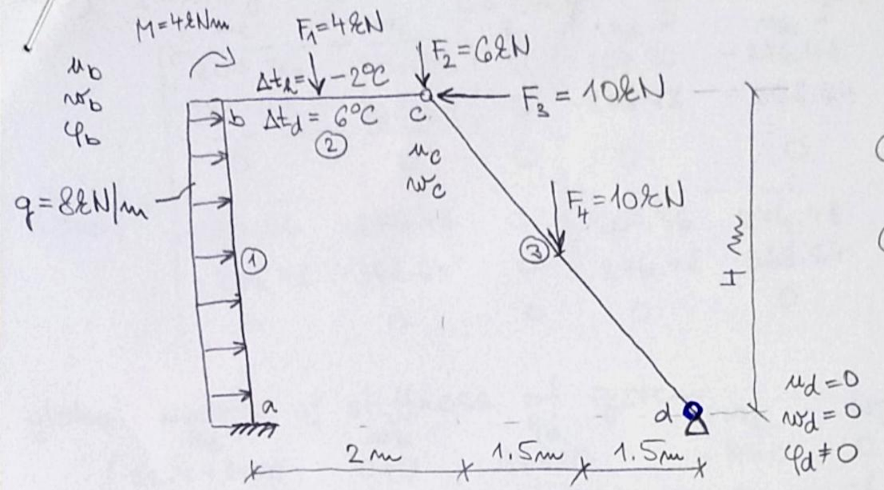
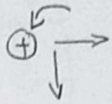




① 0.4×0.6

②③ 0.4×0.3

$E = 24\ GPa$

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

coefficient of thermal expansion

$A_{①} = 0.24\ m^2$

$A_{②③} = 0.12\ m^2$

$I_{①} = 7.2 \cdot 10^{-3}\ m^4$

$I_{②③} = 9 \cdot 10^{-4}\ m^4$

1) $n_p = 5$

2) $\{r\} = \{u_b;\ w_b;\ \varphi_b;\ u_c;\ w_c\}^T$

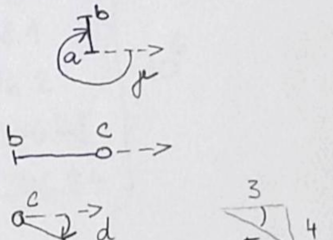
$\{S\} = \{0;\ 0;\ -4000;\ -10\,000;\ 6000\}^T$

3) a) $[k_{ab}]$ = tab. 11.4a $\quad \gamma = 270°$

b) $[k_{bc}]$ = tab. 11.4 b $\quad \gamma = 0°$

or tab 11.3 b

c) $[k_{cd}]$ = tab. 11.4 d $\quad \gamma = 233{,}130°$



$s = \sin\gamma = +\frac{4}{5}$

$c = \cos\gamma = +\frac{3}{5}$

ad a) $s = \sin 270° = -1$

$c = \cos 270° = 0$

$$[k_{ab}] = \begin{array}{c} \\ \\ \end{array}\begin{array}{cccccc} u_a & w_a & \varphi_a & u_b & w_b & \varphi_b \end{array}$$

$$[k_{ab}] = \begin{bmatrix} 32.4 & 0 & -64.8 & -32.4 & 0 & -64.8 \\ 0 & 1440 & 0 & 0 & -1440 & 0 \\ -64.8 & 0 & 172.8 & 64.8 & 0 & 86.4 \\ -32.4 & 0 & 64.8 & 32.4 & 0 & 64.8 \\ 0 & -1440 & 0 & 0 & 1440 & 0 \\ -64.8 & 0 & 86.4 & 64.8 & 0 & 172.8 \end{bmatrix} \cdot 10^6 \quad \begin{array}{c} u_a \\ w_a \\ \varphi_a \\ u_b \\ w_b \\ \varphi_b \end{array}$$

ad b)

$$\begin{array}{cccccc} u_b & w_b & \varphi_b & u_c & w_c & \varphi_c \end{array}$$

