PROPERTIES OF LUMBER PRODUCTS

by Roland Hernandez and David W. Green

Visually Graded Structural Lumber

Stress-graded structural lumber is produced under two systems: visual grading and machine grading. Visual structural grading is the oldest stress grading system. It is based on the premise that the mechanical properties of lumber differ from those of clear wood because many growth characteristics of lumber affect its properties: these characteristics can be seen and judged by eye (ASTM D 245). The principal growth feature affecting lumber properties are the size and location of knots, sloping grain, and density.

Grading rules for lumber nominally 2 to 4 in (standard 38 to 89 mm) thick (dimension lumber) are published by grading agencies (listing and addresses are given in "National Design Specification," American Forest & Paper Association, 2005 and later). For most species, allowable properties are based on test results from full-size specimens graded by agency rules, sampled according to ASTM D 2915, and tested according to ASTM D 4761. Procedures for deriving allowable properties from these tests are given in ASTM D 1990. Allowable properties for visually graded hardwoods and a few softwoods are derived from clear-wood data following principles given in ASTM D 2555. Derivation of the allowable strength properties accounts for within-species variability by starting with a nonparametric estimate of the 5th percentile of the data. Thus, 95 of 100 pieces would be expected to be stronger than the assigned property. The allowable strength properties are based on an assumed normal duration of load of 10 yeas. Tables 6.7.6 and 6.7.7 show the grades and allowable properties for the four most commonly used species groupings sold in the United States. The allowable strength values in bending, tension, shear, and compression parallel to the grain can be multiplied by factors for other load durations. Some commonly used facton are 0.90 for permanent (50-years) loading, 1.15 for snow loads (2 months), and 1.6 for wind/earthquake loading (10 min). The most recent edition of "National Design Specification" should be consulted for updated property values and for property values for other species and size classifications.

Allowable properties are assigned to visually graded lumber at two moisture content levels: green and 19 percent maximum moisture content (assumed 15 percent average moisture content). Because of the influence of knots and other growth characteristics on lumber properties, the effect of moisture content on lumber properties is generally less than its effect on clear wood. The C_M factors of Table 6.7.8 are for adjusting the properties in Tables 6.7.6 and 6.7.7 from 15 percent moisture content to green. The Annex of ASTM D 1990 provides formulas that can be used to adjust lumber properties to any moisture content between green and 10 percent. Below about 8 percent moisture content, some properties may decrease with decreasing values. and care should be exercised in these situations (Green and Kretschmann, 1995).

Shrinkage in commercial lumber differs from that in clear wood primarily because the grain in lumber is seldom oriented in purely radial and tangential directions. Approximate formulas used to estimate shrinkage of lumber for most species are

$$S_w = 6.031 - 0.215M$$
$$S_t = 5.062 - 0.181M$$

where S_w is the shrinkage across the wide [8-in (203-mm)] face of the lumber in a 2 × 8 (standard 38 × 184 mm), S_t is the shrinkage across the narrow [2-in (51-mm)] face of the lumber, and M is moisture content (percent). As with clear wood, shrinkage is assumed to occur below a moisture content of 28 percent. Because extractives make wood less

Table 6.7.6 Base Design Values for Visually Graded Dimension Lumber*
(Tabulated design values are for normal load duration and dry service conditions)

