GENERAL REQUIREMENTS FOR STRUCTURAL DESIGN

1.1 Scope

1.1.1 Practice Defined

1.1.1.1 This Specification defines the method to be followed in structural design with the following wood products:

- visually graded lumber
- mechanically graded lumber
- structural glued laminated timber
- timber piles
- timber poles
- prefabricated wood I-joists
- structural composite lumber
- wood structural panels

It also defines the practice to be followed in the design and fabrication of single and multiple fastener connections using the fasteners described herein.

1.1.1.2 Structural assemblies utilizing panel products shall be designed in accordance with principles of engineering mechanics (see References 32, 33, 34 and 53 for design provisions for commonly used panel products).

1.1.1.3 This Specification is not intended to preclude the use of materials, assemblies, structures or designs not meeting the criteria herein, where it is demonstrated by analysis based on recognized theory, full scale or prototype loading tests, studies of model analogues or extensive experience in use that the material, assembly, structure or design will perform satisfactorily in its intended end use.

1.1.2 Competent Supervision

The design values and structural design provisions given in this Specification are for designs made and carried out under competent supervision.

1.2 General Requirements

1.2.1 Conformance With Standards

The quality of wood products and fasteners, and the design of load-supporting members and connections shall conform to the standards specified herein.

1.2.2 Framing and Bracing

All members shall be so framed, anchored, tied, and braced that they have the required strength and rigidity. Adequate bracing and bridging to resist wind and other lateral forces shall be provided.

1.3 Standard as a Whole

The various Chapters, Sections, Subsections and Articles of this Specification are interdependent and, except as otherwise provided, the pertinent provisions of each Chapter, Section, Subsection and Article shall apply to every other Chapter, Section, Subsection and Article.

1.4 Design Loads

1.4.1 Loading Assumptions

Wood buildings or other wood structures, and their structural members, shall be designed and constructed to safely support all anticipated loads. This Specification is predicated on the principle that the loading assumed in the design represents actual conditions.

1.4.2 Governed by Codes

Minimum design loads shall be in accordance with the building code under which the structure is designed, or where applicable, other recognized minimum design load standards.

1.4.3 Loads Included

Design loads include any or all of the following loads or forces: dead, live, snow, wind, earthquake, erection and other static and dynamic forces.

1.4.4 Load Combinations

Combinations of design loads and forces, and load combination factors shall be in accordance with the building code under which the structure is designed, or where applicable, other recognized minimum design load standards (see Reference 5 for additional information). The governing building code shall be permitted to be consulted for load combination factors.

1.5 Specifications and Plans

1.5.1 Sizes

The plans or specifications, or both, shall indicate whether wood products sizes are stated in terms of standard nominal, standard net or special sizes, as specified for the respective wood products in Chapters 4, 5, 6, 7, 8 and 9.

1.6 Notation

Except where otherwise noted, the symbols used in this Specification have the following meanings:

A = area of cross section, in.^{2}
A_m = gross cross-sectional area of main wood member(s), in.^{2}
A_n = cross-sectional area of notched member, in.^{2}
A_s = sum of gross cross-sectional areas of side member(s), in.^{2}
C_D = load duration factor
C_F = size factor for sawn lumber
C_L = beam stability factor
C_M = wet service factor
C_P = column stability factor
C_T = buckling stiffness factor for dimension lumber
C_V = volume factor for structural glued laminated timber or structural composite lumber
C_b = bearing area factor
C_c = curvature factor for structural glued laminated timber
C_{cs} = critical section factor for round timber piles
C_d = penetration depth factor for connections
C_{di} = diaphragm factor for nailed connections
C_{eg} = end grain factor for connections
C_f = form factor
C_{fu} = flat use factor
C_g = group action factor for connections
C_i = incising factor for dimension lumber
C_r = repetitive member factor for dimension lumber, prefabricated wood I-joists, and structural composite lumber
C_{sp} = single pile factor for timber piles
C_{st} = metal side plate factor for 4" shear plate connections
C_t = temperature factor
C_{tn} = toe-nail factor for nailed connections
C_u = untreated factor for timber poles and piles
C_Δ = geometry factor for connections

COV_E = coefficient of variation for modulus of elasticity

D = diameter, in.

D_r = root diameter, in.

E, E' = tabulated and allowable modulus of elasticity, psi

E_m = modulus of elasticity of main member, psi

E_s = modulus of elasticity of side member, psi

F_b, F_b' = tabulated and allowable bending design value, psi

F_{b1}' = allowable edgewise bending design value, psi

F_{b2}' = allowable flatwise bending design value, psi

F_{bE} = critical buckling design value for bending members, psi

F_c, F_c' = tabulated and allowable compression design value parallel to grain, psi

F_{cE} = critical buckling design value for compression members, psi

F_{cE1}, F_{cE2} = critical buckling design value for compression member in planes of lateral support, psi

$F_{c\perp}, F_{c\perp}'$ = tabulated and allowable compression design value perpendicular to grain, psi

F_e = dowel bearing strength, psi

F_{em} = dowel bearing strength of main member, psi

F_{es} = dowel bearing strength of side member, psi

$F_{e\parallel}$ = dowel bearing strength parallel to grain, psi

$F_{e\perp}$ = dowel bearing strength perpendicular to grain, psi

$F_{e\theta}$ = dowel bearing strength at an angle to grain, psi

F_{rt}' = allowable radial tension design value perpendicular to grain, psi

F_t, F_t' = tabulated and allowable tension design value parallel to grain, psi

F_v, F_v' = tabulated and allowable shear design value parallel to grain (horizontal shear), psi

F_{yb} = bending yield strength of fastener, psi

F_θ' = allowable bearing design value at an angle to grain, psi

G = specific gravity

I = moment of inertia, in.^{4}

K = shear stiffness coefficient

K_D = diameter coefficient for dowel-type fastener connections with D < 0.25 in.

K_M = moisture content coefficient for sawn lumber truss compression chords

K_T = truss compression chord coefficient for sawn lumber

K_{bE} = Euler buckling coefficient for beams

K_{cE} = Euler buckling coefficient for columns

K_e = buckling length coefficient for compression members

K_f = column stability coefficient for bolted and nailed built-up columns

K_r = radial stress coefficient

K_t = temperature coefficient

K_v = shear coefficient

K_x = spaced column fixity coefficient

K_θ = angle to grain coefficient for dowel-type fastener connections with D < 0.25 in.

L = span length of bending member, ft.

L = distance between points of lateral support of compression member, ft.

L_c = length from tip of pile to critical section, ft.

M = maximum bending moment, in./lbs.

M_r, M_r' = nominal and allowable design moment, in./lbs.

N, N' = nominal and allowable lateral design value at an angle to grain for a single split ring connector unit or shear plate connector unit, lbs.

P = total concentrated load or total axial load, lbs.

P, P' = nominal and allowable lateral design value parallel to grain for a single split ring connector unit or shear plate connector unit, lbs.

P_r = parallel to grain nominal rivet capacity, lbs.

P_w = parallel to grain nominal wood capacity for timber rivets, lbs.

Q = statical moment of an area about the neutral axis, in.^{3}

Q, Q' = nominal and allowable lateral design value perpendicular to grain for a single split ring connector unit or shear plate connector unit, lbs.

Q_r = perpendicular to grain nominal rivet capacity, lbs.

Q_w = perpendicular to grain nominal wood capacity for timber rivets, lbs.

R = radius of curvature, in.

R_B = slenderness ratio of bending member

R_d = reduction term for dowel-type fastener connections

R_r, R_r' = nominal and allowable design reaction, lbs.

S = section modulus, in.^{3}

T = temperature, °F

V = shear force, lbs.

V_r, V_r' = nominal and allowable design shear, lbs.

W = total uniform load, lbs.

W, W' = nominal and allowable withdrawal design value for fastener, lbs per inch of penetration

Z, Z' = nominal and allowable lateral design value for a single fastener connection, lbs.

$Z_{\parallel}$ = nominal lateral design value for a single dowel-type fastener connection with all wood members loaded parallel to grain, lbs.

$Z_{m\perp}$ = nominal lateral design value for a single dowel-type fastener wood-to-wood connection with main member loaded perpendicular to grain and side member loaded parallel to grain, lbs.

