Wood

Because of its availability, relatively low cost, ease of use, and durability (if properly designed), continues to be an important civil engineering material. Wood is used extensively for buildings, bridges, utility poles, floors, roofs, trusses, and piles.

Civil engineering applications include both natural wood and engineered wood products, such as laminates, plywood, and strand board. In order to use wood efficiently, it is important to understand its basic properties and limitations.

Natural wood

Laminate wood

Playwood

strand board

Wood Handbook, which is an excellent document describing the characteristics and properties of wood (USDA-FS, 1999).

Wood is a natural, renewable product from trees. Biologically, a tree is a woody plant that attains a height of at least 6 m (20 ft), normally has a single self-supporting trunk with no branches for about 1.5 m (4 ft) above the ground, and has a definite crown. Among 600 tree classification, exogenous trees for example are broadly classified as deciduous and conifers, producing hardwoods and softwoods, respectively. The terms *hardwood* and *softwood* are classifications within the tree family, not a description of the woods' characteristics. In general, softwoods are softer, less dense, and easier to cut than hardwoods. However, exceptions exist such as balsa, a very soft and lightweight wood that is botanically a hardwood.


Structure of Wood

Wood has a distinct structure that affects its use as a construction material. Civil and construction engineers need to understand the way the tree grows and the anisotropic nature of wood in order to properly design and construct wood structures.

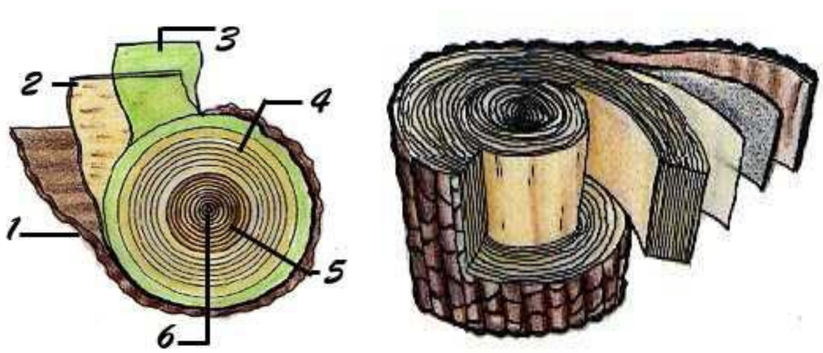
Growth Rings

The concentric layers in the stem of exogenous trees are called *growth rings* or *annual rings,* as shown. The wood produced in one growing season constitutes a single growth ring.

To understand the way the tree grows and anisotropic nature of wood as civil and construction engineers in order to properly design and construct wood structures.

The six wood forms are:

1. **Bark**: it is the protective outer layer round a tree.
2. **Phloem**: it is the living part of a tree that moves the sugar rich sap of the tree from leaves to roots.
3. **Cambium**: it is the active growing part of the tree; these thin layers of cells produce phloem on their one side and sapwood on the other.
4. **Sapwood**: it is living cells of wood that are responsible for movement of fluids and sap from the tree roots to the tree leaves.
5. **Heartwood**: it is composed of dead cells and its function is one of structural strength and support.
6. **Pith**: it is the inner central core of the tree. It has acts as a storage area for the tree storing micro- nutrient.

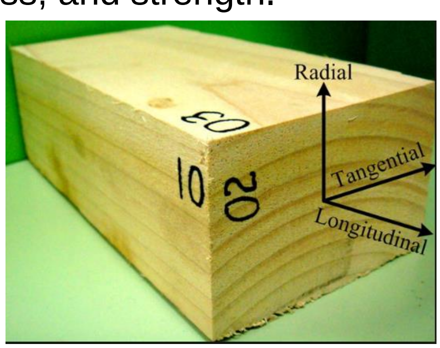


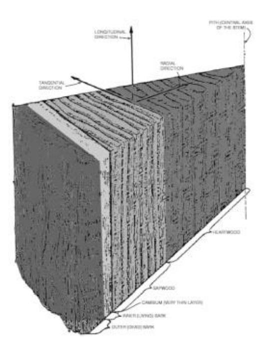
Anisotropic Nature of Wood

Wood is an anisotropic material; in that it has different and unique properties in each direction. The three axis orientations in wood are:

1- longitudinal, or parallel to the grain
2- Radial, or cross the growth rings
3- Tangential, or tangent to the growth rings.

