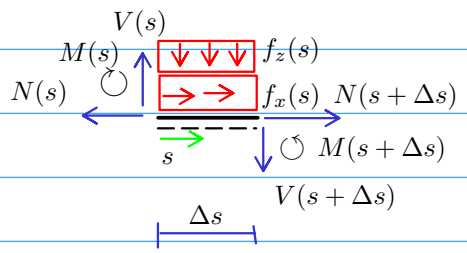
$\rightarrow: 1,2 \cdot \cos\alpha + 1,643 \cdot \sin\alpha - 1,946 = 0$ ✓

$\uparrow: -0,595 - 1,2 \cdot \sin\alpha + 1,643 \cdot \cos\alpha = 0$ ✓









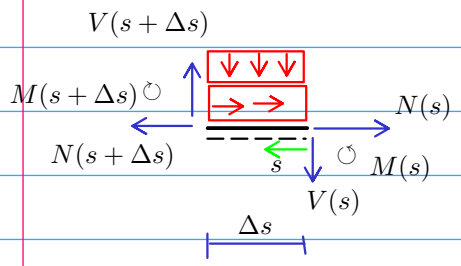
$$\rightarrow: N(s+\Delta s) - N(s) + f_x(s)\Delta s = 0$$

$$\frac{N(s+\Delta s) - N(s)}{\Delta s} = -f_x(s)$$

$$\frac{dN(s)}{ds} = -f_x(s) \leftrightarrow N(s) = -\int f_x(s)ds$$

$$V(s) = -\int f_z(s)ds$$

$$M(s) = \int V(s)ds$$



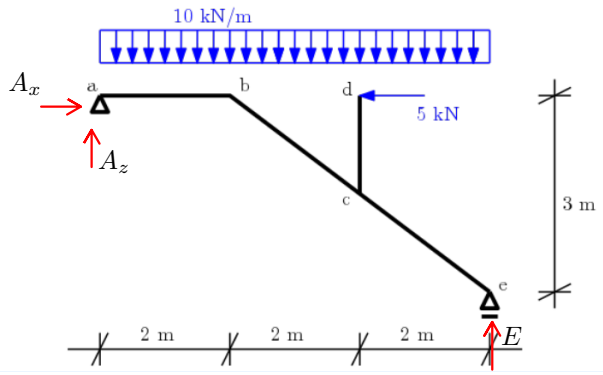
$$N(s) = \int f_x(s)ds$$

$$V(s) = \int f_z(s)ds$$

$$M(s) = -\int V(s)ds$$

$f_z(s) = 12s$ $\qquad V(s) = -\int f_z(s)ds = -6s^2 + C$

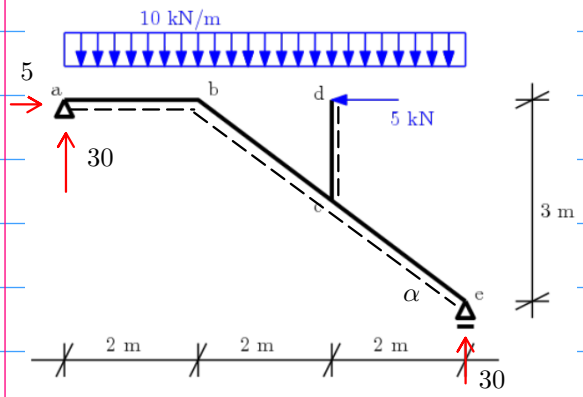
Příklad IV.2 Vykreslete průběhy vnitřních sil po konstrukci. Na intervalu b-c vyjádřete průběhy vnitřních sil analyticky.



$\circlearrowleft_A$: $-10 \cdot 6 \cdot 3 + 6 \cdot E = 0 \implies E = 30\text{kN}$

$\uparrow$: $A_z + E - 10 \cdot 6 = 0 \implies A_z = 30\text{kN}$

$\rightarrow$: $A_x - 5 = 0 \implies A_x = 5\text{kN}$



$\cos\alpha = 0,8$

$\sin\alpha = 0,6$

$A - B$

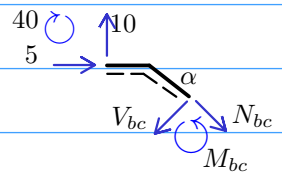
$N(s) = -5\text{kN}$

$V(s) = -\int f_z(s)ds = -10s + 30$ [kN] $\qquad -10s + 30 = 0 \implies s = 3$ (extrém mimo int.)

$M(s) = \int V(s)ds = -5s^2 + 30s$ [kNm] $\qquad d^2M/ds^2 = -10 > 0 \implies$ konkávní

$V(2) = 10\text{kN} \qquad M(2) = 40\text{kNm} \qquad M(1) = 25\text{kNm}$

B



$\searrow$: $N_{bc} + 5 \cdot \cos\alpha - 10 \cdot \sin\alpha = 0 \implies N_{bc} = 2\text{kN}$

$\swarrow$: $V_{bc} - 5 \cdot \sin\alpha - 10 \cdot \cos\alpha = 0 \implies V_{bc} = 11\text{kN}$

$M_{bc} = 40\text{kNm}$

$B - C$

$f_x(s) = 10 \cdot \sin\alpha = 6\text{kN/m} \qquad f_z(s) = 10 \cdot \cos\alpha = 8\text{kN/m}$

$N(s) = -\int f_x(s)ds = -6s + C_1 \implies N(0) = 2 \implies C_1 = 2$

$N(s) = -6s + 2$ [kNm] $\qquad N(2,5) = -13\text{kN}$

$V(s) = -\int f_z(s)ds = -8s + C_2 \implies V(0) = 11 \implies C_2 = 11$

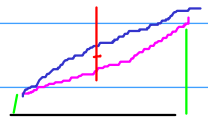
$V(s) = -8s + 11$ [kNm] $\qquad V(2,5) = -9\text{kN}$

$$M(s) = \int V(s)ds = -4s^2 + 11s + C_3 \implies M(0) = 40 \implies C_3 = 40$$

$$M(s) = -4s^2 + 11s + 40 \text{ [kNm]} \qquad V(s) = 0 = -8s + 11 \implies s_{\max} = 1,375\text{m}$$

$$M(2,5) = 42,5\text{kNm} \qquad M(1,375) = 47,563\text{kNm}$$

$D - C$



$$N = 0\text{kN}$$

$$V = -5\text{kN}$$

$$M(s) = -\int(-5)ds = 5s \qquad M(1,5) = 7,5\text{kNm}$$

$E - C$

$$N(s) = -30 \cdot \sin\alpha + 10 \cdot \sin\alpha \cdot s = -18 + 6s \qquad N(0) = -18\text{kN} \qquad N(2,5) = -3\text{kN}$$

$$V(s) = -30 \cdot \cos\alpha + 10 \cdot s \cdot \cos\alpha = -24 + 8s \qquad V(0) = -24\text{kN} \qquad V(2,5) = -4\text{kN}$$

$$M(s) = -\int V(s)ds = 24s - 4s^2 \qquad M(2,5) = 35\text{kNm} \qquad M(1,25) = 23,75\text{kNm}$$

$$d^2M/ds^2 = -8 < 0(\text{konkavni})$$