Some basic characteristics of wood

Hutcheon, N. B.; Henkins, J. H.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000810
Canadian Building Digest, 1967-01

Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 85

Some Basic Characteristics of Wood

Originally published January 1967.

N.B. Hutcheon and J.H. Jenkins

Please note

Wood has always been and continues to be a material of great importance to mankind. It is highly versatile. It is relatively light in weight, yet has good strength in both tension and compression; and provides rigidity, toughness and insulating properties. It can be bent or twisted into special shapes, and it is readily worked, fastened and finished. The finished surface is pleasant to the touch and the visual patterns provided can be of great beauty. Consequently wood is widely used in buildings in a variety of ways.

Despite its wide range of application and the profligate use made of it when it is abundant, wood, like most other materials, should not be applied without thought for the conditions under which it will serve or for the inherent properties that will determine its suitability. A natural substance, wood reflects the conditions under which it was grown through the variations in its properties, which vary in different directions. There are marked variations also from one species to another. Consequently there is a continuing challenge in the development of wood technology to recognize the inherent nature of wood and to understand the implications of it at every stage, from the harvesting of the trees to their final conversion to the end uses.

This challenge exists also in varying degrees for the building designer who must know how best to employ wood to achieve the desired results in any given application and how to select and to specify it. It is of overriding importance that the designer should understand fully the anisotropic or directional character of wood, particularly in respect of its strength and moisture response, and it is with these features of wood that this Digest will be mainly concerned.

Growth of a Tree

The growth of a tree trunk takes place primarily by the multiplication of cells on either side of a thin layer called the cambium, which is immediately under the bark. From the inner surface of the cambium is deposited new wood, which increases the volume of the tree. Each year a layer of wood is deposited outside the previous wood of trunk and branch by this tissue, which at the same time generates the bark from its outer surface. This bark varies in colour and texture, depending on the species.

There is often a difference between the new wood formed early in the season and that formed later, so that well-marked annual growth rings are developed in the trunk cross-section. Although growth takes place mainly at the cambium, the living cells of the adjacent rings formed from past growth continue to function as part of the living tree, making a concentric ring of material known as sapwood. The older layers of sapwood gradually become less active and add to the heartwood core. With the accumulation of certain materials, heartwood may sometimes darken so that it becomes visually distinguishable from sapwood, but there are no consistent differences between the two with regard to ultimate quality.

At the centre of the trunk there is a small core, called the pith, usually darker in colour. This was part of the primary growth formed in the elongation of stems and the formation of branches. Branches originate at the pith and become intergrown with the trunk, giving rise to knots in sawn wood.

The basic structure of wood is made up of cells of various shapes and sizes firmly grown together. In dry wood these cells may be empty or partly filled with gums, resins or other deposits. Those that are considerably elongated are called fibres, the length of which may vary within one tree and from one species to another, being shorter, on the average, in hardwoods than in softwoods. The fibres, which are the chief source of the strength of wood or the paper made from it, lie parallel to the long axis of the tree, thus imparting excellent strength properties in this direction. Hardwoods have, in addition, a system of larger cells, known as vessels, through which the sap moves vertically. Both hardwoods and softwoods have systems of cells called rays and these provide for horizontal movement of sap.

Composition of Wood

The main constituent of wood is cellulose, which accounts for up to 70 per cent by weight of dry wood substance. There are two types; one, the alpha cellulose which is the constituent of major importance in the making of paper. The main cementing action that bonds cells together and imparts rigidity to the wood is provided by lignin, in amounts from 18 to 28 per cent. There are, in addition, certain minerals present that can be recovered as ash when wood is burned, in amounts up to 1 per cent. These three constituents form the essential dry wood substance. Wood may contain, in addition to substantial amounts of water, certain chemical compounds that may be extracted from the wood by solvents of various kinds. These include tannins, starch, oils, waxes and resins, which may contribute colour, taste and odour as well as resistance to decay to the wood.

Moisture in Wood

Water, which is an essential agent in the life process of a tree, is present in large quantities in the tree and in the green log after felling. As wood has a highly cellular structure and since the weight of the dry wood substance may be as little as 20 to 30 lb per cu ft (the lower value being for some softwoods) it is not surprising that fully saturated wood may contain a weight of water greatly in excess of the weight of dry wood substance. The moisture content of "green", i.e. freshly cut, lumber varies with the species and the portion of the log from which it is cut. Douglas fir, for example, has a relatively low "green" moisture content. The moisture content of freshly-sawn lumber containing sapwood may at times exceed 100 per cent of the dry weight.