The anisotropic nature of wood affects physical and mechanical properties such as shrinkage, stiffness, and strength.





Chemical Composition

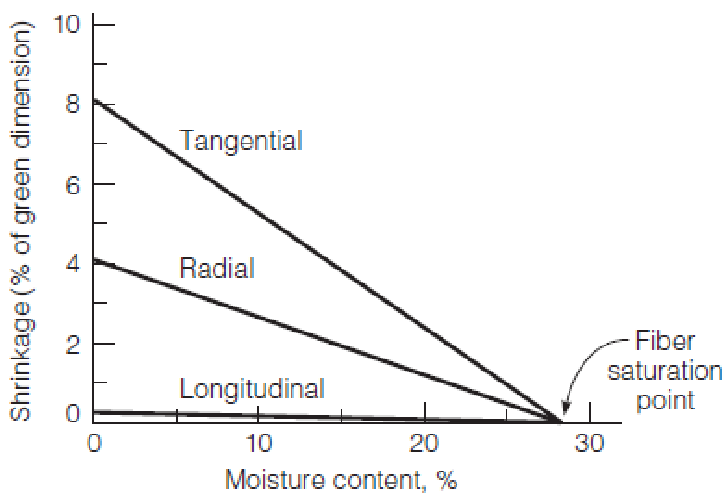
Wood is composed of cellulose, lignin, hemi-cellulose, extractives, and ash-producing minerals.

Moisture Content

The moisture content of a wood specimen is the weight of water in the specimen expressed as a percentage of the oven-dry weight of the wood. An oven-dried wood sample is a sample that has been dried in an oven at 100°C to 105°C until the wood attains a constant weight.

Physical properties such as weight, shrinkage, and strength depend on the moisture content of wood. When the moisture content of wood is above the fiber saturation point, the wood is dimensionally stable.

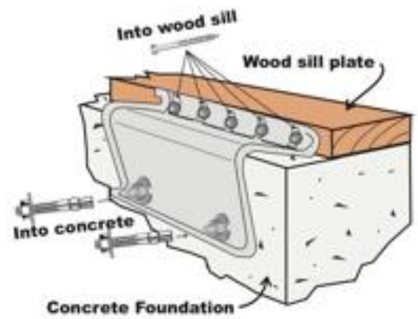
However, moisture fluctuations below the FSP always result in dimensional changes. Shrinkage is caused by loss of moisture from the cell walls, and conversely, swelling is caused by the gain of moisture in the cell walls.

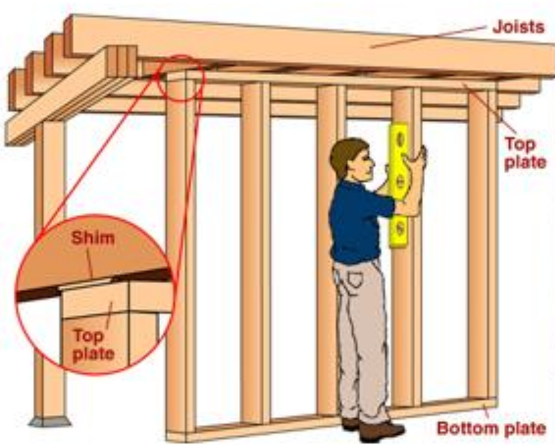


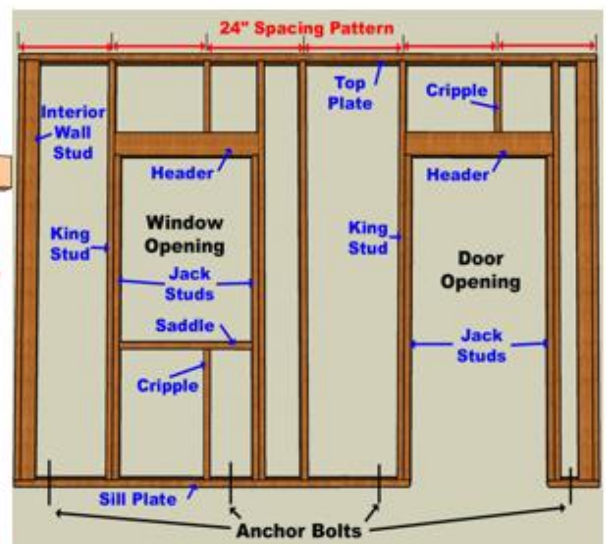
Wood Production

Wood is harvested from forests as *logs.* They are transported to saw mills, where they are cut into dimensional shapes to produce a variety of products for engineering applications:

1. *Dimension lumber* is wood from 2 in. to 5 in. thick, sawn on all four sides. Dimension lumber is typically used for studs, sill and top plates, joists, beams, rafters, trusses, and decking.

