Design of Tension Members (Sec. 3.8 NDS 01 and Chapter 7 Text)

Wood members are stressed in tension in a number of structured applications, i.e. trusses. (Tension II to grain) Table 4.3.1 NDS

$$f_t \le F_t' \quad \rightarrow \quad F_t' = F_t * C_D * C_M * C_{w*} \quad \cdots$$

$$F_t = \text{Tabulated value (Supp.)}$$

$$\text{where } f_t = \frac{T}{A_{net}}$$

$$\triangleright \; A_{net} \rightarrow (NDS\ Sec. 3.1.2)$$

The cross sectional area to be used in the tension stress calculation is the net area of the member. This area is calculated by subtracting the projected area of any bolt holes from the gross-cross-sectional area of the members.

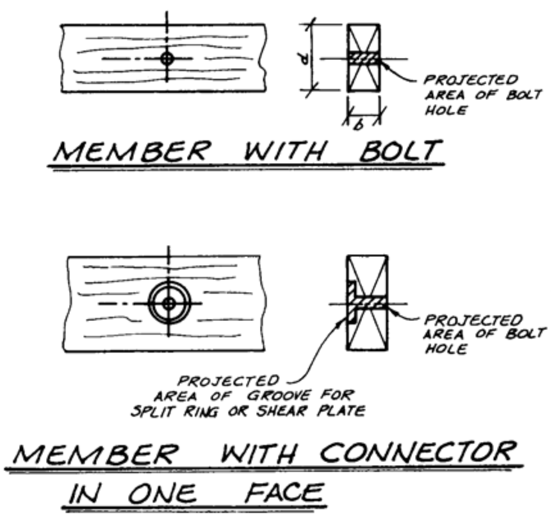


Figure 7.2 *Net-section* through two wood members. One member is shown cut at a bolt hole. The other is at a joint with a split ring or shear plate connector in one face plus the projected area of a bolt. The bolt is required to hold the entire assembly (wood members and connectors) together. Photographs of split ring and shear plate connectors are included in Chap. 13 (Fig. 13.23*a* and *b*).

The projected areas for fasteners to be deducted from the gross area are as follows:

Nail holes—disregarded.

Bolt holes—computed as the hole diameter times the width of the wood member. The hole diameter is between $\frac{1}{32}$ and $\frac{1}{16}$ in. larger than the bolt diameter (NDS Sec. 8.1.2). In this book the bolt hole, for strength calculation purposes, is conservatively taken as the bolt diameter plus $\frac{1}{8}$ in.

Lag bolt holes—a function of the connection details. See NDS Appendix L for lag bolt dimensions. Drill diameters for lead holes and shank holes are given in NDS Sec. 9.1.2.

Split ring and shear plate connectors—a function of the connection details. See NDS Appendix K for the projected areas of split rings and shear plates.

If more than one fastener is used, the sum of the projected areas of all the fasteners *at the critical section* is subtracted from the gross area. For staggered fastener pattern, see NDS Sec. 3.1.2.

Example 7.2 Text for Spruce Pine Fir (south) No. 1

Determine the required size of the lower (tension chord) in the truss shown below. The loads are (DL + snow) and the effects of roof slope on the magnitude of snow load have already been taken into account. Joints are assumed pinned. Connections will be made with a single row of ¾"-diameter bolts. Trusses are 4 ft-0in on centers. Use No. 2 southern pine surfaced dry. MC < 0.19. Use NDS01.

