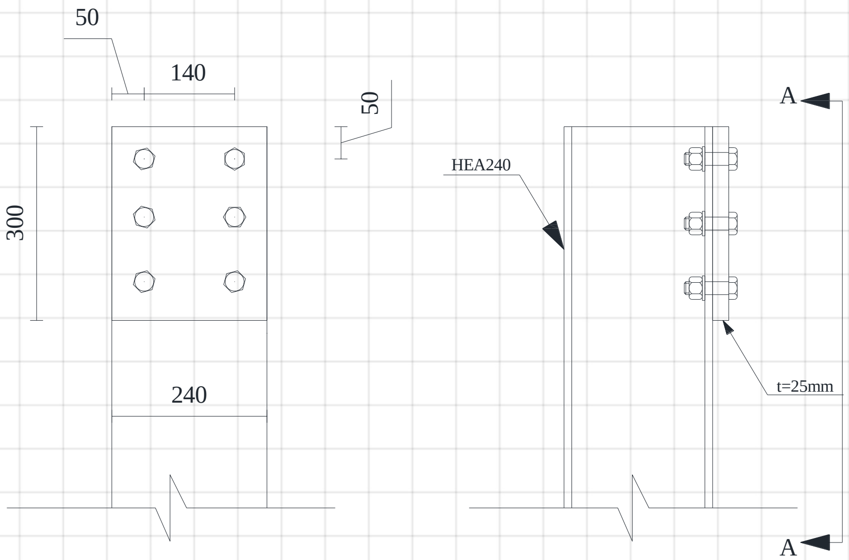
In this video, three different bolt sizes are used for a thick plate connected to the top of a column, HEA240 steel class S235 to show how the bolt size affects the failure mode of a T-Stub.

a) Determine the effective length for circular and non-circular patterns for the first row of the bolts on the top.

For three bolt diameter, M20, M12 and M8 with the class of 8.8, determine:

b) Each failure mode resistance.
c) Prying force, if applicable, for each mode.
d) Dominant failure mode and possible failure pattern schematically.

All dimensions in the figure are in mm.



Sec A-A

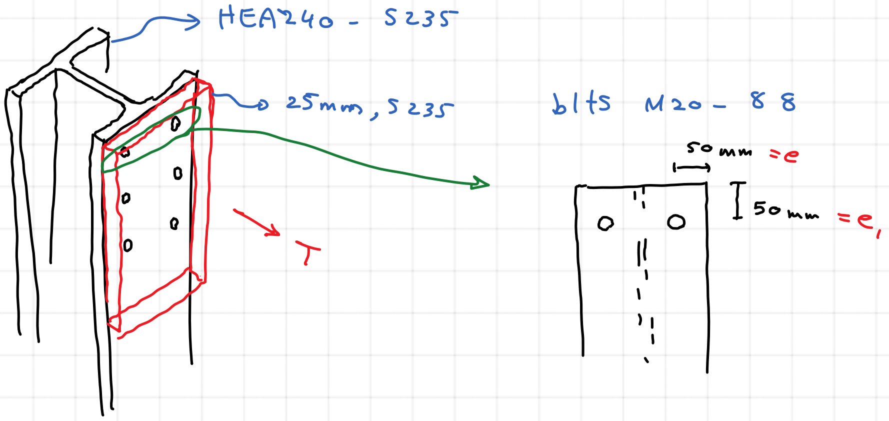
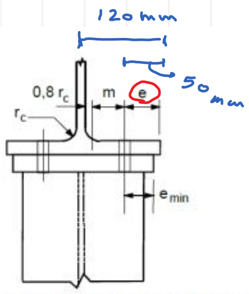


Table 6.4: Effective lengths for an unstiffened column flange

Bolt-row Location	Bolt-row considered individually		Bolt-row considered as part of a group of bolt-rows	
	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$
Inner bolt-row	$2\pi m$	$4m + 1{,}25e$	$2p$	p
End bolt-row	The smaller of: $2\pi m$ $\pi m + 2e_1$	The smaller of: $4m + 1{,}25e$ $2m + 0{,}625e + e_1$	The smaller of: $\pi m + p$ $2e_1 + p$	The smaller of: $2m + 0{,}625e + 0{,}5p$ $e_1 + 0{,}5p$
Mode 1:	$\ell_{eff,1} = \ell_{eff,nc}$ but $\ell_{eff,1} \le \ell_{eff,cp}$		$\sum\ell_{eff,1} = \sum\ell_{eff,nc}$ but $\sum\ell_{eff,1} \le \sum\ell_{eff,cp}$	
Mode 2:	$\ell_{eff,2} = \ell_{eff,nc}$		$\sum\ell_{eff,2} = \sum\ell_{eff,nc}$	

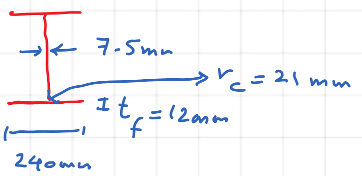
$e_1 = 50mm$

$e = 50mm$



a) Welded end-plate narrower than column flange.

