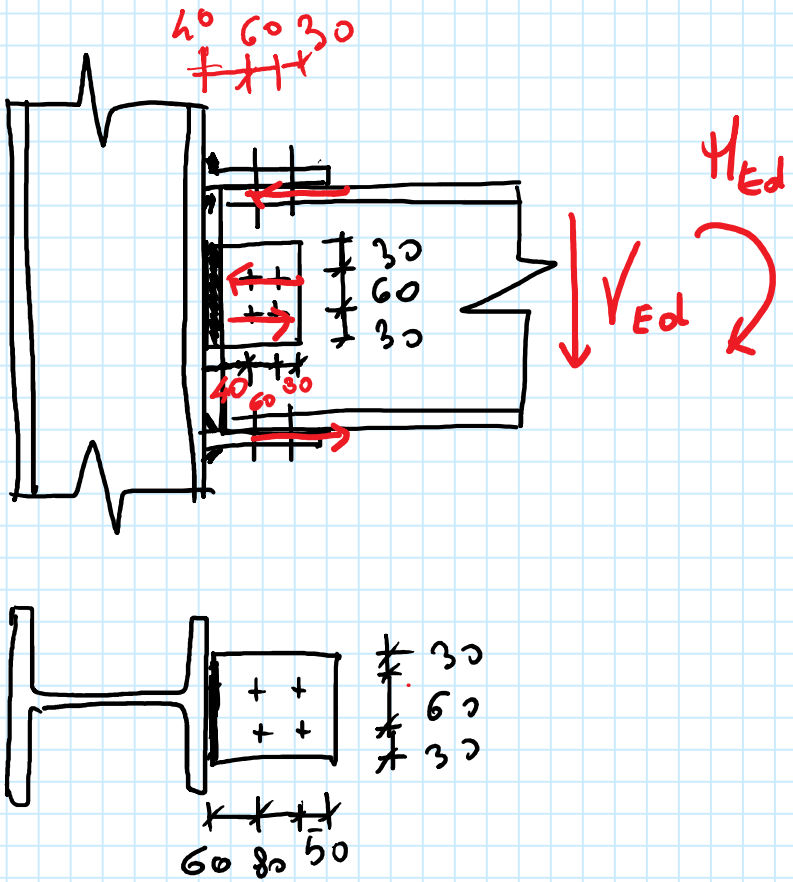


Trem IPE 240 S235

M_{Ed} = 60 kNm V_{Ed} = 70 kN

Ali	M18	8.8	fila lati estremità
Anima	M16	5.6	

a_{ali} = 15 mm

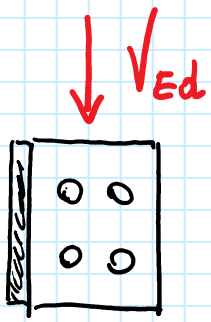
a_{anima} = 10 mm

l_{ali} = 120 mm

l_{anima} = 110 mm

t_p = 10 mm

Verifica a taglio dei bulloni



sigla	M12	M14	M16	M18
A (mm^2)	113	154	201	254
A_{res} (mm^2)	84.3	115	157	192
A_{res} / A	0.75	0.75	0.78	0.75

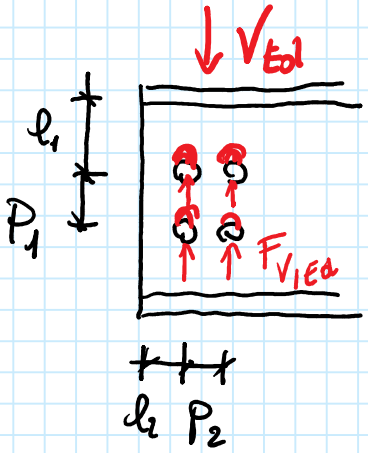
$$F_{V,Ed} = \frac{V_{Ed}}{4} = \frac{70}{4} = 17,5 \text{ KN}$$

$$F_{V,Rd} = 0,6\, A\, \frac{f_{ub}}{\gamma_{M2}} = 0,6 \times 201 \times \frac{500}{1,25} \times \frac{1}{10^3} = 48,2 \text{ KN}$$

$$F_{V,Ed} = 17,5 \text{ KN} \leq F_{V,Rd} = 48,2 \text{ KN}$$

OK!

Verifica a rifollamento dell'anima delle travi



$$F_{V,Ed} = 17,5 \text{ KN}$$

$$K = 2,5$$

$$\alpha = \frac{e_1}{3 d_0} > 1 \Rightarrow \alpha = 1 \qquad \alpha = \frac{p_1}{3 d_0} - 0,25 \qquad \alpha = 0,926$$

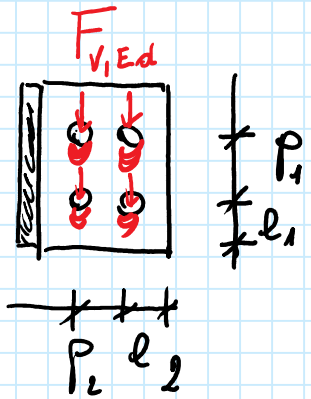
$$F_{b,Rd} = 2,5 \times 0,926 \times 16 \times 6,2 \times \frac{360}{1,25} \times \frac{1}{10^3} = 66,2 \text{ KN}$$

$$F_{V,Rd} = 17,5 \text{ KN} \leq F_{b,Rd} = 66,2 \text{ KN}$$

OK!

