American Institute of Timber Construction

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AITC 119-96
STANDARD SPECIFICATIONS FOR
STRUCTURAL GLUED LAMINATED TIMBER OF HARDWOOD SPECIES

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Cost efficiency in the design of structural glued laminated timber requires that the stress values as determined by the design be specified rather than a particular species or stress combination. It is recommended that the designer specify the primary stress used in the design, such as extreme fiber in bending, together with the actual computed design values such as those for modulus of elasticity, compression perpendicular to grain and horizontal shear. This method of specifying provides timely availability and economy of material and allows the manufacturer the most latitude in selecting raw material -- thus promoting better utilization of available forest resources. Tables of design values are conveniently arranged to aid the designer in specifying required stress values. Not all design values as shown in the tables are readily available in all areas. Please check for availability before specifying.

Manufacture of glued laminated timber has been developed based on ASTM D 3737-93c, *Standard Method for Establishing Stresses for Structural Glued Laminated Timber (Glulam)* (Ref. 9), as modified by subsequent research and by American National Standard ANSI/AITC A190.1-1992, *Structural Glued Laminated Timber* (Ref. 1). These specifications contain data relating to design values and the adjustment of stresses for the design of glued laminated timber hardwood members. They are, however, neither a design manual nor an engineering textbook. For additional design information see the AITC *Timber Construction Manual,* Fourth Edition (Ref. 10).

The majority of these combinations may be specified and used if confirmed with the manufacturer. AITC has also developed procedures which will allow new combinations to be used and approved based on AITC 500-91, *Determination of Design Values for Structural Glued Laminated Timber* (Ref. 8). This Standard and AITC's “GLDV” computer program determines design values for combinations, and allows laminators to develop more efficient layups that better utilize the wood resource. This procedure has been submitted to the national evaluation service and approved NER 466. Grades and amounts used in glued laminated timber can now be evaluated very quickly, thus allowing more flexibility in using available laminating lumber.

Preface

These specifications consolidate, expand and update previously issued laminating specifications and supplements related to specific species or mixtures of species. They represent the latest research available from the U.S. Forest Products Laboratory, various colleges and universities, and the American Institute of Timber Construction. With these specifications a designer can specify the required stress levels for a glued laminated timber member. It is the responsibility of a glued laminated timber manufacturer to produce a member with design values that meet or exceed those requirements. When the design stress level allows a choice, manufacturers will select laminating combinations to fit their varying raw material supplies, thus better utilizing available forest resources.

Annexes attached to this standard are considered mandatory.

1. GENERAL

1.1 Structural Glued Laminated Timber

1.1.1 The term *structural glued laminated timber* as employed herein refers to an engineered, stress-rated product of a timber laminating plant, comprising assemblies of suitably selected and prepared wood laminations bonded together with adhesives. The grain of all laminations is approximately parallel longitudinally.

1.1.2 Separate laminations shall not exceed 2 in. in net thickness. They may be comprised of pieces end joined to form any length, of pieces placed or glued edge to edge to make any width, or of pieces bent to curved form during gluing.

1.1.3 These specifications are applicable to laminated timbers with the number of laminations indicated in Tables 1 and 2.

1.1.4 Production of structural glued laminated timber under these specifications shall be in accordance with the American National Standard ANSI/AITC A190.1-1992, *Structural Glued Laminated Timber*.

1.1.5 End joints in laminated timber combinations listed herein shall be plain scarf joints, finger joints or other types which qualify for the design values in accordance with the procedures in the American National Standard ANSI/AITC A190.1-1992, *Structural Glued Laminated Timber*.

1.1.6 Design of glued laminated members and their fastenings shall be in accordance with the provisions of these specifications and the *Timber Construction Manual.*

1.2 Design Values

1.2.1 Some of the design values contained herein have been developed by AITC using procedures developed with analytical studies confirmed by full-scale load tests.

1.3 Species

1.3.1 Hardwood species most commonly used for laminating are included in these specifications.

1.4 Specification of Design Values

1.4.1 Principal Stress -- Bending. Table 1 is applicable to members consisting of 4 or more laminations stressed primarily in bending with the load applied perpendicular to the wide faces of the laminations. The table includes combinations manufactured from visually graded lumber and combinations manufactured from E-rated lumber. There are five groupings of bending stress, F_b, levels with a number of options within groupings to give the same bending stress, but with some variations in the other design values shown for each option.

NOTE: Many designs can utilize more than one of the options listed with an F_b grouping. Where these other design values (F_t, F_c, $F_{c\perp}$, F_v and E) become critical in design, the designer should specify the stresses as required by design. Obviously, the specifying of values that are much higher than actually required will eliminate certain combinations and may result in a member that is not as readily available as would otherwise be the case. The arbitrary selection of the highest possible design values in all stress categories may result in a member impossible to manufacture under these specifications. It is also possible for the designer to specify a given combination that meets the design requirements, but this may limit availability.

1.4.1.1 Design values in Table 1 are primarily for bending members with loads applied perpendicular to the wide faces of the laminations, which is the most common direction of loading for glued laminated timbers. Design values for loads applied perpendicular to the wide faces of the

laminations causing bending about the X-X axis are designated in the table by the subscript x. Two columns of design values are shown in Table 1 for bending with the load applied perpendicular to the wide faces of the laminations, F_{bx}. The first (column 3) is for the most common use of bending members where the tension portion of the bending stress occurs on the face of the member containing the tension zone laminations. The second (column 4) is for use where the face of the member containing the compression zone laminations is stressed in tension, such as a short overhang on a simple beam. For continuous beams or beams cantilevered over a support where high tensile stresses exist on both the top and bottom of a member, see 1.4.1.3.

1.4.1.2 Design values for members stressed in bending about the Y-Y axis (loads applied parallel to the wide faces of the laminations) and members axially loaded are also shown in Table 1. The design values for loads applied parallel to the wide faces of the laminations causing bending about the Y-Y axis are designated by the subscript y. Neither the X-X nor Y-Y subscripts are commonly used in wood references or textbooks.

1.4.1.3 Design values in bending with the load applied perpendicular to the wide faces of the laminations, F_{bx}, listed in column 3, Table 1, are for the most common installation of the member as a simple beam. This implies compressive stress occurring at the top of the member and tensile stress occurring at the bottom or soffit of the member (positive moment). For conditions where the beam support configuration and/or loading pattern produce negative moment which becomes significant and the resulting tensile stress on the top of the member exceeds the minimum design values listed in column 4 for the compression zone in tension (1,200 psi for 24F; 1,000 psi for 20F; 800 psi for 16F; 700 psi for 14F combinations, and 600 psi for 12F combinations), *Tension Zone* grade requirements, including end joint spacing, shall be applied to the top zones of the member so that the basic design values for bending listed in column 3, Table 1, shall be allowed.

A bending tensile stress in the negative moment area 200 psi higher than that tabulated in column 4 is obtained by applying only tension zone end jointing spacing restrictions to both top and bottom of the member. When specified with Tension Zone requirements both top and bottom, design values in bending, F_{bx}, listed in column 3, Table 1, apply to either positive or negative moment loading conditions. Cantilever or continuous beams which are stressed higher in the negative moment area than values listed in column 4, Table 1 should be identified by the designer. The manufacturer shall then provide Tension Zone laminations in this area as required by the designer.

1.4.1.4 Balanced combinations for bending members which have equal or nearly equal positive and negative bending moments are included in Table 1.

1.4.1.5 Combinations in Table 2 are usually best suited for members with bending stresses caused by loads applied parallel to the wide faces of the laminations. Design values are also shown for members loaded perpendicular to the wide faces of the laminations. In addition, Table 2 also contains combinations for members with 2 or 3 laminations. These combinations are applicable to members loaded either perpendicular or parallel to the wide faces of the laminations.

1.4.1.6 The design values in bending about the X-X axis, F_{bx}, in Column 3, Table 1 and Column 17, Table 2 are based on the use of special tension laminations for most combinations in Table 1 and all combinations in Table 2 when these combinations are used for bending members. When special tension laminations for Table 1 combinations are omitted from bending members, the tabular design values for bending, F_{bx}, are multiplied by 0.75 for members greater than 15 inches

in depth, or by 0.85 for members up to 15 inches in depth. For Table 2 combinations, bending members 15 inches and less in depth, use design values for bending in Column 16, Table 2, or for members greater than 15 inches in depth multiply the design value in bending by 0.75 when special tension laminations are not used. Special tension laminations are not required for arches and the above provisions do not apply.

1.4.2 Principal Stress -- Axial. Table 2 contains combinations for members stressed primarily in axial tension or compression.

1.4.3 Members subjected to combined axial and bending stresses. When a combination of axial and bending stresses exists in a member, they shall be checked by the equations as shown in the *Timber Construction Manual*. The designer shall specify the required tabular design values in bending, F_b, and compression parallel to grain, F_c, or tension parallel to grain, F_t ; however, the stresses specified shall be available in a single combination. When the predominant stress is bending, the combinations in Table 1 are usually more appropriate. The required tabular design values for axial and bending stresses shall be specified regardless of whether the combination has been specified.

2. Lumber

2.1 General

2.1.1 For that portion of the cross section that is not a structural part of the member, the strength provisions of this specification need not apply.

2.1.2 When a top or bottom lamination is specially selected to meet appearance requirements, the basic structural requirements of the required grade still apply.

2.1.3 Appearance requirements shall be in accordance with the AITC 110-84, *Standard Appearance Grades for Structural Glued Laminated Timber*, (Ref. 6).

2.2 Species

2.2.1 This specification is applicable to members laminated from any of the hardwood species listed in Table 3.

2.3 Grading

2.3.1 Visually-graded lumber shall be graded for visual characteristics in accordance with the National Grading Rule of the American Softwood Lumber Standard, PS 20-94, (Ref. 17) of 2.3.2. Special tension laminations shall be graded in accordance with the procedures shown in Annex A. E-rated lumber shall be graded in accordance with the procedures shown in Annex C.

2.3.2 The slope of grain requirements for visually-graded lumber used in members stressed principally in bending perpendicular to the wide faces of the laminations are shown in Table 5. When slope of grain for visually-graded lumber is not shown, the slope shall be that of the basic dimension grades shown. For tension or compression members, the requirements given in Table 6 apply to all laminations.

3. Adhesives

3.1 Adhesives used shall comply with the specifications contained in the American National Standard ANSI/AITC A190.1-1992, *Structural Glued Laminated Timber*.

3.2 Wet-use adhesives may be specified for all moisture conditions but are required when the moisture content exceeds 16% for repeated or prolonged periods of service or when the wood is preservatively treated either before or after gluing.

3.3 Many of the species listed individually in Table 3 are generally available in commercial categories without individual species

identification. It is recommended that the laminator work closely with the adhesive suppliers to determine if any need exists for species identification prior to adhesive qualification. Each of the adhesive-species-treatment combinations shall be qualified. However, red oak and white oak shall be considered in the same group for qualification. All other species are to be considered on an individual basis.

4. Design Values

4.1 General

Although ASTM D 3737 procedures permit higher design stresses for some hardwood species and grade combinations, it is the intent of this standard to limit hardwood beam stresses to those values shown in the tables when the values are determined using data in ASTM D 2555-88 (Ref. 15), Table 2. It is recommended that higher values be based upon supplemental clear wood data developed following ASTM D 5536-94 (Ref. 18) or upon verification by full size beam testing.

