TOPIC 5

Timber as a construction material

Introduction

- Wood, because of its availability, relatively low cost, ease of use, and durability (if properly designed), continues to be an important civil engineering material
- Wood is used extensively used for buildings, bridges, utility poles, floors, roofs, trusses, and piles.
- Civil engineering applications include both natural wood and engineered wood products, such as laminates, plywood, and strand board (flakeboard).
- Wood is a natural, renewable product from trees
- Trees are classified based on their growth:
  - Endogenous – trees that grow with intertwined fibers, eg palm trees
  - Exogenous - grow from the center out by adding concentric layers of wood around the central core
- Endogenous trees are not generally used for engineering applications. Thus, this topic considers only exogenous trees

Introduction

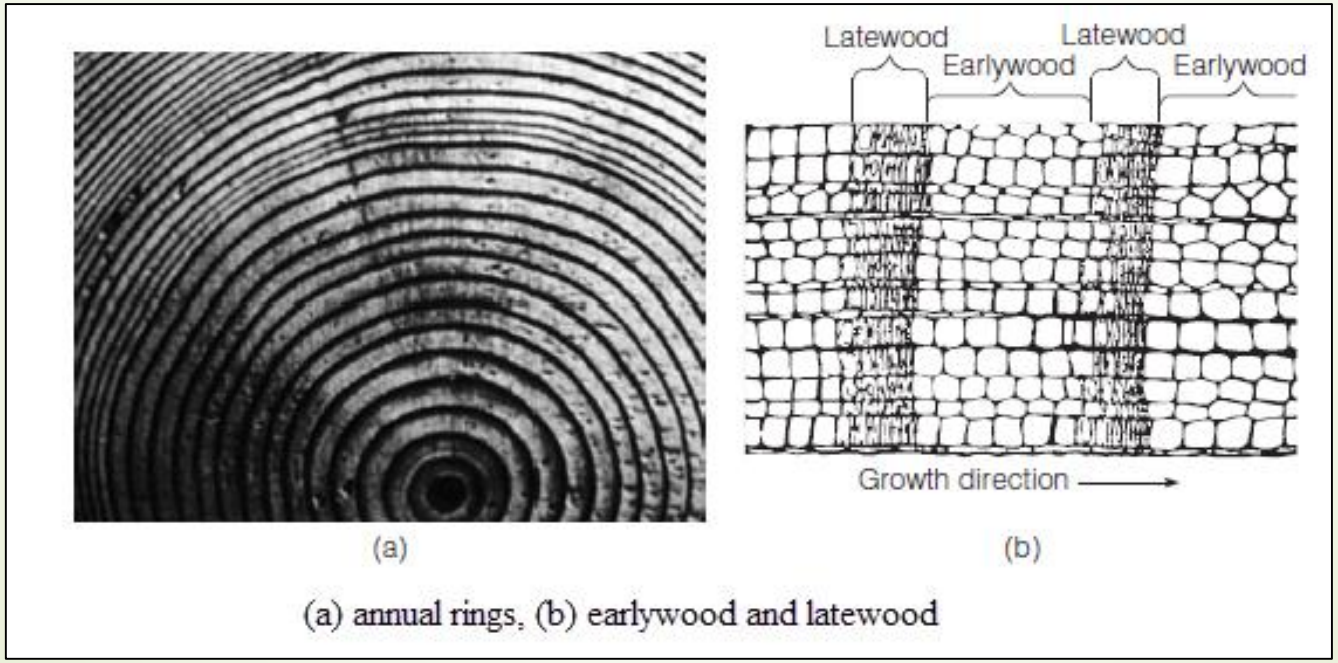
Introduction

- Exogenous trees are broadly classified as:
  - Deciduous – trees that produce hardwoods
  - Conifers – trees that produce softwoods
- In general, softwoods are softer, less dense, and easier to cut than hardwoods
- Deciduous trees generally shed their leaves at the end of each growing season
- Many hardwoods are used for furniture and decorative veneers, due to their pleasing grain pattern.
- The decorative properties of some hardwoods increase their value and cost. This makes them uneconomical for construction lumber.
- Conifers, also known as evergreens, have needlelike leaves and normally do not shed them at the end of the growing season
- Conifers are widely used for construction. Conifers grow in large stands, permitting economical harvesting. They mature rapidly, making them a renewable resource

Structure of wood

Growth Rings

- Wood has a distinct structure that affects its use as a construction material
- The concentric layers in the stem of exogenous trees are called growth rings or annual rings.



