chapter 2. WOOD AS A BUILDING MATERIAL

2.1 WOOD AS A CONSTRUCTION MATERIAL

Wood is an organic material, produced by a large number of woody plants and quite variable in properties. In fact, the term "wood" is not much more definitive than the term "metal." Many species with differing characteristics are used in construction for many purposes. Compare for example balsa and birch, or redwood and rosewood. Wood is naturally grown, and the variability within a species, due to genetic and environmental influences, is substantial. In general, the variation for most wood properties (the ratio of highest to lowest for any property) is more than 2:1.

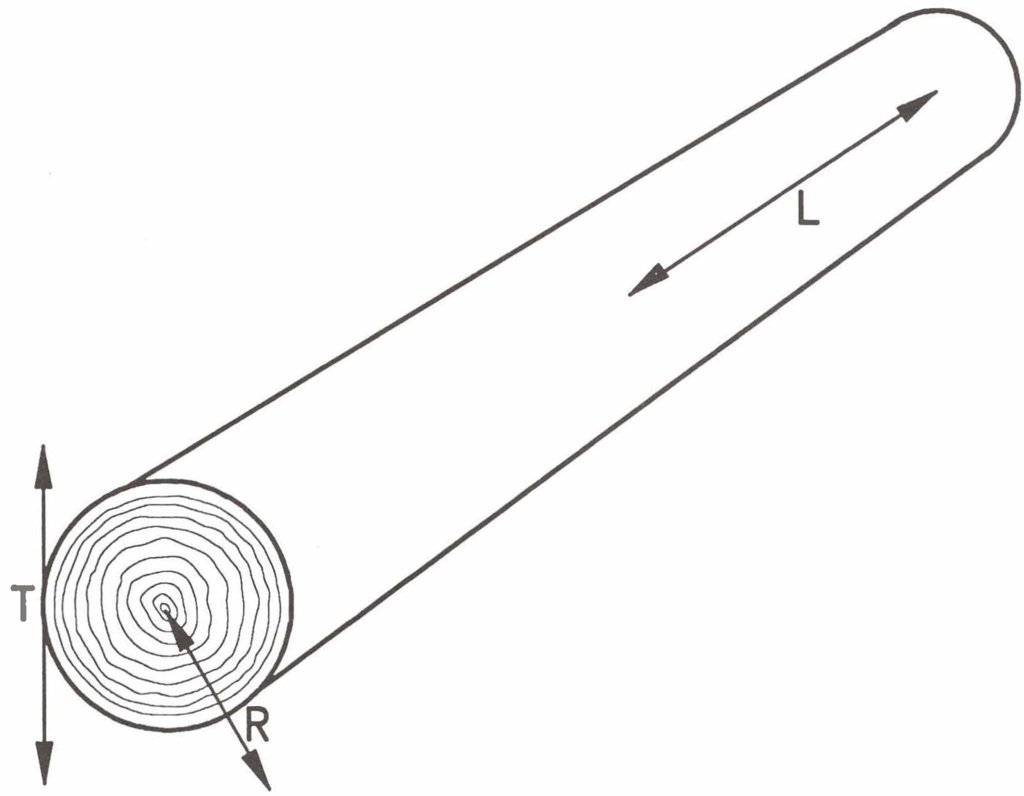
Wood has three cardinal directions related to the trunk of the tree. Parallel to the long axis of the stem is called the longitudinal (L) direction. The other two, radial (R) and tangential (T), are transverse to the stem of the tree and can be easily seen on the end of a log. These directions (see **Figure 2-1**), are important because wood properties vary according to grain orientation. Wood properties are also affected by the presence of imperfections such as knots and pitch pockets. The grading process takes into consideration these imperfections, as well as defects that might occur in manufacturing.