$Z_{s\perp}$ = nominal lateral design value for a single dowel-type fastener wood-to-wood connection with main member loaded parallel to grain and side member loaded perpendicular to grain, lbs.

$Z_{\perp}$ = nominal lateral design value for a single dowel-type fastener wood-to-wood, wood-to-metal, or wood-to-concrete connection with wood member(s) loaded perpendicular to grain, lbs.

a_p = minimum end distance load parallel to grain, in.

a_q = minimum end distance load perpendicular to grain, in.

b = breadth of rectangular bending member, in.

c = distance from neutral axis to extreme fiber, in.

d = depth of bending member, in.

d = least dimension of rectangular compression member, in.

d = pennyweight of nail or spike

d_e = effective depth of member at a connection, in.

d_n = depth of member remaining at a notch, in.

d_1, d_2 = cross-sectional dimensions of rectangular compression member in planes of lateral support, in.

e = eccentricity, in.

e_p = minimum edge distance unloaded edge, in.

e_q = minimum edge distance loaded edge, in.

f_b = actual bending stress, psi

f_{b1} = actual edgewise bending stress, psi

f_{b2} = actual flatwise bending stress, psi

f_c = actual compression stress parallel to grain, psi

f_c' = concrete compressive strength

f_c = actual compression stress perpendicular to grain, psi

f_r = actual radial stress in curved bending member, psi

f_t = actual tension stress parallel to grain, psi

f_v = actual shear stress parallel to grain, psi

ℓ = span length of bending member, in.

ℓ = distance between points of lateral support of compression member, in.

ℓ_b = bearing length, in.

ℓ_c = clear span, in.

ℓ_e = effective span length of bending member, in.

ℓ_e = effective length of compression member, in.

ℓ_{e1}, ℓ_{e2} = effective length of compression member in planes of lateral support, in.

$\ell_{e/d}$ = slenderness ratio of compression member

ℓ_m = length of dowel bearing in wood main member, in.

ℓ_n = length of notch, in.

ℓ_s = length of dowel bearing in wood side member, in.

ℓ_u = laterally unsupported span length of bending member, in.

ℓ_1, ℓ_2 = distances between points of lateral support of compression member in planes 1 and 2, in.

ℓ_3 = distance from center of spacer block to centroid of group of split ring or shear plate connectors in end block for a spaced column, in.

m.c. = moisture content based on oven-dry weight of wood, %

n = number of fasteners in a row

n_c = number of rivets per row

n_R = number of timber rivet rows

p = depth of fastener penetration into wood member, in.

r = radius of gyration, in.

s = center to center spacing between adjacent fasteners in a row, in.

s_p = spacing between rivets parallel to grain, in.

s_q = spacing between rivets perpendicular to grain, in.

t = thickness, in.

t = exposure time (hrs.)

t_m = thickness of main member, in.

t_s = thickness of side member, in.

x = distance from beam support face to load, in.

g = load/slip modulus for a connection, lbs./in.

q = angle between direction of load and direction of grain (longitudinal axis of member), degrees

β_{eff} = effective char rate (in./hr.) adjusted for exposure time, t

β_n = nominal char rate (in./hr.), linear char rate based on 1-hour exposure

DESIGN VALUES FOR STRUCTURAL MEMBERS

2.1 General

2.1.1 General Requirement

Each wood structural member or connection shall be of sufficient size and capacity to carry the applied loads without exceeding the allowable design values specified herein.

2.1.2 Responsibility of Designer to Adjust for Conditions of Use

Allowable design values for wood members and connections in particular end uses shall be appropriate for the conditions under which the wood is used, taking into account the differences in wood strength properties with different moisture contents, load durations and types of treatment. Common end use conditions are addressed in this Specification. It shall be the final responsibility of the designer to relate design assumptions and design values, and to make design value adjustments appropriate to the end use.

2.2 Design Values

Design values for wood products in 1.1.1.1 are based on methods specified in each of the wood product chapters. Chapters 4 through 9 contain design provisions for sawn lumber, glued laminated timber, poles and piles, prefabricated wood I-joists, structural composite lumber, and wood structural panels, respectively. Chapters 10 through 13 contain design provisions for connections. Tabulated design values are for normal load duration under the moisture service conditions specified.

2.3 Adjustment of Design Values

2.3.1 Applicability of Adjustment Factors

Tabulated design values shall be multiplied by all applicable adjustment factors to determine allowable design values. The applicability of adjustment factors to sawn lumber, glued laminated timber, poles and piles, prefabricated wood I-joists, structural composite lumber, wood structural panels and connection design values is defined in 4.3, 5.3, 6.3, 7.3, 8.3, 9.3 and 10.3, respectively.

2.3.2 Load Duration Factor, C_D

2.3.2.1 Wood has the property of carrying substantially greater maximum loads for short durations than for long durations of loading. Tabulated design values apply to normal load duration. Normal load duration represents a load that fully stresses a member to its allowable design value by the application of the full design load for a cumulative duration of approximately ten years. When the cumulative duration of the full maximum load does not exceed the specified time period, all tabulated design values except modulus of elasticity, E, and compression perpendicular to grain, $F_{c\perp}$, based on a deformation limit (see 4.2.6) shall be multiplied by the appropriate load duration factor, C_D, from Table 2.3.2 or Figure B1 (see Appendix B) to take into account the change in strength of wood with changes in load duration.

2.3.2.2 The load duration factor, C_D, for the shortest duration load in a combination of loads shall apply for that load combination. All applicable load combinations shall be evaluated to determine the critical load combination. Design of structural members and connections shall be based on the critical load combination (see Appendix B.2).

2.3.2.3 The load duration factors, C_D, in Table 2.3.2 and Appendix B are independent of load combination factors, and both shall be permitted to be used in design calculations (see 1.4.4 and Appendix B.4).

Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

1. Load duration factors shall not apply to modulus of elasticity, E, nor to compression perpendicular to grain design values, $F_{c\perp}$, based on a deformation limit.
2. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives (see Reference 30), or fire retardant chemicals. The impact load duration factor shall not apply to connections.

2.3.3 Temperature Factor, C_t

Tabulated design values shall be multiplied by the following temperature factors, C_t, for structural members that will experience sustained exposure to elevated temperatures up to 150°F (see Appendix C).

Table 2.3.3 Temperature Factor, C_t

Design Values	In Service Moisture Conditions[1]	C_t: T≤100°F	100°F<T≤125°F	125°F<T≤150°F
F_t, E	Wet or Dry	1.0	0.9	0.9
F_b, F_v, F_c,	Dry	1.0	0.8	0.7
and $F_{c\perp}$	Wet	1.0	0.7	0.5

1. Wet and dry service conditions for sawn lumber, glued laminated timber, prefabricated wood I-joists, structural composite lumber, and wood structural panels are specified in 4.1.4, 5.1.5, 7.1.4, 8.1.4, and 9.3.3, respectively.

2.3.4 Fire Retardant Treatment

The effects of fire retardant chemical treatment on strength shall be accounted for in the design. Allowable design values, including connection design values, for lumber and structural glued laminated timber pressure-treated with fire retardant chemicals shall be obtained from the company providing the treatment and redrying service. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with fire retardant chemicals (see Table 2.3.2).

3

DESIGN PROVISIONS AND EQUATIONS

3.1 General

3.1.1 Scope

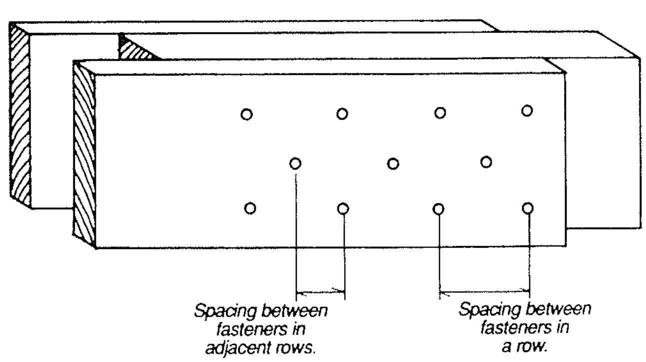
Chapter 3 establishes general design provisions that apply to all wood structural members and connections covered under this Specification. Each wood structural member or connection shall be of sufficient size and capacity to carry the applied loads without exceeding the allowable design values specified herein. Design values and specific design provisions applicable to particular wood products or connections are given in other Chapters of this Specification.