4.1.1 For design values given herein, or adjustments thereof, lumber of the grades required shall be assembled in accordance with the zone requirements indicated in Tables 5 and 6.

4.1.2 Design values given herein and the adjustments required for other conditions of use and loading are also applicable to structural glued laminated timbers that have been pressure impregnated by an approved preservative process in accordance with AITC 109-90, *Standard for Preservative Treatment of Structural Glued Laminated Timber,* (Ref. 5).

4.1.3 Design values for fire retardant treated glued laminated timber, treated before or after gluing, are dependent upon the species and treatment combinations involved. The effect on strength shall be provided for each treatment by the manufacturer of the treatment.

4.1.4 Design values given herein are for normal durations of loading. Adjustments for other durations of loading are given in 4.4.1.

4.1.5 Design values in bending, F_b, given herein are based on a simple span member 5-1/8 in. wide, 12 in. deep, 21 ft in length and loaded with a uniform load. Adjustments for other sizes and loading are given in 4.4.2 and in footnote f to Table 2.

4.1.6 The modulus of elasticity, E, values herein are the average values for the combination shown and reflect the effect of grade. The modulus of elasticity of wood of a given species is variable. The coefficient of variation (C.O.V.) of visually graded lumber of the same species is approximately 0.25 for species used in laminating. Tests and experience have shown that this variability is considerably reduced by the laminating effect. For glued laminated timber made from 4 laminations of visually graded lumber, the C.O.V. is approximately 0.15, for 10 laminations 0.10 and for 16 or more laminations 0.08. The variation in modulus of elasticity is especially important in designs where stiffness is of prime importance such as in the design of long columns, lateral stability calculations or in calculations for ponding.

A standard deviation (s) is the average value multiplied by the coefficient of variation. In a normal frequency distribution, approximately 2/3 of the individual values will be within one standard deviation (above and below) the average value. Also about 95% of the individual values will be within two standard deviations of the average value. Thus, if a combination of glued laminated timber has an average E of 1,700,000 psi and the coefficient of variation is 0.10, 2/3 of the members could be expected to have values between 1,530,000 and 1,870,000 psi and 95% could be expected to have values between 1,360,000 psi and 2,040,000 psi.

In a case where only the lower portion of the variation in E is of engineering importance, similar useful interpretations are possible. In a normal frequency distribution, 5/6 of the individual values lie above a value located at one standard deviation below the mean (1,530,000 psi in the above example). In the same distribution, 95% of the individual values lie above a value located at 1.645 s (1,420,000 psi in the above example).

4.1.6.1 Tabulated E values shown for bending about the X-X axis of members in Table 1 are higher than those tabulated for bending about the Y-Y axis because the laminations in the outer zones have higher E values than those in the inner zones.

4.1.6.2 Modulus of elasticity values for bending members listed in Tables 1 and 2 are based on a span to depth ratio of approximately 21 and include an adjustment for shear deflection. These E values can be used for determining deflection for most designs without the necessity of calculating the shear deflection.

4.1.7 Tabulated compression perpendicular to grain design values in Tables 1 and 2 are based on the average stress to obtain a deformation of 0.04 in. obtained when testing in accordance with the standard method ASTM D 245-93 (Ref. 13), for compression perpendicular to grain. In special applications where deformation is critical, use of a reduced compression perpendicular to grain design value shall be considered. The following equation is used for a deformation of 0.02 in. which is 50% of that associated with the values tabulated in Tables 1 and 2.

$$F_{c\perp(0.02)} = 0.73\ F_{c\perp}$$

where $F_{c\perp(0.02)}$ = compression perpendicular to grain at 50% of deformation limit associated with tabulated $F_{c\perp}$ values (0.02 in.), and $F_{c\perp}$ = compression perpendicular to grain at 0.04 in. deformation limit.

4.2 Radial Tension or Compression

4.2.1 When a curved member is loaded in bending, radial stresses are induced.

4.2.2 When the bending moment, M, is in the direction tending to increase curvature (decrease the radius), the radial stress is compression across the grain, F_{rc}. The design value in radial compression, F_{rc} is equal to the design value in compression perpendicular to grain, $F_{c\perp}$ of the grade and species being used.

4.2.3 When M is in the direction tending to decrease curvature (increase the radius), the radial stress is tension across the grain. The design value in radial tension perpendicular to grain, F_{rt} , shall be limited to 1/3 the design value in horizontal shear, F_v. These values are subject to adjustments for duration of load and wet conditions of use. For wet conditions of use, the wet-use factor for radial tension is 0.875.

4.3 Condition of Use

4.3.1 Dry condition of use design values shall be applicable when the moisture content in service is less than 16%, as in most covered structures.

4.3.2 Wet condition of use design values shall be applicable when the moisture content in service is greater than 16%, as may occur in members directly exposed to precipitation or in covered locations of high humidity.

4.4 Adjustment of Design Values

4.4.1 Duration of Load

4.4.1.1 Normal load duration contemplates fully stressing a member to the design value by the application of the full design load for a duration of approximately 10 years (applied either continuously or cumulatively). Tabular design values are based on normal load duration (C_D =1.0).

4.4.1.2 When the duration of load is other than that for normal load duration, the tabular design values except for modulus of elasticity and compression parallel to grain are adjusted by the duration of load factor C_D as shown in 4.4.1.3.

4.4.1.3 The duration of load factors C_D are shown below:

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	1.60	Wind/Earthquake Load
Impact*	2.0	Impact Load

* The impact load duration factor shall not apply to glued laminated timber members preservatively treated with waterborne preservatives to the heavy retention required for marine exposure, nor to members pressure treated with fire retardant chemicals.

4.4.2 Volume Factor, C_V

4.4.2.1 The tabular design values in bending about the X-X axis are based on a simple span member 5-1/8 in. wide, 12 in. deep, 21 ft in length and loaded with a uniform load. When a different size member is used or a different loading condition exists, the tabular design value F_{bx} is multiplied by the volume factor C_V calculated as follows:

$$C_V = K_L \left[(5.125/b)^{1/x} (12/d)^{1/x} (21/L)^{1/x} \right] \leq 1.0$$

where: K_L = loading condition coefficient (see following Table),

b = width (breadth) of bending member, in. For multiple piece width layups, b = width of widest piece used in the layup. Thus b $\leq$ 10.75 in.,

d = depth of bending member, in.,

L = length of bending member between points of zero moment, ft.,

x = 10 for hardwoods,

Single Span Beam	**K_L**
Concentrated load at mid-span	1.09
Uniformly distributed load	1.00
Two equal concentrated loads at 1/3 points of span	0.96
Continuous Beam or Cantilever	
All loading conditions	1.00

4.4.3 Lateral Stability

4.4.3.1 Design values for bending contained in these specifications are applicable to members which are adequately braced. When deep, slender members not adequately braced are used, a reduction to the tabulated design values in bending must be applied based on a computation of the beam stability factor of the member. In the check of lateral stability, the beam stability factor shall be applied in design as shown in the *Timber Construction Manual*.

4.4.3.2 A reduction in the design value in bending determined by applying the beam stability factor is not cumulative with a reduction in design value due to the application of the volume factor. In no case shall the design value in bending exceed the stress as determined by applying the volume factor or beam stability factor, whichever governs.

4.4.4 Curvature Factor

4.4.4.1 For the curved portion of members, the design value in bending, F_b, shall be adjusted by multiplying it by the following curvature factor:

$$C_c = 1 - 2000\left(\frac{t}{R}\right)^2$$

where: t = thickness of lamination in.,

R = radius of curvature of lamination in.

No curvature factor need be applied to the design value in the straight portion of an assembly, regardless of curvature elsewhere.

5. Connections and Fasteners

5.1 Bolts, Lag Screws, Nails and Spikes. Design values for dowel type connections and fasteners for glued laminated timber are contained in the *National Design Specification® for Wood Construction*, 1991 (Ref. 3). Specific gravity values from Table 3 are used with those tables to determine the dowel capacities.

5.2 Shear Plates and Split Rings. Timber connector group information for hardwood glued laminated timber is provided in Tables 4A and 4B. The timber connector group is used with tables in the *AITC Timber Construction Manual* to determine the capacity of shear plates and split ring connectors.

5.3 See AITC 104-84, *Typical Construction Details*, (Ref. 4), for additional information on connections.

6. DIMENSIONS

6.1 Standard Sizes. American National Standard ANSI/AITC A190.1-1992 permits the use of any width or depth of glued laminated timber. The use of standard finished sizes, however, constitutes recommended practice to the extent that other considerations will permit. The laminator may use different thicknesses of lumber to develop the specified depth provided the volume of the higher grades of lumber equals or exceeds that specified in laminating combinations which are based on laminations of equal thickness. The depth and width of the glued laminated timber should be as agreed upon by buyer and seller.

6.2 Depth and Width

6.2.1 Straight and curved members shall be furnished in accordance with the width and depth dimensions required by the design.

6.2.2 The typical standard net finished widths are as follows:

Nominal Width, In.	Net Finished Width, in.
3	2-1/2
4	3 1/8
6	5 1/8
8	6 3/4
10	8 3/4
12	10 3/4
14	12 1/4
16	14 1/4

Other finished widths may be used to meet the size requirements of a design or to meet other special requirements.

6.3 Radius of Curvature

6.3.1 The ability to bend laminations is dependent upon many factors relating to both wood properties and manufacturing techniques and it may be advisable for the designer to consult with the laminator prior to specifying. Two prime considerations are thickness of laminations, t, and bending radii, R.

The recommended minimum radii of curvature for curved structural glued laminated hardwood timbers are 6 ft 3 in. for a lamination thickness of ¾ in.; and 12 ft 6 in. for a lamination thickness of 1-1/2 in. Other

radii of curvature may be used with these thicknesses and other radius-thickness combinations may be used provided the t/R ratio does not exceed 1/100.

7. APPEARANCE GRADES

7.1 Appearance grades shall be in accordance with the current AITC 110-84, *Standard Appearance Grades for Structural Glued Laminated Timber*, unless otherwise specified on drawings or specifications.

7.2 For those combinations permitting the mixing of species, the potential for difference in color or grain of adjacent laminations must be recognized. For those architectural appearance applications where such possible differences in color or grain are important, the designer shall specify a combination symbol which will restrict the laminations to a single species or group of species with similar characteristics. In some cases, this may restrict availability.

8. INSPECTION AND QUALITY CONTROL

8.1 The assurance that quality materials and workmanship are used in structural glued laminated timber members shall be vested in the laminator's day-to-day quality control operations. Visual inspections and physical tests of samples of production are also required to assure conformance with this Standard and American National Standard ANSI/AITC A190.1-1992 *Structural Glued Laminated Timber*.

9. MARKING

9.1 The laminating combinations in Table 1 were developed primarily to resist bending loads. The grades of lumber in laminations on the compression side may not be the same as those on the tension side. Therefore, straight or slightly cambered glued laminated timber bending members shall be stamped "TOP" with letters approximately 2 in. high on the top at both ends of the member. Axially-loaded members or bending members which are fabricated in such a manner that they cannot be installed upside down need not be marked.

