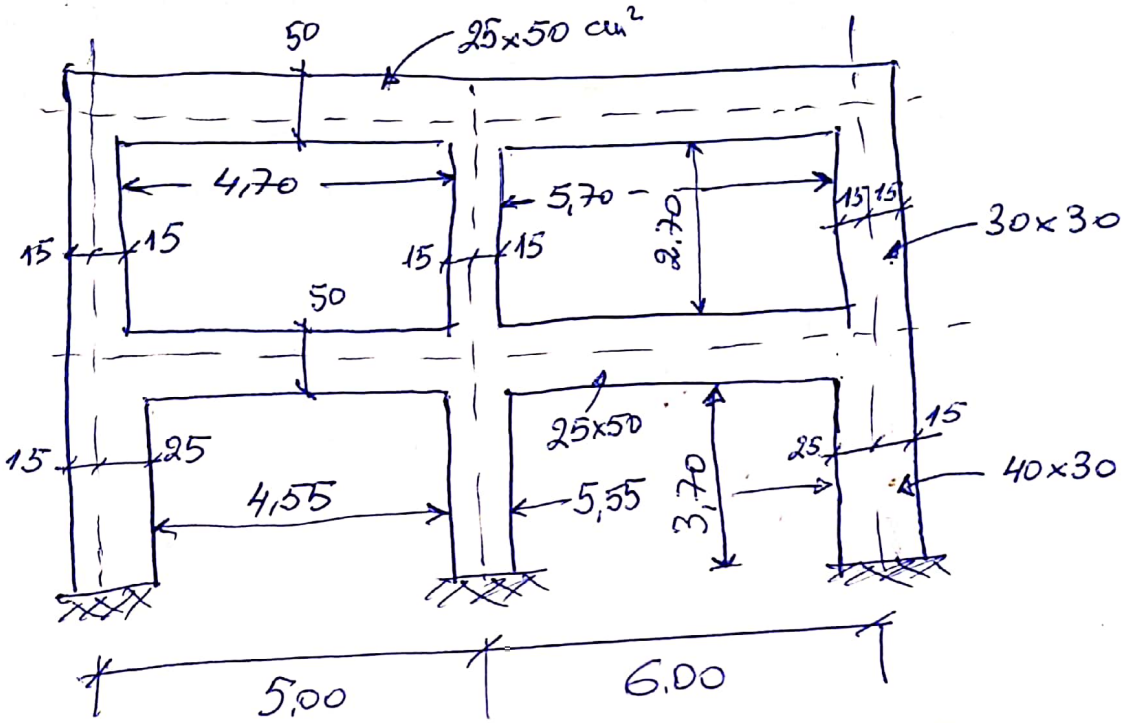
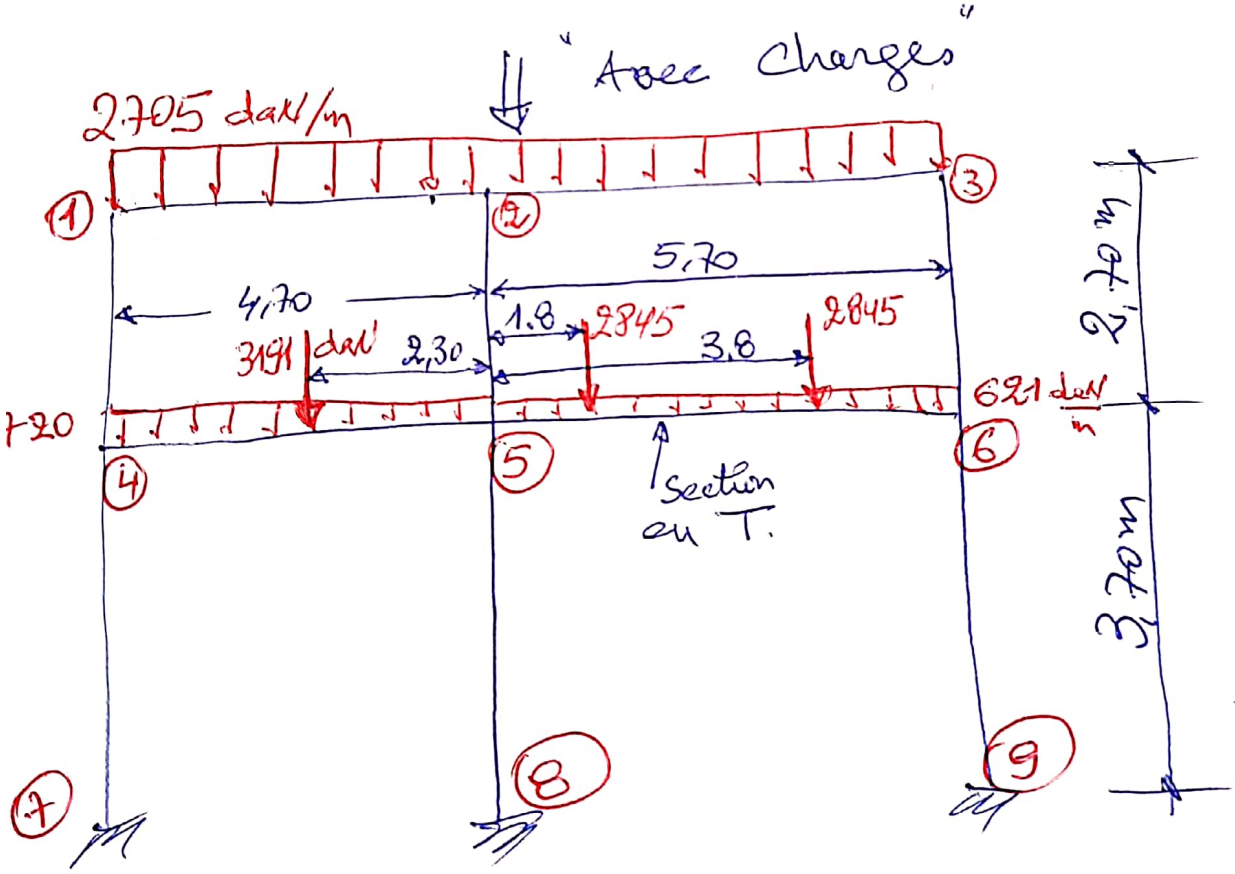
Méthode de "CAQUOT"