Verifica a rifollamento delle piastre

$F_{V,Ed} = 17,5 \text{ KN}$



$$F_{b,Rd} = k \alpha d t \frac{f_u}{\gamma_{M2}}$$

$$\frac{e_2}{d_0} = \frac{30}{17} = 1,76 > 1,5$$

$$\frac{p_2}{d_0} = \frac{60}{17} = 3,52 > 3,0$$

$\Rightarrow \quad k = 2,5$

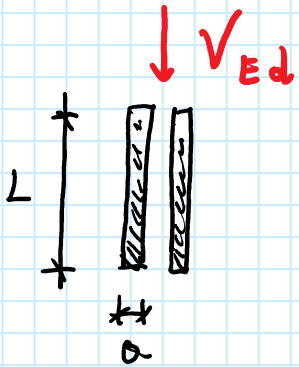
$$\alpha = \frac{e_1}{3 d_0} = \frac{30}{3 \times 17} = 0,5882$$

$$\alpha = \frac{p_1}{3 d_0} - 0,25 = \frac{60}{3 \times 17} - 0,25 = 0,9264$$

$$F_{b,Rd} = 2,5 \times 0,5882 \times 16 \times 10 \times \frac{360}{1,25} \times \frac{1}{10^3} = 67,7 \text{ KN}$$

$$F_{v,Ed} = 17,5 \text{ KN} \leq F_{b,Rd} = 67,7 \text{ KN}$$ OK!

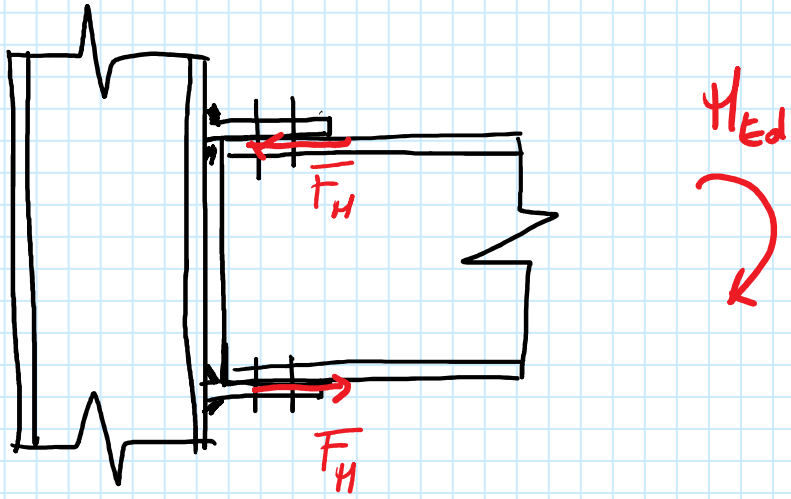
Verifica del cordone



$$t = \frac{V_{Ed}}{2aL} = \frac{70 \times 10^3}{2 \times 10 \times 120} = 29,2 \text{ MPa}$$

$$f_{v,w,d} = \frac{f_u}{\sqrt{3}\,\beta_w \gamma_{M2}} = \frac{360}{\sqrt{3} \times 0,8 \times 1,25} = 207,8 \text{ MPa}$$

$$t = 29,2 \text{ MPa} \leq f_{v,w,d} = 207,8 \text{ MPa}$$ OK!



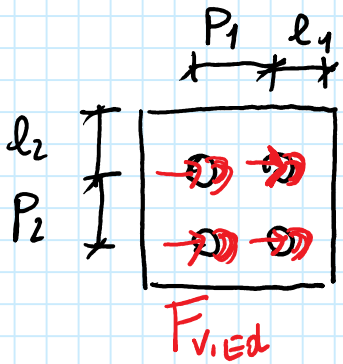
sigla	M12	M14	M16	M18
A (mm^2)	113	154	201	254
A_{res} (mm^2)	84.3	115	157	192
A_{res} / A	0.75	0.75	0.78	0.75

$$F_H = \frac{M_{Ed}}{h} = \frac{60}{0,24} = 250\ KN$$

$$F_{V,Ed} = \frac{250}{4} = 62,5\ KN$$

$$F_{V,Rd} = 0,6\ A\ \frac{f_{ub}}{\gamma_{M2}} = 0,6 \times 254 \times \frac{800}{1,25} \times \frac{1}{10^3} = 97,5\ KN$$

$$F_{V,Ed} = 62,5\ KN \leq F_{V,Rd} = 97,5\ KN \qquad OK!$$



$$F_{V,Ed} = 62,5 \text{ KN}$$

$$\frac{e_2}{d_0} = \frac{30}{19} = 1,57 > 1,5$$

$$\frac{P_2}{d_0} = \frac{60}{19} = 3,15 > 3,0$$

$$\Rightarrow \quad k = 2.5$$

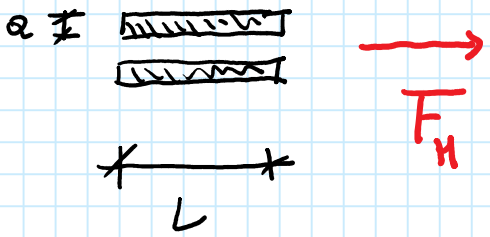
$$\alpha = \frac{e_1}{3d_0} = \frac{50}{3 \times 19} = 0,8771$$

$$\alpha = \frac{P_1}{3d_0} - 0,25 = \frac{80}{3 \times 19} - 0,25 = 1,15 \rightarrow 1,0$$

$$F_{b,Rd} = 2,5 \times 0,8771 \times 18 \times 9,8 \times \frac{360}{1,25} \times \frac{1}{10^3} = 111,4 \text{ KN}$$

$$F_{V,Ed} = 62,5 \text{ KN} \leq F_{b,Rd} = 111,4 \text{ KN} \qquad \text{OK!}$$

