Structure & Physical Properties of Wood

Sections 10.1-10.3, 10.6-10.7†

† Mamlouk, M.S., and Zaniewski, J.P. (2006). *Materials for Civil and Construction Engineers*, 2nd ed., Prentice Hall

Other resources: Canadian Wood Council (http://www.cwc.ca)

What we are going to talk about …

- Types of wood
- Structure of wood
- Physical properties

Introduction

Wood is one of the earliest construction material used

Earliest timber frames were in 500-200 BC

The Urnes stave church (c. 1150)

Horyu-ji (c. 711) and possibly even earlier, as one of the hinoki (Japanese cypress) posts appears to have been felted in the year 594.

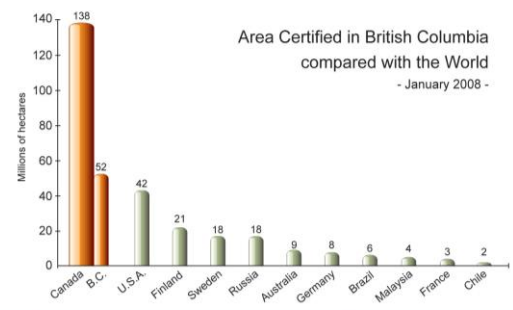
Intro to Forestry

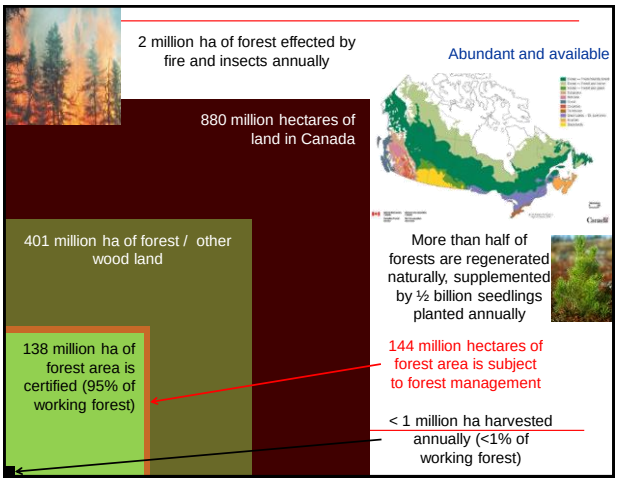
Introduction

Wood's attributes

- easy to use
- durable
- high strength (considering its density)
- low weight
- widely available
- low cost

Introduction





Types of Wood

- Hardwood
  - ✓ broadleaved or deciduous trees
- Softwood
  - ✓ coniferous or evergreen trees

