Building materials

Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building Materials

Lecture 11

Department of Materials Engineering and Chemistry

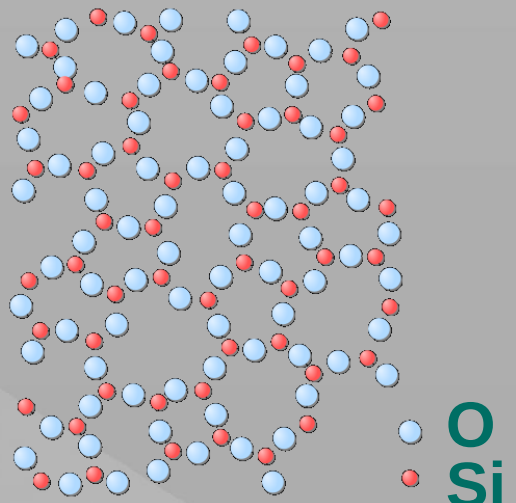
Faculty of Civil Engineering

Building materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass

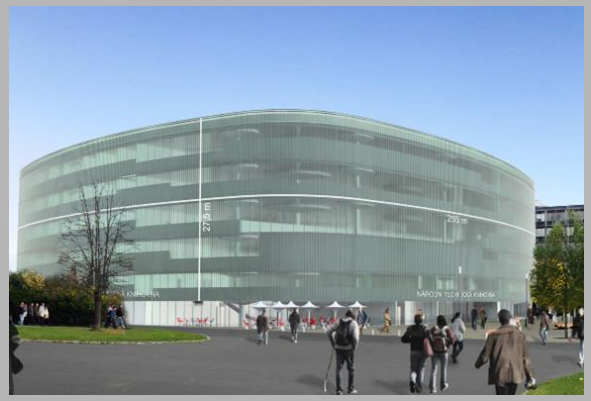
- amorphous
- composed of about 75% silica (SiO_2) + Na_2O, CaO + several minor additives
- homogenous
- transparent
- solid and hard
- brittle
- chemical resistant
- gas-tight

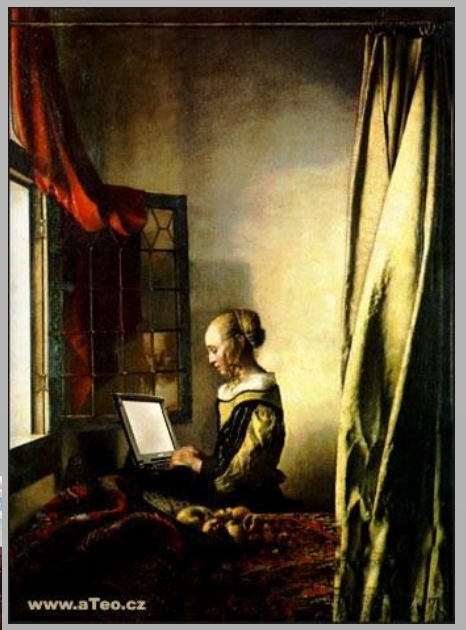


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass in buildings

- glazing
- facades
- roof constructions
- partitions
- floors,stairs…





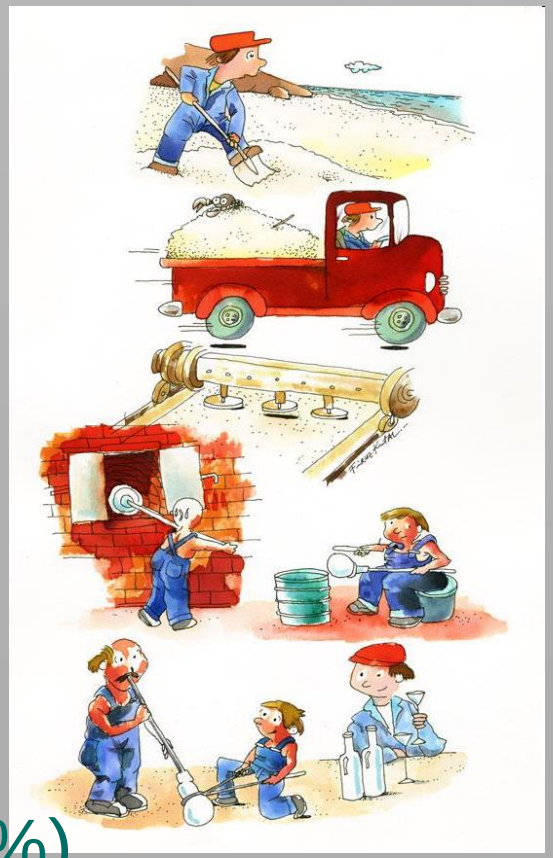
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass manufacture