(a) annual rings, (b) earlywood and latewood

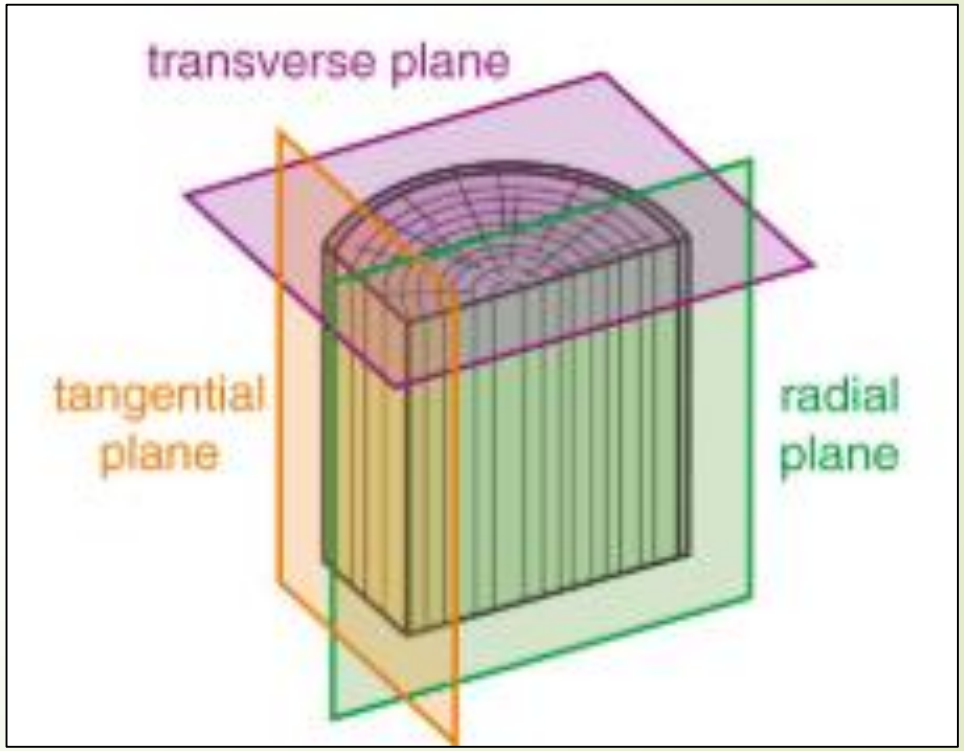
Structure of wood

- The wood section of the tree is composed of sapwood and heartwood.
- Heartwood is often darker colored and occurs at the center of the cross section and is surrounded by sapwood.
- Sapwood functions as a storehouse for starches and as a pipeline to transport sap.
- Generally, faster growing species have thick sapwood regions. In its natural state, sapwood is not durable when exposed to conditions that promote decay.
- Heartwood is not a living part of the tree. It is composed of cells that have been physically and chemically altered by mineral deposits.
- The heartwood provides structural strength for the tree. Also, the heartwood of some species is decay resistant due to the presence of extractives (waxes, fatty acids, etc)