10. PROTECTION DURING SHIPPING AND FIELD HANDLING

10.1 End sealers, surface sealers, primer coats and wrappings are allowed for the protection of the members. However, they do not necessarily preclude damage resulting from negligence and other factors beyond the control of the laminator during shipping, handling, storing and placing of the members. The protection specified shall be commensurate with the end use and final finish of the member. It may also vary with the method of shipment and with exposure to climatic and other details. See the current AITC 111-79, *Recommended Practice for Protection of Structural Glued Laminated Timber During Transit, Storage and Erection*, (Ref. 7).

11. TABLES OF DESIGN VALUES AND LAYUP PROCEDURES

11.1 The following Tables contain information on design values and manufacture of selected combinations of hardwood glued laminated timber. Other species and other combinations are allowed when developed by the procedures included in the current AITC 500-91 which allows for greater optimization of available species and grades of lumber.

Table 1 has been developed primarily for members that are loaded in bending perpendicular to the wide faces of the laminations. However, design values have been included for members loaded in bending parallel to the wide faces of the laminations and for axial loads.

Table 2 has been developed primarily for axially loaded members and loading in bending about the Y-Y axis. A single grade of

species is used throughout the depth of the member.

Table 3 contains the average specific gravity for lumber at moisture contents of 12% and ovendry for selected species. The specific gravities of other species shall be determined by obtaining the average specific gravity for "green" lumber from ASTM D 2555-88 and adjusting to the specific gravity at 12% and ovendry by the appropriate equation in ASTM D 2395-93 (Ref. 16).

Table 4 contains the Timber Connector Groups for use with split ring and shear plate connectors.

Table 5 contains manufacturing requirements for the tabulated hardwood combinations listed in Table 1.

Table 6 contains manufacturing requirements for the tabulated hardwood combinations listed in Table 2.

Table 1 Design Values for Structural Glued Laminated Timber

For normal duration of load and dry conditions of use [a, b, c, l]

		Bending About X - X Axis						Bending About Y - Y Axis					Axially Loaded		
		Loaded Perpendicular to Wide Faces of Laminations						Loaded Parallel to Wide Faces of Laminations							
		Extreme Fiber in Bending F_{bx}		Compression Perpendicular to Grain $F_{c\perp x}$											
Combination Symbol[d]	Species Outer Laminations/ Core Laminations[e]	Tension Zone Stressed in Tension[f k] psi	Compression Zone Stressed in Tension[g] psi	Tension Face[j] psi	Compression Face[j] psi	Shear Parallel to Grain (Horizontal) F_{vx} psi	Modulus of Elasticity E_x Million psi	Extreme Fiber in Bending F_{by}[h] psi	Compression Perpendicular to Grain $F_{c\perp y}$[j] psi	Shear Parallel to Grain (Horizontal) F_{vy} psi	Shear Parallel to Grain (Horizontal) (For members with multiple piece laminations which are not edge glued)[i] F_{vy} psi	Modulus of Elasticity E_y Million psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E Million psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Visually Graded Hardwoods															
The following combination is **NOT BALANCED** and is intended for simple span members.[m]															
12F-V1	D	1200	600	285	285	125	1.2	1050	285	110	45	1.0	600	800	1.0
The following combination is **BALANCED** and is for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.															
12F-V2	D	1200	1200	285	285	125	1.2	1050	285	110	45	1.1	625	860	1.1
The following 2 combinations are **NOT BALANCED** and are intended for simple span members.[m]															
14F-V1	C	1400	700	405	405	155	1.3	1250	405	135	55	1.1	700	950	1.1
14F-V2	B	1400	700	590	590	180	1.3	1450	590	160	65	1.1	750	1200	1.1
The following 2 combinations are **BALANCED** and are for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.															
14F-V3	C	1400	1400	405	405	155	1.3	1250	405	135	55	1.1	725	950	1.1
14F-V4	B	1400	1400	590	590	180	1.3	1450	590	160	65	1.1	775	1200	1.1
Wet-use factors		0.80	0.80	0.53	0.53	0.875	0.833	0.80	0.53	0.875	0.875	0.833	0.80	0.73	0.833

Table 1 Design Values for Structural Glued Laminated Timber

For normal duration of load and dry conditions of use [a, b, c, l]

		Bending About X - X Axis						Bending About Y - Y Axis					Axially Loaded		
		Loaded Perpendicular to Wide Faces of Laminations						Loaded Parallel to Wide Faces of Laminations							
		Extreme Fiber in Bending F_{bx}		Compression Perpendicular to Grain $F_{c\perp x}$											
Combination Symbol[d]	Species Outer Laminations/ Core Laminations [e]	Tension Zone Stressed in Tension [f k] psi	Compression Zone Stressed in Tension [g] psi	Tension Face [j] psi	Compression Face [j] psi	Shear Parallel to Grain (Horizontal) F_{vx} psi	Modulus of Elasticity E_x Million psi	Extreme Fiber in Bending F_{by} [h] psi	Compression Perpendicular to Grain $F_{c\perp y}$ [j] psi	Shear Parallel to Grain (Horizontal) F_{vy} psi	Shear Parallel to Grain (Horizontal) (For members with multiple piece laminations which are not edge glued) [i] F_{vy} psi	Modulus of Elasticity E_y psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E Million psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Visually Graded Hardwoods															
The following 2 combinations are **NOT BALANCED** and are intended for simple span members.[m]															
16F-V1	B	1600	800	590	590	180	1.4	1400	590	160	65	1.2	800	1200	1.2
16F-V2	A	1600	800	835	835	200	1.5	1700	835	175	75	1.3	875	1250	1.3
The following 2 combinations are **BALANCED** and are for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.															
16F-V3	B	1600	1600	590	590	180	1.4	1400	590	160	65	1.2	850	1200	1.2
16F-V4	A	1600	1600	835	835	200	1.6	1700	835	175	75	1.3	900	1300	1.3
The following one combination is **NOT BALANCED** and is intended for simple span members.[m]															
20F-V1	A	2000	1000	835	835	200	1.7	1700	835	175	75	1.4	975	1400	1.4
The following one combination is **BALANCED** and is for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.															
20F-V2	A	2000	2000	835	835	200	1.7	1700	835	175	75	1.4	1000	1400	1.4
Wet-use factors		0.80	0.80	0.53	0.53	0.875	0.833	0.80	0.53	0.875	0.875	0.833	0.80	0.73	0.833

Table 1 Design Values for Structural Glued Laminated Timber

For normal duration of load and dry conditions of use [a, b, c, l]

		Bending About X - X Axis						Bending About Y - Y Axis					Axially Loaded		
		Loaded Perpendicular to Wide Faces of Laminations						Loaded Parallel to Wide Faces of Laminations							
		Extreme Fiber in Bending F_{bx}		Compression Perpendicular to Grain $F_{c\perp x}$											
Combination Symbol[d]	Species Outer Laminations/ Core Laminations [e]	Tension Zone Stressed in Tension [f k] psi	Compression Zone Stressed in Tension [g] psi	Tension Face [j] psi	Compression Face [j] psi	Shear Parallel to Grain (Horizontal) F_{vx} psi	Modulus of Elasticity E_x Million psi	Extreme Fiber in Bending F_{by} [h] psi	Compression Perpendicular to Grain $F_{c\perp y}$ [j] psi	Shear Parallel to Grain (Horizontal) F_{vy} psi	Shear Parallel to Grain (Horizontal) (For members with multiple piece laminations which are not edge glued) [i] F_{vy} psi	Modulus of Elasticity E_y Million psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E Million psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
E-Rated Hardwoods															
The following combination is **NOT BALANCED** and is intended for simple span members.[m]															
16F-E1	ABCD	1600	800	440	440	125	1.4	1250	285	110	45	1.2	825	975	1.2
The following combination is **BALANCED** and is for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.															
16F-E2	ABCD	1600	800	440	440	125	1.4	1400	285	110	45	1.2	900	1000	1.2
The following combination is **NOT BALANCED** and is intended for simple span members.[m]															
20F-E1	ABC	2000	1000	590	590	155	1.6	1350	405	135	55	1.3	950	1050	1.3
The following combination is **BALANCED** and is for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.															
20F-E2	ABC	2000	2000	590	590	155	1.6	1600	405	135	55	1.3	1050	1100	1.3
The following combination is **NOT BALANCED** and is intended for simple span members.[m]															
24F-E1	AB	2400	1200	770	770	180	1.8	1550	590	160	65	1.5	1000	1400	1.5
The following combination is **BALANCED** and is for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.															
24F-E2	AB	2400	2400	770	770	180	1.8	1650	590	160	65	1.5	1050	1400	1.5
The following 3 combinations are **NOT BALANCED** and are intended for simple span members.[m]															
24F-E3	YP	2400	1200	590	590	155	1.8	1450	405	135	55	1.5	975	1200	1.5
24F-E4	RM	2400	1200	895	895	220	1.8	1650	710	195	80	1.6	1050	1350	1.6
24F-E5	RO	2400	1200	1075	1075	235	1.8	1700	900	205	85	1.5	1100	1450	1.5
Wet-use factors		0.80	0.80	0.53	0.53	0.875	0.833	0.80	0.53	0.875	0.875	0.833	0.80	0.73	0.833

Footnotes -- Table 1 Design.

[a] The combinations in this table are applicable to members consisting of 4 or more laminations and are intended primarily for members stressed in bending due to loads applied perpendicular to the wide faces of the laminations. Design values are also tabulated for loading both perpendicular and parallel to the wide faces of the laminations. For combinations and design values applicable to members loaded primarily axially or parallel to the wide faces of the laminations, see Table 2. For members of 2 or 3 laminations, see Table 2.

[b] The tabulated design values are for dry service conditions. To obtain wet service design values, multiply the tabulated values by the factors shown at the end of the table.

[c] The tabulated design values are for normal duration of loading. For other durations of loading, see 4.4.1.3.

[d] The combinations symbols relate to a specific combination of grades and species in Table 5 that will provide the design values shown for the combination. The first two numbers in the combination symbol correspond to the design value in bending shown in Column 3. The letter in the combination symbol (either a "V" or an "E") indicates whether the combination is made from visually graded, V, or E-rated, E, lumber in the outer zones.

[e] The symbols used for hardwood species are A, B, C, and D. YP is for Yellow Poplar, RM is for Red Maple and RO is for Red Oak (Northern). See Table 3 for a listing of Hardwood species.

[f] The tabulated design values for bending about the X-X axis in this table are applicable to a member 5-1/8 in. wide, 12 in. deep, 21 ft. long, uniformly loaded and used for a simple span. When other conditions exist, the requirements of 4.4.2 apply.

[g] Design values in this column are for extreme fiber stress in bending when the member is loaded such that the compression zone laminations are subjected to tensile stresses. For more information, see 1.4.1.3. The values in this column may be increased 200 psi where end joint spacing restrictions are applied to the compression zone when stressed in tension.

[h] Footnote f of Table 2 applies.

[i] These values for shear parallel to grain (horizontal), F_{vy}, apply to members manufactured using multiple piece laminations with unbonded edge joints. For members manufactured using single piece laminations or using multiple piece laminations with bonded edge joints the shear parallel to grain (horizontal) values in column 11 apply.
For members with 5, 7 or 9 laminations, unbonded edge joints occurring in each lamination shall be no closer than 1-1/2 inches in adjacent laminations. The values in column 12 shall be reduced by 20%.

