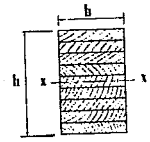
PROPERTIES OF SECTIONS—STRUCTURAL GLUED LAMINATED MEMBERS

1⅝ inch laminations only.

This table is in the order of ascending section moduli.



Net Finished Size* in inches b × h	Number of 1⅝″ Laminations*	Area of Section in Square Inches	Section Modulus $S = \frac{bh^2}{6}$	Moment of Inertia $I = \frac{bh^3}{12}$	Weight in Pounds per Lineal Foot at 12% Moisture Content	Total Board Feet Required Per Lineal Foot of Piece	Net Finished Size* in Inches b × h	Number of 1⅝″ Laminations*	Area of Section in Square Inches	Section Modulus $S = \frac{bh^2}{6}$	Moment of Inertia $I = \frac{bh^3}{12}$	Weight in Pounds per Lineal Foot at 12% Moisture Content	Total Board Feet Required Per Lineal Foot of Piece
2¼ x 6½	4	14.6	15.8	51.5	3.45	2.00	7 x 26	16	182.	789.	10,250.	43.0	21.33
3¼ x 6½	4	21.1	22.9	74.4	4.98	2.67	12½ x 19½	12	244.	792.	7,724.	57.5	28.00
2¼ x 8⅛	5	18.3	24.8	101.	4.31	2.50	11 x 21⅛	13	232.	818.	8,642.	54.8	26.00
4¼ x 6½	4	27.6	29.9	97.3	6.52	3.33	7 x 27⅝	17	193.	890.	12,300.	45.6	22.67
5 x 6½	4	32.5	35.2	114.	7.67	4.00	9 x 24⅜	15	219.	891.	10,860.	51.8	25.00
2¼ x 9¾	6	21.9	35.7	174.	5.18	3.00	14½ x 19½	12	283.	919.	8,960.	66.7	32.00
3¼ x 8⅛	5	26.4	35.8	145.	6.23	3.33	12½ x 21⅛	13	264.	930.	9,820.	62.3	30.33
5¼ x 6½	4	34.1	37.0	120.	8.05	4.00	11 x 22¾	14	250.	949.	10,790.	59.1	28.00
4¼ x 8⅛	5	34.5	46.8	190.	8.15	4.17	7 x 29¼	18	205.	998.	14,600.	48.3	24.00
2¼ x 11⅜	7	25.6	48.5	276.	6.04	3.50	9 x 26	16	234.	1,014.	13,180.	55.2	26.67
3¼ x 9¾	6	31.7	51.5	251.	7.48	4.00	12½ x 22¾	14	284.	1,078.	12,270.	67.1	32.67
5 x 8⅛	5	40.6	55.0	223.	9.59	5.00	14½ x 21⅛	13	306.	1,078.	11,390.	72.3	34.67
5¼ x 8⅛	5	42.7	57.8	235.	10.1	5.00	11 x 24⅜	15	268.	1,089.	13,280.	63.3	30.00
4¼ x 9¾	6	41.4	67.3	328.	9.78	5.00	7 x 30⅞	19	216.	1,112.	17,170.	51.0	25.33
3¼ x 11⅜	7	37.0	70.1	399.	8.72	4.67	9 x 27⅝	17	249.	1,145.	15,810.	58.7	28.33
7 x 8⅛	5	56.9	77.0	313.	13.4	6.67	7 x 32½	20	228.	1,232.	20,030.	53.7	26.67
5 x 9¾	6	48.8	79.2	386.	11.5	6.00	12½ x 24⅜	15	305.	1,238.	15,090.	71.9	35.00
5¼ x 9¾	6	51.2	83.2	406.	12.1	6.00	11 x 26	16	286.	1,239.	16,110.	67.5	32.00
3¼ x 13	8	42.3	91.6	595.	9.97	5.33	14½ x 22¾	14	330.	1,251.	14,230.	77.9	37.33
4¼ x 11⅜	7	48.3	91.7	521.	11.4	5.83	9 x 29¼	18	263.	1,283.	18,770.	62.1	30.00
5 x 11⅜	7	56.9	108.	613.	13.4	7.00	7 x 34⅛	21	239.	1,359.	23,180.	56.4	28.00
7 x 9¾	6	68.3	111.	541.	16.1	8.00	11 x 27⅝	17	304.	1,399.	19,320.	71.7	34.00
