WESTERN WOODS USE BOOK

SECOND EDITION

STRUCTURAL DATA
& DESIGN TABLES

WESTERN WOOD PRODUCTS ASSOCIATION

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Western
Wood Products
Association

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Preface:

The Western Woods Use Book had its beginning in the Structural Timber Handbook on Pacific Coast Woods published in 1916. In 1930 the first Douglas Fir Use Book was published and the 1961 Edition was the latest revision. To engineers, architects and others engaged in the construction industry, who require accurate and reliable information concerning the qualities and uses of the Western species, the Western Wood Products Association offered the first edition of the Western Woods Use Book.

In changing from a book relating only to Douglas Fir to one covering the Western species, major revisions were necessary. All design tables relating to varying species properties were revised and the book format and organization of material were changed to reflect a more logical process of design. All chapters were brought up to date to reflect information contained in the latest standards. A new chapter on Sound Control was added and the section on Lateral Forces—Design was revised to include plywood.

The second edition of the Western Woods Use Book incorporates all necessary revisions to accommodate the changes made in the National Design Specification for Wood Construction published by the National Forest Products Association. In addition, Chapter IV on Design Values has been produced in the form of a supplement and placed in the back of the book in order to accomodate future changes, if any, without making the complete book out of date.

The cooperation and assistance of the National Forest Products Association, American Plywood Association, American Institute of Timber Construction, Southern Forest Products Association and the American Wood Preservers Institute are hereby acknowledged and greatly appreciated.

The Western Woods Use Book is intended for the use of architects, engineers, and students preparing for these professions. Data and formulas given are technical and should be used with knowledge of engineering principles and assumptions, as many factors other than simple fundamental formulas enter into structural analysis. It is recommended, therefore, that structural problems be referred to a qualified engineer or architect.

Additional technical information on the use of lumber and wood products is available from the Western Wood Products Association and the following organizations:

American Institute of Timber Construction
333 West Hampden Avenue
Englewood, Colorado 80110

American Plywood Association
1119 A Street
Tacoma, Washington 98401

American Wood Preservers Institute
1651 Old Meadow Road
McLean, Virginia 22101

National Forest Products Association
1619 Massachusetts Avenue, N. W.
Washington, D. C. 20036

Southern Forest Products Association
P. O. Box 52468
New Orleans, Louisiana 70150

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CHAPTER I

The Western Woods

THE WESTERN WOODS

The major softwood supply of the United States is contained in the growing region of the seventeen species of Western Woods. Covering the twelve western states, the area extends east and west from the Black Hills of South Dakota to the Pacific Ocean and from the Mexican border on the south to the Canadian border on the north.

The hills and mountains of this region have produced many billions of feet of lumber in the diverse range of soil and climatic conditions. In addition to the stands of mature trees ready for harvesting, there are millions of acres of new forests developing into a mature crop. Protection from fire and disease and scientific forest management practices assure a permanent supply of forest products manufactured from the Western Woods.

These timber stands also provide a prime recreational area of millions of acres because the timber-producing practices of the region are geared to the compatible use of the land for many purposes, including wildlife habitat, water production and grazing. The forest roads built and maintained for timber management also provide access to millions of people for camping, fishing, hunting, skiing and many other ways of enjoying this important national resource.

The hundreds of sawmills in this region, in addition to providing employment and stability in their communities, produce the wood products necessary to build and furnish millions of homes and apartments needed for adequate housing for the nation. In addition, Western Woods are used in churches, schools, farm buildings, warehouses, bridges and various other types of engineered timber structures. Modern prefabricated construction utilizes increasing amounts of lumber due to its ease of fabrication and high strength to weight ratio.

Species and Marketing Combinations

The seventeen species of Western Woods are combined into eleven principal marketing groups since a number of the species are grown, harvested, manufactured and marketed together and have similar performance properties which make them interchangeable in use. For identification and standardization of recommended design values and because some species cannot be visually separated in lumber form, some species are given a common designation and assigned common design values. The principal species and species combinations manufactured by mills of the Western Woods region for which design values are assigned are shown below.