[j] The compression perpendicular to grain design values in this Table are not subject to the duration of load adjustments in 4.4.1.

[k] When special tension laminations are not used, the design values in bending about the X-X axis, F_{bx}, shall be multiplied by 0.75 for bending members over 15 in. deep, and 0.85 for beams $\leq$ 15 in. in depth.

[l] This table lists up to 5 zones for grades of laminations. When AITC 500-96 is used for developing laminating combinations, the number of zones may be larger.
[m] These combinations are also allowed for arches.

Table 2 Design Values for Structural Glued Laminated Timber

For normal duration of load and dry conditions of use.[a, b, c]

			All Loading		Axially Loaded			Bending about Y - Y Axis							Bending About X - X Axis		
					Tension Parallel to Grain F_t	Compression Parallel to Grain F_c		Loading Parallel to Wide Faces of Laminations							Loaded Perpendicular to Wide Faces of Laminations		
								Extreme Fiber in Bending [f] F_{by}			Shear Parallel to Grain [g] (Horizontal) F_{vy}				Extreme Fiber in Bending [h] F_{bx}		Shear Parallel to Grain [g] (Horizontal) F_{vx}
Combination Symbol	Species[d] Group	Grade[e]	Modulus of Elasticity E	Compression Perpendicular to Grain [l] $F_{c\perp}$	2 or More Lams	4 or More Lams	2 or 3 Lams	4 or More Lams	3 Lams	2 Lams	4 or More Lams (For members with multiple piece lams)[k]	4 or More Lams	3 Lams	2 Lams	2 Lams to 15 in. Deep	4 or More Lams [j,m]	2 or More Lams
			Million psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Visually Graded Hardwoods																	
H1	A	N3	1.3	835	425	900	900	1250	1100	875	75	175	165	150	925	1200	200
H2	A	N2	1.5	835	875	1300	1300	1700	1550	1300	75	175	165	150	1200	1500	200
H3	A	N1	1.7	835	1000	1450	1450	2000	1800	1550	75	175	165	150	1600	1800	200
H4	A	SS	1.7	835	1150	1600	1600	2000	1850	1600	75	175	165	150	1700	2000	200
H5	B	N3	1.2	590	350	800	800	1050	900	750	65	160	150	135	750	1000	180
H6	B	N2	1.3	590	750	1150	1150	1450	1300	1050	65	160	150	135	1000	1200	180
H7	B	N1	1.5	590	850	1300	1300	1650	1500	1300	65	160	150	135	1350	1600	180
H8	B	SS	1.5	590	950	1450	1450	1700	1550	1350	65	160	150	135	1400	1700	180
H9	C	N3	1.0	405	300	625	625	900	800	625	55	135	130	115	675	900	155
H10	C	N2	1.2	405	625	900	900	1200	1100	925	55	135	130	115	875	1100	155
H11	C	N1	1.3	405	725	1000	1000	1400	1300	1100	55	135	130	115	1150	1400	155
H12	C	SS	1.3	405	825	1100	1100	1450	1350	1150	55	135	130	115	1200	1500	155
H13	D	N3	0.9	285	250	575	575	775	675	550	45	110	105	95	575	775	125
H14	D	N2	1.1	285	550	825	825	1050	950	800	45	110	105	95	750	925	125
H15	D	N1	1.2	285	625	925	925	1200	1100	950	45	110	105	95	1000	1150	125
H16	D	SS	1.2	285	700	1050	1050	1250	1150	1000	45	110	105	95	1050	1300	125
Wet-use factors			0.833	0.53	0.80	0.73	0.73	0.80	0.80	0.80	0.875	0.875	0.875	0.875	0.80	0.80	0.875

Table 2 Design Values for Structural Glued Laminated Timber

For normal duration of load and dry conditions of use.[a, b, c]

			All Loading		Axially Loaded			Bending about Y - Y Axis							Bending About X - X Axis		
					Tension Parallel to Grain F_t	Compression Parallel to Grain F_c		Loading Parallel to Wide Faces of Laminations							Loaded Perpendicular to Wide Faces of Laminations		
								Extreme Fiber in Bending [f] F_{by}			Shear Parallel to Grain [g] (Horizontal) F_{vy}				Extreme Fiber in Bending [h] F_{bx}		Shear Parallel to Grain [g] (Horizontal) F_{vx}
Combination Symbol	Species[d] Group	Grade[e]	Modulus of Elasticity E	Compression Perpendicular to Grain [l] $F_{c\perp}$	2 or More Lams	4 or More Lams	2 or 3 Lams	4 or More Lams	3 Lams	2 Lams	4 or More Lams (For members with multiple piece lams)[k]	4 or More Lams	3 Lams	2 Lams	2 Lams to 15 in. Deep	4 or More Lams [j,m]	2 or More Lams
			Million psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
E-Rated Hardwoods																	
H17	A	1.5E3	1.4	1015	1000	1500	1350	1850	1750	1550	75	175	165	150	1200	1450	200
H18	A	1.8E3	1.7	1015	1150	1950	1850	2100	2000	1750	75	175	165	150	1450	1850	200
H19	A	1.8E6	1.7	1015	1450	2000	1900	2300	2200	1950	75	175	165	150	1650	2000	200
H20	A	2.0E3	1.9	1015	1350	2300	2200	2400	2300	2100	75	175	165	150	1700	2200	200
H21	A	2.0E6	1.9	1015	1700	2430	2300	2400	2400	2300	75	175	165	150	2100	2600	200
H22	B	1.5E3	1.4	770	1000	1500	1350	1850	1750	1550	65	160	150	135	1200	1450	180
H23	B	1.8E3	1.7	770	1150	1950	1850	2100	2000	1750	65	160	150	135	1450	1850	180
H24	B	1.8E6	1.7	770	1450	2000	1900	2300	2200	1950	65	160	150	135	1650	2000	180
H25	B	2.0E3	1.9	770	1350	2300	2200	2400	2300	2100	65	160	150	135	1700	2200	180
H26	B	2.0E6	1.9	770	1700	2400	2300	2400	2400	2300	65	160	150	135	2100	2600	180
H27	C	1.5E3	1.4	590	1000	1500	1350	1850	1750	1550	55	135	130	115	1200	1450	155
H28	C	1.8E3	1.7	590	1150	1950	1850	2100	2000	1750	55	135	130	115	1450	1850	155
H29	C	1.8E6	1.7	590	1450	2000	1900	2300	2200	1950	55	135	130	115	1650	2000	155
H30	C	2.0E3	1.9	590	1350	2300	2200	2400	2300	2100	55	135	130	115	1700	2200	155
H31	C	2.0E6	1.9	590	1700	2400	2300	2400	2400	2300	55	135	130	115	2100	2600	155
H32	D	1.5E3	1.4	440	1000	1500	1350	1850	1750	1550	45	110	105	95	1200	1450	125
H33	D	1.5E6	1.4	440	1250	1500	1400	2000	1900	1700	45	110	105	95	1250	1600	125
H34	D	1.8E3	1.7	440	1150	1950	1850	2100	2000	1750	45	110	105	95	1450	1850	125
H35	D	1.8E6	1.7	440	1450	2000	1900	2300	2200	1950	45	110	105	95	1650	2000	125
H36	D	2.0E3	1.9	440	1350	2300	2200	2400	2300	2100	45	110	105	95	1700	2200	125
H37	D	2.0E6	1.9	440	1700	2400	2300	2400	2400	2300	45	110	105	95	2100	2600	125
Wet-use factors			0.833	0.53	0.80	0.73	0.73	0.80	0.80	0.80	0.875	0.875	0.875	0.875	0.80	0.80	0.875

Footnotes -- Table 2 -- Design

[a] The combinations in this table are intended primarily for members loaded either axially or in bending with the loads acting parallel to the wide faces of the laminations. Design values for bending due to loading applied perpendicular to the wide faces of the laminations are also included; however, the combinations in Table 1 are usually better suited for this condition of loading. The design values for bending about the X-X axis, F_{bx}, shown in Column 16 are for members from 2 laminations to 15 in. deep without special tension laminations. Design values approximately 15% higher for members with 4 or more laminations are shown in Column 17. These higher design values; however, require special tension laminations which may not be readily available.

[b] The tabulated design values are for dry conditions of use. To obtain wet-use design values, multiply the tabulated values by the factors shown at the end of the table.

[c] The tabulated design values are for normal duration of loading. For other durations of loading, see 4.4.1.3.

[d] The symbols used for species groups are A, B, C and D. See Table 3.

[e] Grade designations are as follows:

Visually Graded Hardwood Species

SS is select structural, structural joists and planks or structural light framing grade .
N1 is No. 1 structural joists and planks or structural light framing grade; or No. 1 boards graded as dimension lumber.
N2 is No. 2 structural joists and planks or structural light framing grade; or No. 2 boards graded as dimension lumber.
N3 is No. 3 structural joists and planks or structural light framing grade; or No. 3 boards graded as dimension lumber.

E-Rated Grades -- All Species

2.0E6 has 1/6 edge characteristic with 2.0E.
1.8E6 has 1/6 edge characteristic with 1.8E.
1.5E6 has 1/6 edge characteristic with 1.5E.

2.0E3 has 1/3 edge characteristic with 2.0E.
1.8E3 has 1/3 edge characteristic with 1.8E.
1.5E3 has 1/3 edge characteristic with 1.5E.

[f] The values of F_{by} were calculated based on members 12 in. in depth (bending about Y-Y axis). When the depth is less than 12 in., the values of F_{by} can be increased by multiplying by the flat use factor C_{fu} for glued laminated timber.

Depth in.	Flat Use Factor C_{fu}
10-3/4	1.01
8-3/4	1.04
6-3/4	1.07
5-1/8	1.10
3-1/8	1.16

[g] The design values in shear parallel to grain (horizontal shear) contained in this table are based on members without wane.

[h] The tabulated design values for bending about the X-X axis in this table are applicable to a member 5-1/8 in. wide, 12 in. deep, 21 ft long, uniformly loaded and used for a simple span. When other conditions exist, the requirements of 4.4.2 apply.

[i] The design values are for members of from 2 laminations to 15 in. in depth without tension laminations.

[j] The design values are for members of 4 or more laminations in depth and require special tension laminations. When these values are used in design and the member is specified by combination symbol, the designer should also specify the required design value in bending.

[k] These values for shear parallel to grain, F_{vy}, apply to members manufactured using multiple piece laminations with unbonded edge joints. For members using single piece laminations or using multiple piece laminations with bonded edge joints, the shear parallel to grain values tabulated in columns 13, 14 and 15 apply. For members with 5, 7 or 9 laminations the values in column 12 shall be

reduced by 20%. Unbonded edge joints occurring in each lamination shall be no closer than 1-1/2 in. in adjacent laminations.

[l] The compression perpendicular to grain design values in this Table are not subject to the duration of load adjustments in 4.4.1.

[m] When special tension laminations are not used, the design values in bending about the X-X axis, F_{bx}, shall be multiplied by 0.75 for bending members over 15 in. deep. For bending members 15 in. and less in depth, use the design values in Column 16 (see 1.4.1.6).

