4.8

	Nominal Size	Dressed (in. x in.)	Area (in^2)	I_x (in^4)	S_x (in^3)	I_y (in^4)	S_y (in^3)
a.	2 x 4	1.5 x 3.5	5.25	5.359	3.063	0.984	1.313
b.	8 x 8	7.5 x 7.5	56.25	263.7	70.31	263.7	70.31
c.	4 x 10	3.5 x 9.25	32.38	230.8	49.91	33.05	18.89
d.	6 x 16	5.5 x 15.5	85.25	1707	220.2	214.9	78.15

4.10 a. Timbers; 5 in. and thicker, width more than 2 in. > thickness
b. Dimension Lumber; 2 to 4 in. thick, 2 to 4 in. wide
c. Dimension Lumber; 2 to 4 in. thick, 4 in. and wider
d. Dimension Lumber, 2 to 4 in. thick, 5 in. and wider
e. Timbers; 5 in. and thicker, width not more than 2 in. > thickness
f. Dimension Lumber; 2 to 4 in. thick, 2 to 4 in. wide
g. Dimension Lumber; 2 to 4 in. thick, 2 in. and wider, ≤ 10 ft long

4.16 Reference design values for No. 1 DF-L

Dimension Lumber (NDS Supplement Table 4A)
c. 4 x 16 – Dimension Lumber
d. 4 x 4 – Dimension Lumber
e. 2 x 10 – Dimension Lumber

F_b = 1000 psi
F_t = 675 psi
F_v = 180 psi
$F_{c\perp}$ = 625 psi
F_c = 1500 psi
E = 1,700,000 psi
E_{min} = 620,000 psi

Beams and Stringers (NDS Supplement Table 4D)
f. 6 x 12 – Beams & Stringers
h. 10 x 14 – Beams & Stringers

F_b = 1350 psi
F_t = 675 psi
F_v = 170 psi
$F_{c\perp}$ = 625 psi
F_c = 925 psi
E = 1,600,000 psi
E_{min} = 580,000 psi

Posts and Timbers (NDS Supplement Table 4D)
a. 10 x 10 – Posts & Timbers
b. 12 x 14 – Posts & Timbers
g. 6 x 8 – Posts & Timbers

F_b = 1200 psi
F_t = 825 psi
F_v = 170 psi
$F_{c\perp}$ = 625 psi
F_c = 1000 psi
E = 1,600,000 psi
E_{min} = 580,000 psi

4.12 Visually graded sawn lumber other than Southern Pine

	Size	Size Category	NDS Supplement
a.	10 x 12	P & T	Table 4D
b.	14 x 14	P & T	Table 4D
c.	4 x 8	Dimension	Table 4A
d.	4 x 4	Dimension	Table 4A
e.	2 x 12	Dimension	Table 4A
f.	6 x 12	B & S	Table 4D
g.	8 x 12	B & S	Table 4D
h.	8 x 10	P & T	Table 4D

4.21 a. Snow (S): $C_D = 1.15$
b. Wind (W): $C_D = 1.6$
c. Floor Live Load (L): $C_D = 1.0$
d. Roof Live Load (L_r): $C_D = 1.25$
e. Dead Load (D): $C_D = 0.9$

4.34 $SV = \frac{6}{30} = 0.2\%$ per 1% change in MC = 0.002 in./in./percent change in MC
$\Delta MC = 10 - 19 = -9$ (drying)
Shrinkage = $(SV)(\Delta MC)\,d = (0.002)(-9)(13.25 \text{ in.}) = 0.24$ in.
Depth after shrinkage = 13.25 – 0.24 in. = 13 in.

4.23 Compression perpendicular to grain ($F_{c\perp}$), average modulus of elasticity (E), and reduced modulus of elasticity for stability calculations (E_{min}) are not adjusted by C_D in ASD calculations.
Average modulus of elasticity (E) and reduced modulus of elasticity for stability calculations (E_{min}) are not adjusted by λ in LRFD calculations.

