DESIGN OF WOOD STRUCTURES – ASD/LRFD (7th edition)

4.1 a. narrow, needle-like leaves; evergreens; conifers
b. broadleafed; deciduous
c. softwoods

4.2 See Fig. 4.3.
a. Annual Ring – wood cells developed on the outside of the tree in one growing season
b. Latewood (summerwood) – smaller, darker, more dense, from late in growing season
Earlywood (springwood) – larger, light color, less dense, from early in growing season
c. Heartwood –center of log; inactive cells; collects deposits as tree ages; darker
Sapwood – outer, living, active cells; stores food and transports water

---

4.3 a. Amount of water expressed as percent of dry weight of wood material:

$$MC = \frac{moistweight - ovendryweight}{ovendryweight} x100\%$$

b. FSP = MC at point of “no free water” and fully saturated (bound water) wood.
c. EMC = MC wood assumes in service for a given set of atmospheric conditions

---

4.4 a. $MC \le 19\%$
b. $MC > 19\%$
Note: These values are for sawn lumber; for glulam see Chap. 5 (dry MC < 16%).

4.5 EMC for buildings in “dry southwest states” is approximately 9%, ranging from 7% to 12% (Ref. 4.4)

4.6 *National Design Specification for Wood Construction* (NDS) with *Commentary*
Design Values for Wood Construction (NDS Design Values Supplement)
Special Design Provisions for Wind & Seismic (NDS Wind & Seismic Supplement)
ASD/LRFD *Manual for Engineered Wood Construction*

4.7 bending stress (F_b)
tension stress parallel to grain (F_t)
shear stress parallel to grain (F_v)
compression stress parallel to grain (F_c)
compression stress perpendicular to grain ($F_{c\perp}$)
modulus of elasticity (E)

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

4.9
a. Nominal 2 to 4 in. thick; any width; practically 2 x 2 to 4 x 16.
b. Minimum nominal dimension of 5 in. or larger; includes beams & stringers (width more than 2 in. > thickness) and posts & timbers (square; not more than 2 in. out of square).
c. Design values for the main size categories are determined following different procedures.
   Dimension Lumber- primarily from in-grade test program: ASTM D1990.
   Timbers – tests of small clear specimens: ASTM D2555 & D245
   Dimension Lumber: NDS Supplement Tables 4A, 4B, 4C, 4E, 4F
   Timbers: NDS Supplement Table 4D

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, $\leq$ 10 ft long

---

4.11 Visually graded is graded visually by inspecting and marking each piece. NDS Supplement Tables 4A, 4B, 4D, 4E, and 4F
MSR refers to lumber graded mechanically by subjecting each piece to a nondestructive test that measure E about the weak axis. A visual check is also included. MSR grading is only used for lumber with thickness $\leq$ 2 in. NDS Supplement Table 4C

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

4.13 Visually graded sawn lumber – 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 4B
d.	4 x 4	Dimension	Table 4B
e.	2 x 12	Dimension	Table 4B
f.	6 x 12	B & S	Table 4D
g.	8 x 12	B & S	Table 4D
h.	8 x 10	P & T	Table 4D

4.14 Stress grades of visually graded Hem-Fir

a. Dimension Lumber (NDS Supplement Table 4A)
Select Structural; No.1 & Btr; No.1; No.2; No.3; Stud; Construction; Standard; Utility

b. Beams and Stringers (NDS Supplement Table 4D)
Select Structural; No.1; No.2

c. Posts and Timbers (NDS Supplement Table 4D)
Select Structural; No.1; No.2

4.15 Stress grades of visually graded Southern Pine

a. Dimension Lumber-stress grades vary with size (NDS Supplement Table 4B)

2 in. – 4 in. thick 2 in. – 12 in. wide	Dense Select Structural; Select Structural; Non-Dense Select Structural; No.1 Dense; No.1; No.1 Non-Dense; No. 2 Dense; No. 2; No.2 Non-Dense; No.3 and Stud
2 in. – 4 in. thick 4 in. wide	Construction; Standard; Utility

2 – 4 in. thick 2 in. and wider	Dense Structural 86; Dense Structural 72; Dense Structural 65

b. Beams & Stringers and c. Posts & Timbers (NDS Supplement Table 4D)

5 in. x 5 in. and larger	Dense Select Structural; Select Structural; No. 1 Dense; No.1; No.2 Dense; No. 2; Dense Structural 86; Dense Structural 72; Dense Structural 65

4.16 Reference design values for No. 2 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 = 900 psi
F_t = 575 psi
F_v = 180 psi
$F_{c\perp}$ = 625 psi
F_c = 1350 psi
E = 1,600,000 psi
E_{min} = 580,000 psi

Beams and Stringers (NDS Supplement Table 4D)

f. 6 x 12 – Beams & Stringers
h. 10 x 14 – Beams & Stringers

F_b = 875 psi
F_t = 425 psi
F_v = 170 psi
$F_{c\perp}$ = 625 psi
F_c = 600 psi
E = 1,300,000 psi
E_{min} = 470,000 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 = 750 psi
F_t = 475 psi
F_v = 170 psi
$F_{c\perp}$ = 625 psi
F_c = 700 psi
E = 1,300,000 psi
E_{min} = 470,000 psi

4.17 Nominal design values (LRFD) for No. 2 DF-L

<u>Dimension Lumber</u> (NDS Supplement Table 4A)

c. 4 x 16 – Dimension Lumber
d. 4 x 4 – Dimension Lumber
e. 2 x 10 – Dimension Lumber