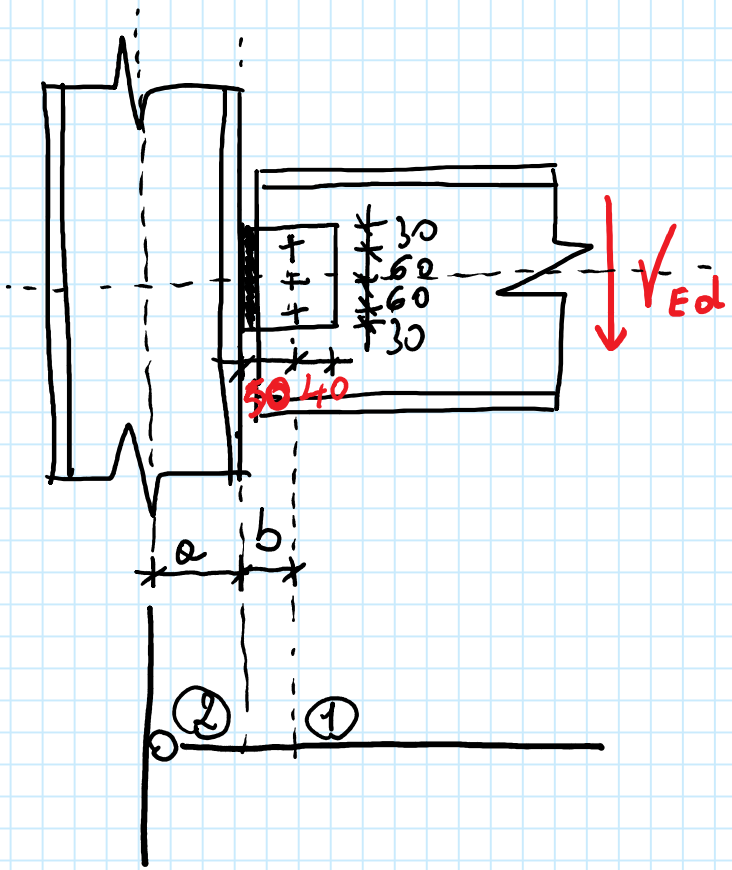
Verifica dei cordoni d'angolo

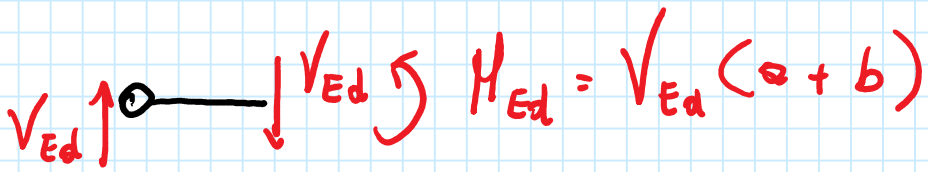


$$t = \frac{F_H}{2aL} = \frac{250}{2 \times 15 \times 120} \times 10^3 = 69{,}4 \text{ MPa}$$

$$f_{v,w,d} = 207{,}8 \text{ MPa}$$

$$t = 69{,}4 \text{ MPa} < f_{v,w,d} = 207{,}8 \text{ MPa}$$ Ok!





Colonne HEB 160

Trem IPE 240 S235

V_{Ed} : 70 kN

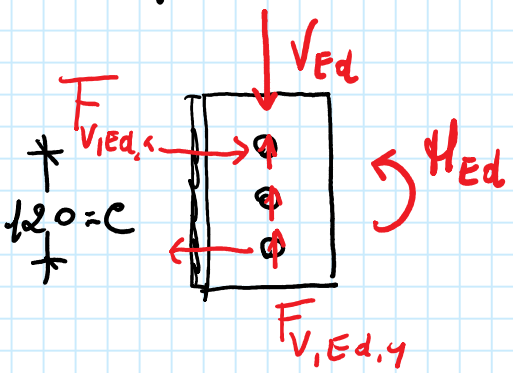
3 M18 8.8 filletti all'estremità

a : 10 mm

L = 180 mm

t_p = 10 mm

Verifica dei bulloni



$$V_{Ed} = 70.0 \text{ kN}$$

$$M_{Ed} = 70,0 \times \left(\frac{0,16}{2} + 0,05 \right) = 9,1 \text{ kNm}$$

$$F_{V,Ed,y} = \frac{V_{Ed}}{3} = \frac{70.0}{3} = 23,3 \text{ kN}$$

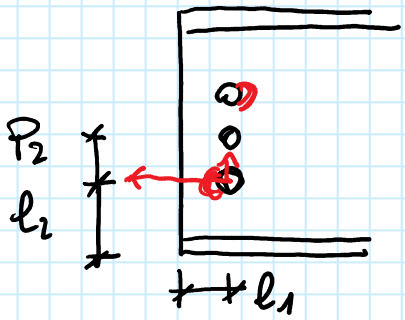
$$F_{V,Ed,x} = \frac{M_{Ed}}{c} = \frac{9,1}{0,12} = 75,8 \text{ kN}$$

$$F_{V,Ed} = \sqrt{F_{V,Ed,x}^2 + F_{V,Ed,y}^2} = \sqrt{75,8^2 + 23,3^2} = 79,3 \text{ kN}$$

$$F_{V,Rd} = 0,6 \, A \, \frac{f_{ub}}{\gamma_{M2}} = 94,5 \text{ kN}$$

OK!

