

TD N°01 :

Exercice N°01 :

Prédimensionnement des éléments structures :

1) Plancher :

$$h_t \geq \frac{L}{22.5}$$

L : longueur max nus de la poutrelle

$$L_{\max} = 3.8 - 0.25 \rightarrow L_{\max} = 3.55 \text{ m}$$

$$\rightarrow h_t \geq \frac{355}{22.5} \rightarrow h_t \geq 15.77 \text{ cm}$$

→ Plancher (16+4) cm

$$h_t = 20 \text{ cm}$$

1.1) Poutre principale (PP) :

Remarques : les sections minimales des poteaux suivant la zone sismique (RPA99 modifié 2003)

- Poteaux rectangulaires au carré, poteaux circulaires :

Min (a, b) ≥ 25 cm → zone 1 et 2a

Min (a, b) ≥ 30 cm → zone 2b et 3

D ≥ 25 cm → zone 1

D ≥ 30 cm → zone 2a

D ≥ 30 cm → zone 2b et 3

$$L_{pp}/15 \leq h \leq L_{pp}/10$$

$$L_{pp} = 3.8 - 0.25 = 3.55 \text{ m}$$

$$355/15 \leq h \leq 355/10$$

$$23.66 \leq h \leq 35.5$$

$$\rightarrow h = 30 \text{ cm}$$

$$0.3 \cdot h \leq b \leq 0.7 \cdot h$$

$$0.3 \cdot 30 \leq b \leq 0.7 \cdot 30$$

$$9 \leq b \leq 21$$

⊕ vérification PRA :

$$b \geq 20 \text{ cm}$$

$$h \geq 30 \text{ cm}$$

$$h/b \leq 4$$

$$b = 25 \text{ par ce que poteaux carré (25x25) cm}^2$$

$$\rightarrow (b \times h) = (25 \times 30) \text{ cm}^2$$

1.2) Poutre secondaire (PS) :

$$L_{ps}/15 \leq h \leq L_{ps}/10$$

$$L_{ps} = 3.8 - 0.25 = 3.55 \text{ m}$$

$$355/15 \leq h \leq 355/10$$

$$23.66 \leq h \leq 35.5$$

$$\rightarrow h = 30 \text{ cm}$$

$$0.3 \cdot h \leq b \leq 0.7 \cdot h$$

$$0.3 \cdot 30 \leq b \leq 0.7 \cdot 30$$

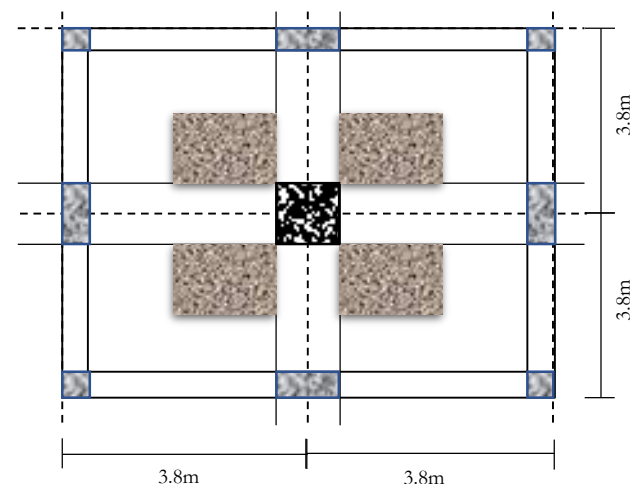
$$9 \leq b \leq 21$$

⊕ vérification PRA :

$$\rightarrow b = 25 \text{ cm}$$

$$\Rightarrow (b \times h) = (25 \times 30) \text{ cm}^2$$

2) Prédimensionnement du poteau le plus sollicité :



$$\text{Surface afférent } S_f = (3.55 \times 3.55) \rightarrow S_f = 12.6 \text{ m}^2$$

$$B_r (\text{m}^2) \geq 0.064 \cdot N_u (\text{MN})$$

$$B_r = (a-2)(b-2) \text{ cm}^2 \rightarrow B_r = (a-0.02)(b-0.02) \text{ m}^2$$

$$\rightarrow B_r = (a-0.02)^2 = (b-0.02)^2$$

$$G = 5.8 \text{ KN/m}^2$$

$$Q = 1.5 \text{ KN/m}^2$$

La charge permanent :