Green wood begins to lose moisture as soon as it is cut if the surrounding air is at less than 100 per cent relative humidity. The higher the temperature and the lower the humidity of the surrounding air, the more rapid will be the moisture loss. As drying proceeds through evaporation from the exposed surfaces, all the larger cells will gradually be emptied and the point reached at which the contained water is more or less tightly held in the fine structure of the cell walls. This condition, which is referred to as the fibre saturation point, is commonly reached at a moisture content of around 25 to 30 per cent.

This moisture condition is of great significance because in drying down to this point green wood will have experienced relatively little change in properties and very little if any shrinkage, having mainly been reduced in weight. In drying below this point shrinkage develops progressively, roughly in proportion to reduction of moisture content below the fibre saturation point. As it affects the further drying of the wood and its subsequent manufacture, this inherent characteristic is of great importance. It also affects use of wood, since changes of moisture content in service will also produce changes in dimension, including swelling upon re-wetting.

As wood is dried progressively from the fibre saturation point, a definite equilibrium moisture content will be developed at each level of relative humidity, given enough time. The curve of Figure 1, showing this relationship, applies reasonably well to all common woods. Moderate temperature variation from room temperature has no appreciable effect. The same curve may be applied also to subsequent wetting and drying in service. More accurate information regarding the kind of wood and the differences between wetting and drying may be found in the literature.

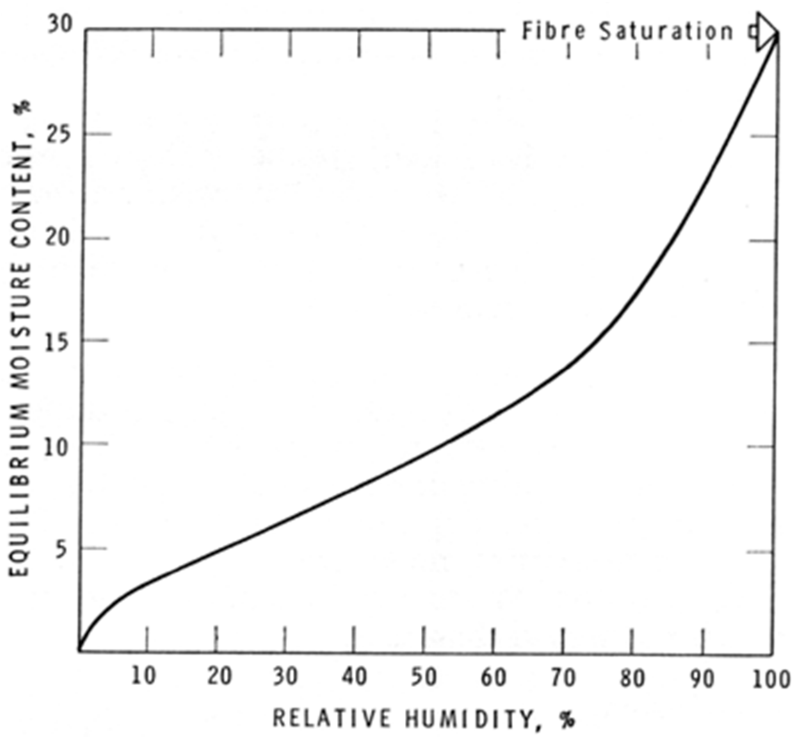

Figure 1. Moisture content of wood at various relative humidities.

The relation between dimensional and moisture content changes is shown by Figure 2. These curves are greatly simplified, but may be taken as roughly representative of a number of common woods. It may be noted at once that a higher shrinkage is shown for the flat grain or tangential direction than for the edge grain or radial direction, as referred to the tree cross-section. For Canadian woods the range of radial shrinkage is from 1.7 to 6.7 per cent, that of tangential shrinkage from 3.7 to 10 per cent. The shrinkage along the length of the grain is not shown, but it is normally very much smaller, being from 0.1 to 0.3 per cent in total, except for some abnormal conditions that can develop. These inherent characteristics of wood give rise to some important considerations.

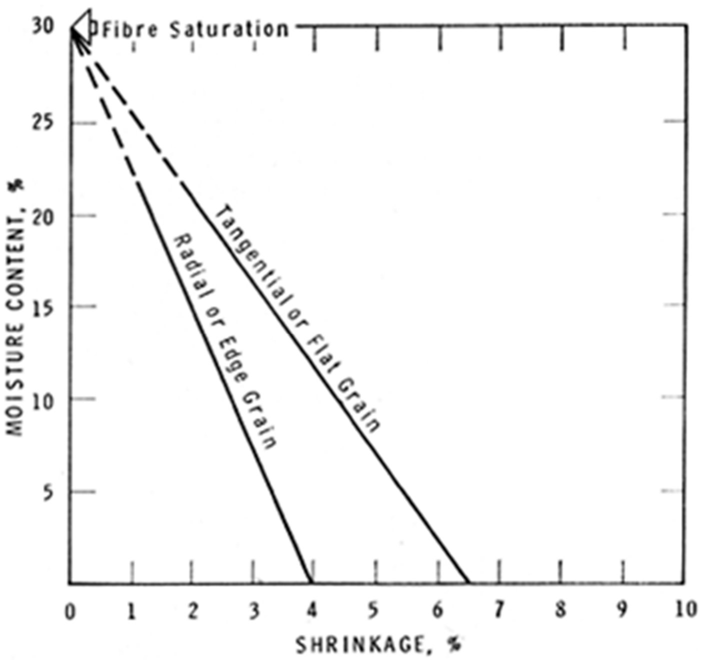

Figure 2. Shrinkage on drying to various moisture contents from fibre saturation.