Verifica a rifollamento dell'anima delle trave



$$F_{V,Ed} = 79,3 \text{ kN}$$

$$\frac{l_2}{d_0} = \frac{60}{19} = 3,16 > 1,5$$

$$\frac{p_2}{d_0} = \frac{60}{19} = 3,16 > 3,0$$

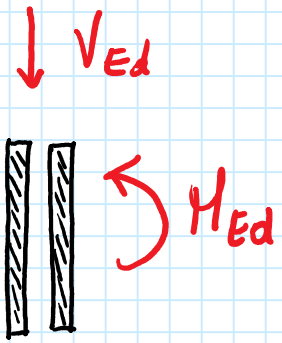
$$\Rightarrow \quad k = 2,5$$

$$\alpha = \frac{l_1}{3 d_0} = \frac{40}{3 \times 19} = 0,7018$$

$$F_{b,Rd} = 2,5 \times 0,7018 \times 18 \times 6,2 \times \frac{360}{1,25} \times \frac{1}{10^3} = 56,4 \text{ kN}$$

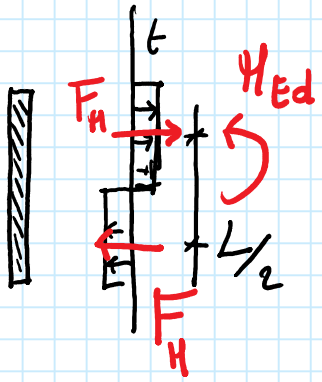
$$F_{V,Ed} = 79,3 \text{ kN} \leq F_{b,Rd} = 56,4 \text{ kN} \qquad \text{NO}$$

Verifica dei cordoni d'angolo



$$V_{Ed} = 70 \text{ kN}$$

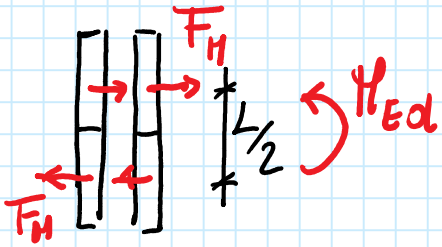
$$M_{Ed} = V_{Ed}\, a = 70{,}0 \times \frac{0{,}16}{2} = 5{,}6 \text{ kN}$$



Il momento è sopportato attraverso il campo di tensioni t indicato in figura.

Il diagramma delle t è costante a tratti perché si assume il cordone plasticizzato.

$$F_V = \frac{V_{Ed}}{4} = \frac{70}{4} = 17,5 \text{ kN}$$



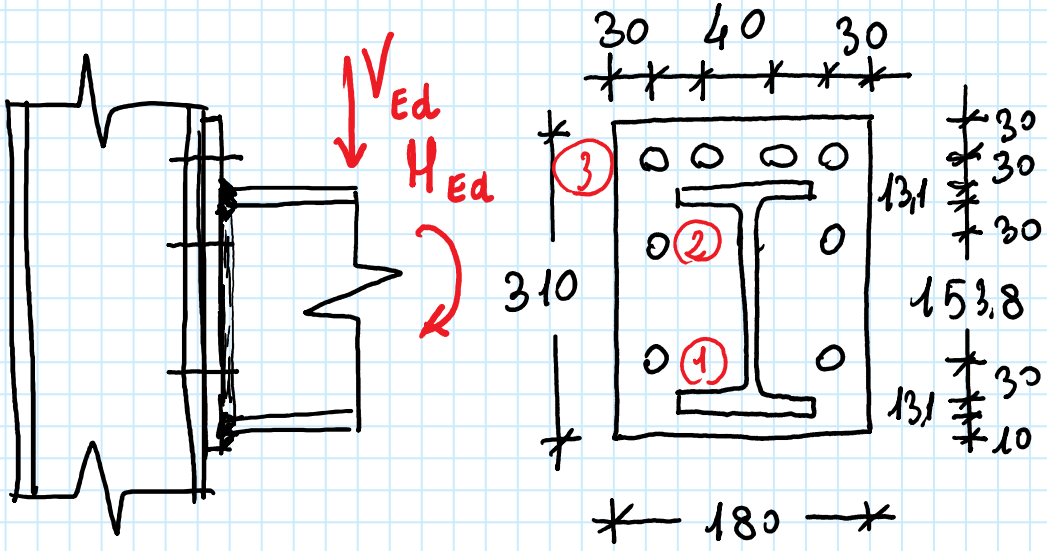
$$F_H = \frac{M_{Ed}}{2 \times L/2} = \frac{M_{Ed}}{L} = \frac{5,6}{0,18} = 31,1 \text{ kN}$$

$$F_{w,Ed} = \sqrt{F_H^2 + F_V^2} = \sqrt{31,1^2 + 17,5^2} = 35,7 \text{ kN}$$

$$t = \frac{F_{w,Ed}}{a \, L/2} = \frac{35,7}{10 \times \frac{180}{2}} \times 10^3 = 39,6 \text{ MPa}$$

$$f_{v,w,d} = 207,8 \text{ MPa}$$

$$t = 39,6 \text{ MPa} \leq f_{v,w,d} = 207,8 \text{ MPa}$$ OK!