3.1.2 Net Section Area

3.1.2.1 The net section area is obtained by deducting from the gross section area the projected area of all material removed by boring, grooving, dapping, notching, or other means. The net section area shall be used in calculating the load carrying capacity of a member, except as specified in 3.6.3 for columns. The effects of any eccentricity of loads applied to the member at the critical net section shall be taken into account.

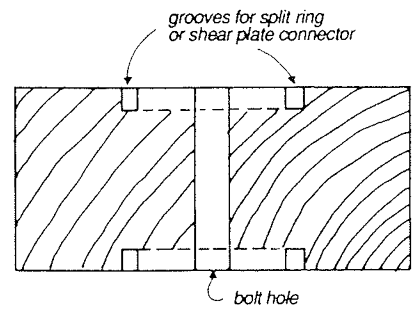
3.1.2.2 For parallel to grain loading with staggered bolts, drift bolts, drift pins or lag screws, adjacent fasteners shall be considered as occurring at the same critical section if the parallel to grain spacing between fasteners in adjacent rows is less than 4 fastener diameters (see Figure 3A).

Figure 3A Spacing of Staggered Fasteners



3.1.2.3 The net section area at a split ring or shear plate connection shall be determined by deducting from the gross section area the projected areas of the bolt hole and the split ring or shear plate groove within the member (see Figure 3B and Appendix K). Where split ring or shear plate connectors are staggered, adjacent connectors shall be considered as occurring at the same critical section if the parallel to grain spacing between connectors in adjacent rows is less than or equal to one connector diameter (see Figure 3A).

Figure 3B Net Cross Section at a Split Ring or Shear Plate Connection



3.1.3 Connections

Structural members and fasteners shall be arranged symmetrically at connections, unless the bending moment induced by an unsymmetrical arrangement (such as lapped joints) has been accounted for in the design. Connections shall be designed and fabricated to insure that each individual member carries its proportional stress.

3.1.4 Time Dependent Deformations

Where members of structural frames are composed of two or more layers or sections, the effect of time dependent deformations shall be accounted for in the design (see 3.5.2 and Appendix F).

3.1.5 Composite Construction

Composite constructions, such as wood-concrete, wood-steel, and wood-wood composites, shall be designed in accordance with principles of engineering mechanics using the design values for structural members and connections specified herein.

3.2 Bending Members – General

3.2.1 Span of Bending Members

For simple, continuous and cantilevered bending members, the span shall be taken as the distance from face to face of supports, plus 1/2 the required bearing length at each end.

3.2.2 Lateral Distribution of Concentrated Load

Lateral distribution of concentrated loads from a critically loaded bending member to adjacent parallel bending members by flooring or other cross members shall be permitted to be calculated when determining design bending moment and vertical shear force (see 15.1).

3.2.3 Notches

3.2.3.1 Bending members shall not be notched except as permitted by 4.4.3, 5.4.4, 7.4.4, and 8.4.1. A gradual taper cut from the reduced depth of the member to the full depth of the member in lieu of a square-cornered notch reduces stress concentrations.

3.2.3.2 The stiffness of a bending member, as determined from its cross section, is practically unaffected by a notch with the following dimensions:

notch depth ≤ (1/6) (beam depth)

notch length ≤ (1/3) (beam depth)

3.2.3.3 See 3.4.3 for effect of notches on shear strength.

3.3 Bending Members – Flexure

3.3.1 Strength in Bending

The actual bending stress or moment shall not exceed the allowable bending design value.

3.3.2 Flexural Design Equations

3.3.2.1 The actual bending stress induced by a bending moment, M, is calculated as follows:

$$f_b = \frac{Mc}{I} = \frac{M}{S} \qquad (3.3\text{-}1)$$

For a rectangular bending member of breadth, b, and depth, d, this becomes:

$$f_b = \frac{M}{S} = \frac{6M}{bd^2} \qquad (3.3\text{-}2)$$

3.3.2.2 For solid rectangular bending members with the neutral axis perpendicular to depth at center:

$$I = \frac{bd^3}{12} = \text{moment of inertia} \qquad (3.3\text{-}3)$$

$$S = \frac{I}{c} = \frac{bd^2}{6} = \text{section modulus} \qquad (3.3\text{-}4)$$

3.3.3 Beam Stability Factor, C_L

3.3.3.1 When the depth of a bending member does not exceed its breadth, $d \leq b$, no lateral support is required and $C_L = 1.0$.

3.3.3.2 When rectangular sawn lumber bending members are laterally supported in accordance with 4.4.1, $C_L = 1.0$.

3.3.3.3 When the compression edge of a bending member is supported throughout its length to prevent lateral displacement, and the ends at points of bearing have lateral support to prevent rotation, $C_L = 1.0$.

3.3.3.4 When the depth of a bending member exceeds its breadth, $d > b$, lateral support shall be provided at points of bearing to prevent rotation and/or lateral displacement at those points. When such lateral support is provided at points of bearing, but no additional lateral support is provided throughout the length of the bending member, the unsupported length, ℓ_u, is the distance between such points of end bearing, or the length of a cantilever. When a bending member is provided with lateral support to prevent rotational and/or lateral displacement at intermediate points as well as at the ends, the unsupported length, ℓ_u, is the distance between such points of intermediate lateral support.

3.3.3.5 The effective span length, ℓ_e, for single span or cantilever bending members shall be determined in accordance with Table 3.3.3.

3

DESIGN PROVISIONS AND EQUATIONS

Table 3.3.3 Effective Length, ℓ_e, for Bending Members

Cantilever[1]	when $\ell_u/d < 7$	when $\ell_u/d \geq 7$
Uniformly distributed load	$\ell_e = 1.33\ \ell_u$	$\ell_e = 0.90\ \ell_u + 3d$
Concentrated load at unsupported end	$\ell_e = 1.87\ \ell_u$	$\ell_e = 1.44\ \ell_u + 3d$
Single Span Beam[1,2]	when $\ell_u/d < 7$	when $\ell_u/d \geq 7$
Uniformly distributed load	$\ell_e = 2.06\ \ell_u$	$\ell_e = 1.63\ \ell_u + 3d$
Concentrated load at center with no intermediate lateral support	$\ell_e = 1.80\ \ell_u$	$\ell_e = 1.37\ \ell_u + 3d$
Concentrated load at center with lateral support at center	$\ell_e = 1.11\ \ell_u$	
Two equal concentrated loads at 1/3 points with lateral support at 1/3 points	$\ell_e = 1.68\ \ell_u$	
Three equal concentrated loads at 1/4 points with lateral support at 1/4 points	$\ell_e = 1.54\ \ell_u$	
Four equal concentrated loads at 1/5 points with lateral support at 1/5 points	$\ell_e = 1.68\ \ell_u$	
Five equal concentrated loads at 1/6 points with lateral support at 1/6 points	$\ell_e = 1.73\ \ell_u$	
Six equal concentrated loads at 1/7 points with lateral support at 1/7 points	$\ell_e = 1.78\ \ell_u$	
Seven or more equal concentrated loads, evenly spaced, with lateral support at points of load application	$\ell_e = 1.84\ \ell_u$	
Equal end moments	$\ell_e = 1.84\ \ell_u$	

1. For single span or cantilever bending members with loading conditions not specified in Table 3.3.3:
   $\ell_e = 2.06\ \ell_u$ when $\ell_u/d < 7$
   $\ell_e = 1.63\ \ell_u + 3d$ when $7 \leq \ell_u/d \leq 14.3$
   $\ell_e = 1.84\ \ell_u$ when $\ell_u/d > 14.3$
2. Multiple span applications shall be based on table values or engineering analysis.