(Extension aux portiques)

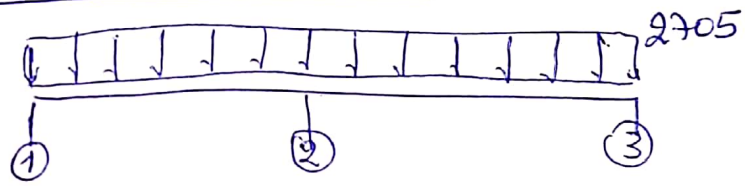




* Calcul des Inerties

barre	bo(m)	b(m)	h(m)	I m^4 ($\times 10^{-3}$)	
1-2	0,25	—	0,5	2,6042	
2-3	0,25	—	0,5	2,6042	
1-4	0,30	—	0,3	0,675	2-5, 3-6
4-7	0,30	—	0,4	1,6	5-8, 6-9
4-5	0,25	1,25	0,5	4,9085	
5-6	0,25	1,45	0,5	5,1536	

* Poutre 1-2-3 :

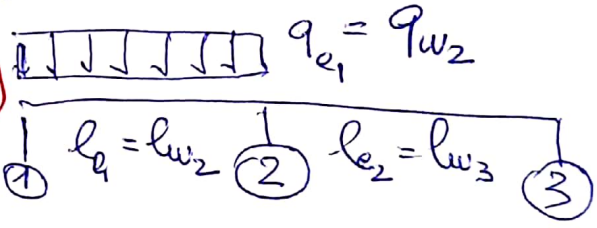


$l_{e_1} = l_{w_2} = 4{,}70m$

$l_{e_2} = l_{w_3} = 5{,}70m$

$h_{s_1} = h_{s_2} = h_{s_3} = 2{,}70m$.