F_{bn} $= F_b (K_F) = 900$ psi $(2.54) = 2.29$ ksi $(\Phi_b = 0.85)$
F_{tn} $= F_t (K_F) = 575$ psi $(2.70) = 1.55$ ksi $(\Phi_t = 0.8)$
F_{vn} $= F_v (K_F) = 180$ psi $(2.88) = 0.518$ ksi $(\Phi_v = 0.75)$
$F_{c\perp n}$ $= F_{c\perp} (K_F) = 625$ psi $(1.67) = 1.04$ ksi $(\Phi_c = 0.9)$
F_{cn} $= F_c (K_F) = 1350$ psi $(2.40) = 3.24$ ksi $(\Phi_c = 0.9)$
E $= 1{,}600{,}000$ psi
$E_{\text{min-}n}$ $= E_{\text{min}} (K_F) = 580{,}000$ psi $(1.76) = 1021$ ksi $(\Phi_s = 0.85)$

<u>Beams and Stringers</u> (NDS Supplement Table 4D)

f. 6 x 12 – Beams & Stringers
h. 10 x 14 – Beams & Stringers

F_{bn} $= F_b (K_F) = 875$ psi $(2.54) = 2.22$ ksi $(\Phi_b = 0.85)$
F_{tn} $= F_t (K_F) = 425$ psi $(2.70) = 1.15$ ksi $(\Phi_t = 0.8)$
F_{vn} $= F_v (K_F) = 170$ psi $(2.88) = 0.490$ ksi $(\Phi_v = 0.75)$
$F_{c\perp n}$ $= F_{c\perp} (K_F) = 625$ psi $(1.67) = 1.04$ ksi $(\Phi_c = 0.9)$
F_{cn} $= F_c (K_F) = 600$ psi $(2.40) = 1.44$ ksi $(\Phi_c = 0.9)$
E $= 1{,}300{,}000$ psi
$E_{\text{min-}n}$ $= E_{\text{min}} (K_F) = 470{,}000$ psi $(1.76) = 827$ ksi $(\Phi_s = 0.85)$

<u>Posts and Timbers</u> (NDS Supplement Table 4D)

a. 10 x 10 – Posts & Timbers
b. 12 x 14 – Posts & Timbers
g. 6 x 8 – Posts & Timbers

F_{bn} $= F_b (K_F) = 750$ psi $(2.54) = 1.91$ ksi $(\Phi_b = 0.85)$
F_{tn} $= F_t (K_F) = 475$ psi $(2.70) = 1.28$ ksi $(\Phi_t = 0.8)$
F_{vn} $= F_v (K_F) = 170$ psi $(2.88) = 0.490$ ksi $(\Phi_v = 0.75)$
$F_{c\perp n}$ $= F_{c\perp} (K_F) = 625$ psi $(1.67) = 1.04$ ksi $(\Phi_c = 0.9)$
F_{cn} $= F_c (K_F) = 700$ psi $(2.40) = 1.68$ ksi $(\Phi_c = 0.9)$
E $= 1{,}300{,}000$ psi
$E_{\text{min-}n}$ $= E_{\text{min}} (K_F) = 470{,}000$ psi $(1.76) = 827$ ksi $(\Phi_s = 0.85)$

4.18

Adjustment Factor	**Design values** *that may require adjustment*
a. Size Factor (C_F)	F_b; F_t; F_c
b. Time Effect Factor (λ)	F_b; F_t; F_v; F_c
c. Load Duration Factor (C_D)	F_b; F_t; F_v; F_c
d. Repetitive Member Factor (C_r)	F_b
e. Temperature Factor (C_t)	F_b; F_t; F_v; F_c; $F_{c\perp}$; E; E_{min}
f. Wet Service Factor (C_M)	F_b; F_t; F_v; F_c; $F_{c\perp}$; E; E_{min}
g. Flat Use Factor (C_{fu})	F_b

4.19

a. Load Duration Factor, C_D: The strength of a wood member is affected by the total accumulated length of time that a load is applied. The shorter the duration of load, the higher the strength of a wood member. C_D is the multiplier that adjusts reference design values (F_b, F_t, F_v and F_c) from normal duration (10 years) to other durations for ASD. See NDS 2.3.2 and Appendix B.
b. Time Effect Factor, λ: The strength of a wood member is affected by the total accumulated length of time that a load is applied. λ is the multiplier that adjusts the LRFD resistance of wood members (F_b, F_t, F_v and F_c) to ensure that consistent reliability is achieved for load duration effects in various LRFD load combinations. See NDS Appendix N.
c. Wet Service Factor, C_M: The moisture content (MC) of a wood member affects its load capacity. Most reference design values for sawn lumber apply to MC $\leq$ 19 percent in service. Higher moisture contents require reduction of design values by C_M. The following reference design values are subject to adjustment for increased moisture content: F_b, F_t, F_v, $F_{c\perp}$, F_c, E and $E_{\min}$. See NDS 4.3.3 and the Adjustment Factors sections of NDS Supplement Tables 4A, 4B, 4C, 4D, 4E, and 4F.
d. Size Factor, C_F: The size of a wood member affects its strength. For visually graded Dimension Lumber, C_F applies to F_b, F_t and F_c. See NDS 4.3.6.1 and the Adjustment Factor section of NDS Supplement Tables 4A and 4F. For Timbers, the size factor applies to F_b. See NDS 4.3.6.2 and the Adjustment Factors section of NDS Supplement Table 4D. For Decking, C_F applies only to F_b. See NDS 4.3.6.4 and the Adjustment Factors section of NDS Supplement Table 4E.
e. Repetitive Member Factor, C_r: Applies to Dimension Lumber, but not to Timbers. When three or more wood members are spaced not more that 24 in. o/c and are connected together by a load distributing element (such as sheathing), the bending design value F_b may be increased by $C_r = 1.15$. This is a 15 percent increase over single member bending design values. The C_r adjustment recognizes that failure of a single member in a repetitive application will not mean failure of the overall system. The load will be distributed to other members.

