Solid construction materials

Plastics

Natural, synthetic or semi-synthetic materials

Typically **organic polymers**, with high molecular mass.

Made of petrochemicals, but also from renewable materials (cellulose, textiles etc.)

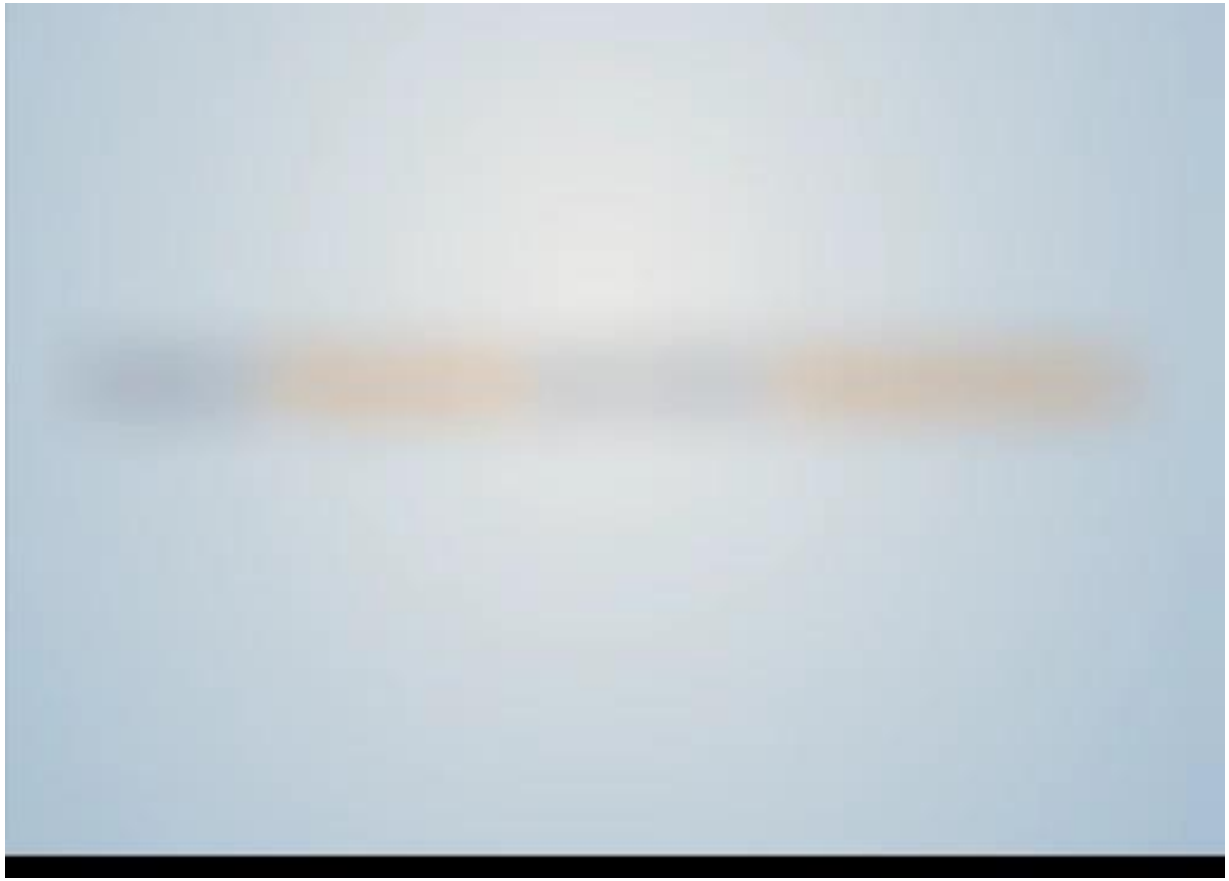
General characteristic: **plasticity**, low cost, relatively easy processing

Made of **carbon chains (and H)**, with some additives:
O, Si, S, N, P

Polymerization degree: gives the number of macromolecules in a polymer. One macromolecule can contain from 100 up to 1 million atoms

In construction: sealants, adhesives, elastomers, glues, corrosion protection materials

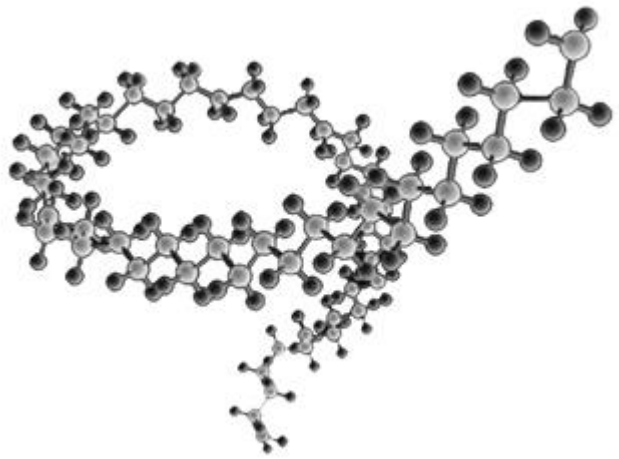
Polymers classification



Plastics

Composition:

- **backbone: organic polymer**
- **side chains:** fine tuning of the characteristics
- **additives**: organic and inorganic, up to 50%
- **fillers:** improove performance, reduce cost. Eg. increase the melting point
- **plasticizers:** reduce rigidity
- **colorants**



Plastics

General characteristics

- low density 900-2200 kg/m^3
- large variety of mechanical properties
- good electric insulators
- good sound and thermal insulators (thermal foam insulators)
- chemical reactivity is low
- good workability

Plastics

Classification:

