D. Design Procedure for Bolted Angles under Tension Loads

In designing a bolted angle under tension loads, there are three design aspects we may consider:

1. How many and what size bolts are necessary?
2. What is the optimal (lightest) size of the angle?
3. Where and how close should the bolts be placed?

The item 2 was already covered previously in Chapter 2 of the lecture notes (in tension members). The design strength formulas are now used to develop a method to deal with items 1 and 3. A suggested design procedure is the following:

Step 1: Design Load.

Determine factored load:

\[
\text{Total Load} = P_u = \max\{1.2P_D + 1.6P_L, 1.4P_D\}
\]

Step 2: Number of bolts and thickness of angle.

There should be enough number of bolts used to handle shear load. Furthermore, the angle must be thick enough to carry the bearing stress. For both case the formula to be used is:

\[
\frac{\text{Total load on angle}}{\text{Number of bolts}} = \frac{(\text{Load on each bolt})}{(\text{Strength of each bolt})} \leq (\text{Strength of each bolt})
\]

The bolt strength depends on the bolt shear and bearing capacity of the hole in the angle.

- **Bolt shear** (Determine number of bolts \(n\)).

  \[
  T_u = P_u/n = \text{Load on each bolt}
  \]

  \[
  \phi R_n = m\phi F_v^b A_b
  \]

- **Bearing capacity** (Determine thickness of the angle \(t\)).

  \[
  \phi R_n = \cdots \text{ Use (J3-1) and (J3-2).}
  \]

  \[
  T_u \leq \phi R_n \text{ Design criterion.}
  \]
Step 3: Angle Selection. (Refer to Chapter 3)
The strength of the angle depends on yielding in the gross area and fracture in the net area.
Yield in the gross area:

\[ P_u \leq 0.9 F_y A_g \]

Fracture in net area:

\[ P_u \leq 0.75 F_u U A_n \]

Step 4: Bolt Spacing.
The bolt spacing (s) and edge distance (L_e) should be large enough to handle the bearing stresses. See formulas and tables given in this section of lecture notes.

Step 5: Check Block Shear Rupture.
Shear yield + Tension fracture:

\[ P_u = \phi P_n = \phi(0.6 F_y A_{gy} + F_u A_{nt}) \]  \hspace{1cm} (J4-3a)

Shear fracture + Tension yield:

\[ P_u = \phi P_n = \phi(0.6 F_u A_{nt} + F_y A_{gt}) \]  \hspace{1cm} (J4-3b)

where \( \phi = 0.75 \).