Wood properties and their implications for wood use (particularly in relation to radiata pine)

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General characteristics of wood

Wood is:

1. cellular
2. Anisotropic
3. Hygroscopic
4. Variable

Physical nature of wood

All of woods physical properties are derived from its basic structural organisation:

1. The amount of cell wall material per unit volume (density)
2. The amount of water present (moisture content)
3. The kinds, types, sizes of cells (anatomy)
4. The arrangement of wall components within the cells (microstructure)
5. The presence of growth features ie. knots, reaction wood, spiral grain

Wood density and specific gravity

$$\text{Density} = \frac{\text{weight}}{\text{Volume}} \quad \text{expressed as kg/m3}$$

$$\text{Specific gravity} = \frac{\text{Density of wood}}{\text{Density of water}} \quad \text{expressed as an index}$$

Because wood is hygroscopic, density can be expressed at different moisture contents other than oven dry, eg.
Green any mc. above f.s.p.
Air dry (usually taken as 12% mc..)
Oven dry (Basic density)

Anatomy

The type of wood cells influence wood properties - both strength and appearance.
Hardwoods differentiated from Softwoods by cell type.
Fibers & vessels in hardwoods
Tracheids in softwoods
Radiata in common with other softwoods is composed mainly of longitudinal cells or trachieds, it also contains horizontal or ray cells and resin canals (both horizontal and vertical) These resin canals are visible on the sawn surface and are a good indicator of grain direction in the piece.

Moisture content

Expressed as a percentage of wood substance present:

$$\text{mc.\%} = \frac{\text{Wt of water}}{\text{Oven dry wt of wood}} \times 100$$

With "green" timber the cell lumen as well as cell wall will contain water.
The point at which the wood cell lumens are empty but the walls are normally saturated is known as the fibre saturation point (fsp.) This is normally around 30%mc. and is the mc. at which shrinkage will commence.
As a result of Hygroscopicity, wood moisture content (mc.) varies with atmospheric conditions below the fsp.

The average moisture content attained under given conditions of temperature and relative humidity is called the equilibrium moisture content (E.M.C.)

Shrinkage

Dimensional changes occur as the mc. varies at levels below the fsp.

Shrinkage is different in the three planes. This is an example of woods anisotropy.
Greatest in the tangential direction, followed by the radial direction and least in the longitudinal direction.
Dimensional changes in wood are called movement and are important to its use in service.(stability)

Grain

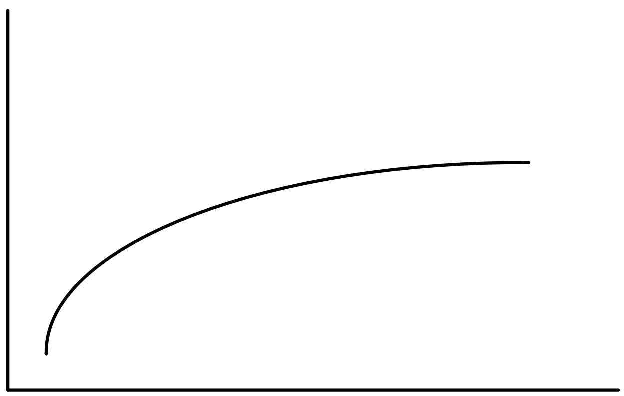
Grain angle affects machining and strength. Grain is taken as the direction in which the cells have their longest dimension or axis. Wood with the grain direction other than along the longitudinal plane suffers a loss in strength. For a slope of 1 in 10 (Engineering grade) the loss is about 20% and for a slope of 1 in 6 (Framing grade), the loss is about 40%. This "sloping grain"may be due to spiral grain or sawing swept logs.

Variability in wood properties

1) **Within tree**

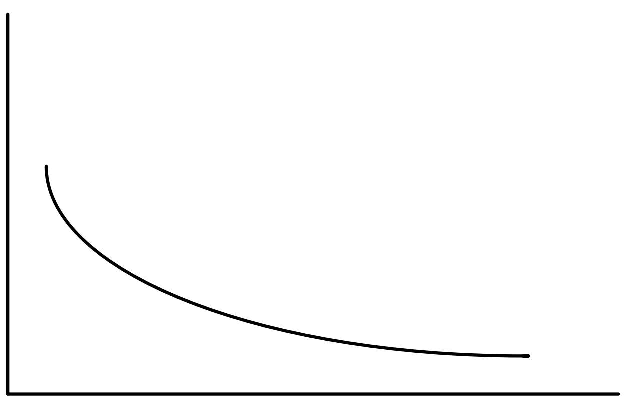
Periodic cambial growth results in the formation of growth rings (usually annual). Wood properties vary across the rings (**earlywood/ latewood**) and between the rings (**sapwood/ heartwood**)

With radiata there are distinct radial patterns from pith to bark.



Pith Bark

Density (Kg/m3)	350	450
Cell length (mm)	1.0	3.5



Pith Bark

Ring width (mm)	15	5
Spiral grain (degrees)	5	1
Longit shrinkage (%)	1.0	0.2

These patterns give rise to the concept of **Corewood** and **Outerwood**.
Corewood is the central zone of low density, fast growth, higher spiral grain angle, shorter cell length, which is generally the least desirable part of the tree. Corewood is generally accepted as being within the first 10 growth rings surrounding the pith.