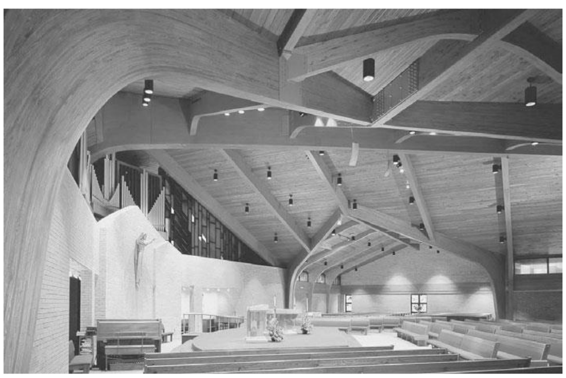




2. *Heavy timber* is wood sawn on all four sides; common shapes include 6x6 in and 8x8 in and larger. Heavy timber includes *Beams and Stringers* (subjected to bending) and *Posts and Timbers* (used as posts or columns).

3. *Round stock* consists of posts and poles used for building poles, marine piling, and utility poles.


4. *Engineered wood consists of products manufactured by bonding together wood strands, veneers, lumber, and other forms of wood fiber to produce a larger and integral composite unit.*



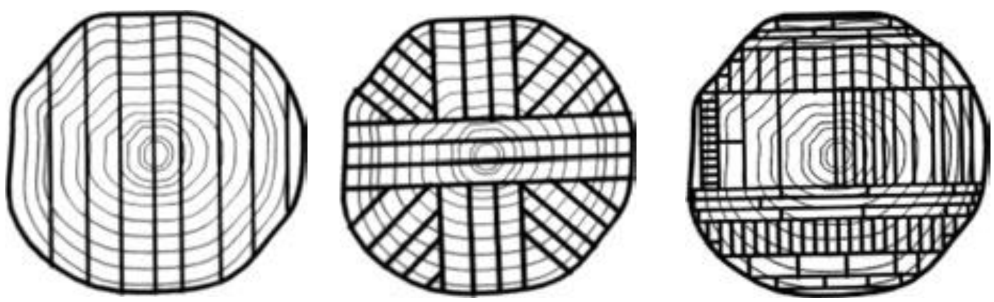

5. *Specialty items are milled and fabricated products to reduce on-site construction time, includes lattice, handrails, spindles, radius edge decking, turned posts, etc.*


Wood Processing Techniques

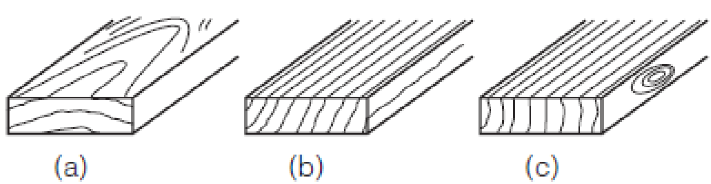
Wood production includes the following steps:

1- Sawing

Sawing into desired shape, the harvested wood is cut into lumber and timber at saw mills using circular saws, band saws, or frame saws. The most common patterns for sawing a log are *live* (*plain) sawing, quarter sawing,* and *combination sawing.*



Common log sawing patterns: (a) live (plain) sawing, (b) quarter sawing, (c) combination sawing.



Types of board cut:
(a) flat sawn, (b) rift sawn, and
(c) quarter-sawn (vertical- or edge-sawn).

2- Seasoning

Green wood, in living trees, contains from 30% to 200% moisture by the oven-dry weight. Seasoning removes the excess moisture from wood. Wood is seasoned by air and kiln drying.

Air drying is inexpensive, but slow. The green lumber is stacked in covered piles to dry. These piles of lumber are made of successive layers of boards separated by 25 mm (1 inch) strips so that air can flow between the layers. The time required for drying varies with the climate and temperature of the area. Normally, three to four months is the maximum air drying time. After air drying the lumber may be kiln dried.

A kiln is a large oven where all variables can be closely monitored. Drying temperatures in a kiln range from 20°C to 50°C, typically requiring 4 to 10 days. Care must be taken to slowly reduce the moisture content of wood. Drying too rapidly can result in an increase in cracking and warping.