- **chemical structure:** homopolymers and copolymers
- **polymeric structure:** linear, branched and crosslinked
- **arrangement of monomers:** block polymers and graft copolymers
- **taciticity:** isotactic, syndiotactic and atactic
- **thermal behavior:** thermoplastics and thermosetting
- **molecular forces:** elastomers and fibers
- **methods of synthesis:** addition polymers and condensation polymers
- **nanostructure:** crystalline or amorphous
- **biodegradability:** biodegradable or not

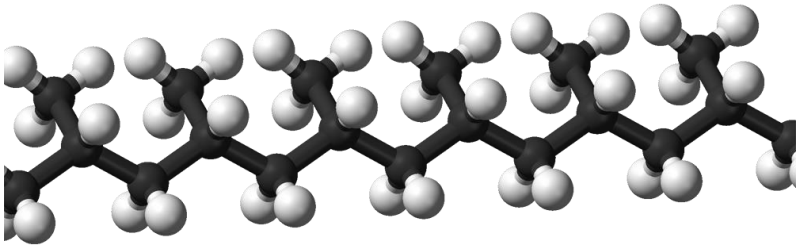
Polymers
Thermoplastic polymers

Thermoplastic polymers: become moldable at elevated temperature and solidifies upon cooling

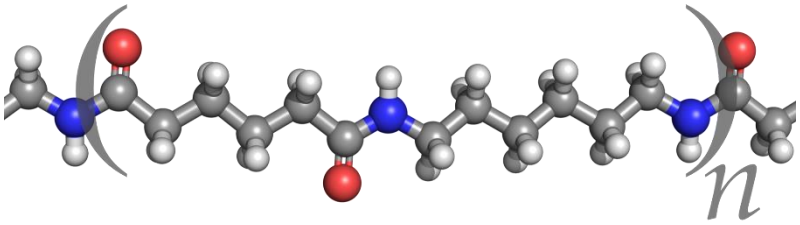
- the **melting-freezing cycles can be repeated** many times without the change of the material structure
- **iong chain molecules** with strong intermolecular bonding
- week**, Van der Waals bonding between macromolecules**
- **semicrystalline** ordered structure or an **amorphous** random structure
- examples of civil engineering thermoplastic polymers: **polypropylene, nylon 66, polycarbonate (amorphous), Polyvinyl chloride (PVC), polystyrene (PS)**

Polymers
Thermoplastic polymers

Polypropilene $(C_3H_6)_x$



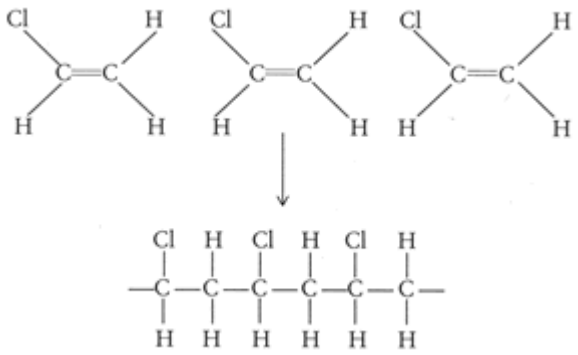
Nylon 6,6 $(C_{12}H_{22}N_2O_2)_n$



Polycarbonate: contain carbonate groups

(−O−(C=O)−O−)

Polymers
Thermoplastic polymers

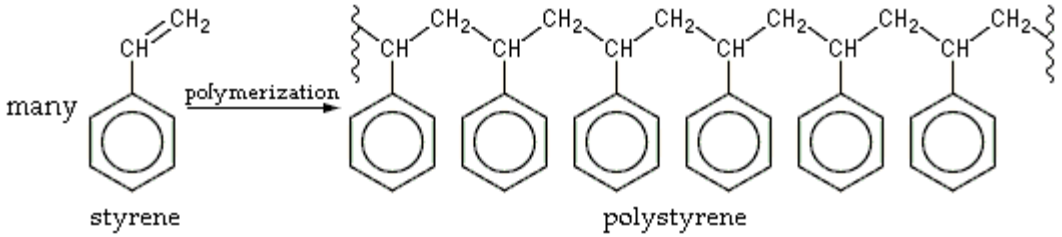


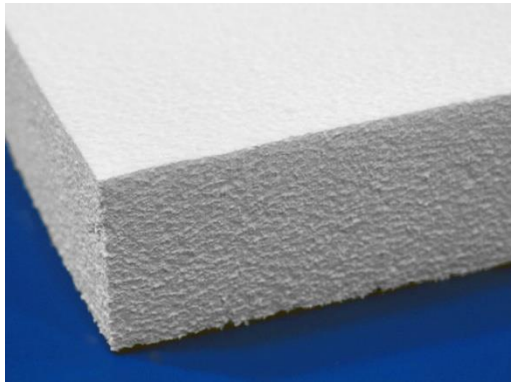
PVC (polyvinyl chloride) $(C_2H_3Cl)_n$

- rigid (sometimes abbreviated as RPVC)
- flexible
- the rigid form of PVC is used in **construction** for pipe and in profile applications such as doors and windows.

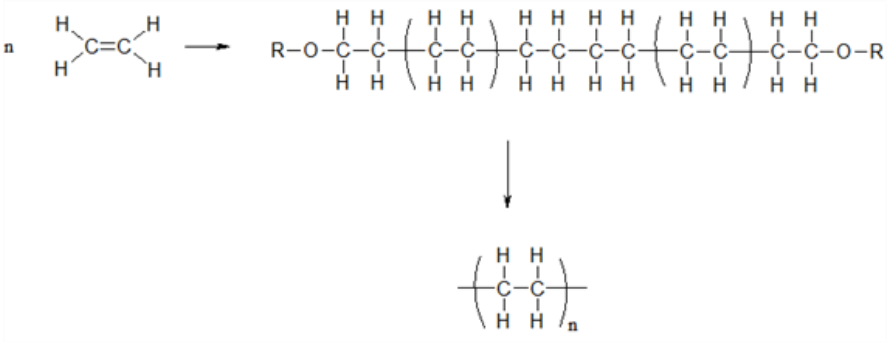
Polymers
Thermoplastic polymers

PS – polystyrene $(C_8H_8)_n$ – foams, sheets, foils





PE – polyethylene $(C_2H_4)_n$ – medical halls, tubes, sheets, foams etc.



