CORRIGE

- **Ces éléments de correction n'ont qu'une valeur indicative. Ils ne peuvent en aucun cas engager la responsabilité des autorités académiques, chaque jury est souverain.**

EPREUVE E4 : ETUDE DES CONSTRUCTIONS

Année 2006

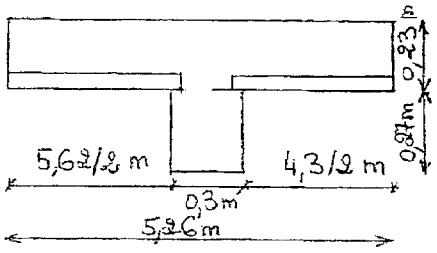
Sous-épreuve : U 41 BTS BATIMENT

Elaboration d'une note de calcul de structures

CORRECTION

ETUDE A :

A_1_ On lit : $L_{14} = 6,96\ m$



La poutre 14 reprend :

C.P. : kN/m

pp retombée poutre : $25 \times 0,27 \times 0,3 = 2,025$

pp dalle : $25 \times 0,23 \times 5,26 = 30,245$

p terre étanchéité : $5,85 \times 5,26 = 30,771$

$g_{14} = 63,041\ kN/m$

C.E. : $1,5 \times 5,26 = 7,890\ kN/m = q_{14}$

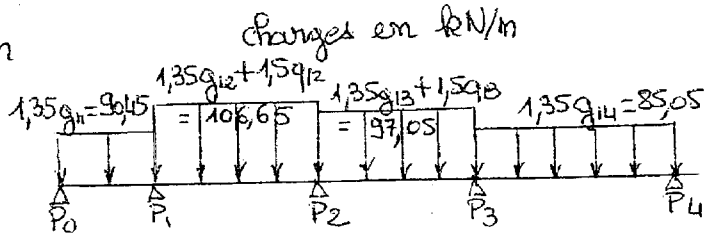
A_2_ B.6.2.1.0 du BAEL

- $q_{11} \leq 2g_{11}$, $q_{12} \leq 2g_{12}$, $q_{13} \leq 2g_{13}$, $q_{14} \leq 2g_{14}$, et $q = 1,5\ kN/m^2 < 5\ kN/m^2$ ok
- $b_0 = 0,3m$ et $h = 0,5m$ partout constants OK
- fissuration peu préjudiciable OK
- mais $\frac{L_{11}}{L_{12}} = \frac{3,185}{5,565} = 0,572 < 0,8$ ~~OK~~

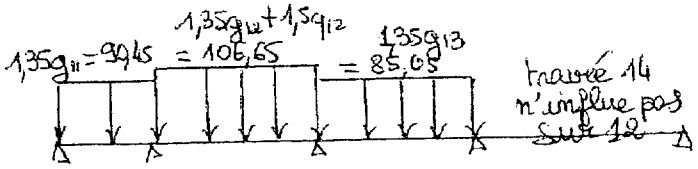
Une des conditions n'est pas vérifiée. Il faut utiliser la méthode Caquot minorée. On utilisera 1 comme coefficient des moments dus aux charges permanentes.

A_3_ moment maximal en

a) P_2



b) travée 12



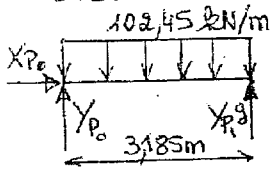
A-4- $p_{11} = 1,35 g_{11} + 1,5 q_{11} = 102,45$ kN/m $p_{12} = 1,35 g_{12} = 93,15$ kN/m

$L'_{11} = L_{11} = 3,185$ m $L'_{12} = 0,8 L_{12} = 0,8 \times 5,565 = 4,452$ m

supprimé.

$$|M_{P_1}| = \frac{102,45 \times 3,185^3 + 93,15 \times 4,452^3}{8,5 \times (3,185 + 4,452)} = 177,613 \text{ kN.m}$$