3.3.3.6 The slenderness ratio, R_B, for bending members shall be calculated as follows:

$$R_B = \sqrt{\frac{\ell_e d}{b^2}} \qquad (3.3\text{-}5)$$

3.3.3.7 The slenderness ratio for bending members, R_B, shall not exceed 50.

3.3.3.8 The beam stability factor shall be calculated as follows:

$$C_L = \frac{1+(F_{bE}/F_b^*)}{1.9} - \sqrt{\left[\frac{1+(F_{bE}/F_b^*)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}} \qquad (3.3\text{-}6)$$

where:

F_b^* = tabulated bending design value multiplied by all applicable adjustment factors except C_{fu}, C_V and C_L (see 2.3)

$F_{bE} = \frac{K_{bE}E'}{R_B^2}$

K_{bE} = 0.745 - 1.225(COV_E)
= 0.439 for visually graded lumber
= 0.561 for machine evaluated lumber (MEL)
= 0.610 for products with $COV_E \leq 0.11$
(see Appendix F.2)

3.3.3.9 See Appendix D for background information concerning beam stability calculations and Appendix F for information concerning coefficient of variation in modulus of elasticity (COV_E).

3.3.3.10 Members subjected to flexure about both principal axes (biaxial bending) shall be designed in accordance with 3.9.2.

3.3.4 Form Factor, C_f

Tabulated bending design values, F_b, for bending members with either a circular cross section or a square cross section loaded in the plane of the diagonal (diamond section) shall be multiplied by the following form factors, C_f:

Table 3.3.4 Form Factors, C_f

	C_f
Round Section	1.18
Diamond Section	1.414

These form factors insure that a circular or diamond shaped bending member has the same moment capacity as a square bending member having the same cross-sectional area. If a circular member is tapered, it shall be considered a beam of variable cross section.

3.4 Bending Members – Shear

3.4.1 Strength in Shear Parallel to Grain (Horizontal Shear)

3.4.1.1 The actual shear stress parallel to grain or shear force at any cross section of the bending member shall not exceed the allowable shear design value. A check of the strength of wood bending members in shear perpendicular to grain is not required.

3.4.1.2 The shear design procedures specified herein for calculating f_v at or near points of vertical support are limited to solid flexural members such as sawn lumber, glued laminated timber, structural composite lumber or mechanically laminated timber beams. Shear design at supports for built-up components containing load-bearing connections at or near points of support, such as between web and chord of a truss, shall be based on test or other techniques.

3.4.2 Shear Design Equations

The actual shear stress parallel to grain induced in a sawn lumber, glued laminated timber, structural composite lumber, timber pole or timber pile bending member shall be calculated as follows:

$$f_v = \frac{VQ}{Ib} \qquad (3.4\text{-}1)$$

For a rectangular bending member of breadth, b, and depth, d, this becomes:

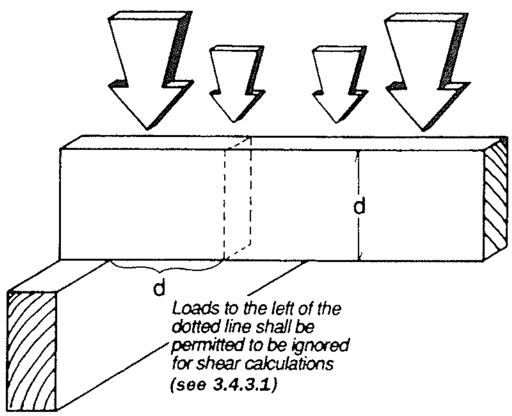
$$f_v = \frac{3V}{2bd} \qquad (3.4\text{-}2)$$

3.4.3 Shear Design

3.4.3.1 When calculating the shear force, V, in bending members:

(a) For beams supported by full bearing on one surface and loads applied to the opposite surface, uniformly distributed loads within a distance from supports equal to the depth of the bending member, d, shall be permitted to be ignored. For beams supported by full bearing on one surface and loads applied to the opposite surface, concentrated loads within a distance, d, from supports shall be permitted to be multiplied by x/d where x is the distance from the beam support face to the load (see Figure 3D).

Figure 3D Shear at Supports



(b) The largest single moving load shall be placed at a distance from the support equal to the depth of the bending member, keeping other loads in their normal relation and neglecting any load within a distance from a support equal to the depth of the bending member. This condition shall be checked at each support.

(c) With two or more moving loads of about equal weight and in proximity, loads shall be placed in the position that produces the highest shear force, V, neglecting any load within a distance from a support equal to the depth of the bending member.

3.4.3.2 For notched bending members, shear force, V, shall be determined by principles of engineering mechanics (except those given in 3.4.3.1).

(a) For bending members with rectangular cross section and notched on the tension face (see 3.2.3), the allowable design shear, V_r', shall be calculated as follows:

$$V_r' = \left[\frac{2}{3}F_v' b d_n\right]\left[\frac{d_n}{d}\right]^2 \qquad (3.4\text{-}3)$$

where:

d = depth of unnotched bending member

d_n = depth of member remaining at a notch

F_v' = allowable shear design value parallel to grain

(b) For bending members with circular cross section and notched on the tension face (see 3.2.3), the allowable design shear, V_r', shall be calculated as follows:

$$V_r' = \left[\frac{2}{3}F_v' A_n\right]\left[\frac{d_n}{d}\right]^2 \qquad (3.4\text{-}4)$$

where:

A_n = cross-sectional area of notched member

(c) For bending members with other than rectangular or circular cross section and notched on the tension face (See 3.2.3), the allowable design shear, V_r', shall be based on conventional engineering analysis of stress concentrations at notches.

(d) A gradual change in cross section compared with a square notch decreases the actual shear stress parallel to grain nearly to that computed for an unnotched bending member with a depth of d_n.

(e) When a bending member is notched on the compression face at the end as shown in Figure 3E, the allowable design shear, V_r', shall be calculated as follows:

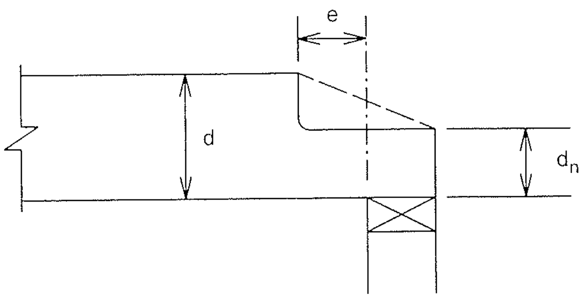
$$V_r' = \frac{2}{3}F_v'\left[d - \left(\frac{d - d_n}{d_n}\right)e\right] \qquad (3.4\text{-}5)$$

where:

e = the distance the notch extends inside the inner edge of the support and must be less than or equal to the depth remaining at the notch, $e \le d_n$. If $e > d_n$, d_n shall be used to calculate f_v using Equation 3.4-2.

d_n = depth of member remaining at a notch meeting the provisions of 3.2.3. If the end of the beam is beveled, as shown by the dashed line in Figure 3E, d_n is measured from the inner edge of the support.

Figure 3E Bending Member End-Notched on Compression Face



3.4.3.3 When connections in bending members are fastened with split ring connectors, shear plate connectors, bolts, or lag screws (including beams supported by such fasteners or other cases as shown in Figures 3F and 3J) the shear force, V, shall be determined by principles of engineering mechanics (except those given in 3.4.3.1).

(a) When the connection is less than five times the depth, 5d, of the member from its end, the allowable design shear, V_r', shall be calculated as follows:

$$V_r' = \left[\frac{2}{3}F_v'bd_n\right]\left[\frac{d_e}{d}\right]^2 \qquad (3.4\text{-}6)$$

where:

for split ring or shear plate connections:

d_e = depth of member, less the distance from the unloaded edge of the member to the nearest edge of the nearest split ring or shear plate connector (see Figure 3F)

for bolt or lag screw connections:

d_e = depth of member, less the distance from the unloaded edge of the member to the center of the nearest bolt or lag screw (see Figure 3F)