Colonne HEB 200 S235

Trem IPE 240 S235

H_{Ed}: 60 KNm V_{Ed}: 70 KN

M 16 6.8 filetti all'estremità

Saldature a completa penetrazione su ali e anime

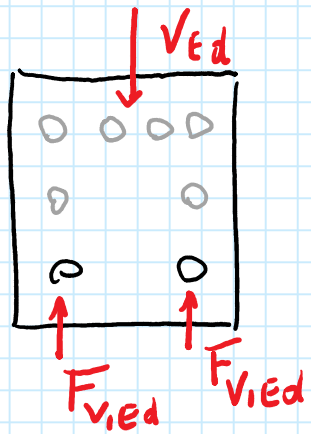
t_p = 30 mm S235

Verifica dei bulloni

Decidiamo come far lavorare i bulloni per portare V_{Ed} ed M_{Ed}

1. Ai bulloni ① facciamo portare il taglio
2. Ai bulloni ② e ③ facciamo portare il momento

Verifica dei bulloni ①



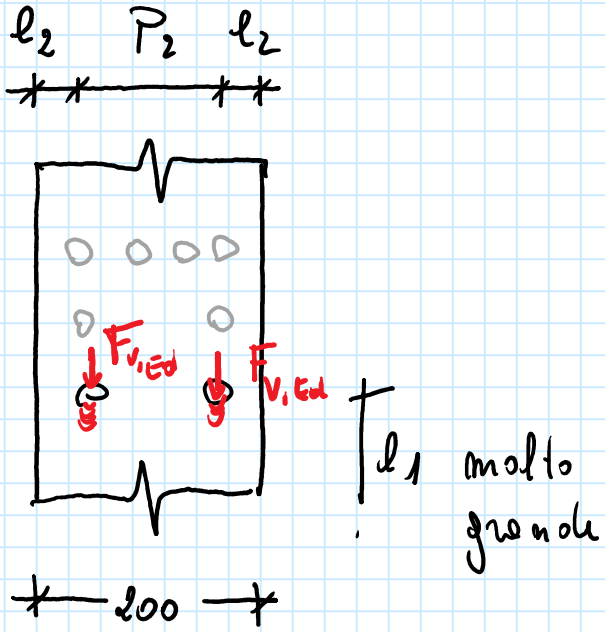
$$F_{V,Ed} = \frac{V_{Ed}}{2} = \frac{70}{2} = 35,0\ kN$$

$$F_{V,Rd} = 0,6\ A\ \frac{f_{ub}}{\gamma_{M2}} = 0,6 \times 201 \times \frac{600}{1,25} \times \frac{1}{10^3} = 57,9\ kN$$

$$F_{V,Ed} = 35,0\ kN \leq F_{V,Rd} = 57,9\ kN \quad \text{OK!}$$

Verifiche a rifollamento

Colonne



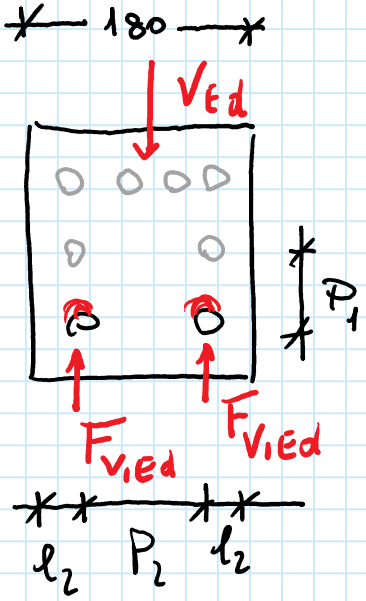
$t_f = 15$ mm

e_1 molto grande $\Longrightarrow \alpha = 1$

$e_2 = 40$ mm

$P_2 = 120$ mm

Piastre



$t_p = 30$ mm

$P_1 = 153{,}8$ mm

$e_2 = 30$ mm

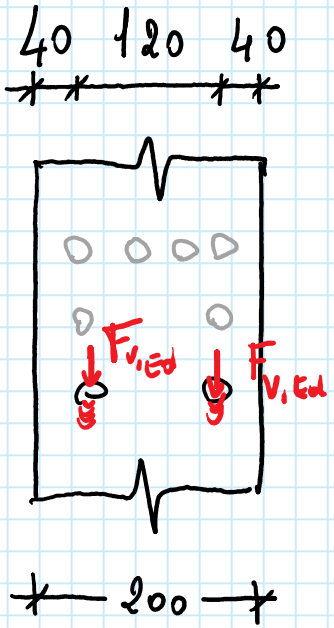
$P_2 = 120$ mm

$\alpha = 1{,}0$ nei due casi

La verifica è più gravosa per le flangie delle colonne che ha spessore minore.

