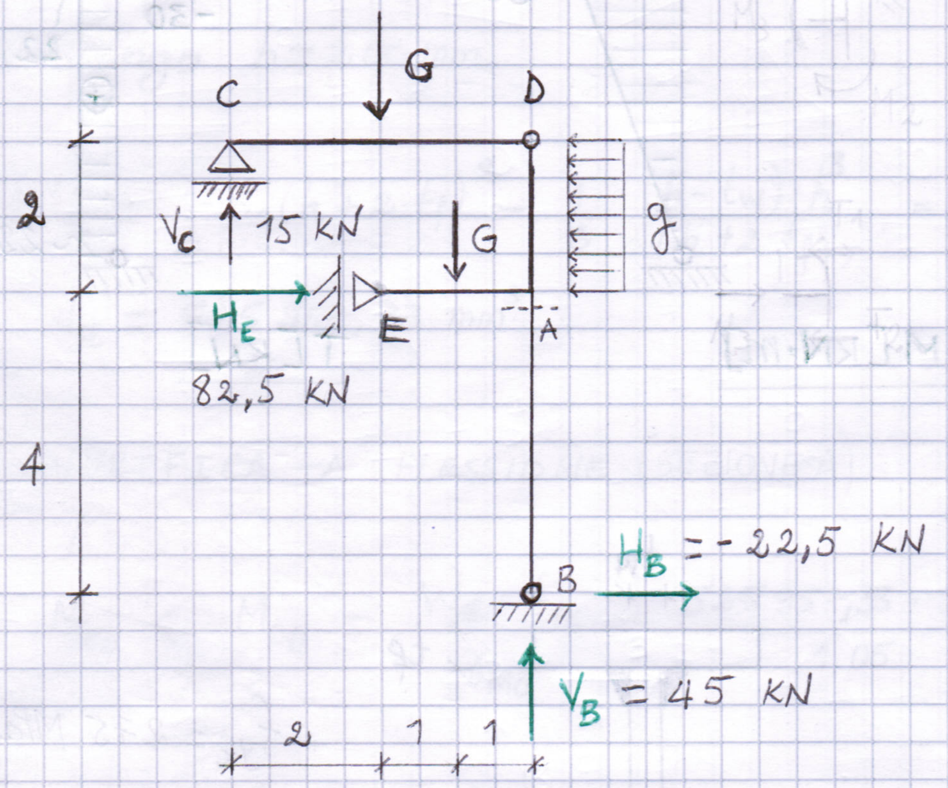
① PROVA SCRITTA DI TECNICA DELLE COSTRUZIONI

31/08/2017 TEMA B



$g = 30$ KN/m

$G = 30$ KN

i) Determinare i diagrammi e i valori significativi dei parametri di sollecitazione (M, N, T)

<u>Equazioni di equilibrio</u>:

$$V_C + V_B - G - G = 0$$

$$H_E + H_B - 2 \cdot g = 0$$

$$-V_C \cdot 4 + G \cdot 2 = 0 \quad \text{(Polo D) tronco CD}$$

$$-V_C \cdot 2 - G \cdot 1 + g \cdot 2 \cdot 1 + V_B \cdot 2 + H_B \cdot 4 = 0 \quad \text{(Polo E) Equilibrio Globale}$$

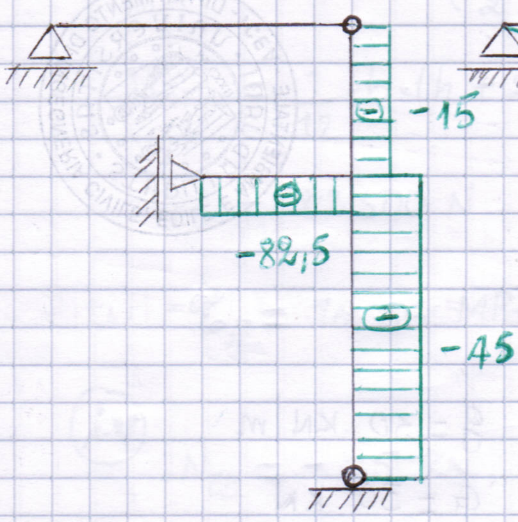
$$V_C = 2 \cdot G - V_B = 15 \text{ KN}$$