Table 1.1

Commercial Species	Botanical Species Included
Douglas Fir—Larch	Douglas Fir — Pseudotsuga menziesii Western Larch — Larix occidentalis
Douglas Fir South	Douglas Fir — Pseudotsuga menziesii[1]
Western Hemlock	Western Hemlock — Tsuga heterophylla

Table 1.1 Continued

Commercial Species	Botanical Species Included
Hem-Fir	Western Hemlock — Tsuga heterophylla True Firs Pacific Silver Fir — Abies amabilis White Fir — Abies concolor Grand Fir — Abies grandis California Red Fir — Abies magnifica Noble Fir — Abies procera
Mountain Hemlock	Mountain Hemlock — Tsuga mertensiana
Alpine Fir	Subalpine Fir — Abies lasiocarpa
Engelmann Spruce	Engelmann Spruce — Picea engelmannii
Lodgepole Pine	Lodgepole Pine — Pinus contorta
Ponderosa Pine — Sugar Pine	Ponderosa Pine — Pinus ponderosa Sugar Pine — Pinus lambertiana
Idaho White Pine	Idaho White Pine — Pinus monticola
Western Cedars	Incense Cedar — Libocedrus decurrens Western Red Cedar — Thuja plicata

[1]**Grown in Arizona, Colorado, Nevada, New Mexico and Utah.**

Because of timber stand composition and mill manufacturing and marketing practices, some other species combinations are shipped and design values for the lowest valued species in the combination are applicable.

PHYSICAL PROPERTIES

Wood is an aggregate of cells, essentially cellulose in composition, which are cemented with lignin. Although cells of the western softwoods vary in shape and size according to their function, the greater portion are elongated and are positioned vertically in the standing tree. Known as tracheids, they vary from ⅛ to ⅓ of an inch in length and 1/100 of these dimensions in width.

Annual Growth Rings

New wood cells are formed in the cambium, a microscopic layer between the bark and the wood. Through the winter months, the trees are dormant. In the spring, the cambium begins to form new thin-walled springwood cells with large cavities. Through the summer, cell walls increase in thickness and, in the fall, newly formed summerwood cell cavities gradually decrease in size until growth virtually ceases. Differences in cell-wall thicknesses between those last formed in the fall and the thin-walled cells formed in the spring result in rings of annual growth which are visible on the ends of lumber. This change in growth characteristics occurs annually and, thus, the age of the tree may be determined by counting the growth rings.

Heartwood and Sapwood

The end of a log shows three distinct zones: the bark, a light-colored zone just beneath it called the sapwood, and an inner zone, often darker in color, called heartwood. At the structural center of the heartwood is the pith or "heart center."

The young tree is composed primarily of sapwood which functions in sap conduction and food storage. As the tree increases in diameter, inner sapwood cells cease their conductive function and form the inactive heartwood. Deposits in these inactive cells give the heartwood of many species a darker color than the sapwood.

As all heartwood was once sapwood, there is no consistent difference between heartwood and sapwood in dry weight or in strength. For normal uses, no distinction need be made between heartwood and sapwood. Toxic extractives in the cells generally make heartwood more durable when in contact with soil and under other conditions conducive to decay. Where wood is to be treated with preservative, deeper and more effective penetration can be attained in sapwood than in heartwood.

Weight of Western Woods

Solid wood substance is heavier than water, its specific gravity being about 1.5 regardless of the species. Despite this fact, dry wood of most species floats in water because a portion of its volume is occupied by air-filled cavities. Variation among species in the size of cells and in the thickness of cell walls affects the amount of solid wood substance present and, hence, the specific gravity. Thus, specific gravity of wood is a measure of its solid wood substance and an index of its strength properties.

The relationship of strength to specific gravity has been used extensively in determining the range of strength and stiffness properties which exist throughout the growth range of a species. The specific gravity of over 30,000 trees of the western softwoods has recently been determined by the U.S. Forest Service. These data are incorporated in the current strength, stiffness and weight assignments herein.

Table 1.2

Species	Specific Gravity	Weight lbs/ft^3	Weight* Factor
Douglas Fir-Larch	.48	36.3	.252
Douglas Fir South	.43	32.5	.226
Hem-Fir	.42	31.8	.221
Mountain Hemlock — Hem-Fir	.42	31.8	.221
Western Hemlock	.42	31.8	.221
Engelmann Spruce — Alpine Fir	.33	24.9	.173
Lodgepole Pine	.39	29.5	.205
Ponderosa Pine — Sugar Pine	.39	29.5	.205
Idaho White Pine	.35	26.5	.184
Western Cedars	.35	26.5	.184

***To calculate the weight per lineal foot for a particular size and species, multiply the cross sectional area of the member in square inches by the species weight factor shown.**

To determine the weight per cubic foot or per linear foot at higher moisture contents, multiply the above weights by the following factors.