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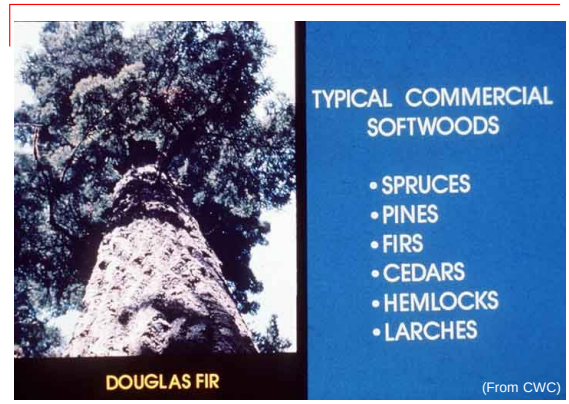
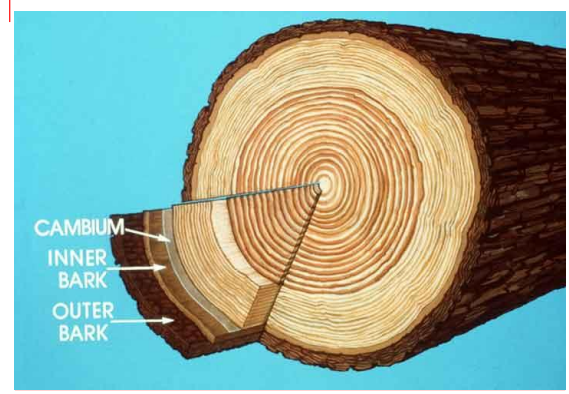
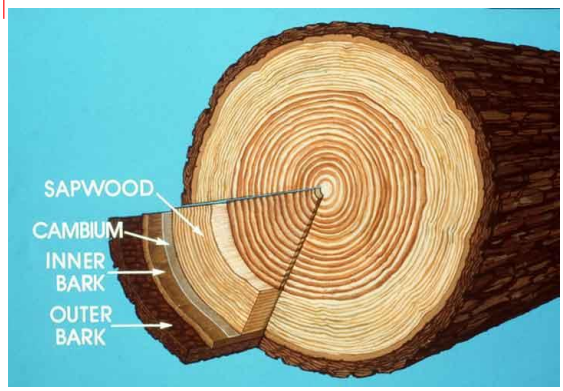
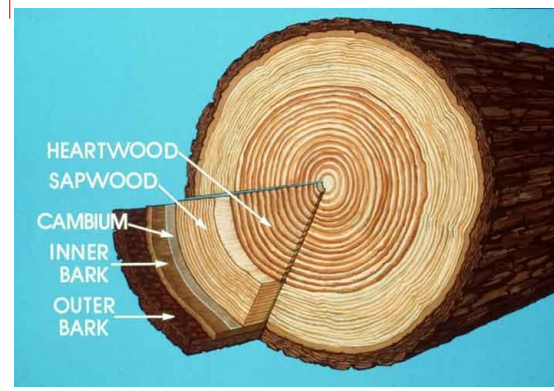
CVG 2141 - Civil Engineering Materials Wood - 9