Plancher : $5.8 \times 12.6 = 73.08 \text{ KN}$

PP: $(0.25 \times 0.3 \times 3.55) \times 25 = 6.65 \text{ KN}$

PS: $(0.25 \times 0.3 \times 3.55) \times 25 = 6.65 \text{ KN}$

$N_G = 86.38 \text{ KN}$

La charge variable :

$N_Q = 1.5 \times 12.6 \rightarrow N_Q = 18.9 \text{ KN}$

A l'ELU : $N_u = 1.35 \times N_G + 1.5 \times N_Q$

$N_u = 1.35 \times 86.38 + 1.5 \times 18.9$

$N_u = 144.963 \text{ KN}$

$(a - 0.02)^2 \geq 0.064 \times 144.963 \times 10^{-3}$

$(a - 0.02) \geq \sqrt{(0.064 \times 144.963 \times 10^{-3})}$

$a \geq [\sqrt{(0.064 \times 144.963 \times 10^{-3})} + 0.02] \times 10^2$

$a \geq 11.63 \text{ cm}$

$b \geq 11.63 \text{ cm}$

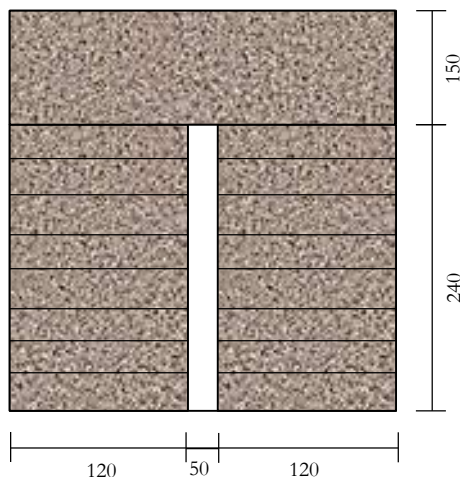
Alors : (25*25) vérifier

TD N°02 :

Exercice N°01 :

Prédimensionnement des escaliers suivante :

$h_e = 3.06 \text{ m}$



$240 = 8 \times 30 \rightarrow 8 \text{ marches} \rightarrow 9 \text{ contre-marches}$

Le palier de repos est situé à $3.06/2 = 1.53 \text{ m}$

$\rightarrow 153/9 = 17 \text{ cm (h)}$

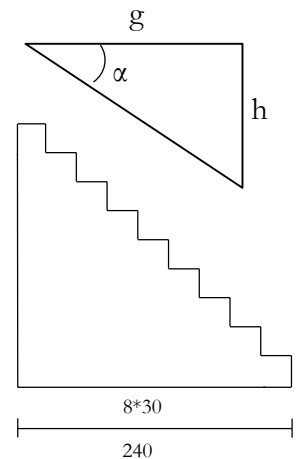
Inclinaison de l'escalier :

$Tg(\alpha) = h/g = 17/30$

$\rightarrow \alpha = 29.53^\circ$

$tg(\alpha) = (158-17)/240$

$\rightarrow \alpha = 29.53^\circ$



Epaisseur de palier :

$L_{\text{palier}}/30 \leq e_{\text{palier}} \leq L_{\text{palier}}/20$; $L_{\text{palier}} = 150 \text{ cm}$

$150/30 \leq e_{\text{palier}} \leq 150/20$

$5 \leq e_{\text{palier}} \leq 7.5$

$e_{\text{palier}} = 7.5 \text{ cm}$

-épaisseur de paillais :

$L_{\text{paillais}}/30 \leq e_{\text{paillais}} \leq L_{\text{paillais}}/20$

$L_{\text{paillais}} = 2.40/\cos(\alpha) \rightarrow L_{\text{paillais}} = 2.75 \text{ m}$

