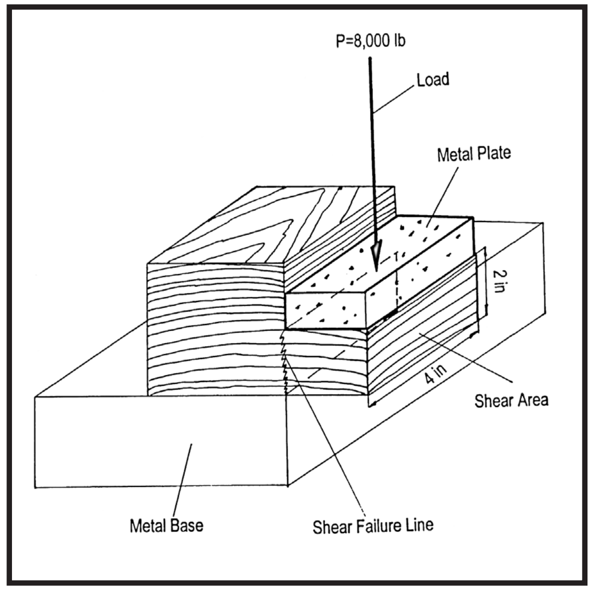

Figure 4. Sheer stress of a sample.

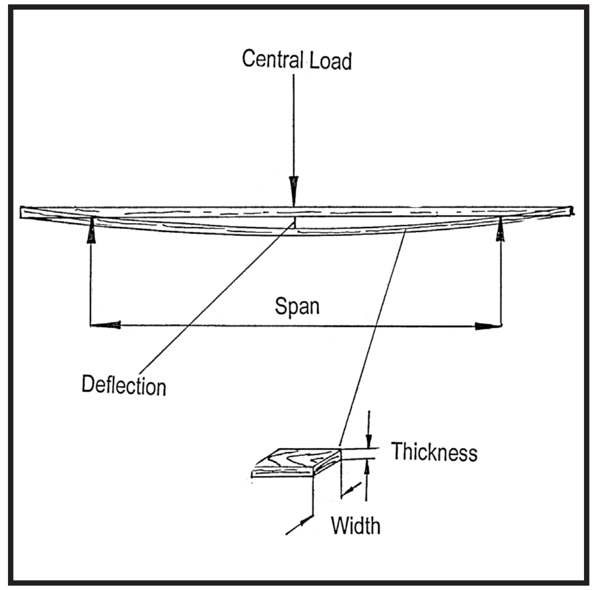

Figure 5. Bending of a wood beam.

The Oklahoma Cooperative Extension Service
Bringing the University to You!

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; home economics; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of Cooperative Extension are:

- The federal, state, and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and based on factual information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government, and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

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Strength Properties of Wood for Practical Applications

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FAPC Wood Products Specialist

Mechanical properties of wood play an important role when used for different design applications. Wood is widely used for structural purposes. This fact sheet summarizes some of the basic concepts related to mechanical characteristics of wood, including viscoelasticity, compression, shear, bending strength properties and how such characteristics should be taken into consideration for an efficient practical design.

Viscoelasticity

In contrast to metals and plastics, wood is an orthotropic material, meaning its properties will be independent in three directions – longitudinal, tangential and radial, as illustrated in Figure 1. Another unique property of wood is its viscoelasticity, which can be described as having both plastic and elastic characteristics when exposed to a certain deformation.

Elastic materials easily stretch under an applied load. However, they return to their original conditions once the load is released. In contrast, plastic materials stay at the stretched condition even if the load is released after a long period time. The behavior of wood products is between the above two types of conditions.

A bookshelf example can be used to illustrate the viscoelasticity of wood: A number of books are put on a shelf and, in time, it will have a limited amount of sagging deformation. When all books are removed from the shelf, it will never return to its original flat condition. Thus, there will be a residual deformation left because of its viscoelasticity. Figure 2 illustrates the viscoelastic behavior of wood, as in the bookshelf example.