4.20 Wood has the ability to support higher stresses for short periods of time. Both the load duration factor (C_D) and the time effect factor (λ) are employed to adjust wood strength properties based on the duration of applied design loads. The load duration factor (C_D) is used to adjust reference design values in allowable stress design (ASD), and is based on the shortest duration load in an ASD load combination. The time effect factor (λ) is used to adjust nominal design values in load and resistance factor design (LRFD), and is based on the dominant transient load in an LRFD load combination. Time effect factors (λ) are intended to ensure consistent reliability for load duration effects across various load combinations.

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): $C_D = 0.9$

4.22 a. 1.2D + 1.6S + L: $\lambda = 0.8$
b. 1.2D + W + L + 0.5S: $\lambda = 1.0$
c. 1.2D + 1.6L + 0.5S: $\lambda = 0.8$ (for L due to occupancy)
d. 1.2D + 1.6L_r + L: $\lambda = 0.8$
e. 1.4D: $\lambda = 0.6$

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.
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 λ in LRFD calculations.

4.24 Most reference design values apply to dry service conditions*. Dry service conditions are defined as:
a. Sawn Lumber MC ≤ 19 percent
b. Glulam MC < 16 percent
When the moisture content exceeds these limits, the reference design values are reduced by a wet service factor C_M that is less than 1.0
* *Southern Pine has C_M included in some of the reference design values* (NDS Supplement Table 4B). *Many of the reference design values for Timbers* (NDS Supplement Table 4D) *have already been adjusted for C_M.*

4.25 The load capacity of wood decreases as the temperature increases. Reductions in strength caused by heating up to 150 degrees F are generally reversible when the temperature returns to normal. Reductions in strength may not be reversible when heating exceeds 150 degrees F. Reduction in strength occurs when the member is subjected to the full design capacity.
When a wood member is consistently heated above 100 degrees F and is subjected to the full design load, an adjustment for temperature effects will be required. This may occur in an industrial plant, but reductions are not normally required in ordinary roof structures. See NDS 2.3.3 and Appendix C.

4.26 Pressure preservative treated wood has chemicals impregnated in the treated zone which resist attack by decay, termites and other insects, and marine borers. Reference design values apply directly to preservative treated wood, and an adjustment factor is not required unless the member has been incised to increase the penetration of preservatives.
Fire-retardant-treated wood has much higher concentrations of chemicals than preservative treated wood. At one time a 10 percent reduction in reference design values was specified. However, the reduction in strength varies with the treating process, and the NDS refers the designer to the company providing the fire retardant treatment for appropriate reduction factors.

4.27 Wood that is *continuously submerged* in fresh water will not decay and does not need to be preservative treated. However, wood that is partially submerged, or wood that undergoes cycles of submersion followed by exposure to the atmosphere, should be preservative treated. Wood that is submerged in salt water should be preservative treated to protect from marine borers. Preservative treated wood has an extensive record of resisting attack in both fresh water and salt water environments.

4.28 Critical ASD load combination for a fully braced member

ASD Combination	**Load**	C_D	**Load/**C_D*
D (roof + floor)	3 + 6 = 9 k	0.9	10 k
D + L	9 + 10 = 19 k	1	19 k
D + L_r	9 + 5 = 14 k	1.25	11.2 k
D + 0.6W	9 + 10.2 = 19.2 k	1.6	12 k
D + ¾ (L + L_r)	9 + ¾ (10 + 5) =20.25 k	1.25	16.2 k
D + ¾(0.6W + L + L_r)	9 + ¾ (10.2 + 10 + 5) = 27.75 k	1.6	17.4 k

* The largest load in this column defines the critical ASD load combination for a fully braced member: **D + L**
Note: Actual loads (i.e., loads that have not been divided by C_D) should be used in design calculations. The load duration factor should then be used to adjust the appropriate reference design values. In this problem, the actual critical load is 19 k and C_D = 1.0. The above analysis is used to define the critical combination only for fully braced members, tension members, or connections.

4.29 Critical ASD load combination for a fully braced member
[0.6W = 0.6(17 k) = 10.2 k] > [0.7E = 0.7(12 k) = 8.4 k]
[S = 18 k] > [L_r = 7 k]

Combination	**Load**	C_D	**Load/**C_D*
D (roof + floor)	5 + 6 = 11 k	0.9	12.2 k
D + L	11 + 15 = 26 k	1	26.0 k
D + S	11 + 18 = 29 k	1.15	25.2 k
D + L_r	11 + 7 = 18 k	1.25	14.4 k
D + 0.75(L + S)	11 + 0.75(15 + 18) = 35.75 k	1.15	31.1 k
D + 0.75(L + L_r)	11 + 0.75(15 + 7) = 27.5 k	1.25	22.0 k
D + (0.6W or 0.7E)	11 + 10.2 = 21.2 k	1.6	13.3 k
D + 0.75(0.6W or 0.7E) + 0.75L + 0.75(L_r or S)	11 + 0.75(10.2 + 15 + 18) = 43.4 k	1.6	27.1 k

* The largest load in this column defines the critical ASD load combinationfor a fully braced member: **D + 0.75(L + S)**

Note: Actual loads (i.e., loads that have not been divided by C_D) should be used in design calculations. The load duration factor should then be used to adjust the appropriate reference design values. In this problem, the actual critical load is 35.75 k and C_D = 1.15. The above analysis is used to define the critical combination only for fully braced members, tension members, or connections.