- **melting of components at 1400 - 1600°C**

Components:

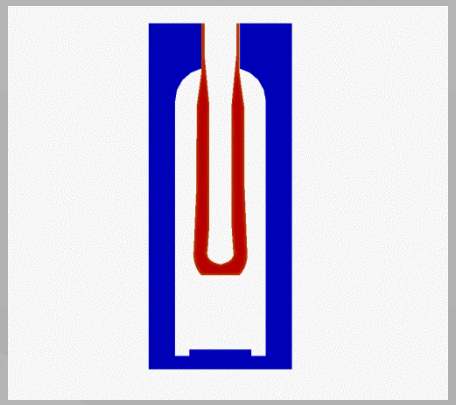
- **sand** (60-80% SiO_2)
- **fluxes**
  - to lower the melting point (soda ash - Na_2CO_3)
  - to widen the range of workability (lime)
  - better chemical durability (MgO, Al_2O_3)
- **broken glass** - „cullet“ (to 30%)
  - to improve heat transfer during melting

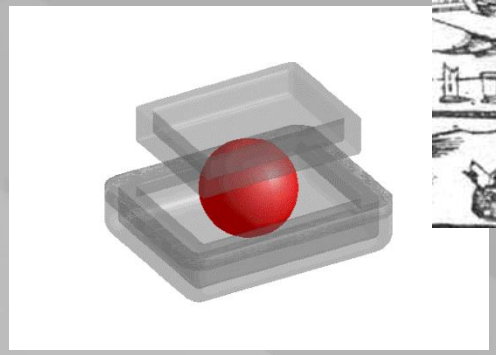


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass shaping

- hollow glass
  - blowing
- blocks, roof tiles
  - molding
- flat glass
  - drawing
  - rolling
  - float
- fibers
  - extruding
  - spinning





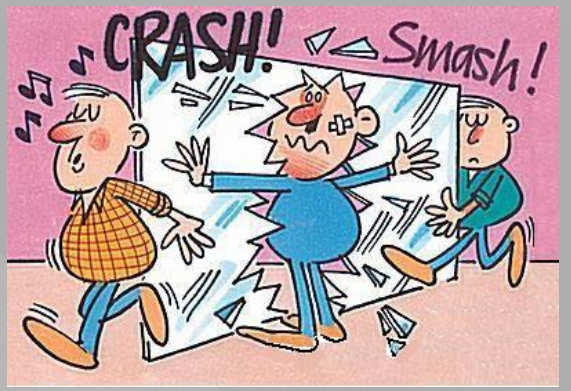
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass properties

- can be influenced by composition

Common soda-lime glass:

- density: **2200 – 3600** kg.m^{-3}
  - lead glass: up to 6000 kg.m^{-3}
- compressive strength: **700 – 1200 MPa**
- bending strength: **30 – 90 MPa**
- Young's modulus: **50 – 90 GPa**
- λ = **0,6 – 0,9 W.m^{-1}.K^{-1}**
- hardness (Mohs) : **6 - 7**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass properties

- **transparency**
  - depends on type and thickness (up to 92%)
  - differs for different wavelengths (UV x IR)
  - can be influenced by the coating by oxides
- **strength**
  - depends on surface quality (polishing)
  - tensile strength decreases with increasing thickness
  - toughening (heat, chemicals)
- **fragility**
  - high E and low tensile strength

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass products

- flat glass
- formed glass
- foamed glass
- fibers
- microspheres
- aerogel

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Flat glass - float proces





How is flat glass made?