Plastics
Thermosetting polymers

Thermosetting: irreversibly hardened by curing from a soft solid or viscous liquid prepolymer or resin. **Curing is induced by heat or suitable radiation**.

It results in chemical reactions that create extensive **cross-linking** between polymer chains to produce an infusible and insoluble polymer network.

The principal thermosetting polymers that are **used in construction** are **polyesters, vinylesters and epoxy resins.**

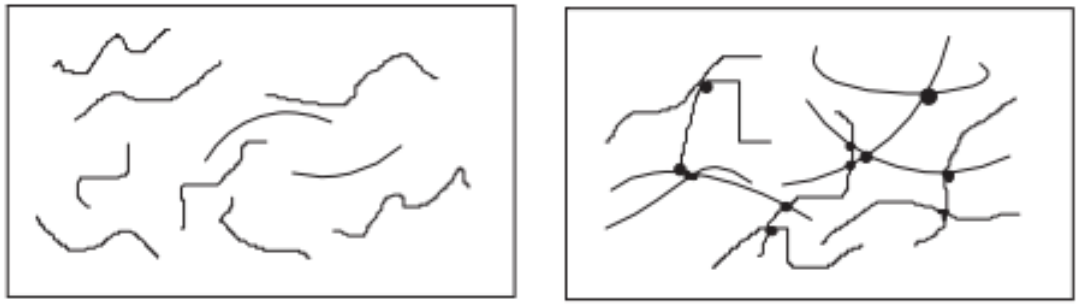
Formed in a two-stage chemical reaction of a **polymer** (e.g. polyester, vinylester or epoxy) is reacted with a **curing agent**

- production of a long-chain polymerised molecules
- cross-linking of the chains (room temperature or application of heat and pressure).

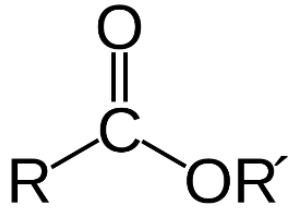
Plastics
Thermosetting polymers

As the **cross-linking is by strong chemical bonds**, thermosetting polymers are **rigid** materials and their mechanical properties are affected by heat.

The starting material for making thermosets is usually malleable or liquid prior to curing, and is often designed to be molded into the final shape. It may also be used as an adhesive. **Once hardened, a thermoset cannot be melted** for reshaping, in contrast to thermoplastic polymers.



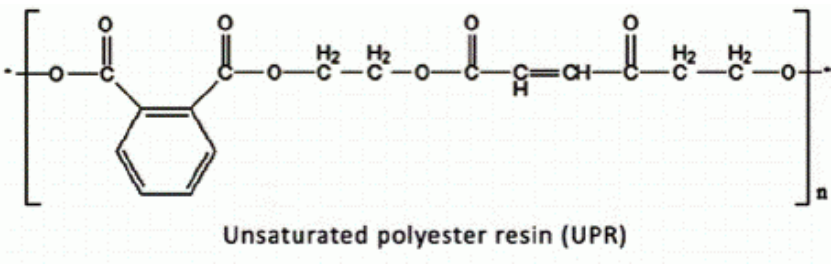
Plastics
Thermosetting polymers



Polyesters: contain the **ester** functional group in their main chain

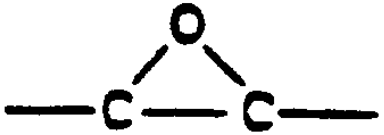
viscous liquids that are capable of **hardening permanently**

used as glues, (water) proof material etc.



Unsaturated polyester resin (UPR)

Plastics
Thermosetting polymers



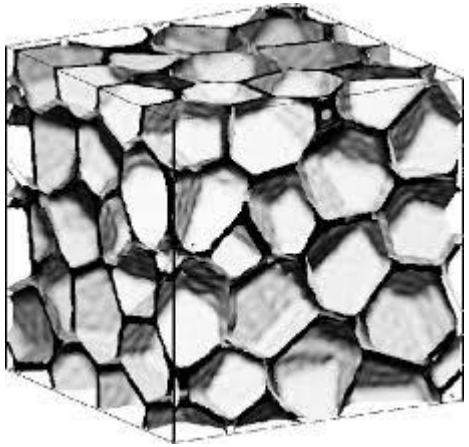
Epoxy or vinylester: polymers that contain epoxy groups

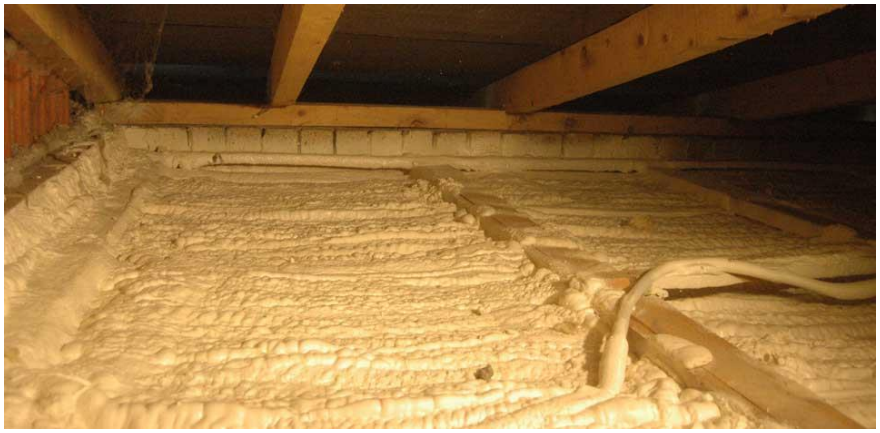
Applications in construction: metal coatings, electrical insulators, paint brushes manufacturing, fiber-reinforced plastic materials and structural adhesives

