Steel Design to Eurocode 3

Tension Members

As the tensile force increases on a member it will straighten out as the load is increased. For a member that is purely in tension, we do not need to worry about the section classification since it will not buckle locally.

A tension member fails when it reached the ultimate stress and the failure load is independent of the length of the member. Tension members are generally designed using rolled section, bars or flats.

Tensile Resistance

EN 1993-1-1 Clause 6.2.3(1) Equation 6.5 states that the design tensile force ($N_{t,Ed}$) must be less than the design tensile resistance moment ($N_{t,Rd}$)

$$\frac{N_{t,Ed}}{N_{t,Rd}} \leq 1.0 \quad (6.5)$$

The tensile resistance is limited by the lesser of:

- Design Plastic Resistance $N_{pl,Rd}$
- Design Ultimate Resistance $N_{u,Rd}$

Design Plastic Resistance, $N_{pl,Rd}$

$N_{pl,Rd}$ is the plastic design resistance, and is concerned with the yielding of the gross cross-section.

Equation 6.6 gives the expression used to calculate $N_{pl,Rd}$:

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}} \quad (6.6)$$

Design Ultimate Resistance, $N_{u,Rd}$

$N_{u,Rd}$ is the design ultimate resistance of the net cross-section, and is concerns with the ultimate fracture of the net cross-section, which will normally occur at fastener holes.

Equation 6.7 gives the expression used to calculate $N_{u,Rd}$:

$$N_{u,Rd} = \frac{0.9 A_{net} f_u}{\gamma_{M2}} \quad (6.7)$$

Partial Factors γ_M

γ_M		UK N.A. Value
γ_{M0}	Resistance of cross-sections	1.0
γ_{M2}	Resistance of cross-sections in tension to fracture	1.25

Characteristic Strengths f_y and f_u

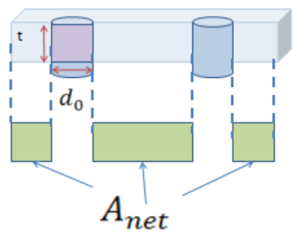
The UK National Annex says you should get the values of f_y and f_u from the product standards. For hot-rolled sections you can use the table below.

Steel grade	f_y (N/mm^2)				f_u (N/mm^2)		
	$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$		$63 < t \leq 80$	$t < 3$	$3 < t \leq 100$
S 275	275	265	255		245	430-580	410-560
S 355	355	345	335		325	510-680	470-630

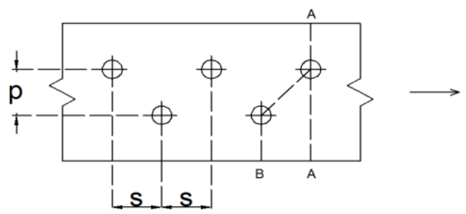
Extract from Table 7 of EN 10025-2

A_{net} for Non staggered fasteners

$A_{net} = A - \Sigma d_0 t$



A_{net} for Staggered Fasteners:



The total area to be deducted should be taken as the greater of:

a) The maximum sum of the sectional areas of the holes on any line perpendicular to the member axis

b) $$t\left(n d_0 - \sum \frac{s^2}{4p}\right)$$

where:

t is the thickness of the plate

p is the spacing of the centres of the same two holes measured perpendicular to the member axis

s is the staggered pitch of the two consecutive holes

n is the number of holes extending in any diagonal or zig-zag line progressively across the section

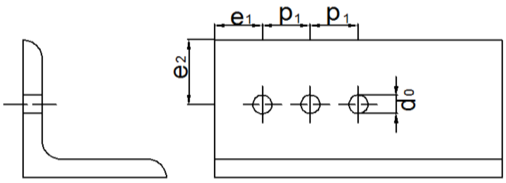
d_0 is the diameter of the hole

Angles with welded end connections

Clause 4.13(2) of EN 1993-1-8 states that for an equal angle, or unequal angle welded along its larger leg, the effective area = gross area.

Angles Connected by a single row of bolts

Refer to EN 1993-1-8.



For 1 bolt:

$$N_{u,Rd} = \frac{2.0(e_2 - 0.5d_0)tf_u}{\gamma_{M2}} \quad (3.11)$$

For 2 bolts:

$$N_{u,Rd} = \frac{\beta_2 A_{net} f_u}{\gamma_{M2}} \quad (3.12)$$

For 3 or more bolts:

$$N_{u,Rd} = \frac{\beta_3 A_{net} f_u}{\gamma_{M2}} \quad (3.13)$$

Values of reduction factors β_2 and β_3 can be found in Table 3.8:

Pitch p_1	$\leq 2.5\ d_0$	$\geq 5.0\ d_0$
β_2 (for 2 bolts)	0.4	0.7
β_3 (for 3 or more bolts)	0.5	0.7
Note: For intermediate values of pitch p_1 values of β may be determined by linear interpolation.		

EN 1993-1-8Table 3.8

Tension Member Design Steps Summary

1. Determine the design axial load N_{Ed}
2. Choose a section
3. Find f_y and f_u from the product standards
4. Get the gross area A and the net area A_{net}
5. Substitute the values into the equations to work out $N_{pl,Rd}$ and $N_{u,Rd}$

$$N_{pl,Rd} = \frac{Af_y}{\gamma_{M0}} \quad (6.6)$$

$$N_{u,Rd} = \frac{0.9A_{net}f_u}{\gamma_{M2}} \quad (6.7)$$

For angles connected by a single row of bolts, use the required equation to work out $N_{u,Rd}$ from EN 1993-1-8 which will depend on the number of bolts.

For 1 bolt:

$$N_{u,Rd} = \frac{2.0(e_2 - 0.5d_0)}{\gamma_{M2}} \quad (3.11)$$

For 2 bolts:

$$N_{u,Rd} = \frac{\beta_2 A_{net} f_u}{\gamma_{M2}} \quad (3.12)$$

For 3 or more bolts:

$$N_{u,Rd} = \frac{\beta_3 A_{net} f_u}{\gamma_{M2}} \quad (3.13)$$

6. The design tensile Resistance is the lesser of the values of $N_{pl,Rd}$ and $N_{u,Rd}$
7. Carry out the tension check:

$$\frac{N_{t,Ed}}{N_{t,Rd}} \leq 1.0 \quad (6.5)$$