$276/30 \leq e_{\text{paillais}} \leq 276/20$

$9.2 \leq e_{\text{paillais}} \leq 13.8$

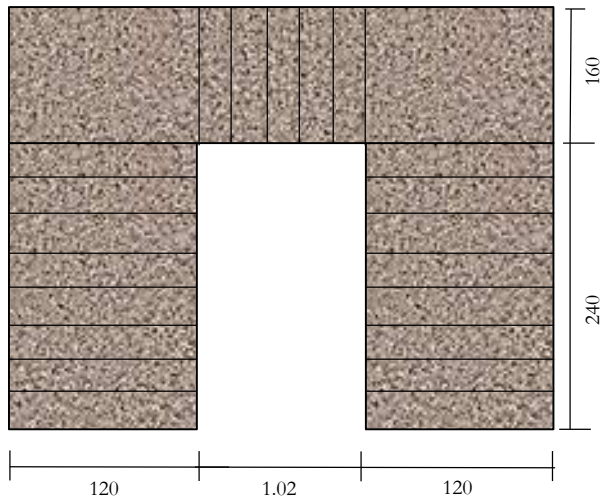
$e_{\text{paillais}} = 13 \text{ cm}$

$e_{\text{palier}} = 13 \text{ cm}$

Exercice N°02 :

Prédimensionnement des escaliers suivante :

$$h_c = 4.08 \text{ m}$$



R_1 = palier de repos est situé à : 1.53 m

R_2 = palier de repos est situé à : 1.53+1.02 = 2.55 m

Volée 1 : 8 marches & 9 contres-marches

$$153/9=17 \text{ cm}$$

Volée 3 : 8 marches & 9 contres-marches

$$\text{Volée 2 : } 4.08 - 3.06 = 1.02/17 = 6 \text{ cm}$$

$$\Rightarrow 5 \text{ marches } (5 \times 30)$$

Exercice N°03 :

Soit une semelle carrée en BA cours un poteau carré (40*40) soumis à une effort axial N , on donne :

$$G = 150 \text{ KN}$$

$$Q = 250 \text{ KN}$$

$$\sigma_{\text{sol}} = 2.5 \text{ bar}$$

Pré dimensionner la semelle étudier

Solution :

$$1) \quad a/b = A/B = 1 \rightarrow A = B$$

$$N_{\text{ser}}/A^2 < \sigma_{\text{sol}} \quad ; \quad N_{\text{ser}} = G + Q = 100 \text{ KN}$$

$$A^2 > N_{\text{ser}} / \sigma_{\text{sol}} \rightarrow A > \sqrt{(N_{\text{ser}} / \sigma_{\text{sol}})}$$

$$\Rightarrow A > \sqrt{(400 \times 10^{-3} / 0.25)}$$

$$\Rightarrow A > 1.26 \text{ m}$$

$$A = B = 1.3 \text{ m}$$

$$2) \quad h = d + 0.05 \text{ m}$$

$$d > \max \begin{cases} (A - a)/4 = (1.3 - 0.4)/4 = 0.225 \\ (B - b)/4 \end{cases}$$

$$d = 25 \text{ cm}$$

$$h = 0.25 + 0.05 \rightarrow h = 0.30 \text{ m}$$

verification:

$$\sigma = (P_{\text{ser}} + PP_{\text{semelle}})/(A \times B)$$

PP_{semelle} : poids propre

$$P_{\text{ser}} : N_{\text{ser}}$$

$$PP_{\text{semelle}} = (A \times B \times h) \times 25$$

$$= (1.3 \times 1.3 \times 0.3) \times 25 \rightarrow PP_{\text{semelle}} = 12.675 \text{ KN}$$

$$\sigma = (0.4 + 12.675 \times 10^{-3}) / 1.3^2 = 0.24 \text{ MPa}$$

$$\sigma = 0.24 \text{ MPa} < \sigma_{\text{sol}} = 0.25 \text{ MPa} \quad \text{C.V}$$

Exercice N°04 :

