

V-V

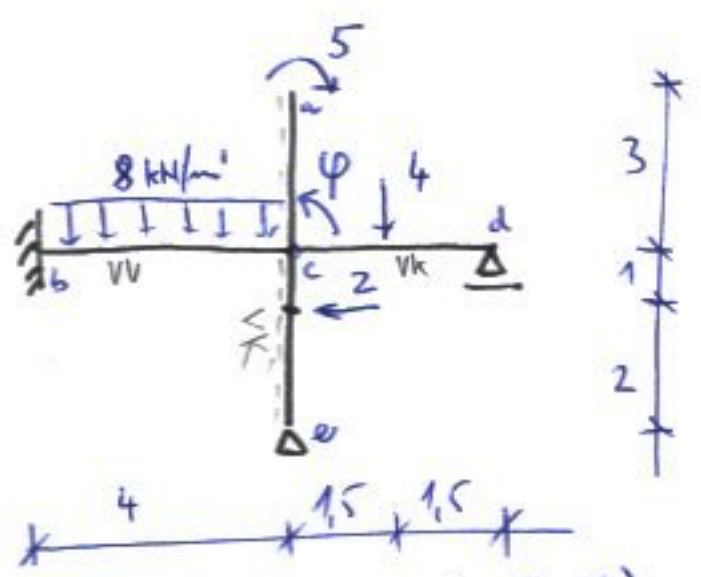
$$M_{ab} = \bar{M}_{ab} + \frac{2EI}{l} \left(2\varphi_a + \varphi_b + 3 \frac{\Delta v_b - \Delta v_a}{l} \right)$$

$$M_{ba} = \bar{M}_{ba} + \frac{2EI}{l} \left(2\varphi_b + \varphi_a + 3 \frac{\Delta v_b - \Delta v_a}{l} \right)$$

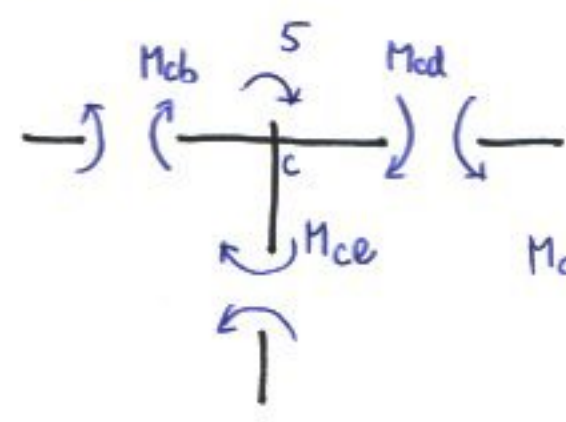
V-K

$$M_{ab} = \bar{M}_{ab} + \frac{3}{4} \frac{2EI}{l} \left(2\varphi_c + 2 \frac{\Delta v_b - \Delta v_a}{l} \right)$$

Pr. VYKRESLETE PRÁDĚNÍ V, M



$EI = 30\,000 \text{ kNm}^2$



$M_{cd} + M_{ce} + M_{cb} + 5 = 0$

$$\begin{aligned} \text{V} \quad M_{cb} &= \bar{M}_{cb} + k \left(2\varphi_c + \varphi_b + 3 \frac{\Delta v_c - \Delta v_b}{l} \right) = -106 + \frac{2EI}{4} 2\varphi_c = -106 + 30\,000 \varphi_c \\ \text{V} \quad M_{ce} &= \bar{M}_{ce} + \frac{3k}{2} \left(\varphi_c + \frac{\Delta v_e - \Delta v_c}{l} \right) = \frac{2 \cdot 1 \cdot 2}{2 \cdot 3^2} (2+3) \frac{F_{ab}}{2l^2} (6+l) + \frac{3 \cdot 2EI}{2 \cdot 3} \varphi_c = 1,1 + 30\,000 \varphi_c \\ \text{V} \quad M_{cd} &= \bar{M}_{cd} + \frac{3k}{2} \left(\varphi_c + \frac{\Delta v_d - \Delta v_c}{l} \right) = \frac{3}{16} \cdot 4 \cdot 3 + \frac{3 \cdot 2EI}{2 \cdot 3} \varphi_c = 2,25 + 30\,000 \varphi_c \end{aligned}$$

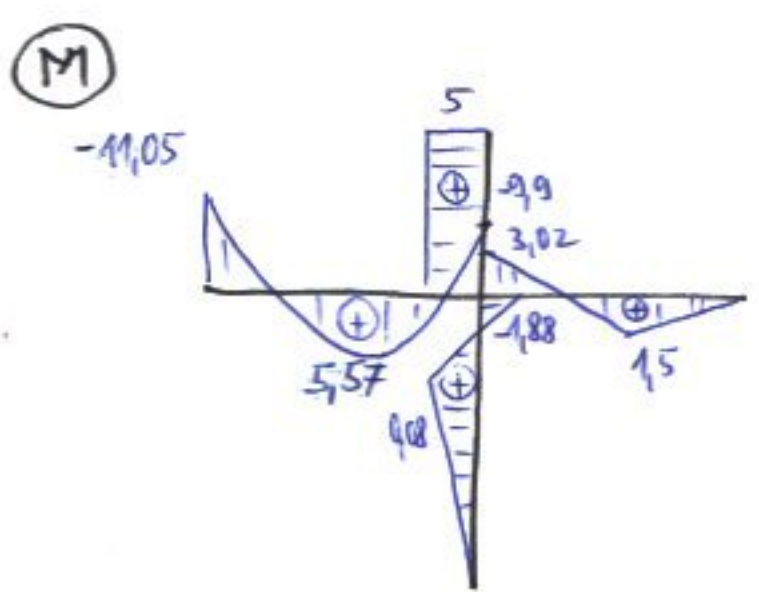
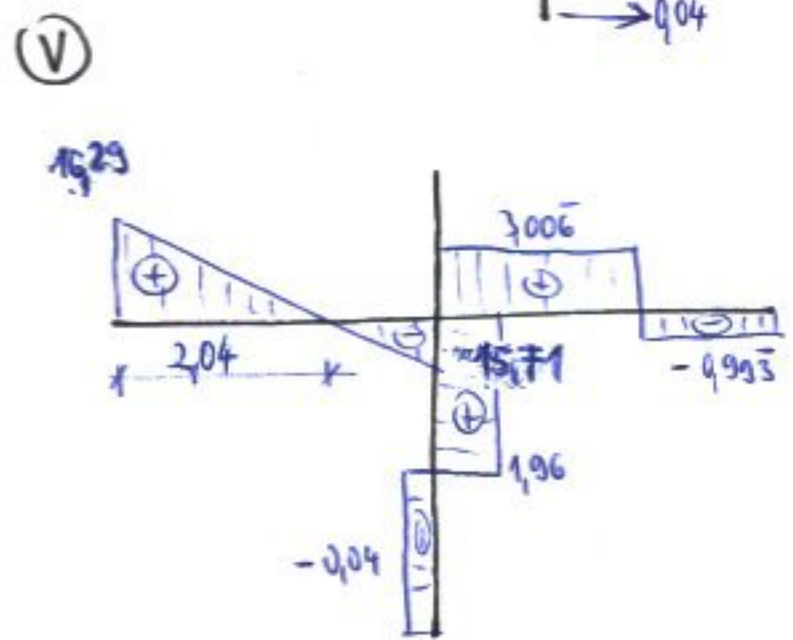
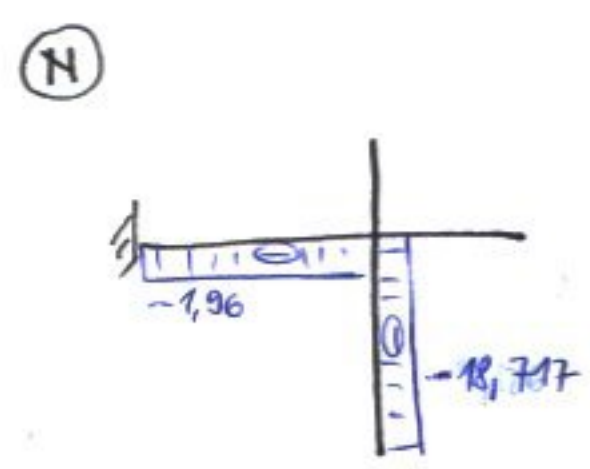
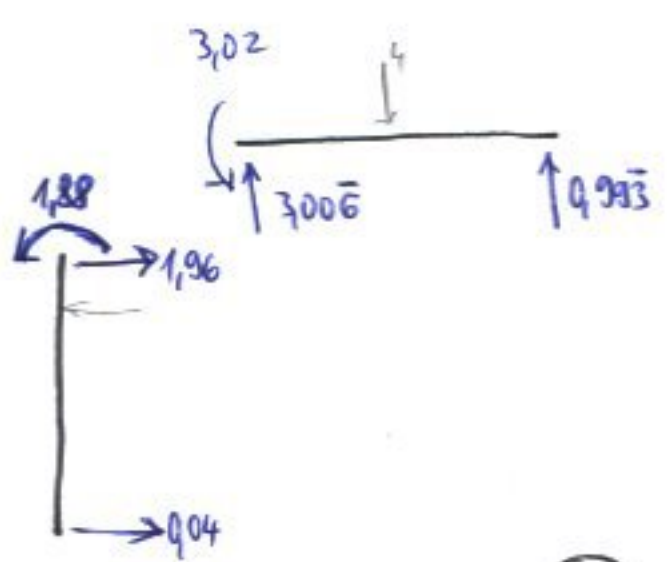
$$2,25 + 1,1 + 106 + 3 \cdot 30\,000 \varphi_c + 5 = 0 \quad \varphi_c = 2,562 \cdot 10^{-5} \text{ rad}$$

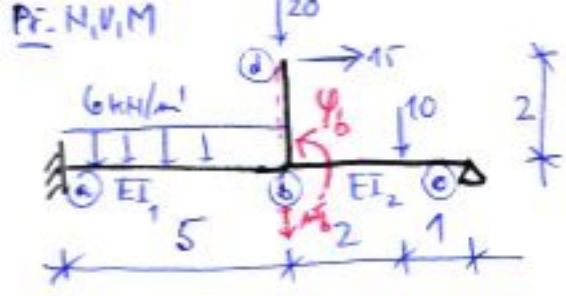
$$\begin{aligned} &= -9,9 \text{ kNm} \\ &= 1,88 \text{ kNm} \\ &= 3,02 \text{ kNm} \end{aligned}$$

BACK SUBSTITUTION

$$M_{bc} = -106 + k \varphi_c = -106 + 15\,000 \varphi_c = 11,05$$

$$z_{cb} = -16 + \frac{3 \cdot 2EI}{4} \varphi_c = -16 + 15\,000 \varphi_c = -15,71$$