Isolons la travée 11 :



$$\begin{cases} X_{P_0} = 0 \\ Y_{P_0} + Y_{P_1}^g - 102,45 \times 3,185 = 0 \\ Y_{P_1}^g \times 3,185 - 177,613 - 102,45 \times \frac{3,185^2}{2} = 0 \end{cases}$$

d'où, $Y_{P_1}^g = 218,92$ kN et $Y_{P_0} = 107,39$ kN

$x_{c_{max}} = \frac{107,39}{102,45} = 1,048$ m $\Rightarrow$ $M_{\max \text{ travée 11}} = \frac{107,39 \times 1,048}{2} = 56,28$ kN.m

A-6-1- F.P.P. $\Rightarrow$ calcul avec E.L.U.
sur appui $\Rightarrow$ calcul en section rectangulaire. $b_0 = 0,3$m

$f_{bu} = \frac{0,85 f_{cj}}{\theta \gamma_b} = 14,17$ MPa $f_{su} = \frac{f_e}{\gamma_s} = 434,8$ MPa

$\mu_u = \frac{0,196}{0,3 \times 0,45^2 \times 14,17} = 0,228 > 0,186$ pivot B
$< \mu_{lu} = 0,260$ pas d'aciers comprimés

$\alpha_u = 0,328$ $z_u = 0,391$ m

$A_{calc} = \frac{0,196}{434,8 \times 0,391} = 11,53$ cm^2 $A_{min} = 1,3$ cm^2

Choix : 3HA16 + 3HA16 ($A_{réelle} = 12,06$ cm^2)

$d_{réelle} = 50 - 2 - 0,8 - 1,6 = 45,6$ cm > 45 cm OK

A-3-2 $\bar{\tau}_u = \min\left(\frac{0,2 f_{cj}}{\gamma_b} ; 5\,MPa\right) = 3,33\,MPa$

$\tau_u = \frac{|V_u|}{b_0 d} = \frac{0,225}{0,3 \times 0,45} = 1,67\,MPa \leq \bar{\tau}_u$ On peut mettre des armatures d'âmes droites.

Pour entourer 2 lits de 3HA16, choisissons 1 cadre + 1 étrier.

si $\phi_t = 6\,mm$, $A_t = 4 \times \frac{\pi \times 0,006^2}{4} = 1,131\,cm^2$

$s_{tmax} = \min\left(0,9 \times 0,45 ; 40\,cm ; \frac{1,131.10^{-4} \times 500}{0,4 \times 0,3}\right) = 40\,cm$

$k = 0$ car reprise de bétonnage sans traitement

$s_{t0} \leq \frac{0,9 \times 1,131.10^{-4} \times 434,8}{0,3 \times 1,67} = 0,088\,m \Rightarrow s_{t0} = 8\,cm$

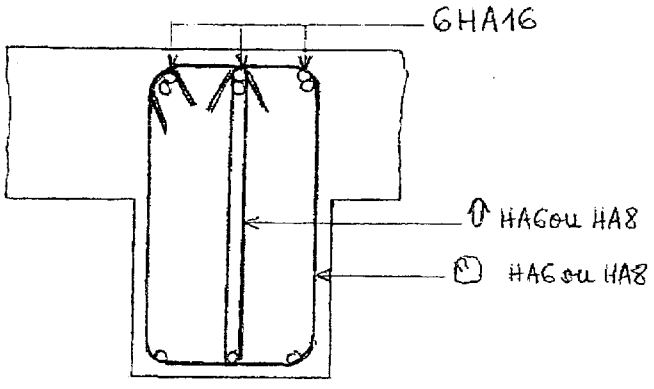
1er lit à 4 cm du nu d'appui.

si $\phi_t = 8\,mm$, $A_t = 4 \times \frac{\pi \times 0,008^2}{4} = 2,011\,cm^2$

$s_{tmax} = \min\left(0,9 \times 0,45 ; 40\,cm ; \frac{2,011.10^{-4} \times 500}{0,4 \times 0,3}\right) = 40\,cm$