Table 3 Specific Groups and Names for Hardwood Species[a]

Common Name	Botanical Name	Average Specific Gravity Ovendry	Average Specific Gravity at 12% M.C.
Group A			
Ash, White	Fraxinus americana	0.63	0.59
Beech, American	Fagus grandifolia	0.67	0.63
Birch, Sweet	Betula alleghaniensis	0.72	0.66
Birch, Yellow	Betula lenta	0.65	0.60
Hickory, Bitternut	Carya cordiformis	0.74	0.69
Hickory, Mockernut	Carya tomentosa	0.77	0.71
Hickory, Nutmeg	Carya myristiciformis	0.66	0.62
Hickory, pecan	Carya illinoensis	0.73	0.68
Hickory, pignut	Carya glabra	0.81	0.75
Hickory, shagbark	Carya ovata	0.77	0.71
Hickory, shellbark	Carya laciniosa	0.76	0.70
Hickory, water	Carya aquatica	0.76	0.70
Oak, Northern Red	Quercus rubra	0.66	0.62
Oak, White	Quercus alba	0.70	0.66
	minimum	0.63	0.59
Group B			
Elm, rock	Ulmus thomasii	0.62	0.63
Maple, Black	Acer nigrum	0.60	0.57
Maple, Red	Acer rubrum	0.58	0.54
Mixed Oak:			
Black	Quercus velutina	0.66	0.62
Cherrybark	Quercus facata	0.72	0.66
Northern Red	Quercus rubra	0.66	0.62
Southern Red	Quercus falcata	0.62	0.58
Laurel	Quercus laurifolia	0.66	0.62
Pin	Quercus palustris	0.69	0.64
Scarlet	Quercus coccinea	0.73	0.68
Water	Quercus nigra	0.66	0.62
Chestnut	Quercus prinus	0.69	0.64
Live	Quercus virginiana	1.04	0.93
Post	Quercus stellata	0.72	0.66
Swamp Chestnut	Quercus michauxii	0.72	0.66
White	Quercus alba	0.72	0.66
Bur	Quercus macrocarpa	0.72	0.66
Overcup	Quercus lyrata	0.66	0.62
Swamp White	Quercus bicolor	0.77	0.71
Sweetgum	Liquidambar styraciflua	0.53	0.50
	minimum	0.53	0.50
Group C			
Ash, Black	Fraxinus nigra	0.51	0.49
Elm, American	Ulmus americana	0.53	0.50
Tupulo, water	Nyssa aquatica	0.51	0.49
Yellow Poplar	Liriodendron tulipifera	0.45	0.43
	minimum	0.45	0.43
Group D			
Aspen, Bigtooth	Populus grandidentata	0.40	0.38
Aspen, Quaking	Populus tremuloides	0.39	0.37
Cottonwood, Eastern	Populus deltoides	0.41	0.39
Mixed Maple:			
Black	Acer nigrun	0.60	0.57
Red	Acer rubrum	0.58	0.54
Silver	Acer saccharinum	0.50	0.47
Sugar	Acer saccharum	0.67	0.63
	minimum	0.39	0.37

[a] For bolts, lag screws, nails and spikes, use the average specific gravity ovendry listed in this table with the tables in the AITC *Timber Construction Manual* or the *National Design Specification® for Wood Construction*. When the species is designated by Group only, use the minimum value listed under the appropriate group. The average specific gravity at 12% MC can be used to determine the unit weight of the species to calculate approximate beam weights.

Table 4A Design – Timber Connector Groups for Shear Plates and Split Rings Used on the Faces of Hardwood Glued Laminated Timbers for Table 1 Combinations [a, b]

Combination Symbol	Depth of Member	Tension Face		Side Face		Compression Face	
		Species or Species Group	Timber Conn. Group	Species or Species Group	Timber Conn. Group	Species or Species Group	Timber Conn. Group
12F-V1	4 or more Lams	D	D	D	D	D	D
12F-V2	4 or more Lams	D	D	D	D	D	D
14F-V1	4 or more Lams	C	C	C	C	C	C
14F-V2	4 or more Lams	B	B	B	B	B	B
14F-V3	4 or more Lams	C	C	C	C	C	C
14F-V4	4 or more Lams	B	B	B	B	B	B
16F-V1	4 or more Lams	B	B	B	B	B	B
16F-V2	4 or more Lams	A	A	A	A	A	A
16F-V3	4 or more Lams	B	B	B	B	B	B
16F-V4	4 or more Lams	A	A	A	A	A	A
20F-V1	4 or more Lams	A	A	A	A	A	A
20F-V2	4 or more Lams	A	A	A	A	A	A
16F-E1	4 or more Lams	D	D	D	D	D	D
16F-E2	4 or more Lams	D	D	D	D	D	D
20F-E1	4 or more Lams	C	C	C	C	C	C
20F-E2	4 or more Lams	C	C	C	C	C	C
24F-E1	4 or more Lams	B	B	B	B	B	B
24F-E2	4 or more Lams	B	B	B	B	B	B
24F-E3	4 or more Lams	YP	C	YP	C	YP	C
24F-E4	4 or more Lams	RM	B	RM	B	RM	B
24F-E5	4 or more Lams	RO	A	RO	A	RO	A

Table 4B Design – Timber Connector Groups for Shear Plates and Split Rings Used on the Faces of Hardwood Glued Laminated Timbers for Table 2 Combinations [a, b]

Species or Species Groups	Timber Connector Group Any Face
A	A
B	B
C	C
D	D

FOOTNOTES FOR TABLES 4A and 4B

a The Timber Connector group used for design of shear plates and split rings is the same species grouping listed for the combination **except that Rock Elm and Mixed Oaks are in Timber Connector grouping A and Sweet Gum is in Group C.**

b See Table 3 for the specific species listed in each hardwood species group.

Table 5 - Grade Requirements for Members Stressed Principally in Bending and Loaded Perpendicular to the Wide Faces of Laminations Visually Graded Hardwood Species [1,2,5]

Combination Symbol	Depth of Member	Tension Lamination[3]	Minimum Grade of Lamination [4, 6, 7]										
			Percent/Grade/Species or Species Group Each Zone					Percent/Slope of Grain of Each Zone [8]					
			Outer Tension Zone	Inner Tension Zone	Core [9] Zone	Inner Compression Zone	Outer Compression Zone	Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone
1	2	3	4	5	6	7	8	9	10	11	12	13
Visually Graded												
The following combination is **NOT BALANCED** and is intended for simple span members.												
12F-V1[10]	4 lams to >12 in.	302-20	25% SS/D	--	N2/D	--	25% N1/D	1:15				1:10
	12 in. to 15 in.	302-22	25% SS/D	--	N2/D	--	25% N1/D	1:15				1:10
	>15 in.	302-24	25% SS/D	--	N2/D	--	25% N1/D	1:15				1:10
The following combination is **BALANCED** and is intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending (Footnote 3 applies both top and bottom for bending members).												
12F-V2[10]	4 lams to 15 in.	302-20	25% SS/D	--	N2/D	--	25% SS/D	1:14		1:6		1:14
	> 15 in.	302-22	25% SS/D	--	N2/D	--	25% SS/D	1:14		1:6		1:14
The following 2 combinations are **NOT BALANCED** and are intended for simple span members.												
14F-V1	4 lams to <12 in.	302-20	25% SS/C	--	N2/C	--	25% N1/C					
	12 in. to 15 in.	302-22	25% SS/C	--	N2/C	--	25% N1/C					
	>15 in.	302-24	25% SS/C	--	N2/C	--	25%N1/C					
14F-V2	4 lams and greater	302-20	10% SS/B	--	N2/B	--	10% N2/B					
The following 2 combinations are **BALANCED** and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending. (Footnote 3 applies both top and bottom for bending members.)												
14F-V3	4 lams to 15 in.	302-20	25% SS/C	--	N2/C	--	25% SS/C	1:15		1:6		1:15
	> 15 in.	302-24	25% SS/C	--	N2/C	--	25% SS/C	1:15		1:6		1:15
14F-V4	4 lams and greater	302-20	10% SS/B	--	N2/B	--	10% SS/B	1:12		1:8		1:12

Table 5 (cont.) - Grade Requirements for Members Stressed Principally in Bending and Loaded Perpendicular to the Wide Faces of Laminations Visually Graded Hardwood Species and E-Rated Hardwood Species [1,2,5]

Combination Symbol	Depth of Member	Tension Lamination [3]	Minimum Grade of Lamination [4, 6, 7]									
			Percent/Grade/Species or Species Group Each Zone					Percent/Slope of Grain Each Zone [8]				
			Outer Tension Zone	Inner Tension Zone	Core [9] Zone	Inner Compression Zone	Outer Compression Zone	Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone
1	2	3	4	5	6	7	8	9	10	11	12	13
Visually Graded (cont.)												
The following 2 combinations are **NOT BALANCED** and are intended for simple span members.												
16F-V1	>4 lams to 15 in.	302-20	25% SS/B	--	N2/B	--	25% N1/B	1:14	--	1:4	--	1:10
	>15 in.	302-22	25% SS/B	--	N2/B	--	25% N1/B	1:14	--	1:4	--	1:10
16F-V2	4 lams and greater	302-20	5% N1/A	--	N2/A	--	N2/A	1:12	--	1:6	--	1:8
The following 2 combinations are **BALANCED** and are intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending (Footnote 3 applies both top and bottom for bending members).												
16F-V3	4 lams to 15 in.	302-20	25% SS/B	--	N2/B	--	25% SS/B	1:14	--	1:6	--	1:14
	>15 in.	302-22	25% SS/B	--	N2/B	--	25% SS/B	1:14	--	1:6	--	1:14
16F-V4	4 lams and greater	302-20	5% SS/A	--	N2/A	--	5% SS/A	1:12	--	1:8	--	1:12
The following combination is **NOT BALANCED** and is intended for simple span members.												
20F-V1[11]	4 lams to <12 in.	302-20	25% SS/A	--	N2/A	--	25% N1/A	1:15	--	1:4	--	1:12
	12 in. to 15 in.	302-22	25% SS/A	--	N2/A	--	25% N1/A	1:15	--	1:4	--	1:12
	>15 in.	302-24	25% SS/A	--	N2/A	--	25% N1/A	1:15	--	1:4	--	1:12
The following combination is **BALANCED** and is intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending. (Footnote 3 applies both top and bottom for bending members).												
20F-V2[11]	4 lams to <12 in.	302-20	25% SS/A	--	N2/A	--	25% SS/A	1:15	--	1:6	--	1:15
	12 in. to 15 in.	302-22	25% SS/A	--	N2/A	--	25% SS/A	1:15	--	1:6	--	1:15
	>15 in.	302-24	25% SS/A	--	N2/A	--	25% SS/A	1:15	--	1:6	--	1:15

Table 5 (cont.) - Grade Requirements for Members Stressed Principally in Bending and Loaded Perpendicular to the Wide Faces of Laminations Visually Graded Hardwood Species and E-Rated Hardwood Species [1,2,5]