$EI_1 = 150\,000 \text{ kNm}^2$
 $EI_2 = 50\,000 \text{ kNm}^2$
 $EA_1 = EA_2$

$M_{ba} + 30 + M_{bc} = 0$

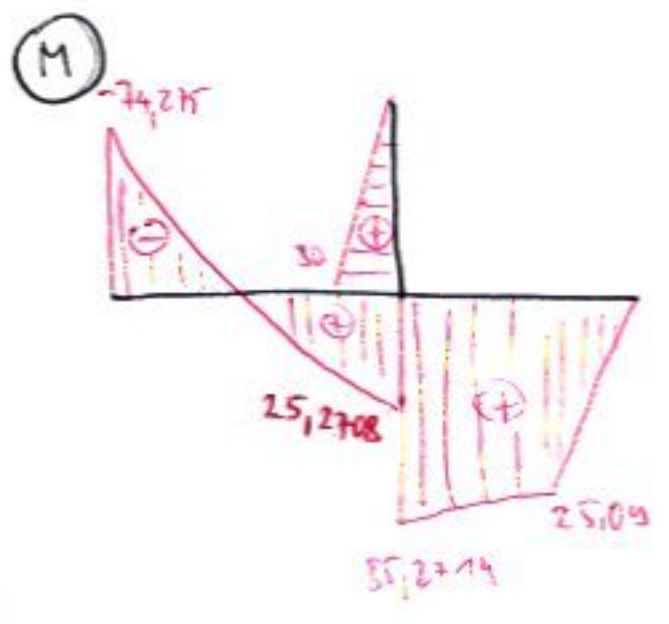
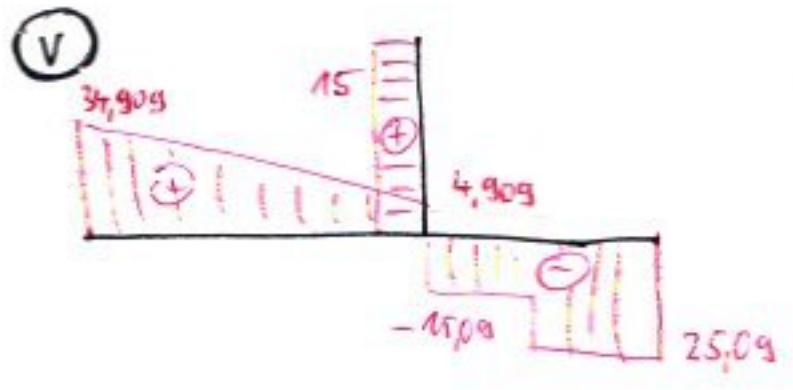
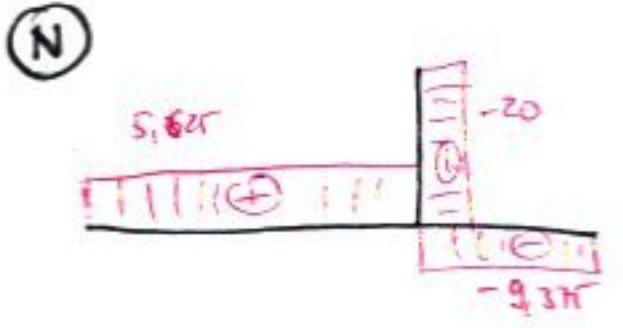
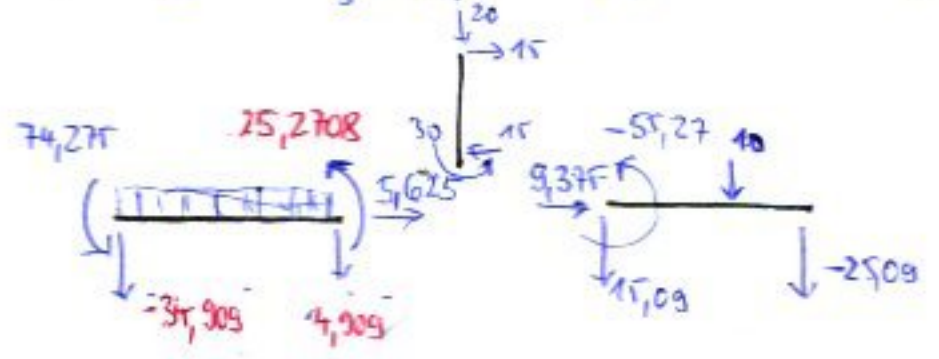
$Z_{ba} + Z_{bc} - 20 = 0$

$M_{ba} = -\frac{fL^2}{12} + \frac{2 \cdot 150\,000}{5} \left(2\varphi_b + 3 \frac{\omega_b}{5} \right) = -12,5 + 60\,000 \left(2\varphi_b + 0,6\omega_b \right) = -12,5 + 120\,000\varphi_b + 36\,000\omega_b$
 $M_{bc} = \frac{10 \cdot 2 \cdot 1}{2 \cdot 3^2} (1+3) + \frac{3 \cdot 50\,000}{3} \left(\varphi_b + \frac{\omega_b}{3} \right) = 4,4 + 50\,000\varphi_b - 16\,667\omega_b$
 $Z_{ba} = -\frac{6 \cdot 5}{2} + \frac{6 \cdot 150\,000}{5^2} \left(\varphi_b + \frac{2\omega_b}{5} \right) = -15 + 36\,000\varphi_b + 14\,400\omega_b$
 $Z_{bc} = -\frac{10 \cdot 1}{3} \left[\frac{2 \cdot (1+3)}{2 \cdot 3^2} + 1 \right] - \frac{6 \cdot 50\,000}{2 \cdot 3^2} \left(\varphi_b - \frac{\omega_b}{3} \right) = -4,8148 - 16\,667\varphi_b + 5556\omega_b$

$M_{ba} + M_{bc} + 30 = -12,5 + 4,4 + 30 + (120\,000 + 50\,000)\varphi_b + (36\,000 - 16\,667)\omega_b = 21,9\bar{4} + 170\,000\varphi_b + 19\,333\omega_b$
 $Z_{ba} + Z_{bc} - 20 = -15 - 4,8148 - 20 + (36\,000 - 16\,667)\varphi_b + (14\,400 + 5556)\omega_b = -39,815 + 19\,333\varphi_b + 19\,956\omega_b$
 $\varphi_b = -4,00066 \cdot 10^{-4} \text{ rad}$ $\omega_b = 2,3827 \cdot 10^{-3} \text{ m}$

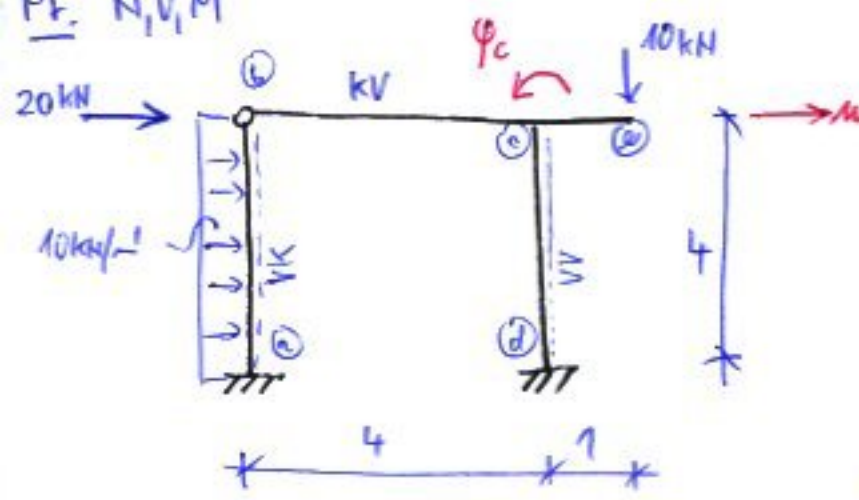
$M_{ab} = \frac{fL^2}{12} + \frac{2 \cdot 150\,000}{5} \left(\varphi_b + \frac{3\omega_b}{5} \right) = 12,5 + 60\,000\varphi_b + 36\,000\omega_b = 74,275 \text{ kNm}$
 $Z_{ab} = -\frac{fL}{2} - \frac{6 \cdot 150\,000}{5^2} \left(\varphi_b + \frac{3\omega_b}{5} \right) = -15 - 36\,000\varphi_b - 21\,600\omega_b = \dots \text{ kN}$

$\frac{T_{max}}{V_{max}} = \frac{5}{3}$

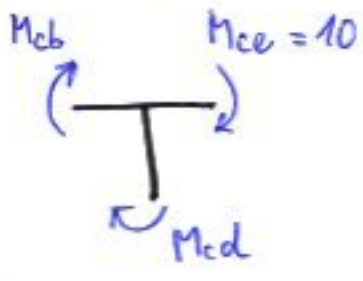


koniec 8 cv.

Pr. N, V, M



$EI = 125000 \text{ kNm}^2$



NEODJEVI SE PIZI VYHRESLOVA'N' SIL NA POUTECI



(1) $M_{cb} + M_{cd} + 10 = 0$

(2) $Z_{ba} + Z_{cd} - 20 = 0$

$M_{ab} = \frac{fL^2}{8} + \frac{3 \cdot 2EI}{2L} \frac{w}{L} = 20 + 23437 w$

$Z_{ab} = -\frac{5fL}{8} - \frac{3 \cdot 2EI}{2L^2} \frac{w}{L} = -25 - 5859 w$

$Z_{ba} = -\frac{3fL}{8} + \frac{3 \cdot 2EI}{2L^2} \frac{w}{L} = -15 + 5859 w$

$M_{cb} = \frac{3 \cdot 2EI}{2L} (\varphi_c) = 93750 \varphi_c$

$Z_{bc} = -\frac{3 \cdot 2EI}{2L^2} \varphi_c = -23438 \varphi_c$

$Z_{cb} = -Z_{bc} = 23438 \varphi_c$

| |
|--------|
| 65,22 |
| -36,30 |
| -3,696 |
| -43,04 |
| 10,76 |
| -10,76 |

$M_{dc} = \frac{2EI}{L} (\varphi_c + 3 \frac{w}{L}) = 62500 \varphi_c + 4687 w$ 61,74

$M_{cd} = \frac{2EI}{L} (2\varphi_c + 3 \frac{w}{L}) = 125000 \varphi_c + 4687 w$ 33,05

$Z_{dc} = -\frac{3 \cdot 2EI}{L^2} (\varphi_c + 2 \frac{w}{L}) = -4687 \varphi_c - 23438 w$ -23,70

$Z_{cd} = \frac{3 \cdot 2EI}{L^2} (\varphi_c + 2 \frac{w}{L}) = 4687 \varphi_c + 23438 w$ 23,70

(1) $93750 \varphi_c + 125000 \varphi_c + 4687 w + 10 = 0$

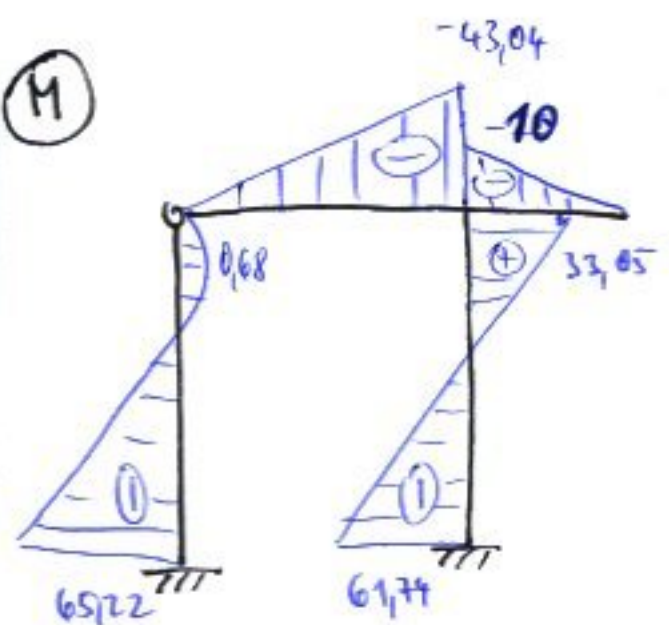
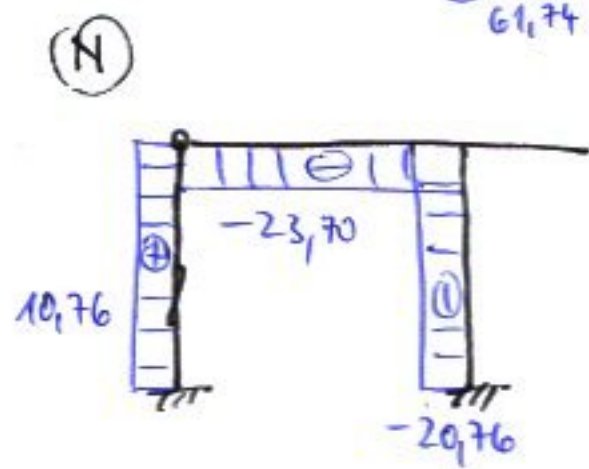
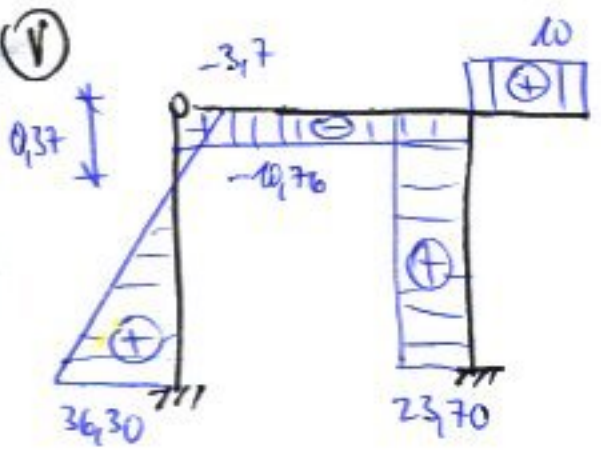
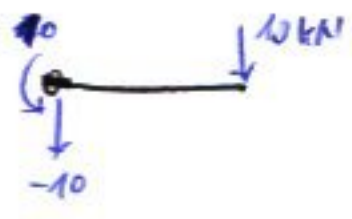
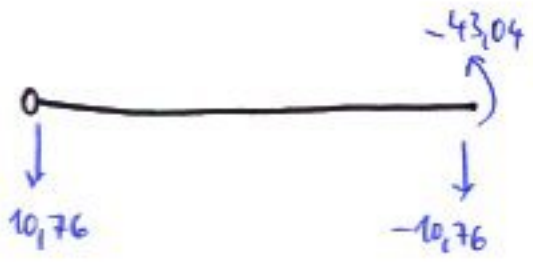
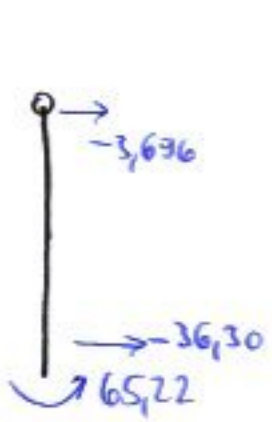
$218750 \varphi_c + 4687 w + 10 = 0$