$s_{t0} \leq \frac{0,9 \times 2,011.10^{-4} \times 434,8}{0,3 \times 1,67} = 0,157\,m \Rightarrow s_{t0} = 13\,cm$

A-3-3-



ETUDE B:

B_1_ $\lambda = \frac{\sqrt{12}\, L_f}{a} = \frac{\sqrt{12} \times 3}{0,2} = 51,96 > 50$ et $\lambda < 70$

$\alpha = 0,6 \times \left(\frac{50}{51,96}\right)^2 = 0,556$

$B_r = (0,2-0,02) \times (0,4-0,02) = 0,0684\ m^2$

$A_{th} = \left[\frac{N_u}{\alpha} - \frac{B_r \times f_{c28}}{0,9\,\gamma_b}\right] \times \frac{1}{f_{su}} = \left[\frac{0,558}{0,556} - \frac{0,0684 \times 25}{0,9 \times 1,5}\right] \times \frac{1}{434,8} = -6,05.10^{-4}\ m^2 < 0$

On met la section d'armatures minimale.

$A_{min\,1} = 4u = 4 \times (0,2+0,4) \times 2 = 4,8\ cm^2$

$A_{min\,2} = 0,2\%\, B = 0,2\% \times 0,2 \times 0,4 = 1,6\ cm^2$

$\Big\}$ $\underline{A = 4,8\ cm^2}$

$s_l \leq \min(a+10\,cm ; 40\,cm) = 30\,cm$. Il faut donc 6 aciers.

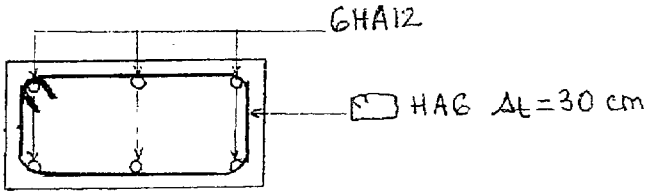
Choix: 6 HA 12 ($6,79\ cm^2$)

B_2_ $\phi_t = \frac{\phi_l}{3} = \frac{12}{3} = 4\,mm \Rightarrow \underline{\phi_t = 6\,mm}$

$s_t \leq \min(40\,cm ; a+10\,cm ; 15\phi_l) = 30\,cm \Rightarrow \underline{s_t = 30\,cm}$

$\phi_l < 20\,mm$ et $A = A_{min} \Rightarrow$ pas besoin d'épingle.

B_3_



ETUDE C :

C-1- $A \geq \sqrt{\frac{N_u \times a}{b \times q}} = \sqrt{\frac{0,558 \times 0,2}{0,4 \times 0,3}} = 0,964\,m$ On choisit : $\underline{A = 1m}$

$B \geq \sqrt{\frac{N_u \times b}{a \times q}} = \sqrt{\frac{0,558 \times 0,4}{0,2 \times 0,3}} = 1,93\,m$ On choisit : $\underline{B = 2m}$

$d \geq \frac{B-b}{4} = \frac{2-0,4}{4} = 0,4m \Rightarrow \underline{h = 0,45m}$

$P_{semelle\,u} = 1,35 \times 0,025 \times 1 \times 2 \times 0,45 = 0,03\,MN.$

$\frac{0,558 + 0,03}{1 \times 2} = 0,294\,MPa \leq q = 0,3\,MPa$ OK

Les dimensions conviennent.