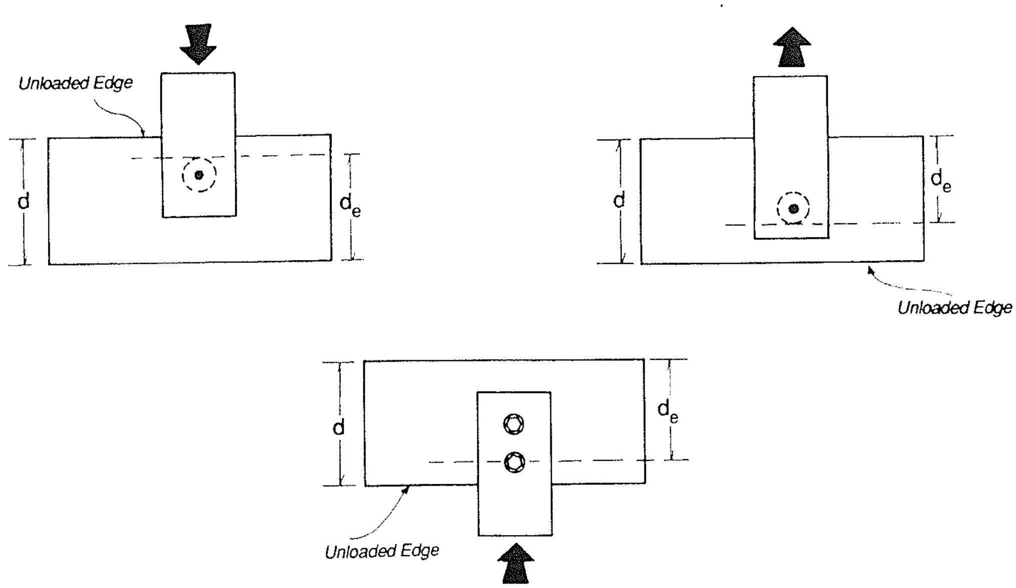
(b) When the connection is at least five times the depth, 5d, of the member from its end, the allowable design shear, V_r', shall be calculated as follows:

$$V_r' = \frac{2}{3}F_v'bd_e \qquad (3.4\text{-}7)$$

(c) When concealed hangers are used, the allowable design shear, V_r', shall be calculated based on the provisions in 3.4.3.2 for notched bending members.

3 DESIGN PROVISIONS AND EQUATIONS

Figure 3F Effective Depth, d_e, of Members at Connections



3.5 Bending Members – Deflection

3.5.1 Deflection Calculations

If deflection is a factor in design, it shall be calculated by standard methods of engineering mechanics considering bending deflections and, when applicable, shear deflections. Consideration for shear deflection is required when the published modulus of elasticity has not be adjusted to include the effects of shear deflection (see Appendix F).

3.5.2 Long Term Loading

Where total deflection under long term loading must be limited, increasing member size is one way to provide extra stiffness to allow for this time dependent deformation (see Appendix F). Total deflection, Δ_T, shall be calculated as follows:

$$\Delta_T = K_{cr}\,\Delta_{LT} + \Delta_{ST}$$

where:

K_{cr} = time dependent deformation (creep) factor

= 1.5 for seasoned lumber, glued laminated timber, prefabricated wood I-joists, or structural composite lumber used in dry service conditions as defined in 4.1.4, 5.1.5, 7.1.4, and 8.1.4, respectively

= 2.0 for glued laminated timber used in wet service conditions as defined in 5.1.5

= 2.0 for wood structural panels used in dry service conditions as defined in 9.1.4

= 2.0 for unseasoned lumber or for seasoned lumber used in wet service conditions as defined in 4.1.4

Δ_{LT} = immediate deflection due to the long term component of the design load

Δ_{ST} = deflection due to the short term or normal component of the design load

3.6 Compression Members – General

3.6.1 Terminology

For purposes of this Specification, the term "column" refers to all types of compression members, including members forming part of trusses or other structural components.

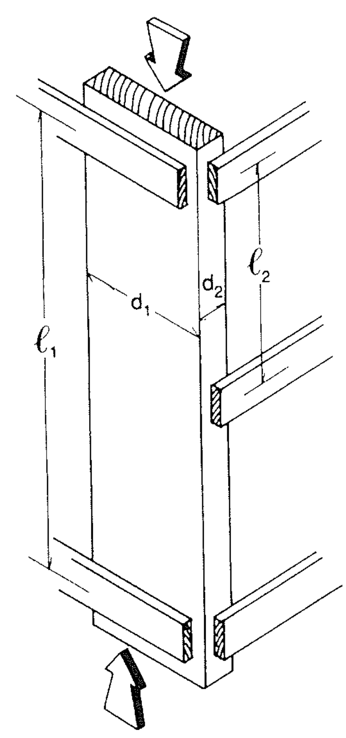
3.6.2 Column Classifications

3.6.2.1 Simple Solid Wood Columns. Simple columns consist of a single piece or of pieces properly glued together to form a single member (see Figure 3G).

3.6.2.2 Spaced Columns, Connector Joined. Spaced columns are formed of two or more individual members with their longitudinal axes parallel, separated at the ends and middle points of their length by blocking and joined at the ends by split ring or shear plate connectors capable of developing the required shear resistance (see 15.2).

3.6.2.3 Built-up Columns. Individual laminations of mechanically laminated built-up columns shall be designed in accordance with 3.6.3 and 3.7, except that nailed or bolted built-up columns shall be designed in accordance with 15.3.

Figure 3G Simple Solid Column



3.6.3 Strength in Compression Parallel to Grain

The actual compression stress or force parallel to grain shall not exceed the allowable compression design value. Calculations of f_c shall be based on the net section area (see 3.1.2) when the reduced section occurs in the critical part of the column length that is most subject to potential buckling. When the reduced section does not occur in the critical part of the column length that is most subject to potential buckling, calculations of f_c shall be based on gross section area. In addition, f_c based on net section area shall not exceed the tabulated compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, $f_c \le (F_c)(C_D)(C_M)(C_t)(C_F)(C_i)$.

3.6.4 Compression Members Bearing End to End

For end grain bearing of wood on wood, and on metal plates or strips see 3.10.

3.6.5 Eccentric Loading or Combined Stresses

For compression members subject to eccentric loading or combined flexure and axial loading, see 3.9 and 15.4.

3.6.6 Column Bracing

Column bracing shall be installed where necessary to resist wind or other lateral forces (see Appendix A).

3.6.7 Lateral Support of Arches, Studs and Compression Chords of Trusses

Guidelines for providing lateral support and determining ℓ_e/d in arches, studs and compression chords of trusses are specified in Appendix A.11.

3.7 Solid Columns

3.7.1 Column Stability Factor, C_P

3.7.1.1 When a compression member is supported throughout its length to prevent lateral displacement in all directions, $C_P = 1.0$.

3.7.1.2 The effective column length, ℓ_e, for a solid column shall be determined in accordance with principles of engineering mechanics. One method for determining effective column length, when end-fixity conditions are known, **is to multiply actual column length by the appropriate effective length factor specified in Appendix G, $\ell_e = (K_e)(\ell)$.**

3.7.1.3 For solid columns with rectangular cross section, the slenderness ratio, R_e/d, shall be taken as the larger of the ratios ℓ_{e1}/d_1 or ℓ_{e2}/d_2 (see Figure 3G) where each ratio has been adjusted by the appropriate buckling length coefficient, K_e, from Appendix G.

3.7.1.4 The slenderness ratio for solid columns, ℓ_e/d, shall not exceed 50, except that during construction ℓ_e/d shall not exceed 75.

3.7.1.5 The column stability factor shall be calculated as follows:

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \qquad (3.7\text{-}1)$$

where:

F_c^* = tabulated compression design value multiplied by all applicable adjustment factors except C_P (see 2.3)

$F_{cE} = \dfrac{K_{cE}\,E'}{(\ell_e/d)^2}$

$K_{cE} = 0.510 - 0.839(COV_E)$

= 0.3 for visually graded lumber

= 0.384 for machine evaluated lumber (MEL)

= 0.418 for products with $COV_E \le 0.11$ (see Appendix F.2)

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for glued laminated timber or structural composite lumber

3.7.1.6 For especially severe service conditions and/or extraordinary hazard, use of lower allowable design values may be necessary. See Appendix H for background information concerning column stability calculations and Appendix F for information concerning coefficient of variation in modulus of elasticity (COV_E).

3.7.2 Tapered Columns

For design of a column with rectangular cross section, tapered at one or both ends, the representative dimension, d, for each face of the column shall be derived as follows:

$$d = d_{min} + (d_{max} - d_{min})\left[a - 0.15\left(1 - \frac{d_{min}}{d_{max}}\right)\right] \qquad (3.7\text{-}2)$$

where:

d_{min} = the minimum dimension for that face of the column

d_{max} = the maximum dimension for that face of the column

Support Conditions

Large end fixed, small end unsupported or simply supported	a = 0.70
Small end fixed, large end unsupported or simply supported	a = 0.30
Both ends simply supported:	
Tapered toward one end	a = 0.50
Tapered toward both ends	a = 0.70
For all other support conditions:	

$$d = d_{min} + (d_{max} - d_{min})(1/3) \qquad (3.7\text{-}3)$$

Calculations of f_c and C_P shall be based on the representative dimension, d. In addition, f_c at any cross section in the tapered column shall not exceed the tabulated compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, $f_c \le (F_c)(C_D)(C_M)(C_t)(C_i)$.