Combinaison de charges (ex. surcharges)



- Travée 1-2 chargée :

Noeud ① :

$K_{n_1} = K_{w_1} = 0 \Rightarrow D_1 = K_{e_1} + K_{s_1}$

$l'_{e_1} = 0{,}8\, l_{e_1} \rightarrow M'_{e_1} = \dfrac{q_{e_1} \cdot l'^2_{e_1}}{8.5}$

$M_{e_1} = M'_{e_1}\left(1 - \dfrac{K_{e_1}}{D_1}\right)$

$M_{s_1} = M'_{e_1} \dfrac{K_{s_1}}{D_1}$

Nœud ② :

$l'_{w_2} = \chi_1 \, l_{w_2}$

$l_{e_2} = \chi_3 \, l_{e_2}$

$K_{s_1} + K_{n_1} \overset{?}{\leq} 1{,}5 K_{e_1} \Rightarrow \begin{cases} \chi_1 = 0{,}8 \\ \gamma_1 = 1 - \dfrac{K_{s_1} + K_{n_1}}{7{,}5 K_{e_1}} \end{cases}$

$K_{s_3} + K_{n_3} \overset{?}{\leq} 1{,}5 K_{w_3} \rightarrow \begin{cases} \chi_3 = 0{,}8 \\ \gamma_3 = 1 - \dfrac{K_{s_3} + K_{n_3}}{7{,}5 K_{w_3}} \end{cases}$

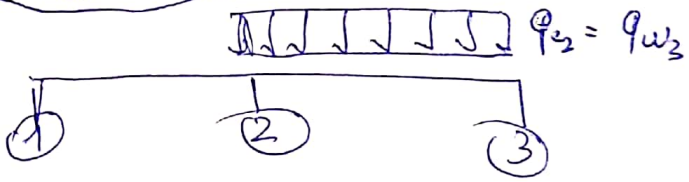
$D_2 = K_{s_2} + K_{e_2} + K_{w_2}$

$\rightarrow M'_{w_2} = \dfrac{q_{w_2} \cdot l'^2_{w_2}}{8{,}5}$; $q_{e_2} = 0 \rightarrow M'_{e_2} = 0$

$\Rightarrow$ $M_{e_2} = M'_{w_2} \cdot \dfrac{K_{e_2}}{D_2}$; $M_{w_2} = M'_{w_2}\left(1 - \dfrac{K_{w_2}}{D_2}\right)$

et $M_{s_2} = M'_{w_2} \cdot \dfrac{K_{s_2}}{D_2}$

— Travée 2-3 chargée :



Nœud ② :

$q_{w_2} = 0 \rightarrow M'_{w_2} = 0$, l'_{e_2} (déjà calculée)

$\rightarrow M'_{e_2} = \dfrac{q_{e_2} \cdot l'^2_{e_2}}{8{,}5}$ $\rightarrow$

$M_{e_2} = M'_{e_2}\left(1 - \dfrac{K_{e_2}}{D_2}\right)$

$M_{s_2} = M'_{e_2} \dfrac{K_{s_2}}{D_2}$

$M_{w_2} = M'_{e_2} \dfrac{K_{w_2}}{D_2}$

→ **Noeud (1) : (de Rive)**

$K_{n_1} = K_{w_1} = 0$; $l'_{e_1} = 0,8\, l_{e_1} = 0,8 \times 4,7 = 3,76\,m$

$K_{n_2} = K_{n_3} = 0$; $h'_{s_1} = h'_{s_2} = h'_{s_3} = 0,8 \times 2,7 = 2,16\,m$

$$K_{e_1} = \frac{I_{e_1}}{l'_{e_1}} = \frac{2,6042 \cdot 10^{-3}}{3,76} = 0,6926 \cdot 10^{-3}\ m^3$$

$$K_{s_1} = \frac{I_{s_1}}{h'_{s_1}} = \frac{0,675 \cdot 10^{-3}}{2,16} = 0,3125 \cdot 10^{-3}\ m^3$$

$$\Rightarrow D_1 = K_{e_1} + K_{s_1} = 1,0051 \times 10^{-3}\ m^3$$

$$M'_{e_1} = \frac{q_{e_1} \cdot l'^{2}_{e_1}}{8.5} = \frac{2705 \cdot 3,76^2}{8.5} = 4499\ daN.m$$

$$\begin{cases} M_{e_1} = M'_{e_1}\left(1 - \dfrac{K_{e_1}}{D_1}\right) = 4499\left(1 - \dfrac{0,6926 \cdot 10^{-3}}{1,0057 \cdot 10^{-3}}\right) = 1399\ \dfrac{daN}{m} \\ M_{s_1} = M'_{e_1}\left(\dfrac{K_{s_1}}{D_1}\right) = 4499\left(\dfrac{0,3125 \cdot 10^{-3}}{1,0057 \cdot 10^{-3}}\right) = 1399\ \dfrac{daN}{m} \end{cases}$$