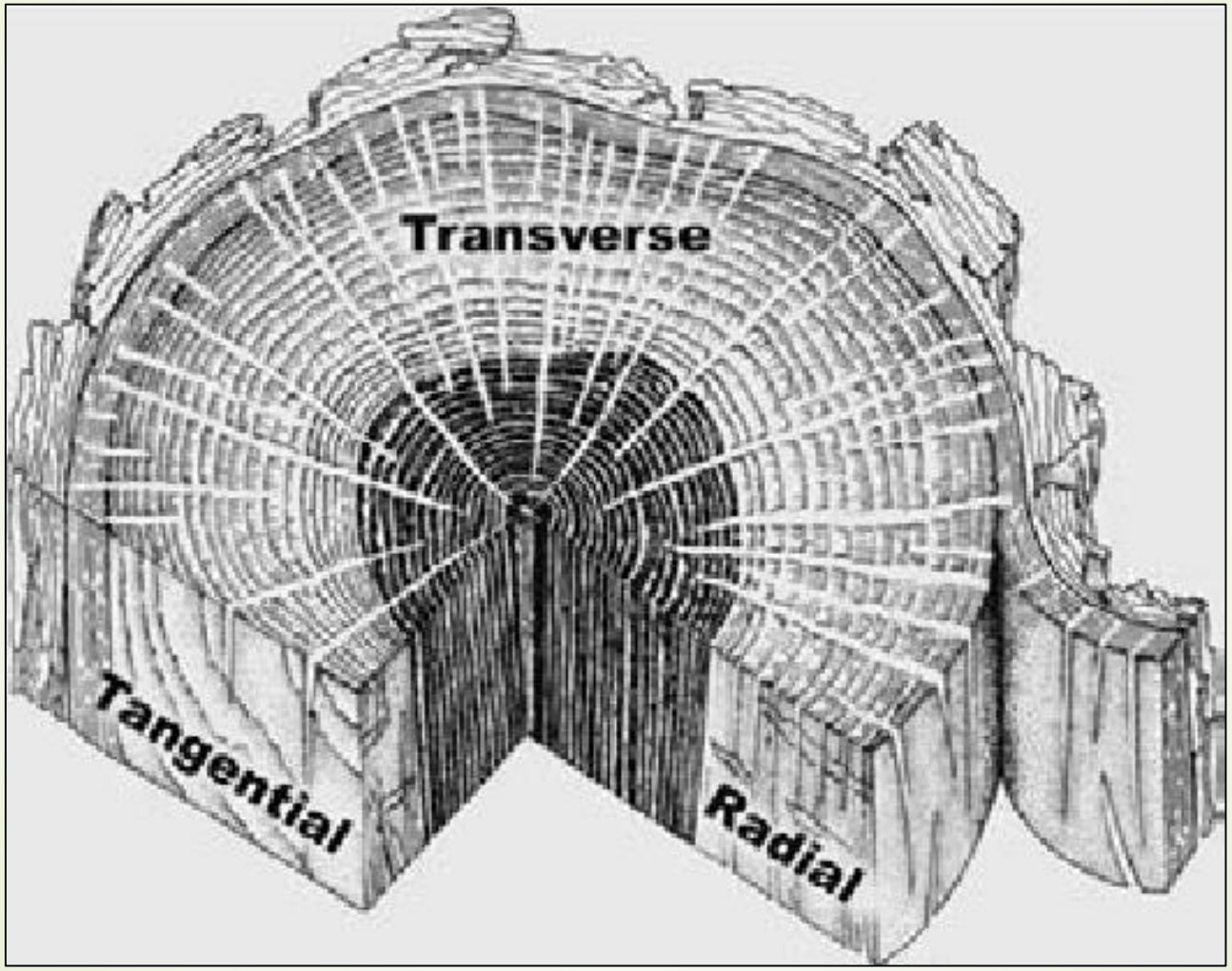
Structure of wood

Anisotropic Nature of Wood

- Wood is an anisotropic material in that it has different and unique properties in each direction
- The three axis orientations in wood are:
  - longitudinal, or parallel to the grain;
  - radial, or cross the growth rings; and
  - tangential, or tangent to the growth rings



Structure of wood



Moisture Content

- Wood is composed of cellulose, lignin, hemicellulose, extractives, and ash-producing minerals.
- Cellulose accounts for approximately 50 percent of the wood substance by weight
- The moisture content of a wood specimen is the weight of water in the specimen expressed as a percentage of the oven-dry weight of the wood
- An oven-dried wood sample is a sample that has been dried in an oven at 100°C to 105°C (212°F to 220°F) until the wood attains a constant weight.
- Physical properties such as weight, shrinkage, and strength depend on the moisture content of wood
- Moisture exists in wood as either:
  - bound - water held within the cell wall by adsorption forces
  - free water - water that exists as either condensed water or water vapor in the cell cavities.