Moisture Content	Adjustment Factor
30%	1.073
40%	1.156
50%	1.238
60%	1.321
70%	1.403

The specific gravity as determined on the basis of green volume, oven-dry weight is shown in the preceding table. Also shown is the average weight per cubic foot of wood and factors to determine the weight of lumber when used at a maximum moisture content of 19 per cent such as in most covered structures. Adjustment factors for other moisture content conditions, such as exposed use, are also provided. Weights for species combinations are based on the heaviest species in the combination, thus providing conservative estimates of building weights for design purposes.

Moisture in Wood

The moisture content of wood is the weight of the water in wood expressed as a percentage of the weight of the wood from which all water has been removed (oven dry). Moisture is removed from lumber either by air drying or by use of special drying kilns. Wood may contain moisture in two forms, either as "free water" in the cell cavities or as "absorbed water" in the cell walls.

When green wood begins to lose moisture, the cell walls remain saturated until the free water has been evaporated. The point at which evaporation of free water is complete and cell walls begin to lose their moisture is called the "fiber saturation point." This point occurs between 25 and 30 percent moisture content for the western softwoods.

Moisture content is determined by weighing a representative sample, drying it at 200°-212°F until no further loss in weight takes place, weighing after drying and then dividing the difference between the original and final weights by the final oven-dry weight.

Electric moisture meters are also available for determining the moisture content of wood. Since their operation depends only upon inserting small needles into the surface of lumber, individual pieces may be non-destructively tested for moisture content. The resistance type of portable meter measures the relation between the electrical resistance of wood and its moisture content. Most resistance-type meters are designed to measure moisture content between 6 and 70 percent. The dependable accuracy range is between 6 and 30 percent. While not as accurate, the higher range is useful in indicating an approximate moisture content for comparative purposes.

Capacitance-type portable meters are also available and utilize the relationship between the dielectric constant of wood and its moisture content. This type of moisture meter generates a radio frequency current through electrodes which only require surface contact. The power loss in the circuit is indicated, and, since the specific gravity of the wood also influences the current through the circuit, conversion tables based on the average specific gravity of each species are necessary. Variation in specific gravity within a species also affects the accuracy of moisture content determinations made with this type of meter. The range of capacitance-type meters lies between zero and 25 percent moisture content.

THE WESTERN WOODS

Dimensional Stability and Strength

Moisture content variations above the fiber saturation point have no effect upon the volume or strength of wood. As wood dries below the fiber saturation point and begins to lose moisture from the cell walls, shrinkage begins and strength and stiffness properties increase. With slight seasonal variations, wood in use over a period of time attains an equilibrium moisture content (emc) corresponding to the humidity and temperature of the surrounding air. For example, at 70° F., the (emc) of wood varies from 20.6 percent at 90 percent relative humidity to 6 percent at 29 percent relative humidity.

Wood in service usually is exposed to both long-term (seasonal) and short-term (daily) changes in the relative humidity and temperature of the surrounding air. The changes in moisture content of the wood caused by these conditions are usually gradual and short-term fluctuations tend to influence only the wood surfaces.

Moisture content standards of the grading rules generally provide for maximum 12 percent for dry finish-type lumber and maximum 19 percent for dry framing-type lumber. Lumber may be ordered unseasoned, and the size standards provide for larger sizes to account for shrinkage as the lumber reaches equilibrium moisture content. The average shrinkage of softwood lumber, which is compensated for by unseasoned size differentials, is 2.35 percent in thickness and 2.80 percent in width.

Increase in strength begins when the cell walls begin to lose moisture, as the wood is dried below the fiber saturation point. Design values for Western Woods reflect these increases which are different for various strength and stiffness properties. Where lumber is to be used under moisture conditions exceeding 19 percent, design values should be reduced. Reduction factors are shown in the design value section. See Supplement.