HEA 240



$m = 120\,mm - 50\,mm - \frac{7.5\,mm}{2} - 0.8 \times 21\,mm = 49.45\,mm$

$e_{min} = 50\,mm$

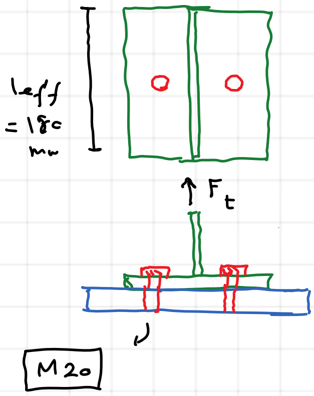
cp: $\begin{cases} l_{eff} = 2\pi m = 311\,mm \\ l_{eff} = \pi m + 2e_1 = 255\,mm \end{cases}$

nc: $\begin{cases} l_{eff} = 4m + 1.25e = 260\,mm \\ l_{eff} = 2m + 0.625e + e_1 = 180\,mm \end{cases}$

$l_{eff.cp} = 255\,mm$

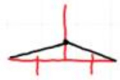
$l_{eff.nc} = 180\,mm$

$\begin{cases} \text{Mode 1: } l_{eff,1} = \min\{l_{eff.nc}, l_{eff.cp}\} = 180\,mm \\ \text{Mode 2: } l_{eff,2} = l_{eff.nc} = 180\,mm \end{cases}$

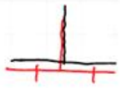


Mode 1 → Weak flange strong bolt ⇒

Mode 2 → moderate flange & bolt ⇒



Mode 3 → Strong flange weak bolt ⇒



$$M20 \rightarrow A_s = 245\ mm^2 \rightarrow F_{t,Rd} = \frac{0.9\, A_s\, f_{ub}}{\gamma_{M2}} = 141\ kN$$

(A_s = 245 mm², f_{ub} = 800 MPa, γ_{M2} = 1.25)

Table 6.2: Design Resistance $F_{T,Rd}$ of a T-stub flange

	Prying forces may develop, i.e. $L_b \leq L_b^*$		No prying forces
Mode 1	Method 1	Method 2 (alternative method)	$F_{T,1\text{-}2,Rd} = \frac{2M_{pl,1,Rd}}{m}$
without backing plates	$F_{T,1,Rd} = \frac{4M_{pl,1,Rd}}{m}$	$F_{T,1,Rd} = \frac{(8n-2e_w)M_{pl,1,Rd}}{2mn-e_w(m+n)}$	
with backing plates	$F_{T,1,Rd} = \frac{4M_{pl,1,Rd}+2M_{bp,Rd}}{m}$	$F_{T,1,Rd} = \frac{(8n-2e_w)M_{pl,1,Rd}+4nM_{bp,Rd}}{2mn-e_w(m+n)}$	
Mode 2	$F_{T,2,Rd} = \frac{2M_{pl,2,Rd}+n\Sigma F_{t,Rd}}{m+n}$		
Mode 3	$F_{T,3,Rd} = \Sigma F_{t,Rd}$		

Mode 1: Complete yielding of the flange
Mode 2: Bolt failure with yielding of the flange
Mode 3: Bolt failure

L_b is - the bolt elongation length, taken equal to the grip length (total thickness of material and washers), plus half the sum of the height of the bolt head and the height of the nut or
- the anchor bolt elongation length, taken equal to the sum of 8 times the nominal bolt diameter, the grout layer, the plate thickness, the washer and half the height of the nut

$L_b^* = \frac{8{,}8m^3 A_s}{\Sigma \ell_{eff,1} t_f^3}$

$F_{T,Rd}$ is the design tension resistance of a T-stub flange
Q is the prying force