4.30 ASD – Hem-Fir No.2, fully braced; bending about strong axis

a. **2 x 10 joists** at 16 in. o.c. (C_r = 1.15); D + S load combination (C_D = 1.15)
C_F applies for bending, tension and compression; other factors equal to unity
$F_b' = F_b\,(C_D)(C_F)(C_r)$ = 850 psi (1.15)(1.1)(1.15) = 1237 psi
$F_t' = F_t\,(C_D)(C_F)$ = 525 psi (1.15)(1.1) = 664 psi
$F_v' = F_v\,(C_D)$ = 150 psi (1.15) = 173 psi
$F_{c\perp}' = F_{c\perp}$ = 405 psi
$F_c' = F_c\,(C_D)(C_F)$ = 1300 psi (1.15)(1.0) = 1495 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,300,000 psi
$E_{min}' = E_{min}$ = 470,000 psi

b. **6 x 14** (Beams & Stringers); supports permanent load (C_D = 0.9)
$C_F = (12/13.5)^{0.111}$ = 0.987 for bending; other factors equal to unity
$F_b' = F_b\,(C_D)(C_F)$ = 675 psi (0.9)(0.987) = 600 psi
$F_t' = F_t\,(C_D)$ = 350 psi (0.9) = 315 psi
$F_v' = F_v\,(C_D)$ = 140 psi (0.9) = 126 psi
$F_{c\perp}' = F_{c\perp}$ = 405 psi
$F_c' = F_c\,(C_D)$ = 500 psi (0.9) = 450 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,100,000 psi
$E_{min}' = E_{min}$ = 400,000 psi

c. **4 x 14 purlins** at 8 ft o.c.; D + L_r load combination (C_D = 1.25)
C_F applies for bending, tension and compression; other factors equal to unity
$F_b' = F_b\,(C_D)(C_F)$ = 850 psi (1.25)(1.0) = 1063 psi
$F_t' = F_t\,(C_D)(C_F)$ = 525 psi (1.25)(0.9) = 591 psi
$F_v' = F_v\,(C_D)$ = 150 psi (1.25) = 188 psi
$F_{c\perp}' = F_{c\perp}$ = 405 psi
$F_c' = F_c\,(C_D)(C_F)$ = 1300 psi (1.25)(0.9) = 1463 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,300,000 psi
$E_{min}' = E_{min}$ = 470,000 psi

d. **4 x 6 beams** at 4 ft o.c.; D + L load combination (C_D = 1.0); C_M applies
C_F applies for bending, tension and compression; other factors equal to unity
$F_b' = F_b\,(C_D)(C_M)(C_F)$ = 850 psi (1.0)(1.0)(1.3) = 1105 psi
  C_M = 1.0 for bending since $F_b\,(C_F)$ = 1105 psi < 1150 psi
$F_t' = F_t\,(C_D)(C_M)(C_F)$ = 525 psi (1.0)(1.0)(1.3) = 683 psi
$F_v' = F_v\,(C_D)(C_M)$ = 150 psi (1.0)(0.97) = 146 psi
$F_{c\perp}' = F_{c\perp}\,(C_M)$ = 405 psi (0.67) = 271 psi
$F_c' = F_c\,(C_D)(C_M)(C_F)$ = 1300 psi (1.0)(0.8)(1.1) = 1144 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E\,(C_M)$ = 1,300,000 psi (0.9) = 1,170,000 psi
$E_{min}' = E_{min}\,(C_M)$ = 470,000 psi (0.9) = 423,000 psi

---

4.31 LRFD (K_F and Φ apply) – Hem-Fir No.2, fully braced; bending about strong axis

a. **2 x 10 joists** at 16 in. o.c. (C_r = 1.15); 1.2D + 1.6S load combination (λ = 0.8)
C_F applies for bending, tension and compression; other factors equal to unity
A = 13.88 in^2; S_x = 21.39 in^3
<u>Bending moment</u>
$F_{bn} = F_b\ (K_F)$ = 850 psi (2.54) = 2159 psi = 2.16 ksi
$F_{bn}' = F_{bn}\ (\Phi_b)(\lambda)(C_F)(C_r)$ = 2.16 ksi (0.85)(0.8)(1.1)(1.15) = 1.86 ksi
$M_n' = F_{bn}'\ (S_x)$ = 1.86 ksi (21.39 in^3) = 39.7 k-in.
<u>Tension</u>
$F_{tn} = F_t\ (K_F)$ = 525 psi (2.7) = 1418 psi = 1.42 ksi
$F_{tn}' = F_{tn}\ (\Phi_t)(\lambda)(C_F)$ = 1.42 ksi (0.8)(0.8)(1.1) = 0.998 ksi
$T_n' = F_{tn}'\ (A)$ = 0.998 ksi (13.88 in^2) = 13.9 k
<u>Flexural Shear</u>
$F_{vn} = F_v\ (K_F)$ = 150 psi (2.88) = 432 psi = 0.432 ksi
$F_{vn}' = F_{vn}\ (\Phi_v)(\lambda)$ = 0.432 ksi (0.75)(0.8) = 0.259 ksi
$V_n' = F_{vn}'\ (2/3)(A)$ = 0.259 ksi (2/3)(13.88 in^2) = 2.4 k
<u>Compression perpendicular to grain (bearing)</u>
$F_{c\perp n} = F_{c\perp}\ (K_F)$ = 405 psi (1.67) = 676 psi = 0.676 ksi
$F_{c\perp n}' = F_{c\perp n}\ (\Phi_c)$ = 0.676 ksi (0.9) = 0.609 ksi
<u>Compression parallel to grain</u>
$F_{cn} = F_c\ (K_F)$ = 1300 psi (2.4) = 3120 psi = 3.12 ksi
$F_{cn}' = F_{cn}\ (\Phi_c)(\lambda)(C_F)$ = 3.12 ksi (0.9)(0.8)(1.0) = 2.25 ksi
$P_n' = F_{cn}'\ (A)$ = 2.25 ksi (13.88 in^2) = 31.2 k
Note that C_P would also apply for column buckling of an axially loaded member.
<u>Modulus of Elasticity</u>
$E' = E$ = 1,300,000 psi = 1300 ksi
$E_{\text{min-}n} = E_{\text{min}}\ (K_F)$ = 470,000 psi (1.76) = 827,200 psi = 827 ksi
$E_{\text{min-}n}' = E_{\text{min-n}}\ (\Phi_s)$ = 827 ksi (0.85) = 703 ksi