Combination Symbol	Depth of Member	Tension Lamination [3]	Minimum Grade of Lamination [4, 6, 7]									
			Percent/Grade/Species or Species Group Each Zone					Fraction Edge Knot Each Zone				
			Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone	Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone
1	2	3	4	5	6	7	8	9	10	11	12	13
E-Rated												
The following combination is **NOT BALANCED** and is intended for simple span members.												
16F-E1[12]	>4 lams to 15 in.	302-20	15% 1.5 E6/D	15% 1.5E3/D	N2/D	--	25% 1.5 E3/D	1/6	1/3	--	--	1/3
	>15 in.	302-22	15% 1.5 E6/D	15% 1.5E3/D	N2/D	--	25% 1.5 E3/D	1/6	1/3	--	--	1/3
The following combination is **BALANCED** and is intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending (Footnote 3 applies both top and bottom for bending members).												
16F-E2[12]	>4 lams to 15 in.	302-20	15% 1.5 E6/D	15% 1.5E3/D	N2/D	15% 1.5 E3/D	15% 1.5 E6/D	1/6	1/3	--	1/3	1/6
	>15 in.	302-22	15% 1.5 E6/D	15% 1.5 E3/D	N2/D	15% 1.5 E3/D	15% 1.5 E6/D	1/6	1/3	--	1/3	1/6
The following combination is **NOT BALANCED** and is intended for simple span members.												
20F-E1	>4 lams to 12 in.	302-20	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	15% 1.8 E3/C	1/6	1/3	--	1/3	1/3
	>12 in. to 15 in.	302-22	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	15% 1.8 E3/C	1/6	1/3	--	1/3	1/3
	>15 in.	302-24	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	15% 1.8 E3/C	1/6	1/3	--	1/3	1/3
The following combination is **BALANCED** and is intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending (Footnote 3 applies both top and bottom for bending members).												
20F-E2	>4 lams to 12 in.	302-20	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	20% 1.8 E6/C	1/6	1/3		1/3	1/6
	>12 in. to 16-1/2 in.	302-22	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	20% 1.8 E6/C	1/6	1/3		1/3	1/6
	>16-1/2 in.	302-24	20% 1.8 E6/C	10% 1.5 E3/C	N2/C	10% 1.5 E3/C	20% 1.8 E6/C	1/6	1/3		1/3	1/6

Table 5 (cont.) - Grade Requirements for Members Stressed Principally in Bending and Loaded Perpendicular to the Wide Faces of Laminations Visually Graded Hardwood Species and E-rated Hardwood Species[1,2,5]

Combination Symbol	Depth of Member	Tension Lamination [3]	Minimum Grade of Lamination [4, 6, 7]									
			Percent/Grade/Species or Species Group Each Zone [8]					Fraction/Edge Knot Each Zone[9]				
			Outer Tension Zone	Inner Tension Zone	Core [9] Zone	Inner Compression Zone	Outer Compression Zone	Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone
1	2	3	4	5	6	7	8	9	10	11	12	13
The following combination is **NOT BALANCED** and is intended for simple span members.												
24F-E1	4 lams to <12 in.	302-20	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E3/B	1/6	1/3	--	1/3	1/3
	12 in. to 15 in.	302-22	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E3/B	1/6	1/3	--	1/3	1/3
	>15 in. to 25-1/2 in.	302-24	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E3/B	1/6	1/3	--	1/3	1/3
	>25-1/2 in.	302-26	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E3/B	1/6	1/3	--	1/3	1/3
The following combination is **BALANCED** and is intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending (Footnote 3 applies both top and bottom for bending members).												
24F-E2	4 lams to <12 in.	302-20	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E6/B	1/6	1/3	--	1/3	1/6
	12 in. to 15 in.	302-22	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E6/B	1/6	1/3	--	1/3	1/6
	>15 in. to 21 in.	302-24	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E6/B	1/6	1/3	--	1/3	1/6
	>21 in.	302-26	10% 2.0 E6/B	15% 1.8 E3/B	N2/B	15% 1.8 E3/B	10% 2.0 E6/B	1/6	1/3	--	1/3	1/6
The following combination is NOT BALANCED and is intended for simple span members.												
24F-E3	4 lams to <12 in.	302-20	10% 2.0 E6/YP	15% 1.8 E3/YP	N2/YP	15% 1.8 E3/YP	10% 2.0 E3/YP	1/6	1/3	--	1/3	1/3
YELLOW	12 in. to 15 in.	302-22	10% 2.0 E6/YP	15% 1.8 E3/YP	N2/YP	15% 1.8 E3/YP	10% 2.0 E3/YP	1/6	1/3	--	1/3	1/3
POPLAR	>15 in. to 22 1/2 in.	302-24	10% 2.0 E6/YP	15% 1.8 E3/YP	N2/YP	15% 1.8 E3/YP	10% 2.0 E3/YP	1/6	1/3	--	1/3	1/3
	>22 1/2 in.	302-26	10% 2.0 E6/YP	15% 1.8 E3/YP	N2/YP	15% 1.8 E3/YP	10% 2.0 E3/YP	1/6	1/3	--	1/3	1/3

Table 5 (cont.) - Grade Requirements for Members Stressed Principally in Bending and Loaded Perpendicular to the Wide Faces of Laminations Visually Graded Hardwood Species and E-rated Hardwood Species[1,2,5]

Combination Symbol	Depth of Member	Tension Lamination [3]	Minimum Grade of Lamination [4, 6, 7]									
			Percent/Grade/Species or Species Group Each Zone [8]					Fraction/Edge Knot Each Zone[9]				
			Outer Tension Zone	Inner Tension Zone	Core [9] Zone	Inner Compression Zone	Outer Compression Zone	Outer Tension Zone	Inner Tension Zone	Core Zone	Inner Compression Zone	Outer Compression Zone
1	2	3	4	5	6	7	8	9	10	11	12	13
The following combination is **NOT BALANCED** and is intended for simple span members.												
24F-E4 RED MAPLE	4 lams to <12 in.	302-20	10% 2.0 E6/RM	15% 1.8 E3/RM	N2/RM	15% 1.8 E3/RM	10% 2.0 E3/RM	1/6	1/3	--	1/3	1/3
	12 in. to 15 in.	302-22	10% 2.0 E6/RM	15% 1.8 E3/RM	N2/RM	15% 1.8 E3/RM	10% 2.0 E3/RM	1/6	1/3	--	1/3	1/3
	>15 in.	302-24	10% 2.0 E6/RM	15% 1.8 E3/RM	N2/RM	15% 1.8 E3/RM	10% 2.0 E3/RM	1/6	1/3	--	1/3	1/3
The following combination is **NOT BALANCED** and is intended for simple span members.												
24F-E5 RED OAK	4 lams to <12 in.	302-20	10% 2.0 E6/RO	15% 1.8 E3/RO	N2/RO	15% 1.8 E3/RO	10% 2.0 E3/RO	1/6	1/3	--	1/3	1/3
	12 in. to 15 in.	302-22	10% 2.0 E6/RO	15% 1.8 E3/RO	N2/RO	15% 1.8 E3/RO	10% 2.0 E3/RO	1/6	1/3	--	1/3	1/3
	>15 in.	302-24	10% 2.0 E6/RO	15% 1.8 E3/RO	N2/RO	15% 1.8 E3/RO	10% 2.0 E3/RO	1/6	1/3	--	1/3	1/3

FOOTNOTES FOR TABLE 5

[1] The combinations in this table are primarily applicable to members stressed in bending due to a load applied perpendicular to the wide faces of the laminations.

[2] The combinations are applicable to arches, compression members, tension members and bending members. For bending members, footnote 3 applies. All combinations are applicable to members with four or more laminations. The tension lamination requirements in footnote 3 do not apply to arches, compression members or tension members.

[3] In addition to the grade requirements tabulated for the outer tension zone, the grading restrictions as contained in AITC 302-20, 302-22, 302-24 and 302-26 tension lamination requirements are applicable to the outer 5 percent of the total depth of bending members. These special tension lamination requirements are shown in Column 3.

The 302 tension laminations required for some bending members may be omitted provided the design value in bending about the X-X axis, F_{bx}, in Column 3 of Table 1 is multiplied by 0.75 for members greater than 15 inches in depth, or by 0.85 for members up to 15 inches in depth. This reduction does not apply to arches which do not require special tension laminations.

[4] Percent values are based on the total depth of the member. All fractional numbers of laminations must be rounded upward to the next whole number. For the inner tension and compression zones, the resulting excess of percentage resulting from rounding upward of the outer zone may be subtracted from the inner zone requirements.

When lamination thickness exceeds 1-1/2 in., divide the depth of the member by the actual thickness of the laminations used and multiply by 1-1/2 in. Use this depth to obtain the percentage of grades required for the various zones. For instance, if a member 17-1/2 in. deep is laminated with 1-3/4 in. thick laminations, divide 17-1/2 in. by 1-3/4 in. and multiply by 1-1/2 in., which equals 15 in. Enter the table with a depth of 15 in. to determine percentage of grades to use. The actual depth of the member shall be used to determine the special tension lamination requirements from Column 3.

Where lamination thicknesses vary by more than 3/16 in. in the same member, the total thickness of each grade of lumber required in the tension and compression zones is determined by using the thickest lamination in the member as the basic lamination thickness. For instance, if the thickest lamination used is 1-3/8 in. and 1.6 in. of N1 grade is required in a zone (based on multiplying the percentage required for that zone in the table by the depth of the member in inches), then a total thickness of at least 2-3/4 in. of N1 grade is required in that zone. In no case shall the special tension lamination requirements in footnote 3 be less than 5 percent of the total depth of the member in inches.

[5] The combinations in Table 5 have been established based on procedures given in ASTM D 3737 as modified by subsequent research. Other combinations of grades and species may be used provided their design values have been established following the procedure used to establish the Table 5 combinations. Combinations other than those shown in Table 5 must be approved using AITC 500.

[6] Where specified to have an extreme fiber in bending stress on the compression side, which results in tension on the compression (top) side greater than the value given in Column 4 of Table 1 (except for balanced combinations but not exceeding 200 psi

higher than the value in Column 4), tension zone end joint spacing restrictions shall be applied to both the tension and compression zones.

[7] Grade designations are as follows:

Visually Graded - Hardwoods

SS is select structural joists and planks or structural light framing grade.

N1 is No. 1 structural joists and planks or structural light framing grade.

N2 is No. 2 structural joists and planks or structural light framing grade.

N3 is No. 3 structural joists and planks or structural light framing grade.

Boards shall be graded as "dimension" lumber.

E-Rated Grades

2.0 E6 has 2.0 E with 1/6 edge characteristic.
1.8 E6 has 1.8 E with 1/6 edge characteristic.
1.5 E6 has 1.5 E with 1/6 edge characteristic.
2.0 E3 has 2.0 E with 1/3 edge characteristic.
1.8 E3 has 1.8 E with 1/3 edge characteristic.
1.5 E3 has 1.8 E with 1/3 edge characteristic.

[8] Where slope of grain is not tabulated, it shall be the slope of grain required for the grade. Slope of grain is not specified for E-rated lumber except for tension laminations, but slope of grain in areas of the piece not mechanically E-rated must be in accordance with Annex C.

[9] No. 3 lumber may be used for up to 40% of the inner core laminations of E-rated combinations if the volume of the next inner zone is increased by 5%. For example, the 2400 F_b -1.8 E combination could have 40% No. 3 material in the core if both the inner tension and inner compression zones are increased to 20% 1.8 E-1/3 material. A similar substitution may be made for visually graded combinations.

[10] For quaking aspen, the long span E of the lumber must average 1.3 million psi for Select Structural and 1.2 million psi for No. 2.