Semelle circulaire de diamètre D, on donne :

$$d = 40 \text{ cm.}$$

$$G=260 \text{ KN, } Q=300 \text{ KN, } \sigma_{\text{sol}}=25 \text{ bars, } N_{\text{ser}}=560 \text{ KN}$$

$$\frac{560}{\frac{\pi D^2}{4}} \leq \sigma_{\text{sol}}$$

$$D \geq \sqrt{\frac{4 * N_{\text{ser}}}{\pi * \sigma_{\text{sol}}}}$$

$$D \geq \sqrt{\frac{4 * 0.560}{\pi * 0.25}} \Rightarrow D \geq 1.68 \Rightarrow D = 1.7$$

$$d' \geq \frac{D-d}{4} = \frac{170-40}{4} \Rightarrow d' \geq 32.5 \Rightarrow 35 \text{ cm}$$

$$h = d + 0.05 \rightarrow h = 0.35 + 0.05 \rightarrow h = 0.40 \text{ m.}$$

verification:

$$\sigma = \frac{N_{\text{ser}} + PP_{\text{semelle}}}{\frac{\pi * D^2}{4}}$$

$$PP_{\text{semelle}} = \left(\frac{\pi * D^2}{4} * h \right) 25$$

$$PP_{\text{semelle}} = \left(\frac{\pi * 1.7^2}{4} * 0.4 \right) 25$$

$$PP_{\text{semelle}} = 22.68 \text{ KN}$$

$$\sigma = \frac{0.5 + 22.68 * 10^{-3}}{\frac{\pi * 1.7^2}{4}}$$

$$\sigma = 0.256 \text{ MPa} > \sigma_{\text{sol}}$$

Conditions non-verifier.

Alor augmenter le diamètre de semelle.

TD N°03 : calculs des armatures transversales

Exercice N°01 :

$$h = ?$$

$$S_t \leq \frac{0.9 * f_e * A_t (\cos \alpha + \sin \alpha)}{\bar{b} * \gamma_s (\tau_u - 0.3 * f_{tj} * K)}$$

$$S_t \leq \frac{0.9 * f_e * A_t}{\bar{b} * \gamma_s \tau_u} \Rightarrow S_t \leq \frac{0.9 * f_e * A_t}{\bar{b} * \gamma_s \frac{T_u}{\bar{b} * d}}$$

$$S_t \leq \frac{0.9 * f_e * A_t * d}{\gamma_s * T_u}$$

$$f_e = 400, A_t = 4\phi 8 = 2.01 \text{ cm}^2, d = 0.9h, \gamma_s = 1.15$$

$$\frac{P_u * L}{2} = 0.11(2.605 - 0.15) = 0.27 \text{ MN}$$

$$d \geq \frac{S_t \gamma_s T_u}{0.9 f_e A_t}$$

$$d \geq \left[\frac{11 * 10^{-2} * 1.15 * 0.27}{0.9 * 400 * 2.01 * 10^{-4}} \right] 10^2$$

$$d \geq 47.44 \Rightarrow h = \frac{d}{0.9}$$

$$h = \frac{47.44}{0.9} \Rightarrow h = 52.71 \Rightarrow h \square 55 \text{ cm}$$

$$\text{Section } (b * h) = (30 * 55) \text{ cm}^2$$

Vérification de cisaillement

$$\tau_{\text{max}} = \frac{T_{\text{max}}}{\bar{b} * d} \leq \bar{\tau}$$

$$F.P \Rightarrow \bar{\tau} = \min(0.15 f_{cj} / \gamma_b; 4 \text{ MPa})$$

$$\Rightarrow \bar{\tau} = \min \left(\frac{0.15 * 25}{1.5} = 2.5 \text{ MPa}; 4 \text{ MPa} \right)$$

$$\bar{\tau} = 2.5 \text{ MPa}$$

$$\tau_{\text{max}} = \frac{T_{\text{max}}}{\bar{b} * d} = \frac{0.270}{0.9 * 0.55} = 1.81 \text{ MPa} \leq \bar{\tau} = 2.5 \text{ MPa}$$

$$\tau_{\text{max}} < \bar{\tau}$$

Conditions vérifier.