Species and commercial grade	Size classification, in	Design values, lb/in² Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of elasticity E	Grading rules agency
Douglas-fir–Larch								
Select structural		1,500	1,000	180	625	1,700	1,900,000	WCLIB
No. 1 and better	2–4 thick	1,200	800	180	625	1,550	1,800,000	WWPA
No. 1		1,000	675	180	625	1,500	1,700,000	
No. 2	2 and wider	900	575	180	625	1,350	1,600,000	
No. 3		525	325	180	625	775	1,400,000	
Stud		700	450	180	625	850	1,400,000	
Construction	2–4 thick	1,000	650	180	625	1,650	1,500,000	
Standard		575	375	180	625	1,400	1,400,000	
Utility	2–4 wide	275	175	180	625	900	1,300,000	
Hem–Fir								
Select structural		1,400	925	150	405	1,500	1,600,000	WCLIB
No. I and better	2–4 thick	1,100	725	150	405	1,350	1,500,000	WWPA
No. I		975	625	150	405	1,350	1,500,000	
No. 2	2 and wider	850	525	150	405	1,300	1,300,000	
No. 3		500	300	150	405	725	1,200,000	
Stud		675	400	150	405	800	1,200,000	
Construction	2–4 thick	975	600	150	405	1,550	1,300,000	
Standard		550	325	150	405	1,300	1,200,000	
Utility	2–4 wide	250	150	150	405	850	1,100,000	
Spruce–Pine–Fir								
Select structural	2–4 thick	1,250	700	135	425	1,100	1,500,000	NLGA
No. 1 – No. 2		875	450	135	425	1,150	1,400,000	
No. 3	2 and wider	500	250	135	425	650	1,200,000	
Stud		675	350	135	425	725	1,200,000	
Construction	2–4 thick	1,000	500	135	425	1,400	1,300,000	
Standard		550	275	135	425	1,150	1,200,000	
Utility	2–4 wide	275	125	135	425	750	1,100,000	

*Lumber dimensions: Tabulated design values are applicable to lumber that will be used under dry conditions such as in most covered structures. For 2 - to 4-in-thick lumber, the dry dressed sizes shall be used regardless of the moisture content at the time of manufacture or use. In calculating design values, the natural gain in strength and stiffness that occurs as lumber dries has been taken into consideration as well as the reduction in size that occurs when unseasoned lmber shrinks. The gain in load-carrying capacity due to increased strength and stiffness resulting from drying more than offsets the design effect of size reductions due to shrinkage. Size factor C_F, flat-use factor C_{fu}, and wet-use factor C_M are given in Table 6.7.8.

SOURCE: Table used by permission of the American Forest & Paper Association, Washington, DC.

Table 6.7.7 Design values for Visually Graded Southern Pine Dimension Lumber*
(Tabulated design values are for normal load duration and dry services conditions)

		Design values, lb/in²						
Commercial grade	Size classification, in	Bending F_b	Tension parallel to grain F_t	shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of elasticity E	Grading rules agency
Dense select structural	2–4 thick	3,050	1,650	175	660	2,250	1,900,000	SPIB
Select structural		2,850	1,600	175	565	2,100	1,800.000	
Nondense select structural	2–4 wide	2,650	1,350	175	480	1,950	1,700,000	
No. 1 dense		2,000	1,100	175	660	2,000	1,800,000	
No. 1		1,850	1,050	175	565	1,850	1,700,000	
No. 1 nondense		1,700	900	175	480	1,700	1,600,000	
No. 2 dense		1,700	875	175	660	1,850	1,700,000	
No. 2		1,500	825	175	656	1,650	1,600,000	
No. 2 nondense		1,350	775	175	480	1,600	1,400,000	
No. 3 end stud		850	475	175	565	975	1,400,000	
Construction	2–4 thick	1,100	625	175	565	1,850	1,500,000	
Standard		625	350	175	565	1,500	1,300,000	
Utility	4 wide	300	175	175	565	975	1,300,000	
Dense select structural	2–4 thick	2,700	1,500	175	660	2,150	1,900,000	
selecctstructural		2,550	1,400	175	565	2,000	1,800,000	
Nondense select structural	5–6 wide	2,350	1,200	175	480	1,850	1,700,000	
No. 1 dense		1,750	950	175	660	1,950	1,800,000	
No. 1		1,650	900	175	565	1,750	1,700,000	
No. 1 nondense		1,500	800	175	480	1,600	1,600,000	
No. 2 dense		1,150	775	175	660	1,750	1,700,000	
No. 2		1,250	725	175	565	1,600	1,600,000	
No. 2 nondense		1,150	675	175	480	1,500	1,400,000	
No. 3 and stud		750	425	175	565	925	1,400,000	
Dense select structural	2–4 thick	2,450	1,350	175	660	2,050	1,900,000	
select structural		2,300	1,300	175	565	1,900	1,800,000	
Nondense select structural	8 wide	2,100	1,100	175	480	1,750	1,700,000	
No. 1 dense		1,650	875	175	660	1,800	1,800,000	
No. 1		1,500	825	175	565	1,650	1,700,000	
No. 1 nondense		1,350	725	175	480	1,550	1,600,000	
No. 2 dense		1,400	675	175	660	1,700	1,700,000	
No. 2		1,200	650	175	565	1,550	1,600,000	
No. 2 nondense		1,100	600	175	480	1,450	1,400,000	
No. 3 and stud		700	400	175	565	875	1,400,000	
Dense select structural	2–4 thick	2,150	1,200	175	660	2,000	1,900,000	
select structural		2,050	1,100	175	565	1,850	1,800,000	
Nondense select structural	10 wide	1,850	950	175	480	1,750	1,700,000	
No. 1 dense		1,450	775	175	660	1,750	1,800,000	
No. 1		1,300	725	175	565	1,600	1,700,000	
No. 1 nondense		1,200	650	175	480	1,500	1,600,000	
No. 2 dense		1,200	625	175	660	1,650	1,700,000	
No. 2		1,050	575	175	565	1,500	1,600,000	
No. 2 nondense		950	550	175	480	1,400	1,400,000	
No. 3 and stud		600	325	175	565	850	1,400,000	
Dense select structural	2–4 thick	2,050	1,100	175	660	1,950	1,900,000	
Select structural		1,900	1,050	175	565	1,800	1,800,000	
Nondense select structural	12 wide	1,750	900	175	480	1,700	1,700,000	
No. 1 dense		1,350	725	175	660	1,700	1,800,000	
No.1		1,250	675	175	565	1,600	1,700,000	
No. 1 nondense		1,150	600	90	480	1,500	1,600,000	
No. 2 dense		1,150	575	90	660	1,600	1,700,000	
No. 2		975	550	90	565	1,450	1,600,000	
No. 2 nondense		900	525	90	480	1,350	1,400,000	
No. 3 and stud		575	325	90	565	825	1,400,000	