6.12 $\ell_u = 60\text{ in.};\ \ell_u/d = 6.5 < 7;\ \ell_e = 2.06\ell_u = 123.6\text{ in.}$

$$R_B = \sqrt{\frac{\ell_e \cdot d}{b^2}} = 9.66;\quad F_{bE} = \frac{1.2 \cdot E_{min}}{R_B^2} = 7458\text{ psi};\quad F_b^* = 2100\text{ psi}$$

$$C_L = \frac{1+F_{bE}/F_b^*}{1.9} - \sqrt{\left[\frac{1+F_{bE}/F_b^*}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}} = 0.981$$

c. $F_b' = 2100(0.981) = 2061\text{ psi}$

e. 2061 > 1353 psi bending ok

f. $E_{minn} = .58\text{x}10^3(1.5/.85) = 1.02\text{x}10^3$ ksi

g. $E'_{minn} = 1.02\text{x}10^3(.85) = .87\text{x}10^3$ ksi

$F_{bEn} = 1.2\ E'_{minn}/R_B^2 = 11.19$ ksi

$F^*_{bn} = 2.91$ ksi

$C_L = .983$

6.27 $w_D = 15(2)\left[\frac{14.76}{14}\right] = 31.6\text{ plf}$ (See solution to 6.25)

$w_s = 50(2) = 100\text{ plf}$

a. Assume 2 x 12; Dimension lumber, $S = 31.6\text{ in.}^3$

b. $F_b = 1000\text{ psi},\quad F_v = 180\text{ psi}$

c. $C_D = 1.15,\quad C_F = 1.0,\quad C_r = 1.15$ (rep. use)

$F_b' = 1000(1.15)(1.15) = 1323\text{ psi};\quad F_v' = 180(1.15) = 207\text{ psi}$

d. $M = w\ell^2/8 = (131.6)14^2/8 = 3224\text{ ft}\cdot\text{lb}$

$f_b = \frac{M}{S}(12) = \frac{3224(12)}{31.6} = 1224\text{ psi} < 1323\text{ psi}$ ok

$V = w\ell/2 = 131.6(14)/2 = 921\text{ lb}$

$f_v = \frac{3}{2}\frac{V}{A} = \frac{3}{2}\frac{921}{16.875} = 82\text{ psi} < 207\text{ psi}$

e. $F_{bn} = 1.0K_F = 2.54\text{ ksi},\qquad F_{vn} = .180K_F = .518\text{ ksi}$

f. $F'_{bn} = 2.54(1.15)(.85)(.8) = 1.99\text{ksi}$

$F'_{vn} = .518(.75)(.8) = .311\text{ ksi}$

g. $M'_n = F'_{bn}S = 62.9$ k-in

$V'_n = (2/3)F'_{vn}A = 3.50$ k

h. $w_u = 1.2(31.6)+1.6(100) = 197.9$ plf

$M_u = w_uL^2/8 = 58.2$ k-in

$V_u = w_uL/2 = 1.39$ k

62.9 > 58.2 k-in bending ok

3.50 > 1.39 k shear ok

[Note: no details given for notch, but should be checked in final design check. Also, horizontal plane method is conservative for shear.]

6.33 a. $F_{c\perp} = 625\text{ psi};\quad b = 3.5\text{"};\quad A = 12\text{"} > 3\text{"},\ B = L_b = 5\text{"} < 6\text{"}$

$C_b = \frac{L_b + 0.375}{L_b} = 1.075$

$F'_{c\perp} = 625(1.075) = 672\text{ psi};\quad R = F'_{c\perp}\cdot b\cdot L_b = 11{,}758\text{ lb.}$

b. $F_{c\perp} = 650\text{ psi};\quad b = 5.125\text{"};\quad A = 0\text{"} < 3\text{"};\quad B = L_b = 12\text{"} > 6\text{"}\quad C_b = 1.0$

$C_M = 0.53;\qquad F'_{c\perp} = 650(0.53) = 345\text{ psi}$

$R = F'_{c\perp}\cdot b\cdot L_b = 21{,}187\text{ lb}$

c. $F_{c\perp} = 625\text{ psi};\quad b = 5.5\text{"};\qquad A = 8\text{"} > 3\text{"};\quad B = L_b = 10\text{"} > 6\text{"}\quad C_b = 1.0$

$C_M = 0.67;\quad F_{c\perp}' = 625(0.67) = 419\text{ psi}$

$R = F'_{c\perp}\cdot b\cdot L_b = 23{,}031\text{ lb.}$

d. 0.04 in.