Effect of Moisture on Decay

Wood maintained either constantly dry or continuously submerged in water does not decay. Decay is caused by certain fungi which are microscopic plants that require warmth, oxygen, food and moisture for survival. Moisture in particular is the key to understanding the activity of such a fungus. The moisture in wood below the fiber saturation point of 25 to 30 percent is held semi-chemically by the cell walls and is not available to the fungus. As discussed previously, the equilibrium moisture content of wood in normal use is usually below 19 percent. Therefore, except in such special uses as tanning factories, where steam or water spray may be present, the moisture content of the wood is too low to support the decay causing fungi.

It is thus obvious that the term "dry rot" is misleading and unfortunate. It perpetuates the incorrect assumption that wood is subject to decay under all conditions, wet or dry. The term "dry rot" is descriptive only of the condition of a piece of wood which has repeatedly been wet enough for decay to occur and later is observed in a dry and decayed condition.

Where conditions are present which are conducive to decay, preservative treatment or durable species are usually required by building codes. For foundation plates and sills, FOUNDATION LUMBER of Western Red Cedar or Incense Cedar is frequently specified due to the effective durability of the heartwood of these species.

Thermal Conductivity

The western softwoods have relatively low thermal conductivity and thus provide significant insulation value. The term commonly used to rate thermal conductivity of various materials is "k", the amount of heat (Btu's) transferred in one hour through one square foot of material one inch thick with a difference in temperature of 1° F. The thermal conductivity of wood increases with increased moisture content and with increased density. The "k" values for the Western Woods are shown in the table below.

Table 1.3

Species	"k"*	R/in.
Douglas Fir – Larch	1.06	.94
Douglas Fir South	.99	1.01
Hem-Fir	.92	1.08
Mountain Hemlock	.98	1.02
Alpine Fir	.75	1.34
Engelmann Spruce	.80	1.26
Lodgepole Pine	.92	1.08
Ponderosa Pine – Sugar Pine	.89	1.12
Idaho White Pine	.84	1.19
Western Cedars	.75	1.33
Western Hemlock	.99	1.01

***"k" values shown are for wood at 12 percent moisture content. For other moisture contents, there is a change in "k" of approximately 0.01 for each 1 percent moisture content difference – an increase in "k" for an increase in moisture content and a decrease in "k" for a decrease in moisture content.**

Thermal Expansion

In most structural design, the coefficient of thermal expansion (increase in dimension per unit of length, thickness or width for a temperature rise of 1° F) of wood can be neglected since it is very small.

Longitudinally, the coefficient of thermal expansion is independent of specific gravity and varies from 0.0000017 to 0.0000025 for different species. Across the grain, the values vary directly with the specific gravity from 0.000014 to 0.000022 for the Western Woods.

The coefficient of thermal expansion varies slightly with temperature, but for all ordinary uses may be considered constant. In the longitudinal direction, thermal expansion of wood is from 1/10 to 1/3 as great as the expansion of metals, concrete and glass.

Electrical Properties

Dry wood is an excellent insulator against transmission of direct electrical current and low frequency alternating current. Electrical resistance of wood, however, varies appreciably with wood moisture content. Variations in the distribution of a fixed amount of moisture in the area of measurement also have a considerable effect upon electrical resistance. Variations in species, specific gravity and amount of inorganic ash content have a much smaller effect upon electrical resistance.

Below fiber saturation point (25 to 30% moisture content) electrical resistance of wood increases very rapidly with decrease in moisture content, whereas above fiber saturation point electrical resistance changes much more slowly. Resistance is also affected by temperature, approximately doubling with each drop of 10° C.

Electrical resistivity (specific resistance) of a material is the electrical resistance in ohms between opposing faces of a cubic centimeter unit. Electrical resistivity of wood varies from about 10^{16} to 10^{18} ohm-centimeters for oven dry wood to 10^5 to 10^6 ohm-centimeters for wood at fiber saturation.

Dielectric Constant

The ratio of the capacitance of a condenser having a wood dielectric to the capacitance of the same condenser with a vacuum dielectric is termed the dielectric constant for the wood used. Dielectric constant values differ along the grain from across the grain, being as much as 30 per cent greater in the parallel-to-grain direction.