*For size factor C_F appropriate size adjustment factors have already been incorporated in the tabulated design values for most thicknesses of southern pine dimension lumber. For dimension lumber 4 in thick, 8 in and wider, tabulated bending design values F_b shall be permitted to be multplied by the size factior C_F = 1.1. for dimension lumber wider than 12 in, tabulated bending, tension, and compression parallel-to-grain design values for 12-in-wide lumber shall be multiplied by the size factor C_F = 0.9. Repetitive member factor C_r, flat-use factor C_{fu}, and wet-service factor CM are giveninTable6.7.8.

SOURCE: Table used by permission of the American Forest & Paper Association, Washington, DC.

Table 6.7.8 Adjustment Factors

Size factor C_F for Table 6.7.6 (Douglas-Fir–Larch, Hem-Fir, Spruce-Pine-Fir)

Tabulated bending, tension, and compression parallel to grain design values for dimension lumber 2 to 4 in thick shall be multiplied by the following size factors:

		F_b thickness, in			
Grades	Width, in	2 & 3	4	F_t	F_c
Select structural	2, 3, and 4	1.5	1.5	1.5	1.15
No. 1 and better	5	1.4	1.4	1.1	1.1
No. 1, no. 2, no. 3	6	1.3	1.3	1.3	1.1
	8	1.2	1.3	1.2	1.05
	10	1.1	1.2	1.1	1.0
	12	1.0	1.1	1.0	1.0
	14 and wider	0.9	1.0	0.9	0.9
Stud	2, 3, and4	1.1	1.1	1.1	1.05
	Sand6	1.0	1.0	1.0	1.0
Construction and standard	2, 3, and 4	1.0	1.0	1.0	1.0
Utility	4	1.0	1.0	1.0	1.0
	2 and 3	0.4	—	0.4	0.6

Repetitive-member factor C_r for Tables 6.7.6 and 6.7.7

Bending design values F_b for dimension lumber 2 to 4 in thick shall be multiplied by the repetitive factor C_r = 1.15, when such members are used as joists, truss chords, rafters, studs, planks, decking, or similar members which are in contact or spaced not more than 24 in on centers, are not less than 3 in number, and are joined by floor, roof, or other load-distributing elements adequate to support the design load.