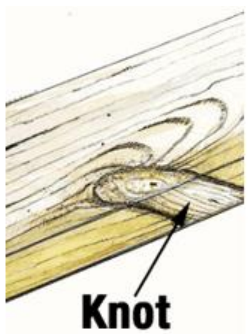
3- Surfacing

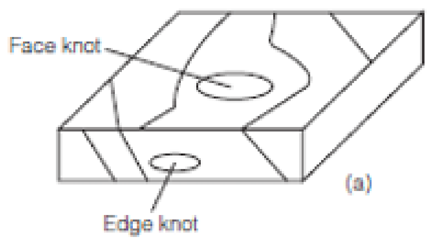
Surfacing (planning) of the wood surface, to produce a smooth face, can be done before or after drying. Post drying surfacing is superior, because it removes small defects developed during the drying process. When surfacing is done before seasoning, the dimensions are slightly increased to compensate for shrinkage during seasoning.

Defects in Lumber

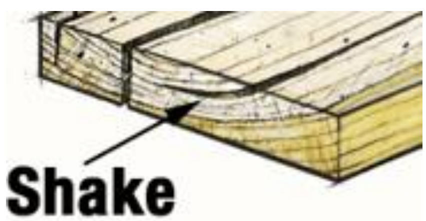
Lumber may include defects that affect its appearance, its mechanical properties, or both. These defects can have many causes, such as natural growth of the wood, wood diseases, animal parasites, too rapid seasoning, or faulty processing. Common defect types are shown below:

1. **Knots** are branch bases that have become incorporated into the wood of the tree trunk or another limb. Knots degrade the mechanical properties of lumber, affecting the tensile and flexural strengths.

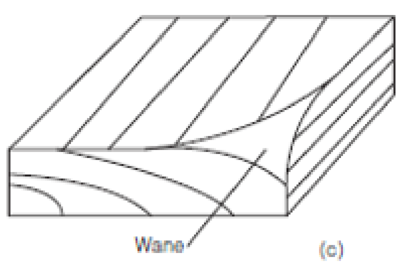




2. **Shakes** are lengthwise separations in the wood occurring between annual rings. They develop prior to cutting the lumber and could be due to heavy winds.



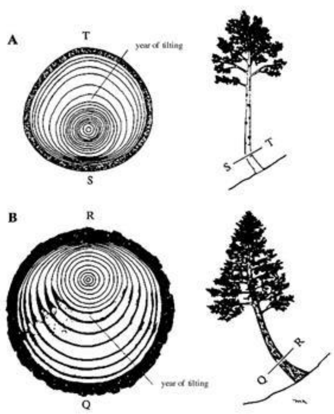
3. **Wane** is bark or other soft material left on the edge of the board or absence of material.



4. **Sap Streak** is a heavy accumulation of sap in the fibers of the wood, which produces a distinctive streak in color.

5. **Reaction Wood**

is abnormally woody tissue that forms in crooked stems or limbs. Reaction wood causes the pith to be off center from the neutral axis of the tree. It creates internal stresses which can cause warping and longitudinal cracking.

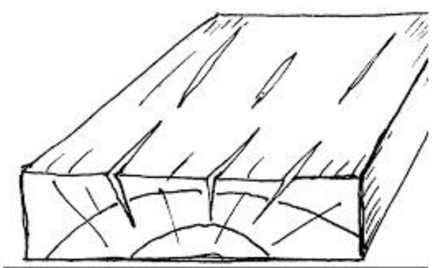


6. **Pitch Pockets** are well-defined openings between annual rings that contain free resin. Normally, only Douglas fir, pines, spruces, and western larches have pitch pockets.

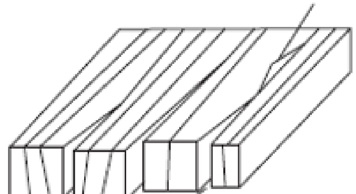



7. **Bark Pockets** are small patches of bark embedded in the wood. These pockets form as a result of an injury to the tree, causing death to a small area of the cambium. The surrounding tree continues to grow, eventually covering the dead area with a new cambium layer.

8. **Checks** are ruptures in wood along the grain that develop during seasoning. They can occur on the surface or end of a board. Surface checking results from the differential shrinkage between radial and tangential directions and is confined mostly to planer surfaces.