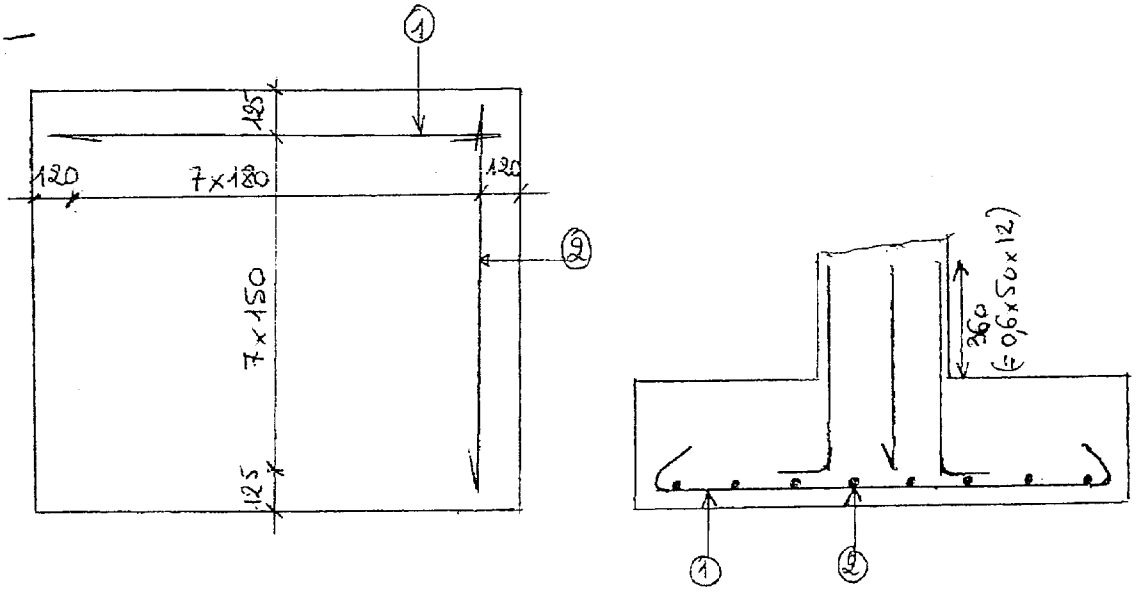
C-2- $A_1 = \frac{1,1 \times N_u \times (B-b)}{8 \cdot d_1 \cdot f_{su}} = \frac{1,1 \times 0,558 \times (1,50-0,4)}{8 \times 0,34 \times 434,8} = 5,71\,cm^2$

① Choix : 8 HA 10 (e = 15 cm) (6,28 cm^2)

$A_2 = \frac{1,1 \times N_u \times (A-a)}{8 \cdot d_2 \cdot f_{su}} = \frac{1,1 \times 0,558 \times (1,3-0,2)}{8 \times 0,33 \times 434,8} = 5,88\,cm^2$

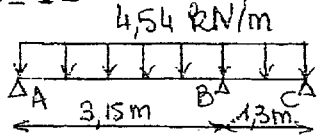
② Choix : 8 HA 10 (e = 18 cm)

C-3-



ETUDE D :

D_1_



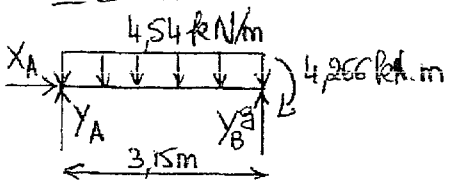
Appliquons le théorème des 3 moments :

$M_A = M_C = 0$ car appuis de rive

$$2\times(3,15+1,3)\,M_B = 6EI\left[-\frac{4,54\times 1,3^3}{24\,EI} - \frac{4,54\times 3,15^3}{24\,EI}\right]$$

d'où, $M_B = -4,266$ kN.m

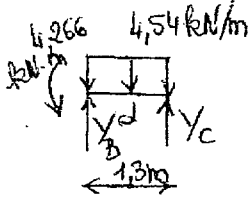
Isolons la travée 1 :



$$\begin{cases} X_A = 0 \\ Y_A + Y_B^g - 4,54\times 3,15 = 0 \\ Y_B^g \times 3,15 - 4,54\times\frac{3,15^2}{2} - 4,266 = 0 \end{cases}$$