$$V_B = 2 \cdot G - V_C = 45 \text{ KN}$$

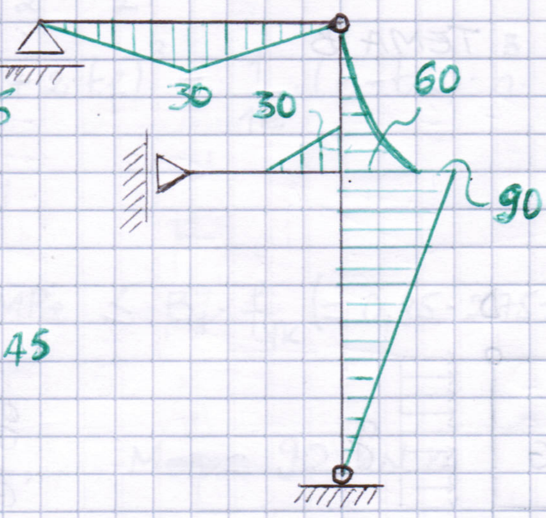
$$V_C = G \cdot 2/4 = 15 \text{ KN}$$

$$H_E = 2 \cdot g - H_B = 82{,}5 \text{ KN}$$

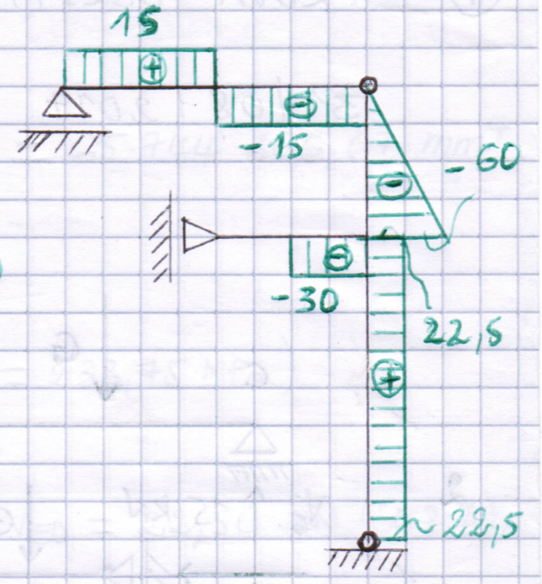
$$H_B = (V_C \cdot 2 + G \cdot 1 - g \cdot 2 \cdot 1 - V_B \cdot 2)/4 = 22{,}5 \text{ KN} \ (\longleftarrow)$$



N [kN]



M [kN·m]



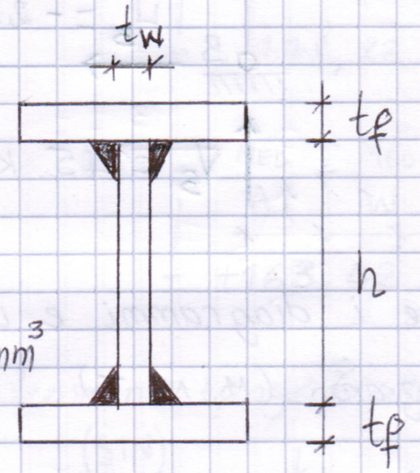
T [kN]

(ii)

SEZIONE A

$M_{ED} = 90$ kNm

$V_{ED} = 22,5$ kN



$f_{yk} = 275$ MPa

$$\begin{cases} t_w \cong 0,8\, t_f = 8 \\ b \cong 0,85\, h = 195,5 \to 200 \end{cases}$$

$$W_{el,MIN} = \frac{M_{ED} \cdot \gamma_{M0}}{f_{yk}} = 343\,636,36\ mm^3$$

IPOTIZZO $\begin{cases} h = 230\ mm \\ t_f = 10\ mm \end{cases}$ $\quad t_w = 0,8 \cdot t_f = 8\ mm$

$$J = \frac{1}{12}\, b \cdot (h + 2\, t_f)^3 - \frac{1}{12}\,(b - t_w) \cdot h^3 \quad (*)$$

$$W_{el} = \frac{b \cdot (h + 2 \cdot t_f)^3 - (b - t_w) \cdot h^3}{12} \cdot \frac{2}{(h + 2 t_f)} \quad (**)$$

$$= \frac{1}{6}\, b \cdot (h + 2 \cdot t_f)^2 - \frac{1}{6} \cdot \frac{(b - t_w) \cdot h^3}{h + 2 t_f}$$

Per trovare b $\begin{cases} b \gg t_w \\ h \gg 2 \cdot t_f \end{cases}$

$$W_{el,} = \frac{(b \cdot (h + 2 \cdot t_f)^2}{6} - \frac{b \cdot h^3}{6 \cdot (h + 2 t_f)} + \frac{t_w \cdot h^3}{6 \cdot (h + 2 t_f)}$$

$$W_{el} \simeq \frac{b \cdot [(h+2\cdot t_f)^2 - h^2]}{6} + \frac{t_w \cdot h^2}{6}$$ N.B. Uso questa equazione solo per trovare b !!!

$$\Rightarrow b \simeq \frac{6 \cdot W_{el} - t_w \cdot h^2}{(h+2\cdot t_f)^2 - h^2} \cong 170{,}68 \text{ mm}$$ (h scelto va bene)

Pongo $b = 200$ mm

$$W_{el} = \frac{1}{6} b \cdot (h + 2\cdot t_f)^2 - \frac{1}{6} \frac{(b - t_w)\cdot h^3}{(h + 2 \cdot t_f)} = \frac{J}{(h + 2\, t_f)}$$