2.1.1 Species and Commercial Groupings

Each species has its own characteristic properties. The number of species is so great that if each was marketed separately, it would create an impossible situation. Consequently, commercial groupings are made to combine species of similar properties and appearance. This often happens when similar species are intermingled in the forest. An example is the grouping of the many oaks into two categories: red and white with softwoods, Hem-fir in the West may include western hemlock and any of the six true firs grown there. Southern pine comprises a mixture of any of the ten southern pines, and Canadian spruce-pine-fir can include any of the trees from those three botanical genera that are present in a mill's log supply. Before shipment lumber products are sorted at the mill into four broad categories: appearance or finish grades, structural and construction grades, special purpose grades, and cutting or industrial grades.

2.1.2 Performance Properties

Wood performance is dependent on a wide range of characteristics, the importance of which depends on how the piece is intended to be used. These characteristics include the following (see page 2-3).



Any surface of a wood product which is tangential to the annual rings, such as a flat grained board, is called a tangential (T) face, as are the properties measured across that face. Similarly, a radial (R) surface is one which cuts across the annual rings at a right angle, such as a vertical grained board. The longitudinal (L) direction is parallel to the grain and to the length of the log.

CARDINAL DIRECTIONS IN WOOD

Figure 2–1

- Strength
- Stiffness
- Hardness
- Finish Retention
- Treatability with Preservatives
- Resistance to

  shrinkage/swelling
  warping
  checking
  weathering
  decay
  photodegradation
  color changes
  insect attack

This manual is primarily concerned with building products manufactured from western softwoods, used where they are exposed to weathering or where they are part of the envelope that protects the structure from the weather. Therefore, some properties, such as strength and stiffness, are not discussed. They are well covered elsewhere. Of greater concern here are those properties that govern deterioration or changes in size and shape. Deterioration refers to the loss of the ability of a wood product to serve its intended purpose in appearance, strength, or other functions. The purpose might include, for example, providing a protective envelope or structural support.

2.1.3 Wood Products and Species Properties

The product properties of sawn lumber are relatively easy to identify. Manufacturing factors that affect performance, such as grain angle or size and shape, are important, but these are fairly well defined and their effects well established. When wood is used as a raw material in the manufacture of more refined wood products, the performance characteristics may be more related to factors in the manufacturing process than to the intrinsic qualities of the natural wood. Thus, an important rule is that the more a product is changed from natural wood, the less relevant is information regarding the properties of the natural wood.

For example, in the case of natural durability, lumber is considered to possess exactly the characteristic resistance that the wood in the tree trunk possesses (although it may be affected to a degree by kiln-drying conditions). It is equally valid to assume that when this lumber is further manufactured into glued laminated beams, the heartwood durability is unaffected. When the same wood is manufactured into plywood in a hot press, a claim that the product contains the same resistance as the original wood is probably far less certain. When the product is manufactured into a particleboard, the relationship becomes doubtful, and it is probably nonexistent in a wet-process hardboard or cardboard.

2.1.4 The Changing Products of the Forest

The characteristics of wood harvested over the years have changed as the supply of old growth timber has been replaced by wood from younger, more vigorous trees. In virtually all cases, this change is adverse to building use. Resistance to insects and decay, texture, dimensional stability, weather resistance, and strength are all less satisfactory in wood from younger and smaller trees. The most important change is in the percentage of pieces containing juvenile wood. The actual volume of the juvenile core is increased by the more rapid growth of young trees in today's managed forests. Additionally, there is less of the higher quality mature wood surrounding the lower quality core because the trees are harvested when their diameter is smaller. This results in a lower specific gravity, a lower concentration of heartwood extractives, proportionally less heartwood, and frequently a sharper transition from springwood to summerwood in an annual ring. Juvenile wood, produced during the first 5 to 15 years of growth at any point in the trunk, constitutes a major part of the log in short rotation trees. Its high longitudinal shrinkage is particularly damaging because of the twisting and bowing that often results as it dries. Smaller logs also mean a smaller average radius of the annual rings with an increased tendency to cup, as well as more severe checking when drying and when exposed to weathering. Strength is affected by both the lower specific gravity and the increased juvenile wood content.