EXERCICE N°02 :

$$S_t \leq \frac{0.9 * f_e * A_t (\cos \alpha + \sin \alpha)}{\bar{b} * \gamma_s (\tau_u - 0.3 * f_{ij} * K)}$$

$$S_t \leq \frac{0.9 * f_e * A_t}{\bar{b} * \gamma_s \tau_u}$$

$$\tau_u \leq \frac{0.9 * f_e * A_t * d}{\bar{b} * \gamma_s * S_t} + 0.3 f_{ij}$$

$$\tau_u \leq \frac{0.9 * 400 * 1.13 * 10^{-4}}{100 * 10^{-3} * 0.3 * 1.15} + 0.3 * 2.1$$

$$\tau_u \leq 1.81 \text{ MPa}$$

$$\tau_u \leq \frac{T_u}{b * d} \Rightarrow T_u = \tau_u * \bar{b} * d$$

$$T_u = 1.81 * 0.3 * 0.9 * 0.5$$

$$T_u = 0.24 \text{ MN}$$

$$T_u = \frac{P_u L}{2} \Rightarrow P_u = \frac{T_u L}{2} = \left(\frac{0.242 * 2}{6200 * 10^{-3}} \right) 10^3$$

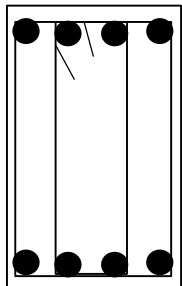
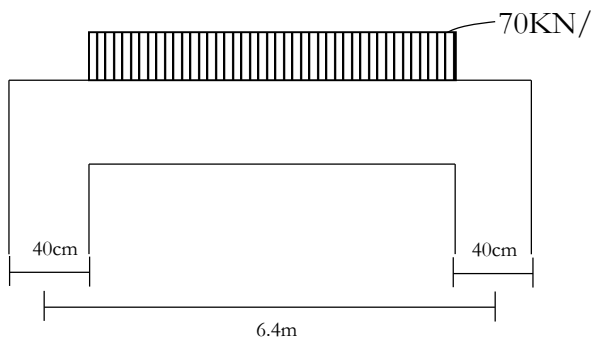
$$P_u = 78.78 \text{ KN}$$

CONTROLE :

Vérifier le cisaillement de la poutre (40x60).

- Calculer S_t et disposé le cadre (méthode de caque).

$f_e = 235 \text{ MPa}$; $\gamma_s = 1.15$; $f_{c28} = 25 \text{ MPa}$; $K=1$; F.P



TD N°04 : FLEXION COMPOSER

EXERCICE N°01 :