$$W_{el} = 525\,957{,}33 \text{ mm}^3$$

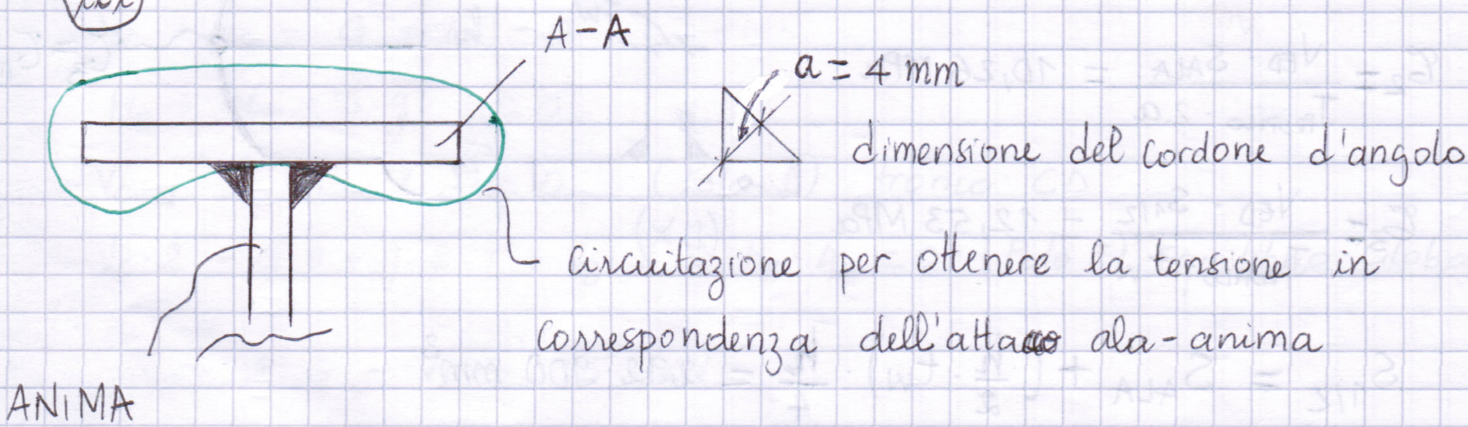
VERIFICA A FLESSIONE (SEZIONE A)

$$M_{ED} < M_{RD} = \frac{W_{el} \cdot f_{YK}}{\gamma_{M0}} = \frac{525\,957{,}33 \cdot 275}{1{,}05} = 137{,}8 \text{ KN}\cdot\text{m}$$

VERIFICA A TAGLIO

$$V_{ED} < V_{RD} = \frac{A_V \cdot f_{YK}}{\sqrt{3} \cdot \gamma_{M0}} = \frac{(h \cdot t_w) \cdot f_{YK}}{\sqrt{3} \cdot \gamma_{M0}} = 278{,}23 \text{ KN}$$

(iii)



$$\tau_{ATTACCO} = \frac{V_{ED} \cdot S_{ALA}}{J_{Profilo} \cdot 2a}$$

Se ipotizzo che $2 \cdot a = t_h$ è come se avessi una sezione compatta e la saldatura è "implicitamente" verificata

$$S_{ALA} = (t_f \cdot b) \cdot \left(\frac{h}{2} + \frac{t_f}{2}\right) = 240\,000 \ mm^3$$

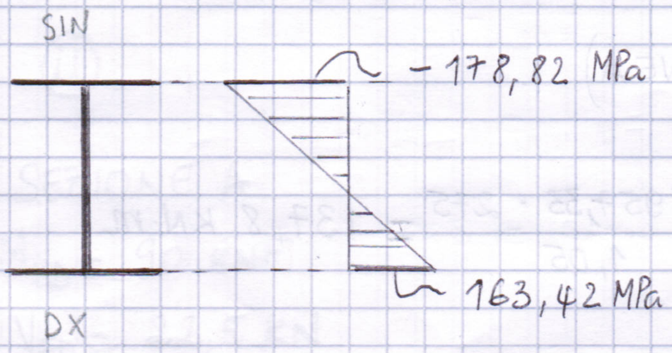
$$J_{PROFILO} = \frac{1}{12} \cdot b \cdot (h + 2 \cdot t_f)^3 - \frac{1}{12} \cdot (b - t_w) \cdot h^3 = 65 \cdot 744 \cdot 666{,}67 \ mm^4$$

$$V_{ED} = 22\,500 \ N$$

$$\tau_{//} = 10{,}26 \ MPa \le \beta_1 \cdot f_{yk} \ (= 0{,}85 \cdot 275 = 233{,}75 \ MPa)$$

iv $N_{ED} = -45 \ kN \quad M_{ED} = 90 \ kN \cdot m \quad V_{ED} = 22{,}50 \ kN$ (SEZ. A)

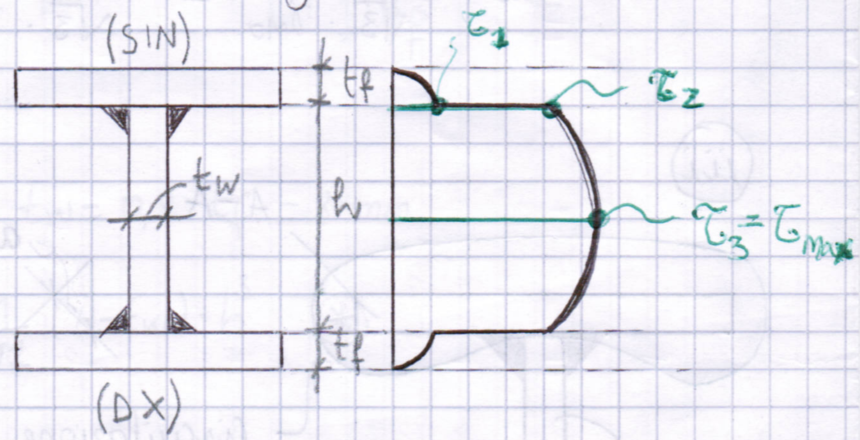
diagramme delle tensioni normali



$$\sigma_{SUP} = \frac{N_{ED}}{A} - \frac{M_{ED}}{W} = -\frac{45\,000}{5840} - \frac{90\,000\,000}{525\,957{,}33} = -178{,}82 \ MPa$$

$$\sigma_{INF} = \frac{N_{ED}}{A} + \frac{M_{ED}}{W} = -\frac{45\,000}{5840} + \frac{90\,000\,000}{525\,927{,}33} = +163{,}42 \ MPa$$