Increases in wood density and in moisture content both result in appreciable increase in dielectric constant values. The capacitance type of moisture meter is based upon the variation of the dielectric value of wood with corresponding moisture content changes. Over the range of frequencies from middle audio to high radio frequency, the dielectric constant ranges from less than 10 for dry wood to about 50 for wet wood.

Resistivity of Wood at Radio Frequencies

Low frequency parallel resistivity of wood is much greater than corresponding resistivity at high (radio) frequencies. The resistivity (r) of wood is approximately inversely proportional to the frequency (f) as evident in the following equation where the power factor (cos Ø) and the dielectric constant (ε) vary only slightly with frequency:

$$r = \frac{1.8 \times 10^{12}}{\varepsilon f \cos \emptyset}$$

This reduction in resistivity with increase in current frequency is the principle upon which the curing of glue lines in wood by radio frequency heating is based.

Where wood is employed as a dielectric (as in high-frequency gluing) the power (P) dissipated in the wood as heat is proportional to the capacitance of the condenser (C), the power factor of the wood (cos Ø), the voltage (E) and the frequency (f). This is indicated in the equation:

$$P = 2 \pi f E^2 C \cos \emptyset$$

As high voltage (E) in the foregoing equation is difficult to generate, presents insulating problems and tends to produce arcing, the power (P) necessary to produce heat is best increased by increasing the current frequency (f). The heat thus generated affords a rapid means of polymerizing synthetic resin wood glues.

Chemical Resistance

The Western Woods are highly resistant to a number of chemicals and are thus used for various types of tanks, containers and equipment in which chemicals are used and for structures near such equipment.

Wood owes its extensive use in chemical equipment largely to its superiority over cast iron and steel in resistance to mild acids and solutions of acidic salts. Iron is superior to wood in resistance to alkalies.

The spread between strength properties of the species after exposure to chemicals is not great. The table below shows the percentage of original (wet-breaking strength) in tests after exposure to different solutions for the duration of exposure indicated. In designing for chemical resistance, the wet-use design values are applicable when there is exposure to aqueous solutions.

Table 1.4 **Percentage of Original Wet Breaking Strength Remaining After Exposure for the Duration Indicated***

J.D. Ross, Forest Products Journal, January, 1956.

	Acids				Bases		Salts				
	* 1	2	3	4	5	6	7	8	9	10	11
Douglas Fir	91	67	65	99	51	105	111	106	107	32	56
Hem-Fir and Western Hemlock	92	68	67	100	59	92	107	108	103	12	56
Western Red Cedar	82	71	59	94	40	90	84	120	121	25	43
Incense Cedar	90	52	60	85	39	110	84	93	102	48	55
Ponderosa Pine	90	64	65	98	43	87	92	93	98	4	52
Sugar Pine	86	65	62	87	33	85	103	98	113	18	45
Idaho White Pine	86	68	67	95	54	87	100	100	104	17	63
Western Larch	85	66	58	102	40	89	86	125	93	20	51

* 1 – 5% Sulfuric acid, room temperature, 105 days.
2 – 5% Hydrochloric acid, room temperature, 71 days.
3 – 5% Nitric acid, room temperature, 72 days.
4 – 5% Acetic acid, room temperature, 176 days.
5 – 1% Sodium Hydroxide, room temperature, 87 days.
6 – Calcium Hydroxide, saturated, room temperature, 151 days.
7 – 20% Sodium carbonate, room temperature, 93 days.
8 – 20% Calcium chloride, room temperature, 105 days.
9 – 20% Sodium chloride, room temperature, 161 days.
10 – 5¼% Sodium hypochlorite, room temperature, 21 days.
11 – 5% Sodium carbonate, boiling, 36 days.

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Friction Properties

The coefficient of friction depends on the moisture content of the wood and surface roughness, and varies little with species. Coefficients of static friction on unpolished steel of 0.65 for dry wood and 0.40 for green wood have been established. Coefficients of static friction for smooth wood on smooth wood are 0.60 for dry wood and 0.83 for green wood.

Coefficients of sliding friction differ from those for static friction, and depend on the rate of relative movement between the rubbing parts. Coefficients for wood on steel of 0.70 for dry wood and 0.15 for green wood have been established at a relative movement of 4 meters per second.