5¼ x 11⅜	7	59.7	113.	644.	14.1	7.00	12½ x 26	16	325.	1,408.	18,310.	76.7	37.33
3¼ x 14⅝	9	47.5	116.	847.	11.2	6.00	9 x 30⅞	19	278.	1,430.	22,070.	65.6	31.67
4¼ x 13	8	55.3	120.	778.	13.0	6.67	14½ x 24⅜	15	353.	1,436.	17,500.	83.4	40.00
5 x 13	8	65.0	141.	915.	15.3	8.00	7 x 35¾	22	250.	1,491.	26,650.	59.1	29.33
3¼ x 16¼	10	52.8	143.	1,162.	12.5	6.67	11 x 29¼	18	322.	1,569.	22,940.	75.9	36.00
9 x 9¾	6	87.8	143.	695.	20.7	10.00	9 x 32½	20	293.	1,584.	25,750.	69.0	33.33
5¼ x 13	8	68.3	148.	961.	16.1	8.00	12½ x 27⅝	17	345.	1,590.	21,960.	81.5	39.67
7 x 11⅜	7	79.6	151.	859.	18.8	9.33	14½ x 26	16	377.	1,634.	21,240.	89.0	42.67
4¼ x 14⅝	9	62.2	152.	1,108.	14.7	7.50	9 x 34⅛	21	307.	1,747.	29,800.	72.5	35.00
5 x 14⅝	9	73.1	178.	1,303.	17.3	9.00	11 x 30⅞	19	340.	1,748.	26,980.	80.2	38.00
4¼ x 16¼	10	69.1	187.	1,520.	16.3	8.33	12½ x 29¼	18	366.	1,782.	26,070.	86.3	42.00
5¼ x 14⅝	9	76.8	187.	1,369.	18.1	9.00	14½ x 27⅝	17	401.	1,844.	25,470.	94.5	45.33
9 x 11⅜	7	102.	194.	1,104.	24.2	11.67	9 x 35¾	22	322.	1,917.	34,270.	75.9	36.67
9 x 13	8	91.0	197.	1,282.	21.5	10.67	11 x 32½	20	358.	1,936.	31,470.	84.4	40.00
5 x 16¼	10	81.3	220.	1,788.	19.2	10.00	12½ x 30⅞	19	386.	1,986.	30,660.	91.1	44.33
4¼ x 17⅞	11	76.0	226.	2,023.	17.9	9.17	14½ x 29¼	18	424.	2,068.	30,240.	100.	48.00
5¼ x 16¼	10	85.3	231.	1,877.	20.1	10.00	9 x 37⅜	23	336.	2,095.	39,160.	79.4	38.33
11 x 11⅜	7	125.	237.	1,349.	29.5	14.00	11 x 34⅛	21	375.	2,135.	36,430.	88.6	42.00
7 x 14⅝	9	102.	250.	1,825.	24.2	12.00	12½ x 32½	20	406.	2,201.	35,760.	95.9	46.67
9 x 13	8	117.	254.	1,648.	27.6	13.33	9 x 39	24	351.	2,282.	44,490.	82.8	40.00
5 x 17⅞	11	89.4	266.	2,380.	21.1	11.00	14½ x 30⅞	19	448.	2,304.	35,560.	106.	50.67
4¼ x 19½	12	82.9	269.	2,626.	19.6	10.00	11 x 35¾	22	393.	2,343.	41,880.	92.8	44.00
5¼ x 17⅞	11	93.8	280.	2,499.	22.2	11.00	12½ x 34⅛	21	427.	2,426.	41,390.	101.	49.00
7 x 16¼	10	114.	308.	2,503.	26.8	13.33	9 x 40⅝	25	366.	2,476.	50,290.	86.3	41.67
11 x 13	8	143.	310.	2,014.	33.8	16.00	14½ x 32½	20	471.	2,553.	41,480.	111.	53.33
4¼ x 21⅛	13	89.8	316.	3,339.	21.2	10.83	11 x 37⅜	23	411.	2,561.	47,860.	97.0	46.00
5 x 19½	12	97.5	317.	3,090.	23.0	12.00	12½ x 35¾	22	447.	2,663.	47,590.	105.	51.33
9 x 14⅝	9	132.	321.	2,346.	31.1	15.00	9 x 42¼	26	380.	2,678.	56,560.	89.7	43.33
5¼ x 19½	12	102.	333.	3,244.	24.2	12.00	11 x 39	24	429.	2,789.	54,380.	101.	48.00