Diagramma delle tensioni tangenziali



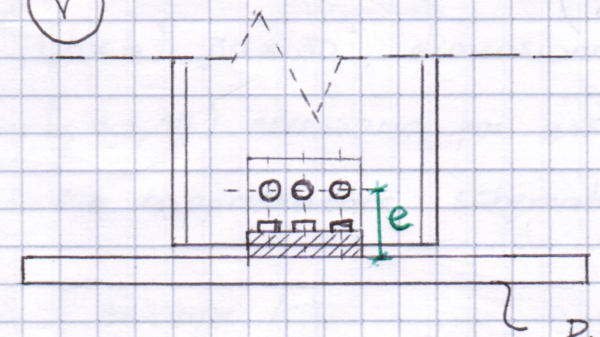
$$\tau_1 = \frac{V_{ED} \cdot S_{ALA}}{J_{PROFILO} \cdot b} = 0{,}41 \ MPa$$

$$\tau_2 = \frac{V_{ED} \cdot S_{ALA}}{J_{PROFILO} \cdot 2a} = 10{,}26 \ MPa$$

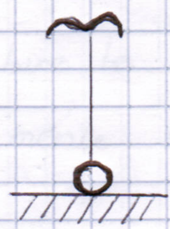
$$\tau_3 = \frac{V_{ED} \cdot S_{1/2}}{J_{PROFILO} \cdot t_w} = 12{,}53 \ MPa$$

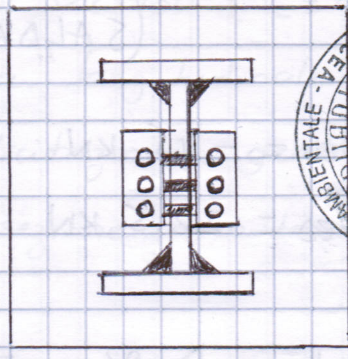
$$S_{1/2} = S_{ALA} + \left(\frac{h}{2} \cdot t_w\right) \cdot \frac{h}{4} = 292 \cdot 900 \ mm^3$$

(V)



PIASTRA DI BASE



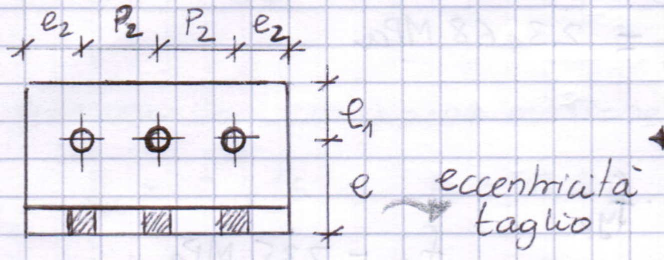


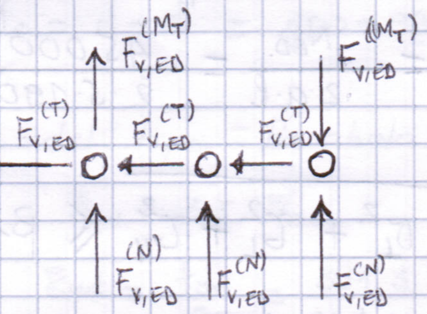
La colonna non appoggia direttamente sulla piastra di base quindi N_{ED} viene trasferito alla piastra di base tramite i bulloni dell'anima

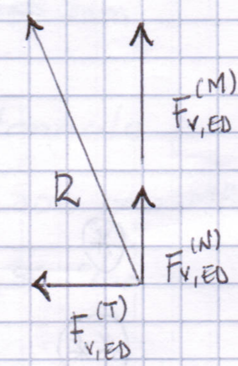
$V_{ED} = 22{,}5$ KN

$N_{ED} = -45$ KN

$\boxed{\text{M16 CL 8.8}}$







$e_1 = 60\,mm$ $P_2 = 60\,mm$

$e_2 = 50\,mm$ $e = 70\,mm$

$M_T = T \cdot e = 22{,}5 \cdot 0{,}07 = 1{,}575\ KN \cdot m$

$$F_{V,ED}^{(N)} = \frac{N_{ED}}{n \cdot n_f} = \frac{45}{3 \cdot 2} = 7{,}500\ KN$$

$$F_{V,ED}^{(T)} = \frac{V_{ED}}{n \cdot n_f} = \frac{22{,}5}{3 \cdot 2} = 3{,}750\ KN$$

$$F_{V,ED}^{(M_T)} = \frac{M_T}{h} \cdot \frac{1}{n_f} = \frac{1{,}575}{0{,}12} \cdot \frac{1}{2} = 6{,}56\ KN$$