3.7.3 Round Columns

The design of a column of round cross section shall be based on the design calculations for a square column of the same cross-sectional area and having the same degree of taper. Design values and special design provisions for round timber poles and piles are provided in Chapter 6.

3.8 Tension Members

3.8.1 Tension Parallel to Grain

The actual tension stress or force parallel to grain shall be based on the net section area (see 3.1.2) and shall not exceed the allowable tension design value.

3.8.2 Tension Perpendicular to Grain

Designs that induce tension stress perpendicular to grain shall be avoided whenever possible (see References 16 and 19). When tension stress perpendicular to grain cannot be avoided, mechanical reinforcement sufficient to resist all such stresses shall be considered (see References 52 and 53 for additional information).

3.9 Combined Bending and Axial Loading

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:

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

and

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

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

3.9.2 Bending and Axial Compression

Members subjected to a combination of bending about one or both principal axes and axial compression (see Figure 3I) shall be so proportioned that:

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'\left[1-(f_c/F_{cE1})\right]} + \frac{f_{b2}}{F_{b2}'\left[1-(f_c/F_{cE2})-(f_{b1}/F_{bE})^2\right]} \leq 1.0 \quad (3.9\text{-}3)$$

where:

$$f_c < F_{cE1} = \frac{K_{cE}E'}{(\ell_{e1}/d_1)^2} \text{ for either unaxial or biaxial bending}$$

and

$$f_c < F_{cE2} = \frac{K_{cE}E'}{(\ell_{e2}/d_2)^2} \text{ for biaxial bending}$$

and

$$f_{b1} < F_{bE} = \frac{K_{bE}E'}{(R_B)^2} \text{ for biaxial bending}$$

f_{b1} = actual edgewise bending stress (bending load applied to narrow face of member)

f_{b2} = actual flatwise bending stress (bending load applied to wide face of member)

d_1 = wide face dimension (see Figure 3I)

d_2 = narrow face dimension (see Figure 3I)

Effective column lengths, ℓ_{e1} and ℓ_{e2}, shall be determined in accordance with 3.7.1.2. F_c', F_{cE1} and F_{cE2} shall be determined in accordance with 2.3 and 3.7. F_{b1}', F_{b2}' and F_{bE} shall be determined in accordance with 2.3 and 3.3.3.

3.9.3 Eccentric Compression Loading

See 15.4 for members subjected to combined bending and axial compression due to eccentric loading, or eccentric loading in combination with other loads.

Figure 3H Combined Bending and Axial Tension

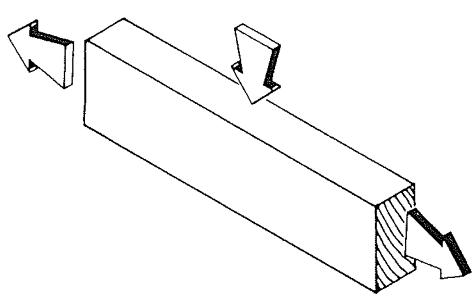
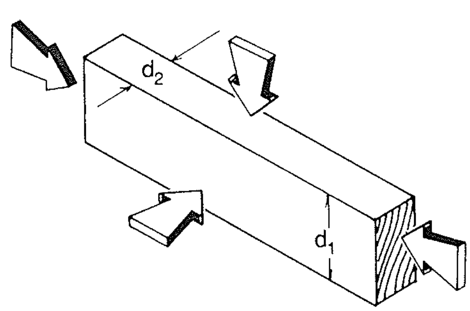


Figure 3I Combined Bending and Axial Compression



3.10 Design for Bearing

3.10.1 Bearing Parallel to Grain

3.10.1.1 The actual compressive bearing stress parallel to grain shall be based on the net bearing area and shall not exceed the tabulated compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, $f_c \leq F_c^*$.

3.10.1.2 F_c^*, the tabulated compression design values parallel to grain multiplied by all applicable adjustment factors except the column stability factor, applies to end-to-end bearing of compression members provided there is adequate lateral support and the end cuts are accurately squared and parallel.

3.10.1.3 When $f_c > (0.75)(F_c^*)$ bearing shall be on a metal plate or strap, or on other equivalently durable, rigid, homogeneous material with sufficient stiffness to distribute the applied load. When a rigid insert is required for end-to-end bearing of compression members, it shall be equivalent to 20-gage metal plate or better, inserted with a snug fit between abutting ends.

3.10.2 Bearing Perpendicular to Grain

The actual compression stress perpendicular to grain shall be based on the net bearing area and shall not exceed the allowable compression design value perpendicular to grain, $f_{c\perp} \leq F_{c\perp}'$. When calculating bearing area at the ends of bending members, no allowance shall be made for the fact that as the member bends, pressure upon the inner edge of the bearing is greater than at the member end.

3.10.3 Bearing at an Angle to Grain

The allowable bearing design value at an angle to grain (see Figure 3J and Appendix J) shall be calculated as follows:

$$F_\theta' = \frac{F_c^* F_{c\perp}'}{F_c^* \sin^2\theta + F_{c\perp}' \cos^2\theta} \qquad (3.10\text{-}1)$$

where:

θ = angle between direction of load and direction of grain (longitudinal axis of member), degrees

3.10.4 Bearing Area Factor, C_b

Tabulated compression design values perpendicular to grain, $F_{c\perp}$, apply to bearings of any length at the ends of a member, and to all bearings 6" or more in length at any other location. For bearings less than 6" in length and not nearer than 3" to the end of a member, the tabulated compression design value perpendicular to grain, $F_{c\perp}$, shall be permitted to be multiplied by the following bearing area factor, C_b:

$$C_b = \frac{\ell_b + 0.375}{\ell_b} \qquad (3.10\text{-}2)$$

where:

ℓ_b = bearing length measured parallel to grain, in.

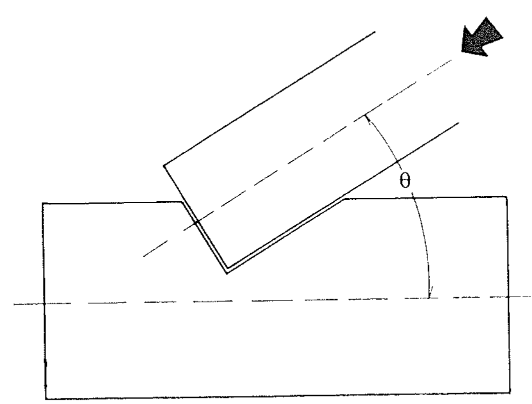
This equation gives the following bearing area factors, C_b, for the indicated bearing length on such small areas as plates and washers:

Table 3.10.4 Bearing Area Factors, C_b

ℓ_b	0.5"	1"	1.5"	2"	3"	4"	6" or more
C_b	1.75	1.38	1.25	1.19	1.13	1.10	1.00

For round bearing areas such as washers the bearing length, ℓ_b, shall be equal to the diameter.

Figure 3J Bearing at an Angle to Grain



4

SAWN LUMBER

4.1 General

4.1.1 Application

Chapter 4 applies to engineering design with sawn lumber. Design procedures, design values and other information herein apply only to lumber complying with the requirements specified below.

4.1.2 Identification of Lumber

4.1.2.1 When the design values specified herein are used, the lumber, including end-jointed or edge-glued lumber, shall be identified by the grade mark of, or certificate of inspection issued by, a lumber grading or inspection bureau or agency recognized as being competent (see Reference 31). A distinct grade mark of a recognized lumber grading or inspection bureau or agency, indicating that joint integrity is subject to qualification and quality control, shall be applied to glued lumber products.

4.1.2.2 Lumber shall be specified by commercial species and grade names, or by required levels of design values as listed in Tables 4A, 4B, 4C, 4D, 4E and 4F.