$$[k_{bc}] = [k^*_{bc}] = \begin{bmatrix} 1440 & 0 & 0 & -1440 & 0 & 0 \\ 0 & 8.1 & -16.2 & 0 & -8.1 & 0 \\ 0 & -16.2 & 32.4 & 0 & 16.2 & 0 \\ -1440 & 0 & 0 & 1440 & 0 & 0 \\ 0 & -8.1 & 16.2 & 0 & 8.1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \cdot 10^6 \quad \begin{array}{c} u_b \\ w_b \\ \varphi_b \\ u_c \\ w_c \\ \varphi_c \end{array}$$

c) $s = \sin\gamma = \dfrac{4}{5}$ $c = \cos\gamma = \dfrac{3}{5}$ $\dfrac{EA}{l} = 576 \cdot 10^6$

$$[k_{cd}] = \begin{array}{c} \\ \\ \end{array}\begin{array}{cccccc} u_c & w_c & \varphi_c & u_d & w_d & \varphi_d \end{array}$$

$$[k_{cd}] = \left[\begin{array}{cccccc} 207.36 & 276.48 & 0 & -207.36 & -276.48 & 0 \\ 276.48 & 368.64 & 0 & -276.48 & -368.64 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -207.36 & -276.48 & 0 & 207.36 & 276.48 & 0 \\ -276.48 & -368.64 & 0 & 276.48 & 368.64 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right] \cdot 10^6 \quad \begin{array}{c} u_c \\ w_c \\ \varphi_c \\ u_d \\ w_d \\ \varphi_d \end{array}$$

global matrix of stiffness of system

$$\begin{array}{ccccc} u_b & w_b & \varphi_b & u_c & w_c \end{array}$$

$$k = \left[\begin{array}{ccccc} 32.4+1440 & 0+0 & 64.8+0 & -1440 & 0 \\ 0+0 & 1440+8.1 & 0+(-16.2) & 0 & -8.1 \\ 64.8+0 & 0+(-16.2) & 172.8+32.4 & 0 & 16.2 \\ -1440 & 0 & 0 & 1440+207.36 & 0+276.48 \\ 0 & -8.1 & 16.2 & 0+276.48 & 8.1+368.64 \end{array}\right] \cdot 10^6 \quad \begin{array}{c} u_b \\ w_b \\ \varphi_b \\ u_c \\ w_c \end{array}$$

$$k = \left[\begin{array}{ccccc} 1442.4 & 0 & 64.8 & -1440 & 0 \\ 0 & 1448.1 & -16.2 & 0 & -8.1 \\ 64.8 & -16.2 & 205.2 & 0 & 16.2 \\ -1440 & 0 & 0 & 1647.36 & 276.48 \\ 0 & -8.1 & 16.2 & 276.48 & 376.74 \end{array}\right] \cdot 10^6$$

4) $\{\bar{R}^*_{ab}\}$ = tab. 11.2 a (tab. 14.10 row 13)

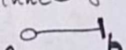
$\{\bar{R}^*_{bc}\}_{F_1}$ = (tab. 11.2 c) use tab. 14.11 row 2

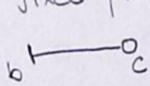
$\{\bar{R}^*_{cd}\}$ = simply supported beam

$\{\bar{R}^*_{bc}\}_t$ = tab. 11.5 b

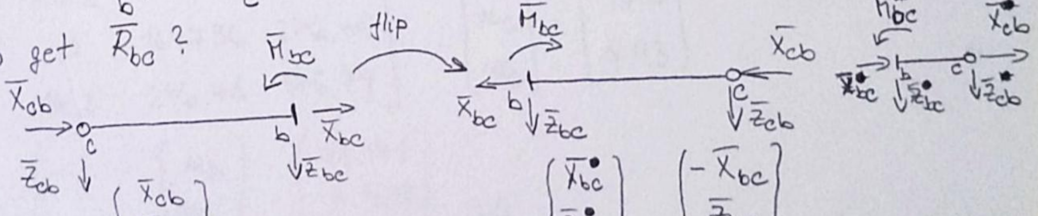
$\{\bar{R}^*_{ab}\} = \{0 ; -16 ; 10.\bar{6} ; 0 ; -16 ; -10.\bar{6}\}^T \cdot 10^3$