Polymers
Foamed polymers

Foamed polymers: rigid two-phase system

- Produced by addition of a blowing agent to the molten resin (epoxi). A gas is released, causing the expansion of the polymer, by forming of small bubbles
- Can be thermoplastic or thermosetting
- Generally every polymer can be foamed





Insulators

Insulators

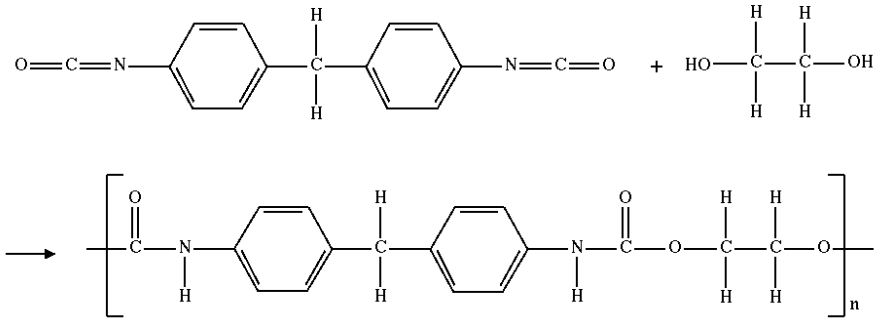
Classified according

- composition: natural or synthetic materials
- form: batts, blankets, loose-fill, spray foam, and panels
- structural contribution: insulating concrete forms, structured panels, and straw bales
- functional mode: conductive, radiative, convective
- resistance to heat transfer
- environmental impacts, and more

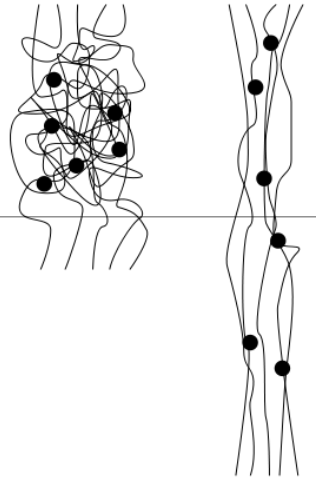
Examples: silica aerogel, **polyurethane**, urea foam, polystyrene, wood, cellulose, **concrete foams** etc.

Insulators
Polyurethane

Polymer foams composed of organic units joined by carbamate (urethane – NH_2COOH) links



Insulators
Elastomers



An **elastomer** is
a polymer with viscoelasticity and
very weak inter-
molecular forces, *elastic*
polymer (rubber)

- monomers made of C, H, O, Si
- cross-linked by vulcanisation, which precents the molecules from sliding, therefore completely will recover their shape after the removal on the external force

Building insulation materials

Building insulation refers broadly to any object in a building used as insulation for any purpose

Types:

- thermal insulation
- acoustic insulation
- fire insulation
- impact insulation (vibration)

Materials:

- spray foams (polyurethanes – see Polymers)
- structural insulation
- fibreglass batts

Insulating materials

Fibreglass batts, blankets

Rock wool made out of mineral

Different plastic fibres

Wood - timber

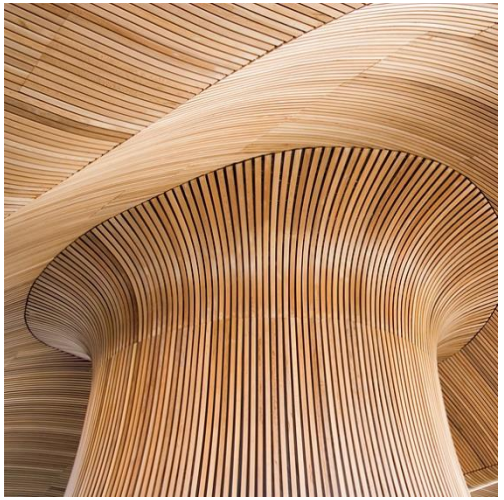
Wood is a **porous and fibrous structural tissue** found in the stems and roots of trees, and other woody plants

It is an organic material.

One of the main construction materials from thousands of years

Used for:

- wooden buildings, timber framed buildings
- wooden bridges
- wooden towers
- carpentry
- furniture




reTHINK
WOOD®

Wood

Chemistry of wood

The chemical composition of wood varies from species to species, but is approximately

- 50% carbon
- 42% oxygen
- 6% hydrogen
- 1% nitrogen
- 1% other elements (mainly Ca, K, Na, Mg, Fe, S, Cl, Si, P)

Components:

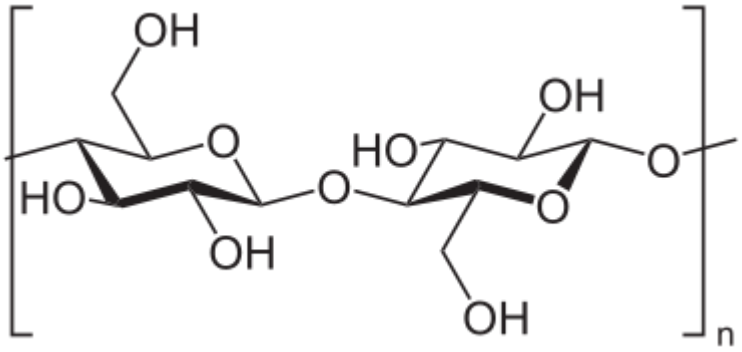
- water
- cellulose
- five-carbon sugars
- lignin
- These three components are interwoven, and **direct covalent linkages** exist between the **lignin and the hemicellulose**