(2) $-15 + 5859 w + 4687 \varphi_c + 23438 w - 20 = 0$

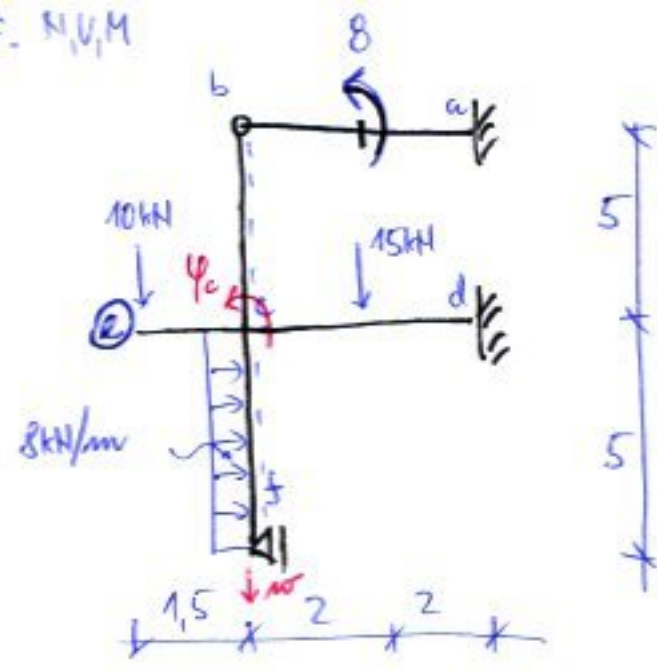
$4687 \varphi_c + 29297 w - 35 = 0$

$\varphi_c = -4,591 \cdot 10^{-4} \text{ rad}$

$w = 1,9293 \cdot 10^{-3} \text{ m}$



Pr. N, V, M



$I_x = 93$
 $E = 306 \text{ Pa}$
 $EI = 93750 \text{ kNm}^2$
 $10 \cdot 15 = 15$
 $(1) M_{cf} + M_{cd} + M_{cb} - 15 = 0$

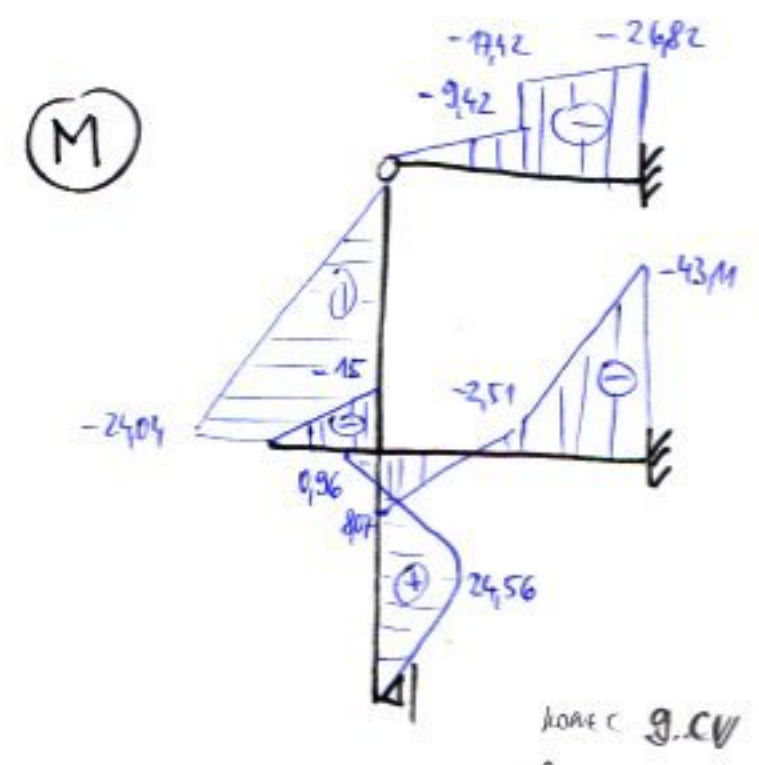
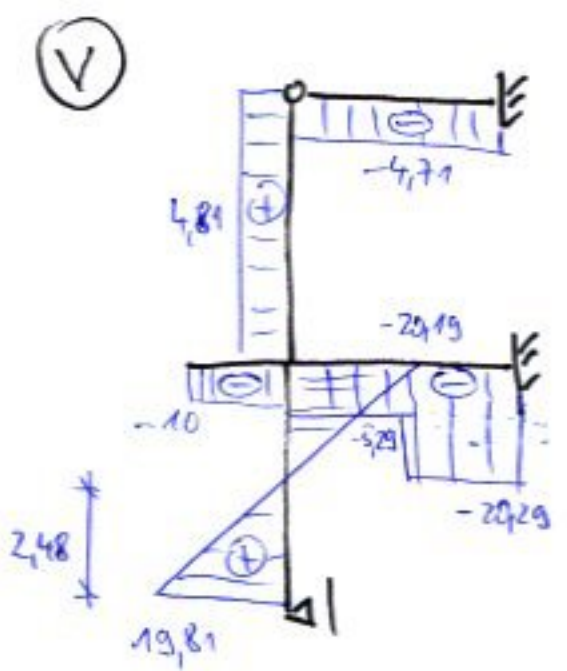
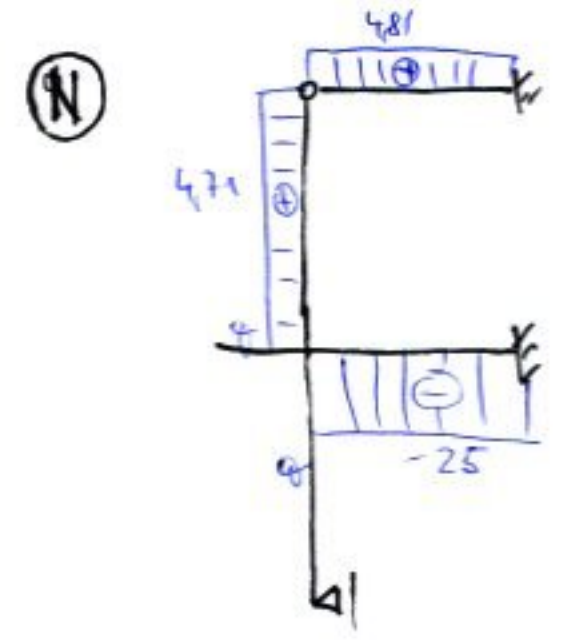
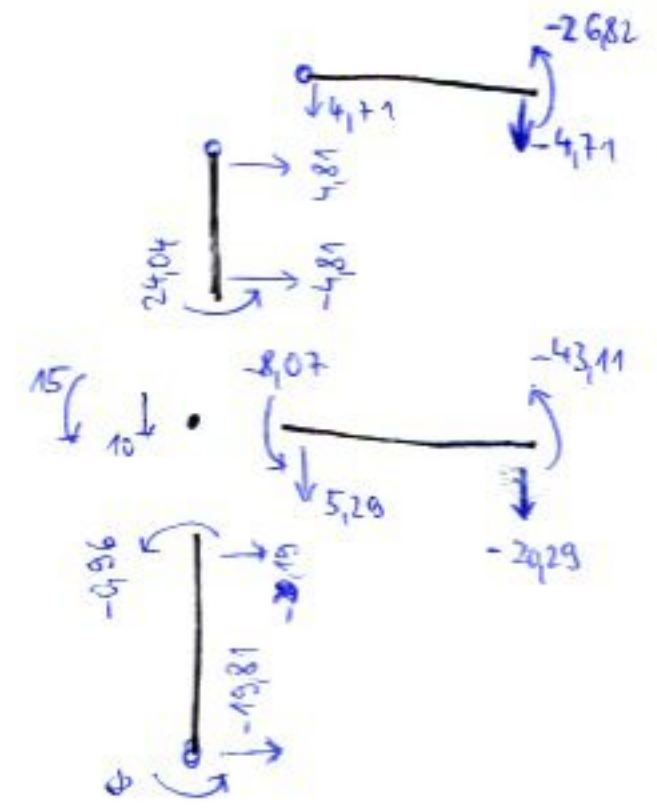
$(2) z_{ba} + z_{cd} - 10 = 0$

$M_{cf} = -25 + 56250 \psi_c = -0,96$
 $z_{fc} = -15 - 11250 \psi_c = -19,81$
 $z_{cf} = -25 + 11250 \psi_c = -20,19$
 $M_{cd} = 7,5 + 93750 \psi_c - 35156 \omega = -8,07$
 $M_{dc} = -7,5 + 46875 \psi_c - 35156 \omega = -43,11$
 $z_{cd} = -7,5 - 35156 \psi_c + 17578 \omega = 5,29$
 $z_{dc} = -7,5 + 35156 \psi_c - 17578 \omega = -20,29$