CVG 2141 - Civil Engineering Materials Wood - 10



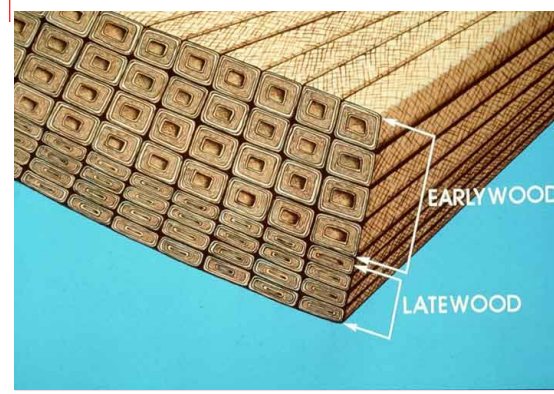

SAPWOOD
CAMBIUM
INNER BARK
OUTER BARK

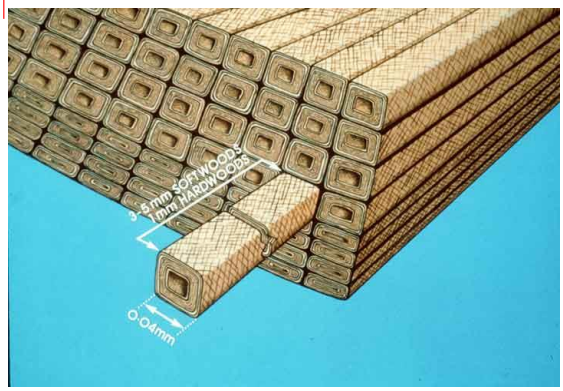

HEARTWOOD
SAPWOOD
CAMBIUM
INNER BARK
OUTER BARK

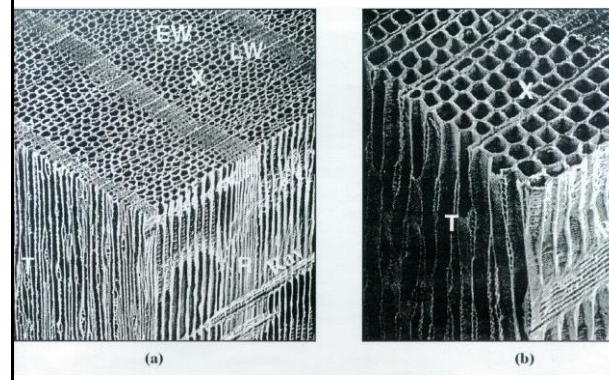

PITH

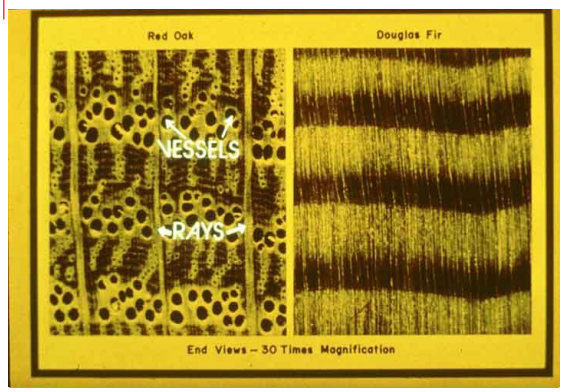

ANNUAL LAYER OF GROWTH


EARLYWOOD (SPRINGWOOD)
LATEWOOD (SUMMERWOOD)


EARLYWOOD
LATEWOOD







How Tree Growth affects physical properties of wood

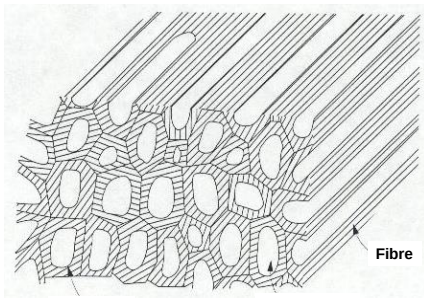
Fast Growth

- Large annual rings
- Lower density
- Higher taper and grain deviation

Slow Growth

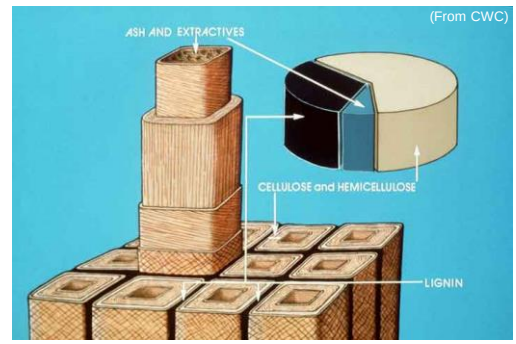
- Narrower annual rings
- Higher density
- Less taper and grain deviation

Wood Cell



(From "Civil Engineering Materials" by Somayaji)

Chemical Composition of Wood



Cellulose

- Main constituent of wood (40 – 50% wt.)
- Forms as bundles called microfibrils
- Provides axial strength through strong bonds within & between fibres

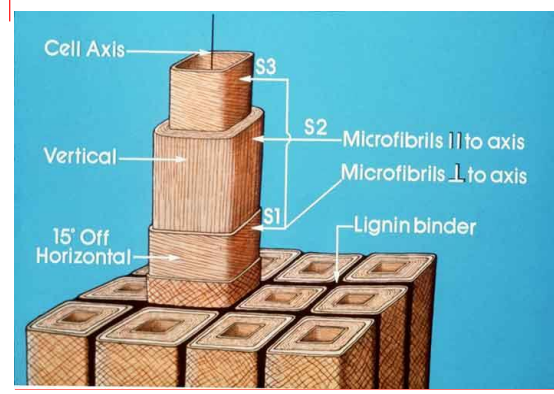
(From CWC)

Lignin

- Role of a binding matrix
  - Binds fibres within cells
  - Binds cell walls
- Provides rigidity & compressive strength to cell walls