Natural durability results from chemicals formed in the tree as heartwood is developed. These extractive chemicals are found in greatest concentration in the outer heartwood at the base of the tree. The concentration decreases toward the center of the trunk and toward the top of the tree. Smaller trees thus have both a higher percentage of sapwood and a lower durability in the heartwood. Extractives and their concentration, along with specific gravity, are the primary factors that affect general dimensional stability: shrinkage and swelling. More rapid growth also changes the "texture" of the wood, a term not well defined but one that is used in comparing working or machining qualities. Extractives and texture are also the two most important factors that determine how well wood holds up when exposed to weathering.

2.2 CAUSES OF WOOD DETERIORATION

The deterioration of wood buildings can be discussed in terms of exposure hazards and their effects. Although some of these conditions do not necessarily lead to deterioration by themselves, they often lead to circumstances where degradation is promoted.

HAZARDS

- Exposure to sunlight
- Exposure to moisture and heat cycles
- Changes in moisture content
- Attack by insects and decay fungi

PRINCIPAL EFFECTS

- Surface erosion (photodegradation)
- Checking, splitting, and warping
- Shrinkage and swelling
- Disintegration and decay

2.2.1 Exposure to Sunlight

Sunlight causes surface erosion or photodegradation, a photochemical process that results in disintegration of the wood cell wall. It will occur to some degree whenever light reaches the wood surface, that is, if the wood can be seen through whatever finish has been applied. The disintegrated wood materials generally accumulate on the surface and provide protection against further deterioration unless removed by rainfall or some other means. Dense wood, including the dense bands of the annual rings, is more resistant, so the wood will develop a washboard surface over time. The average rate of 1/4 inch to 1/3 inch per 100 years is generally low enough so that it is not a problem with most sawn lumber. The rate for western red cedar is two and one-half times greater and can be a real problem with thinner boards in severe exposures. With cedar-faced plywood the face veneer may disappear in less than ten years.

2.2.2 Exposure to Moisture and Heat Cycles

The cyclical exposure to these weathering elements leads to various types of degradation, including checking and splitting of wood as well as separation at the glueline of bonded wood products. Wood will absorb or lose moisture depending on its moisture content and the relative humidity of the surrounding air, and will either swell or shrink as it does so. These changes occur rapidly at the surface, but are controlled by the much slower diffusion of moisture below the surface. This cycling of moisture and the attendant changes in size and shape cause stresses in the wood. Checking and splits will develop when these stresses exceed the wood strength in tension perpendicular to the grain; when stresses are below the wood strength, creep often occurs.

Glue bonds in wood products have varying degrees of water resistance. Even water-proof bonding systems can fail if the inter-surface stresses are too great, although these failures are most often adjacent to the glueline, not in it. Plywood and particle-board are made by hot pressing. The heat and pressure used cause the wood cells to flatten out and to stay set semipermanently. Unfortunately, cycling moisture contents do result in relaxation and recovery, causing swelling from the pressed size.

The most important factors affecting the severity of checking are the species, the size, the product type, and the exposure condition. Plywood checking patterns are determined by the manufacturing process. Glulam beams check differently from sawn timbers, often with more serious consequences; sawn timbers from the center of the tree (heart center or boxed heart) check worst of all. Composite panels such as particleboard, hardboard, and flakeboard follow different patterns of weathering because they are more prone to erosion and loss of internal bond. They tend to disintegrate due to loss of bond between particles or fibers as weathering progresses. The edges of particle and hardboards are particularly vulnerable to shrinkage and swelling because of the openings between the matted fibers and in the exposed cut fibers.

Depending on their size and location, checks and splits may or may not seriously affect strength. However, they provide crevices where moisture can collect; when the checks are very deep, this moisture is more likely to be absorbed into the wood than to evaporate. Continuing cyclical exposure causes the original smaller openings to consolidate and enlarge. As these checks and splits grow, they become more effective at trapping moisture, which, in turn, can be absorbed, especially when the checks and splits are located on a horizontal surface or when they are running horizontally on a vertical surface. The absorption of excessive moisture in solid, laminated, and composite wood products leads to decay, in addition it can cause structural disintegration in composite panels.