$$\alpha = \frac{153{,}8}{3 \times 14} - 0{,}25 = \cancel{2{,}47}\ 1{,}0$$

Verifica a rifollamento delle piastre



$$\frac{e_2}{d_0} = \frac{40}{17} = 2,35 > 1,5$$

$$\frac{p_2}{d_0} = \frac{120}{17} = 7,06 > 3,0$$

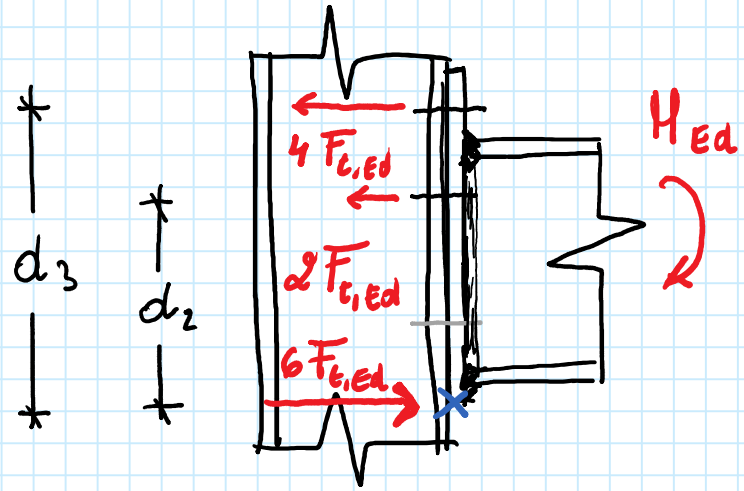
$$\Rightarrow k = 2,5$$

$$\alpha = 1,0$$

$$F_{b,Rd} = k\,\alpha\,d\,t\,\frac{f_u}{\gamma_{M2}} = 2,5 \times 1 \times 16 \times 15 \times \frac{360}{1,25} \times \frac{1}{10^3} = 172,8 \text{ KN}$$

$$F_{V,Ed} = 35,0 \text{ KN} \leq F_{b,Rd} = 172,8 \text{ KN} \quad \text{OK!}$$

Verifica dei bulloni ② e ③



$d_2 = 10 + 13{,}1 + 30 + 153{,}8 = 206{,}9$ mm

$d_3 = 206.9 + 30 + 13{,}1 + 30 = 280$ mm

Dall'equilibrio alla rotazione rispetto a × determiniamo le forze di trazione nei bulloni:

$$2\,F_{t,Ed}\,d_2 + 4\,F_{t,Ed}\,d_1 = M_{Ed}$$

$$F_{t,Ed} = \frac{M_{Ed}}{2\,d_2 + 4\,d_3} = \frac{60{,}0}{2 \times 0{,}2069 + 4 \times 0{,}28} = 39{,}1 \text{ KN}$$

OK!

$$F_{t,Rd} = 0{,}9\,A_{res}\,\frac{f_{ub}}{\gamma_{M2}} = 0{,}9 \times 154 \times \frac{600}{1{,}25} \times \frac{1}{10^3} = 67{,}8 \text{ KN}$$

Verifica a punzonamento

$F_{t,Ed} = 39,1\ kN$

Verifico la lamiera di spessore minore, la flangia della colonna.

$t = t_f = 15\ mm$

$d_1 = 30,14\ mm \quad d_2 = 26,67\ mm \quad d_m = \frac{30,14 + 26,67}{2} = 28,41\ mm$

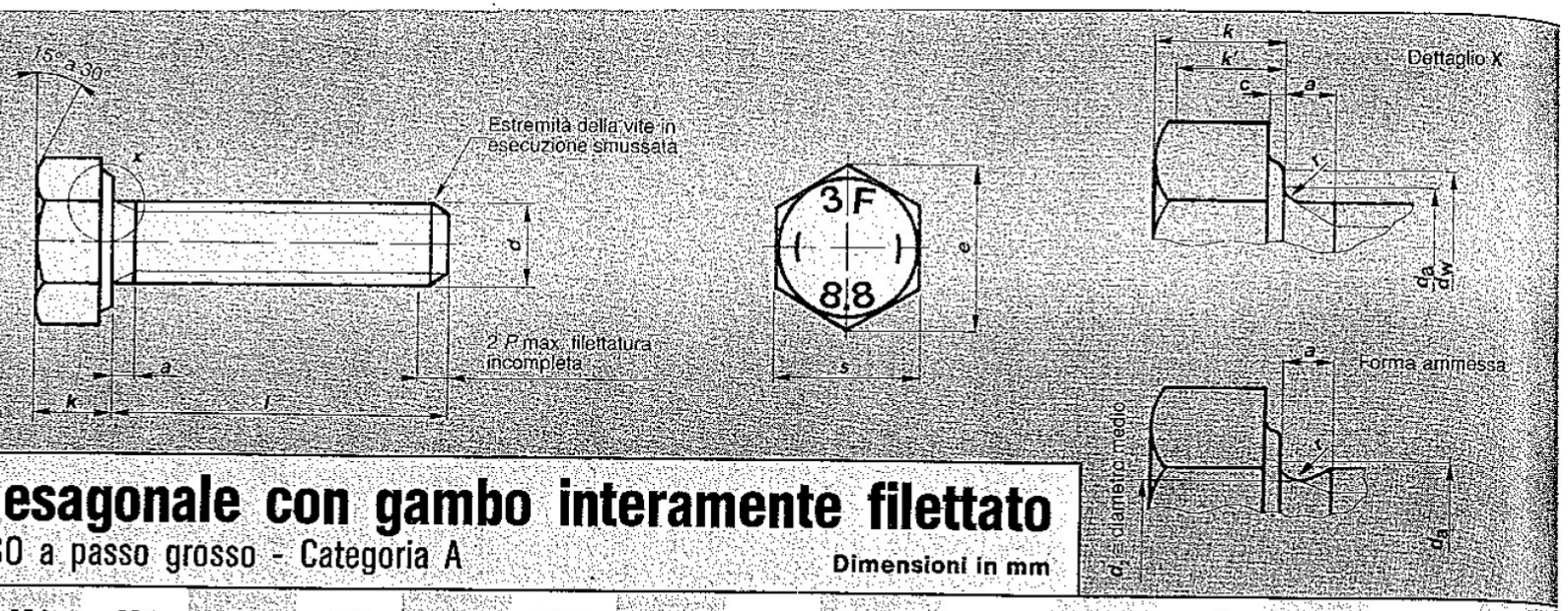
$$B_{p,Rd} = 0,6\,\pi\, d_m\, t\, \frac{f_u}{\gamma_{M2}} = 0,6 \times 3,14 \times 28,41 \times 15 \times \frac{360}{1,25} \times \frac{1}{10^3} = 231,2\ kN$$