Other Components

- Hemicellulose (20 – 25 % wt.)
  - Works with lignin as a binding agent
  - Important to making paper
- Extractives (≤ 10% wt.)
  - Chemicals which provide colour, odour, taste & decay resistance to wood
- Water
  - Found in cell walls & cell cavities

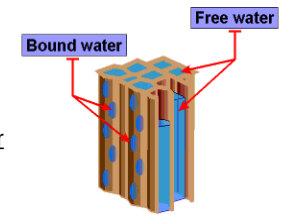


Orthotropic Nature of Wood

- Orthotropic material → properties are different in its principal directions
  - longitudinal → along its axis & parallel to grain
  - radial → along radius across annual rings & perpendicular to grain
  - tangential → along tangent to annual rings & perpendicular to grain

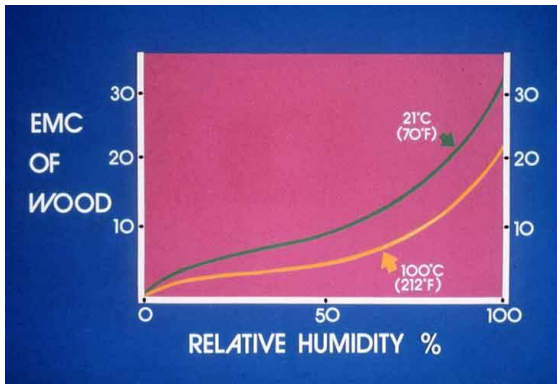
Moisture in Wood

- Hygroscopic material
- Water exists in wood as:
- ✓ free water – liquid filling cell cavities
- ✓ bound or adsorbed water – liquid or vapour chemically bound by hydrogen-bonding to the cellulose of the wood cell walls



(From http://timber.ce.wsu.edu)

Wood is a hygroscopic material



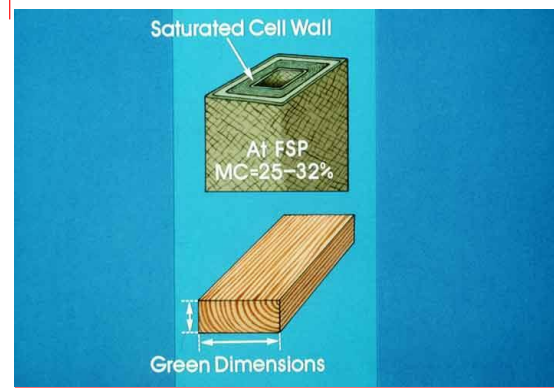
Moisture Content (MC)

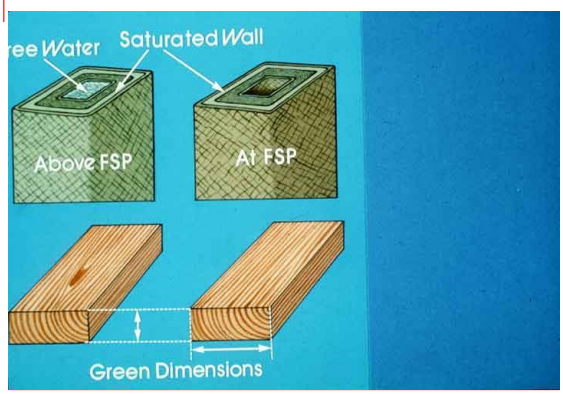
- Weight of water in wood expressed as % of OD weight, i.e.,

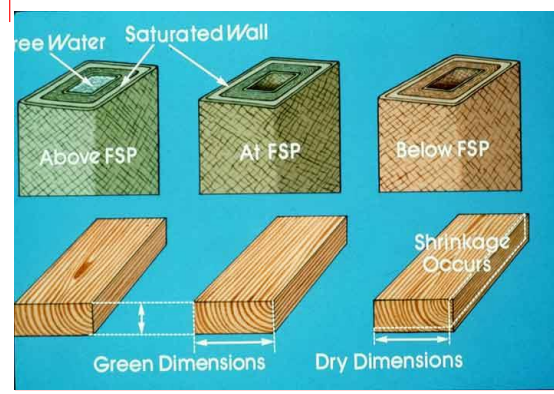
$$MC(\%) = \frac{\text{weight of moist wood - weight of OD wood}}{\text{OD weight}} \times 100$$