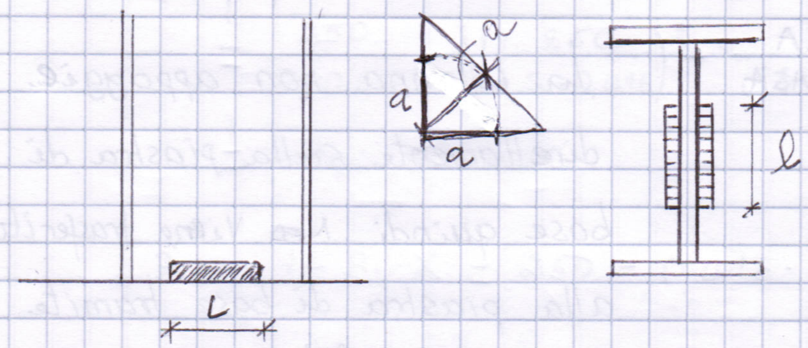
$$R = \sqrt{\left(F_{V,ED}^{(M_T)} + F_{V,ED}^{(N)}\right)^2 + F_{V,ED}^{(T)\,2}} = \sqrt{(6{,}56 + 7{,}5)^2 + 3{,}75^2} = 14{,}55\ KN = F_{V,ED}$$

$$F_{V,RD} = \frac{0{,}6 \cdot f_{ub} \cdot A_{res.}}{\gamma_{M_2}} = \frac{0{,}6 \cdot 800 \cdot 157}{1{,}25} = 60{,}29 > F_{V,ED}$$

(vi) (SALDATURA S235)

$N_{ED} = -45$ kN

$V_{ED} = 22,5$ kN



$a = 5$ mm

$l = 190$ mm

$$\tau_{//} = \frac{V_{ED}}{2 \cdot a \cdot l} = \frac{22500}{2 \cdot 5 \cdot 190} = 11,84 \text{ MPa}$$

$$\sigma_{\perp} = \frac{N_{ED}}{2 \cdot a \cdot l} = \frac{45000}{2 \cdot 5 \cdot 190} = 23,68 \text{ MPa}$$

(*) $\sqrt{\sigma_{\perp}^2 + \tau_{\perp}^2 + \tau_{//}^2} \leq \beta_1 \cdot f_{yk}$

(**) $|\sigma_{\perp}| + |\tau_{\perp}| \leq \beta_2 \cdot f_{yk}$

$f_{yk} = 235$ MPa

$\beta_1 = 0,85$ $\beta_2 = 1$

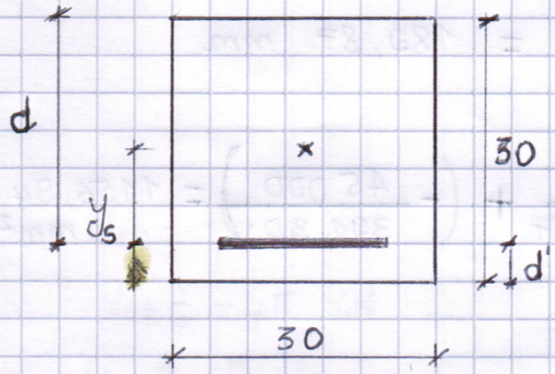
(*) $26,47 \leq \overbrace{0,85}^{\beta_1} \cdot 235$

(**) $23,68 \leq \overbrace{1}^{\beta_2} \cdot 235$

vii) Data una sezione in Calcestruzzo C25/30 ($\gamma_c = 1,5$) di dimensioni ($b \times h$) 30×30, dimensionare l'armatura longitudinale (Acciaio B450C, $\gamma_s = 1,15$) necessaria per assorbire le sollicitazioni agenti nella sezione A e rappresentare schematicamente la sezione armata;

Sezione A:

$T = 22,5$ KN $N = -45,0$ KN $M = 90,0$ KNm



Copriferro $c = 50$ mm

$$f_{cd} = \frac{0,85 \cdot 25}{1,50} = 14,17 \text{ MPa}$$

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{450}{1,15} = 391,30 \text{ MPa}$$

$$y_s = d - d' = 300 - 50 = 250 \text{ mm}$$

Assumendo un'approsimazione del tipo Parabola - Rettangolo:

$\beta_2 = 0,416$ $\beta_1 = 0,81$ $\varepsilon_{cu} = 3,5$ ‰ $E_s = 200\,000$ MPa

$$\varepsilon_{yd} = \frac{f_{yd}}{E_s} = \frac{391,3}{200\,000} = 1,96 \text{ ‰}$$

$$X_{lim} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} \cdot d$$

$$= \frac{0,0035}{0,0035 + 0,00196} \cdot 250 = 160,26 \text{ mm}$$

$$z_{lim} = d - \beta_2 \cdot X_{lim} = 250 - 0,416 \cdot 160,26 = 183,33 \text{ mm}$$

$$M_{Rd,lim} = b \cdot \beta_1 \cdot x_{lim} \cdot f_{cd} \cdot (d - \beta_2 \cdot x_{lim})$$

$$= 300 \cdot 0,81 \cdot 160,26 \cdot 14,17 \cdot (250 - 0,416 \cdot 160,26)$$

$$M_{Rd,lim} = 101,1670671 \text{ KNm}$$

$$M_{s,Ed} = M_{Ed} + N_{Ed} \cdot y_s$$ N_{Ed} essendo Negativo

$$= 90 \cdot 10^6 + 45 \cdot 10^3 \cdot 100$$

$$M_{s,Ed} = 94,5 \text{ KNm}$$

$M_{s,Ed} < M_{Rd,lim}$ cui assicura che basta l'armatura tesa.