$F_{t,Ed} = 39,1\ kN \leq B_{p,Rd} = 231,2\ kN$ OK!

FONTANA

ESTRATTO

UNI 5739



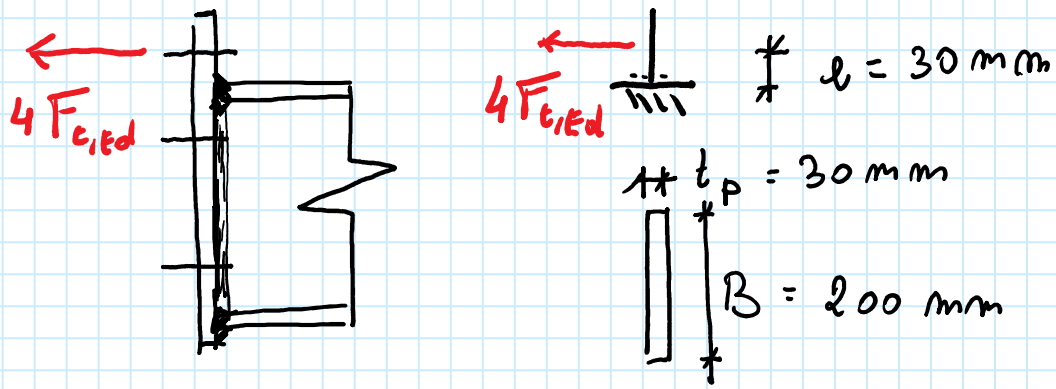
Viti a testa esagonale con gambo interamente filettato

Filettatura metrica ISO a passo grosso - Categoria A

Dimensioni in mm

filettatura *d*		M4	M5	M6	M7	M8	M10	M12	M14	M16	M18	M20	M22	M24	M27	M30
passo *P*		0,7	0,8	1	1	1,25	1,5	1,75	2	2	2,5	2,5	2,5	3	3	3,5
a	max.	2,1	2,4	3	3	3,75	4,5	5,25	6	6	7,5	7,5	7,5	9	9	10,5
	min.	0,7	0,8	1	1	1,25	1,5	1,75	2	2	2,5	2,5	2,5	3	3	3,5
c	min.	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,2	0,2	0,2	0,2	0,2	0,2	0,2
	max.	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,8	0,8	0,8	0,8	0,8	0,8	0,8
d_a	max.	4,7	5,7	6,8	7,8	9,2	11,2	13,7	15,7	17,7	20,2	22,4	24,4	26,4	30,4	33,4
d_w	min.	5,9	6,9	8,9	9,6	11,6	15,6	17,4	20,5	22,5	25,3	28,2	30	33,6	38	42,7
e	min.	7,66	8,79	11,05	12,12	14,38	18,90	21,10	24,49	26,75	30,14	35,53	35,72	39,98	45,20	50,85
k	min.	2,68	3,35	3,85	4,65	5,15	6,22	7,32	8,62	9,82	11,28	12,28	13,78	14,78	16,65	18,28
	max.	2,92	3,65	4,15	4,95	5,45	6,58	7,68	8,98	10,18	11,72	12,72	14,22	15,22	17,35	19,12
k'	min.	1,9	2,3	2,7	3,2	3,6	4,4	5,1	6	6,9	7,9	8,6	9,6	10,3	11,7	12,8
r	min.	0,2	0,2	0,25	0,25	0,4	0,4	0,6	0,6	0,6	0,6	0,8	0,8	0,8	1	1
s	max.	7	8	10	11	13	17	19	22	24	27	30	32	36	41	46
	min.	6,78	7,78	9,78	10,73	12,73	16,73	18,67	21,67	23,67	26,67	29,67	31,61	35,38	40	45
l																

Verifica a flessione delle piastre



Sezione resistente delle piastre.