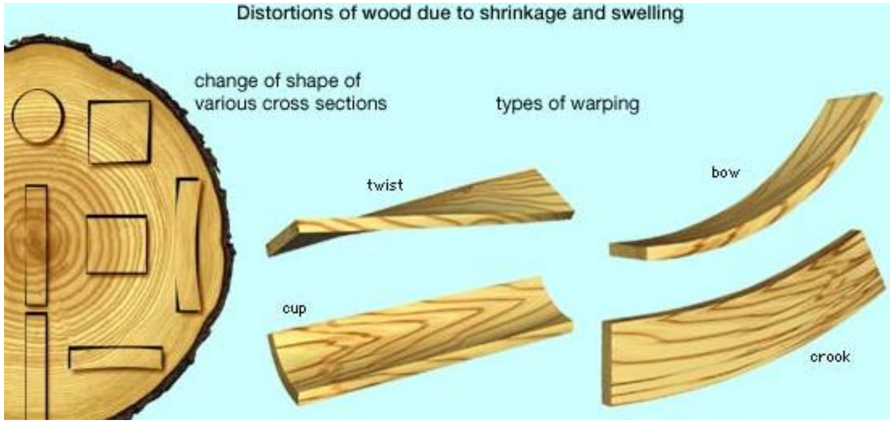
9. **Splits** are lengthwise separations of the wood caused by either mis-handling or seasoning.



10. **Warp** is a distortion of wood from the desired true plane. The four major types of warps are *bow, crook, cup,* and *twist.* Bow is a longitudinal curvature from end to end. Crook is the longitudinal curvature side to side. Both of these defects result from differential longitudinal shrinkage. Cup is the rolling of both edges up or down.

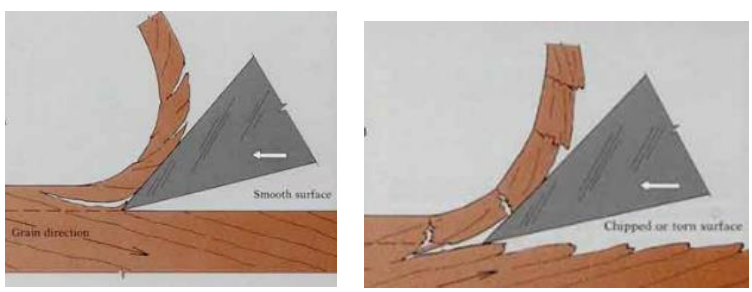
Twist is the lifting of one corner out of the plane of the other three.

Warp results from differential shrinkage, differential drying due to the production environment, or from the release of internal tree stress.



11. **Raised, Loosened, or Fuzzy Grain** may occur during cutting and dressing of lumber.

12. **Chipped or Torn Grain** occurs when pieces of wood are scooped out of the board surface or chipped away by the action of the cutting and planning tools.



13. **Machine Burn** is an area that has been darkened by overheating during cutting.

Physical Properties

1-**Specific Gravity and Density:** The specific gravity is an excellent index for the amount of substance a dry piece of wood actually contains. Therefore, specific gravity, or density, is a commonly cited property and is an indicator of mechanical properties within a clear, straight-grained wood. The dry density of wood ranges from 160 kg/m^3 for balsa to more than 1000 kg/m^3 for some species.

2-Thermal Properties: Thermal conductivity, specific heat, thermal diffusivity, and coefficient of thermal expansion are the four significant thermal properties of wood:

I. Thermal conductivity: is a measure of the rate at which heat flows through a material. The reciprocal of thermal conductivity is the thermal resistance (insulating) value (R). Wood has a thermal conductivity that is a fraction of that of most metals and three to four times greater than common insulating materials. The thermal conductivity ranges from 0.06 W/(m°K) for balsa to 0.17 W/(m°K) for rock. Structural woods average 0.12 W/(m°K) as compared to 200 W/(m°K) for aluminum and 0.04 W/(m°K) for wool.

ii- Specific Heat :Specific heat of a material is the ratio of the quantity of heat required to raise the temperature of the material one degree to that required to raise the temperature of an equal mass of water one degree. Temperature and moisture content largely control the specific heat of wood.

iii- Thermal Diffusivity: Thermal diffusivity is a measure of the rate at which a material absorbs heat from its surroundings. The thermal diffusivity for wood is much smaller than that of other common building materials. Generally, wood has a thermal diffusivity value averaging 0.006 mm/sec., compared with steel, which has a thermal diffusivity of 0.5 mm/sec.