Compression

Compression of wood and wood-based materials plays an important role in almost any construction projects. If the compression strength or bending strength of a 2-inch by 4-inch beam is not known, deflection due to bearing a load may cause significant deformation, which could even lead to its failure during service life. Therefore, most softwood construction lumber is graded based

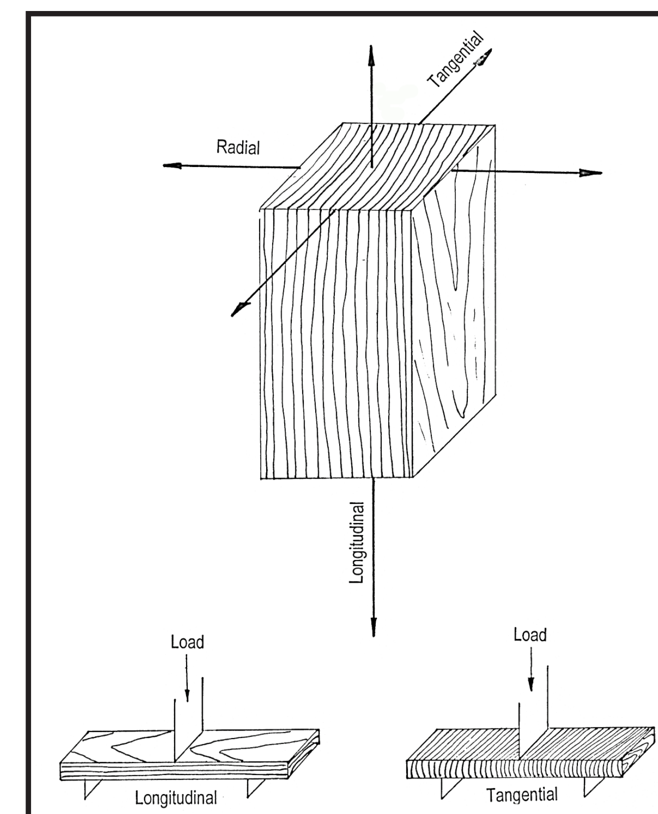

Figure 1. Orthotropic structure of wood.

on allowable load resistance, which can be determined from a stress test. However, strength properties of hardwood lumber are not that critical because a majority of it is used for furniture manufacturing and is not exposed to substantial loads.

Compression or shear strength of a wood beam or truss used extensively for construction can be calculated based on the following equation:

Sigma (σ) = P/A, where σ is stress, P is load and A is surface area.

In general, stress is the load per unit area and is expressed in pound per square inch (psi), kilogram per square centimeter (kg/cm^2) or any other units. Figures 3 and 4 show compression and shear stress developed by a perpendicularly applied load on small wood blocks.

MOE and MOR

In the case of bending a beam, we are dealing with modulus of elasticity (MOE) and modulus of rupture (MOR) to evaluate its load resistance. While MOE is a measure of the stiffness of a body, MOR is related to maximum strength that can be resisted by a member. Both are expressed as stress similar to most of the other mechanical properties of wood. The following two equations are used to calculate MOE and MOR of wood with a rectangular cross section:

$$MOE = (P L^3) / (48 I D)$$

$$MOR = (P_{max} L) / (b d^2)$$

$$I = (bd^3) / 12$$

Where:

P = load below proportional limit (lb.)

P_{max} = failure load (lb.)

L = test span (in.)

b = width of the sample (in.)

d = thickness of the sample (in.)

D = center deflection (in.)

I = moment of inertia, which is the inertia of a rigid body with respect to its rotation and, in the case of a rectangular cross section, is expressed as in^4.

In general, depending on the species, wood has MOE and MOR values of 800,000–2,500,000 psi and 5,000–15,000 psi, respectively. If a Red Oak with an approximate MOE value of 2,000,000 psi is used to make the bookshelf mentioned above, its deflection deformation will be less than that of Aspen, which has a lower MOE.

Both MOE and MOR values of different species can be obtained from various references for a particular design. Table 1 displays some of the mechanical properties, including MOE and MOR, of several species. Figure 5 also illustrates a typical beam bending with deflection as a result of a central load.

Moisture Content

The moisture content of wood also is an important parameter influencing almost all mechanical properties. Strength properties of wood increase with its decreasing moisture content. For example, air-dried wood with average moisture content of 12-13 percent will have higher strength properties than that of wood with 20 percent moisture content. In general, wood is dried to 15-20 percent moisture for typical structural application rather than using it in green condition. Strength properties of wood also can be estimated using the following equation for given moisture content, so that wood can be used with a higher efficiency for any applications:

$$P = P_{12} (P_{12} / P_g)^{(12\text{-}M / Mp\text{–}12)}$$

Where:

P = property value

P_{12} = property value at 12 percent moisture content

P_g = property value at green moisture content

M = moisture content

M_p = moisture content at which property is changed (M_p is assumed 25 percent for most species, based on USDA Forest Service, 1999).