b. **6 x 16** (Beams & Stringers); 1.2D + 1.6L (storage) load (λ = 0.7)
$C_F = (12/15.5)^{0.111}$ = 0.972 for bending; other factors equal to unity
A = 85.25 in^2; S_x = 220.2 in^3
<u>Bending moment</u>
$F_{bn} = F_b\ (K_F)$ = 675 psi (2.54) = 1714.5 psi = 1.71 ksi
$F_{bn}' = F_{bn}\ (\Phi_b)(\lambda)(C_F)$ = 1.71 ksi (0.85)(0.7)(0.972) = 0.992 ksi
$M_n' = F_{bn}'\ (S_x)$ = 0.992 ksi (220.2 in^3) = 218 k-in.
<u>Tension</u>
$F_{tn} = F_t\ (K_F)$ = 350 psi (2.7) = 945 psi = 0.945 ksi
$F_{tn}' = F_{tn}\ (\Phi_t)(\lambda)$ = 0.945 ksi (0.8)(0.7) = 0.529 ksi
$T_n' = F_{tn}'\ (A)$ = 0.529 ksi (85.25 in^2) = 45.1 k
<u>Flexural Shear</u>
$F_{vn} = F_v\ (K_F)$ = 140 psi (2.88) = 403 psi = 0.403 ksi
$F_{vn}' = F_{vn}\ (\Phi_v)(\lambda)$ = 0.403 ksi (0.75)(0.7) = 0.212 ksi
$V_n' = F_{vn}'\ (2/3)(A)$ = 0.212 ksi (2/3)(85.25 in^2) = 12.0 k

Compression perpendicular to grain (bearing)
$F_{c\perp n} = F_{c\perp}\,(K_F)$ = 405 psi (1.67) = 676 psi = 0.676 ksi
$F_{c\perp n}' = F_{c\perp n}\,(\Phi_c)$ = 0.676 ksi (0.9) = 0.609 ksi
Compression parallel to grain
$F_{cn} = F_c\,(K_F)$ = 500 psi (2.4) = 1200 psi = 1.20 ksi
$F_{cn}' = F_{cn}\,(\Phi_c)(\lambda)$ = 1.20 ksi (0.9)(0.7) = 0.756 ksi
$P_n' = F_{cn}'\,(A)$ = 0.756 ksi (85.25 in^2) = 64.4 k
Note that C_P would also apply for column buckling of an axially loaded member.
Modulus of Elasticity
$E' = E$ = 1,100,000 psi = 1100 ksi
$E_{\text{min-}n} = E_{\text{min}}\,(K_F)$ = 400,000 psi (1.76) = 704,000 psi = 704 ksi
$E_{\text{min-}n}' = E_{\text{min-n}}\,(\Phi_s)$ = 704 ksi (0.85) = 598 ksi

c. **4 x 14 purlins** at 8 ft o.c.; 1.2D + 1.6L$_r$ load combination (λ = 0.8)
C_F applies for bending, tension and compression; other factors equal to unity
A = 46.38 in^2; S_x = 102.4 in^3
Bending moment
$F_{bn} = F_b\,(K_F)$ = 850 psi (2.54) = 2159 psi = 2.16 ksi
$F_{bn}' = F_{bn}\,(\Phi_b)(\lambda)(C_F)$ = 2.16 ksi (0.85)(0.8)(1.0) = 1.47 ksi
$M_n' = F_{bn}'\,(S_x)$ = 1.47 ksi (102.4 in^3) = 150 k-in.
Tension
$F_{tn} = F_t\,(K_F)$ = 525 psi (2.7) = 1418 psi = 1.42 ksi
$F_{tn}' = F_{tn}\,(\Phi_t)(\lambda)(C_F)$ = 1.42 ksi (0.8)(0.8)(0.9) = 0.816 ksi
$T_n' = F_{tn}'\,(A)$ = 0.816 ksi (46.38 in^2) = 37.9 k
Flexural Shear
$F_{vn} = F_v\,(K_F)$ = 150 psi (2.88) = 432 psi = 0.432 ksi
$F_{vn}' = F_{vn}\,(\Phi_v)(\lambda)$ = 0.432 ksi (0.75)(0.8) = 0.259 ksi
$V_n' = F_{vn}'\,(2/3)(A)$ = 0.259 ksi (2/3)(46.38 in^2) = 8.0 k
Compression perpendicular to grain (bearing)
$F_{c\perp n} = F_{c\perp}\,(K_F)$ = 405 psi (1.67) = 676 psi = 0.676 ksi
$F_{c\perp n}' = F_{c\perp n}\,(\Phi_c)$ = 0.676 ksi (0.9) = 0.609 ksi
Compression parallel to grain
$F_{cn} = F_c\,(K_F)$ = 1300 psi (2.4) = 3120 psi = 3.12 ksi
$F_{cn}' = F_{cn}\,(\Phi_c)(\lambda)(C_F)$ = 3.12 ksi (0.9)(0.8)(0.9) = 2.02 ksi
$P_n' = F_{cn}'\,(A)$ = 2.02 ksi (46.38 in^2) = 93.8 k
Note that C_P would also apply for column buckling of an axially loaded member.
Modulus of Elasticity
$E' = E$ = 1,300,000 psi = 1300 ksi
$E_{\text{min-}n} = E_{\text{min}}\,(K_F)$ = 470,000 psi (1.76) = 827,200 psi = 827 ksi
$E_{\text{min-}n}' = E_{\text{min-n}}\,(\Phi_s)$ = 827 ksi (0.85) = 703 ksi

d. **4 x 6 beams** at 4 ft o.c.; 1.2D + 1.6L (occupancy) load ($\lambda = 0.8$); C_M applies
C_F applies for bending, tension and compression; other factors equal to unity
$A = 19.25$ in^2; $S_x = 17.65$ in^3

Bending moment

$F_{bn} = F_b (K_F) = 850$ psi (2.54) = 2159 psi = 2.16 ksi

$C_M = 1.0$ for bending since $F_b (C_F) = 1105$ psi < 1150 psi

$F_{bn}' = F_{bn} (\Phi_b)(\lambda)(C_M)(C_F) = 2.16$ ksi (0.85)(0.8)(1.0)(1.3) = 1.91 ksi

$M_n' = F_{bn}' (S_x) = 1.91$ ksi (17.65 in^3) = 33.7 k-in.