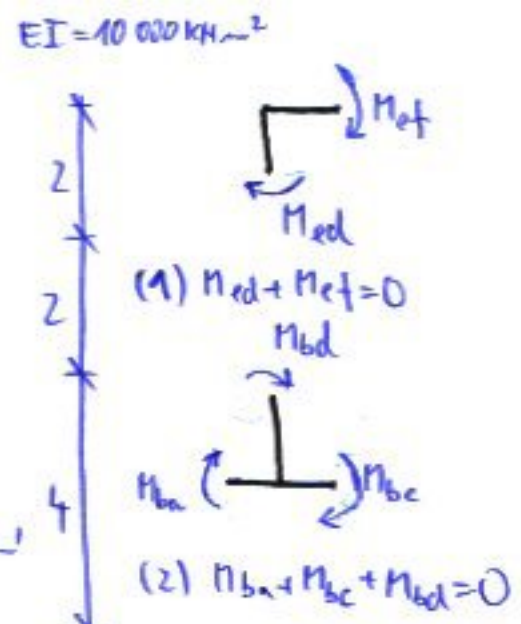
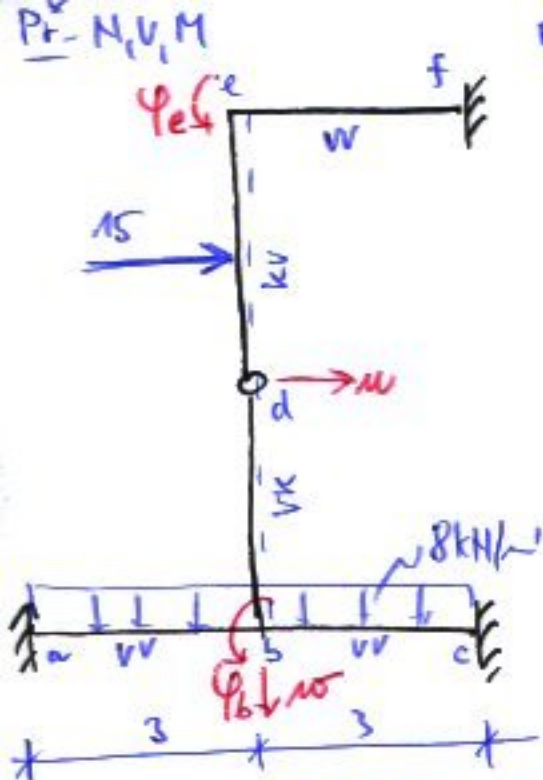
$M_{cb} = 56250 \psi_c = 24,04$
 $z_{cb} = -11250 \psi_c = -4,81$
 $z_{bc} = 11250 \psi_c = 4,81$
 $M_{ab} = \frac{8}{2 \cdot 4^2} (4^2 - 3 \cdot 2^2) - 17578 \omega = 1 - 17578 \omega = -26,82$
 $z_{ba} = -\frac{8}{4} \left(1 + \frac{4^2 - 3 \cdot 2^2}{2 \cdot 4^2} \right) + 4395 \omega = -2,25 + 4395 \omega = 4,71$
 $z_{ab} = 2,25 - 4395 \omega = -4,71$

$(1) \begin{bmatrix} 206250 & -35156 \\ -35156 & 21973 \end{bmatrix} \begin{pmatrix} \psi_c \\ \omega \end{pmatrix} = \begin{pmatrix} 32,5 \\ 19,7 \end{pmatrix}$
 (2)

$\psi_c = 4,273 \cdot 10^{-4} \text{ rad}$
 $\omega = 1,583 \cdot 10^{-3} \text{ rad}$



конек г.св



$$M_{ab} = 6 + 6667 \varphi_b + 6667 w \quad 22,33$$

$$M_{ba} = -6 + 13333 \varphi_b + 6667 w \quad 6,19$$

$$z_{ab} = -12 - 6667 \varphi_b - 4445 w \quad -29,50$$

$$z_{ba} = -12 + 6667 \varphi_b + 4445 w \quad -2,50$$

$$M_{bc} = 6 + 13333 \varphi_b - 6667 w \quad -22,76$$

$$M_{cb} = -6 + 6667 \varphi_b - 6667 w \quad -30,61$$

$$z_{bc} = -12 - 6667 \varphi_b + 4445 w \quad 5,79$$

$$z_{cb} = -12 + 6667 \varphi_b - 4445 w \quad -29,79$$

$$M_{bd} = 7500 \varphi_b + 1875 w \quad 16,57$$

$$z_{bd} = -1875 \varphi_b - 469 w \quad -4,14$$

$$z_{db} = 1875 \varphi_b + 469 w \quad 4,14$$

$$M_{ef} = 13333 \varphi_e - 6667 w \quad 13,42$$

$$M_{fe} = 6667 \varphi_e - 6667 w \quad -3,53$$

$$z_{ef} = -6667 \varphi_e + 4445 w \quad -3,30$$

$$z_{fe} = 6667 \varphi_e - 4445 w \quad 3,30$$

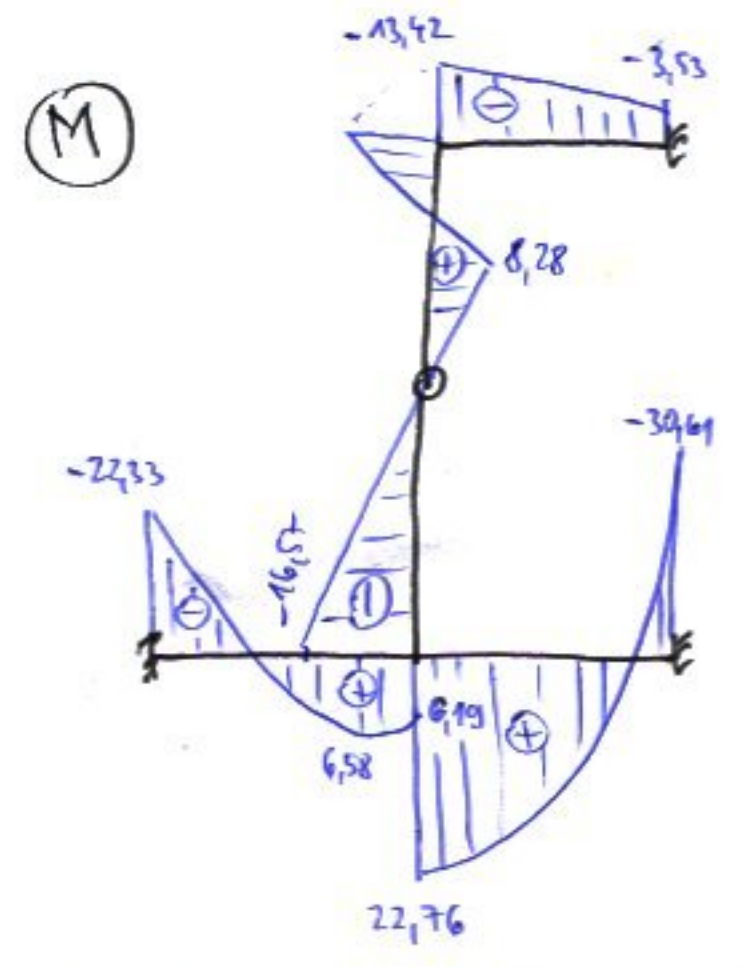
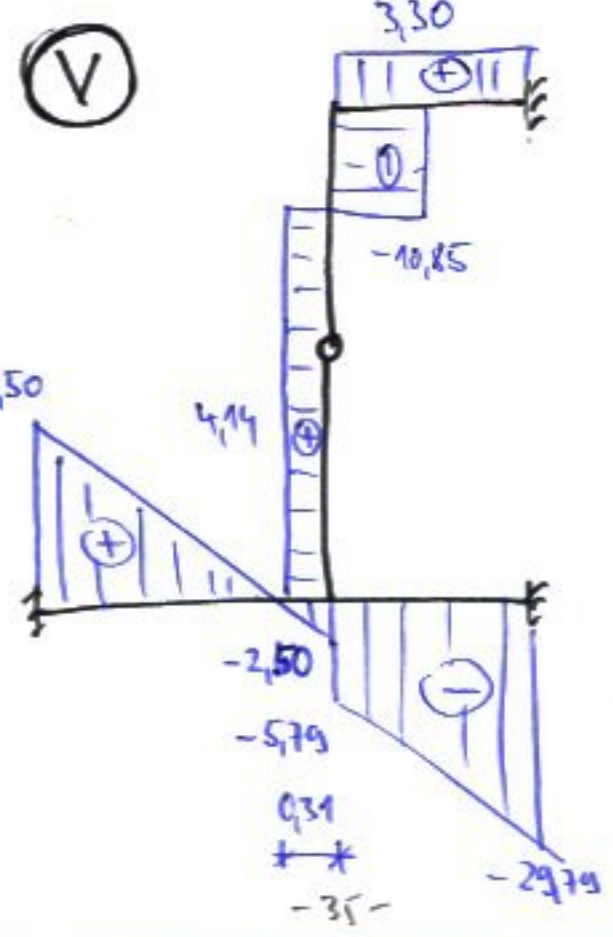
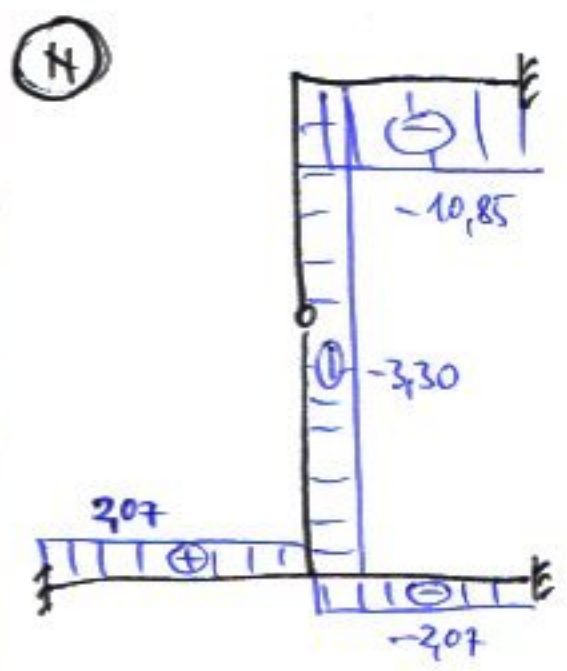
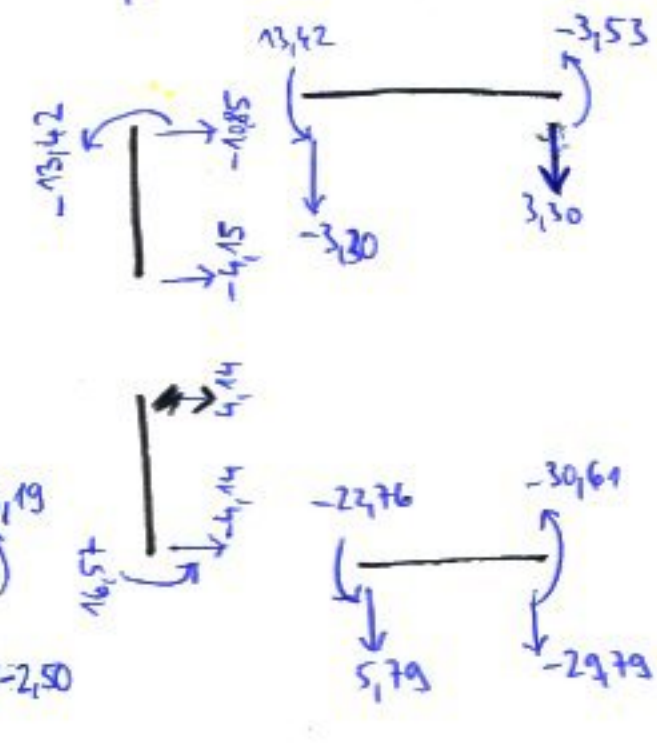
$$\begin{matrix} -13,42 \\ -4,14 \\ 4,14 \end{matrix} \begin{matrix} M_{ed} = 7500 \varphi_e - 1875 w - 11,25 \\ z_{de} = -1875 \varphi_e + 469 w - 469 \\ z_{ed} = 1875 \varphi_e - 469 w - 1031 \end{matrix} \quad \begin{matrix} (1) \\ (2) \\ (3) \\ (4) \end{matrix} \begin{bmatrix} 34166 & 0 & 0 & 1875 \\ 0 & 13335 & -6667 & 0 \\ 0 & -6667 & 20833 & -1875 \\ 1875 & 0 & -1875 & 938 \end{bmatrix} \begin{pmatrix} \varphi_b \\ w \\ \varphi_e \\ w \end{pmatrix} = \begin{pmatrix} 11,25 \\ 0 \\ 24 \\ 469 \end{pmatrix}$$