[11] For white oak, the long span E of the lumber must average 1.7 million psi for Select Structural and 1.6 million psi for No. 2. Species from Group B may also be used in this combination if the long span E requirements shown herein are met.

[12] A visual grade of lumber with long span E of 1.5 million psi or a *National Design Specification® for Wood Construction* listed E value of 1.4 million psi is acceptable.

TABLE 6 Manufacturing Requirements for Members with Two or More Laminations of the same Grade and Species (Table 2) Stressed in Bending Perpendicular to the Wide Faces of the Laminations[1, 2, 3, 7]

Combination Number	Minimum [5] Grade of Laminations	Species Group	Tension Laminations Required [6] 4 lams to < 12 in. deep	12 in. to 15 in. deep	> 15 in. deep	Slope of Grain [4]
Visually Graded - Hardwood Species						
H1	N3	A	302-20	302-20	302-20	1:8
H2	N2	A	302-20	302-20	302-20	1:10
H3	N1	A	302-20	302-22	302-22	1:10
H4	SS	A	302-20	302-20	302-24	1:15
H5	N3	B	302-20	302-20	302-20	1:10
H6	N2	B	302-20	302-20	302-20	1:10
H7	N1	B	302-20	302-20	302-22	1:14
H8	SS	B	302-20	302-20	302-22	1:14
H9	N3	C	302-20	302-20	302-20	1:12
H10	N2	C	302-20	302-20	302-20	1:12
H11	N1	C	302-20	302-20	302-22	1:14
H12	SS	C	302-20	302-20	302-22	1:14
H13	N3	D	302-20	302-20	302-22	1:14
H14	N2	D	302-20	302-20	302-22	1:14
H15	N1	D	302-20	302-20	302-22	1:14
H16	SS	D	302-20	302-20	302-22	1:14
E-Rated - Hardwood Species						
H17	1.5E3	A	302-20	302-20	302-20	1:10
H18	1.8E3	A	302-20	302-20	302-20	1:10
H19	1.8E6	A	302-20	302-20	302-22	1:14
H20	2.0E3	A	302-20	302-20	302-20	1:12
H21	2.0E6	A	302-22	302-24	302-26	1:18
H22	1.5E3	B	302-20	302-20	302-20	1:10
H23	1.8E3	B	302-20	302-20	302-22	1:14
H24	1.8E6	B	302-20	302-20	302-22	1:14
H25	2.0E3	B	302-20	302-22	302-22	1:14
H26	2.0E6	B	302-22	302-24	302-26	1:18
H27	1.5E3	C	302-20	302-20	302-20	1:10
H28	1.8E3	C	302-20	302-20	302-20	1:14
H29	1.8E6	C	302-20	302-20	302-22	1:14
H30	2.0E3	C	302-20	302-22	302-22	1:14
H31	2.0E6	C	302-22	302-24	302-26	1:18
H32	1.5E3	D	302-20	302-20	302-20	1:10
H33	1.5E6	D	302-20	302-20	302-20	1:12
H34	1.8E3	D	302-20	302-20	302-22	1:14
H35	1.8E6	D	302-20	302-20	302-22	1:14
H36	2.0E3	D	302-20	302-22	302-22	1:14
H37	2.0E6	D	302-22	302-24	302-26	1:18

FOOTNOTES FOR TABLE 6

[1] Tension laminations required by this table are to be used only when the design values for bending about the X-X axis, F_{bx}, exceed those listed in Column 16 of Table 2 but are not greater than those listed in Column 17. These tension laminations may be omitted for bending members over 15 in. deep provided the design value in Column 17 is multiplied by 0.75. This reduction does not apply to arches.

[2] Tabulated combinations in this table are primarily intended for members loaded axially or in bending with the loads acting parallel to the wide faces of the laminations. The combinations may also be used as bending members loaded perpendicular to the wide faces of the laminations; however, combinations in Table 1 for four or more laminations are usually better suited for this condition of loading.

[3] It is not intended that these combinations be used for deep bending members which are loaded perpendicular to the wide faces of the laminations. If higher design values in bending about the X-X axis are specified for these combinations than those contained in Column 16 of Table 2, see Footnote 1.

[4] Slope of grain is not specified for E-rated lumber, except for special tension laminations, but slope in areas of the piece not mechanically E-rated must be accordance with Annex C.

[5] Grade designations are as shown in footnote 7 of Table 5.

[6] The outer 5 percent of laminations on the tension side of bending members must be replaced with the special tension lamination shown in this table. Percent values are based on the total depth of members. Laminations of different thicknesses may be used in the same member provided that the total thickness of tension lamination(s) equals or exceeds 5 percent of the depth.

[7] Not all possible combinations are shown in these tables. Other combinations may be available. Consult the manufacturer.

ANNEX A

GRADING REQUIREMENTS EXCERPTED FROM AITC 302-20, 302-22, 302-24, 302-26 TENSION LAMINATION RECOMMENDATIONS

CONTENTS

A1. AITC 302-20 TENSION LAMINATION - MEMBERS IN BENDING

A1.1 General Provisions. In addition to the basic requirements of the grades tabulated in these specifications, the following limitations shall apply:

A1.1.1 A one-foot length of a lamination shall be considered as a cross section.

A1.1.2 Knots shall not occur within two knot diameters of any finger joint.

A1.1.3 Knots shall not occupy more than ¼ of the cross section.

A1.1.4 The general slope of grain shall not exceed 1:12. Where more restrictive slope of grain requirements are required by the laminating combinations, these shall apply.

A1.1.5 Any cross section shall have at least 50% clear wood free of strength reducing characteristics with a slope of grain no steeper than 1:12. (Knots plus associated localized cross grain, or knots plus associated localized cross grain plus localized cross grain not associated with a knot, or localized cross grain not associated with a knot may occupy up to ½ of the cross section.)

A1.2 Visually Graded Combinations

A1.2.1 In addition to the general provisions in A1.1, the following applies to visually graded combinations.

A1.2.2 Growth rate requirements (including “dense” if required) shall apply to the full length of the piece. Pieces shall have near average or above average specific gravity for the species.

A1.2.3 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A1.3 E-Rated Combinations

A1.3.1 Laminations must be visually graded and E-rated in accordance with all of the requirements for the E-rated grade shown for the outer tension lamination. In addition to these, the general grading provisions in A1.1 apply.

A1.3.2 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A2. AITC 302-22 TENSION LAMINATION - MEMBERS IN BENDING

A2.1 GENERAL PROVISIONS. In addition to the basic requirements of the grades tabulated in these specifications, the following limitations shall apply:

A2.1.1 A one-foot length of a lamination shall be considered as a cross section.

A2.1.2 Knots shall not occur within two knot diameters of any finger joint.

A2.1.3 Knots shall not occupy more than ¼ of the cross section.

A2.1.4 Any cross section shall have at least 60% clear wood free of strength reducing characteristics with a slope of grain no steeper than 1:16. (Knots plus associated localized cross grain, or knots plus associated localized cross grain plus localized cross grain not associated with a knot, or localized cross grain not associated with a knot may occupy up to 40% of the cross section).

A2.1.5 The general slope of grain shall not exceed 1:16. Where more restrictive slope of grain requirements are required by the laminating combinations, these shall apply.

A2.2 Visually Graded Combinations

A2.2.1 In addition to the general provisions in A2.1, the following applies to visually graded combinations.

A2.2.2 Growth rate requirements (including “dense” if required) shall apply to the full length of the piece. Pieces shall have near average or above average specific gravity for the species.

A2.2.3 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A2.3 E-Rated Combinations

A2.3.1 Laminations must be visually graded and E-rated in accordance with all of the requirements for the E-rated grade shown for the outer tension lamination. In addition to these, the general grading provisions in A2.1 apply.

A2.3.2 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A3. AITC 302-24 TENSION LAMINATION - MEMBERS IN BENDING

A3.1 General Provisions. In addition to the basic requirements of the grades tabulated in these specifications, the following limitations shall apply:

A3.1.1 A one-foot length of a lamination shall be considered as a cross section.

A3.1.2 Knots shall not occupy more than 1/5 of the cross section.

A3.1.3 Any cross section shall have at least 2/3 clear wood free of strength reducing characteristics with a slope of grain no steeper than 1:16. (Knots plus associated localized cross grain, or knots plus associated localized cross grain plus localized cross grain not associated with a knot, or localized cross grain not associated with a knot may occupy up to 1/3 of the cross section).

A3.1.4 Maximum size single strength-reducing characteristics when not in the same horizontal projection must be at least 2 ft. apart measured center to center.

A3.1.5 The general slope of grain shall not exceed 1:16. Where more restrictive slope of grain requirements are required by the laminating combinations, these shall apply.

A3.2 Visually Graded Combinations

A3.2.1 In addition to the general provisions in A3.1, the following applies to visually graded combinations.

A3.2.2 Growth rate requirements (including “dense” if required) shall apply to the full length of the piece. Pieces shall have near average or above average specific gravity for the species.

A3.2.3 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which

measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A3.3 E-Rated Combinations

A3.3.1 Laminations must be visually graded and E-rated in accordance with all of the requirements for the E-rated grade shown for the outer tension lamination. In addition to these, the general grading provisions in A3.1 apply.

A3.3.2 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A3.A. AITC 302-26 TENSION LAMINATION - MEMBERS IN BENDING

A3.A.1 General Provisions. In addition to the basic requirements of the grades tabulated in these specifications, the following limitations shall apply:

A3.A.1.1 Any cross section containing an edge knot must have 80% clear and straight-grained wood with a slope of grain not steeper than 1:16. (An edge knot is a knot that has any portion of itself or its associated localized cross grain at or within 1/2 in. of the edge of the piece. This 1/2 in. is determined based on the average of the measurements on the two wide faces.)

A3.A.2 Visually Graded Combinations

A3.A.2.1 In addition to the general provisions in A3.A.1, the following applies to visually graded combinations.

A3.A.2.2 Growth rate requirements (including “dense” if required) shall apply to the full length of the piece. Pieces shall have near average or above average specific gravity for the species.

A3.A.2.3 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

A3.A.3 E-Rated Combinations

A3.A.3.1 Laminations must be visually graded and E-rated in accordance with all of the requirements for the E-rated grade shown for the outer tension lamination. In addition to these, the general grading provisions in A3.A.1 apply.

A3.A.3.2 Pieces containing wide-ringed or lightweight pith associated wood at the ends of the piece occupying over 1/8 of the cross section shall be excluded. (The next inch of wood outside the area of the pith associated wood shall be of the same rate of growth as the remainder of the wood located away from the pith. The line along which measurement of this inch is made shall correspond to the line used in the standard grading rules for rate of growth and percentage of summerwood. If a distance of 1 in. is not available along this line, the measurement will be made over such lesser portion as exists.)

ANNEX B
DESIGN VALUES FOR END GRAIN IN BEARING PARALLEL TO GRAIN, F_g

B-1 The following table lists the design Values for end grain in bearing parallel to grain, F_g.

B-1.1 These design values apply to the net area in bearing and are subject to adjustments for duration of load.

B-1.2 When the stress in end grain bearing exceeds 75% of the adjusted design value, bearing should be on a metal plate, strap or other durable, rigid, homogenous material of adequate strength.

B-1.3 These values are based on dry conditions of use. Multiply the tabulated values by 0.57 to obtain wet conditions of use design values.