Tension

$F_{tn} = F_t (K_F) = 525$ psi (2.7) = 1418 psi = 1.42 ksi

$F_{tn}' = F_{tn} (\Phi_t)(\lambda)(C_M)(C_F) = 1.42$ ksi (0.8)(0.8)(1.0)(1.3) = 1.18 ksi

$T_n' = F_{tn}' (A) = 1.18$ ksi (19.25 in^2) = 22.7 k

Flexural Shear

$F_{vn} = F_v (K_F) = 150$ psi (2.88) = 432 psi = 0.432 ksi

$F_{vn}' = F_{vn} (\Phi_v)(\lambda)(C_M) = 0.432$ ksi (0.75)(0.8)(0.97) = 0.251 ksi

$V_n' = F_{vn}' (2/3)(A) = 0.251$ ksi (2/3)(19.25 in^2) = 3.2 k

Compression perpendicular to grain (bearing)

$F_{c\perp n} = F_{c\perp} (K_F) = 405$ psi (1.67) = 676 psi = 0.676 ksi

$F_{c\perp n}' = F_{c\perp n} (\Phi_c)(C_M) = 0.676$ ksi (0.9)(0.67) = 0.408 ksi

Compression parallel to grain

$F_{cn} = F_c (K_F) = 1300$ psi (2.4) = 3120 psi = 3.12 ksi

$F_{cn}' = F_{cn} (\Phi_c)(\lambda)(C_M)(C_F) = 3.12$ ksi (0.9)(0.8)(0.8)(1.1) = 1.98 ksi

$P_n' = F_{cn}' (A) = 1.98$ ksi (19.25 in^2) = 38.1 k

Note that C_P would also apply for column buckling of an axially loaded member.

Modulus of Elasticity

$E' = E (C_M) = 1{,}300{,}000$ psi (0.9) = 1,170,000 = 1170 ksi

$E_{\text{min-}n} = E_{\text{min}} (K_F) = 470{,}000$ psi (1.76) = 827,200 psi = 827 ksi

$E_{\text{min-}n}' = E_{\text{min-n}} (\Phi_s)(C_M) = 827$ ksi (0.85)(0.9) = 633 ksi

---

4.32 ASD – Select Structural Southern Pine, fully braced; bending about strong axis

a. **2 x 6 joists** at 24 in. o.c. (C_r = 1.15); D + S load combination (C_D = 1.15)
C_F is already included in NDS Table 4B values; other factors equal to unity
$F_b' = F_b (C_D)(C_r)$ = 2100 psi (1.15)(1.15) = 2777 psi
$F_t' = F_t (C_D)$ = 1450 psi (1.15) = 1668 psi
$F_v' = F_v (C_D)$ = 175 psi (1.15) = 201 psi
$F_{c\perp}' = F_{c\perp}$ = 565 psi
$F_c' = F_c (C_D)$ = 1800 psi (1.15) = 2070 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,800,000 psi
$E_{min}' = E_{min}$ = 660,000 psi

b. **4 x 12 beam**; D + 0.75(L + L_r) load combination (C_D = 1.25)
C_F = 1.1 for bending; other factors equal to unity
$F_b' = F_b (C_D)(C_F)$ = 1600 psi (1.25)(1.1) = 2200 psi
$F_t' = F_t (C_D)$ = 1100 psi (1.25) = 1375 psi
$F_v' = F_v (C_D)$ = 175 psi (1.25) = 219 psi
$F_{c\perp}' = F_{c\perp}$ = 565 psi
$F_c' = F_c (C_D)$ = 1650 psi (1.25) = 2063 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,800,000 psi
$E_{min}' = E_{min}$ = 660,000 psi

c. **2 x 10 purlins** at 4 ft o.c.; D + L_r load combination (C_D = 1.25)
C_F is already incorporated in NDS Table 4B values; other factors equal to unity
$F_b' = F_b (C_D)$ = 1700 psi (1.25) = 2125 psi
$F_t' = F_t (C_D)$ = 1150 psi (1.25) = 1438 psi
$F_v' = F_v (C_D)$ = 175 psi (1.25) = 219 psi
$F_{c\perp}' = F_{c\perp}$ = 565 psi
$F_c' = F_c (C_D)$ = 1650 psi (1.25) = 2063 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,800,000 psi
$E_{min}' = E_{min}$ = 660,000 psi

d. **4 x 10 beams** at 4 ft o.c.; D + 0.75(L + 0.6W) load combination (C_D = 1.6)
C_F = 1.1 for bending; other factors equal to unity
$F_b' = F_b (C_D)(C_F)$ = 1700 psi (1.6)(1.1) = 2992 psi
$F_t' = F_t (C_D)$ = 1150 psi (1.6) = 1840 psi
$F_v' = F_v (C_D)$ = 175 psi (1.6) = 280 psi
$F_{c\perp}' = F_{c\perp}$ = 565 psi
$F_c' = F_c (C_D)$ = 1650 psi (1.6) = 2640 psi
Note that C_P would also apply for column buckling of an axially loaded member.
$E' = E$ = 1,800,000 psi
$E_{min}' = E_{min}$ = 660,000 psi