6.20 $\ell_u = 96\text{ in.};\quad \ell_u/d = 8.5 > 7.0;\quad \ell_e = 1.63\cdot\ell_u + 3d = 190.2\text{ in.};\ R_B = 13.21$

$F_b^* = 2090\text{ psi};\ E_{min} = 660{,}000\text{ psi};\quad F_{bE} = 1.2\cdot E_{min}/R_B^2 = 4539\text{ psi}$

6.16 $\ell_u = 120\text{ in.};\quad \ell_u/d = 6.2 < 7.0;\quad \ell_e = 2.06\ell_u = 247.2\text{ in.}$

$F_{bx}^{+*} = 2400(1.15) = 2760\text{ psi}\quad R_B = \sqrt{\frac{\ell e\cdot d}{b^2}} = 13.8;$

6.38 $F_{bx}^{+} = F_{bx}^{-} = 2000$ psi (bal. layup); $F_{vx} = 210$ psi ; $E_x = 1.5\text{x}10^6$ psi ;
$E_y = 1.2\text{x}10^6$ psi

a. $W_D = (16\text{ psf})(24') = 384$ plf ; $W_{L_r} = (20\text{ psf})(24') = 480$ plf ; $W_{TL} = 864$ plf

Optimum Cantilever: $L_c = 0.172 \cdot L = 6.88$ ft

From structural analysis: $V_{max} = 20.25$ k ; $M_{max} = M^{-}_{max} = 118.5\text{ k}\cdot\text{ft}$

Assume $5\frac{1}{8}\text{x}28.5$; $A = 146.1$ in.^{2}, $S = 693.8$ in.^{3}; $I = 9886.6$ in.^{4}

$$C_D = 1.25; \quad C_v = \left(\frac{21}{L}\right)^{1/10}\left(\frac{12}{d}\right)^{1/10}\left(\frac{S.125}{d}\right)^{1/10} = 0.876$$

lateral stability: assume lateral support at column. $\ell_u = 6.88$ ft

$$\frac{\ell_u}{d} = 2.9 < 7; \quad \ell_e = 154.4\text{ in.}; \quad R_B = \sqrt{\frac{\ell_e \cdot d}{b^2}} = 12.94$$

$$E'_{y\min} = .62\text{x}10\text{^}6\text{ psi}; \quad F_{bE} = \frac{1.2 \cdot E'_{y\min}}{R_B^{\ 2}} = 4443\text{ psi};$$

$F^{*}_{bx} = (2000)(1.25) = 2500$ psi

$$F_{bE}/F^{*}_{bx} = 1749; \quad C_L = \frac{1 + F_{bE}/F^{*}_{bx}}{1.9} - \sqrt{\left[\frac{1 + F_{bE}/F^{*}_{bx}}{1.9}\right]^2 - \frac{F_{bE}/F^{*}_{bx}}{0.95}} = 0.946$$

Use C_V, not C_L

$F'_{bx} = 2500(0.876) = 2191$ psi

$f_b = \frac{M}{S} = 2055\text{ psi} < 2191\text{ psi}$ ok

$F'_{vx} = F_{vx} \cdot C_D = 237$ psi

$f_v = \frac{3}{2}\frac{V}{A} = 208\text{ psi} < 237\text{ psi}$ ok

$5\frac{1}{8}\text{x}28.5$ 20F – 1.5E Balanced DF glulam (Member A_D)

b. $L_c = 0.2L = 8$ ft (optimum L_c changes when unbal. loading is considered)
Suspended load: $L_{sus} = L - L_c = 32$ ft; $A_T = 32 \text{ x } 24 = 768\text{ft}^2 > 600$
$L_r = 20R_1R_2 = 20(0.6)(1.0) = 12$ psf ; $W_{L_r} = 12(24) = 288$ plf
$W_{TL} = 672$ plf ; with reduced L_r, must check unbal. load from analysis:

