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STRUCTURAL USES OF WOOD

Wood from trees has a long history of usage for structural purposes, most notably in regions where large stands of trees exist. At the time of the early colonization of the United States, vast areas of this country were covered with forests. It was, indeed, a major problem for early settlers of the eastern, southeastern, and midwestern areas. Travel was difficult because of the dense growth, and up to the middle of the nineteenth century, was mostly accomplished by using the many navigable rivers. As in many other countries today, land for cultivation of crops or grazing of animals had to be claimed by burning off or otherwise destroying forest lands.

While much of that early dense forest was lost—most notably vast stands of hardwood trees—a considerable amount of timber was used for construction. Thus a heritage of wood construction was developed and an extensive industry was established. This industry extends to today, with wood remaining as a major source for building construction uses.

We no longer build extensively with construction that directly utilizes the source. Log cabins, roughly hacked boards, and pole construction with peeled logs do not account for the majority of buildings. Today, wood as a building material is treated as an industrialized product, receiving considerable processing on the way to the construction site.

Still, a major use—and one treated extensively in this book—is that of the lightly processed pieces of wood that are cut directly from the logs, smoothed up a bit, and used as quickly as possible in their solid-sawn form. This product is what we generally refer to as *lumber*, and the lumberyard is still a major business in almost every large community in the United States. Wood is indeed the all-American building material.

This chapter deals with some of the basic issues concerning the use of wood, with concentration on the direct usage for structural lumber.

1.1 SOURCES OF WOOD

The particular type of tree from which wood comes is called the *species*. Although there are thousand of species of trees, most structural wood comes from a few dozen species that are selected for commercial processing.

The two groups of trees used for building purposes are the *softwoods* and *hardwoods*. Most softwood trees like pine and spruce are coniferous, or cone bearing, whereas hardwood trees have broad leaves exemplified by oak and maple. Softwoods are mostly indeed softer than hardwoods, although there are other properties that define the types.

The two species of trees used most extensively for structural wood in the United States are Douglas Fir and Southern Pine. However, several other species are also used, depending partly on regional availability. Although the terms *timber* and *lumber* are often used interchangeably, current industry usage tends to reserve timber for structural wood members of large cross-sectional area.

1.2 TREE GROWTH

The trees used for lumber in the United States are exogenous; that is, they increase in size by growth of new wood on the outer surface under the bark. The cross section of a tree trunk reveals the layers of new wood that are formed annually. These layers, called *annual rings*, are typically composed of alternating light and dark material. In most areas, the lighter, more porous layers are grown in the warmer months of the year (spring and summer in the northern hemisphere), and the denser, darker layers are grown in the colder months.

The number of layers of annual rings at the base of the tree trunk indicates the age of a tree. To build up a trunk large enough to saw structural lumber from requires several years of growth, the number of years depending on the climate and the type of tree. In a real sense, however, no matter how many years it takes, wood is a renewable source of building materials.

The youngest band of annual rings at the outer edge of the tree is called the *sapwood*. This is usually lighter in color than wood at the center of the log, which is called the *heartwood*. For specific purposes either the sapwood or the heartwood may be the more desirable material. However, how an individual piece of lumber is cut from the log with respect to orientation to the general pattern of the annual rings is often of greater concern.

The structure of wood is composed primarily of long and slender cells called *fibers*. These cells have a hollow, tubular form with an orientation of their lengths in the longitudinal direction of the log (up the tree for transporting of water and nutrients during growth). This gives cut pieces of wood a character described as its *grain*, with the grain being directed along the length of cut pieces of lumber. This in turn provides a reference for viewing various structural actions as relating to the grain; that is, as being *parallel to the grain, perpendicular to the grain*, or at some *angle to the grain*.

The fibrous, tubular cells of the wood are composed primarily of *cellulose* and the material that binds the cells is called *lignin*. These two materials are the main chemical components of wood.

1.3 DENSITY OF WOOD

The difference in the arrangement and size of the cell cavities and the thickness of the cell walls determine the specific gravity, or relative *density*, of various species of wood. The strength of wood is closely related to its density. The term *close grained* refers to wood with narrow, closely spaced annual rings. Certain woods, such as Douglas Fir and Southern Yellow Pine, show a distinct contrast between the springwood and summerwood, and the proportion of summerwood affords a visual basis for approximating strength and density. The solid material in wood is about 1.53 times the weight of water, but the wood cells contain open spaces in varying degrees. These spaces are typically filled partly with air and partly with water. The weight of wood varies with regard to the amount of open cell space and the amount of trapped water. For purposes of computation in this book, the average weight of structural softwood is taken as 35 lb per cu ft (pcf).