Posizione del baricentro:

$$X = \frac{d}{2\cdot\beta_2} - \sqrt{\left(\frac{d}{2\cdot\beta_2}\right)^2 - \frac{M_{Esd}}{\beta_1\cdot\beta_2\cdot b\cdot f_{cd}}}$$

$$= \frac{250}{2\cdot 0{,}416} - \sqrt{\left(\frac{250}{2\cdot 0{,}416}\right)^2 - \frac{94{,}5\cdot 10^6}{0{,}81\cdot 0{,}416\cdot 300\cdot 14{,}17}}$$

$$= 144{,}53 \ mm$$

$$z = d - \beta_2\cdot X = 250 - 0{,}416\cdot 144{,}53 = 189{,}87 \ mm$$

$$A_s = \frac{M_{s,Ed}}{f_{yd}\cdot z} + \frac{N_{Ed}}{f_{yd}} = \frac{94{,}5\cdot 10^6}{391{,}30 + 189{,}87} + \left(-\frac{45\,000}{391{,}30}\right) = 1156{,}94 \ mm^2.$$

Assuma come armatura:

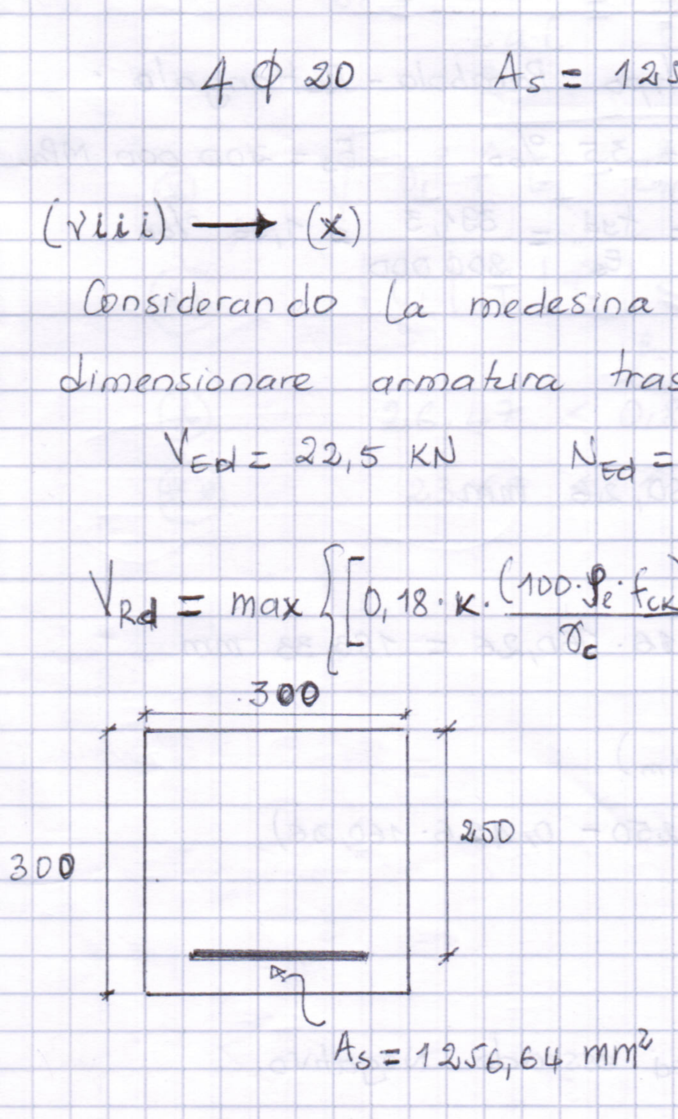
$4\phi 20 \qquad A_s = 1256{,}64 \ mm^2$

(viii) $\longrightarrow$ (x)

Considerando la medesima geometria e materiale del punto (vii), dimensionare armatura trasversale sez. A

$V_{Ed} = 22{,}5$ KN $\qquad N_{Ed} = -45$ KN $\qquad M_{Ed} = 90$ KNm

$$V_{Rd} = \max\left\{\left[0{,}18\cdot k\cdot\frac{(100\cdot\rho_e\cdot f_{ck})^{1/3}}{\gamma_c} + 0{,}15\cdot\sigma_{cp}\right] b_w\cdot d\,;\,(\nu_{min} + 0{,}15\cdot\sigma_{cp})\, b_w\cdot d\right\}$$



$$k = 1 + \left(\frac{200}{d}\right)^{1/2} = 1{,}894 < 2$$

$$\rho_e = \frac{A_s}{(b_w\cdot d)} = \frac{1256{,}64}{300\cdot 250} = 0{,}01675 < 0{,}02$$