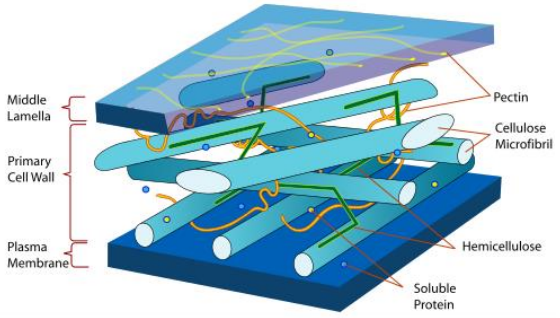
Softwood lignin: derived from coniferyl alcohol

Hardwood lignin: derived from coniferyl alcohol and sinapyl alcohol

Wood components

- **Cellulose** $(C_6H_{10}O_5)_n$: semi-crystalline polymer derived from glucose, constitutes about 41–43% of wood. Organic compound

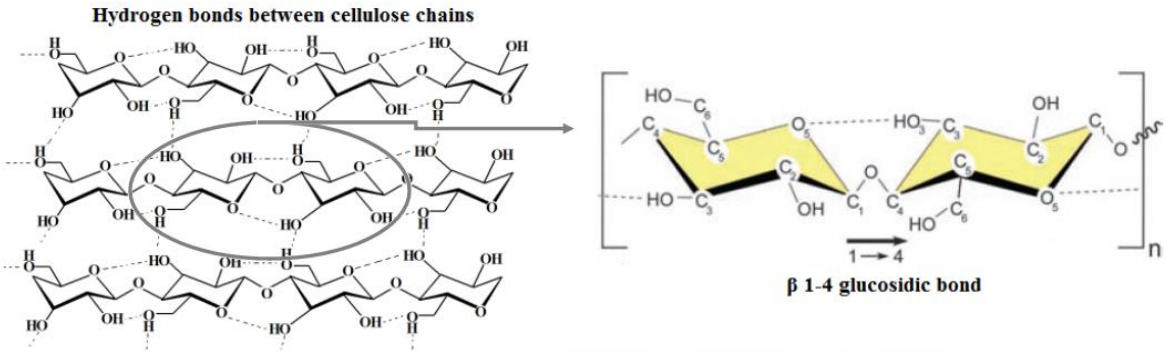


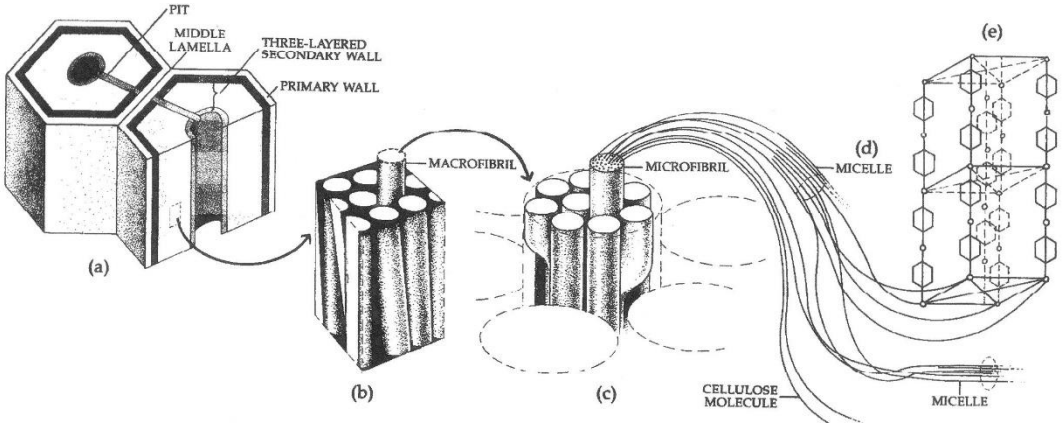


- Consists of **crystalline** and **amorphous** regions
- By treating it with strong acid, the amorphous regions can be broken up, obtaining nanocrystalline cellulose , a novel material with many desirable properties.
- Recently, nanocrystalline cellulose was used as the filler phase in bio-based polymer matrices to produce nanocomposites with superior thermal and mechanical properties