Le forze trasmesse dai bulloni generano flessione nelle piastre. Se le piastre si plasticizzano non riescirà più a trasmettere il momento ai bulloni. Dobbiamo fare la verifica a flessione delle piastre.

$$M_{Ed} = 4 F_{t,Ed}\, l = 4 \times 39{,}1 \times 0{,}03 = 4{,}7\ KN\,m$$

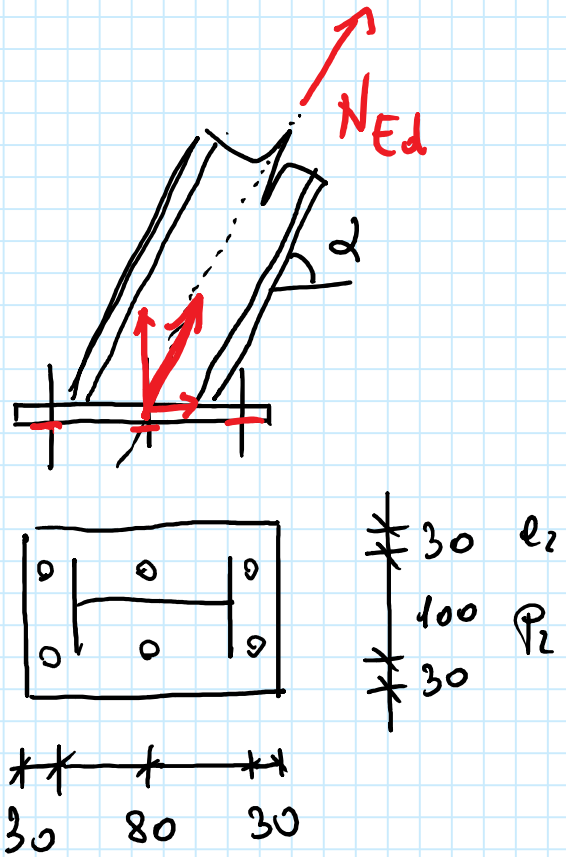
$$M_{pl,Rd} = W_{pl} \frac{f_y}{\gamma_{M0}} = 45 \times \frac{235}{1{,}05} \times \frac{1}{10^3} = 10{,}1\ KN\,m$$

$$W_{pl} = 2\,S_{1/2} = 2\,B\,\frac{t_p}{2}\,\frac{t_p}{4} = 20 \times \frac{3{,}0^2}{4} = 45\ cm^3$$

$M_{Ed} = 4{,}7\ KN\,m$ OK!

$\leq$

$M_{pl,Rd} = 10{,}1\ KN\,m$



$N_{Ed} = 200$ kN

M 14 6.8 foli Hot. estremità

$t_p = 14$ mm

$\alpha = 60°$

Verifica dei bulloni

$$F_{v,Ed} = \frac{N_{Ed}}{n_b} \cos\alpha = \frac{200}{6} \cos 60° = 16{,}67 \text{ kN}$$

$$F_{t,Ed} = \frac{N_{Ed}}{n_b} \sin\alpha = \frac{200}{6} \sin 60° = 28{,}87 \text{ kN}$$

$$F_{v,Rd} = 0{,}6\, A\, \frac{f_{ub}}{\gamma_{M_2}} = 0{,}6 \times 154 \times \frac{600}{1{,}25} \times \frac{1}{10^3} = 44{,}35 \text{ kN}$$

$$F_{t,Rd} = 0{,}9\, A_{res}\, \frac{f_{ub}}{\gamma_{M_2}} = 0{,}9 \times 115 \times \frac{600}{1{,}25} \times \frac{1}{10^3} = 49{,}68 \text{ kN}$$

$$\begin{cases} \dfrac{F_{v,Ed}}{F_{v,Rd}} + \dfrac{F_{t,Ed}}{1{,}4\, F_{t,Rd}} = \dfrac{16{,}67}{44{,}35} + \dfrac{28{,}87}{1{,}4 \times 49{,}68} = 0{,}78 < 1 \\ F_{t,Ed} = 28{,}87 \text{ kN} < F_{t,Rd} = 49{,}68 \text{ kN} \end{cases}$$

OK!

Rifollamento

$F_{Ed} = F_{V,Ed} = 16,67$

$F_{Ed} < F_{b,Rd}$ OK!

$$F_{b,Rd} = k_2 \, d \, t \, \frac{f_u}{\gamma_{M2}} = 2,5 \times 0,667 \times 14 \times 14 \times \frac{360}{1,25} \times \frac{1}{10^3} = 94,08 \text{ kN}$$

$$\frac{e_2}{d_0} = \frac{30}{15} = 2 > 1,5$$

$$\frac{p_2}{d_0} = \frac{100}{15} = 6,67 > 3$$

$\Rightarrow \quad k = 2,5$

$$\alpha = \frac{l_1}{3 d_0} = \frac{30}{3 \times 15} = 0,6667$$

$$\alpha = \frac{P_1}{30} - 0,25 = \frac{80}{3 \times 15} - 0,25 = 1,53$$

$$\frac{f_{mb}}{f_m} > 1$$

Punzonamento

$$F_{Ed} = F_{t,Ed} = \underline{28,87}\ KN \qquad F_{Ed} < B_{p,Rd} \quad OK!$$

$$B_{p,Rd} = 0,6\,\pi\, d_m\, t\, \frac{f_u}{\gamma_{M2}} = 0,6 \times 3,14 \times 23,08 \times 14 \times \frac{360}{1,25} \times \frac{1}{10^3}$$

$$= \underline{175,32}\ KN$$

$$\left.\begin{array}{l} d_1 = 21,67\ mm \\ d_2 = 24,49\ mm \end{array}\right| \Rightarrow \quad d_m = \frac{21,67 + 24,49}{2} = 23,08\ mm$$