③ $\sigma_c = \dfrac{|N_{Ed}|}{A_c} = \dfrac{45\,000}{90000} = 0{,}5 \text{ MPa}$

$$V_{min} = 0{,}035\ k^{3/2} \cdot f_{ck}^{1/2}$$

$$= 0{,}035 \cdot 1{,}894^{3/2} \cdot 25^{1/2}$$

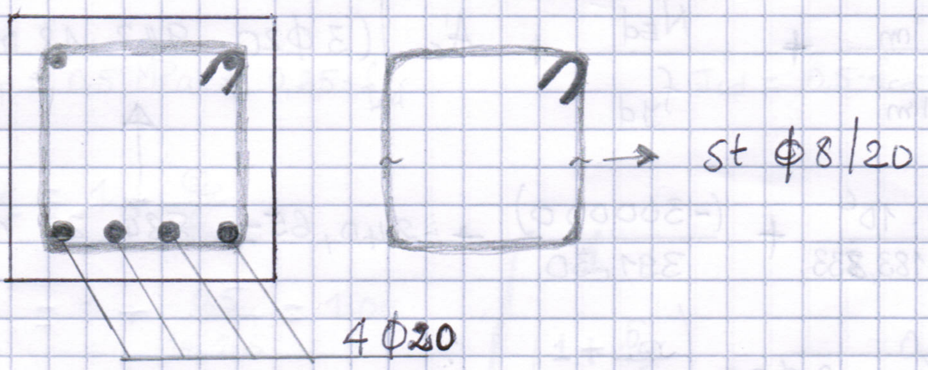
$$= 0{,}456$$

$$V_{Rd} = \max\left\{\left[0{,}18 \cdot 1{,}894 \cdot \frac{(100 \cdot 0{,}01675 \cdot 25)^{1/3}}{1{,}50} + 0{,}15 \cdot 0{,}5\right] \cdot 250 \cdot 300\ ;\ (0{,}456 + 0{,}15 \cdot 0{,}50) \cdot 250 \cdot 300\right\}$$

$$= \max\{64{,}8 \text{ KN}\ ;\ 39{,}85 \text{ KN}\}$$

$\Rightarrow V_{Rd} = 64{,}82$ KN

$$\begin{cases} S_{min} = 0{,}8 \cdot d = 200 \text{ mm} \\ A_{st,min} = 1{,}5 \cdot b_w = 450 \dfrac{mm^2}{m} = 450 \ mm^2/m \end{cases} \Longrightarrow \text{st } \phi 8/20 \quad A_{st} = 502{,}4 \ \frac{mm^2}{m}$$



(ix) Considerando la medesina geometria e materiali del punto (Vii), dimensionare l'armatura longitudinale necessaria per assorbire le sollicitazioni agenti nella sezione A, considerando uno sforzo normale di compressione agente nella sezione pari a $N_{Ed} = -300$ KN, e rappresentare schematicamente la sezione armata:

$N = -300$ KN $\qquad T = 22{,}5$ KN $\qquad M = 90{,}0$ KNm

CLS: C25/30 $\qquad f_{cd} = 14{,}17$ MPa

$\qquad f_{yd} = 391{,}30$ MPa

Assumendo un' approssimazione del tipo PARABOLA - RETTANGOLO

$$\begin{cases} x_{lim} = 160,26 \text{ mm} \\ z_{lim} = 183,33 \text{ mm} \\ M_{Rd,lim} = 101,167 \text{ mm} \end{cases}$$

$$M_{s,Ed} = M_{Ed} - N_{Ed} \cdot y_s = 90 \cdot 10^6 - (-300 \cdot 10^3 \cdot 100) = 120,00 \text{ kNm}$$

$M_{s,Ed} > M_{Rd,lim}$, Devo aggiungere armatura compressa

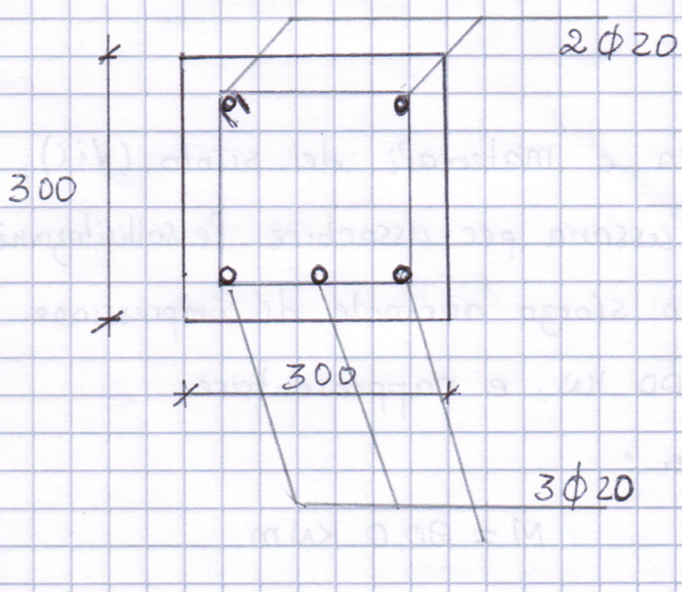
$$\Delta M_{s,Ed} = M_{s,Ed} - M_{Rd,lim} = 120,00 - 101,167$$