12½ x 13	8	163.	352.	2,289.	38.4	18.67	14½ x 34⅛	21	495.	2,814.	48,020.	117.	56.00
5 x 21⅛	13	106.	372.	3,928.	24.9	13.00	9 x 43⅞	27	395.	2,888.	63,350.	93.2	45.00
7 x 17⅞	11	125.	373.	3,332.	29.5	14.67	12½ x 37⅜	23	467.	2,910.	54,380.	110.	53.67
5¼ x 21⅛	13	111.	390.	4,124.	26.2	13.00	11 x 40⅝	25	447.	3,026.	61,460.	105.	50.00
11 x 14⅝	9	161.	392.	2,867.	38.0	18.00	14½ x 35¾	22	518.	3,089.	55,210.	122.	58.67
9 x 16¼	10	146.	396.	3,218.	34.5	16.67	9 x 45½	28	410.	3,105.	70,650.	96.6	46.67
5 x 22¾	14	114.	431.	4,906.	26.9	14.00	12½ x 39	24	488.	3,169.	61,790.	115.	56.00
7 x 19½	12	137.	444.	4,325.	32.2	16.00	11 x 42¼	26	465.	3,273.	69,130.	110.	52.00
12½ x 14⅝	9	183.	446.	3,258.	43.1	21.00	14½ x 37⅜	23	542.	3,376.	63,090.	128.	61.33
5¼ x 22¾	14	119.	453.	5,151.	28.2	14.00	12½ x 40⅝	25	508.	3,438.	69,840.	120.	58.33
9 x 17⅞	11	161.	479.	4,284.	38.0	18.33	11 x 43⅞	27	483.	3,529.	77,420.	114.	54.00
11 x 16¼	10	179.	484.	3,933.	42.2	20.00	14½ x 39	24	566.	3,676.	71,680.	133.	64.00
5 x 24⅜	15	122.	495.	6,034.	28.8	15.00	12½ x 42¼	26	528.	3,719.	78,560.	125.	60.67
14½ x 14⅝	9	212.	517.	3,780.	50.1	24.00	11 x 45½	28	501.	3,795.	86,350.	118.	56.00
5¼ x 24⅜	15	128.	520.	6,336.	30.2	15.00	14½ x 40⅝	25	589.	3,988.	81,020.	139.	66.67
7 x 21⅛	13	148.	521.	5,499.	34.9	17.33	12½ x 43⅞	27	548.	4,010.	87,980.	129.	63.00
12½ x 16¼	10	203.	550.	4,470.	47.9	23.33	11 x 47⅛	29	518.	4,071.	95,930.	122.	58.00
5 x 26	16	130.	563.	7,323.	30.7	16.00	12½ x 45½	28	569.	4,313.	98,120.	134.	65.33
9 x 19½	12	176.	570.	5,561.	41.4	20.00	14½ x 42¼	26	613.	4,314.	91,130.	145.	69.33
11 x 17⅞	11	197.	586.	5,235.	46.4	22.00	11 x 48¾	30	536.	4,357.	106,200.	127.	60.00
5¼ x 26	16	137.	592.	7,690.	32.2	16.00	12½ x 47⅛	29	589.	4,627.	109,010.	139.	67.67
7 x 22¾	14	159.	604.	6,868.	37.6	18.67	11 x 50⅜	31	554.	4,652.	117,180.	131.	62.00
14½ x 16¼	10	236.	638.	5,185.	55.6	26.67	14½ x 43⅞	27	636.	4,652.	102,060.	150.	72.00
12½ x 17⅞	11	223.	666.	5,949.	52.7	25.67	12½ x 48¾	30	609.	4,951.	120,680.	144.	70.00
9 x 21⅛	13	190.	669.	7,071.	44.9	21.67	14½ x 45½	28	660.	5,003.	113,820.	156.	74.67
7 x 24⅜	15	171.	693.	8,448.	40.3	20.00	12½ x 50⅜	31	630.	5,287.	133,160.	149.	72.33
11 x 19½	12	215.	697.	6,797.	50.6	24.00	14½ x 47⅛	29	683.	5,367.	126,460.	161.	77.33
14½ x 17⅞	11	259.	772.	6,901.	61.2	29.33	14½ x 48¾	30	707.	5,743.	139,990.	167.	80.00
9 x 22¾	14	205.	776.	8,831.	48.3	23.33	14½ x 50⅜	31	730.	6,133.	154,470.	172.	82.67