iv- Coefficient of Thermal Expansion: The coefficient of thermal expansion is a measure of dimensional changes caused by a temperature variance. Thermal expansion coefficients for completely dry wood are positive in all directions. For both hard and soft woods, the longitudinal (parallel to the grain) coefficient values range from 0.009 to 0.0014 mm/m/°C

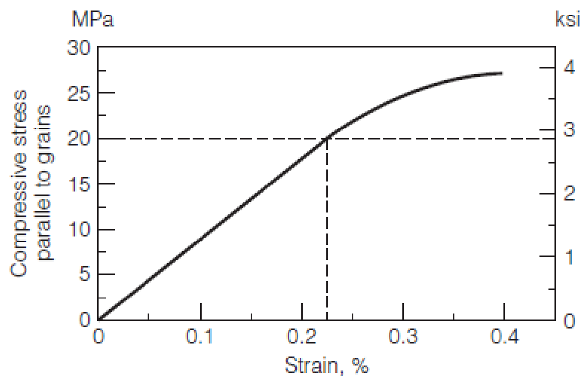
Electrical Properties

Air-dry wood is a good electrical insulator. As the moisture content of the wood increases, the resistivity decreases by a factor of three for each 1% change in moisture content. However, when wood reaches the fiber saturation point, it takes on the resistivity of water alone.

Mechanical Properties

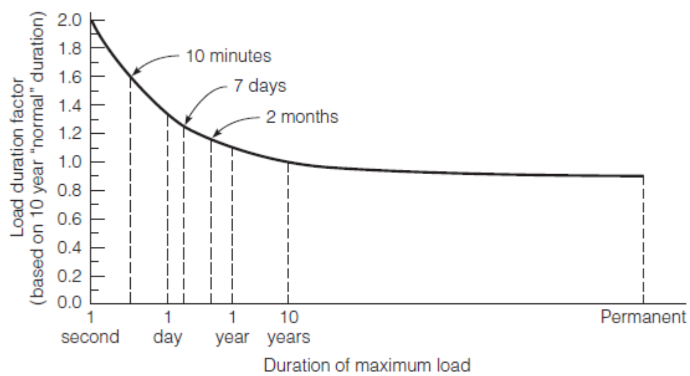
Knowing the mechanical properties of wood is a prerequisite to a proper design of a wood structure. Typical mechanical properties of interest to civil and construction engineers include:

i- **Modulus of Elasticity**: The typical stress–strain relation of wood is linear up to a certain limit, followed by a small nonlinear curve after which failure occurs, as shown, the modulus of elasticity of wood is the slope of the linear portion of the representative stress–strain curve.



ii- **Strength Properties**: Strength properties of wood vary to a large extent, depending on the orientation of grain relative to the direction of force. For example, the tensile strength in the longitudinal direction (parallel to grain) is more than 20 times the tensile strength in the radial direction (perpendicular to grain). Also, tensile strength parallel to grain is larger than the compressive strength in the same direction for small, clear specimens.

iii- **Load Duration**: Wood can support higher loads of short duration than sustained loads. Under sustained loads, wood continues to deform. The design values of material properties contemplate fully stressing the member to the tabulated design values for a period of 10 years and/or the application of 90% of the full maximum load continuously throughout the life of the structure. If the maximum stress levels are exceeded, the structure can deform prematurely.



iv. Damping Capacity: Damping is the phenomenon in which the amplitude of vibration in a material decreases with time. Reduction in amplitude is due to internal friction within the material and resistance of the support system. Moisture content and temperature largely govern the internal friction in wood. At normal ambient temperatures, an increase in moisture content produces a proportional increase in internal friction up to the fiber-saturation point.

Testing to Determine Mechanical Properties

Standard mechanical testing methods for wood are designed almost exclusively to obtain data for predicting performance. To achieve reproducibility in the testing environment, specifications include methods of material selection and preparation (controlled by ASTM and other standards).

Tests for structural-size lumber include (ASTM D198):

- Flexure (bending)
- Compression (short column)
- Compression (long column)
- Tension

Tests for small-clear wood specimens include (ASTM D143):

- Static bending (flexure)
- Impact bending
- Compression parallel to the grain
- Compression perpendicular to the grain
- Tension parallel to the grain
- Tension perpendicular to the grain