$M_{p\ell,1,Rd} = 0{,}25\Sigma\ell_{eff,1} t_f^2 f_y / \gamma_{M0}$

$M_{p\ell,2,Rd} = 0{,}25\Sigma\ell_{eff,2} t_f^2 f_y / \gamma_{M0}$

$M_{bp,Rd} = 0{,}25\Sigma\ell_{eff,1} t_{bp}^2 f_{y,bp} / \gamma_{M0}$

$$M_{pl,1,2,Rd} = 0.25\, t^2\, \frac{l_{eff} \cdot f_y}{\gamma_{M0}}$$

$t = 12mm$

$l_{eff} = 180mm$

$f_y = 235\ MPa$

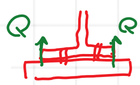
$\gamma_{M0} = 1$

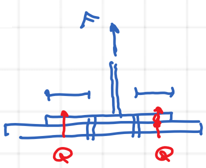
$M_{pl,1,2,Rd} = 1.52\ kN.m$

$n = \min\{e_{min} = 50mm,\ 1.25m\ (m = 49.45\ mm)\} =$

$n = 50\ mm$

$n = e_{min}$ but $n \leq 1{,}25m$





$$F_{T,1} = \frac{4 M_{pl,1,Rd}}{m} = \frac{4 \times 1.52\ kN\,m}{49.45\ mm} = 123\ kN$$

$$F_{T,2} = \frac{2 M_{pl,2,Rd} + n \sum F_{t,Rd}}{m + n} = \frac{2 \times 1.52\ kN \cdot m + 50\ mm \times 2 \times 141\ kN}{49.45\ mm + 50\ mm} = 172\ kN$$

$$F_{T,3} = \sum F_{t,Rd} = 2 \times 141\ kN = 282\ kN$$

$A_s := 245\ mm^2$ $\quad f_y := 235\ MPa$ $\quad f_{ub} := 800\ MPa$ $\quad m := 49.45\ mm$ $\quad n := 50\ mm$

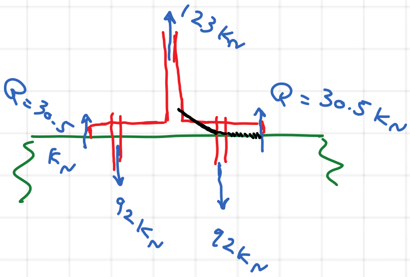
$l_{eff} := 180\ mm$ $\quad \gamma_{M2} := 1.25$ $\quad \gamma_{M0} := 1$ $\quad t := 12\ mm$

$$F_{t.Rd} := \frac{0.9 \cdot A_s \cdot f_{ub}}{\gamma_{M2}} = 141.12\ kN \qquad M_{pl.Rd} := \frac{0.25 \cdot t^2 \cdot l_{eff} \cdot f_y}{\gamma_{M0}} = 1.523\ kN \cdot m$$

$$F_{t.1.Rd} := \frac{4 \cdot M_{pl.Rd}}{m} = 123.179\ kN \qquad Q_1 := \frac{M_{pl.Rd}}{n} = 30.456\ kN \qquad F_{B.1} := \frac{F_{t.1.Rd}}{2} + Q_1 = 92.045\ kN$$

$$F_{t.2.Rd} := \frac{2 \cdot M_{pl.Rd} + n \cdot 2 \cdot F_{t.Rd}}{m + n} = 172.525\ kN \qquad Q_2 := \frac{\frac{F_{t.2.Rd}}{2} \cdot m - M_{pl.Rd}}{n} = 54.858\ kN \qquad F_{B.2} := \frac{F_{t.2.Rd}}{2} + Q_2 = 141.12\ kN$$

$$F_{t.3.Rd} := 2 \cdot F_{t.Rd} = 282.24\ kN$$



Proof Load

Proof load is defined as the maximum tensile force that can be applied to a bolt that will not result in plastic deformation. A material must remain in its elastic region when loaded up to its proof load typically between 85-95% of the yield strength. Acceptable clamp load is typically 75% of proof load.

Thread d (mm)	Pitch P (mm) (in)	Nominal Stress Area $A_{s,nom}$ (mm^2) (in2)	Property Class 4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
			Proof Load - F_p (N) (kgf, lbf)								
M3	0.50	5.03	1130	1560	1410	1910	2210	2920	3270	4180	4880
M3.5	0.60	6.78	1530	2100	1900	2580	2980	3940	4410	5630	6580
M4	0.70	8.78	1980	2770	2460	3340	3860	5100	5710	7290	8520
M5	0.80	14.2	3200	4400	3980	5400	6250	8230	9230	11800	13800
M6	1.00	20.1	4520	6230	5630	7640	8840	11600	13100	16700	19500
M7	1.00	28.9	6500	8920	8090	11000	12700	16800	18800	24000	28000
M8	1.25	36.6	8240	11400	10200	13900	16100	21200	23800	30400	35500
M10	1.50	58.0	13000	18000	16200	22000	25500	33700	37700	48100	56300
M12	1.75	84.3	19000	26100	23600	32000	37100	48900[d)]	54800	70000	81800
M14	2.00	115	25900	35600	32200	43700	50600	66700[d)]	74800	95500	112000
M16	2.00	157	35300	48700	44000	59700	69100	91000[d)]	102000	130000	152000
M18	2.50	192	43200	59500	53800	73000	84500	115000		159000	186000
M20	2.50	245	55100	76000	68600	93100	108000	147000		203000	238000
M22	2.50	303	68200	93900	84800	115000	133000	182000		252000	294000
M24	3.00	353	79400	109000	98800	134000	155000	212000		293000	342000
M27	3.00	459	103000	142000	128000	174000	202000	275000		381000	445000
M30	3.50	561	126000	174000	157000	213000	247000	337000		466000	544000
M33	3.50	694	156000	215000	194000	264000	305000	416000		570000	673000
M36	4.00	817	184000	253000	229000	310000	359000	490000		678000	792000
M39	4.00	976	220000	303000	273000	371000	429000	586000		810000	947000