*With glued laminated structural lumber, many additional sizes may be obtained. Greatest economy will result by using standard widths and depths that are multiples of standard board and dimensions lumber thicknesses.

LUMBER GRADES

Every piece of lumber, due to the individuality of the tree from which it is produced, has individual characteristics; consequently an infinite number of lumber grades could be developed. For economy and convenience in distribution and merchandising, it is necessary to limit the number of grades.

Each lumber grade is a grouping of pieces, all slightly different but all suitable for the use for which the grade is intended. The purpose of a grading rule is to describe as accurately as possible the pieces which may be accepted in each grade. Though grade descriptions list the maximum characteristics which may be accepted, the majority of pieces that fall within a grade will contain less than the maximum characteristics permitted.

Lumber grade classifications may be roughly described as appearance grades, construction grades, and stress grades. Grade selection will depend upon use requirements, appearance, or economics.

To keep pace with progress in the development of new methods of grading lumber, and to meet changing conditions, the West Coast Lumber Inspection Bureau issues new Standard Grading and Dressing Rules from time to time. The West Coast Lumber Inspection Bureau serves the buyers and users of lumber by providing uniform inspection and identification of grades with registered grade stamps or certification. Arrangements can also be made for reinspection of delivered lumber.

Appearance Grades:

Appearance grades of Douglas fir are used where the wood surface is exposed to view. These grades are customarily available in three levels of appearance quality and may be obtained in vertical grain (V.G.), flat grain (F.G.), or mixed grain (M.G.). They are manufactured for use as:

Finish
Casing and base
Flooring
Ceiling, siding and rustic
Bevel siding
Stepping

Construction Grades:

Construction grades are divided into three size classifications; boards, dimension, and timbers.

Douglas fir boards are available in five grades and are used as sub-floors, roof and wall sheathing, concrete forms, and similar types of construction.

Dimension lumber is sub-divided into two width classifications; Light Framing is available in widths up to four inches, and Joists and Planks are in widths six inches and wider. There are eight grades of Light Framing and seven grades of Joists and Planks. More than half of the Dimension grades are stress-graded.

The non-stress grades are used for studding, blocking, bridging, short span joists and rafters, and in laminated decks where deflection is the governing factor. These grades are also used for form work, crating, and numerous other applications.

Timbers of Douglas fir are also subdivided into two width classifications; Beams and Stringers, which are rectangular in shape, and Posts and Timbers, which are generally square. The majority of these grades are stress-graded.

The non-stress grades are extensively used for blocking, props, mine timbering and general construction purposes.

Stress Grades:

Stress-grades of Douglas fir are especially suited for all types of engineered construction such as bridges, docks, warehouses, trusses, towers, and other structures where members are loaded to their full capacity.

Grades for Laminating Glued Structural Members:

The laminations of structural glued laminated members are of nominal two-inch thickness or less. As such members are usually loaded to their maximum capacity, laminations are required to be of assured strength.

Though standard grades, both stress-grades and non-stress grades, are used for the laminations of members, they are specially selected as to growth characteristics in accordance with laminating standards.

LUMBER GRADES

Standard Grades and Classifications:

Paragraph numbers refer to general paragraphs for Douglas fir in the "Standard Grading and Dressing Rules" of the West Coast Lumbermen's Association, Portland 5, Oregon.

- lumber
  - boards — 1" to 1½" thick 2" and wider.
    - appearance grades
      - Finish
        - Para. 101: "B & Btr.", "C", "D" — V.G.
        - Para. 102: "C & Btr.", "D" — F.G. or M.G.
      - Casing and Base
        - Para. 103: "B & Btr.", "C", "D" — V.G.
        - Para. 104: "C & Btr.", "D" — F.G. or M.G.
      - Flooring
        - Para. 105: "B & Btr.", "C", "D" — V.G.
        - Para. 106: "C & Btr.", "D" — F.G. or M.G.; "E" — M.G.
      - Ceiling, Siding and Rustic
        - Para. 107: "C & Btr.", "D", "E" — V.G., F.G. or M.G.
      - Bevel Siding
        - Para. 108 graded under Para. 208: "B & Btr.", "C", "D" — V.G.
      - Stepping
        - Para. 110: "B & Btr.", "C", "D" — V.G.
    - boards, sheathing and form lumber
      - Para. 120: Select Merchantable, Construction, Standard, Utility, Economy
  - dimension — 2" to 4" thick any width.
    - Light Framing
      - 2" to 4" thick 4" wide. — Para. 122: Dense Select Structural*, Select Structural*
      - 2" to 4" thick 2" to 4" wide. — Para. 122: Construction, Standard, Utility, Economy
      - 2" to 4" thick 4" wide. — Para. 153: 1500 "f" Industrial*, 1200 "f" Industrial*
    - Joists and Planks
      - 2" to 4" thick 6" and wider. — Para. 123: Dense Select Structural*, Select Structural*, Dense Construction*, Construction*, Standard*, Utility, Economy
  - timbers — 5" thick and thicker, 5" wide and wider.
    - Beams and Stringers
      - 5" and thicker, rectangular, width more than 2" greater than thickness. — Para. 124: Dense Select Structural*, Select Structural*, Dense Construction*, Construction*, Standard (No. 1 Mining), Utility (No. 2 Mining)
    - Posts and Timbers
      - 5"x5" and larger, width not more than 2" greater than thickness. — Para. 125: Dense Select Structural*, Select Structural*, Dense Construction*, Construction*, Standard (No. 1 Mining), Utility (No. 2 Mining)

* These grades are stress graded.