→ **Noeud (2) : (Voisin du noeud de rive)**

$l_{w_2} = 4,7\,m$; $l_{e_2} = 5,70\,m$

$l'_{w_2} = \gamma_1 l_{w_2}$; $l'_{e_2} = \gamma_3 l_{e_2}$ (2-3 : travée de Rive)

$K_{s_1} = 0,3125 \times 10^{-3} < 1,5 \times 0,6925 \cdot 10^{-3}$ (K_{e_1})

$$\Rightarrow \gamma_1 = \frac{1 - 0,3125 \cdot 10^{-3}}{7,5 \cdot 0,6925 \cdot 10^{-3}} = 0,9398 \rightarrow l'_{w_2} = 9398 \cdot 4,7$$

$$\Rightarrow l'_{w_2} = 4,42\,m$$

$K_{s3} = K_{s1}$; $l'_{w3} = 0,8\, l_{w3} = 0,8 \cdot 5,7 = \underline{4,56\,m}$

$$K_{w3} = \frac{I_{w3}}{l'_{w3}} = \frac{2,6042 \cdot 10^{-3}}{4,56} = 0,5711 \cdot 10^{-3}\ m^3$$

$$K_{s3} + K_{n3} = 0,3125 \cdot 10^{-3} < 1,5\, K_{w3} \left(= 1,5 \times 0,5711 \cdot 10^{-3}\right)$$

$$\Rightarrow \chi_3 = 1 - \frac{K_{s3} + K_{n3}}{7,5 \cdot K_{w3}} = 0,927 \rightarrow l'_{e2} = 0,927 \times 5,7$$

$$l'_{e2} = 5,28\,m$$

$$M'_{w2} = \frac{q_{w2} \cdot l'^{2}_{w2}}{8.5} = \frac{2,705 \cdot 4.42^2}{8.5} = 6217\ daN.m$$

$$M'_{e2} = \frac{q_{e2} \cdot l'^{2}_{e2}}{8.5} = \frac{2705 \cdot 5,28^2}{8.5} = 8872\ daN.m$$

$$K_{w2} = \frac{I_{w2}}{l'_{w2}} = \frac{2,6042 \cdot 10^{-3}}{4,42} = 0,5892 \cdot 10^{-3}\ m^3$$

$$K_{e2} = \frac{I_{e2}}{l_{e2}} = \frac{2,6042 \cdot 10^{-3}}{5,28} = 0,4932 \cdot 10^{-3}\ m^3$$

$$\Rightarrow D_2 = 1,3949 \cdot 10^{-3}\ m^3 \quad \left(K_{s2} = 0,3125 \cdot 10^{-3}\ m^3\right)$$

$$\Rightarrow M_{w2} = M'_{e2} \cdot \frac{K_{w2}}{D_2} + M'_{w2}\left(1 - \frac{K_{w2}}{D_2}\right)$$

$$= 8872 \cdot \frac{0,5892 \cdot 10^{-3}}{1,3949\ 10^{-3}} + 6217\left(1 - \frac{0,5892 \cdot 10^{-3}}{1,3949 \cdot 10^{-3}}\right)$$

$$M_{w2} = 7338\ daN.m$$

$$M_{e2} = M'_{e2}\left(1 - \frac{K_{e2}}{D_2}\right) + M'_{w_2}\frac{K_{e2}}{D_2}$$

$$= 8872\left(1 - \frac{0,4932.10^{-3}}{1,3949.10^{-3}}\right) + 6217.\frac{0,4932.10^{-3}}{1,3949.10^{-3}} = 7933 \frac{daN}{m}.$$

