Douglas-fir Shrinkage and Dimensional Stability

Douglas-fir is an important building timber in North America, particularly in the Pacific north West, where it has a reputation for being naturally dimensionally stable – the ability to "season well in position" and retaining its shape during use (WWPA, 1996). Traditionally, much of the Douglas-fir lumber in North America has been dried to 19% or less before shipping. Many builders prefer to manufacture structures with "green" lumber and leave it to dry "*in situ*". Wood used for remanufacturing applications is more likely to be dried in a kiln. Nevertheless, shrinkage (particularly longitudinal shrinkage) has been reported as one of the major causes of degrade of lumber grades of "second growth" Douglas-fir (Mackay, 1989; Nault, 1989). In the New Zealand experience, drying distortion has been found to be comparatively low (McConchie, *et al.* 1992, 1995a, 1996).

Negative correlations have been reported between rapid growth and wood properties of Douglas-fir (King, 1986; Vargas-Hernandez and Adams, 1992).

Free and Bound Water

All wood shrinks as it dries out and swells as it absorbs moisture. Moisture occurs in wood in two ways. First, as free water, which fills the cell cavities and second, as bound water, which is contained within the individual cell walls. As wood dries, there is no loss of moisture from its walls until all the free water in the cell cavity has been removed. The stage at which the cell cavities are completely devoid of moisture but the walls are still fully saturated is known as the fiber-saturation point (FSP).

The FSP varies in the different species and even in different pieces of wood of the same species. It has an extreme range of 20% to 35% moisture content, but in most woods, occurs between 25 and 30 percent. Up to this point there is no change in the dimension of individual cells since only the free water has left the cell. Below the FSP however, the bound water starts to leave the cell walls causing changes in the wood dimensions.

The shrinkage in the wood dimensions can result in warping, checking, splitting, or performance problems that detract from its usefulness. Therefore, it is important that this shrinkage be understood as much as possible.

Wood Structure

Wood is made up of fibres, small needle-shaped structures about 3mm long and about 0.2mm wide and have walls which are crystalline in structure. The orientation of the the crystalline parts of the cell walls (predominantly along the longitudinal axis of the cells) mean that below the FSP, moisture changes result in changes in the cross sectional dimensions of the wood. High microfibril angles, spiral grain and compression wood normally associated with poor properties of juvenile wood are less pronounced in Douglas-fir (Cown, 1999; McConchie *et al.* 1995). In contrast to radiata pine, where the juvenile wood zone has been assumed to comprise about 10 growth rings from the pith (Cown, 1997) it has been estimated that in "second growth" Douglas-fir, wood with juvenile characteristics may extend to about 20 rings from the pith (Josza, 1989).

If the shrinkage of cells took place uniformly throughout a piece of wood, there would be no undue stresses set up, and checking would not result. However, due to the variable moisture distribution within a given piece, some parts may reach the FSP in advance of others, and consequently, changes in dimension are variable throughout the piece of wood.

The amount of moisture present and resultant shrinkage at different areas in a piece of wood depends on a number of variables such as the x-sectional dimensions, the time the wood has been seasoning, species, seasoning conditions, density, amount of earlywood and latewood of individual growth rings, whether the wood is heartwood or sapwood, and the original moisture content.

Douglas-fir produces a high percentage of heartwood (50% moisture content - MC) compared to many other species, so that freshly sawn lumber will have a relatively low average MC even before drying.

Variability

One of the most prominent features of shrinkage is its variability. Shrinkage takes place chiefly in the radial (along the radius of the tree cross section) and tangential directions (perpendicular to the radius of the tree). In general, the shrinkage at right angles to the grain of the wood is quite pronounced (shrinkage along the length of grain is negligible), ranging from approximately 2 to 8 percent of the original green size in the radial direction and from about 4 to 14 percent in the tangential direction. Within a given piece of wood, and for all practical purposes, the tangential shrinkage is about twice that of the radial shrinkage. The alignment of the growth rings significantly affects the shape of a piece of wood as it shrinks.

Wood density and spiral grain are less variable from pith-to-bark in Douglas-fir than in radiata pine, and this also lessens the negative impact of juvenile wood characteristics.