Wood components

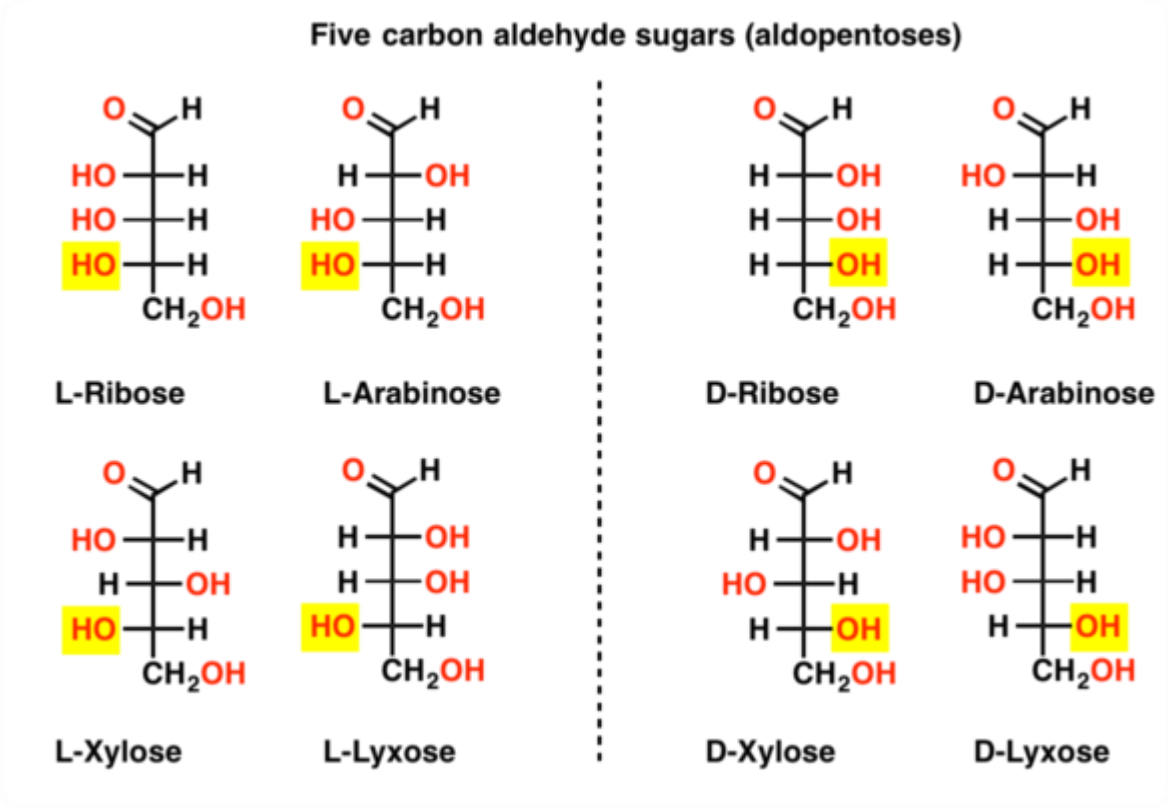
Cellulose

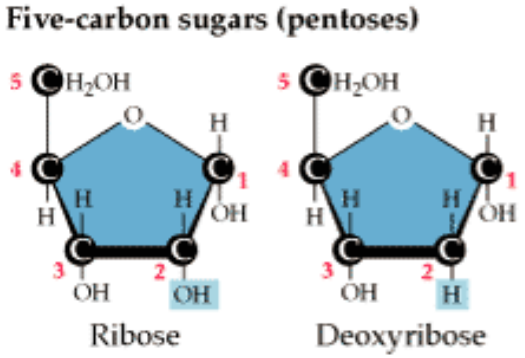




Wood components

Five-carbon sugars: monosaccharaide with five carbon atoms





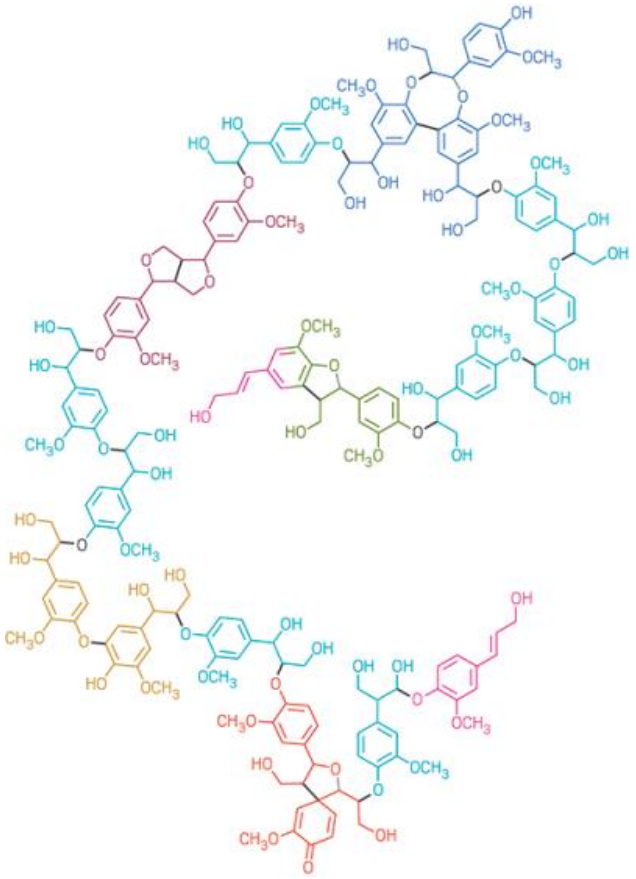
Wood components

Lignin

Complex, organic polymer

Chemical structure: cross-linked phenolic polymers

Lignin fills the spaces in the cell wall between cellulose, hemicellulose, and pectin components



Bitumen and asphalt

Bitumen: a sticky, black and highly viscous liquid or semi-solid form of petroleum (hydrocarbon mixture)

Primary use: **road construction**, mixed with glue or binder aggregate and as waterproofing product for roofing