$$M_{e2} = 7933 \text{ daN/m}$$

$$M_{S_2} = \frac{K_{S_2}}{D_2}\left(M'_{e_2} - M'_{w_2}\right)$$

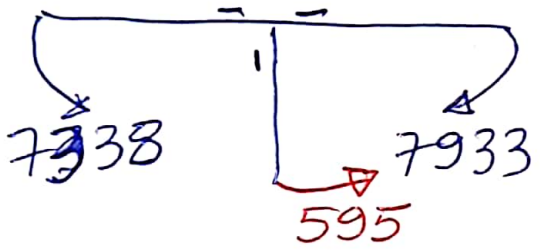
$$= \frac{0,3125.10^{-3}}{1,3949.10^{-3}}(8872 - 6217) = 595 \text{ daN.m}$$

$$M_{S_2} = 595 \text{ daN.m}$$

Equilibre du noeud (2) :

$$7338 + 595 = 7933$$

Ok



Noeud (3) _ (Noeud de rive)

$$K_{S3} = K_{S_2} = K_{S_1} = 0,3125.10^{-3}\ m^3$$

$$l'_{w_3} = 4,56 = 0,8 \times 5,7\ m \ ; \ K_{w_3} = 0,5711.10^{-3}\ m^3$$

$$D_3 = 0,3125.10^{-3} + 0,5711.10^{-3}$$

$$D_3 = 0,8836.10^{-3}\ m^3$$

$$M'_{w_3} = \frac{q_{w_3} \cdot l_{w_3}^2}{8.5} = \frac{2705 \cdot 4,56^2}{8.5} = 6617 \text{ daN.m}$$

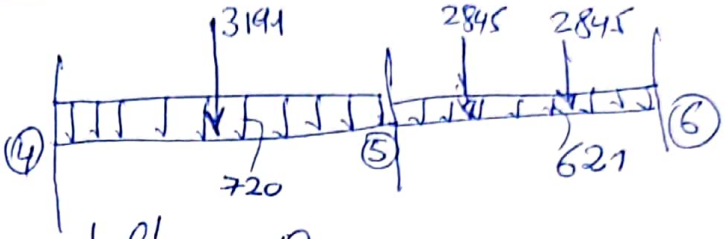
$$M_{w_3} = M'_{w_3}\left(1 - \frac{k_{w_3}}{D_3}\right) = 6617 \cdot \left(1 - \frac{0,5711.10^{-3}}{0,8836.10^{-3}}\right) = \underline{2340 \text{ daN.m}}$$

$$M_{s_3} = M'_{w_3} \cdot \frac{k_{s_3}}{D_3} = 6617 \cdot \frac{0,3125.10^{-3}}{0,8836.10^{-3}} = 2340 \text{ daN.m}$$

Ok

---

* Poutre 4-5-6.



→ Nœud ④ :

$h'_{n4} = 0,9\, h_{n4} = 0,9 \times 2,7 = 2,43 \text{ m}$ | $l'_{w4} = 0$

$h'_{s4} = 0,8\, h_{s4} = 0,8 \times 3,7 = 2,96 \text{ m}$ | $l'_{e4} = 0,8\, l_{e4} = 0,8 \times 4,5 = 3,64 \text{ m}$

$$k_{n4} = \frac{I_{n4}}{h'_{n4}} = \frac{0,675.10^{-3}}{2,43} = 0,2778.10^{-3} \text{ m}^3$$

$$k_{e4} = \frac{I_{e4}}{l'_{e4}} = \frac{4,9085.10^{-3}}{3,64} = 1,3485.10^{-3} \text{ m}^3$$

$$k_{s4} = \frac{I_{s4}}{h'_{s4}} = \frac{1,6.10^{-3}}{2,96} = 0,5405.10^{-3} \text{ m}^3$$

$$D_4 = 2,1668.10^{-3} \text{ m}^3$$

$$M'_{e4} = \frac{q_{e4} \cdot l'_{e4}}{8.5} + l'_{e4} \cdot k_{e4} \cdot Q_{e4}$$

$$\frac{a_e}{l'_{e4}} = \frac{2,25}{3,64} = 0,618 \Rightarrow k_{e4} = \frac{1}{2,125} \cdot \frac{2,25}{3,64}\left(1 - \frac{2,25}{3,64}\right)\left(2 - \frac{2,25}{l'}\right)$$