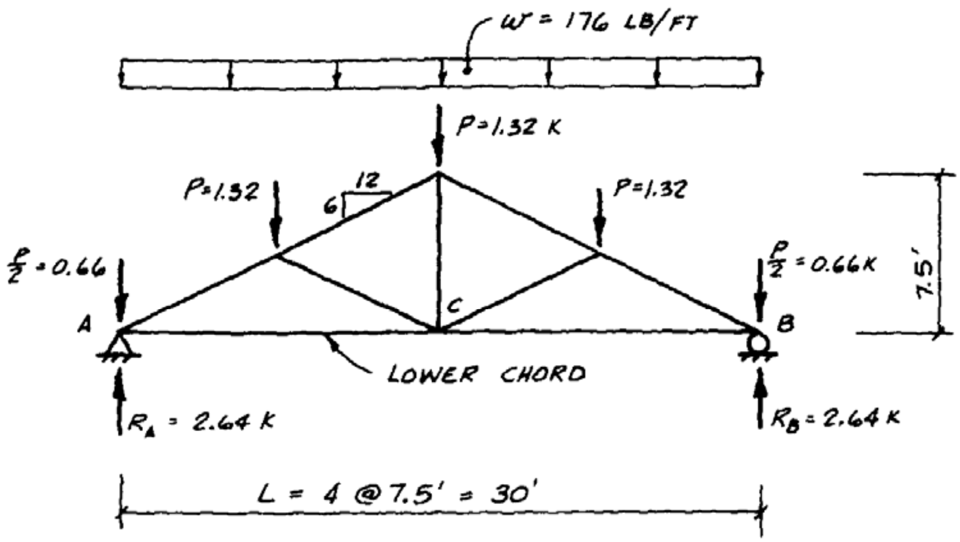


Figure 7.3a Uniform load on top chord converted to concentrated joint loads.

Total load horizontal plane $= 14(DL) + 30(SNOW) = 44\ psf$ x 4 (truss spacing) = 176 plf

Truss analysis - load to joint

$$P = 0.176\ x\ 7.5 = 1.32\ kips$$

Force in lower chord:

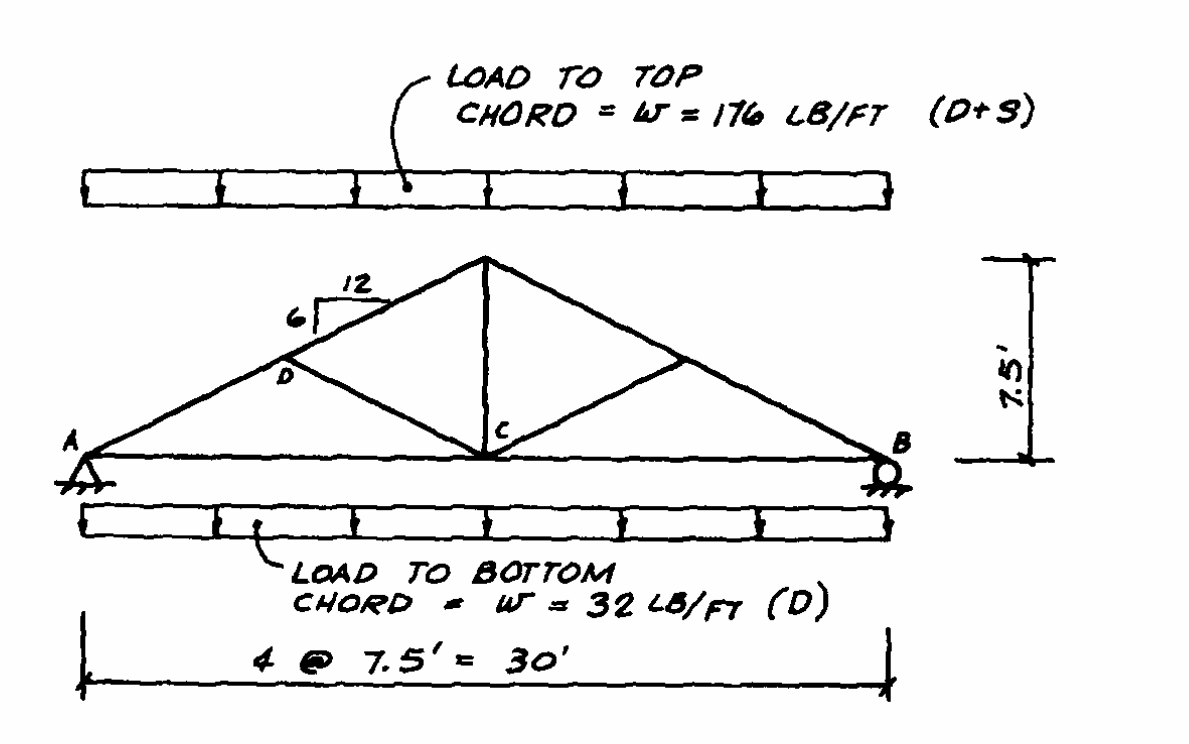
$T_{A\text{-}C}$ = (2.64- 0.66) x 2 = 3.96 Kips (service loads)