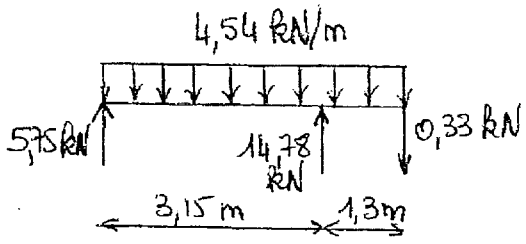
$Y_B^g = 8,55$ kN $\qquad Y_A = 5,75$ kN

Isolons la travée 2 :

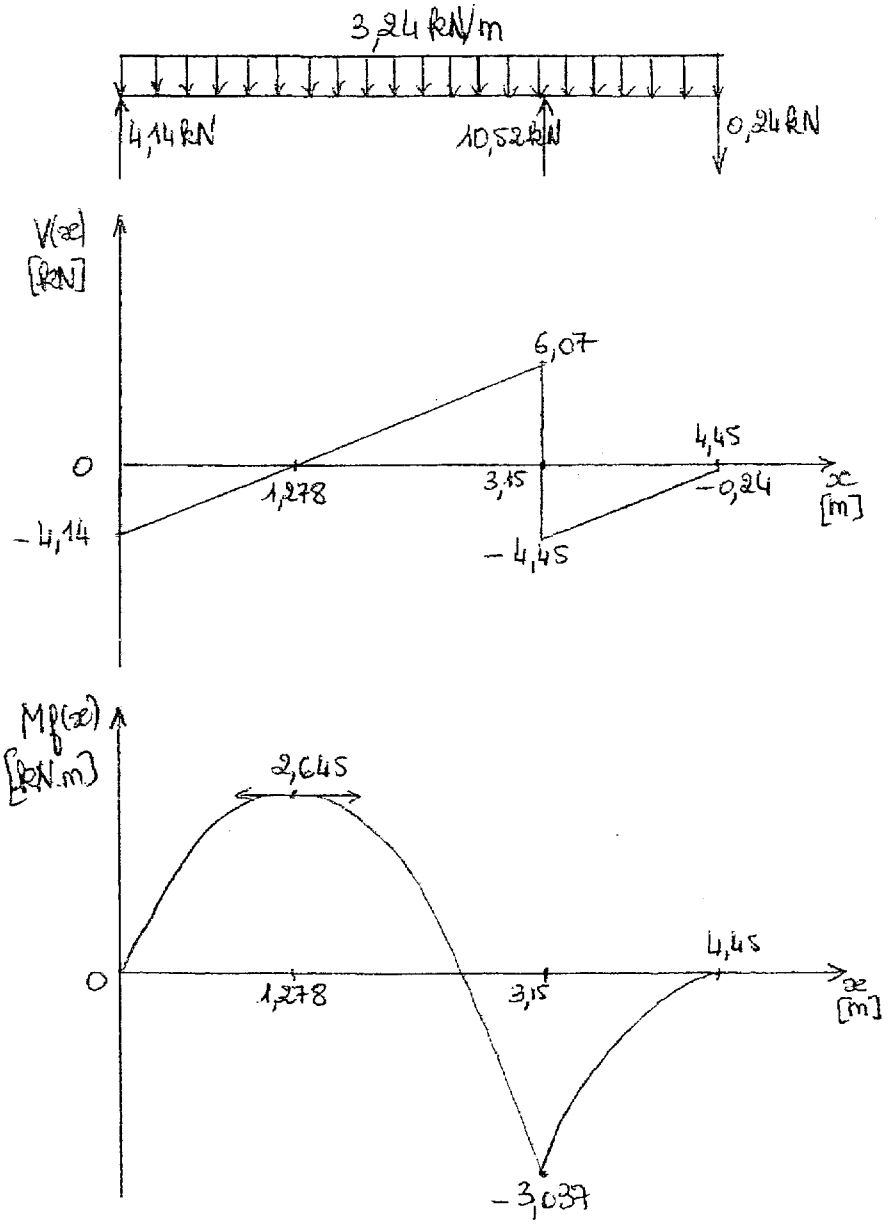


$$\begin{cases} Y_B^d + Y_C - 4,54\times 1,3 = 0 \\ Y_C \times 1,3 - 4,54\times\frac{1,3^2}{2} + 4,266 = 0 \end{cases}$$