$$\varphi_b = -6,21 \cdot 10^{-4} \text{ rad}$$

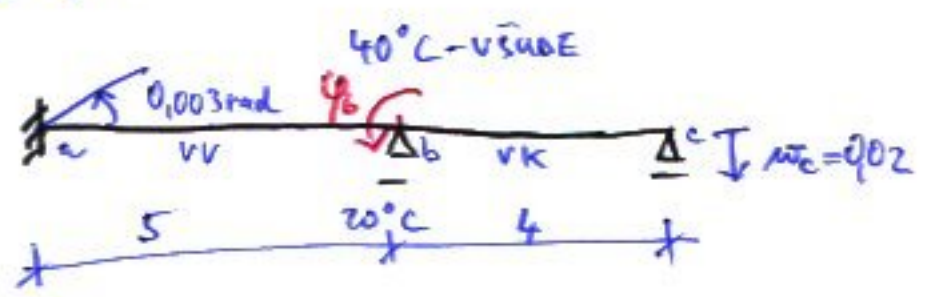
$$w = 3,07 \cdot 10^{-3} \text{ m}$$

$$\varphi_e = 2,54 \cdot 10^{-3} \text{ rad}$$

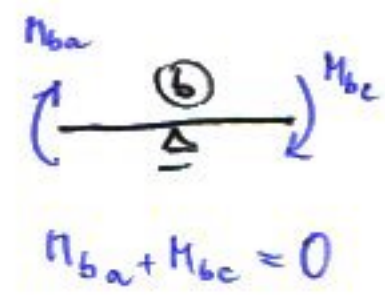
$$w = 1,13 \cdot 10^{-2} \text{ m}$$



Pr. V, M



40°C
20°C
 $d = 12 \cdot 10^{-6} \text{ k}^{-1}$
 $EI = 30\,000 \text{ kNm}^2$



$$M_{ab} = \frac{EI}{h} \Delta t + \frac{2EI}{L} (2\varphi_a + \varphi_b) = -24 + 42\,000 (2 \cdot 0,003 + \varphi_b) = -24 + 72 + 12\,000 \varphi_b = 48 + 12\,000 \varphi_b \quad 12,78$$

$$\overline{M_{ba}} = -\frac{EI}{h} \Delta t + \frac{2EI}{L} (\varphi_a + 2\varphi_b) = +24 + 12\,000 (\varphi_a + 2\varphi_b) = +24 + 36 + 24\,000 \varphi_b = 60 + 24\,000 \varphi_b \quad -10,44$$

$$Z_{ab} = \frac{-6EI}{L^2} (\varphi_a + \varphi_b) = -7200 \cdot 0,003 - 7200 \varphi_b = -21,6 - 7200 \varphi_b \quad -0,468$$

$$Z_{ba} = 21,6 + 7200 \varphi_b \quad 0,468$$

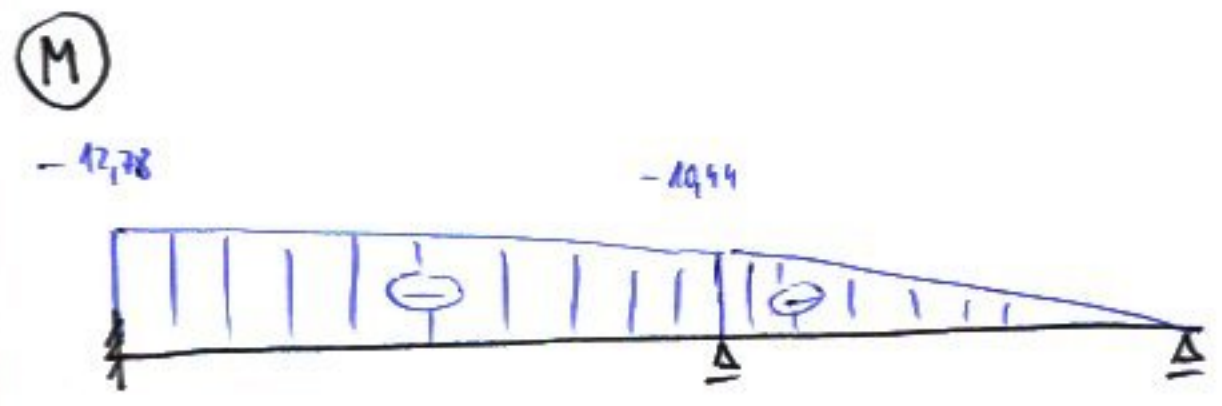
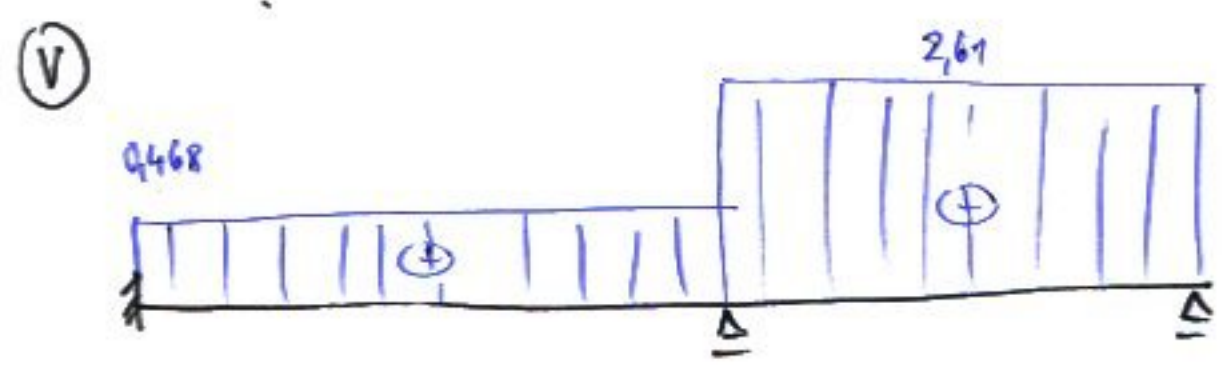
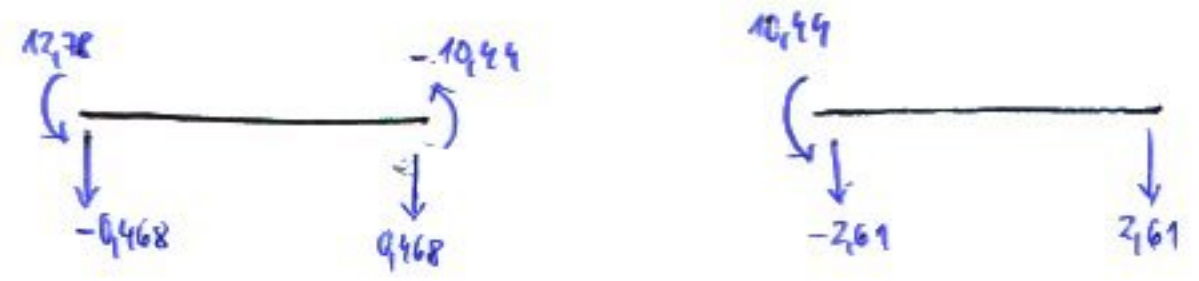
$$\overline{M_{bc}} = \frac{3EI}{2h} \Delta t + \frac{3EI}{L} (\varphi_b + \frac{0,02}{L}) = -36 + 22\,500 \varphi_b + 112,5 = 76,5 + 22\,500 \varphi_b \quad 19,44$$

$$Z_{bc} = -\frac{3EI}{2hL} \Delta t - \frac{3EI}{L^2} (\varphi_b + \frac{0,02}{L}) = +9 - 5625 \varphi_b - 28,125 = -19,125 - 5625 \varphi_b \quad -2,61$$

$$Z_{cb} = -9 + 5625 \varphi_b + 28,125 = 19,125 + 5625 \varphi_b \quad 2,61$$

$$M_{ba} + M_{bc} = 60 + 24\,000 \varphi_b + 76,5 + 22\,500 \varphi_b = 136,5 + 46\,500 \varphi_b = 0$$

$$\varphi_b = -2,935 \cdot 10^{-3} \text{ rad}$$



↑
10000 10000

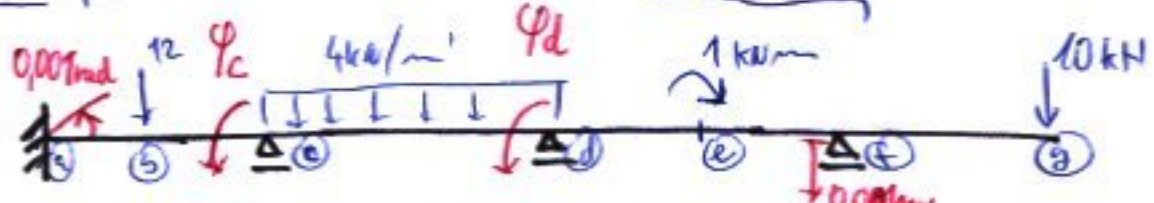
P.V. V, M

PERECENI NA V-K

$$I = \frac{1}{12} \cdot 0,2 \cdot 0,3^3 = 4,5 \cdot 10^{-4} \text{ m}^4$$

$$E = 30 \text{ GPa}$$

$$EI = 13500 \text{ kNm}^2$$



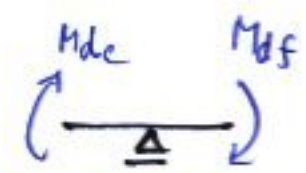
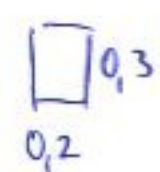
$$M_{ac} = 3 + 13500(2 \cdot 0,001 + \varphi_c) = 30 + 13500\varphi_c \quad 27,096$$

$$M_{ca} = -3 + 13500(0,001 + 2\varphi_c) = 10,5 + 27000\varphi_c \quad 4,692$$

$$M_{cd} = 1,3 + 13500(2\varphi_c + \varphi_d) = 1,3 + 27000\varphi_c + 13500\varphi_d \quad -4,692 \quad (1) \quad M_{ca} + M_{cd} = 0$$

$$M_{dc} = -1,3 + 13500(\varphi_c + 2\varphi_d) = -1,3 + 13500\varphi_c + 27000\varphi_d \quad -4,673$$

$$M_{df} = \frac{-10 \cdot 1}{2 \cdot 2^2}(2^2 - 3 \cdot 0) + \frac{-1}{2 \cdot 2^2}(2^2 - 3 \cdot 1^2) + 20250(\varphi_d + \frac{0,001}{2}) = -5 - 0,125 + 20250\varphi_d + 10,125 = 5 + 20250\varphi_d$$

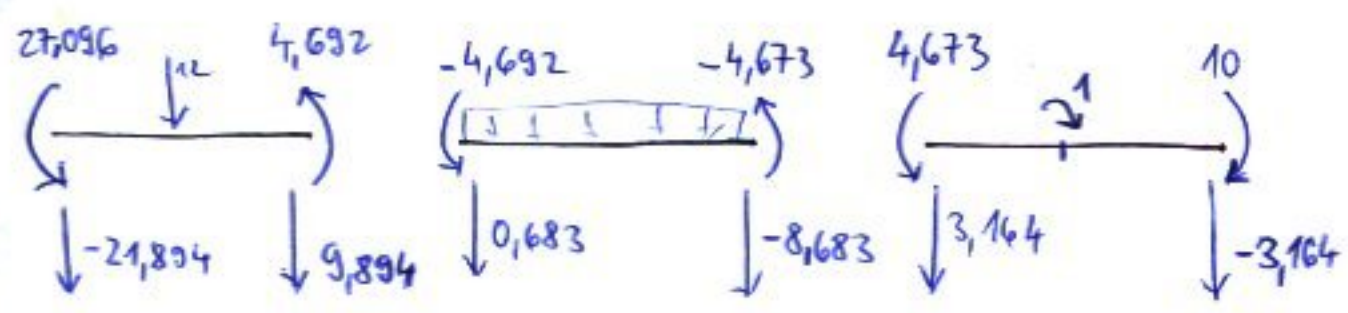


(2) $M_{dc} + M_{df} = 0$

$$\begin{bmatrix} 54000 & 13500 \\ 13500 & 47250 \end{bmatrix} \begin{Bmatrix} \varphi_c \\ \varphi_d \end{Bmatrix} = \begin{Bmatrix} -11,83 \\ -3,6 \end{Bmatrix}$$