$$\Delta M_{s,Ed} = 18,833 \text{ kNm}$$

$$A'_s = \frac{\Delta M_{s,ed}}{f_{yd}(d-d')} = \frac{18,833 \cdot 10^6}{391,30\,(250-50)} = 240,65 \text{ mm}^2 \;(2\phi 20 \rightarrow 628,32 \text{ mm}^2)$$

$$A_s = \frac{M_{Rd,lim}}{f_{yd} \cdot z_{lim}} + \frac{N_{Ed}}{f_{yd}} + A'_s \quad \left[(3\phi 20 \;\; 942,48 \text{ mm}^2)\right]$$

$$= \frac{101,167 \cdot 10^6}{391,30 \cdot 183,333} + \frac{(-300000)}{391,30} + 240,65 = 884,22 \text{ mm}^2$$

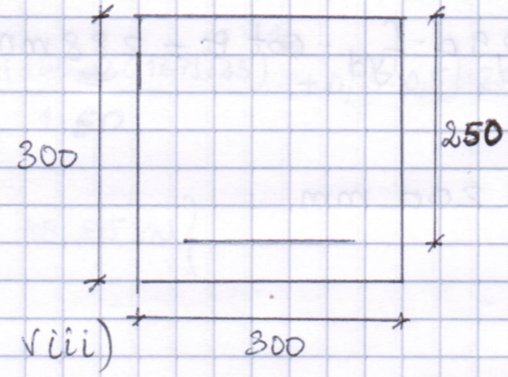


(x) Considerando la medesima geometria e materiali del punto (viii), dimensionare l'armatura trasversale eventualmente necessaria per assorbire le sollecitazioni agenti nella sezione A, considerando che il taglio agente sia $V_{Ed} = 120$ KN, e rappresentare schematicamente la sezione armata

Sezione A.

$N_{Ed} = -45$ KN

$V_{Ed} = 120$ KN



$\sigma_{cp} = \frac{N_{Ed}}{b_w \cdot d} = \frac{45000}{300 \cdot 300} \overset{!}{=} 0{,}5$ MPa

$V_{Rd,c} = 64{,}82$ KN (Dal punto viii)

$$\begin{cases} V_{RD,SD} = \frac{A_{SW}}{s} \cdot 0{,}9 \cdot d \cdot f_{yd} \cdot \cot\theta \\ V_{RD,CD} = 0{,}9 \cdot d \cdot b_w \cdot \alpha_c \cdot f'_{cd} \cdot \frac{1}{\cot\theta + \tan\theta} \end{cases}$$

$\sigma_{cp} = 0{,}5$ MPa $\leq 0{,}25 \cdot f_{cd}$

$f'_{cd} = 0{,}5 \cdot f_{cd} = 0{,}5 \cdot 14{,}17 = 7{,}0833$ MPa

$\alpha_c = 1 + \frac{\sigma_{cp}}{f_{cd}} \overset{!}{=} 1 + \frac{0{,}5}{14{,}166} = 1{,}04$

$$\alpha_c = \begin{cases} 1 & \sigma_{cp} = 0 \\ \left(1 + \frac{\sigma_{cp}}{f_{cd}}\right) & 0 \leq \sigma_{cp} < 0{,}25 \cdot f_{cd} \\ 1{,}25 & 0{,}85 \cdot f_{cd} \leq \sigma_{cp} \leq 0{,}5 \cdot f_{cd} \\ 2{,}5\left(1 - \frac{\sigma_{cp}}{f_{cd}}\right) & 0{,}5 f_{cd} < \sigma_c < f_{cd} \end{cases}$$

$\theta = 21{,}8°$

$$\begin{cases} \cot\theta = 2{,}5 \\ \tan\theta = 0{,}4 \end{cases}$$

Scelgo staffe $\phi 10$ $A_{SW} = 157$ mm² (2 bracci)

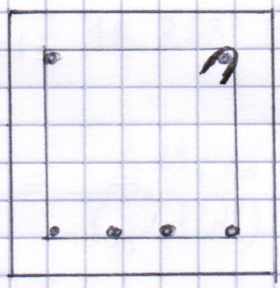
$A_{st} = \frac{A_{SW}}{s} = 785 \frac{mm^2}{m} > A_{st,min}$

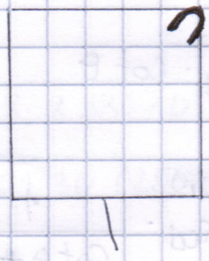
Dove

$$\begin{cases} A_{st,min} = 1{,}5 \cdot b_w = 1{,}5 \cdot 300 = 450 \ \frac{mm^2}{m} \\ S_{min} = \min \{ 0{,}8 \cdot d = 200 \ mm \ ; \ 333 \ mm \} \end{cases}$$

$$S = \frac{A_{sw}}{V_{Ed}} \cdot 0{,}9\, d \cdot f_{yd} \cdot \cot \theta = 288 \ mm$$

$\longrightarrow$ $S = 200 \ mm$





St $\phi_{10/20}$