$$\underline{k_{e4} = 0,153}$$

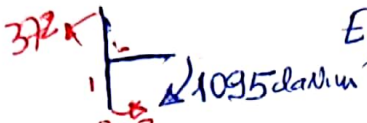
$$M'_{e4} = \frac{720 \cdot 3{,}64^2}{8.5} + 3{,}64 \cdot 0{,}153 \cdot 3191 = 2900 \text{ daN.m}$$

$$M_{e4} = M'_{e4}\left(1 - \frac{K_{e4}}{D_4}\right) = 2900\left(1 - \frac{1{,}3485 \cdot 10^{-3}}{2{,}1668 \cdot 10^{-3}}\right) \rightarrow M_{e4} = 1095 \text{ daN.m}$$

$$M_{n4} = M'_{e4} \cdot \frac{K_{n4}}{D_4} = 2900 \cdot \frac{0{,}2778 \cdot 10^{-3}}{2{,}1668 \cdot 10^{-3}} \rightarrow M_{n4} = 372 \text{ daN.m}$$

$$M_{54} = M'_{e4} \cdot \frac{K_{54}}{D_4} = 2900 \cdot \frac{0{,}5405 \cdot 10^{-3}}{2{,}1668 \cdot 10^{-3}} \rightarrow M_{54} = 723 \text{ daN.m}$$

Equilibre des noeuds (4) Ok



— Noeud (5) :

$h'_{55} = 0{,}8\, h_5 = 0{,}8 \cdot 3{,}7 = 2{,}96 \text{ m}$; $h'_{n5} = 0{,}9\, h_{n5} = 0{,}9 \times 2{,}7 = 2{,}42 \text{ m}$

$K_{55} = 0{,}5405 \cdot 10^{-3} \text{ m}^3$ $\quad K_{n5} = 0{,}2789 \cdot 10^{-3} \text{ m}^3$

$K_{n4} + K_{54} = 0{,}2778 \cdot 10^{-3} + 0{,}5405 \cdot 10^{-3} < 1{,}5\, K_{e4}$

$$\rightarrow \chi_4 = 1 - \frac{K_{n4} + K_{54}}{7{,}5\, K_{e4}} = 0{,}9191 \rightarrow l'_{w5} = \chi_4\, l_{w5} = 4{,}18 \text{ m}$$

$l'_{w6} = 0{,}8\, l_{w6} = 0{,}8 \times 5{,}55 = 4{,}44 \text{ m}$

$l'_{e5} = \chi_6 \cdot l_{e5}$

$K_{w6} = \frac{5{,}1536 \cdot 10^{-3}}{4{,}44} = 1{,}1607 \cdot 10^{-3} \text{ m}^3$

$K_{n6} + K_{56} = 0{,}8183 \cdot 10^{-3} < 1{,}5\, K_{w6} \rightarrow \chi_6 = 1 - \frac{0{,}8183 \cdot 10^{-3}}{7{,}7 \cdot 1{,}1607 \cdot 10^{-3}}$

$\chi_6 = 0{,}906$

$\Rightarrow l'_{e5} = 0{,}906 \times 5{,}55 = 5{,}03 \text{ m}$

$$k_{e5} = \frac{5,1536 \cdot 10^{-3}}{5,03} = 1,0246 \cdot 10^{-3}\ m^3$$

$$k_{w5} = \frac{4,9085 \cdot 10^{-3}}{4,18} = 1,1743 \cdot 10^{-3}\ m^3$$

$$\Rightarrow \underline{\gamma_5 \simeq 3,0172 \cdot 10^{-3}\ m^3}$$

$$\frac{2,3}{4,18} = 0,55 \rightarrow k_{w5} = 0,169$$

$$\frac{1,8}{5,03} = 0,358 \rightarrow k_{e5_1} = 0,18$$

$$\frac{3,8}{5,03} = 0,755 \rightarrow k_{e5_2} = 0,07$$

$$\Rightarrow \underline{M'_{w5}} = \frac{720 \cdot 4,18^2}{8.5} + 4,18\,(0,169)\,3191 = \underline{3734\ daN.m}$$

$$\underline{M'_{e5}} = \frac{621 \cdot 4,44^2}{8.5} + 4,44\,(0,18+0,067)\,2845 = \underline{4560\ daN.m}$$