Flat-use factor C_{fu} for Tables 6.7.6 and 6.7.7

Bending design values adjusted by size factors are based on edgewise use (load applied to narrow face). When dimension lumber is used flatwise (load applied to wide face), the bending design value F_b shall also be multiplied by the following flat-use factors:

	Thickness, in	
Width, in	2 and 3	4
2 and 3	1.0	—
4	1.1	1.0
5	1.1	1.05
6	1.15	1.05
8	1.15	1.05
10 and wider	1.2	1.1

Wet-use factor C_M for Tables 6.7.6 and 6.7.7

When dimension lumber is used where moisture content will exceed 19 percent tor an extended period, design values shall be multiplied by the appropriate wet-service factors from the following table:

F_b	F_t	F_v	$F_{c\perp}$	F_c	E
0.85*	1.0	0.97	0.67	0.8†	0.9

*When $F_bC_F \le 1150$ lb/in², $C_M = 1.0$.
†When $F_cC_F \le 750$ lb/in², $C_M = 1.0$.
SOURCE: Used by permission of the American Forest & Paper Association, Washington, DC.

hygroscopic. less shrinkage is expected in redwood. western redcedar, and northern while cedar (Green. 1989).

The reversible effect of temperature on lumber properties appears to be similar to that on clear wood. For simplicity, “National Design Specification” uses conservative factors to account for reversible reductions in properties as a result of heating to 150°F (65°C) or less (Table 6.7.9). No increase in properties is taken for temperatures colder than normal because in practice it is difficult to ensure that the wood temperature remains consistently low. Permanent effects of temperature are not given in “National Design Specification” (see Green et al., 2003)

Table 6.7.9 Temperature Factors C_t for Short-Term Exposure (Reversible Effect)

		C_t		
Design values	In-service moisture conditions	$T \le 100°F$	$100°F < T \le 125°F$	$125°F < T \le 150°F$
F_t, E	Green or dry	1.0	0.9	0.9
F_b, F_v, F_c, and $F_{c\perp}$	≤ 19% green	1.0	0.8	0.7
		1.0	0.7	0.5

SOURCE: Table used by permission of the American Forest & Paper Association, Washington, DC.

Mechanically Graded Structural Lumber

Machine-stress-rated (MSR) lumber and machine-evaluated lumber (MEL) are two types of mechanically graded lumber. The three basic components of both mechanical grading systems are (1) sorting and prediction of strength though machine-measured nondestructive determination of properties coupled with visual assessment of growth characteristics, (2) assignment of allowable properties based upon strength prediction, and (3) quality control to ensure that assigned properties are being obtained. Grade names for MEL start with an M designation. Grade "names" for MSR lumber are a combination of the allowable bending stress and the average modulus of elasticity; e.g., 1650f-1.4E means an allowable bending stress of 1.650 lb/in^2 (11.4 MPa) and modulus of elasticity of 1.4×10^6 lb/in^2 (9.7 GPa). Selected grades of mechanically graded lumber and their allowable properties are given in Table 6.7.10. Additional grades are available (see AF&PA, 2005).

Structural Composite Lumber

Types of Structural Composite Lumber Structural composite lumber refers to several types of reconstituted products that have been developed to meet the demand for high-quality material for the manufacturer of engineered wood products and structures. Two distinct types are commercially available: laminated veneer lumber (LVL) and parallel-strand lumber (PSL).

Laminated veneer lumber is manufactured from layers of veneer With the grain of all the layers parallel. This contrasts with plywood, which consists of adjacent layers with the grain perpendicular. Most manufacturers use sheets of $^1/_{10}$- to $^1/_6$-in-(2.5- to 4.2-mm-) thick veneer. These veneers are stacked up to the required thickness and may be laid end to end to the desired length with staggered end joints in the veneer. Waterproof adhesives are generally used to bond the veneer under pressure. The resulting product is a billet of lumber that may be up to 1¼ in (44 mm) thick, 4 ft (1.2 m) wide. and 80 ft (24.4 m) long. The billets are then ripped to the desired width and cut to the desired length. The common sizes of LVL closely resemble those of Sawn dimension lumber.