Example: If a Douglas Fir beam has MOR values of 7,700 psi at green moisture content and 12,400 psi at 12 percent air-dry conditions, its MOR value at 18 percent moisture content can be calculated as below:

$$P = 12{,}400\ (12{,}400 / 7{,}700)^{(-6 / 13)}$$

$$P = 12{,}400 \times 1.610^{-0.461}$$

$$P = 12{,}400 / (1.610)^{0.461}$$

$$P = 9{,}959 \text{ psi}$$

Specie	MOE (psi)	MOR (psi)	Compression // to the grain (psi)	Shear // to the grain (psi)	Specific gravity
Douglas Fir	1,950,000	12,400	3,780	900	0.48
Sitka Spruce	1,570,000	10,200	5,610	1,150	0.40
White Pine	1,240,000	8,600	4,800	900	0.35
Eastern Redcedar	880,000	8,800	3,520	1,010	0.47
Red Pine	1,630,000	11,000	6,070	1,210	0.46
Cottonwood	1,100,000	6,800	4,020	790	0.34
Red Oak	2,200,000	15,400	6,770	2,020	0.63
Red Maple	2,200,000	13,400	6,540	1,850	0.54
White Oak	1,030,000	10,300	6,060	1,820	0.64
Black Walnut	1,680,000	14,600	1,010	1,370	0.55

Table 1. Some of the mechanical properties of various species at 12 percent moisture content. (From Wood Handbook, 1999)

Further Information

Detailed information about mechanical properties of wood and wood products also can be found in the following literature:

Wood Handbook (1999). Wood as an engineering material. USDA Forest Products Lab: Madison, Wisconsin.

Hoadley, B. (2000). Understanding Wood. The Taunton Press: Newtown, Connecticut.

Ambsore, J. (1994). Simplified Design of Wood Structures. John Wiley & Sons, Incorporated: New York.

Smith, I., Landis, E., & Gong, M. (2003). Fracture and Fatigue in Wood. John Wiley & Sons, Incorporated: New York.

Bowyer, J., Smulsky, R., & Haygreen, J. (2007). Forest Products & Wood Science, An Introduction. Blackwell Publishing Incorporated: Malden, Massachusetts.

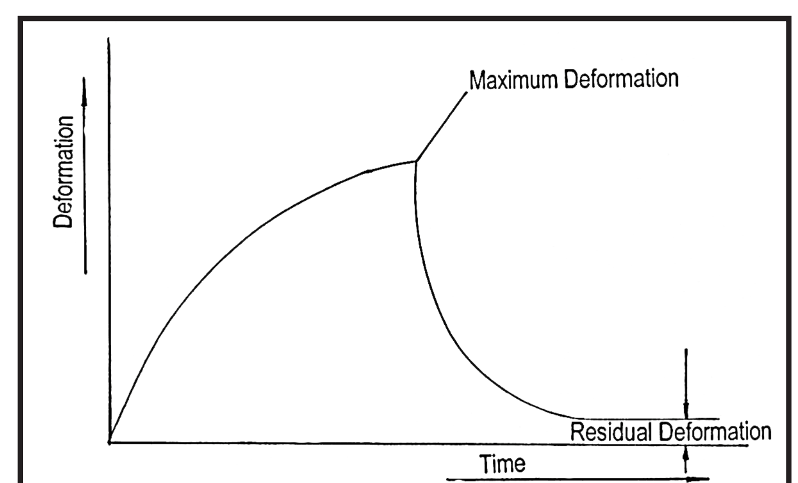

Figure 2. Viscoelastic behavior of wood.

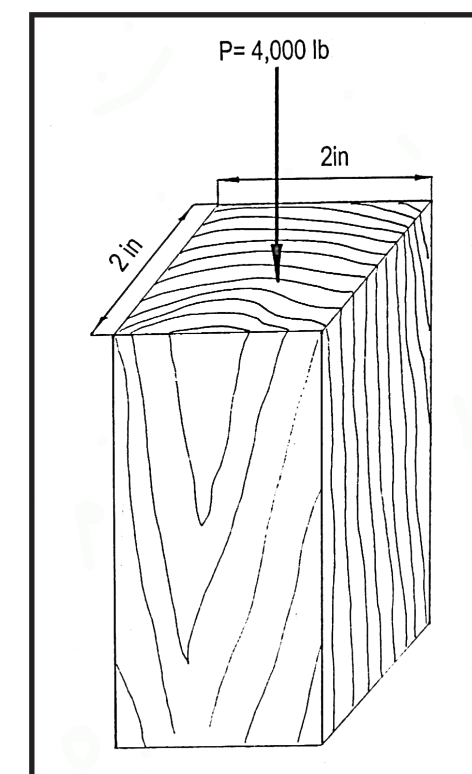

Figure 3. Compression parallel to grain.