Steel Design - LRFD
AISC Steel Manual 14th edition
Tension Limit States

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In steel design it is often necessary to design tension members. In order to design the tension member according to LRFD, ϕT_n must be determined for the trial tension member. Once ϕT_n is determined it can then be compared to the factored tension T_u to evaluate the adequacy of the selected member. This is often an iterative process. In order to determine the adequacy of the selected tension member four tension limit states must be considered:

A. Yielding of the gross cross-section.

B. Fracture of the effective net cross-section.

C. Block shear.

D. Slenderness Limit.

Limit states A, B, and C are strength limit states, whereas limit state D is a serviceability limit state. For each strength limit state ϕT_n must be calculated. The smallest value of ϕT_n governs the design and must satisfy the following basic LRFD formula:

$$\phi T_n \geq T_u.$$

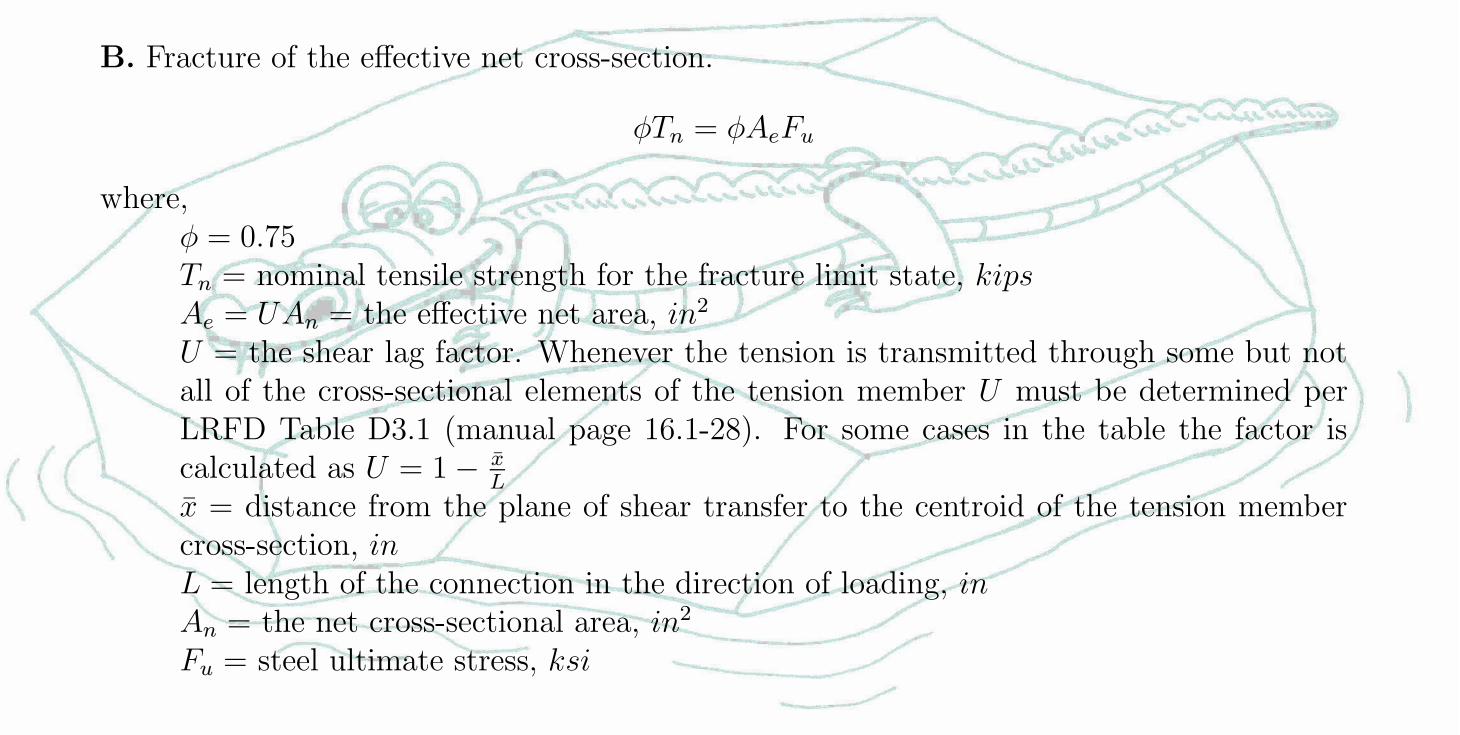
Relevant information for each limit state is summarized below.

A. Yielding of the gross cross-section.

$$\phi T_n = \phi A_g F_y$$

where,

$\phi = 0.9$
$T_n =$ nominal tensile strength for the yield limit state, *kips*
$A_g =$ gross cross-sectional area of the tension member, in^2
$F_y =$ yield stress of the steel material, *ksi*



B. Fracture of the effective net cross-section.

$$\phi T_n = \phi A_e F_u$$

where,

$\phi = 0.75$
$T_n =$ nominal tensile strength for the fracture limit state, *kips*
$A_e = UA_n =$ the effective net area, in^2
$U =$ the shear lag factor. Whenever the tension is transmitted through some but not all of the cross-sectional elements of the tension member U must be determined per LRFD Table D3.1 (manual page 16.1-28). For some cases in the table the factor is calculated as $U = 1 - \frac{\bar{x}}{L}$
$\bar{x} =$ distance from the plane of shear transfer to the centroid of the tension member cross-section, *in*
$L =$ length of the connection in the direction of loading, *in*
$A_n =$ the net cross-sectional area, in^2
$F_u =$ steel ultimate stress, *ksi*

C. Block Shear.

For the block shear limit state ϕT_n is determined according to the following expression:

$$\phi T_n = \phi[0.6F_uA_{nv} + U_{bs}F_uA_{nt}] \leq \phi[0.6F_yA_{gv} + U_{bs}F_uA_{nt}]$$

where,

$\phi = 0.75$
T_n = nominal tensile strength for the block shear limit state, *kips*
F_u = steel ultimate stress, *ksi*
F_y = steel yield stress, *ksi*
A_{nt} = net tension area, in^2
A_{gv} = gross shear area, in^2
A_{nv} = net shear area, in^2
U_{bs} = block shear reduction factor = 1.0 for uniform stress distribution, 0.5 for nonuniform stress distribution see manual page 16.1-412 for guidance and examples.

D. Slenderness Limit.

The slenderness limit for tension members is specified by AISC and is prescribed in the following formula:

$$\frac{L}{r} \leq 300$$

where,

L = the laterally unsupported length of the tension member, *in*
$r = \sqrt{\frac{I}{A}}$ = the minimum radius of gyration of the tension member cross-section, *in*
I = the minimum moment of inertia of the tension member cross-section, in^4
A = the cross-sectional area of the tension member, in^2