Fibre Saturation Point (FSP)

- MC at which all free water is removed
  - cell cavities empty
  - cell walls saturated with bound water
- MC > FSP ⇨ properties remain constant as MC changes
  - although density decreases as wood dries
- MC < FSP ⇨ properties change as MC changes
  - drying marked by reduction in cross-section dimensions
- FSP varies from species to species, but it averages around 25 – 30%







Fiber Saturation Point

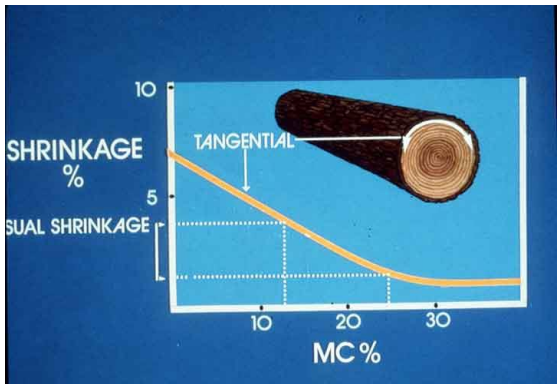
- **Below this point there will be dramatic changes in most physical and mechanical properties**

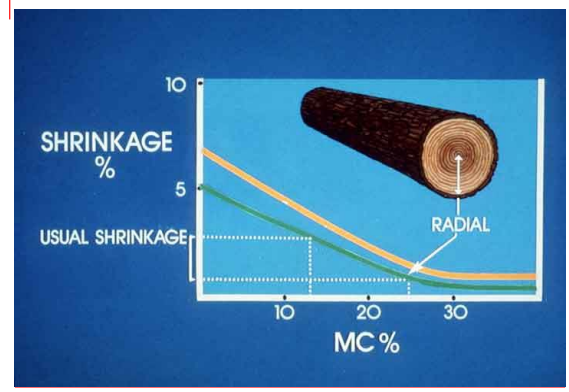
Shrinkage & Swelling

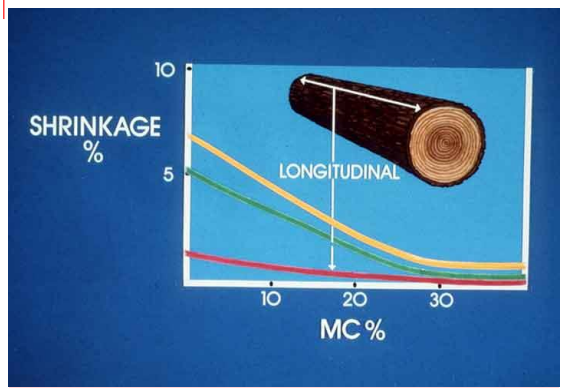
- Shrinkage ⇨ reduction in volume as wood dries below FSP
- Swelling ⇨ increase in volume caused by moisture gain in cell walls up to FSP
- Shrinkage depends on:
  - tree species
  - thickness of cell wall (latewood shrinks more)
  - arrangement of cells
  - grain pattern

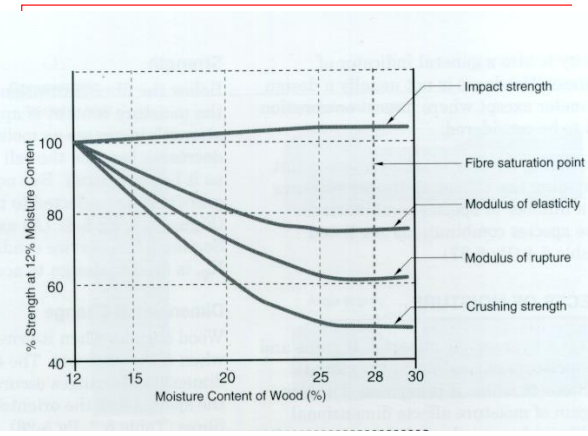
CVG 2141 - Civil Engineering Materials Wood - 39