Parallel-strand lumber is manufactured from strands or elongated flakes of wood. One North American product is made from veneer clipped to ½ in (13 mm) wide and up to 8 ft (2.4 m) long. Another product is made from elongated flakes and technology similar to that used to produce oriented strandboard. A third product is made from mats of interconnected strands crushed from small logs that are assembled into the desired configuration. All the products use waterproof adhesive that is cured under pressure. The size of the product is controlled during manufacture through adjustments in the amount of material and pressure applied. Parallel-strand lumber is commonly available in the same sizes as structural timbers or lumber.

Properties of Structural Composite Lumber Standard design values have not been established for either LVL or PSL. Rather, standard procedures are available for developing these design values (ASTM D 5456). Commonly, each manufacturer follows these procedures and submits supporting data to the appropriate regulatory authority to established design properties for the product. Thus. design information for LVL and PSL varies among manufacturers and is given in their product literature. Generally the engineering design properties compare favorably with or exceed those of high-quality solid dimension lumber. Example design values accepted by U.S. building codes are given in Table 6.7.11.

Glued-Laminated Timber

Structural glued-laminated limber (glulam) is an engineered, stress-rated product of a timber laminating plant. It is comprised of assemblies of suitably selected and prepared wood laminations bonded together with adhesives. The grain of all laminations is approximately parallel longitudinally. Individual laminations are typically made from nominal 2-in- (standard 38-mm-) thick lumber when used for straight or slightly cambered members and nominal 1-in- (standard 19-mm-) thick lumber when used for curved members. Individual lamination pieces may be joined end to end to produce laminated timbers much longer than the laminating stock itself. Pieces may also be placed or glued edge to edge to make members wider than the input stock. Straight members up to 140 ft (42 m) long and more than 7 ft (2.1 m) deep have been manufactured, with size limitations generally resulting from transportation constraints. Curved members have been used in domed structures spanning over 500 ft (152 m).

The arrangement of lumber grades in the laminated cross section depends on the anticipated loading parallel or perpendicular to the wide faces of the laminations. When loads are applied perpendicular to the wide faces of the laminations, referred to as horizontally laminated, glulam cross sections are typically designed as bending combinations. **Bending combinations** have higher-grade laminations in the outer top and bottom layers to carry the highest stresses and lower-grade laminations in the core layers where stresses are minimal. In situations where all laminations are subjected to the same load, such as compression, tension, or in bending with loads applied parallel to the wide faces of the laminations (vertically laminated), glulam cross sections are typically designed as axial combinations. **Axial combinations** typically have the same lumber grade throughout the cross section.

Manufacture Glulam members used in structural applications in the United States must be manufactured by a laminating plant that meets the requirements of the national standard, ANSI A190.1. This standard contains requirements for production, testing, and certification of the product. Plants meeting these requirements can place their product quality mark on the glulam, which contains vital information regarding the type, species, and properties of the glulam combination. Figure 6.7.2 shows examples of glulam product quality marks and describes the features required in the mark.

Manufacturing standards cover many softwoods and hardwoods; Douglas-fir and southern pine are the most commonly used softwood species. Glulam members can be used in either dry- or wet-use conditions. Dry use, which is defined as a condition resulting in a moisture content of 16 percent or less, permits manufacturing with nonwaterproof adhesives: however, nearly all manufacturers in North America use waterproof adhesives exclusively. For wet-use conditions, these waterproof adhesives are required. For wet-use conditions in which the moisture content is expected to exceed 20 percent, pressure preservative treatment is recommended (AWPA C28). Lumber can be pressure-mated with water-based preservatives prior to gluing, provided that special procedures are followed in the manufacture. For treatment after gluing, oil-based preservatives are generally recommended.

Glulam is generally manufactured at moisture content below 16 percent. For most dry-use applications, it is important to protect the glulam timber from increases in moisture content. End sealers, surface sealers, primer coats, and wrapping may be applied at the manufacturing plant to provide protection from changes in moisture content. Protection will depend upon the final use and finish of the timber.

Special precautions are necessary during handling, storage, and erection to prevent structural damage to glulam members. Padded or non-marring slings are recommended cable slings or chokers should be avoided unless proper blocking protects the members. Technical manuals on transit, storage, and erection of glulam members are provided by both AITC and APA-EWS.