CHAPTER II

Lumber Standards

LUMBER STANDARDS

Several significant developments have been made in standards affecting the use of Western Woods in recent years. Chronologically, the major developments have been:

1. Completion of the *Western Wood Density Survey, Report No. 1, U.S.D.A. Forest Service Research Paper FPL-27* . . . . July, 1965.
2. The inauguration of the American Society for Testing and Materials (ASTM) in establishing and publishing clear wood strength values: *ASTM D 2555, Standard Methods for Establishing Clear Wood Strength Values,* original adoption 1966
3. A major revision of *ASTM D 245, Standard Methods for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber.* This was the first major revision of this Standard since 1949 and incorporated new research and technical information concerning lumber performance 1968
4. A resampling of the strength of Engelmann Spruce throughout the entire growth range and publication of *Mechanical Properties and Specific Gravity of A Randomly Selected Sample of Engelmann Spruce. U.S.D.A. Forest Service Research Paper FPL 128* . . . . January, 1970
5. The culmination of several years work by the lumber industry on lumber standards to supersede Simplified Practice Recommendation 16-53 with the publication of *Product Standard 20-70, American Softwood Lumber Standard,* by the U. S. Department of Commerce. . . . . September, 1970
6. Publication of new grade rules, based on the new Standards, by all of the softwood lumber rules writing agencies. 1970
7. Resamplings of strength properties of five western softwoods and the publication of *Important Structural Properties of Four Western Softwoods: White Pine, Sugar Pine, Western Redcedar and Port-Orford-Cedar. U.S.D.A. Forest Service Research Paper FPL 191* . . . . *1972* and *Mechanical Properties and Specific Gravity of Randomly Sampled Subalpine Fir. U.S.D.A. Forest Service Research Paper FPL 197* *1973*
8. Publication of *Western Lumber Grading Rules '79* . . . . *June 1, 1974*

Western Wood Density Survey

This Survey conducted by the U. S. Forest Service and Forest Products Laboratory was planned to obtain, by systematic sampling, adequate data on the average specific gravity and related quality characteristics, the magnitude of differences between species and the range of variation within the species for the commercial softwood timber stands of the West. Non-destructive calibrated increment borer techniques were used in the sampling of 30,326 trees on 4,225 plots systematically located on commercial forestlands extending throughout the Western Woods growing area. An increment borer is a hollow drill which extracts a core from living trees suitable for analysis of wood density, age, sapwood width, rate of growth and other quality factors. Since density is related to mechanical properties with known correlation, the average and variability of mechanical properties were determined for the species surveyed. The Western Woods included in Report No. 1 were Douglas Fir, five True Firs, Western Hemlock and Western Larch. These data were incorporated into *ASTM Standard D 2555* and were used for determination of design values for Western Woods shown herein.

ASTM D 2555

Commonly called the Clear Wood Standard, the *Standard Methods for Establishing Clear Wood Strength Values, ASTM D 2555,* is the first formal standard ever published dealing with the basic clear wood mechanical properties of U. S. and Canadian woods. The data obtained in the *Western Wood Density Survey* were incorporated for the species surveyed.

The development of safe and efficient design values for lumber has, as a starting point, the need for an authoritative compilation of clear wood strength values for the commercially important species. A primary feature of this Standard are tables presenting the most reliable basic information developed on the strength of clear wood and its variability.

The Standard also provides procedures for establishing, from these data, values applicable to groups of similar species where necessitated by efficient marketing. The Standard establishes limits that determine when a species may be included in a combination without reducing the average properties for the combination. If a species is to be included and the limits are exceeded, the assigned property value for the combination must be reduced to a value such that the limits are not exceeded.

ASTM D 245

Titled, Standard Methods for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber, this Standard covers the basic principles for visually grading structural lumber and for establishing related recommended design values.

The Standard includes necessary procedures for the formulation of structural grades of any desired strength ratio. The term strength ratio represents the anticipated proportionate remaining strength after making allowance for the effect of maximum permitted knots, cross grain and other strength-reducing characteristics in a given grade as compared to clear, straight-grained lumber.