1. Full $D + L_r$ on all spans:
   $V_{max} = 16.13$k ; $M^{+}_{max} = 86\text{k}\cdot\text{ft}$; $M^{-}_{max} = 107.6\text{k}\cdot\text{ft}$
2. L_r on left span only:
   $V_{max} = 11.9$k ; $M^{+}_{max} = 105.4\text{k}\cdot\text{ft}$; $M^{-}_{max} = 61.8\text{k}\cdot\text{ft}$
3. L_r on right span only:
   $V_{max} = 16.12$k ; $M^{+}_{max} = 86\text{k}\cdot\text{ft}$; $M^{-}_{max} = 108\text{k}\cdot\text{ft}$

Design for $V_{max} = 16.13$k , $M^{+}_{max} = 105.4\text{k}\cdot\text{ft}$; $M^{-}_{max} = 108\text{k}\cdot\text{ft}$

$F_{bx}^{+} = F_{bx}^{-} = 2000$ psi (bal. layup); $F_{vx} = 190$ psi ; $E_x = 1.5\text{x}10^6$ psi ;
$E_y = 1.2\text{x}10^6$ psi

Assume same size as "a", $5\frac{1}{8}\text{x}28.5$, $C_V = 0.876$

$\ell_u = 14ft$ (critical distance from column to inflection pt, load case 3)

$\ell_u/d = 6.2 < 7 \qquad \ell_e = 1.87\ell_u = 314.2$ in.; $R_B = \sqrt{\frac{\ell_e \cdot d}{b^2}} = 17.97$

$E'_{y\min} = .62\text{x}10^{\wedge 6}$ psi; $F_{bE} = \frac{1.2 \cdot E'_{y\min}}{R_b^{\,2}} = 2304$ psi ; $F_{bx}^{*} = F_{bx} \cdot C_D = 2500$ psi

$$C_L = \frac{1 + F_{bE}/F_b^*}{1.9} - \sqrt{\left[\frac{1 + F_{bE}/F_b^*}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}} = 0.782$$, use C_L vs. C_V

$F'_{bx} = 2500(0.782) = 1955$ psi

$f_b = \frac{M}{S} = \frac{108}{693.8} = 1868 \text{ psi} < 1955 \text{ psi}$ ok

$F'_{vx} = 237$ psi

$f_v = \frac{3}{2}\frac{V}{A} = 165 \text{ psi} < 237 \text{ psi}$ ok

c. $F_{bxn}^{+} = F_{bxn}^{-} = 2.00\text{K}_F = 5.08$ ksi (bal. layup); $F_{vxn} = .210K_F = .605$ ksi ;
$E_{xn} = 1.5\text{x}10^3$ ksi ; $E_{y\min n} = .62\text{x}103K_F = 1.09\text{x}10^3$ ksi
$W_D = (.016 \text{ ksf})(24') = .384$ klf ; $W_{L_r} = (.020 \text{ ksf})(24') = .480$ klf ;
$W_u = 1.23$ klf
Optimum Cantilever: $L_c = 0.172 \cdot L = 6.88$ ft
From structural analysis: $V_{\max} = 28.83$ k ; $M_{\max}^{+} = M_{\max}^{-} = 169.25 \text{ k} \cdot \text{ft}$
Assume $5\frac{1}{8}\text{x}28.5$; $A = 146.1$ in.^{2}, $S = 693.8$ in.^{3}; $I = 9886.6$ in.^{4}

$$C_v = \left(\frac{21}{L}\right)^{1/10}\left(\frac{12}{d}\right)^{1/10}\left(\frac{5.125}{d}\right)^{1/10} = 0.876$$

lateral stability: assume lateral support at column. $\ell_u = 6.88$ ft

$\frac{\ell_u}{d} = 2.9 < 7$; $\ell_e = 154.4$ in.; $R_B = \sqrt{\frac{\ell_e \cdot d}{b^2}} = 12.94$