Design Glulam members are available in standard sizes with standardized design properties. The following standard widths are established to match the widths of standard sizes of lumber, less an allowable amount for finishing the edge, of the manufactured beams:

3 or 3$^1/_8$ in (76 or 79 mm)
5 or 5$^1/_8$ in (127 or 130 mm)
6¾ in (171 mm)
8½ or 8¾ in (216 or 222 mm)
10½ or 10¾ in (267 or 273 mm)

Standard beam depths are common multiples of lamination thickness of either $^{13}/_8$ or $^{11}/_2$ in (35 or 38 mm). There are no standard beam lengths, although most user will be on spans where the length is from 10 to

Table 6.7.10 Design Values for Mechanically Graded Dimension Lumber
(Tabulated design values are for normal load duration and dry service conditions.)

Species and commercial grade	Size classification, in	Design values, lb/in² Bending	Tension parallel to grain	Compression parallel to grain	Modulus of elasticity	Grading rules agency
		Machine-stress-rated lumber				
900f-1.0E		900	350	1,050	1,000,000	WCLIB, WWPA, NELMA, NSLB
1200f-1.2E		1,200	600	1,400	1,200,000	NLGA, WCLIB, WWPA, NELMA, NSLB
1250f-1.4E		1,250	800	1,475	1,400,000	WCLIB
1350f-1.3E		1,350	750	1,600	1,300.000	NLGA, WCLIB, WWPA, NELMA, NSLB
1400f-1.2E		1,400	800	1,600	1,200,000	NLGA
1450f-1.3E		1,450	800	1,625	1,300,000	NLGA, WCLIB, WWPA, NELMA, NSLB
1450f-1.5E		1,450	875	1,625	1,500,000	WCLIB
1500f-1.4E		1,500	900	1,650	1,400,000	NLGA, WCLIB, WWPA, NELMA, NSLB
1600f-1.4E		1,600	950	1,675	1,400,000	NLGA, WWPA
1650f-1.3E		1,650	1,020	1,700	1,300,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
1650f-1.5E		1,650	1,020	1,700	1,500,000	WCLIB, WWPA
1650f-1.6E-1075f_t		1,650	1,075	1,700	1,600,000	WCLIB
1650f-1.6E		1,650	1,175	1,700	1,600,000	WCLIB
1650f-1.8E		1,650	1,020	1,750	1,800,000	WCLIB
1700f-1.6E		1,700	1,175	1,725	1,000,000	WCLIB
1750f-2.0E		1,750	1,125	1,725	2,000,000	NLGA
1800f-1.5E		1,800	1,300	1,750	1,500,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
1800f-1.6E		1,800	1,175	1,750	1,600,000	WCLIB
1800f-1.8E		1,800	1,200	1,150	1,800,000	SPIB, WWPA
1950f-1.5E	2 & less in thickness	1,950	1,375	1,800	1,500,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
1950f-1.7E		1,950	1,375	1,800	1,700,000	NLGA
2000f-1.6E		2,000	1,300	1,825	1,600,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
2100f-1.8E	2 & wider	2,100	1,575	1,875	1,800,000	NLGA, WWPA
2250f-1.7E		2,250	1,750	1,925	1,700,000	NLGA, WCLIB, WWPA
2250f-1.8E		2,250	1,750	1,925	1,800,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
2250f-1.9E		2,250	1,750	1,925	1,900,000	WCLIB, WWPA
2250f-2.0E-1600f_t		2,250	1,600	1,925	2,000,000	WCLIB, WWPA
2250f-2.0E		2,250	1,750	1,925	2,000,000	NLGA, WWPA
2400f-1.8E		2,400	1,925	1,975	1,800,000	NLGA, SPIB
2400f-2.0E		2,400	1,925	1,915	2,000,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
2500f-2.2E		2,500	1,750	2,000	2,200,000	WCLIB
2500f-2.2E-1925f_t		2,500	1,925	2,000	2,200,000	WCLIB
2550f-2.1E		2,550	2,050	2,025	2,100,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
2700f-2.0E		2,700	1,800	2,100	2,000,000	WCLIB
2700f-2.2E		2,700	2,150	2,100	2,200,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
2850f-2.3E		2,850	2,300	2,150	2,300,000	NLGA, SPIB, WCLIB, WWPA, NELMA, NSLB
3000f-2.4E		3,000	2,400	2,200	2,400,000	NLGA, SPIB
		Machine-evaluated lumber				
M-10		1,400	800	1,600	1,200,000	NLGA, SPIB
M-11		1,550	850	1,675	1,500,000	NLGA, SPIB
M-12		1,600	850	1,675	1,600,000	NLGA, SPIB
M-13		1,600	950	1,675	1,400,000	NLGA, SPIB
M-14		1,800	1,000	1,750	1,700,000	NLGA, SPIB
M-15		1,800	1,100	1,750	1,500,000	NLGA, SPIB
M-16		1,800	1,300	1,750	1,500,000	SPIB
M-17	2 & less in thickness	1,950	1,300	2,050	1,700,000	SPIB
M-18		2,000	1,200	1,825	1,800,000	SPIB
M-19	2 & wider	2,000	1,300	1,825	1,600,000	NLGA, SPIB
M-20		2,000	1,600	2,100	1,900,000	NLGA, SPIB
M-21		2,300	1,400	1,950	1,900.000	NLGA, SPIB
M-22		2,350	1,500	1,950	1,700,000	NLGA, SPIB
M-23		2,400	1,900	1,975	1,800,000	NLGA, SPIB
M-24		2,700	1,800	2,100	1,900,000	NLGA, SPIB
M-25		2,750	2,000	2,100	2,200,000	NLGA, SPIB
M-26		2,800	1,800	2,150	2,000,000	NLGA, SPIB
M-27		3,000	2,000	2,400	2,100,000	SPIB