Natural bitumen

Refined bitumen

Bitumen and asphalt

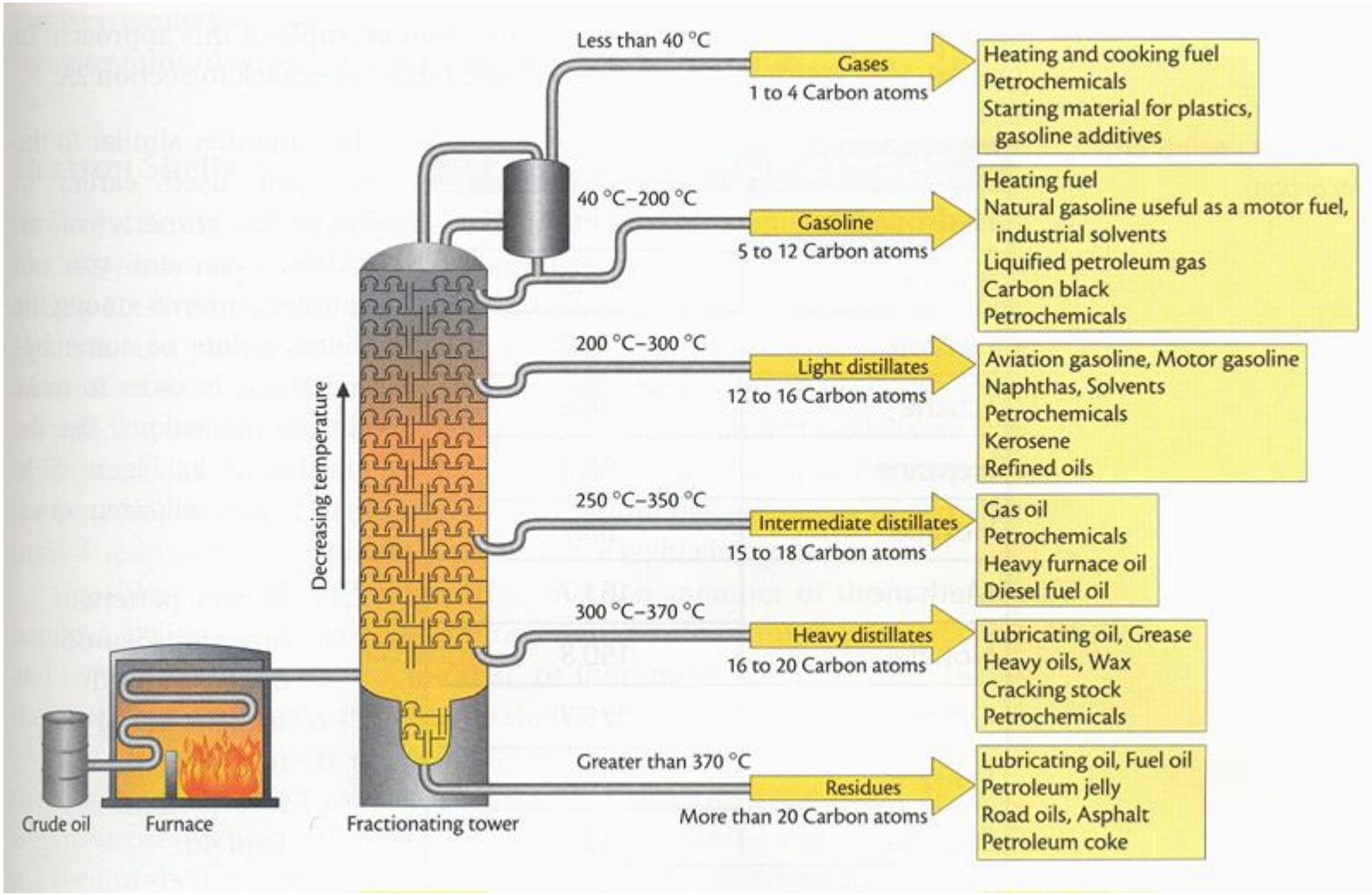
Composed of organic components:

- **saturated hydrocarbons**
- naphthene aromatics, consisting of partially hydrogenated polycyclic **aromatic compounds**
- polar aromatics, consisting of high molecular weight **phenols and carboxylic acids**
- asphaltenes, consisting of high molecular weight **phenols and heterocyclic compounds**

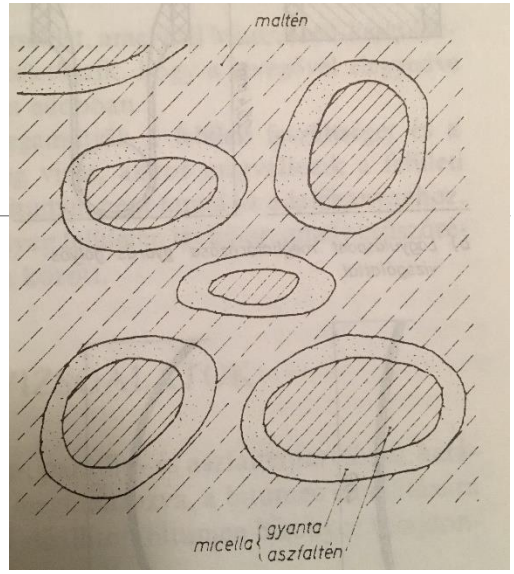
Produced by vacuum destillation

- after the different type hydrocarbons are distilled **from the petroleum**, the remaining product, the fuel oil (**crude oil**) is used for the production of bitumen. **The crude oil is heated to 300-400°C and at 4000-5000 Pa pressure** a **second destillation** is made, the more volatile remaining hydrocarbons are distilled, and **the bitumen is the last fraction** that will remain

Bitumen and asphalt



Bitumen and asphalt



Characteristics:

- elementary composition:
  - C: 80-85m%
  - H: 9-10 m%
  - O: 2-8 m%
  - S: 0.1-7 m%
  - N: <1 m%
- colloid system containing asphaltene grains surrounded with resin. The matrix between the grains is highly viscous, if the temperature increases it becomes liquid
- with time the O_2 from the air breaks the linkage, H atoms and water is formed. Sunlight increases this effect, however it is a very slow process. As an effect the surface becomes rigid. It is called aging

