

F. Design of Tension Members (Specification D1)

Basic concepts of the strength of the structural members in tension were discussed. These concepts are briefly summarized and the general design rules are given below:

Criterion 1 (Yielding): For the case of tension members with no holes (gross area A_g), the yield stress, F_y , controls failure. In this case, the failure happens due to excessive deformation of the member. Therefore, the theoretical or *nominal tension strength* (force) is the stress multiplied by the area, or

$$P_n = F_y A_g$$

For safety, the design capacity of the tension member is determined to be less than the theoretical capacity. The *resistance factor*, ϕ_t , is equal to 0.90 and the design rule in this case is

$$P_u \leq \phi_t P_n = \phi_t F_y A_g = 0.9 F_y A_g \quad (\text{D1-1})$$

Criterion 2 (Fracture): With the connections, the net cross-sectional area is A_n . Furthermore, in a case when only a portion of the tension member is attached to the connecting element, the net area for calculating the fracture case must be reduced by multiplying the *reduction factor* U . The resulting *effective net area* is

$$A_e = U A_n$$

In this case, failure is governed by the *ultimate stress* F_u , which is the maximum stress before rupture or fracture. Therefore, the nominal tension strength is expressed as

$$P_n = F_u A_e$$

The *resistance factor*, ϕ_t , in this case is 0.75 according to AISC/LRFD Specification. Note that this is a much smaller value than 0.9 used in the case of the above criterion because the fracture is a very dangerous phenomena and we admit that the accuracy of computation used for fracture is not high enough. The design rule is

$$P_u \leq \phi_t P_n = \phi_t F_u A_e = 0.75 F_u A_e = 0.75 F_u U A_n \quad (\text{D1-2})$$

Criterion 3 (Slenderness): In order to prevent excessive vibration, AISC/LRFD Specification recommends to use the restriction on the stiffness of tension members:

$$L/r \leq 300 \quad (\text{Specification B7})$$

where L is the length of the member, and r is the *radius of gyration*. A tension member usually has several values of r for different axes. The smallest value should be used in design.

Design Procedure

To design a tension member, you should make sure that all three criteria described above are satisfied. There is no fixed or standard rule for designing tension members, but it is useful to follow the basic three steps:

1. Calculate the design load.
2. Calculate
 - (a) Required gross area (A_g)
 - (b) Required (effective) net area (A_n or A_e)
 - (c) Radius of gyration (r).
3. Pick a member and try different sections that satisfy the criteria. Choose the lightest member.