Radiata in common with most exotic softwoods used in NZ shows a clear differentiation between sapwood and heartwood.

Sapwood	**Heartwood**
Water conducting part of stem	Non-conductive section of stem
High mc.% (160%+)	Lower mc.% (45%)
Resin content low	Resin content higher
Food storage- attractive to fungi & insects	Resistant to decay & insects

Other within tree wood variability due to:

* Knots- radiata branches arranged in whorls
* Cone holes - associated with branch whorls (stem cones characteristic of radiata)
* Resin pockets- with radiata, more severe in some regions than others (eg. Nelson)
* Reaction wood, or compression wood- formed in response to deviation from normal growth habit. Wider /darker growth rings- greater longitudinal shrinkage- more prone to distortion.

Between trees
Genetic differences have resulted in density and fiber length varying up to 50% between extreme trees. Newer tree crops will show lesser genetic vatiation.

Between sites
Wood properties can be significantly influenced by enviroment. Research has found outerwood density is closely related to mean annual temperature. Mature wood density decreases by about 7Kg/m^3 for every one degree increase in latitude and every 100m increase in altitude

How do these properties effect radiata's use?

The two most important are:
Density and Moisture content, with moisture content probably the most important.

Moisture Content
There are two important aspects to consider :

* How moisture content affects processing performance.
* How moisture content affects the performance in service.

If wood products are to perform satisfactorily, mc.must be controlled at all stages. The wood must be:

(i) Dried to the correct moisture content (specified).
(ii) Stored properly to avoid undue moisture change before manufacture.
(iii) Manufactured under controlled conditions.
(iv) Protected properly before use and while being put into service.

For gluing, generally the timber must be less than the maximum recommended by the glue manufacturer, and less than 16%mc if radio frequency curing. Higher mc interferes with the glue cure and can cause steam build up and blown joints.

NZS 3616 requires that shooks for F/J for finishing purposes shall be uniformly dried so that the mc. variation between shooks does not exceed 5%.
If it is greater the subsequent moisture movement and shrinkage?swelling can cause stresses to build up in the glue line which could cause failure. Additionally NZS 3616 requires that the mc.of jointed timber, at time of jointing, shall not exceed the maximum relevant mc. range recommended in Table 4 NZS3602: 1995

To meet these requirements means that the producer requires a consistent quality control procedure for checking wood moisture content before and during shook preparation. Methods for testing mc. include:

Resistance type moisture meters (normally accurate to +_1 $^1/_2$ % mc.) with long insulated probes will measure the core mc. of 75mm stock.

RF moisture meter-accurate to +_3% mc, but very useful for a rapid check of mc.

Oven drying - highly accurate but usefull only to check if some doubt with other methods.

What is the correct moisture of installation? For NZ, NZS 3602:2003 table 4 sets out recommended mc%. For international markets, the customer should be consulted.

Table 4 NZS 3602:2003
Allowable Moisture Content
(at time of installation or in the case of framing timber at time of closure)

	Use category level of finish	Air conditioned or centrally heated	intermittently heated buildings	unheated buildings
1	Timber to which linings are attached to achieve a "level of finish" 3-5	8-18	12-18	12-18
2	Enclosed framing (including roof trusses) to achieve a "level of finish" 0-3	12-18	12-24	12-24
3	Load bearing lintels and beams	8-18	12-20	12-20
4	Weatherbds,exterior joinery & finishing timbers	14-18	14-18	14-18
5	Flooring exposed to ground atmosphere	10-14	12-16	14-18
6	interior joinery and finish, furniture corestock	8-12	10-14	12-16
7	Flooring not exposed to ground atmosphere	8-12	10-14	12-16

Note:
Allowable ranges of moisture content are specified on the basis that 90% of pieces shall be within the specified range, the remainder shall be within a further 2% mc above or below

Wood after drying to below 18% will tend to pick up moisture on exposure to air. Therefore kiln dried timber should always be block stacked, preferably with a cover. They should not be allowed to get rainwet, even in transit! Once wet the prepared timber is more difficult to dry satisfactorily. Don't get it wet!
In the factory, the time the wood is exposed to the air should be minimised. Prompt processing and block stacking when not being worked on, preferably in a controlled atmosphere.

Density

Of all the physical properties, wood density consistently has the most influence on mechanical properties, particularly stiffness. t has an influence on many of the mechanical/physical processes during manufacture e.g. machining, fingerjoint profile preparation, gluing and paint retention.

In general radiata is a good machining timber, higher wood density produces a better machined finish. e.g.outerwood gives a smoother finish than corewood. Luckily however, the range of densities normally encountered with radiata is not great enough to cause problems. kup of grain around knots is common, but good knife maintenance will minimise this problem. The radiata available now should provide good material for machining as there will be less variation in density from corewood to outerwood, less resinous wood and more intergrown knots.