Determine required size of tension member

Assume chord will be a dimensional lumber 1-1/2" thick since M.C ≤ 19% C_M = 1.0.
Table 4.3.1 (NDS 01)

$$F_T' = F_T * C_D * C_M * C_t * C_F * C_i$$
$$C_D \rightarrow \text{Table 2.3.2 (NDS) Dead + Snow Load Combination}$$
$$C_D \rightarrow 1.15 \text{ (snow - shorter duration)}$$
$$C_T = 1.0 \quad \text{Sec. 2.3.4 NDS} \quad T \le 100\ ^\circ F$$
$$C_F = \left(\frac{12}{d}\right)^{1/9} = 1.0 \quad \text{(see note Page 36 Supp. NDS 01}$$
$$\text{thickness} = 1\text{-}1/2'' \text{, thus already incorporated in table value)}$$
$$F_t = \text{Tension parallel to the grain for No. 2 southern pine (1.5'' thick) and assume 6'' wide}$$
$$= 725 \text{ psi} \quad \text{(Table 4B NDS 01 Supplement)}$$
$$F_T' = (725)(1.15)(1)(1) = 834 \text{ psi}$$
$$\text{Reqd. } A_{net} = \frac{P}{F_t'} = \frac{3.95}{.834} = 4.74 \text{ in}^2$$
$$\text{Reqd. Gross Area} = \text{(accounting for bolt hole)}$$
$$A_{gross} = 4.74 + (1.5)(0.75 + 1/8) = 6.053^{(4)}$$
$$A_{gross} = 8.25 \text{ in}^2 > 6.053 \text{ Table 1B Supp.}$$
$$\text{Use 2x6 No. 2 Southern Pine surfaced dry}$$

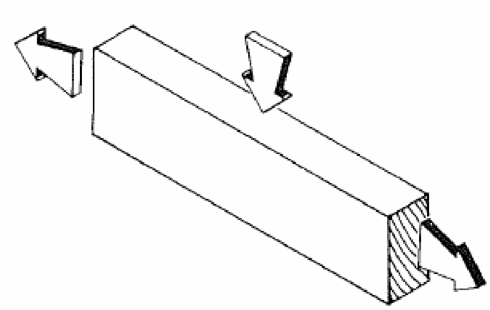
Example of Combined Bending and Tension (Problem 7.12 Text)



Combined Bending and Tension (Sec. 3.9 NDS 01)

Let's take the truss that we've designed the lower chord for tension only, and place an additional distributed load of 32 lb/ft (DL) applied at the lower chord. This load represents the weight of a ceiling supported by the bottom chord of the truss.

Figure 3H Combined Bending and Axial Tension

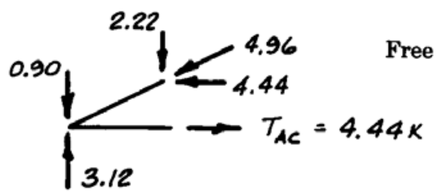


Design Example:

Determine the size of the lower chord of the truss. Use No. 2 Southern pine surface dry (MC ≤ 19%). Connections will be made with a single row of ¾" diameter bolts also. Connections are then assumed to be pinned. Lateral buckling is prevented by ceiling. Trusses are 4' on center.

i) Determine Force in lower chord

Resolve distributed load into joint loads

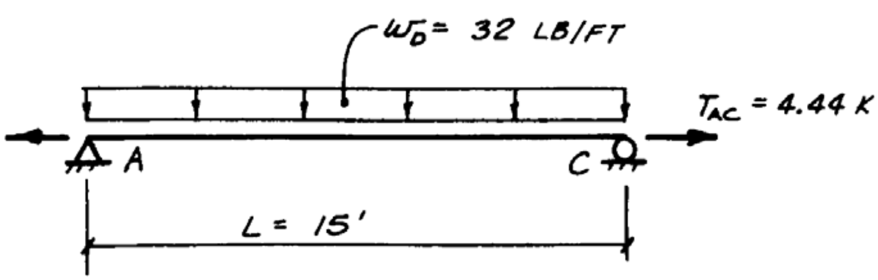


Free body diagram of joint A.