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Flat glass – drawed, float

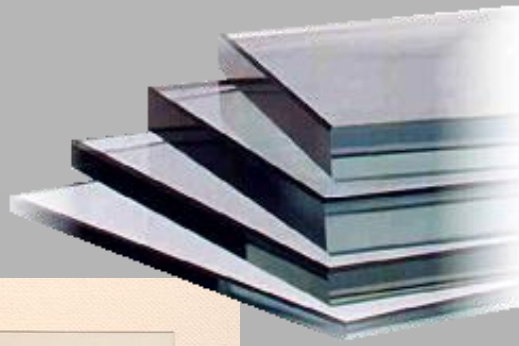
- **thickness 0,5 - 20 mm**

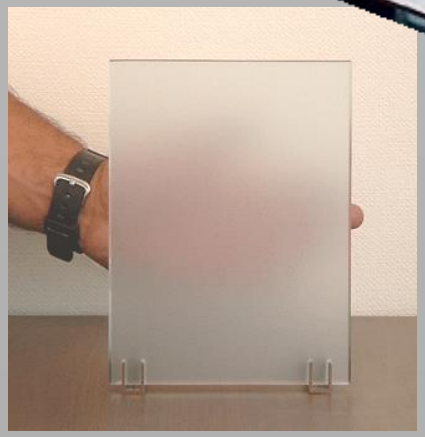
drawed glass – lower quality

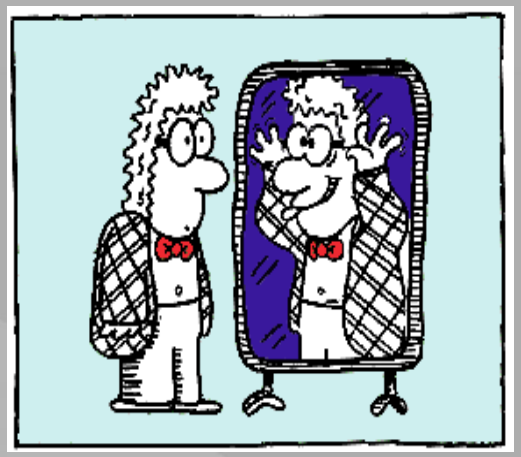
- frosted (by sand or acid)

float glass

- clear
- colored (metal oxides – Fe, Cu, Co, Ni, Ti)
- low E (= low emissivity) - reflects or absorbs IR light
- mirrored

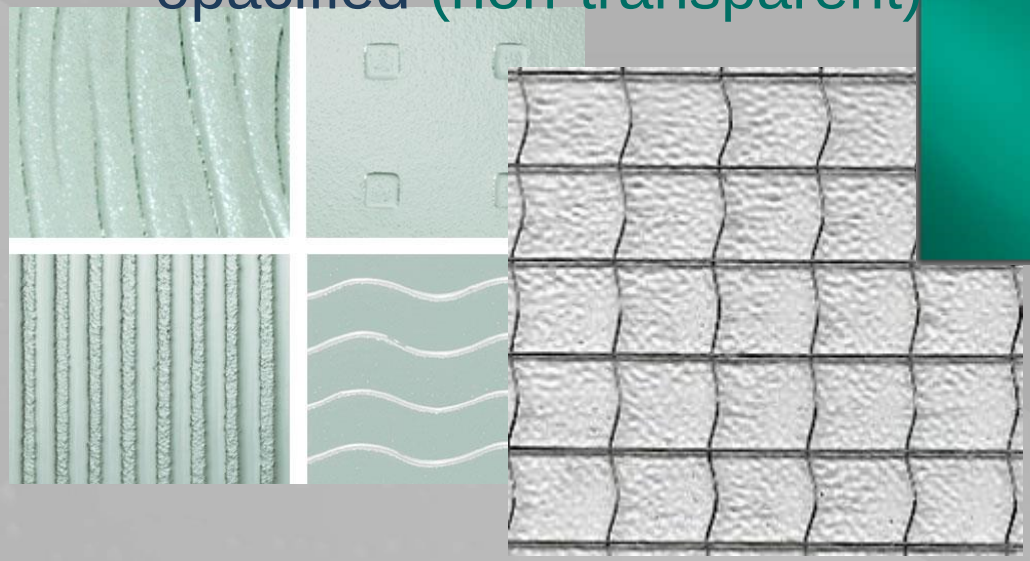






Rolled glass

- passing a stream of molten glass between two steel rollers
- **translucent** (transmission 75 - 88 %)
  - patterned
  - wired
  - opacified (non-transparent)