$$\varphi_c = -2,151 \cdot 10^{-4} \text{ rad}$$

$$\varphi_d = -1,6144 \cdot 10^{-5} \text{ rad}$$



DOPOČET NAKLONU φ_f



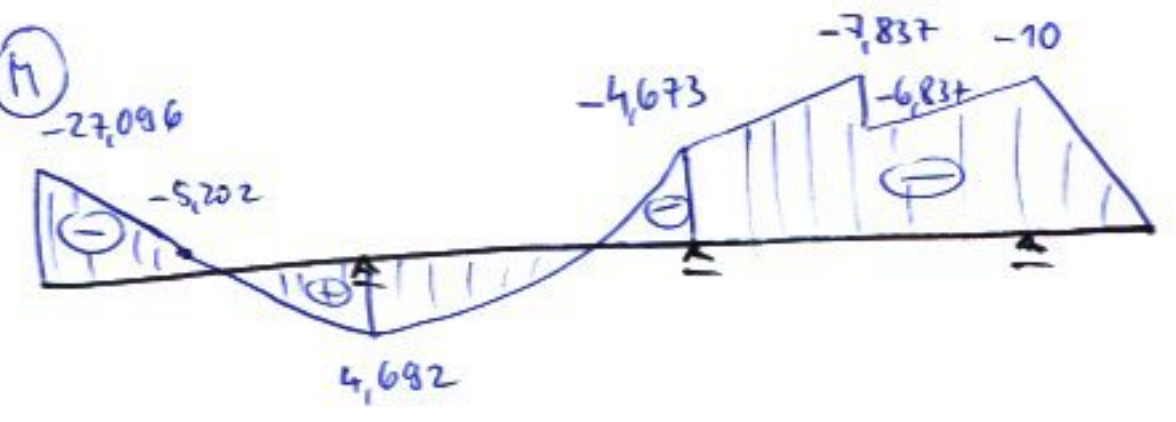
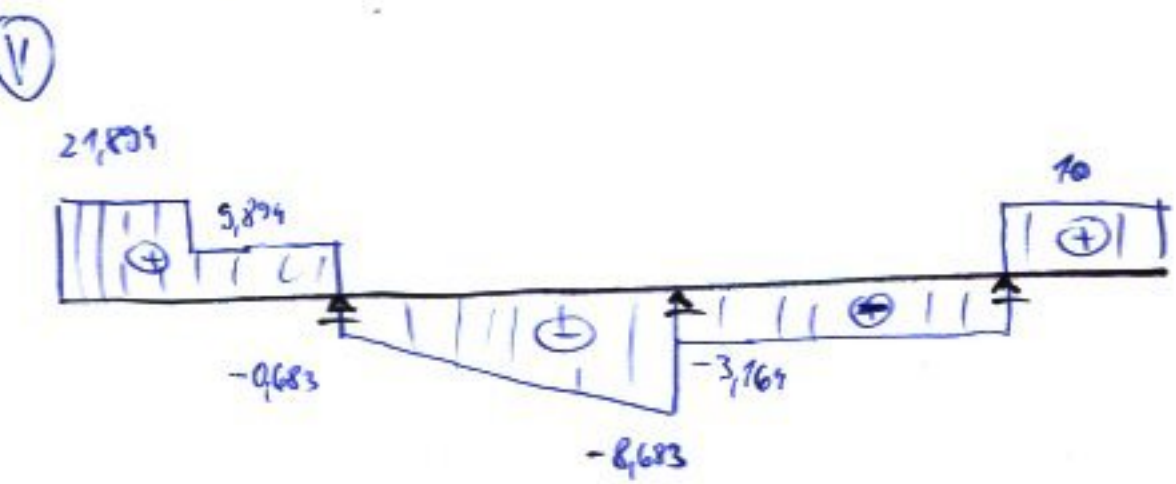
$$M_{df} = \frac{-1 \cdot 1}{2^2}(2 \cdot 2 - 3) + 13500(2\varphi_d + \varphi_f + \frac{3 \cdot 0,001}{2})$$

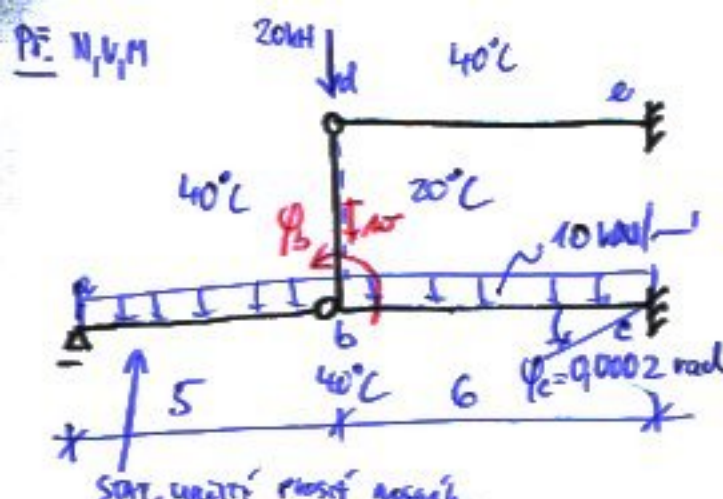
$$= 4,673 =$$

$$= -0,125 - 4,359 + 13500\varphi_f + 20,125$$

$$13500\varphi_f = -10,968$$

$$\varphi_f = -8,129 \cdot 10^{-4} \text{ rad}$$



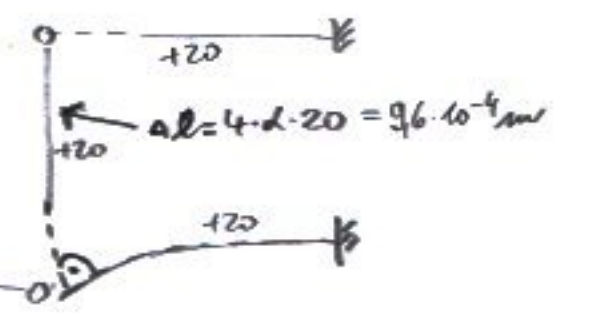


96
 93
 $EI = 135000 \text{ kNm}^2$
 $\alpha = 12 \cdot 10^{-6} \text{ k}^{-1}$
 $t_{ref} = 10^\circ\text{C}$

$(1) M_{bd} + M_{bc} = 0$

$(2) z_{de} + z_{bc} - 25 - 20 = 0$

VLIV TAVROVÉHO VEPLOUTÍ



$M_{bc} = \frac{10 \cdot 6^2}{12} + \frac{EI}{L} \alpha \cdot 20 + \frac{2EI}{6} (\varphi_b + \varphi_c + 3 \frac{-(\alpha + 96 \cdot 10^{-4})}{6}) =$

$= 30 + 54 + 90000\varphi_b + 9 - 22500\alpha - 216 = 77,99 + 90000\varphi_b - 22500\alpha$

$M_{cb} = -30 - 54 + \frac{2EI}{6} (\varphi_b + 2\varphi_c + 3 \frac{-(\alpha + 96 \cdot 10^{-4})}{6}) = -30 - 54 + 45000\varphi_b + 18 -$

$- 22500\alpha - 216 = -87,6 + 45000\varphi_b - 22500\alpha = -307,65$

$z_{bc} = -30 - 22500\varphi_b - 45 + 7500\alpha + 72 = -27,3 - 22500\varphi_b + 7500\alpha = 34,27$

$z_{cb} = -30 + 22500\varphi_b + 45 - 7500\alpha - 7,2 = -32,7 + 22500\varphi_b - 7500\alpha = -94,27$

$M_{bd} = \frac{3EI}{2L} \alpha (20 - 40) + \frac{3EI}{L} (\varphi_b) = -81 + 101250\varphi_b = 77,99$

$z_{bd} = -\frac{3EI}{2L} \alpha (20 - 40) - \frac{3EI}{L} \varphi_b = 20,25 - 25313\varphi_b = -19,50$

$z_{db} = -20,25 + 25313\varphi_b = 19,50$

$M_{ed} = -\frac{3EI}{2L} \alpha (-20) + \frac{3EI}{L} \frac{(-\alpha)}{L} = 81 - 11250\alpha = -64,35$

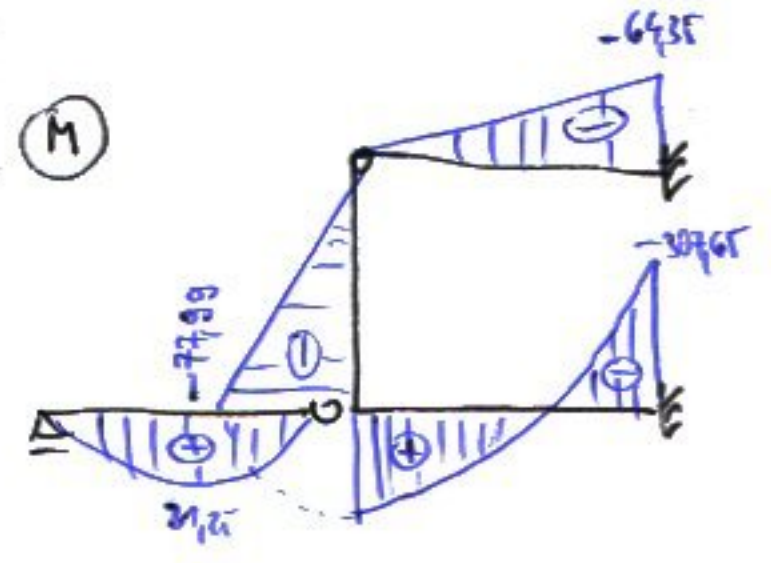
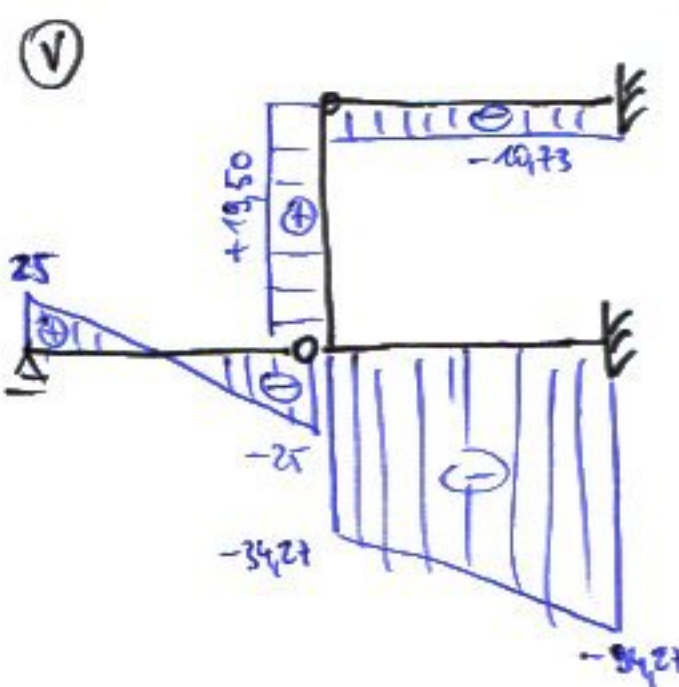
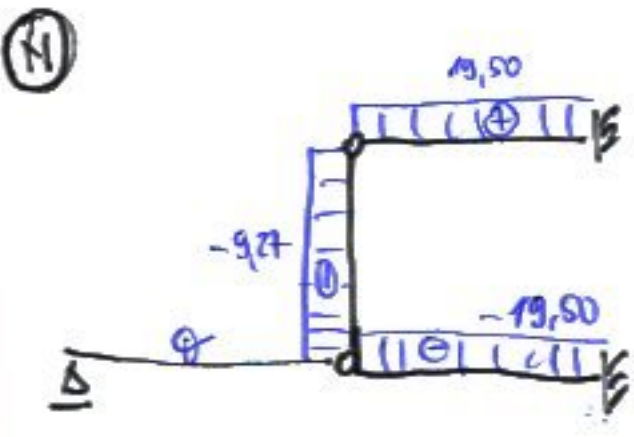
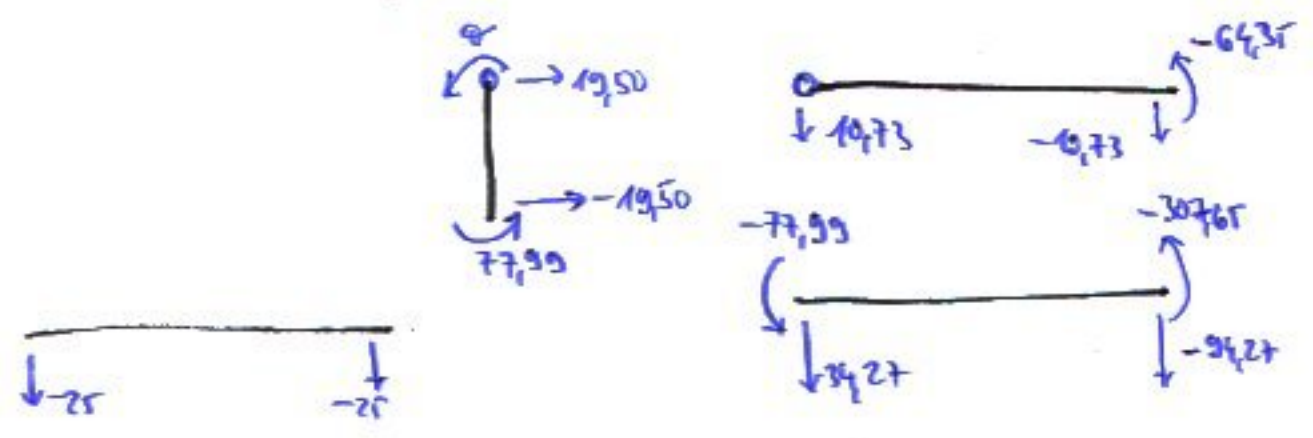
$z_{de} = \frac{3EI}{2L} \alpha (-20) - \frac{3EI}{L} \frac{(-\alpha)}{L} = -13,5 + 1875\alpha = 10,73$