F.P.P ~ ELU

$$N_u = 1.35 N_G + 1.5 N_Q$$

$$N_u = 1.35 * (-170) + 1.5 * (-150)$$

$$N_u = -454.5 \text{ KN}$$

$$M_u = 1.35 M_G + 1.5 M_Q$$

$$M_u = 1.35 * 15 + 1.5 * 15$$

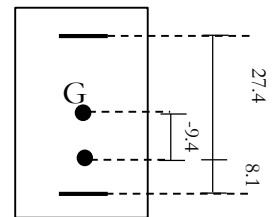
$$M_u = 42.75 \text{ KN.m}$$

$$e_0 = \frac{M_{uG}}{N_u} \Rightarrow e_0 = \frac{42.75}{-454.5} * 10^2$$

$$e_0 = -9.4 \text{ cm}$$

$$e_{a1} = \frac{h}{2} - d'' + |e_0| = 27.4 \text{ cm}$$

$$e_{a2} = \frac{h}{2} - d' - |e_0| = 8.1 \text{ cm}$$



$$A' \geq \frac{N_u * e_{a2}}{(d - d') \sigma_s}$$

$$A' \geq \frac{454.5 * 10^{-3} * 8.1 * 10^{-2}}{(0.405 - 0.05) 347.82} * 10^4$$

$$A' \geq 2.978 \text{ cm}^2$$

$$A \geq \frac{N_u * e_{a1}}{(d - d') \sigma_s}$$

$$A \geq \frac{454.5 * 10^{-3} * 27.4 * 10^{-2}}{(0.405 - 0.05) 347.82} * 10^4$$

$$A \geq 10.08 \text{ cm}^2$$

$$A_{\min} = \frac{B * f_{t28}}{f_e} = \frac{(30 * 45) * 2.1}{400}$$

$$A_{\min} = 7.08 \text{ cm}^2$$

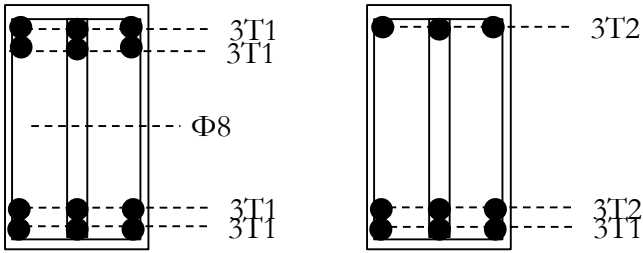
$$A' = 2.98 < A_{\min} = 7.08 \otimes$$

$$A > A_{\min}$$

$$A' = 7.08 \text{ cm}^2 \text{ \& } A = 10.08 \text{ cm}^2$$

Choix des barres :

$$A = 10.08 \text{ cm}^2 \rightarrow 4T14 + 4T12 = 10.68 \text{ cm}^2$$



EXERCICE N°02 :

$$e_0 \leq \frac{h}{2} - d'$$

$$\frac{M_{uG}}{N_u} \leq \frac{h}{2} - d' \Rightarrow N_u \geq \frac{M_{uG}}{\frac{h}{2} - d'}$$

F.F.P □ ELU

$$M_{uG} = 1.35M_G + 1.5M_Q$$

$$M_{uG} = 1.35 \cdot 20 + 1.5 \cdot 11$$

$$M_{uG} = 43.5 \text{ KN.m}$$

$$\Rightarrow N_u \geq \frac{43.5}{\frac{0.4}{2} - 0.05}$$

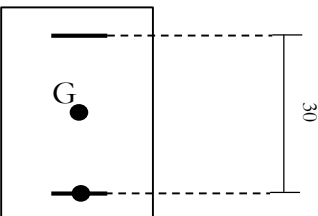
$$N_u \geq 290 \text{ KN} \Rightarrow N_u = -290 \text{ KN}$$

$$e_0 = \frac{M_{uG}}{N_u} \Rightarrow e_0 = \frac{43.5}{-290} \cdot 10^2$$

$$e_0 = -15 \text{ cm}$$

$$e_{a1} = \frac{h}{2} - d'' + |e_0| = 30 \text{ cm}$$

$$e_{a2} = \frac{h}{2} - d' - |e_0| = 0 \text{ cm}$$



$$A \geq \frac{290 \cdot 10^{-3} \cdot 0.3}{(0.36 - 0.05) \cdot 347.82} \cdot 10^4$$

$$A \geq 8.06 \text{ cm}^2$$

$$A_{\min} = \frac{B \cdot f_{t28}}{f_e} = \frac{(25 \cdot 40) \cdot 2.1}{400}$$

$$A_{\min} = 5.25 \text{ cm}^2$$

$$A' = A_{\min} = 5.25 \text{ cm}^2$$

$$3T16 + 3T14 = 10.65 \text{ cm}^2 \dots\dots\dots 1$$

$$3T20 = 9.42 \text{ cm}^2$$

$$A' = A_{\min} = 3T16$$

EXERCICE N°04 :

Soit un poteau BA soumise à la flexion composée.

On donne :

$$N_G = 75 \text{ KN}$$

$$M_G = 92 \text{ KN.m}$$

$$N_Q = 65 \text{ KN}$$

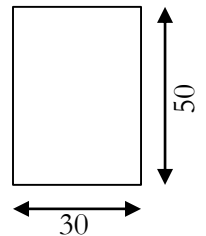
$$M_Q = 82 \text{ KN.m}$$

$$f_{c28} = 30 \text{ MPa} ; \gamma_b = 1.5$$

$$\text{Acier Fe400} ; \gamma_s = 1.15$$

La hauteur de poteau : 4.2 m

- Calcul la section de ferrailage.



