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.

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 concerned 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 \( \gamma_M \)

<table>
<thead>
<tr>
<th>( \gamma_M )</th>
<th>UK N.A. Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma_{M0} )</td>
<td>1.0</td>
</tr>
<tr>
<td>( \gamma_{M2} )</td>
<td>1.25</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>( t \leq 16 )</th>
<th>( 16 &lt; t \leq 40 )</th>
<th>( 40 &lt; t \leq 63 )</th>
<th>( 63 &lt; t \leq 80 )</th>
<th>( t &lt; 3 )</th>
<th>( 3 &lt; t \leq 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 275</td>
<td>275</td>
<td>265</td>
<td>255</td>
<td>430-580</td>
<td>245</td>
<td>410-560</td>
</tr>
<tr>
<td>S 355</td>
<td>355</td>
<td>345</td>
<td>335</td>
<td>510-680</td>
<td>325</td>
<td>470-630</td>
</tr>
</tbody>
</table>

Extract from Table 7 of EN 10025-2

\( A_{net} \) for Non staggered fasteners

\[
A_{net} = A - \sum d_t
\]

\( A_{net} \) 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

\[
t \left( n d_0 - \sum \frac{s^2}{4 \rho} \right)
\]
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.

![Diagram](image)

For 1 bolt:

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

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 $\beta_2$ and $\beta_3$ can be found in Table 3.8:

<table>
<thead>
<tr>
<th>Pitch $p_1$</th>
<th>$\leq 2.5 , d_0$</th>
<th>$\geq 5.0 , d_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_2$ (for 2 bolts)</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>$\beta_3$ (for 3 or more bolts)</td>
<td>0.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Note: For intermediate values of pitch $p_1$, values of $\beta$ may be determined by linear interpolation.

**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 $N_{u,Rd}$

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

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

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:

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

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**EN 1993-1-8 Table 3.8**