$z_{ed} = 13,5 - 1875\alpha = -10,73$

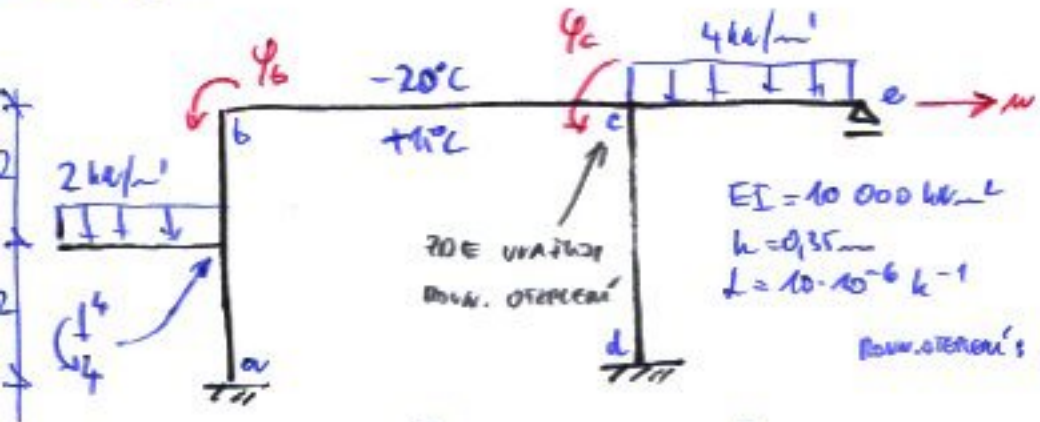
$(1) \begin{bmatrix} 191250 & -22500 \\ -22500 & 9375 \end{bmatrix} \begin{pmatrix} \varphi_b \\ \alpha \end{pmatrix} = \begin{pmatrix} 9,6 \\ 81,8 \end{pmatrix}$

$\varphi_b = 1,570 \cdot 10^{-3} \text{ rad}$

$\alpha = 0,01292 \text{ mm}$



KONEC 11. CV.



$(1) M_{ba} + M_{bc} = 0$ $(2) M_{cb} + M_{ce} + M_{ed} = 0$ $(3) Z_{ba} + Z_{ed} = 0$

$Razn. otprern' d \cdot G \cdot (-25) = -15 \cdot 10^{-5} m$

$M_{ab} = \frac{4 \cdot 2}{4^2} (2 \cdot 4 - 3 \cdot 2) + 5000 \varphi_b + 3750 w = 1 + 5000 \varphi_b + 3750 w$

$M_{ba} = 1 + 10000 \varphi_b + 3750 w$
 $Z_{ab} = -\frac{4}{4} \left(1 + \frac{2 \cdot 2 + 2 \cdot 2}{16} \right) - 3750 \varphi_b - 1875 w = -1.5 - 3750 \varphi_b - 1875 w$

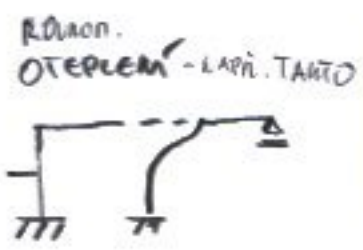
$Z_{ba} = 1.5 + 3750 \varphi_b + 1875 w$
 $M_{bc} = \frac{EI}{k} \alpha (\pi + 20) + 6666 \varphi_b + 3333 \varphi_c = 10 + 6666 \varphi_b + 3333 \varphi_c$

$M_{cb} = -10 + 3333 \varphi_b + 6666 \varphi_c$
 $Z_{bc} = -1667 \varphi_b - 1667 \varphi_c$
 $Z_{cb} = 1667 \varphi_b + 1667 \varphi_c$

$M_{dc} = 5000 \varphi_c + 3750 w + 3750 \cdot (-15 \cdot 10^{-5}) = -0.5625 + 5000 \varphi_c + 3750 w$

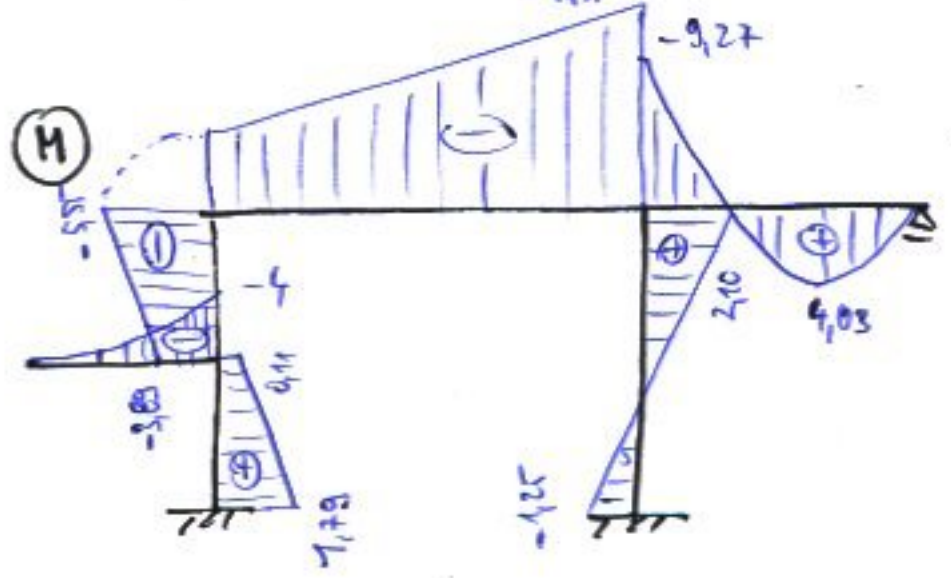
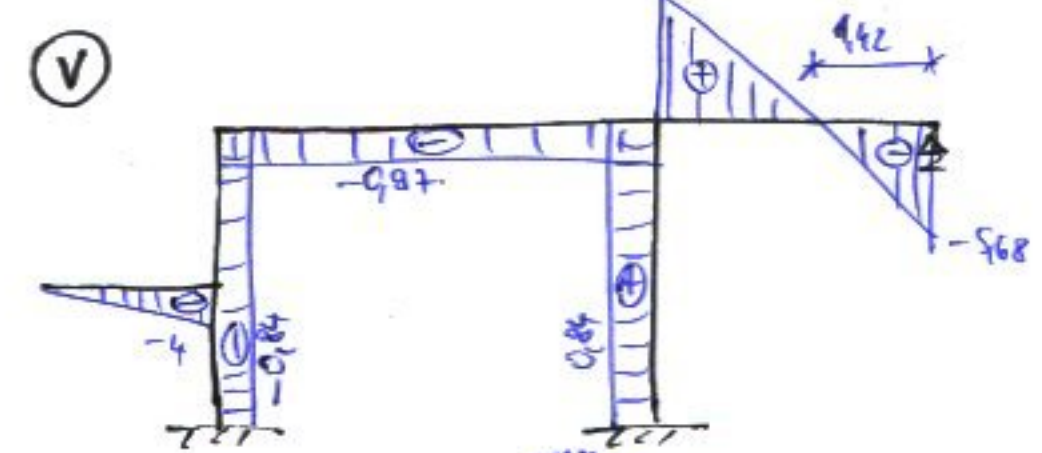
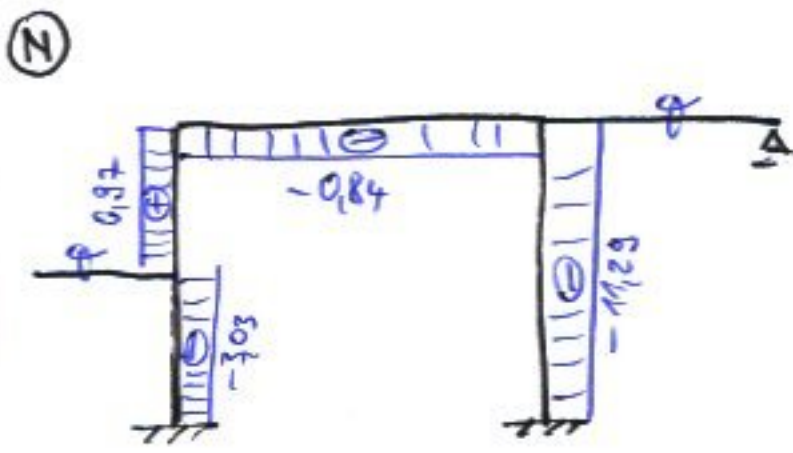
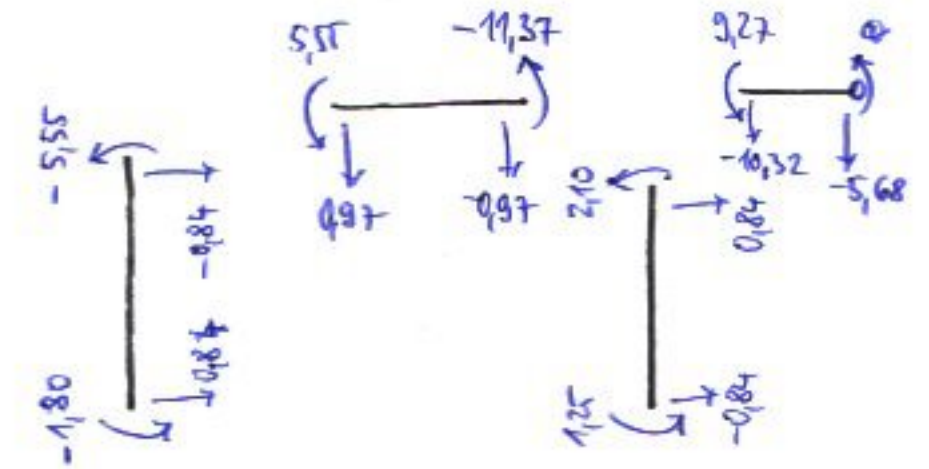
$M_{cd} = -0.5625 + 10000 \varphi_c + 3750 w$
 $Z_{de} = -3750 \varphi_c - 1875 w + 0.28125$