$Y_C = -0,33$ kN $\qquad Y_B^d = 6,23$ kN

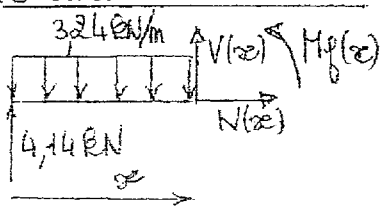


D-2-


3,24 kN/m
4,14 kN
10,52 kN
0,24 kN
V(x) [kN]
6,07
4,45
0
1,278
3,15
-0,24
x [m]
-4,14
-4,45
Mf(x) [kN.m]
2,645
0
1,278
3,15
4,45
x [m]
-3,037

D_3_ $E = 11\,600$ MPa $\quad I = \frac{bR^3}{12} = \frac{0{,}063 \times 0{,}175^3}{12} = 2{,}81 \cdot 10^{-5}\ m^4$

Première méthode : $y''(x) = \frac{M_f(x)}{EI}$



dans la première travée,

$M_f(x) = -3{,}24\frac{x^2}{2} + 4{,}14\,x$

$EI\,y_1''(x) = -1{,}62\,x^2 + 4{,}14\,x$

$EI\,y_1'(x) = -1{,}62\frac{x^3}{3} + 4{,}14\frac{x^2}{2} + k_1$

$EI\,y_1(x) = -1{,}62\frac{x^4}{12} + 4{,}14\frac{x^3}{6} + k_1 x + k_2$

conditions aux limites :

$y_1(0) = 0 = k_2$ et $y_1(3{,}15\ m) = 0$

$EI\,y_1(3{,}15\ m) = -1{,}62 \times \frac{3{,}15^4}{12} + 4{,}14 \times \frac{3{,}15^3}{6} + k_1 \times 3{,}15 = 0$

d'où, $k_1 = -2{,}627$ d'où $y_1(x) = \frac{1}{EI_1}\left[-1{,}62\frac{x^4}{12} + 4{,}14\frac{x^3}{6} - 2{,}627\,x\right]$