In addition to providing for the effects of strength-reducing characteristics, the Standard provides other modifications for design use. Methods are provided for determining allowable stresses at the 5 percent exclusion limit (the allowable stress which is less than the stress permissible for 95 percent of the pieces in a species and grade). The 5 percent exclusion limit is further modified to account for the effect of size, moisture content, duration of load, multiple-member systems and a factor of safety. Details of the methods and calculations for the Western Woods are shown in Determination of Recommended Design Values for Western Softwood Lumber, *1970 Standard Grading Rules*, published separately by the Western Wood Products Association.

Some of the major changes in this Standard over past practices are related to Modulus of Elasticity (E values), tension parallel to grain (Ft values), repetitive member values and the effect of moisture content.

Formerly, all grades of a lumber species were assigned a single modulus of elasticity value. However, in recent years research has shown that the modulus of elasticity varies with grade quality and ASTM D 245 now requires the reduction of 10 percent or 20 percent in E values for grades lower in quality than Select Structural, No. 1 or Appearance.

Since tension parallel to grain values are significantly higher than extreme fiber in bending values in small clear specimens, tension values were formerly assigned the same values developed for bending. With the recent development of equipment capable of testing full-size structural lumber in tension, it was learned that in these sizes, grade characteristics have a more severe effect on tension stresses than for bending. The tension values assigned herein reflect this new information.

Tests have demonstrated that the interaction of assemblies of three or more closely spaced load-carrying members, such as joists, rafters, studs or decking, yield a greater capacity than can be predicted for the sum of the individual members. Therefore, the current design values for such members which are contiguous or are spaced not more than 24 inches and are joined by transverse floor, roof or other load-distributing element reflect an increase in bending values of 15 percent over values for single members.

Modifications in strength and stiffness assignments due to the effect of moisture content are now related to the net dimensions of lumber, and different increases for strength and stiffness due to drying are now specified than formerly when both dry and unseasoned lumber were manufactured to the same size.

American Softwood Lumber Standard

The current softwood lumber standard is *Product Standard PS 20-70*, a voluntary standard developed by the National Bureau of Standards in cooperation with producers, distributors and users. PS 20-70, in common with product standards for other materials, establishes dimensional requirements for standard sizes, technical requirements for the product and methods of grading and marking these products. In addition, however, this Standard provides for a standing American Lumber Standards Committee and an independent Board of Review to determine the competency of inspection agencies engaged in the grading of lumber, to inspect and police the grading of lumber and to require continuing conformance of grading rules to American Lumber Standards.

PS 20-70 has several improvements over the previous lumber standard including (1) sizes related to moisture content resulting in the same end-use sizes for both green and dry lumber, (2) requirements for the establishment of design values including ASTM D 2555 and ASTM D 245 and (3) establishment of the National Grading Rule for dimension lumber.

Under the Standard, uniform grade descriptions and names are established for all softwood species for lumber 2" to 4" in thickness. Grading rules of an agency shall not be certified as conforming to American Lumber Standards if the dimension lumber rules fail to conform to the National Grading Rule. The National Grading Rule for Dimension Lumber classifies dimension into two width categories and five use categories. Dimension up to 4" wide is classified as "Structural Light Framing," "Light Framing" and "Studs." Dimension 6" and wider is classified as "Structural Joists and Planks." In addition, a single "Appearance Framing" grade of 2" and wider dimension is designed for those special uses where a high bending strength ratio coupled with high appearance is needed. The grades established under these classifications are shown in the WWPA Grade Chart on page 14.

The standard provides for the grading of lumber by mechanical means. Denoted Machine Stress Rated Lumber by the Western Wood Products Association, it is lumber that has been evaluated by mechanical stress rating equipment. Machine Stress-Rated Lumber is distinguished from visually stress graded lumber in that each piece is nondestructively tested and marked to indicate: Machine Rated, the extreme fiber stress in bending rating and the modulus of elasticity rating. Equipment and methods of certification are subject to approval of the Board of Review of the American Lumber Standards Committee. Machine Stress-Rated Lumber is also required to meet certain visual grading requirements.

The inspection provisions of the Standard provide that, subject to freedom of agreement between buyer and seller as to the settlement of complaints, the purchase, sale or shipment of American Standard grades of lumber involves agreement to submit to reinspection by the certified inspection agency under whose published rules the lumber was graded, any complaint involving grades, sizes, moisture content or tally. Grading agencies may not inspect lumber which has been used, such as lumber in place in structures, as