Lumber dimensions: Tabulated design values are applicable to lumber that will be used under dry conditions such as in most covered structures. For 2- to 4-in-thick lumber, the dry dressed sizes shall be used regardless of moisture content at the time of manufacture or use. In calculating design values, natural gain in strength and stiffness that occurs as lumber dries has been taken into consideration as well as reduction in size that occurs when unseasoned lumber shrinks. The gain in load-carrying capacity due to increased strength and stiffness resulting from drying more than offsets the design of size reductions due to shrinkage. **Shear parallel to grain F_v and compression perpendicular to grain F_c:** Design values for shear parallel to grain $F_{v\parallel}$ and compression perpendicular to grain $F_{c\perp}$ are identical to the design values given in Tables 6.7.6 and 6.7.7 for No. 2 visually graded lumber of the appropriate species. When the F_v or $F_{c\perp}$ values show on the grade stamp differ from the values shown in the tables, the values shown on the grade stamp shall be used for design. **Modulus of elasticity E and tension parallel to grain F_t:** For any given bending design value F_b, the average modulus of elasticity E and tension parallel to grain F_t design value may vary depending upon species, timber source, or other variables. The E and F_t values included in the F_b adn E grade designations are those usually associated with each F_b level. Grade stamps may show higher or lower values if machine rating indicates the assignment is appropriate. When the E or F_t values shown on a grade stamp differ from the values in Table 6.7.10, the values shown on the grade stamp shall be used for design. The tabulated F_b and F_t values associated with the designated F_b value shall be used for design. **Additional grades are available.**

SOURCE: Table used by permission of the American Forest & Paper Association, Washington, DC.

Table 6.7.11 Example Design Values for Structural Composite Lumber

	Bending stress		Modulus of elasticity		Horizontal shear	
Product	lb/in²	MPa	× 10³ lb/in²	GPa	lb/in²	MPa
LVL	2,800	19.2	2,000	13.8	190	1.31
PSL type A	2,900	20.0	2,000	13.8	210	1.45
PSL, type B	1,500	10.3	1,200	8.3	150	1.03