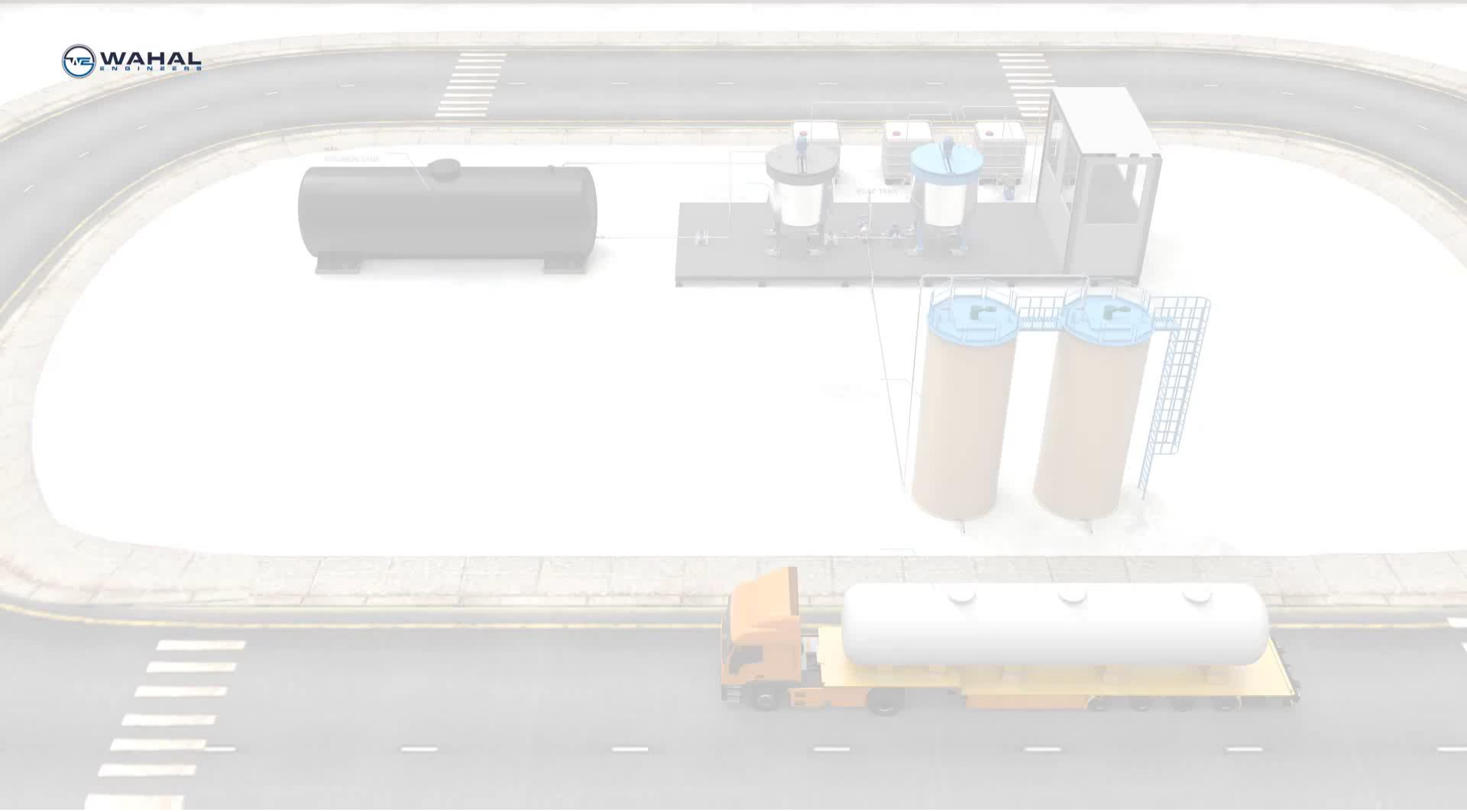
Bitumen and asphalt

Asphalt: usually we call asphalt the bitumen material used for road construction

Additives: limestone, latite (silicon mineral), dross

It is produced by

- heating the pure bitumen to 60-80°C, then applying a preassure on it on the surface where it is used
- semi-heating a bitumen emulsion made with organic oils and fat
- cold, by mixing it with different organic solvents



Pigments and paints

Paint is any liquid composition that, after application to a substrate in a thin layer, converts to a solid film

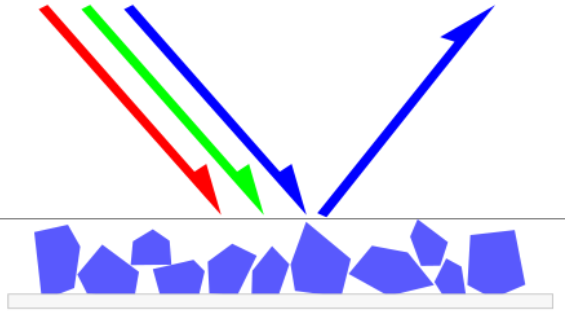
Used to
- protect
- color
- provide texture

Paint can be produced in many colors.

Paint is typically stored and applied as a liquid, but most types dry into a solid

Components:
- pigments
- additives
- diluents
- others: drying components, mildew-resstant, lighning materials etc.

Pigments



Coloring materials

Organic or inorganic materials

White pigments: lead containing materials (TiO_2 , $2PbCO_3 \cdot Pb(OH)_2$, $ZnS+BaSO_4$, $Mg_3(OH)_2Si_4O_{10}$

Black pigments: Carbon containing

Yellow-green: cromium containing $4ZnO\ 4CrO_3\ K_2O\ 3H_2O$

Red: Fe_2O_3 containing

Metallic shine: different metal containing: Al, Cu, Zn, Sn

Special pigments: corrosion-resistant: cromium containing, Pb_3O_4 containing pigments

Organic pigments: many types, eg. aniline pigments

Binding additives:

- water soluble: slaked lime, sodium-silicate, animal and plant glues, casein
- oily: linseed oil, urethane oil, resin varnish etc.

Pigments and paints

Self cleaning paint
TiO_2 nanoparticles

INTRODUCTION

TiO_2

- Photocatalytic Effect