WORKING STRESSES AND STRESS GRADES

The determination of working stresses for stress grades of lumber requires consideration of many factors. Because of the wide range of characteristics in a log, an equally wide and uncontrolled range of strength values would result in the lumber produced unless there is complete knowledge of the effect of these characteristics on strength, as well as a practical means of limiting and segregating pieces of nearly equal value.

As it is not practical to test each piece of lumber to determine its strength, a four step procedure is used which is applicable to any species. The first step is to test clear, straight-grained specimens. The second step is to adjust the test values of clear wood to a basic working stress level. Third, the effect of growth characteristics on clear wood strength are evaluated. Lastly, the several data are translated into grading rules for use in the visual segregation of lumber into grades.

Testing Clear, Straight-Grained Specimens:

The mechanical properties of the various species of wood are evaluated by means of standard tests. By using small, clear specimens prepared from trees widely selected in the forests the effects on strength of growth characteristics are eliminated and the results give the basic strengths of the fibers of the species. Ten different types of standard tests are made on both seasoned and unseasoned specimens to determine values for the different mechanical properties. Variance is found in these values, but this is typical of all structural materials. As a very large number of tests are made, very complete and accurate information is obtained covering the range of variability.

Adjustment of Clear Wood Test Data to Working Stresses:

In the establishment of working stresses, consideration is given to many factors. These include: strength of the clear wood and its variability, strength of structural lumber containing natural growth characteristics of the species and its behavior, manufacturing variables, reliability of grading, tolerance in design, tolerance in construction, possible overloading, degree of maintenance, duration of load, temperature and moisture effects, and other unforeseen conditions.

Some of these factors are well understood or can be evaluated accurately from available data. Others must depend on engineering judgment and experience. The most important of the factors considered are the strength and variability of the clear wood, the duration of stress, unforeseen conditions, and the degree of engineering judgment.

The several factors considered comprise a composite reduction which, to meet modern engineering philosophy, is described herein as a "reduction factor." All of these factors are separately and collectively analyzed to the probability of minimum conditions occurring simultaneously to cause failure.

As the determination of working stresses assumes that each piece will safely carry its full design load for the life of the structure, it follows that the stress values must be related to the lower portion of the strength range of the species. The statistical studies indicate that the true factor of safety as related to the fiber strength of a species, is about 2½ on the average quality of stress-grades, about one piece in one hundred will be as low as 1¼, and an occasional piece will have a factor as high as 5. The average over-all reduction factor for Douglas fir, which has a basic clear wood working stress of 2,200 lbs. per sq. in. for full load permanently applied and an average modulus of rupture of 7,600 lbs. per sq. in., is about 3½.

By applying the reduction factor, which includes a duration of load adjustment to convert the short period of test loading to a condition of full load permanently applied, basic working stresses for clear, unseasoned wood are derived.

Wood has an unusual property not found in other construction materials. This is its ability to carry a proportionately greater load as the duration of the period of loading is shortened, and higher stress values can be used for shorter duration loads without encroaching on the reduction factor. For maximum economy, the working stresses at the permanent load level are adjusted to a duration of loading that is more in keeping with loadings normally anticipated in the design of structures. This adjustment is a 10 per cent increase applied to the basic clear wood working stresses in recognition of a "normal condition of loading". For a complete discussion of "normal condition of loading" and other duration of load adjustments, refer to page 12.

Strength Properties of Wood:

As wood is not a homogeneous material, it has different strength properties with respect to the direction of the fibers. Hence, as a member may be loaded in many ways, it is necessary to consider the effect of the growth characteristics as they apply to the different types of stress induced by the method of loading. These stresses are:

WORKING STRESSES AND STRESS GRADES

1. Extreme fiber in bending "f":

A majority of all lumber is stressed in bending. Typical are the joists, stringers and beams carrying loads on spans between supports.

2. Tension parallel to grain "t":

Tension parallel to grain stresses occur in members stressed axially, such as the bottom chords and about half of the web members of trusses.

3. Compression parallel to grain "c":

Much of the structural lumber used is stressed axially in compression parallel to the grain. This type of stress is induced in studs, posts, struts, the top chord and some of the web members of trusses.