$$M_{s5} = \frac{k_{s5}}{D_5}\left(M'_{e5} - M'_{w5}\right) = \frac{0,5405 \cdot 10^{-3}}{3,0172 \cdot 10^{-3}}\left(3734 - 4560\right) =$$

$$\underline{M_{s5} = -148\ daN.m}$$

$$M_{n5} = \frac{k_{n5}}{D_5}\left(M'_{e5} - M'_{w5}\right) = \frac{0,2789 \cdot 10^{-3}}{3,0172 \cdot 10^{-3}}\left(3734 - 4560\right) =$$

$$\underline{M_{n5} = 76,05\ daN.m}$$

$$M_{w5} = M_{e5}\frac{k_{w5}}{D_5} + M'_{w5}\left(1 - \frac{k_{w5}}{D_5}\right)$$

$$= \frac{3734}{4560} \cdot \frac{1,1743 \cdot 10^{-3}}{3,0172 \cdot 10^{-3}} + \frac{3734}{4560}\left(1 - \frac{1,1743 \cdot 10^{-3}}{3,0172 \cdot 10^{-3}}\right)$$

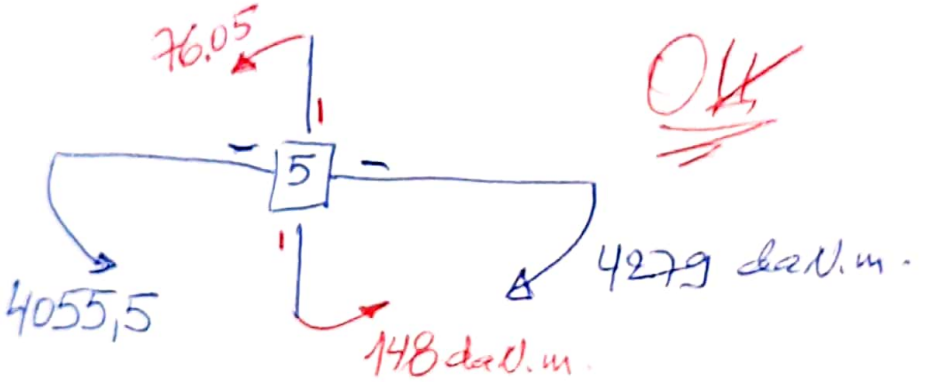
$$\underline{M_{w5} = 4055,5\ daN.m}$$

$$M_{e5} = M'_{e5}\left(1 - \frac{K_{e5}}{D_5}\right) + M'_{w5}\frac{K_{o5}}{D_5}$$

$$= 4560\left(1 - \frac{1,0246.10^{-3}}{3,0172.10^{-3}}\right) + 3734.\frac{1,0246.10^{-3}}{3,0172.10^{-3}} =$$

$$M_{e5} = 4279 \text{ daN.m}$$

Equilibre du noeud :



OK

- Noeud 6

$K_{w6} = 1,1607.10^{-3} m^3$;
$K_{n6} = 0,2778.10^{-3}$
$K_{s6} = 0,5405.10^{-3}$
} $D_6 = 1,979.10^{-3} m^3$

$l'_{w6} = 0,8.5,55 = 4,44 m$

$\frac{3,75}{4,44} = 0,844 \rightarrow k = 0,065$

$\frac{1,75}{4,44} = 0,394 \rightarrow k = 0,18$

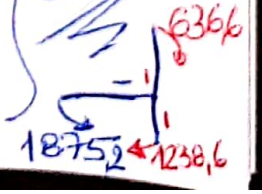
$$M'_{w6} = \frac{621.4,44^2}{8,5} + 4,44.2845(0,18+0,065) = 4535 \text{ daN.m}$$

$$M_{w6} = M'_{w6}\left(1 - \frac{K_{w6}}{D_6}\right) = 1875,2 \text{ daN.m}$$

$$M_{s6} = M'_{w6}\frac{K_{s6}}{D_6} = 1238,6 \text{ daN.m}$$

$$M_{n6} = M'_{w6}\frac{K_{n6}}{D_6} = 636,6 \text{ daN.m}$$

équilibre OK



- On calculera les moments en travée en prenant les valeurs de l et non plus l'.
- Les efforts tranchants d'appui sont calculés par la méthode générale applicable aux poutres continues en faisant état des moments de continuité déterminés ci-dessus.