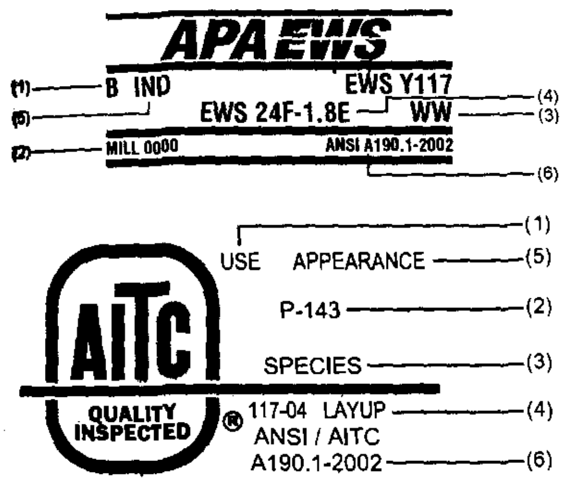

Fig. 6.7.2 Typical product quality stamps showing vital information for glulam combination 1, structural use of member (B, simple span bending member; C, compression member; T, tension member; CB, continous or cantilevered span bending member); 2, mill number; 3, species; 4, strucrtural grade designation, indicating species, design bending strength and stiffness; 5, appearance grade desigation (framing, industrial, architectural, or premium); 6, identification of conformance to ANSI A 190/1 stamdard/

20 times the depth. Technical publications containing allowable spans for various loadings of standard sizes of beams are available from either AITC or APA-EWS.

The design stresses for beams in bending for dry-use applications are standardized in multiples of 200 lb/in² (1.4 MPa) with the range of 2,000 to 3,000 lb/in² (13.8 to 20.7 MPa). Modulus of elasticity values associated with there design stresses in bending vary from 1.6 to 2.0 × 10⁶ lb/in². A bending stress of 2,400 lb/in² (16.5 MPa) and a modulus of elasticity of 1.8 × 10⁶ lb/in² (12.4 GPa) are most commonly specified, and the designer needs to verify the availability of beams with higher values. Design properties must be adjusted for wet-use applications. Detailed information an other design properties for beams as well as design properties and procedures for arches and other uses is given in "National Design Specification" (AF&PA).

Round Timbers

Round timbers in the form of poles, piles, or construction logs represent some of the most efficient uses of forest products because of the minimum of processing required. Poles and piles are generally debarked or peeled, seasoned, graded, and treated with a preservative prior to use. Construction logs are often shaped to facilitate their use. See Table 6.7.12.

Poles The primary use of wood poles is to support utility and transmission lines. An additional use is for building construction. Each of these uses requires that the poles be pressure-treated with preservatives following the applicable AWPA standard (C1). For utility structures, pole length may vary from 30 to 125 ft (9.1 to 38.1 m). Poles for building construction rarely exceed 30 h (9.1 m). Southern pines account for the highest percentage of poles used in the United States because of their favorable strength properties, excellent form, ease of treatment, and availability. Douglas-fir and western redcedar are used for longer lengths; other species are also included in the ANSI O5.1 standard (ANSI 1992) that farms the basis for most pole purchases in the United States.

Design procedures for the use of ANSI O5.1 poles in utility structures are described in the "National Electric Safety Code" (NESC). For building construction, design properties developed based on ASTM D 2899 (see ASTM, 1995) are provided in "Timber Construction Manual" (AITC, 1994) or ASAE EP 388.

Piles Most piles used far foundations in the United States utilize either southern pine or Douglas-fir. Material requirements for timber piles are given in ASTM D 25, and preservative treatment should follow the applicable AWPA standard (C1 or C3). Design stress and procedures are provided in "National Design Specifications."

Construction Logs Log buildings continue to be a popular form of construction because nearly any available species of wood can be used. Logs are commonly peeled prior to fabrication into a variety of shapes. There are no standardized design properties for construction logs, and when they are required, log home suppliers may develop design properties by following an ASTM standard (ASTM D 3957).

Table 6.7.12 Design Stresses for Selected Species of Round Timbers for Building Construction

	Design stress					
	Bending		Compression		Modulus of elasticity	
Type of timber and species	lb/in²	MPa	lb/in²	MPa	× 10⁶ lb/in²	GPa
Poles*						
Southern pine and Douglas-fir	2,100	14.5	1,000	6.9	1.5	10.3
Western redcedar	1,400	9.6	800	5.5	0.9	6.2
Piles†						
Southern pine	1,400	16.5	1,100	8.3	1.5	10.3
Douglas-fir	2,450	16.9	1,250	8.6	1.5	10.3
Red pine	1,900	11.1	900	6.2	1.3	8.8

*From "Timber Construction Manual" (AITC, 1994).
†From "National Design Specification" (AF&PA, 2005)

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