2.2.3 Changes in Moisture Content

Wood swells as it adsorbs moisture and shrinks as it dries. The degree of movement depends on the species and the direction of the grain (longitudinal, radial, and tangential), as well as on the amount of moisture change. Shrinkage and swelling in themselves are not detrimental, if they are accommodated in the design of the building detail. An example of failure indirectly caused by the shrinkage of framing members is the buckling of thin panel siding due to insufficient space provided at the horizontal joint between panels. Shrinkage also creates problems when siding with an excessively high moisture content is installed. When the amount of shrinkage is small, the wood will creep elastically without splitting; but if the shrinkage is excessive or if the nailing is incorrect, then splits will develop between fastenings. These types of failures can be avoided with proper design, material, and installation.

Changes in moisture content can also cause changes in shape, called "warp," due to different rates of shrinkage in different directions, moisture gradients within the piece, or both. This warping is of four distinct types: bow, crook, cup, and twist. Again, these changes in geometry are generally not serious to building or material integrity, but they can lead to performance problems. For example, the cupping of excessively thin lumber siding can expose a felt membrane to weathering, which, in turn, leads to rapid deterioration of the building envelope. These distortions also affect both appearance and structural properties. For example, the axial load-carrying capacity of a tall column can be significantly reduced if, upon drying, the member becomes bowed.

2.2.4 Attack by Insects and Decay Fungi

INSECTS

Insects attack wood products for two purposes: to consume the wood as food and to burrow into the wood for habitation. Both weaken the wood's structural properties and lead to premature failures. Many types of insects attack wood, including termites, beetles, carpenter ants, and carpenter bees. Prevention of insect attack can take three forms: (1) selection of naturally resistant wood species, (2) preservative treatment of wood to deter the infestation, and (3) blocking of access to the wood products by soil poisoning and other barriers. (See Chapter 12 for further discussion.) Keeping the wood dry will control some, but not all, insects.

DECAY

The fungi that cause decay are always present in the environment. They are simple, primitive plants that lack chlorophyll and therefore are unable to manufacture food. They live by digesting food manufactured by other plants, in this case wood. Fungi have 4 growth requirements similar to the basic needs of humans: food, water, air, and a satisfactory temperature. When decay has progressed to a readily detectable stage, the wood has long since lost most of its strength. Major strength reductions occur early in the process, when decay is in the incipient, or previsual, stage of development, as shown in **Table 2-1**. Even experts are unable to detect decay in the field at a 5% weight loss and only with difficulty before weight loss reaches 10%. It is only at that point that the changes in color, odor, and other characteristics begin to become apparent.

Decay will be prevented if any of the four basic requirements is removed, although change in temperature, either elevated or reduced, is seldom used as a control method and is not likely to be effective. Exclusion of air is not common, but is illustrated by untreated wood foundation pilings driven to below the water table level. Making food unavailable is achieved by using the heartwood of a naturally durable species such as redwood or, more dependably, by using wood treated with a toxic preservative. Most wood in use is protected simply by keeping it dry; *decay cannot occur if there is no continuous exposure to water as opposed to the water tightly bound within the wood substance of the cell walls.*

MOLDS AND MILDEWS

Molds and mildews produce dark-gray-to-black colorations. They are also fungi, but affect mainly the appearance of wood products and not the structural characteristics. They tend to grow in high humidity and can be controlled by chemical additives in the applied finish or by reducing the humidity. Other fungi may produce stains in the wood, but these generally occur at the sawmill or before, not in wood in use.

Table 2-1
Approximate Values for Strength Loss in Softwoods at Early Stages of Decay by Brown-Rot Fungi*

Strength Properties--Loss in Percent			
% Weight Loss	Compression Perpendicular to Grain	Compression Parallel to Grain	Tension Parallel to Grain
2	18-24	10	23-40
4	25-35	-----	-----
6	48	25	60
8	48-60	-----	50
10	66	45	-----

*Values obtained from published experimental results and adjusted to equivalent weight-loss levels.

[W. Wayne Wilcox, *Review of Literature on the Effects of Early Stages of Decay on Wood Strength.* Wood and Fiber 9(4):252-257.]