4.1.3 Definitions

4.1.3.1 Structural sawn lumber consists of lumber classifications known as "Dimension," "Beams and Stringers," "Posts and Timbers," and "Decking" with design values assigned to each grade.

4.1.3.2 "Dimension" refers to lumber from 2" to 4" (nominal) thick, and 2" (nominal) or more in width. Dimension lumber is further classified as Structural Light Framing, Light Framing, Studs, and Joists and Planks (see References 42, 43, 44, 45, 46, 47 and 49 for additional information).

4.1.3.3 "Beams and Stringers" refers to lumber of rectangular cross section, 5" (nominal) or more thick, with width more than 2" greater than thickness, graded with respect to its strength in bending when loaded on the narrow face.

4.1.3.4 "Posts and Timbers" refers to lumber of square or approximately square cross section, 5" x 5" (nominal) and larger, with width not more than 2" greater than thickness, graded primarily for use as posts or columns carrying longitudinal load.

4.1.3.5 "Decking" refers to lumber from 2" to 4" (nominal) thick, tongued and grooved or grooved for spline on the narrow face, and intended for use as a roof, floor or wall membrane. Decking is graded for application in the flatwise direction, with the wide face of the decking in contact with the supporting members, as normally installed.

4.1.4 Moisture Service Condition of Lumber

The design values for lumber specified herein are applicable to lumber that will be used under dry service conditions such as in most covered structures, where the moisture content in use will be a maximum of 19%, regardless of the moisture content at the time of manufacture. For lumber used under conditions where the moisture content of the wood in service will exceed 19% for an extended period of time, the design values shall be multiplied by the wet service factors, C_M, specified in Tables 4A, 4B, 4C, 4D, 4E and 4F.

4.1.5 Lumber Sizes

4.1.5.1 Lumber sizes referred to in this Specification are nominal sizes. Computations to determine the required sizes of members shall be based on the net dimensions (actual sizes) and not the nominal sizes. The dressed sizes specified in Reference 31 shall be accepted as the minimum net sizes associated with nominal dimensions (see Table 1A in the Supplement to this Specification).

4.1.5.2 For 4" (nominal) or thinner lumber, the net DRY dressed sizes shall be used in all computations of structural capacity regardless of the moisture content at the time of manufacture or use.

4.1.5.3 For 5" (nominal) and thicker lumber, the net GREEN dressed sizes shall be used in computations of structural capacity regardless of the moisture content at the time of manufacture or use.

4.1.5.4 Where a design is based on rough sizes or special sizes, the applicable moisture content and size used in design shall be clearly indicated in plans or specifications.

4.1.6 End-Jointed or Edge-Glued Lumber

Design values for sawn lumber are applicable to structural end-jointed or edge-glued lumber of the same species and grade. Such use shall include, but not be limited to light framing, studs, joists, planks and decking. When finger jointed lumber is marked "STUD USE ONLY" or "VERT USE ONLY" such lumber shall be limited to use where any bending or tension stresses are of short duration.

4.1.7 Resawn or Remanufactured Lumber

4.1.7.1 When structural lumber is resawn or remanufactured, it shall be regraded, and design values for the regraded material shall apply (see References 16, 42, 43, 44, 45, 46, 47 and 49).

4.1.7.2 When sawn lumber is cross cut to shorter lengths, the requirements of 4.1.7.1 shall not apply, except for bending design values for those Beam and Stringer grades where grading provisions for the middle third of the length of the piece differ from grading provisions for the outer thirds.

4.2 Design Values

4.2.1 Tabulated Values

Design values for visually graded lumber and for mechanically graded dimension lumber are specified in Tables 4A, 4B, 4C, 4D, 4E and 4F (published in the Supplement to this Specification). The design values in Tables 4A, 4B, 4C, 4D, 4E and 4F are taken from the published grading rules of the agencies cited in References 42, 43, 44, 45, 46, 47 and 49).

4.2.2 Other Species and Grades

Design values for species and grades of lumber not otherwise provided herein shall be established in accordance with appropriate ASTM standards and other technically sound criteria (see References 16, 18, 19 and 31).

4.2.3 Basis for Design Values

4.2.3.1 The design values in Tables 4A, 4B, 4C, 4D and 4F are for the design of structures where an individual member, such as a beam, girder, post or other member, carries or is responsible for carrying its full design load. For repetitive member uses see 4.3.9.

4.2.3.2 Visually Graded Lumber. Design values for visually graded lumber in Tables 4A, 4B, 4D, 4E and 4F are based on the provisions of ASTM Standards D245 and D1990.

4.2.3.3 Machine Stress Rated (MSR) Lumber and Machine Evaluated Lumber (MEL). Design values for machine stress rated lumber and machine evaluated lumber in Table 4C are determined by visual grading and nondestructive pretesting of individual pieces.

4.2.4 Modulus of Elasticity, E

4.2.4.1 Average Values. Design values for modulus of elasticity assigned to the visually graded species and grades of lumber listed in Tables 4A, 4B, 4D, 4E and 4F are average values which conform to ASTM Standards D245 and D1990. Adjustments in modulus of elasticity have been taken to reflect increases for seasoning, increases for density where applicable, and, where required, reductions have been made to account for the effect of grade upon stiffness. Tabulated modulus of elasticity design values are based upon the species or species group average in accordance with ASTM Standards D1990 and D2555.

4.2.4.2 Special Uses. Average modulus of elasticity design values listed in Tables 4A, 4B, 4C, 4D, 4E and 4F are to be used in design of repetitive member systems and in calculating the immediate deflection of single members which carry their full design load. In special applications where deflection is a critical factor, or where amount of deformation under long term loading must be limited, the need for use of a reduced modulus of elasticity design value shall be determined. See Appendix F for provisions on adjusted values for special end use requirements.

4.2.5 Bending, F_b

4.2.5.1 Dimension Grades. Allowable bending design values for Dimension grades apply to members with the load applied to either the narrow or wide face.

4.2.5.2 Decking Grades. Allowable bending design values for Decking grades apply only when the load is applied to the wide face.

4.2.5.3 Post and Timber Grades. Allowable bending design values for Post and Timber grades apply to members with the load applied to either the narrow or wide face.

4.2.5.4 Beam and Stringer Grades. Allowable bending design values for Beam and Stringer grades apply to members with the load applied to the narrow face. When Post and Timber sizes of lumber are graded to Beam and Stringer grade requirements, design values for the applicable Beam and Stringer grades shall be used. Such lumber shall be identified in accordance with 4.1.2.1 as conforming to Beam and Stringer grades.

4.2.5.5 Continuous or Cantilevered Beams. When Beams and Stringers are used as continuous or cantilevered beams, the design shall include a requirement that the grading provisions applicable to the middle 1/3 of the length (see References 42, 43, 44, 45, 46, 47 and 49) shall be applied to at least the middle 2/3 of the length of pieces to be used as two span continuous beams, and to the entire length of pieces to be used over three or more spans or as cantilevered beams.

4.2.6 Compression Perpendicular to Grain, $F_{c\perp}$

For sawn lumber, the compression design values perpendicular to grain are based on a deformation limit that has been shown by experience to provide for adequate service in typical wood frame construction. The compression design values perpendicular to grain specified in Tables 4A, 4B, 4C, 4D, 4E and 4F are species group average values associated with a deformation level of 0.04" for a steel plate on wood member loading condition. One method for limiting deformation in special applications where it is critical, is use of a reduced compression design value perpendicular to grain. The following equation shall be used to calculate the compression design value perpendicular to grain for a reduced deformation level of 0.02":

$$F_{c\perp 0.02} = 0.73\, F_{c\perp} \qquad (4.2\text{-}1)$$

where:

$F_{c\perp 0.02}$ = compression perpendicular to grain at 0.02" deformation limit

$F_{c\perp}$ = compression perpendicular to grain at 0.04" deformation limit (as published in Tables 4A, 4B, 4C, 4D, 4E and 4F)

4.3 Adjustment of Design Values

4.3.1 General

Design values (F_b, F_t, F_v, $F_{c\perp}$, F_c, E) from Tables 4A, 4B, 4C, 4D, 4E and 4F shall be multiplied by the adjustment factors specified in Table 4.3.1 to determine allowable design values (F_b', F_t', F_v', $F_{c\perp}'$, F_c', E').