SOLUTION 04 :

F.P.P → calcul à ELU

sollicitation :

$$N_U = 1.35N_G + 1.5N_Q \Rightarrow N_U = 198.5 \text{ KN}$$

$$M_{UG} = 1.35M_G + 1.5M_Q \Rightarrow M_{UG} = 247.2 \text{ KN.m}$$

Exentricité :

$$e_1 = \frac{M_{UG}}{N_U} = \frac{247.2}{198.65} \Rightarrow e_1 = 1.243 \text{ m}$$

$$e_A = \max \left\{ \frac{2 \text{ cm}}{\frac{L}{250}} \right\} = \max \left\{ \frac{2 \text{ cm}}{\frac{420}{250}} \right\} = 1.68 \text{ cm} \Rightarrow e_A = 2 \text{ cm}$$

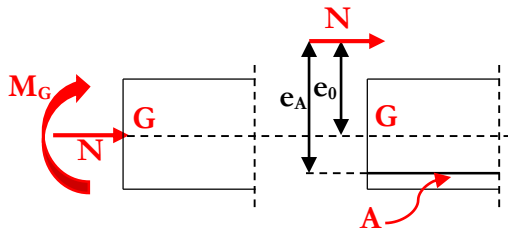
$$e_2 = \frac{3L_f^2}{10^4 \cdot h} (2 + \alpha \cdot \varepsilon);$$

$$\alpha = \frac{M_G}{M_G + M_Q} = 0.528; \varepsilon = 2; L_f = 0.7L_0 = 2.94 \text{ m}$$

$$e_2 = \frac{3 \cdot 2.94^2}{10^4 \cdot 0.495} (2 + 0.528 \cdot 2) \Rightarrow e_2 = 0.0176 \text{ m}$$

$$e = e_1 + e_a + e_2 \Rightarrow e = 1.243 + 0.02 + 0.0176$$

$$\Rightarrow e = 1.280 \text{ m}$$



$$e_0 = e$$

$$e_A = e_0 + \left(d - \frac{h}{2}\right) \Rightarrow e_A = 1.48m$$

Moment : $M_{UA} = N_U * e_A \Rightarrow M_{UA} = 198.65 * 1.48$
 $\Rightarrow M_{UA} = 294.15 \text{ KN.m}$

$$\mu_{BU} = \frac{M_{UA}}{b * d^2 * f_{bu}} = \frac{294.15 * 10^{-3}}{0.3 * 0.45^2 * 17}$$

$$\Rightarrow \mu_{BU} = 0.284$$

$$\mu_{BC} = \frac{0.8 * h}{d} \left(1 - 0.4 \frac{h}{d}\right) \Rightarrow \mu_{BC} = 0.493$$

$\mu_{BU} < \mu_{BC} \Rightarrow$ Section partiellement comprimée
 $\Rightarrow$ assimilation à la Flexion simple

$$\mu_{BU} = 0.284 < \mu_L = 0.8 * \alpha_L (1 - 0.4 \alpha_L) \square 0.392$$

$$\Rightarrow \mathcal{A}' = 0$$

$$\mathcal{A} = \frac{M_{UA}}{\beta * d * \sigma_{St}} = \left[\frac{294.15 * 10^{-3}}{0.828 * 0.45 * 347.82} \right] 10^4$$

$$\mathcal{A} = 22.69 \text{ cm}^2.$$

$$\alpha = 1.25 \left(1 - \sqrt{1 - 2\mu_{BU}}\right) \Rightarrow \alpha = 0.428$$

$$\beta = 1 - 0.4\alpha \Rightarrow \beta = 0.828$$

En flexion composée :

$$\mathcal{A}' = \mathcal{A}' = 0$$

$$A = \mathcal{A} - \frac{N}{\sigma_{St}} \quad A = \left[22.69 * 10^{-4} - \frac{198.65}{347.82} \right] 10^4$$

$$A = 16.97 \text{ cm}^2$$

EXERCICE N°05 :

Soit un poteau BA soumise à la flexion composée.