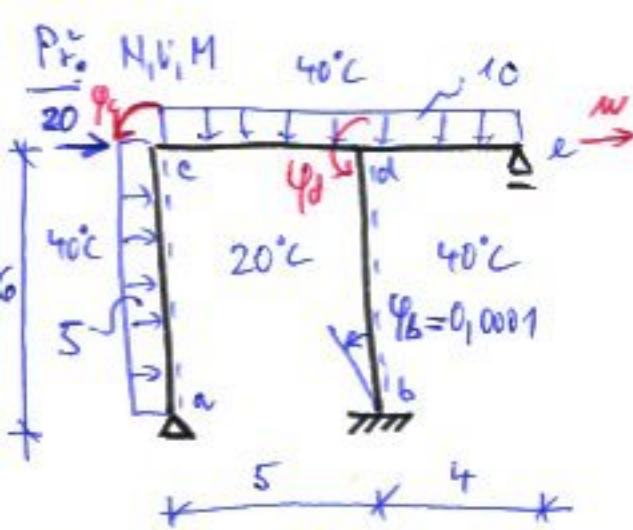
$Z_{ed} = 3750 \varphi_c + 1875 w - 0.28125$
 $M_{ce} = \frac{fL^2}{8} + 7000 \varphi_c = 8 + 7000 \varphi_c$
 $Z_{ce} = -10 - 1875 \varphi_c$
 $Z_{ec} = -6 + 1875 \varphi_c$



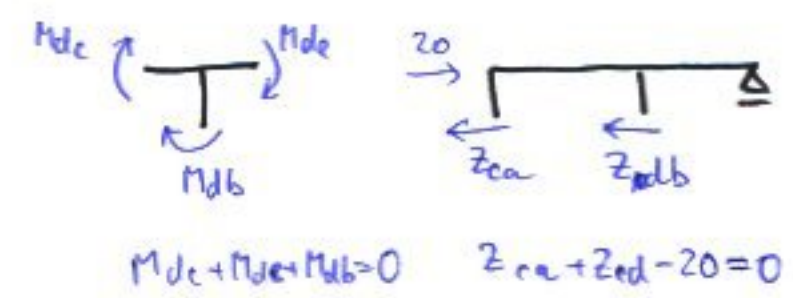
$$\begin{bmatrix} 16666 & 3333 & 3750 \\ 3333 & 24166 & 3750 \\ 3750 & 3750 & 3750 \end{bmatrix} \begin{pmatrix} \varphi_b \\ \varphi_c \\ w \end{pmatrix} = \begin{pmatrix} -11 \\ 2.5625 \\ -1.21875 \end{pmatrix}$$

$\varphi_b = -7.5181 \cdot 10^{-4} \text{ rad}$
 $\varphi_c = 1.6985 \cdot 10^{-4} \text{ rad}$
 $w = 2.5696 \cdot 10^{-4} \text{ m}$

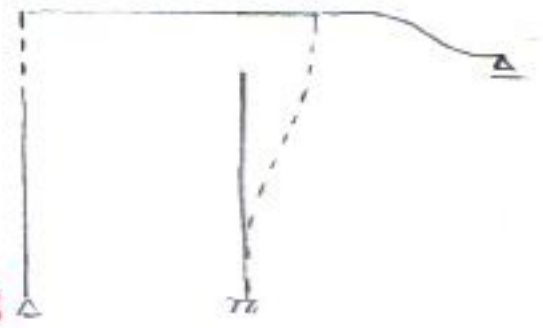




Q_6
 Q_3
 $E = 25 \text{ GPa}$
 $EI = 135000 \text{ kNm}^2$ (1) $M_{cd} + M_{ca} = 0$
 $t_{ref} = 15^\circ\text{C}$
 $\alpha = 12 \cdot 10^{-6} \text{ K}^{-1}$



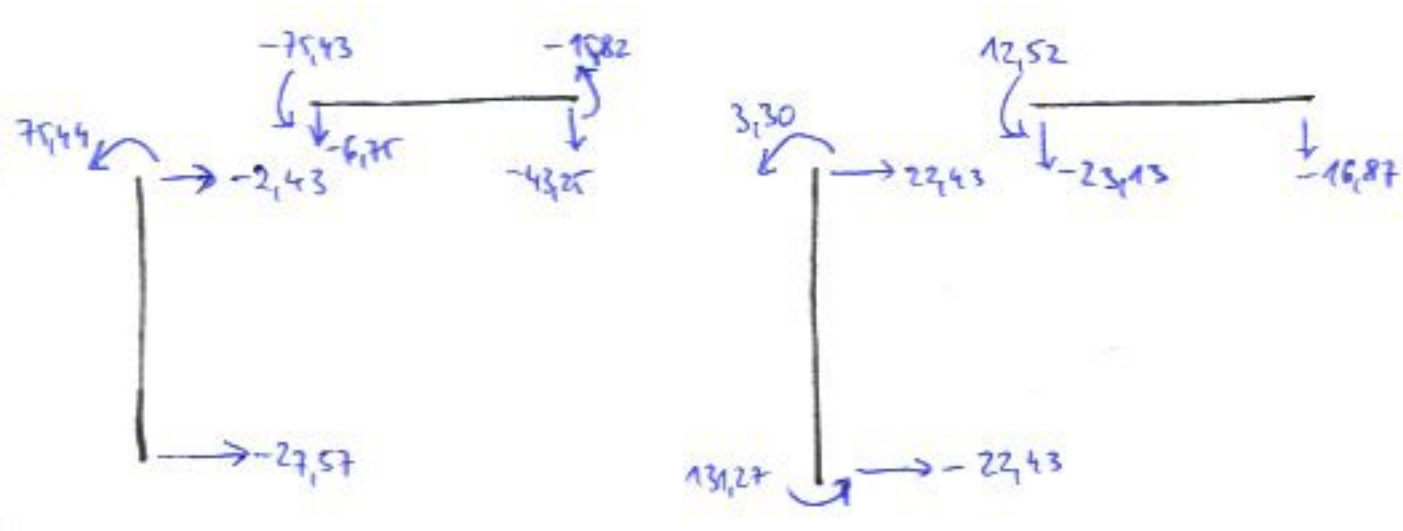
VLIV ROZKOLENENIA TEMPERATURY $+15^\circ\text{C}$
 VYKONAJ NAPRAV TALKO



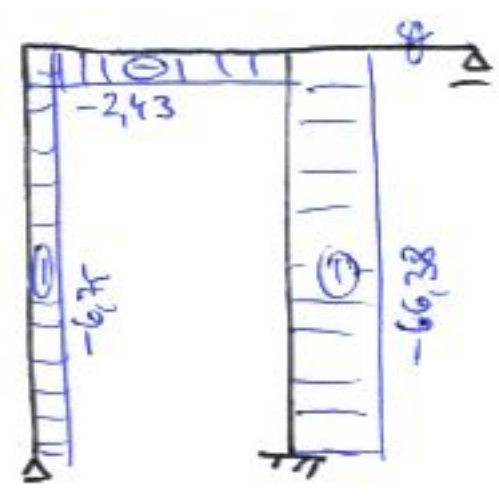
$$\begin{aligned}
 M_{ca} &= -22,5 - \frac{3EI}{2h} \alpha (20-40) + 67500 \varphi_c + 11250 \omega = 58,5 + 67500 \varphi_c + 11250 \omega & 75,44 \\
 Z_{ac} &= -11,25 + \frac{3EI}{2hL} \alpha (20-40) - 11250 \varphi_c - 1875 \omega = -24,75 - 11250 \varphi_c - 1875 \omega & -27,57 \\
 Z_{ca} &= -18,75 - \frac{3EI}{2hL} \alpha (20-40) + 11250 \varphi_c + 1875 \omega = -5,25 + 11250 \varphi_c + 1875 \omega & -2,43 \\
 M_{cd} &= \frac{10 \cdot 5^2}{12} + \frac{EI}{h} \alpha (20-40) + \frac{2EI}{L} (2\varphi_c + \varphi_d) = -33,16 + 108000 \varphi_c + 54000 \varphi_d & -75,43 \\
 M_{dc} &= -20,83 + 54 + 54000 \varphi_c + 108000 \varphi_d = 33,16 + 54000 \varphi_c + 108000 \varphi_d & -15,82 \\
 Z_{cd} &= -25 - 32400 \varphi_c - 32400 \varphi_d & -6,75 \\
 Z_{dc} &= -25 + 32400 \varphi_c + 32400 \varphi_d & -43,25 \\
 M_{bd} &= \frac{EI}{h} \alpha (40-20) + 90000 \varphi_b + 45000 \varphi_d = 54 + 90000 \varphi_b + 45000 \varphi_d + 22500 \omega + 20,25 & 131,27 \\
 M_{db} &= -54 + 45000 \varphi_b + 90000 \varphi_d + 22500 \omega + 22500 \cdot \alpha \cdot 15 \cdot 5 = -2925 + 90000 \varphi_b + 22500 \omega + 22500 \cdot \alpha \cdot 15 \cdot 5 & +3,30 \\
 Z_{bd} &= -22500 \cdot 0,0001 - 22500 \varphi_d - 7500 \cdot \alpha \cdot 15 \cdot 5 - 7500 \omega = -9 - 22500 \varphi_d - 7500 \omega & -22,43 \\
 Z_{db} &= 22500 \cdot 0,0001 + 22500 \varphi_d + 7500 \omega + 7500 \cdot \alpha \cdot 15 \cdot 5 = 9 + 22500 \varphi_d + 7500 \omega & 22,43 \\
 M_{de} &= 20 + 101250 \varphi_d + 25313 \cdot 15 \cdot \alpha \cdot 6 = 47,338 + 101250 \varphi_d & 12,52 \\
 Z_{de} &= -25 - 25313 \varphi_d - 6328 \cdot 15 \cdot \alpha \cdot 6 = -31,83 - 25313 \varphi_d & -23,13 \\
 Z_{ed} &= -15 + 25313 \varphi_d + 6328 \cdot 15 \cdot \alpha \cdot 6 = -8,17 + 25313 \varphi_d & -16,87
 \end{aligned}$$

$$\begin{aligned}
 \varphi_c &= -2,194 \cdot 10^{-4} \text{ rad} \\
 \varphi_d &= -3,439 \cdot 10^{-4} \text{ rad} \\
 \omega &= 2,822 \cdot 10^{-3} \text{ rad}
 \end{aligned}$$

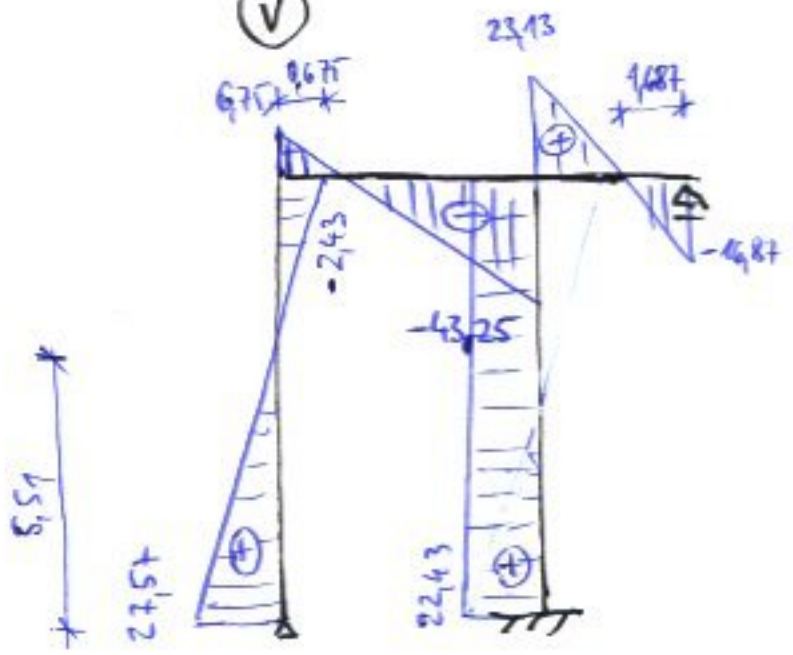
$$\begin{bmatrix} 175000 & 54000 & 11250 \\ 54000 & 209250 & 22500 \\ 11250 & 22500 & 9375 \end{bmatrix} \begin{pmatrix} \varphi_c \\ \varphi_d \\ \omega \end{pmatrix} = \begin{pmatrix} -25,5 \\ -51,255 \\ 16,25 \end{pmatrix}$$



(N)



(V)



(M)