$\{\bar{R}^*_{bc}\}_{F_1}$: bar $\underline{bc}$ is fixed-pinned but table is for pinned-fixed bar





how to get $\bar{R}_{bc}$?



$$\{\bar{R}_{cb}\} = \begin{Bmatrix} \bar{X}_{cb} \\ \bar{Z}_{cb} \\ 0 \\ \bar{X}_{bc} \\ \bar{Z}_{bc} \\ \bar{M}_{bc} \end{Bmatrix} \Longrightarrow \{\bar{R}_{bc}\} = \begin{Bmatrix} \bar{X}^{\bullet}_{bc} \\ \bar{Z}^{\bullet}_{bc} \\ \bar{M}^{\bullet}_{bc} \\ \bar{X}^{\bullet}_{cb} \\ \bar{Z}^{\bullet}_{cb} \\ 0 \end{Bmatrix} = \begin{Bmatrix} -\bar{X}_{bc} \\ \bar{Z}_{bc} \\ -\bar{M}_{bc} \\ -\bar{X}_{cb} \\ \bar{Z}_{cb} \\ 0 \end{Bmatrix}$$

$\{\bar{R}^*_{bc}\}_{F_1} = \{0; -2.75; 1.5; 0; -1.25; 0\}^T \cdot 10^3$

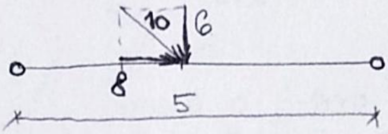
$\{\bar{R}^*_{bc}\}_t$: $\Delta t_1 = 6 - (-2) = 8$

$\Delta t_0 = \frac{1}{2}(6 + (-2)) = 2$

$\{\bar{R}^*_{bc}\}_t = \{57.6; -4.32; 8.64; -57.6; +4.32; 0\}^T \cdot 10^3$

$\{\bar{R}^*_{bc}\} = \{57.6; -7.07; 10.14; -57.6; 3.07; 0\}^T \cdot 10^3$

$\{\bar{R}^*_{cd}\}$:



$\{\bar{R}^*_{cd}\} = \{-4; -3; 0; -4; -3; 0\}^T \cdot 10^3$

- primary vectors in global coordinates

$\oplus$

$\{\bar{R}_{ab}\} = \{-16; 0; 10.\bar{6}; -16; 0; -10.\bar{6}\}^T \cdot 10^3$

$\{\bar{R}_{bc}\} = \{\bar{R}^*_{bc}\} = \{57.6; -7.07; 10.14; -57.6; 3.07; 0\}^T \cdot 10^3$

$\{\bar{R}_{cd}\} = \{0; -5; 0; 0; -5; 0\}^T \cdot 10^3$

- global primary vector of system

$\{\bar{R}\} = \{-16 + 57.6; 0 + (-7.07); -10.\bar{6} + 10.14; -57.6 + 0; 3.07 + (-5)\}^T \cdot 10^3$

$\{\bar{R}\} = \{41.6; -7.07; -0.52\bar{6}; -57.6; -1.93\}^T \cdot 10^3$

5) $\{F\} = \{S\} - \{\bar{R}\}$

$\{F\} = \{-41.6; 7.07; -3.44\bar{3}; 47.6; 7.93\}^T \cdot 10^3$

6) $[k] \cdot \{r\} = \{F\}$

$$\begin{bmatrix} 1472.4 & 0 & 64.8 & -1440 & 0 \\ 0 & 1448.1 & -16.2 & 0 & -8.1 \\ 64.8 & -16.2 & 205.2 & 0 & 16.2 \\ -1440 & 0 & 0 & 1647.36 & 276.48 \\ 0 & -8.1 & 16.2 & 276.48 & 376.74 \end{bmatrix} \cdot 10^6 \cdot \begin{Bmatrix} u_b \\ w_b \\ \varphi_b \\ u_c \\ w_c \end{Bmatrix} = \begin{Bmatrix} -41.6 \\ 7.07 \\ -3.44\bar{3} \\ 47.6 \\ 7.93 \end{Bmatrix} \cdot 10^3$$