Development of Checks

A **check** is defined as a lengthwise separation of wood, normally occurring across or through the rings of annual growth and usually the result of seasoning. For grading purposes, checks are classified as a surface check (occurring only on the surface of the wood), an end check (occurring on the ends), or as a through check (extending from one surface through the piece to the opposite surface). A through check is often called a **split.**

Checks and splits can normally be avoided if wood is dried slowly and evenly on all surfaces. Slow drying allows the strength of the individual cells and the cohesion between them to make adjustments in shape (thus relieving internal stresses). But, when stresses are produced from rapid drying on the sides or ends of a piece, the natural resistance of the wood is then overcome, and separations (checks and splits) occur in the planes of weakness within the wood itself, normally along the wood rays emanating from the centre of the tree outward. The surface checking at the wood rays usually do not penetrate far into the wood, although they may be more pronounced in large rayed species such as oak and in timbers owing to the greater moisture gradient from the interior to the exterior portions of the more sizable material. Douglas fir has a reputation for checking in larger dimension. End grain can be sealed to prevent rapid drying.

In a well-controlled kiln, the drying schedule can be adjusted to neutralize the internal stresses. However, in the storage of logs, and in the natural drying of lumber, the ends tend to lose moisture more rapidly than do the sides, not only because moisture travels along the grain more readily than across it, but also because the ends of the material are more exposed to drying conditions. Rapid drying of the ends can cause local shrinkage with cells splitting apart showing obvious end checking and eventually splitting.

Handling

Since density is largely dependent on the amount of actual wood substance, it is evident that heavier parts of a given piece of lumber will tend to shrink more that then do the lighter portions of the same stick. This uneven shrinkage may cause some warping or bowing of the lumber. Also, since changes in dimension are proportional to the volumetric changes in the amount of water contained within the cell walls, it follows that woods with a high solid content, because they contain more absorbed water, will exhibit greater volumetric change than do those which are lighter in weight. This volumetric shrinkage of wood is directly proportional to the density. In other words, a 10-30% increase in density represents a 10-30% increase in shrinkage.

Shrinkage Values

The following table shows comparative shrinkage values of some common North American and other woods commonly imported into North America. The values shown represent total shrinkage from the woods FSP to various MC levels.

(Canadian wood Council: http://www.cwc.ca/products/lumber/)

Shrinkage Coefficients for Canadian Softwoods					
Species	Direction of shrinkage	Shrinkage (% of green wood) to:			
		19%	15%	12%	6%
Cedar, Western Red	Radial	0.9	1.2	1.4	1.9
	Tangential	1.8	2.5	3.0	4.0
Douglas Fir, Coast	Radial	1.8	2.4	2.9	3.8
	Tangential	2.8	3.8	4.6	6.1
Douglas Fir, Interior	Radial	1.4	1.9	2.3	3.0
	Tangential	2.5	3.4	4.1	5.5
Hemlock, Western	Radial	1.5	2.1	2.5	3.4
	Tangential	2.9	3.9	4.7	6.2
Larch, Western	Radial	1.7	2.2	2.7	3.6
	Tangential	3.3	4.6	5.5	7.3
Pine, Eastern White	Radial	0.8	1.0	1.3	1.7
	Tangential	2.2	3.0	3.7	4.9
Pine, Red	Radial	1.4	1.9	2.3	3.0

	Tangential	2.6	3.6	4.3	5.8
Pine, Western White	Radial	1.5	2.0	2.5	3.3
	Tangential	2.7	3.7	4.4	5.9
Spruce, Eastern	Radial	1.5	2.0	2.4	3.2
	Tangential	2.5	3.6	4.4	5.8
Spruce, Engelmann	Radial	1.4	1.9	2.3	3.0

In the case of Douglas-fir, regional data are given, indicating that properties in old growth stands can be different throughout the natural range. Even these data are averages only, and disguise the high levels of variability which are often found in research studies. Nault (1989) examined longitudinal shrinkage in “second growth Douglas-fir in western Canada and showed that while a small percentage of wood from near the pith (juvenile wood) exceeded 0.2%, there was very high tree-to-tree variation. Mackay (1989) concluded that conventional drying schedules (up to 93^0C) would result in twist of wood high a high proportion of juvenile wood, and recommended higher temperatures.

Equivalent NZ data are available (Cown, 1999):

Shrinkage Coefficients for NZ Douglas-fir		
Direction of Shrinkage	**Shrinkage (% of green wood) to:**	
	12%	**Oven-dry (0%)**
Radial	1.8	3.5
Tangential	3.5	6.5
Longitudinal	0.1	0.1
Volumetric	6.5	11.0

Stability in Service

When dry, Douglas fir has the reputation of retaining its shape and size without shrinking, swelling, cupping, warping, bowing or twisting, and generally won’t check or show a raised grain.

One of the most important characteristics of wood is its time-dependent deformation behavior. Continued deformation under load is called “creep”. Dry lumber creeps much less than wet material, but there is very little technical data on the comparative performance of the Douglas-fir response to load and changing MC levels, apart from the common description as “highly dimensionally stable”.

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