Moisture Content

- The level of saturation at which the cell walls are completely saturated, but no free water exists in the cell cavities, is called the **fiber saturation point** (FSP)
- FSP varies from species to species and within the same species, but is typically in the range of 21% to 32%
- The FSP is of great practical significance, because the addition or removal of moisture below the FSP has a large effect on practically all physical and mechanical properties of wood, whereas above the FSP, the properties are independent of moisture content.
- When the moisture content of wood is above the fiber saturation point, the wood is dimensionally stable
- However, moisture fluctuations below the FSP always result in dimensional changes. Shrinkage is caused by loss of moisture from the cell walls, and conversely, swelling is caused by the gain of moisture in the cell walls.

Production of wood

- A vast industry has developed to harvest and process wood from forests as logs.
- They are transported to saw mills, where they are cut into dimensional shapes to produce a variety of products for engineering applications that include:
  - Dimension lumber is wood from 2 in. to 5 in. thick, sawn on all four sides and lengths of 8 ft. to 24 ft. Dimension lumber is typically used for studs, sill and top plates, joists, beams, rafters, trusses, and decking.
  - Heavy timber is wood sawn on all four sides; common shapes include 6*6 and 8*8 and larger. Heavy timber includes Beams and Stringers (subjected to bending) and Posts and Timbers (used as posts or columns). Heavy timbers are used for heavy frame construction, landscaping, railroad ties, and marine construction.
  - Round stock - consists of posts and poles used for building poles, marine piling, and utility poles.
  - Engineered wood consists of products manufactured by bonding together wood strands, veneers, lumber, and other forms of wood fiber to produce a larger and integral composite unit

Wood cutting techniques

- Sawn wood production includes the following steps:
  - Sawing into desired shape
  - Seasoning
  - Surfacing
  - Grading
  - Preservative treatment (optional)

Sawing

- Process of cutting harvested wood into lumber and timber at saw mills
- The angle between the growth ring and the saw blade produces three categories of board cuts,
  1. Flat-sawn, 45° or less
  2. Rift-sawn, 45° to 80°
  3. Quarter-sawn (vertical- or edge-sawn), 80° to 90°

Wood cutting techniques

Seasoning

- This is the a controlled process that removes the excess moisture from wood
- For structural wood, the recommended moisture content varies from 7% in the dry states to 14% in the damp regions
- Wood is seasoned by air and kiln drying
- Air drying is inexpensive, but slow. The green lumber is stacked in covered piles to dry
- After air drying the lumber may be kiln dried
- A kiln is a large oven where all variables can be closely monitored
- Care must be taken to slowly reduce the moisture content of wood.
- Drying too rapidly can result in an increase in cracking and warping.
- Dried lumber will take on moisture again if exposed to water; therefore, care must be used when storing and transporting wood
- Structural lumber is not typically air-dried prior to kiln drying

Wood cutting techniques

Surfacing (Planing)

- This is the planing of the wood surface to produce a smooth face
- It can be done before or after drying.
- Post drying surfacing is superior, because it removes small defects developed during the drying process.
- When surfacing is done before seasoning, the dimensions are slightly increased to compensate for shrinkage during seasoning.

Grading of wood

- Involves grading the lumber according to quality.
- Typically, lumber is graded according to the characteristics that affect strength, durability, or workability.
- The most common grade-reducing qualities of lumber are knots, checks, pitch pockets, shakes, and stains.