4.33 LRFD (K_F and Φ apply) – Select Structural Southern Pine, fully braced; bending about strong axis

a. **2 x 6 joists** at 24 in. o.c. (C_r = 1.15); 1.2D + 1.6S load combination (λ = 0.8)
C_F is already included in NDS Table 4B values; other factors equal to unity
A = 8.25 in^2; S_x = 7.563 in^3
Bending moment
$F_{bn} = F_b (K_F)$ = 2100 psi (2.54) = 5334 psi = 5.33 ksi
$F_{bn}' = F_{bn} (\Phi_b)(\lambda)(C_r)$ = 5.33 ksi (0.85)(0.8)(1.15) = 4.17 ksi
$M_n' = F_{bn}' (S_x)$ = 5.07 ksi (7.563 in^3) = 31.5 k-in.
Tension
$F_{tn} = F_t (K_F)$ = 1450 psi (2.7) = 3915 psi = 3.92 ksi
$F_{tn}' = F_{tn} (\Phi_t)(\lambda)$ = 3.92 ksi (0.8)(0.8) = 2.51 ksi
$T_n' = F_{tn}' (A)$ = 2.51 ksi (8.25 in^2) = 20.7 k
Flexural Shear
$F_{vn} = F_v (K_F)$ = 175 psi (2.88) = 504 psi = 0.504 ksi
$F_{vn}' = F_{vn} (\Phi_v)(\lambda)$ = 0.504 ksi (0.75)(0.8) = 0.302 ksi
$V_n' = F_{vn}'$ (2/3)(A) = 0.302 ksi (2/3)(8.25 in^2) = 1.7 k
Compression perpendicular to grain (bearing)
$F_{c\perp n} = F_{c\perp} (K_F)$ = 565 psi (1.67) = 944 psi = 0.944 ksi
$F_{c\perp n}' = F_{c\perp n} (\Phi_c)$ = 0.944 ksi (0.9) = 0.849 ksi
Compression parallel to grain
$F_{cn} = F_c (K_F)$ = 1800 psi (2.4) = 4320 psi = 4.32 ksi
$F_{cn}' = F_{cn} (\Phi_c)(\lambda)$ = 4.32 ksi (0.9)(0.8) = 3.11 ksi
$P_n' = F_{cn}' (A)$ = 3.11 ksi (8.25 in^2) = 25.7 k
Note that C_P would also apply for column buckling of an axially loaded member.
Modulus of Elasticity
$E' = E$ = 1,800,000 psi = 1800 ksi
$E_{min\text{-}n} = E_{min} (K_F)$ = 660,000 psi (1.765) = 1,165,000 psi = 1165 ksi
$E_{min\text{-}n}' = E_{min\text{-}n} (\Phi_s)$ = 1165 ksi (0.85) = 990 ksi

b. **4 x 12 beam**; 1.2D + 1.6L + 0.5L_r (occupancy) load combination (λ = 0.8)
C_F = 1.1 for bending; other factors equal to unity
A = 39.38 in^2; S_x = 73.83 in^3
Bending moment
$F_{bn} = F_b (K_F)$ = 1600 psi (2.54) = 4064 psi = 4.06 ksi
$F_{bn}' = F_{bn} (\Phi_b)(\lambda)(C_F)$ = 4.06 ksi (0.85)(0.8)(1.1) = 3.04 ksi
$M_n' = F_{bn}' (S_x)$ = 3.04 ksi (73.83 in^3) = 224 k-in.
Tension
$F_{tn} = F_t (K_F)$ = 1100 psi (2.7) = 2970 psi = 2.97 ksi
$F_{tn}' = F_{tn} (\Phi_t)(\lambda)$ = 2.97 ksi (0.8)(0.8) = 1.90 ksi
$T_n' = F_{tn}' (A)$ = 1.90 ksi (39.38 in^2) = 74.8 k
Flexural Shear
$F_{vn} = F_v (K_F)$ = 175 psi (2.88) = 504 psi = 0.504 ksi
$F_{vn}' = F_{vn} (\Phi_v)(\lambda)$ = 0.504 ksi (0.75)(0.8) = 0.302 ksi
$V_n' = F_{vn}'$ (2/3)(A) = 0.302 ksi (2/3)(39.38 in^2) = 7.9 k

Compression perpendicular to grain (bearing)
$F_{c\perp n} = F_{c\perp} (K_F)$ = 565 psi (1.67) = 944 psi = 0.944 ksi
$F_{c\perp n}' = F_{c\perp n} (\Phi_c)$ = 0.944 ksi (0.9) = 0.849 ksi
Compression parallel to grain
$F_{cn} = F_c (K_F)$ = 1650 psi (2.4) = 3960 psi = 3.96 ksi
$F_{cn}' = F_{cn} (\Phi_c)(\lambda)$ = 3.96 ksi (0.9)(0.8) = 2.85 ksi
$P_n' = F_{cn}' (A)$ = 2.85 ksi (39.38 in^2) = 112 k
Note that C_P would also apply for column buckling of an axially loaded member.
Modulus of Elasticity
$E' = E$ = 1,800,000 psi = 1800 ksi
$E_{\text{min-}n} = E_{\text{min}} (K_F)$ = 660,000 psi (1.76) = 1,161,600 psi = 1162 ksi
$E_{\text{min-}n}' = E_{\text{min-n}} (\Phi_s)$ = 1162 ksi (0.85) = 987 ksi