4. Compression perpendicular to grain "c⊥":

"Side grain bearing" is another name for compression perpendicular to grain. It occurs at the point of bearing of beams, joists and the like, and under concentrated loads.

5. Horizontal shear stress "H":

Members that are stressed in bending are also stressed in horizontal shear at points of support. There the fibers tend to slide over each other horizontally. The stress is a maximum at the center of the depth of a piece. The internal resistance to this action is the horizontal shear value of the wood.

6. Modulus of elasticity "E":

Modulus of elasticity is the measure of stiffness. When this value is known, the amount of deflection due to an applied load can be predetermined.

Effect of Growth Characteristics:

Growth characteristics that affect strength are knots, slope of grain, checks, splits and shake. In a very few species, including Douglas fir, the rate of growth and density influence strength.

Knots:

The size of knots has an effect on bending, tension parallel to grain and compression parallel to grain strengths. In members stressed in bending, their size relative to their location determines their effect. In the tree the presence of the limb which produces the knot does not reduce strength because of the deviation of the fiber around it. In lumber the fibers at knots are cut and this reduces strength. Knots and holes have the same effect on strength, but grading rules frequently limit holes to a smaller size than knots for appearance reasons. For pieces stressed in bending, the size of knots that occur in a zone along the edges of the wide faces in the middle ⅓ of the length of a piece, the more highly stressed portions, is more limited than those elsewhere on the face. For members stressed in axial tension or compression, the stress is uniform over the cross-section, and the size of a knot but not the location affects the strength.

Slope of Grain:

Slope of grain is the deviation of the fibers from a line parallel to the axis of a piece of lumber. The importance of slope of grain on strength must not be minimized. Slope of grain has the greatest effect on bending and tension parallel to grain strengths. Compression perpendicular to grain and horizontal shear strength values are not affected by slope of grain. For compression parallel to grain, a strength value can be assigned when the slope is as steep as 1 in 6. A slope of 1 in 20 or flatter is considered straight grain and does not reduce strength. Local deviations, as around knots, are disregarded as having no effect.

Checks, Splits and Shakes:

Horizontal shear strength in members stressed in bending is affected by the presence of checks, splits and shakes. As there is no way to predetermine the extent of splits or checks in lumber after it has been delivered, it may sometimes be necessary to reevaluate the shear strength based on the actual extent of checks and splits and compare this value against the stress produced in use. Horizontal shear is generally critical only in short heavily loaded beams.

Shakes and checks, as a rule, have little influence on the strength of a post or column, unless so extensive as to split the piece practically in two. Limitations on shakes and checks in Post and Timber grades are made for appearance and are not related to compression, "c", strength.

Checks and splits can be effectively retarded by the use of inexpensive chemicals and end seals. See page 18.

Rate of Growth and Density:

The strength of wood increases in proportion to the amount of wood substance present, the specific gravity. In Douglas fir and a very few other species with a pronounced difference between spring wood and summer wood, the rate of growth, or the number of growth rings per inch is one means of classifying specific gravities.

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The cell walls of the summer wood portion of the growth rings of Douglas fir are much thicker and darker and contain more wood substance than the spring wood portion. It is because of these thicker cell walls in the summer wood that Douglas fir is considered one of the strongest of the soft woods. The amount of summer wood present in the annual rings of Douglas fir is also an indication of better than average specific gravity.

Douglas fir is divided into three specific gravity classifications. These are "medium grain," "close grain," and "dense." "Medium grain" requires a minimum of four growth rings per inch for the strength and stiffness needed in the lower stress grades. "Close grain" calls for at least six rings per inch, but not more than 30, and is a requirement in the higher stress grades. If in addition to close grain, the summer wood portion of the growth rings average ⅓ or more of the ring area over a representative portion of the cross-section of the piece, the piece is classified as "dense" and the strength is increased due to its greater specific gravity.

A lesser number of growth rings may be accepted in "medium grain" and "close grain" when there is a large proportion of summer-wood present. The grading rules specify these alternate conditions.

Modulus of elasticity is not affected by any of these growth characteristics except for non-dense pieces having less than four rings per inch, when it is reduced by about 25 per cent.

Seasoning Effects:

The strength of wood fibers increases materially as moisture content decreases below the fiber saturation point to about 15 per cent m.c. Advantage of part of the total increase is taken by increasing the working stresses for Dimension lumber that may be seasoned before use, or, because of small size, will rapidly season in use before full design loads are reached. With the exception of modulus of elasticity, this increase is limited to the small sizes only, 4-inches and less in thickness, since the increase in fiber strength in the larger sizes, over 5-inches in thickness, is largely offset by secondary stresses that result during the seasoning. Due to the nature of stresses in most members, only the outer fibers of pieces of all sizes need to be seasoned in order to take advantage of the increase in stiffness for drying.