$$\{r\} = \begin{Bmatrix} u_b \\ w_b \\ \varphi_b \\ u_c \\ w_c \end{Bmatrix} = \begin{Bmatrix} 39.171 \\ 4.429 \\ -26.783 \\ 67.736 \\ -27.414 \end{Bmatrix} \cdot 10^{-6}$$

+) $\{R\} = \{\bar{R}\} + \{\hat{R}\}$

$\{\hat{R}\} = [k]\cdot\{r\}$

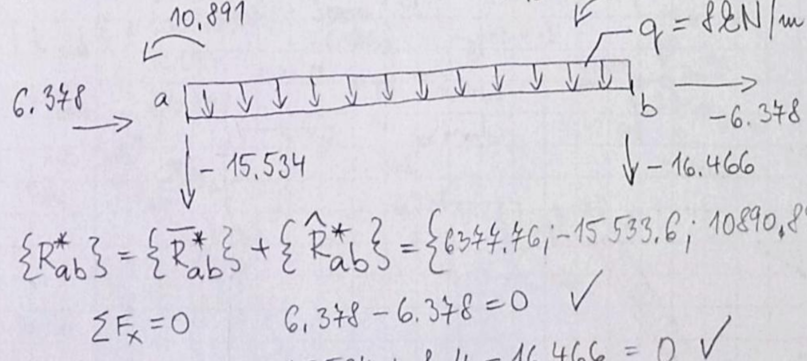
$$\{\hat{R}_{ab}\} = [k_{ab}]\{r_{ab}\} = \begin{bmatrix} & -32.4 & 0 & -64.8 \\ & 0 & -1440 & 0 \\ & 64.8 & 0 & 86.4 \\ & 32.4 & 0 & 64.8 \\ & 0 & 1440 & 0 \\ & 64.8 & 0 & 172.8 \end{bmatrix} \cdot \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 39.171 \\ 4.429 \\ -26.783 \end{Bmatrix} \cancel{10^{6}} \cdot 10^{-6} = \begin{Bmatrix} 466.398 \\ -6377.76 \\ 224,230 \\ -466.398 \\ 6377.76 \\ -2089.822 \end{Bmatrix}$$

$$\{\hat{R}_{bc}\} = [k_{bc}]\{r_{bc}\} = \begin{bmatrix} 1440 & 0 & 0 & -1440 & 0 & 0 \\ 0 & 8.1 & -16.2 & 0 & -8.1 & 0 \\ 0 & -16.2 & 32.4 & 0 & 16.2 & 0 \\ -1440 & 0 & 0 & 1440 & 0 & 0 \\ 0 & -8.1 & 16.2 & 0 & 8.1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} 39,171 \\ 4,429 \\ -26.783 \\ 67.736 \\ -27.414 \\ 0 \end{Bmatrix} = \begin{Bmatrix} -41133.6 \\ 691.813 \\ -1383.626 \\ 41133.6 \\ -691.813 \\ 0 \end{Bmatrix} = \{\hat{R}^*_{bc}\}$$

$$\{\hat{R}_{cd}\} = [k_{cd}]\{r_{cd}\} = \begin{bmatrix} 207.36 & 276.48 & \\ 276.48 & 368.64 & \\ 0 & 0 & \\ -207.36 & -276.48 & \\ -276.48 & -368.64 & \\ 0 & 0 & \end{bmatrix} \begin{Bmatrix} 67.736 \\ -27.414 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix} = \begin{Bmatrix} 6466.314 \\ 8621.752 \\ 0 \\ -6466.314 \\ -8621.752 \\ 0 \end{Bmatrix}$$