B-1.4 The design values for end grain in bearing apply to end-to-end bearing of compression members provided there is a adequate lateral support and the end cuts are accurately squared and parallel. When a rigid insert is required by B-1.2, it shall be of not less than 20 gauge metal, or equivalent, inserted with a snug fit between abutting ends.

B-1.5 When the load in bearing is at an angle to grain, the maximum bearing value shall be determined by the Hankinson formula using the design value for end grain in bearing parallel to grain from this Annex, and the design value in compression perpendicular to grain as provided in Tables 1 or 2.

B-1.6 The design values in the column *Bearing on Full Cross Section* are the average design values of the laminations in the combination. The design values in the column *Bearing on Partial Cross Section* are the design values for the core laminations. These design values should be used for tapered members or members with end bearing on only part of the cross section.

Table B-1 Design Values for End Grain in Bearing Parallel to Grain, F_g

Design values are for normal load duration, dry conditions of use, and Table 1 Combinations[a,b]

Combination Symbol	Bearing on Full Cross Section psi	Bearing on Partial Cross Section psi	Combination Symbol	Bearing on Full Cross Section psi	Bearing on Partial Cross Section psi
Visually Graded					
12F-V1	1250	1250	16F-V1	1800	1800
12F-V2	1800	1800	16F-V2	2000	2000
14F-V1	1350	1350	16F-V3	1800	1800
14F-V2	1800	1800	16F-V4	2000	2000
14F-V3	1350	1350	20F-V1	2000	2000
14F-V4	1800	1800	20F-V2	2000	2000
E-rated					
16F-E1	1500	1250	24F-E1	2100	1800
16F-E2	1550	1250	24F-E2	2100	1800
20F-E1	1750	1350	24F-E3	2000	1550
20F-E2	1800	1350	24F-E4	2100	1900
			24F-E5	2200	2000

[a] For loads of other duration, see 4.4.1.3.
[b] For wet service conditions, multiply tabulated values by 0.57.

Table B-2 Design Values for End Grain in Bearing Parallel to Grain, F_g

Design values are for normal load duration, dry conditions of use, and Table 2 Combinations[a,b]

Combination Symbol	Bearing on Full Cross Section psi	Bearing on Partial Cross Section psi	Combination Symbol	Bearing on Full Cross Section psi	Bearing on Partial Cross Section psi
Visually Graded					
H1	2000	2000	H9	1350	1350
H2	2000	2000	H10	1350	1350
H3	2000	2000	H11	1350	1350
H4	2000	2000	H12	1350	1350
H5	1800	1800	H13	1250	1250
H6	1800	1800	H14	1250	1250
H7	1800	1800	H15	1250	1250
H8	1800	1800	H16	1250	1250
E-rated					
H17	1700	1700	H28	2200	2200
H18	2200	2200	H29	2200	2200
H19	2200	2200	H30	2600	2600
H20	2600	2600	H31	2600	2600
H21	2600	2600	H32	1700	1700
H22	1700	1700	H33	1700	1700
H23	2200	2200	H34	2200	2200
H24	2200	2200	H35	2200	2200
H25	2600	2600	H36	2600	2600
H26	2600	2600	H37	2600	2600
H27	1700	1700			

[a] For loads of other duration, see 4.4.1.3.
[b] For wet service conditions, multiply tabulated values by 0.57.

ANNEX C
E-RATED LUMBER

Contents

Section

C1. GENERAL DESCRIPTION

E-rated laminating lumber is lumber that has been selected by nondestructive measurement and by visual inspection for compliance with the grade stiffness and manufacturing requirements of section 2.1.1 of AITC 117-93, Manufacturing. An E-rated laminating lumber grade includes pieces with edge characteristics (knots, knot holes, burls, distorted grain) of the maximum size allowed for use with the grade in any laminated timber layup combination. E-rated laminating has additional visual restrictions for portions of the lumber not evaluated for stiffness.

C2. LONG-SPAN E

Long-span E as defined herein shall be used as the standard nomenclature for specifying E values of E-rated laminating lumber.

C2.1 Definition
Long-span E is defined as the E calculated from deflection measured in a flat-wise test of lumber with center point loading and a span-depth ratio (l/d) of approximately 100.

C2.2 Measurement
Long-span E shall be measured by the procedures of AITC Test T116.

C2.3 Lumber Production
E-rated laminating lumber may be produced with a system that measures E by means other than direct long-span E measurement. Production equipment used to measure E shall be calibrated to produce E-rated laminating lumber grades meeting the long-span E requirements of those grades. For purposes of calibration long-span E shall be measured by the procedures of AITC Test T116.

C3. E-RATED LAMINATING LUMBER SPECIFICATIONS

C3.1 Grade Names
E-rated laminating lumber grades shall be designated by the grade mean E, the mean long-span E requirement of the grade, the word "LAM", and the denominator of allowable edge knot fraction. For example, a grade with a mean long-span E requirement of 1,900,000 psi and an allowable 1/3 Edge Knot will be named "1.9E LAM-3". (For reasons of spacing on a grade stamp, this may be shortened to 1.9E-3 on a stamp.)

C3.2 E Specifications for E-rated Lumber for Qualification

C3.2.1 Mean Long-Span E

If the sample size is less than 40, the mean long-span E of the lumber shall equal or exceed the specified grade mean E. Alternatively, if the sample size equals or exceeds 40, the mean long-span E of the sample, E_t, shall meet the following criteria:

$$E_t \geq E_s - 1.303\, S_t / \sqrt{n_t}$$

where: S_t = the estimated population standard deviation

$S_t = (E_t - E_{st}) / 1.684$

n_t = sample size (≥ 40)
E_t = mean long-span E of the sample
E_s = grade long-span E
E_{st} = 5th percentile long-span E calculated from the test data

C3.2.2 E Distribution

The distribution of E values within an E-rated lumber grade shall be such that the 5th percentile value shall be equal to or greater than the grade 5th percentile values as shown in the table below.

LONG-SPAN E SPECIFICATIONS

GRADE	MEAN E	5TH PERCENTILE
2.6E LAM	2.6	2.26
2.5E LAM	2.5	2.16
2.4E LAM	2.4	2.06
2.3E LAM	2.3	1.96
2.2E LAM	2.2	1.86
2.1E LAM	2.1	1.77
2.0E LAM	2.0	1.67
1.9E LAM	1.9	1.58
1.8E LAM	1.8	1.48
1.7E LAM	1.7	1.39
1.6E LAM	1.6	1.30
1.5E LAM	1.5	1.21

C3.3 Visual Limitations

C3.3.1 Edge Characteristics

Characteristics such as knots, knot holes, burls, and distorted grain occurring at the edges of the wide faces shall be measured and limited to a fraction of the cross section in conformance with American Lumber Standards--approved procedures in the following categories:

Edge Characteristics	Codes for Edge Characteristic
1/6	6
1/4	4
1/3	3
1/2	2

C3.3.2 Untested Portions

Portions of the lumber not tested by the E-rating device shall conform to the following visual limitations:

Edge Knot - as limited C3.3.1.

Non-Edge Knots - equal to the largest non-edge knots in the tested portion of the piece or the next larger edge knot, whichever is greater.

Cross-Section Knots - displacement of all knots in the same cross section must not exceed the size of the permitted non-edge knot.

Slope of Grain - the general slope of grain in the untested portion shall not exceed:

Slope	Edge Characteristic
1 in 12	≤ 1/6
1 in 10	> 1/6 to ≤ 1/4
1 in 8	> 1/4

C4. PRODUCTION QUALITY CONTROL

C4.1 Supervision

Quality control of E-rated laminating lumber shall be under the supervision of a third party inspection agency.

C4.2 Quality Control

C4.2.1 Formal Quality Control Program Required

A formal quality control program shall be maintained at the production facility to provide conformance to grade specifications on a continuous basis. The quality control program shall be in accordance with the generally accepted quality control practices of the industry.

C4.2.2 E-rated Grade Edge Characteristics

The edge characteristic restrictions applied for layup need not be considered when establishing the E criteria for quality control of an E-rated laminating lumber grade or when evaluating a given lot of E-rated laminating lumber for conformance to the E specifications of the grade of the lot.

C4.2.3 Quality Control Records

Quality control records shall be maintained at the lumber production facility.

C5. REINSPECTION OR TESTING OF INDIVIDUAL LOTS FOR CONFORMANCE TO SPECIFICATIONS

C5.1 Test Method and Evaluation

The procedures of AITC Test T124 shall be used for testing and evaluating individual lots of E-rated laminating lumber for conformance to grade specification.

C5.2 Disposition of Nonconforming Lots

C5.2.1 Regrade

The lumber may be regraded by testing all of the pieces in the lot in accordance with the long-span E testing procedures of AITC Test T116 and eliminating low E pieces from the lot so that the specifications for mean and lower 5th percentile E values of the E-rated grade are met. If the lumber is regraded by commercial testing devices other than a long-span E measuring device conformance to grade specifications shall be verified by AITC Test T124.

C5.2.2 Assign a Lower Grade Level

The lumber may be used at a lower E-rated grade level for which the lot was qualified by the test results.

REFERENCES

1. American National Standard ANSI/AITC A190.1-1992, *Structural Glued Laminated Timber.* American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

2. AITC 109-84, *Standard for Preservative Treatment of Structural Glued Laminated Timber*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

3. *National Design Specification ® for Wood Construction*, 1991, American Forest & Paper Association, 1111 19th St., N.W., Eighth Floor, Washington, DC 20036.

4. AITC 104-84, *Typical Construction Details*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

5. AITC 109-90, *Standard for Preservative Treatment of Structural Glued Laminated Timber*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

6. AITC 110-84, *Standard Appearance Grades for Structural Glued Laminated Timber*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

7. AITC 111-79, *Recommended Practice for Protection of Structural Glued Laminated Timber During Transit, Storage and Erection*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

8. AITC 500-91, *Determination of Design Values for Structural Glued Laminated Timber in Accordance with ASTM D 3737-89a*, American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

9. ASTM D 3737-93c, *Standard Method for Establishing Stresses for Structural Glued Laminated Timber (Glulam),* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

10. *Timber Construction Manual,* Fourth Edition American Institute of Timber Construction, published by John Wiley & Sons, Inc.

11. AITC 117-93 -- Manufacturing, *Standard Specifications for Structural Glued Laminated Timber of Softwood Species,* American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

12. AITC 117-93 -- Design, *Standard Specifications for Structural Glued Laminated Timber of Softwood Species,* American Institute of Timber Construction, 7012 South Revere Parkway, Suite 140, Englewood, CO 80112.

13. ASTM D 245-93, *Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber,* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

14. *Standard Grading Rules For Northeastern Lumber - 1991,* Northeastern Lumber Manufacturers' Association (NELMA), 272 Tuttle Road, P.O. Box 87A, Cumberland Center, ME 04021.

15. ASTM D 2555 - 88, *Test Methods for Establishing Clear Wood Strength Values,* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

16. ASTM D 2395 - 93*, Test Methods for Specific Gravity of Wood and Wood-Base Materials,* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

17. American Softwood Lumber Standard, *Voluntary Product Standard,* PS 20-94, National Institute of Standards and Technology.

18. ASTM D 5536-94, *Standard Practice for Sampling Forest Trees for Determination of Clear Wood Properties,* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.