1.4 DEFECTS IN LUMBER

Any irregularity in wood that affects its strength or durability is called a *defect*. Because of the natural characteristics of the material, several common defects are inherent in wood. The most common are described here.

A *knot* is a portion of a branch or limb that has been surrounded by subsequent growth of the tree. There are several types of knots, and the the strength of a structural member is affected by the size and location of those it may contain. Grading rules for structural lumber are specific concerning the number, size, and position of knots, and their presence is considered when establishing design values for structural response.

A *shake* is a separation along the grain, principally between annual rings. The cross section of a shake is shown in Figure 1.1*a*. Shakes reduce the resistance to shear, and consequently members subjected to bending are directly affected by their presence. The strength of members in longitudinal compression (directed parallel to the wood grain), such as columns and posts, is not greatly affected by shakes.

A *check* is a separation along the grain, the greater part of which occurs across the annual rings (Figure 1.1*b*). Checks generally develop during the process of seasoning (drying out from the green condition). Like shakes, checks also reduce the resistance to shear.

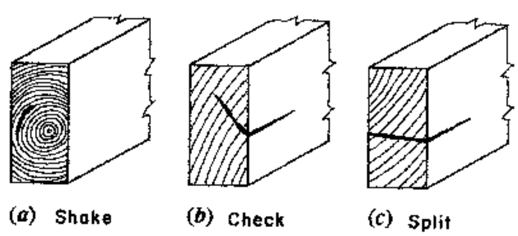

Figure 1.1 Common defects in structural lumber.

A *split* is shown in Figure 1.1*c*. It is a lengthwise separation of the wood that extends through the piece from one surface to another. Splits obviously have a major effect in reducing shear resistance.

A *pitch pocket* is an opening parallel to the annual rings that contains pitch, either solid or liquid.

Logs are typically tapered in form, and when a long piece of lumber is sawn from a relatively short tree trunk, or from a log that is not held straight during sawing, a condition may occur that is described as having a piece of lumber with a *slope of grain*. This has some direct effects on certain structural uses, and is one of many properties of an individual piece of lumber that is noted when the piece is evaluated for structural applications.

A major concern for wood for construction is the general problem of *decay* of the wood. This is actually a natural process for the organic (once living) material, and preserving the wood is literally a nature-defying effort. Some decay occurs within the tree even during its growth period and pockets of decay are another form of defect of the sawn lumber pieces. Old decay may be arrested or suspended by treatment of the wood, or simply be eliminated by cutting out the decayed portions. Often of greater concern is continuing or new decay, which is a major problem for the general development of the construction. Numerous treatments are possible, including the impregnation of the wood mass with chemicals to arrest future decay. Wood generally untreated and exposed to the weather is especially vulnerable in this regard.

1.5 SEASONING OF WOOD

All wood contains moisture, and the serviceability of wood for construction is generally improved by reduction of the amount of moisture below the content in the *freshly-cut* pieces, referred to as *green* wood. The process of removing moisture from green wood is known as *seasoning*; it is accomplished by exposing the wood to relatively drier air for an extended period of time or by heating it in kilns to drive out the moisture. Whether *air dried* or *kiln dried*, seasoned wood is generally stiffer, stronger, and less subject to shape changes.

Drying out of the wood results in shrinkage of the cellular structure of the material. This occurs differently in the three primary directions: along the grain, parallel to the annual rings, and perpendicular to the annual rings. This is where the orientation of the grain, as well as its relative uniformity and absence of large defects, becomes quite important. Shape and dimensional changes of some degree are to be expected, affecting a property described as the *dimensional stability* of the wood. It is quite important that as much of this change as is possible should occur before installation of the wood in the construction assemblage.

The *moisture content* of wood is the ratio of the weight of contained water in a piece of wood to the weight of an oven-dried (zero moist) sample, expressed as a percentage. Specific limits are set for this value for structural applications.