au milieu de la travée

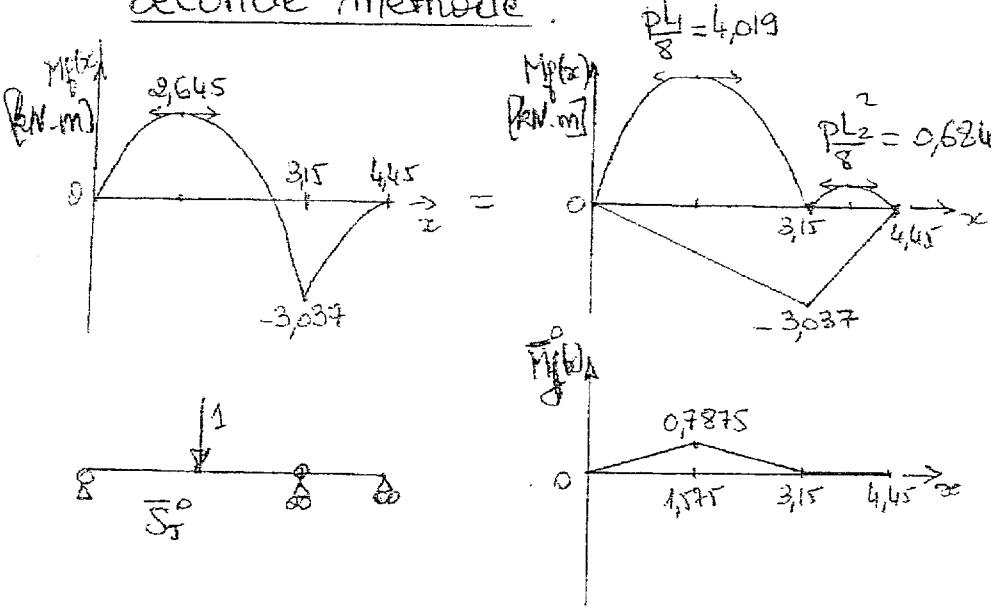
$x = \frac{3{,}15}{2} = 1{,}575\ m$

$y_1(1{,}575\ m) = \frac{10^{-3}}{11600 \times 2{,}81 \cdot 10^{-5}}\left[-1{,}62 \times \frac{1{,}575^4}{12} + 4{,}14 \times \frac{1{,}575^3}{6} - 2{,}627 \times 1{,}575\right]$

$y_1 = -6{,}97$ mm en $x = 1{,}575$ m $\quad Y_1 = 7{,}0$ mm

NB : La flèche maximale se trouve en $x = 1{,}42$ m, valeur qui annule $y_1'(x)$, $y_1(1{,}42\ m) = -7{,}07$ mm, valeur proche de celle obtenue.

Seconde méthode :



$$\Delta_j = \frac{1}{EI} \int_{\text{structure}} M(x)\, \overline{M}_j^{\,0}(x)\, dx$$

$$\Delta_j = \frac{10^{-3}}{11600 \times 2{,}81.10^{5}} \times \left[\int_0^{3{,}15\text{m}} \underset{4{,}019}{\triangle} \times \underset{0{,}7875}{\triangle}\, dx + \int_0^{3{,}15\text{m}} \underset{-3{,}037}{\triangle} \times \underset{0{,}7875}{\triangle}\, dx \right]$$

$$\Delta_j = \frac{10^{-3}}{11600 \times 2{,}81.10^{5}} \times \left(\frac{5}{12} \times 3{,}15 \times 4{,}019 \times 0{,}7875 + \frac{3{,}15}{4} \times (-3{,}037) \times 0{,}7875 \right)$$

$$\Delta_j = 6{,}966 .10^{-3}\,\text{m} = 7{,}0\ \text{mm}$$

D-4-1- $\frac{I}{v} = W = \frac{bh^2}{6} = \frac{0,063 \times 0,175^2}{6} = 3,216.10^{-4} m^3$

$f_{m,d} = k_{mod} \times \frac{f_{mk}}{\gamma_m} = 0,9 \times \frac{24}{1,25} = 17,28$ MPa

$|M_{f\,max}| = 4,27$ kN.m

$|\sigma_{m,d}| = \frac{|M_{f\,max}|}{W} = \frac{4,27.10^{-3}}{3,216.10^{-4}} = 13,277$ MPa

critère de résistance : $\frac{|\sigma_{m,d}|}{k_h \times f_{m,d}} = \frac{13,277}{1,15 \times 17,28} = 0,668 \leq 1$ OK

D-4-2- $|V_{max}| = 8,5$ kN

$\tau_d = \frac{3|V_{max}|}{2A} = \frac{3 \times 8,5.10^{-3}}{2 \times 0,063 \times 0,175} = 1,156$ MPa

$f_{v,d} = k_{mod} \times \frac{f_{v,k}}{\gamma_m} = 0,9 \times \frac{2,7}{1,25} = 1,944$ MPa

critère de résistance : $\frac{\tau_d}{f_{v,d}} = 0,595 \leq 1$ OK

D-4-3-

$u_{net,inst} = u_{g,inst} + u_{q,inst} - u_0$

$= 5 + 2,6 - 0$

$u_{net,inst} = 7,6$ mm

$u_{net,fin} = u_{net,inst}(g) \times (1+k_{def}) + u_{net,inst}(s) = 5 \times (1+0,6) + 2,6 = 10,6$ mm

conditions de flèche :

$u_{net,inst} = 7,6$ mm $\leq \frac{L}{300} = \frac{3150}{300} = 10,5$ mm OK

$u_{net,fin} = 10,6$ mm $\leq \frac{L}{250} = \frac{3150}{250} = 12,6$ mm OK