Shrinkage

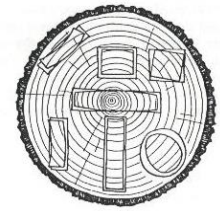


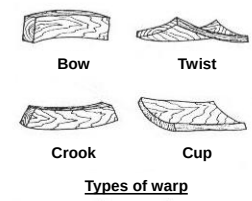






Effects of Shrinkage





Types of warp

Calculation Shrinkage

$$S = D \times M \times c$$

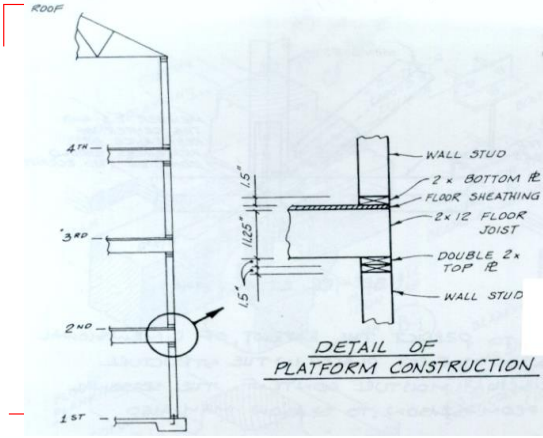
where

S = shrinkage (mm)

D = actual dressed dimension (mm) (thickness or width)

M = percent of moisture change below the fibre saturation point

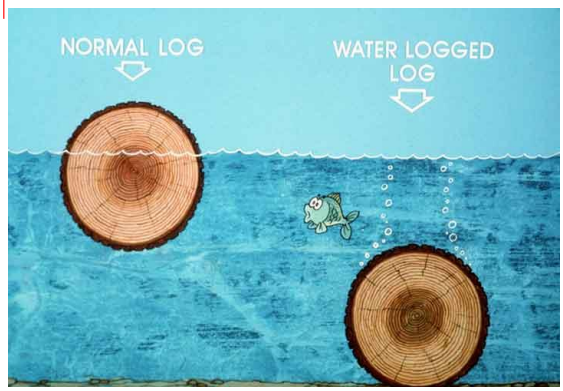
c = shrinkage coefficient



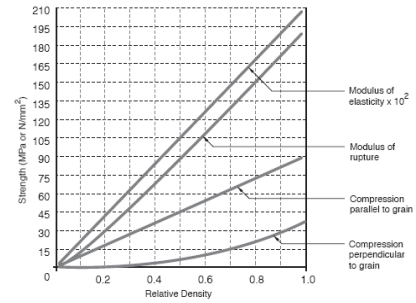
Density & SG

$$\text{Wood density} = \frac{\text{oven-dry weight}}{\text{volume of green wood}}$$

$$SG = \frac{W_{OD}}{\rho_{H_2O} \times V}$$



Strength vs. density



Example

- A sample of wood has a MC of 30%. Its dimensions are 37x88x150 mm. The weights of the sample in green and OD conditions are 0.28 kg and 0.25 kg, respectively. Find the SG.

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$$V_{green} = 0.037 \times 0.088 \times 0.150 = 4.88 \times 10^{-4}\ m^3$$

$$SG\,(green) = \frac{W_{OD}}{\rho_{H_2O} \times V_{green}} = \frac{0.25}{1000 \times 4.88 \times 10^{-4}} = \underline{0.51}$$

Defects in wood: Knots

Other Lumber Defects