1.6 NOMINAL AND DRESSED SIZES

A piece of structural lumber is designated by its nominal cross-sectional dimensions. As an example, a designation of 6 by 12 (written 6×12) indicates a member with a width of 6 in. and a depth of 12 in. However these are actually *nominal dimensions* which roughly describe the shape as sawn from the log. When the member faces are smoothed by planing and/or sanding, the member is said to be *dressed* or *surfaced*. The 6×12 when dressed will have actual dimensions of 5.5×11.5 in. Standard lumber sizes produced by the lumber industry are listed in Table A.3, which yields both the nominal and actual dimensions of the pieces.

1.7 USE CLASSIFICATION OF STRUCTURAL LUMBER

Because the effects of natural defects on the strength of lumber vary with the type of loading, and specific types of defects relate to structural usage of members, structural lumber is classified according to both *size* and *use*. All dimensions used in classification are nominal dimensions and not actual dimensions. The four principal classifications are as follows:

Dimension Lumber. Rectangular cross sections with nominal dimensions that range from 2 in. to 4 in. in thickness and 2 in. or more in width. A further distinction is made between *light framing* 2 in. to 4 in. wide, and *joists* and *planks* 5 in. and wider.

Beams and Stringers. Rectangular cross sections 5 in. or more thick and with a width at least 2 in. greater than the thickness, graded for strength in bending when loaded on the narrow face.

Posts and Timbers. Square or nearly square cross sections with nominal dimensions 5 in. by 5 in. and larger, and with width not more than

2 in. greater than thickness, are graded primarily for use as posts or columns or other uses where bending strength is not a major concern.

Decking. This consists of lumber 2 in. to 4 in. thick and 4 in. or more wide. Jointing of members is provided by tongue and groove edges or edges splined (slotted) for interlocking on the narrow face. Decking is graded for use with the wide face placed flatwise in contact with supporting members.

1.8 GRADING OF STRUCTURAL LUMBER

Grading is necessary to establish the quality of lumber. Structural grades are identified in relation to strength properties and use classifications. Structural grading may be done by mechanical testing of wood samples but is most often accomplished by visual inspection. Once graded, a piece of structural lumber is stamped with the grade and the grading authority or standard used. Use of specific grades is established by the structural designer for each type of structural member, and is ordinarily designated for use on the structural construction documents. The topic of grading is discussed in Chapter 4 as it relates to the process of structural design work.

1.9 FABRICATED WOOD PRODUCTS

Wood is indeed used in solid sawn form for many structures. However, many products—structural and other—are fabricated from wood in some reconstituted form. Reduced to fiber form, wood is used widely—a major use being for paper. Newspapers, bathroom tissue, paper bags, cardboard boxes, and the pages of this book are produced primarily from wood fiber. This constitutes *the* major use of wood by volume.

With wood fiber production in place for many years, a natural outgrowth has been the production of structural products. Wood fiber panels have been produced for many years and are now used extensively for furniture and in many situations in building construction. With the wood reduced to a fine fiber form, strength is limited, so uses are mostly in construction with low structural tasks.

A more recent product is OSB (for oriented strand board), which is produced with wood in small thin pieces laid on top of each other. The grain direction of individual pieces is random with respect to other pieces, which gives the end product a two-way grain effect, similar to that produced with plywood, where alternating plies have their grain directions perpendicular to adjacent plies. This product now sees major use for wall paneling and roof decks, due to its considerable strength.

Another recent product is that produced with shredded strands of wood adhered with the grain direction the same. This produces something very similar to solid-sawn wood, and is used as a replacement for smaller sizes of lumber.

Another fabricated product in wide use is that produced with wood pieces adhered in laminations. This includes thin plywood panels and large forms for girders and columns. This process can also be used to produce curved forms. Laminated products are discussed in Chapter 12.

Fabricated products also include many assembled components, such as trusses and boxed elements. These may use various combinations of solid sawn wood, fiber products, and possibly elements of metal. Some of these products are discussed in Chapter 12. A product of particular note is the truss produced with wood chords and steel web members, as discussed in Section 11.8.

One reason for the expanding use of fiber, particle, and strand products is that the wood source for these products can be from slow-growth trees and parts of trees not usable for sawn lumber. With the steady loss of old-growth forests, this is a major consideration for the fuller use of forest resources.