Strength Ratios:

The term "strength ratio" describes the ratio of the strength of a piece containing a growth characteristic to the basic recommended clear wood working strength of a piece of the same size. Strength ratios for various sizes of knots, for slope of grain and for checks, splits and shakes as they apply to bending, shear and compression parallel to grain have been established. By multiplying the basic clear wood working strengths, at the normal loading level, by the strength ratios for the growth characteristics of a grade, working strength values are determined for the species and grade.

Preparation of Grading Rules for Stress-Grades:

The fourth and final step for the stress-grades of lumber is to prepare grading rules that are applicable to the segregation of pieces by visual inspection. In this operation typical growth characteristics must be correlated with desirable stress levels for design purposes, and by the use of the strength ratios for growth characteristics, appropriate working stresses are assigned to each stress-grade. Seventeen stress-grades fulfill these requirements for Douglas fir. In the dimension sizes four of the stress-grades appear in the Light Framing category and five are allocated to the Joists and Planks. In the timber sizes there are four stress-grades in Beam and Stringer and four in Post and Timber grades. Other grades with even higher working stresses could be written but are deemed impractical because of greater cost and limited availability.

The size classification of the stress-grades contemplates primary uses, but does not exclude other uses. For example: Dimension lumber is of 2-inches to 4-inches in thickness with Light Framing, the narrower, available up to 4-inches wide, and Joists and Planks, the wider, available in 6-inch and wider widths. These grades are prepared primarily for members stressed in bending, as joists, planks and similar members, but may also be used as tension or compression members, as studding, small posts, or truss members. Timbers are the largest sizes of sawn lumber as they have a minimum nominal dimension of 5 inches. In these larger sizes, the Beam and Stringer grades are rectangular in shape with the width more than 2-inches wider than the thickness. The grades contemplate the members being stressed in bending with the load applied on the narrow face. They may also be used as tension or compression members, such as posts or truss members. The Post and Timber grades are usually square, but may be as much as 2 inches wider than the thickness. The contemplated use is where they are stressed in compression parallel to grain. They may also

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be used in tension or in bending. By special order, the Post and Timber sizes may be graded under the Beam and Stringer rules. Appropriate working stresses for all of these stress-grades and for all uses have been assigned.

As wood fibers are strongest in tension parallel to grain, the same value determined for bending stress is used for tension. The greater strength of the fibers permits the tension value to be based on the largest knot permitted in the grade.

Special Grade Requirements for Tension Members:

When Joist and Plank or Beam and Stringer grades are to be used in tension, the slope of grain specified for the middle ⅓ of the length of the piece should be required for the full length of the piece. Without this additional restriction on slope of grain, the strength value for bending assigned to the next lowest grade should be used for tension parallel to grain.

Special Grade Requirements for Multiple Span Members:

Joist and Plank and Beam and Stringer grades ordinarily are graded for use on simple spans. When used as continuous members, the grading provisions customarily applied to the middle ⅓ of the length of the piece must be applied to the middle ⅔ of the length when it is to be used over two spans and to the entire length when it is to be used over three or more spans. This restriction is necessary since a member continuous over several spans is subjected to higher stresses near the ends than a member on a simple span.

Regrading Resawn Lumber:

When stress-grade lumber is resawn it requires regrading, since a growth characteristic permitted in the original size may have a greater effect on the smaller resawn size and the allowable unit stresses for the regraded lumber would then apply.

Establishing Working Stresses for Glued Laminated Members:

The same basic clear wood working stresses are used in deriving working stresses for combinations of grades of laminations in glued laminated structural members. Hence, the assigned working stresses for glued laminated members are comparable to the values assigned to sawn members as they have the same reduction factor.

As growth characteristics, such as knots, will be widely dispersed throughout a laminated member, their effect on the strength of the member will be less than on the individual piece. By statistics and analysis, using lumber with characteristics as they naturally occur, the actual effect of the probable dispersion of growth characteristics in glued laminated structural members of Douglas fir has been used in establishing the stress values for members laminated with various combinations of standard Douglas fir grades. However, some special selection is necessary before the standard grades can be used. Non-stress grades are selected according to special stress-grade requirements and slope of grain is more limited than specified in the standard stress grades. These requirements are outlined in laminating standards.

Laminations used in glued members must be kiln dried before gluing, to a lower moisture content than is normal to commercial drying of 1 and 2 inch construction grades. As the strength of wood increases materially with dryness, glued laminated members, that will be used under continually dry conditions, take maximum advantage of this property of wood. When such members are used under wet conditions, the working stresses are slightly higher than those of sawn lumber due to the dispersion of growth characteristics. Laminating standards list appropriate working stresses for several combinations of Douglas fir grades and for dry or wet conditions of use.