4.3.2 Load Duration Factor, C_D

All tabulated design values except modulus of elasticity, E, and compression perpendicular to grain, $F_{c\perp}$, shall be multiplied by load duration factors, C_D, as specified in 2.3.2.

4.3.3 Wet Service Factor, C_M

Tabulated design values for structural sawn lumber are based on the moisture service conditions specified in 4.1.4. When the moisture content of structural members in use differs from these moisture service conditions, tabulated design values shall be multiplied by the wet service factors, C_M, specified in Tables 4A, 4B, 4C, 4D, 4E and 4F.

4.3.4 Temperature Factor, C_t

When structural members will experience sustained exposure to elevated temperatures up to 150°F (see Appendix C), tabulated design values shall be multiplied by the temperature factors, C_t, specified in 2.3.3.

4.3.5 Beam Stability Factor, C_L

Tabulated bending design values, F_b, shall be multiplied by the beam stability factor, C_L, specified in 3.3.3.

4.3.6 Size Factor, C_F

4.3.6.1 Bending, tension, and compression parallel to grain design values for visually graded dimension lumber 2" to 4" thick shall be multiplied by the size factors specified in Tables 4A, 4B and 4F.

4.3.6.2 When the depth of a rectangular sawn lumber bending member 5" or thicker exceeds 12", the bending design values, F_b, in Table 4D shall be multiplied by the following size factor:

$$C_F = (12/d)^{1/9} \leq 1.0 \qquad (4.3\text{-}1)$$

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Form Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	C_f	-	-	-
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	-
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	-
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	C_b
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	C_P	-	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_T	-

4.3.6.3 For beams of circular cross section with a diameter greater than 13.5", or for 12" or larger square beams loaded in the plane of the diagonal, the size factor shall be determined in accordance with 4.3.6.2 on the basis of an equivalent conventionally loaded square beam of the same cross-sectional area.

4.3.6.4 Bending design values for all species of 2" thick or 3" thick Decking, except Redwood, shall be multiplied by the size factors specified in Table 4E.

4.3.7 Flat Use Factor, C_{fu}

When sawn lumber 2" to 4" thick is loaded on the wide face, multiplying the bending design value, F_b, by the flat use factors, C_{fu}, specified in Tables 4A, 4B, 4C and 4F, shall be permitted.

4.3.8 Incising Factor, C_i

Tabulated design values shall be multiplied by the following incising factor, C_i, when dimension lumber is incised parallel to grain a maximum depth of 0.4", a maximum length of 3/8", and density of incisions up to 1,100/ft^2. Incising factors shall be determined by test or by calculation using reduced section properties for incising patterns exceeding these limits.

Table 4.3.8 Incising Factors, C_i

Design Value	C_i
E	0.95
F_b, F_t, F_c	0.80
F_v, $F_{c\perp}$	1.00

4.3.9 Repetitive Member Factor, C_r

Bending design values, F_b, in Tables 4A, 4B, 4C and 4F for dimension lumber 2" to 4" thick shall be multiplied by the repetitive member factor, C_r = 1.15, when such members are used as joists, truss chords, rafters, studs, planks, decking or similar members which are in contact or spaced not more than 24" on centers, are not less than three in number and are joined by floor, roof or other load distributing elements adequate to support the design load. (A load distributing element is any adequate system that is designed or has been proven by experience to transmit the design load to adjacent members, spaced as described above, without displaying structural weakness or unacceptable deflection. Subflooring, flooring, sheathing, or other covering elements and nail gluing or tongue and groove joints, and through nailing generally meet these criteria.) Repetitive member bending design values in

Table 4E for visually graded Decking have already been multiplied by $C_r = 1.15$.

4.3.10 Form Factor, C_f

Tabulated bending design values, F_b, for bending members with either a circular or square cross section loaded in the plane of the diagonal (diamond section) shall be multiplied by the form factors, C_f, specified in 3.3.4.

4.3.11 Column Stability Factor, C_P

Tabulated compression design values parallel to grain, F_c, shall be multiplied by the column stability factor, C_P, specified in 3.7.

4.3.12 Buckling Stiffness Factor, C_T

Modulus of elasticity, E, shall be permitted to be multiplied by the buckling stiffness factor, C_T, as specified in 4.4.2.

4.3.13 Bearing Area Factor, C_b

Tabulated compression design values perpendicular to grain, $F_{c\perp}$, shall be permitted to be multiplied by the bearing area factor, C_b, as specified in 3.10.4.

4.3.14 Pressure-Preservative Treatment

Tabulated design values apply to sawn lumber pressure treated by an approved process and preservative (see Reference 30). Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives.

4.4 Special Design Considerations

4.4.1 Stability of Bending Members

4.4.1.1 Sawn lumber bending members shall be designed in accordance with the lateral stability calculations in 3.3.3 or shall meet the lateral support requirements in 4.4.1.2 and 4.4.1.3.

4.4.1.2 As an alternative to 4.4.1.1, rectangular sawn lumber beams, rafters, joists or other bending members, shall be designed in accordance with the following provisions to provide restraint against rotation or lateral displacement. If the depth to breadth, d/b, based on nominal dimensions is:

(a) $d/b < 2$; no lateral support shall be required.

(b) $2 < d/b < 4$; the ends shall be held in position, as by full depth solid blocking, bridging, hangers, nailing or bolting to other framing members, or other acceptable means.

(c) $4 < d/b < 5$; the compression edge of the member shall be held in line for its entire length to prevent lateral displacement, as by adequate sheathing or subflooring, and ends at point of bearing shall be held in position to prevent rotation and/or lateral displacement.

(d) $5 < d/b < 6$; bridging, full depth solid blocking or diagonal cross bracing shall be installed at intervals not exceeding 8 feet, the compression edge of the member shall be held in line as by adequate sheathing or subflooring, and the ends at points of bearing shall be held in position to prevent rotation and/or lateral displacement.

(e) $6 < d/b < 7$; both edges of the member shall be held in line for their entire length and ends at points of bearing shall be held in position to prevent rotation and/or lateral displacement.

4.4.1.3 If a bending member is subjected to both flexure and axial compression, the depth to breadth ratio shall be no more than 5 to 1 if one edge is firmly held in line. If under all combinations of load, the unbraced edge of the member is in tension, the depth to breadth ratio shall be no more than 6 to 1.

4.4.2 Wood Trusses

4.4.2.1 Increased chord stiffness relative to axial loads when a 2" x 4" or smaller sawn lumber truss compression chord is subjected to combined flexure and axial compression under dry service condition and has 3/8" or thicker plywood sheathing nailed to the narrow face of the chord in accordance with code required roof sheathing fastener schedules (see References 32, 33 and 34), shall be permitted to be accounted for by multiplying the tabulated modulus of elasticity design value, E, by the buckling stiffness factor, C_T, in column stability calculations (see 3.7 and Appendix H). When $\ell_e < 96"$, C_T shall be calculated as follows:

$$C_T = 1 + \frac{K_M \ell_e}{K_T E} \qquad (4.4\text{-}1)$$

where:

ℓ_e = effective column length of truss compression chord (see 3.7)

K_M = 2300 for wood seasoned to 19% moisture content or less at the time of plywood attachment.

K_M = 1200 for unseasoned or partially seasoned wood at the time of plywood attachment.

K_T = 1 - 1.645(COV_E)
= 0.59 for visually graded lumber
= 0.75 for machine evaluated lumber (MEL)
= 0.82 for products with $COV_E \leq 0.11$ (see Appendix F.2)

When $\ell_e > 96"$, C_T shall be calculated based on ℓ_e = 96".

4.4.2.2 For additional information concerning metal plate connected wood trusses see Reference 9.

4.4.3 Notches

4.4.3.1 End notches, located at the ends of sawn lumber bending members for bearing over a support, shall be permitted, and shall not exceed 1/4 the beam depth (see Figure 4A).

4.4.3.2 Interior notches, located in the outer thirds of the span of a single span sawn lumber bending member, shall be permitted, and shall not exceed 1/6 the depth of the member. Interior notches on the tension side of 3½" or greater thickness (4" nominal thickness) sawn lumber bending members are not permitted (see Figure 4A).

4.4.3.3 See 3.1.2 and 3.4.3 for effect of notches on strength.

Figure 4A Notch Limitations for Sawn Lumber Beams