engineeringtoolbox.com/metric-bolts-minimum-ultimate-tensile-proof-loads-d_2026.html

M12

$A_s := 84.3\ mm^2$ $\quad f_y := 235\ MPa$ $\quad f_{ub} := 800\ MPa$ $\quad m := 49.45\ mm$ $\quad n := 50\ mm$

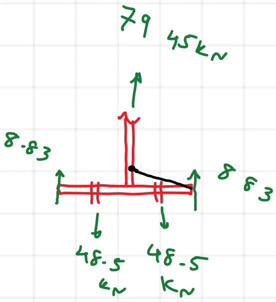
$l_{eff} := 180\ mm$ $\quad \gamma_{M2} := 1.25$ $\quad \gamma_{M0} := 1$ $\quad t := 12\ mm$

$$F_{t.Rd} := \frac{0.9 \cdot A_s \cdot f_{ub}}{\gamma_{M2}} = 48.557\ kN \qquad M_{pl.Rd} := \frac{0.25 \cdot t^2 \cdot l_{eff} \cdot f_y}{\gamma_{M0}} = 1.523\ kN \cdot m$$

$$F_{t.1.Rd} := \frac{4 \cdot M_{pl.Rd}}{m} = 123.179\ kN \qquad Q_1 := \frac{M_{pl.Rd}}{n} = 30.456\ kN \qquad F_{B.1} := \frac{F_{t.1.Rd}}{2} + Q_1 = 92.045\ kN$$

$$F_{t.2.Rd} := \frac{2 \cdot M_{pl.Rd} + n \cdot 2 \cdot F_{t.Rd}}{m+n} = 79.45\ kN \qquad Q_2 := \frac{\frac{F_{t.2.Rd}}{2} \cdot m - M_{pl.Rd}}{n} = 8.832\ kN \qquad F_{B.2} := \frac{F_{t.2.Rd}}{2} + Q_2 = 48.557\ kN$$

$$F_{t.3.Rd} := 2 \cdot F_{t.Rd} = 97.114\ kN$$



M8

$A_s := 36.6\ mm^2$ $\quad f_y := 235\ MPa$ $\quad f_{ub} := 800\ MPa$ $\quad m := 49.45\ mm$ $\quad n := 50\ mm$

$l_{eff} := 180\ mm$ $\quad \gamma_{M2} := 1.25$ $\quad \gamma_{M0} := 1$ $\quad t := 12\ mm$

$$F_{t.Rd} := \frac{0.9 \cdot A_s \cdot f_{ub}}{\gamma_{M2}} = 21.082\ kN \qquad M_{pl.Rd} := \frac{0.25 \cdot t^2 \cdot l_{eff} \cdot f_y}{\gamma_{M0}} = 1.523\ kN \cdot m$$

$$F_{t.1.Rd} := \frac{4 \cdot M_{pl.Rd}}{m} = 123.179\ kN \qquad Q_1 := \frac{M_{pl.Rd}}{n} = 30.456\ kN \qquad F_{B.1} := \frac{F_{t.1.Rd}}{2} + Q_1 = 92.045\ kN$$

$$F_{t.2.Rd} := \frac{2 \cdot M_{pl.Rd} + n \cdot 2 \cdot F_{t.Rd}}{m+n} = 51.823\ kN \qquad Q_2 := \frac{\frac{F_{t.2.Rd}}{2} \cdot m - M_{pl.Rd}}{n} = -4.83\ kN \qquad F_{B.2} := \frac{F_{t.2.Rd}}{2} + Q_2 = 21.082\ kN$$

$$F_{t.3.Rd} := 2 \cdot F_{t.Rd} = 42.163\ kN$$