If a green log is allowed to dry it will develop circumferential shrinkage stresses, not only because it will dry first at the outside but also because as drying progresses the circumferential shrinkage will be greater than the radial shrinkage. It is thus impossible for the log cross-section to shrink uniformly without stressing. In most cases shrinkage stresses will exceed the capability of the wood to accommodate them and radial cracks or splits will form. It is customary, therefore, to saw logs into lumber while they are still "green" and drying below the fibre saturation point has not occurred.

When the log is sawn into lumber, this green or unseasoned lumber will ultimately dry to a moisture content that is dependent upon the atmospheric conditions to which it is exposed. The lower the ultimate moisture content, the greater the shrinkage, which may result not only in a reduction in the width and thickness of the piece, but also in internal stresses that could cause distortion. The development of these shrinkage stresses is influenced by the angle of the grain in the board and by the drying conditions. When proper care is not taken, warping and bowing (forms of twisting) and cupping may occur. Cuts tangential to the annual rings (flat-grain) are more liable to produce cupping than cuts diagonal or vertical to the annual rings. Because of this uneven shrinkage characteristic of wood and the resultant development of shrinkage stresses, it is essential that the proper care and techniques are used when wood is seasoned. With this proper care, however, wood can be dried flat and straight.

Consideration of the magnitude and nature of the shrinkages that are possible brings a realization of the importance of the moisture content of lumber at the time it is fixed in place for use. There is no easy way in which these shrinkage and swelling tendencies can be avoided. They must be recognized and taken into account in design. Painting or varnishing does not eliminate them. It only slows the rate of adjustment of the wood moisture content to changing conditions. It may thus reduce the response to short-time changes greatly, but it has no effect on longer term ones.

The Strength of Wood

The basic strength properties representative of various species are always established on the basis of a large number of tests on clear specimens in the air-dry condition. Such values obtained for white spruce, for example, show that its modulus of rupture in static bending can be about 8500 psi. The crushing strength in compression parallel to the grain at maximum load is about 5000 psi. For a variety of reasons, including the necessity to allow for variations in properties and defects such as knots and checks in commercial sizes and grades of lumber, the safe stresses that can be used in engineering design must be substantially reduced from such values by a factor of 5 or more, in accordance with carefully established formulae. Even with these reductions white spruce is seen to have a quite remarkable, safe load-carrying capacity in proportion to its weight, when it is considered that its density is only about 1/18 that of steel.

It is noteworthy that wood has good tensile strength in relation to its compressive strength along the grain, thus making it most useful for carrying bending loads. This is one of the features that has always made it a valuable natural building material.

An examination of the corresponding properties in directions at right angles to the grain reveals another basic characteristic of wood, namely the substantially lower strength properties in these directions. Again referring to clear, air-dried specimens of white spruce, the compressive stress perpendicular to the grain is about 450 psi at the proportional limit. The maximum tensile strength across the grain is about the same; the maximum shear strength parallel to the grain, about 1000 psi. These reduced strength properties in the cross-grain directions introduce many special and interesting considerations in design with wood for load-carrying purposes.

Other species have similar characteristic strengths, differing with density, origin, growth rate, and other factors. Hardwoods in general show less difference in strength with different grain direction than softwoods.

It now becomes evident that variations in strength with direction of grain, like the dimensional changes due to moisture, are closely related to the directional character of the arrangement of cells and fibres in the wood. The superior properties, most fortunately, are in the long direction. Wood would otherwise be very much less useful than it is.

Conclusion

It has been possible to indicate only briefly some of the inherent characteristics of wood. Their further significance in building applications will be discussed in a future Digest, but a comprehensive treatment is to be found in the excellent book, *Canadian Woods, their Properties and Uses*, which is available from the Queen's Printer, Ottawa.

Wood, although a familiar and highly regarded material presents a unique challenge in use because of its variability and the directional nature of its basic structure and therefore of some of its basic properties. These are the source of some of its attractive features but they require also that it be handled and applied in ways which are appropriate. All those who process and handle wood should be aware of its basic properties but none more than the building designer who should always design and specify the application of wood with due regard for its essential character in order to develop its full potential.