$E'_{y\min n} = 1.09\text{x}10^3(.85) = .93\text{x}10^3$ ksi

$F_{bEn} = \frac{1.2E'_{y\min n}}{R_B^{\,2}} = 6.67$ ksi ; $F_{bxn}^{*} = 5.08(.85)(.8) = 3.46$ ksi

$$C_L = \frac{1+F_{bE}/F^*_{bx}}{1.9} - \sqrt{\left[\frac{1+F_{bE}/F^*_{bx}}{1.9}\right]^2 - \frac{F_{bE}/F^*_{bx}}{0.95}} = 0.973$$

Use C_V, not C_L

$F'_{bxn} = 3.46(0.876) = 3.03\text{ ksi}$

$M'_n = F'_{bn}S = 175$ k-ft > 169.25 k-ft   bending ok

$F'_{vxn} = 605(.75)(.8) = .363\text{ ksi}$

$V'_n = (2/3)F'_{vn}A = 35.36$ k > 28.83 k   shear ok

$5\frac{1}{8}$x28.5 20F – 1.5E Balanced DF glulam (Member A_D)

d. $L_c = 0.2L = 8$ ft (optimum L_c changes when unbal. loading is considered)

Suspended load: $L_{sus} = L - L_c = 32$ ft; $A_T = 32 \times 24 = 768\text{ft}^2 > 600$

$L_r = 20R_1R_2 = 20(0.6)(1.0) = .012\text{ ksf}$; $W_{L_r} = 12(24) = .288\text{ klf}$

$W_d = 1.2(.384) = .46\text{ klf}$

$W_u = .922\text{ klf}$; with reduced L_r, must check unbal. load from analysis:

4. Full $D + L_r$ on all spans:

$V_{max} = 22.12\text{k}$; $M^+_{max} = 118\text{k}\cdot\text{ft}$; $M^-_{max} = 147.28\text{k}\cdot\text{ft}$

5. L_r on left span only:

$V_{max} = 20.27\text{k}$; $M^+_{max} = 14.32\text{k}\cdot\text{ft}$; $M^-_{max} = 73.68\text{k}\cdot\text{ft}$

6. L_r on right span only:

$V_{max} = 22.12\text{k}$; $M^+_{max} = 33\text{k}\cdot\text{ft}$; $M^-_{max} = 147.28\text{k}\cdot\text{ft}$

Design for $V_{max} = 22.12\text{k}$, $M^+_{max} = 149.32\text{k}\cdot\text{ft}$; $M^-_{max} = 147.28\text{k}\cdot\text{ft}$

$F^+_{bxn} = F^-_{bxn} = 2.00K_F = 5.08$ ksi (bal. layup); $F_{vxn} = .210K_F = .605$ ksi;

$E_x = 1.5\text{x}10^3\text{ ksi}$; $E_{y\min n} = .62\text{x}10^3 K_F = 1.09\text{x}10^3\text{ ksi}$

Assume same size as "a", $5\frac{1}{8}\text{x}28.5$, $C_V = 0.876$

$\ell_u = 16ft$ (critical distance from column to inflection pt, load case 3)

$\ell_u/d = 6.74 < 7$ $\ell_e = 1.87\ell_u = 359.04$ in.; $R_B = \sqrt{\frac{\ell_e \cdot d}{b^2}} = 19.74$

$F_{bEn} = \frac{1.2E'_{y\min n}}{R_B^2} = 2.86$ ksi; $F^*_{bxn} = 5082(.85)(.8) = 3.46$ksi

$$C_L = \frac{1+F_{bEn}/F^*_{bn}}{1.9} - \sqrt{\left[\frac{1+F_{bEn}/F^*_{bn}}{1.9}\right]^2 - \frac{F_{bEn}/F^*_{bn}}{0.95}} = 0.73, \text{ use } C_L \text{ vs. } C_V$$

$F'^-_{bxn} = 3.46(0.730) = 2.53\text{ ksi}$

$M'_n = F'_{bxn} S$ = 146.1 k-ft > 147.28 k-ft bending *no good*

$F'_{vxn} = .605(.75)(.8) = .363\,\text{ksi}$

$V'_n = (2/3) F'_{vn} A$ = 35.36 k > 22.13 k shear ok