Wood cutting techniques

Grading of wood

Sample of Stress Grading of Softwood for Structural Applications
According to American Forest & Paper Association

Grade Designation	Design Values, psi				
	Bending	Tension Parallel to Grain	Compression Parallel to Grain	Modulus of Elasticity	Minimum Modulus of Elasticity
900f-1.0E	900	350	1,050	1,000,000	510,000
1650f-1.3E	1,650	1,020	1,700	1,300,000	660,000
1950f-1.5E	1,950	1,375	1,800	1,500,000	760,000
2250f-1.7E	2,250	1,750	1,925	1,700,000	860,000
2400f-2.0E	2,400	1,925	1,975	2,000,000	1,020,000
2850f-2.3E	2,850	2,300	2,150	2,300,000	1,170,000
3000f-2.4E	3,000	2,400	2,200	2,400,000	1,220,000

Wood cutting techniques

Preservative Treatment

- Petroleum-based solutions (Coal-tar creosote, petroleum creosote, creosote solutions, and pentachlorophenol solutions are), and waterborne oxides (salts such as ammoniacal copper arsenate, chromated copper arsenate (CCA) and ammoniacal copper zinc arsenate) are the principal types of wood preservatives.
- The degree of preservation achieved depends on the type of preservative, the degree of penetration, and the amount of the chemical retained within the wood.
- Effective preservatives must be applied under pressure to increase penetration into the wood.
- The advantages of the waterborne preservative over the oil-based are cleanliness and its ability to be painted. The disadvantage of some of these treatments is their removal by leaching when exposed to moist conditions over long periods of time

Defects in Lumber

- Lumber may include defects that affect either its appearance, its mechanical properties, or both.
- These defects can have many causes, such as:
  - natural growth of the wood,
  - wood diseases, animal parasites,
  - too rapid seasoning, or
  - faulty processing
- Common defect types include:
  - **Knots** – Knots are branch bases that have become incorporated into the wood of the tree trunk or another limb. Knots degrade the mechanical properties of lumber, affecting the tensile and flexural strengths
  - **Shakes** – are lengthwise separations in the wood occurring between annual rings. They develop prior to cutting the lumber and could be due to heavy winds.

Defects in Lumber

- Common defect types include:
  - **Wane** – This is bark or other soft material left on the edge of the board or absence of material.
  - **Sap Streak** - is a heavy accumulation of sap in the fibers of the wood, which produces a distinctive streak in color
  - **Reaction Wood** - abnormally woody tissue that forms in crooked stems or limbs. It causes the pith to be off center from the neutral axis of the tree. It creates internal stresses which can cause warping and longitudinal cracking.
  - **Pitch Pockets** - are well-defined openings between annual rings that contain free resin.
  - **Bark Pockets** - are small patches of bark embedded in the wood. These pockets form as a result of an injury to the tree, causing death to a small area of the cambium. The surrounding tree continues to grow, eventually covering the dead area with a new cambium layer.