$$\{\hat{R}^*_{ab}\} = \{6377.76;\ \overset{-15533.6}{\cancel{466.398}};\ 224,230;\ -6377.76;\ -466.398;\ -2089.822\}^T$$

$$\{\hat{R}^*_{cd}\} = \{10777.19;\ 0;\ 0;\ -10777.19;\ 0;\ 0\}^T$$

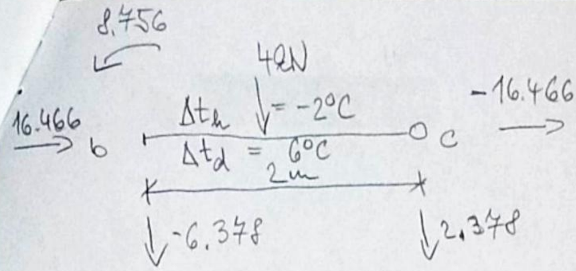


$$\{R^*_{ab}\} = \{\bar{R}^*_{ab}\} + \{\hat{R}^*_{ab}\} = \{6377.76;\ -15533.6;\ 10890.896;\ -6377.76;\ -16466.4;\ -12756.489\}^T$$

$\sum F_x = 0 \qquad 6.378 - 6.378 = 0$ ✓

$\sum F_z = 0 \qquad -15.534 + 8\cdot 4 - 16.466 = 0$ ✓

$\sum M_a = 0 \qquad 10.891 - 12.756 + 16.466\cdot 4 - 8\cdot 4\cdot \frac{4}{2} = 0$ ✓

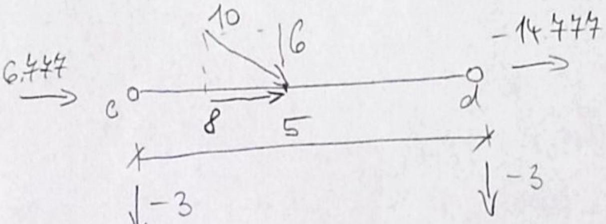


$$\{R^*_{bc}\} = \{\bar{R}^*_{bc}\} + \{\hat{R}^*_{bc}\} = \{16466.4;\ -6378.187;\ 8756.374;\ -16466.4;\ 2378.187;\ 0\}^T$$

$\Sigma F_x = 0 \qquad 16.466 - 16.466 = 0$ ✓

$\Sigma F_z = 0 \qquad -6.378 + 4 + 2.378 = 0$ ✓

$\Sigma M_a = 0 \qquad 8.756 - 2.378 \cdot 2 - 4 \cdot 1 = 0$ ✓



$$\{R^*_{cd}\} = \{\bar{R}^*_{cd}\} + \{\hat{R}^*_{cd}\} = \{6777.19;\ -3000;\ 0;\ -14777.19;\ -3000;\ 0\}^T$$

$\Sigma F_x = 0 \qquad 6.777 + 8 - 14.777 = 0$ ✓

$\Sigma F_z = 0 \qquad -3 + 6 - 3 = 0$ ✓

$\Sigma M_a = 0 \qquad 6 \cdot 2.5 - 3 \cdot 5 = 0$ ✓

$$\{R_{ab}\} = \{6377.76;\ +15533.6;\ 10890.89\bar{6};\ +6377.76;\ -16466.398;\ -12765.488\bar{6}\}^T$$

$$\{R_{bc}\} = \{16466.4;\ -6378.187;\ 8756.374;\ -16466.4;\ -2378.187;\ 0\}^T$$

$$\{R_{cd}\} = \{\cancel{6777.19}\ 6466.314;\ \cancel{-3000}\ -3621.8;\ 0;\ \cancel{-14777.19}\ -6466.314;\ \cancel{-3000}\ -13621.8;\ 0\}^T$$