Estimate trial size of member: from previous example a 2x6 was needed with the additional load in the bottom chord try 2x8

Calculate force in member:

Load diagram for lower truss chord: taking advantage of symmetry



Note that due to load application chord will be subjected to combined bending and tension!!

ii) Member Design

Try 2x8" from NDS 01 supp. For No. 1 – Southern Pine surface dry

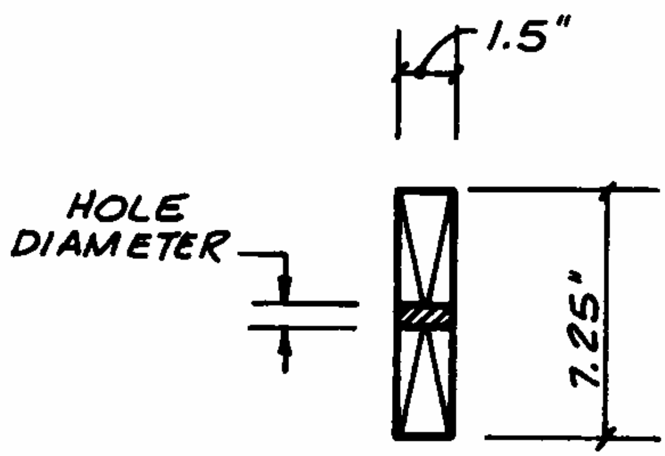
Table 4B

$F_b = 1500\ psi$

$F_T = 825\ psi$

$S_{xx} = 13.14\ in^3,\ \text{thickness} = 1.5",\ \text{wide} = 7\,1/4"$

1. Axial tension: first check tension at net section (midspan-bolt location). Because of bolted connection M=0 at this section.



$A_{net} = (7.25)\,(1.5) - (1.5)\,(1/8 + 0.75) = 9.56\ in^2$

$f_t = \frac{4.44}{9.56} = 0.464\ ksi = 464\ psi\ (reqd)$

$F'_{t_1} = F_{t_{11}} * C_D * C_M * C_t * C_F * C_i\ \ (allowable)$

The duration load factor used for the independent tension check is the C_D of (DL + snow)

$C_D = 1.15$ (Use that of shortest-duration load in the combination- Snow)

$C_M = 1.0$ (MC ≤ 19%)

$C_t = 1.0$ (T $\leq 100^{o}$F)

$C_F = 1.0$ (Table 4B-Adjust. Factors NDS 01 Supp.)

$\therefore \; F'_{t_{11}} = (825)(1.15) = 949 \; psi$

$949 > 464 \; psi$

2. Axial Tension + Bending Tension

The combined tensile stresses are analyzed using a straight-line interaction formula. (NDS, Sec. 3.9.1 page 21) – tension/tension Eq. 3.9-1

3.9.1 Bending and Axial Tension

Members subjected to a combination of bending and axial tension (see Figure 3H) shall be so proportioned that:

$$\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \leq 1.0 \qquad (3.9\text{-}1)$$

and

$$\frac{f_b - f_t}{F_b^{**}} \leq 1.0 \qquad (3.9\text{-}2)$$

where:

F_b^* = tabulated bending design value multiplied by all applicable adjustment factors except C_L

F_b^{**} = tabulated bending design value multiplied by all applicable adjustment factors except C_V

F_b^* = tabulated design value (bending) multiplied by all applicable adjustment factors except C_L (This is because buckling is not an issue in tension).

C_L = beam stability factor = 1.0