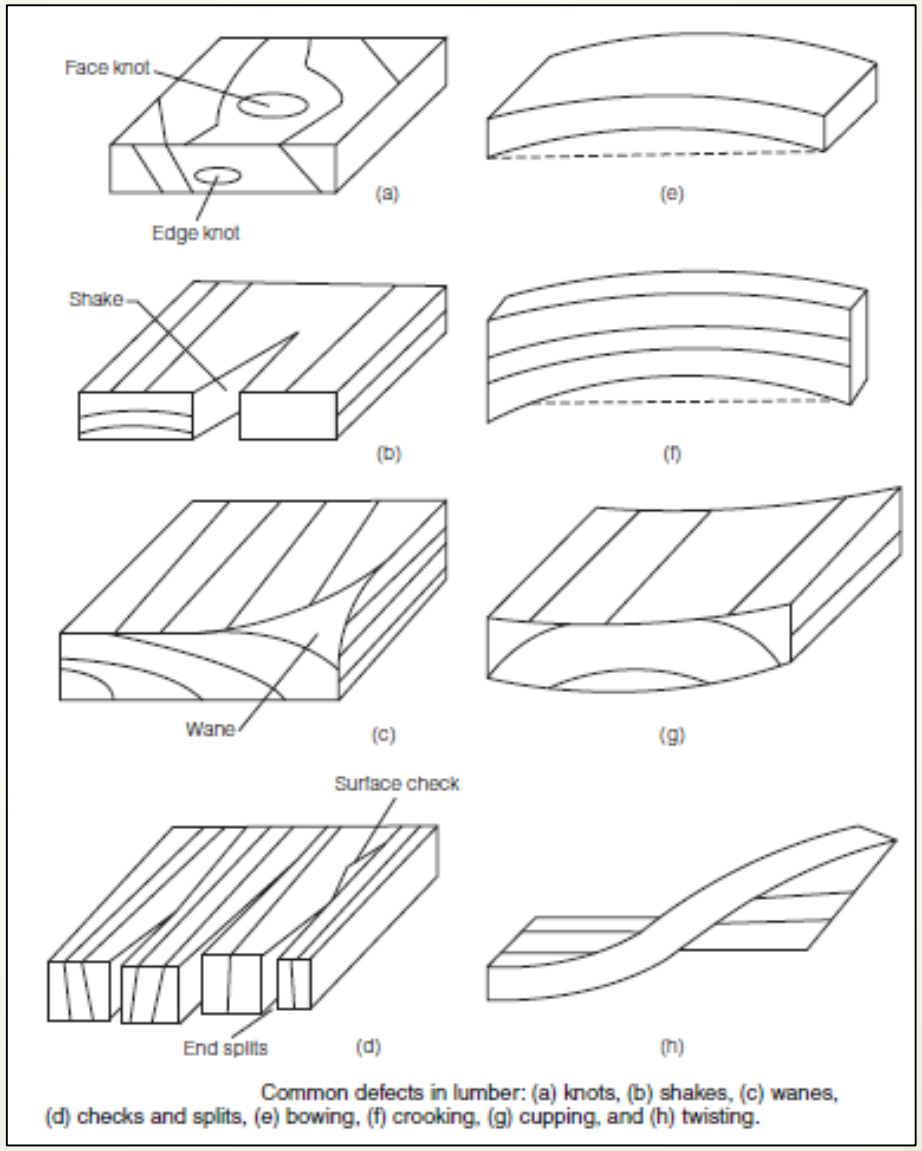
Defects in Lumber

- **Checks** - ruptures in wood along the grain that develop during seasoning. They can occur on the surface or end of a board. Surface checking results from the differential shrinkage between radial and tangential directions and is confined mostly to planer surfaces. Cracks due to end checking normally follow the grain and result in end splitting.
- **Splits** - are lengthwise separations of the wood caused by either mishandling or seasoning
- **Warp** - is a distortion of wood from the desired true plane. The four major types of warp are bow, crook, cup, and twist. Bow is a longitudinal curvature from end to end. Crook is the longitudinal curvature side to side. Both of these defects result from differential longitudinal shrinkage. Cup is the rolling of both edges up or down. Twist is the lifting of one corner out of the plane of the other three. Warp results from differential shrinkage, differential drying due to the production environment, or from the release of internal tree stress.

Defects in Lumber

- **Raised, Loosened, or Fuzzy Grain** - may occur during cutting and dressing of lumber.
- **Chipped or Torn Grain -** occurs when pieces of wood are scooped out of the board surface or chipped away by the action of the cutting and planing tools.
- **Machine Burn –** This is when an area that has been darkened by overheating during cutting.

Defects in Lumber



Common defects in lumber: (a) knots, (b) shakes, (c) wanes, (d) checks and splits, (e) bowing, (f) crooking, (g) cupping, and (h) twisting.

Physical and Mechanical Properties

- Important physical properties include:
  - specific gravity and density,
  - thermal properties, and
  - electrical properties
- Typical mechanical properties of interest to civil and construction engineers include:
  - modulus of elasticity - stress–strain relation of wood
  - strength properties - modulus of rupture in bending, compressive strength parallel and perpendicular to the grain, tensile strength parallel to the grain, and shear strength parallel to the grain.
  - creep – permanent sag in a wood member
  - damping capacity – measure of amplitude of vibration in a material

Thank You!!!