Facsimile of Grade Stamps for Stress Grades of Douglas Fir:

The stress grade may be indicated either by name or by stress value as illustrated.

MILL 750 WCLB® SEL-STR	MILL 750 WCLB® CONST	MILL 750 WCLB® STAND
MILL 750 WCLB 1900 f ®DOUG. FIR	MILL 750 WCLB 1500 f ®DOUG. FIR	MILL 750 WCLB 1200 f ®DOUG. FIR

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Stress Grades: (Allowable Unit Working Stresses for Normal Conditions of Loading, lbs. per sq. in.)

Grade	Grading Rules Paragraph No.	Extreme fiber in bending "f" and tension parallel to grain "t"	Horizontal Shear "H"	Compression perpendicular to grain "c⊥"	Compression parallel to grain "c"
Light Framing, 2″ to 4″ thick—4″ wide.					
Dense Select Structural	122-aa	2050	120*	455	1500
Select Structural	122-a	1900	120*	415	1400
1500 "f" Industrial†	153-b	1500	120*	390	1200
1200 "f" Industrial†	153-c	1200	95*	390	1000

†These grades are specially selected for strength. They are not customarily available as stock lumber items.

Grade	Grading Rules Paragraph No.	"f" and "t"	"H"	"c⊥"	"c"
Joists and Planks, 2″ to 4″ thick—6″ and wider.					
Dense Select Structural	123-aa	2050	120*	455	1650
Select Structural	123-a	1900	120*	415	1500
Dense Construction	123-bb	1750	120*	455	1400
Construction	123-b	1500	120*	390	1200
Standard	123-c	1200	95*	390	1000

Modulus of elasticity "E"—1,760,000 ~~except pieces of less than medium grain, when included in the grade of "Standard", may be considered as having a modulus of elasticity of 1,320,000.~~

***Notes on horizontal shear values:** The tabulated values apply when pieces 2″, 3″ and 4″ thick are used as planks and to the "Select Structural" grade of pieces 2″ thick when used as joists.

The values do not apply to pieces of the grades of "Construction" and "Standard", 2″ thick, when used as joists if the maximum splits permitted in the grades are present. If splits are present, allowable shear value for any grade may be determined from the following, with other values proportionate:

Length of split approximately equal to:	Horizontal Shear "H"
½ the width	120
the width	100
1½ times the width	70

The values do not apply to pieces 3″ and 4″ thick when used as joists if the maximum splits permitted in the grade are present. If splits are present, allowable shear values may be determined for any grade from the following, with other values proportionate:

Nominal thickness of piece	Length of split	Horizontal Shear "H"
3″	2¼″	120
	4½″	80
4″	3″	120
	6″	80

Grade	Grading Rules Paragraph No.	"f" and "t"	"H"	"c⊥"	"c"
Beams and Stringers, 5″ and thicker—more than 2″ wider than thickness.					
Dense Select Structural	124-aa	2050	120**	455	1500
Select Structural	124-a	1900	120**	415	1400
Dense Construction	124-bb	1750	120**	455	1200
Construction	124-b	1500	120**	390	1000

****Notes on horizontal shear values:** The tabulated shear values do not apply to Beams and Stringers when the maximum splits permitted in the grades are present. If splits are present, allowable shear values may be determined from the following, with other values proportionate:

Length of split approximately equal to:	Horizontal Shear "H"
½ the nominal narrow face dimension	120
nominal narrow face dimension	100
1½ times the nominal narrow face dimension	80

Grade	Grading Rules Paragraph No.	"f" and "t"	"H"	"c⊥"	"c"
Posts and Timbers, 5″ x 5″ and larger—width not more than 2″ greater than thickness. (If graded under the Beam and Stringer paragraph, the Beam and Stringer stress values apply.)					
Dense Select Structural	125-aa	1900	120***	455	1650
Select Structural	125-a	1750	120***	415	1500
Dense Construction	125-bb	1500	120***	455	1400
Construction	125-b	1200	120***	390	1200

Modulus of elasticity "E"—1,760,000 if pieces in the Beam and Stringer and Post and Timber grades are permitted to season to a substantial depth from the surface before full load is applied. Otherwise use 1,600,000 which is a minimum value for any condition of service.

*****Notes on horizontal shear values:** For the horizontal shear values shown, checks and shakes must be limited as for a Beam and Stringer grade. Also, when splits are present, the extent of the split may limit the shear value as in the Beam and Stringer grades.