c. **2 x 10 purlins** at 4 ft o.c.; 1.2D + 1.6L_r load combination (λ = 0.8)
C_F is already incorporated in NDS Table 4B values; other factors equal to unity
A = 13.88 in^2; S_x = 21.39 in^3
Bending moment
$F_{bn} = F_b (K_F)$ = 1700 psi (2.54) = 4318 psi = 4.32 ksi
$F_{bn}' = F_{bn} (\Phi_b)(\lambda)$ = 4.32 ksi (0.85)(0.8) = 2.94 ksi
$M_n' = F_{bn}' (S_x)$ = 3.54 ksi (21.39 in^3) = 62.8 k-in.
Tension
$F_{tn} = F_t (K_F)$ = 1150 psi (2.7) = 3105 psi = 3.11 ksi
$F_{tn}' = F_{tn} (\Phi_t)(\lambda)$ = 3.11 ksi (0.8)(0.8) = 1.99 ksi
$T_n' = F_{tn}' (A)$ = 1.99 ksi (13.88 in^2) = 26.6 k
Flexural Shear
$F_{vn} = F_v (K_F)$ = 175 psi (2.88) = 504 psi = 0.504 ksi
$F_{vn}' = F_{vn} (\Phi_v)(\lambda)$ = 0.504 ksi (0.75)(0.8) = 0.302 ksi
$V_n' = F_{vn}' (2/3)(A)$ = 0.302 ksi (2/3)(13.88 in^2) = 2.8 k
Compression perpendicular to grain (bearing)
$F_{c\perp n} = F_{c\perp} (K_F)$ = 565 psi (1.67) = 944 psi = 0.944 ksi
$F_{c\perp n}' = F_{c\perp n} (\Phi_c)$ = 0.944 ksi (0.9) = 0.849 ksi
Compression parallel to grain
$F_{cn} = F_c (K_F)$ = 1650 psi (2.4) = 3960 psi = 3.96 ksi
$F_{cn}' = F_{cn} (\Phi_c)(\lambda)$ = 3.96 ksi (0.9)(0.8) = 2.85 ksi
$P_n' = F_{cn}' (A)$ = 2.85 ksi (13.88 in^2) = 39.6 k
Note that C_P would also apply for column buckling of an axially loaded member.
Modulus of Elasticity
$E' = E$ = 1,800,000 psi = 1800 ksi
$E_{\text{min-}n} = E_{\text{min}} (K_F)$ = 660,000 psi (1.76) = 1,161,600 psi = 1162 ksi
$E_{\text{min-}n}' = E_{\text{min-n}} (\Phi_s)$ = 1162 ksi (0.85) = 987 ksi

d. **4 x 10 beams** at 4 ft o.c.; 1.2D + W + L load combination ($\lambda = 1.0$)
$C_F = 1.1$ for bending; other factors equal to unity
$A = 32.38$ in^2; $S_x = 49.91$ in^3
<u>Bending moment</u>
$F_{bn} = F_b\ (K_F) = 1700$ psi (2.54) = 4318 psi = 4.32 ksi
$F_{bn}' = F_{bn}\ (\Phi_b)(\lambda)(C_F) = 4.32$ ksi (0.85)(1.0)(1.1) = 4.04 ksi
$M_n' = F_{bn}'\ (S_x) = 4.04$ ksi (49.91 in^3) = 202 k-in.
<u>Tension</u>
$F_{tn} = F_t\ (K_F) = 1150$ psi (2.7) = 3105 psi = 3.11 ksi
$F_{tn}' = F_{tn}\ (\Phi_t)(\lambda) = 3.11$ ksi (0.8)(1.0) = 2.48 ksi
$T_n' = F_{tn}'\ (A) = 2.48$ ksi (32.38 in^2) = 80.4 k
<u>Flexural Shear</u>
$F_{vn} = F_v\ (K_F) = 175$ psi (2.88) = 504 psi = 0.504 ksi
$F_{vn}' = F_{vn}\ (\Phi_v)(\lambda) = 0.504$ ksi (0.75)(1.0) = 0.378 ksi
$V_n' = F_{vn}'\ (2/3)(A) = 0.378$ ksi (2/3)(32.38 in^2) = 8.2 k
<u>Compression perpendicular to grain (bearing)</u>
$F_{c\perp n} = F_{c\perp}\ (K_F) = 565$ psi (1.67) = 944 psi = 0.944 ksi
$F_{c\perp n}' = F_{c\perp n}\ (\Phi_c) = 0.944$ ksi (0.9) = 0.849 ksi
<u>Compression parallel to grain</u>
$F_{cn} = F_c\ (K_F) = 1650$ psi (2.4) = 3960 psi = 3.96 ksi
$F_{cn}' = F_{cn}\ (\Phi_c)(\lambda) = 3.96$ ksi (0.9)(1.0) = 3.56 ksi
$P_n' = F_{cn}'\ (A) = 3.56$ ksi (32.38 in^2) = 115 k
Note that C_P would also apply for column buckling of an axially loaded member.
<u>Modulus of Elasticity</u>
$E' = E = 1{,}800{,}000$ psi = 1800 ksi
$E_{\min\text{-}n} = E_{\min}\ (K_F) = 660{,}000$ psi (1.76) = 1,161,600 psi = 1162 ksi
$E_{\min\text{-}n}' = E_{\min\text{-}n}\ (\Phi_s) = 1162$ ksi (0.85) = 987 ksi

---

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

4.35 $SV = \frac{6}{30} = 0.2\%$ per 1% change in MC = 0.002 in./in./percent change in MC
ΔMC = 9 – 19 = -10 (drying)
Shrinkage in 2 x 10 = (SV)(ΔMC) *d* = (0.002)(-10)(9.25 in.) = 0.185 in.
Shrinkage in 2 x plate = (SV)(ΔMC) *d* = (0.002)(-10)(1.5 in.) = 0.03 in.
three 2 x 12’s; twelve 2 x plates
Total shrinkage = 3(0.185 in.) + 12(0.03 in.) = 0.9 in.