On donne :

$$N_G = -250 \text{ KN}$$

$$M_G = 22 \text{ KN.m}$$

$$N_Q = -230 \text{ KN}$$

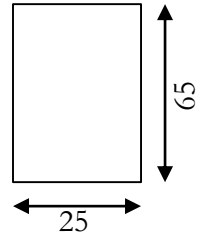
$$M_Q = 25 \text{ KN.m}$$

$$F_{c28} = 30 \text{ MPa} ; \gamma_b = 1.5$$

$$d = 58 \text{ cm} ; d' = 5 \text{ cm}$$

$$\text{Acier Fe500 type 1} ; \gamma_s = 1.15$$

La hauteur de poteau : 4.2 m



- Calcul la section de ferrailage.

EXERCICE 06 :

Soit un poteau en BA transmettant une effort **N** et un moment **M**

On donne :

$$\begin{aligned} N_G &= 120 \text{ KN} & M_G &= 130 \text{ KN.m} \\ N_Q &= 108 \text{ KN} & M_Q &= 112.5 \text{ KN.m} \end{aligned}$$

Section (55x25) cm

Hauteur de poteau : 6 m

Béton : $f_{c28} = 25 \text{ MPa}$; $\gamma_b = 1.5$

Acier : $f_{e500 \text{ HA}}$; $\gamma_s = 1.15$

Fissuration peu préjudiciable ; $d' = 5 \text{ cm}$

- Calculer la section de ferrailage.

SOLUTION :

F.P.P → calcule a ELU

Sollicitation :

$$N_u = 1.35 N_G + 1.5 N_Q \Rightarrow N_u = 324 \text{ KN}$$

$$M_{uG} = 1.35 M_G + 1.5 M_Q$$

$$\Rightarrow M_{uG} = 344.25 \text{ KN.m}$$

Excentricité :

$$e_1 = \frac{344.25}{324} = 1.0625 \text{ m}$$

$$e_a = \max \left\{ \frac{2 \text{ cm}}{250} = \max \frac{2 \text{ cm}}{2.4} \right\} e_a = 2.4 \text{ cm}$$

$$e_2 = \frac{3 L_f^2}{10^4 \cdot d} \cdot (2 + \alpha \cdot 4) = 0.0328 \text{ m}$$

$$\alpha = 0.536$$

$$e = e_1 + e_a + e_2 = 1.1193 \text{ m}$$

$$e_A = e + \left(d - \frac{h}{2} \right)$$

$$e_A = 1.1193 + \left(0.495 - \frac{0.55}{2} \right) = 1.3393 \text{ m}$$

$$M_{UA} = N_u \cdot e_A = 324 \cdot 1.3393 = 434 \text{ KN.m}$$

$$\mu_{bu} = \frac{M_{UA}}{b \cdot d^2 \cdot f_{bu}}$$

$$f_{bu} = 14.17 \text{ MPa}$$

$$\mu_{bu} = \frac{434 \cdot 10^{-3}}{0.25 \cdot 0.495^2 \cdot 14.17} \Rightarrow \mu_{bu} = 0.499$$

$$\mu_{BC} = \frac{0.8 \cdot h}{d} \left(1 - 0.4 \frac{h}{d} \right)$$

$$\mu_{BC} = \frac{0.8 \cdot 0.55}{0.495} \left(1 - 0.4 \frac{0.55}{0.495} \right) \Rightarrow \mu_{BC} = 0.493$$

$$\mu_{bu} = 0.499 > \mu_{BC} = 0.493$$

→ Section entièrement comprimées (S.E.C)

$$i = N_u (d - d') - M_{UA}$$

$$i = 324(0.495 - 0.05) - 434 = -289 \text{ MN.m}$$

$$j = (0.5 - d') b h f_{bu}$$

$$j = (0.5 - 0.05) 0.25 \cdot 0.55 \cdot 14.17 = 0.876 \text{ MN.m}$$

$$i < j$$

$$\psi = \frac{0.375 + \frac{i}{b h^2 f_{bu}}}{0.875 - \frac{d'}{h}}$$