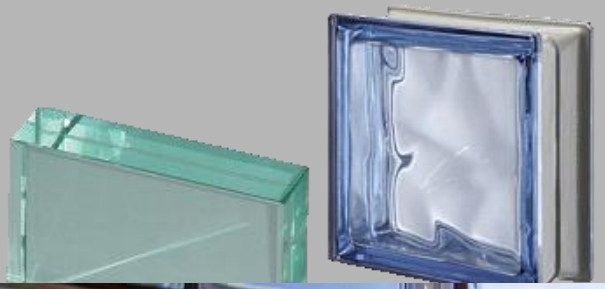


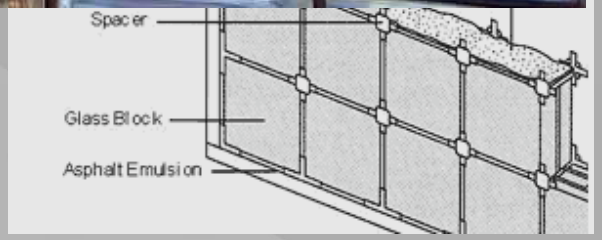
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass building elements

- **hollow blocks**
  - mortar- glass system
- **full blocks**
- **U- profiles**
- **roof tiles**

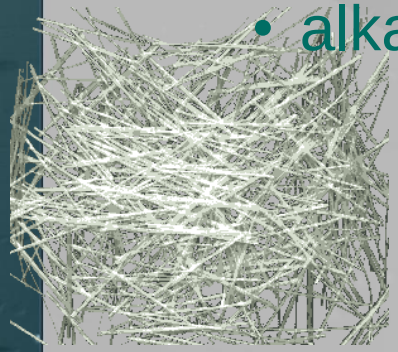


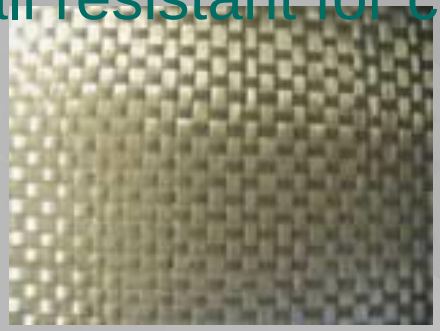


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass fibers

- **long –** continuous filament process
  - – strands (rovings, woven cloth)
    - reinforcement of different materials, laminates - fiberglass
  - – choped
    - fiber-reinforced thermoplastic
    - alkali resistant for cement





Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Mineral wool

- **glass woll** (sand)
- **rock wool** (basalt or slag)

Use:

- thermal insulation
- acoustic insulation

\+ **nearly non-combustible** (resin binder)

\+ **very good water vapor difussion** (breaths)

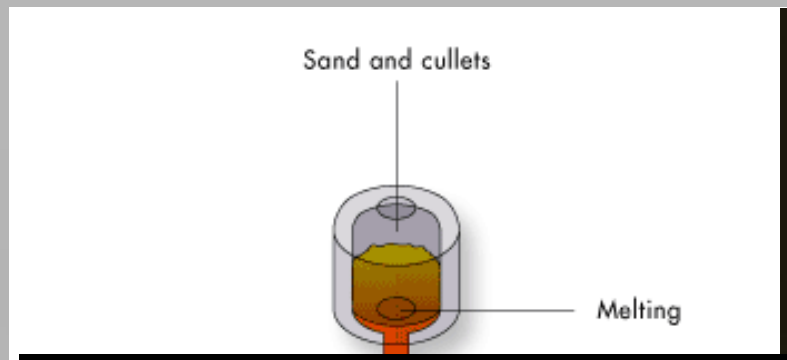
\+ **noise reduction**

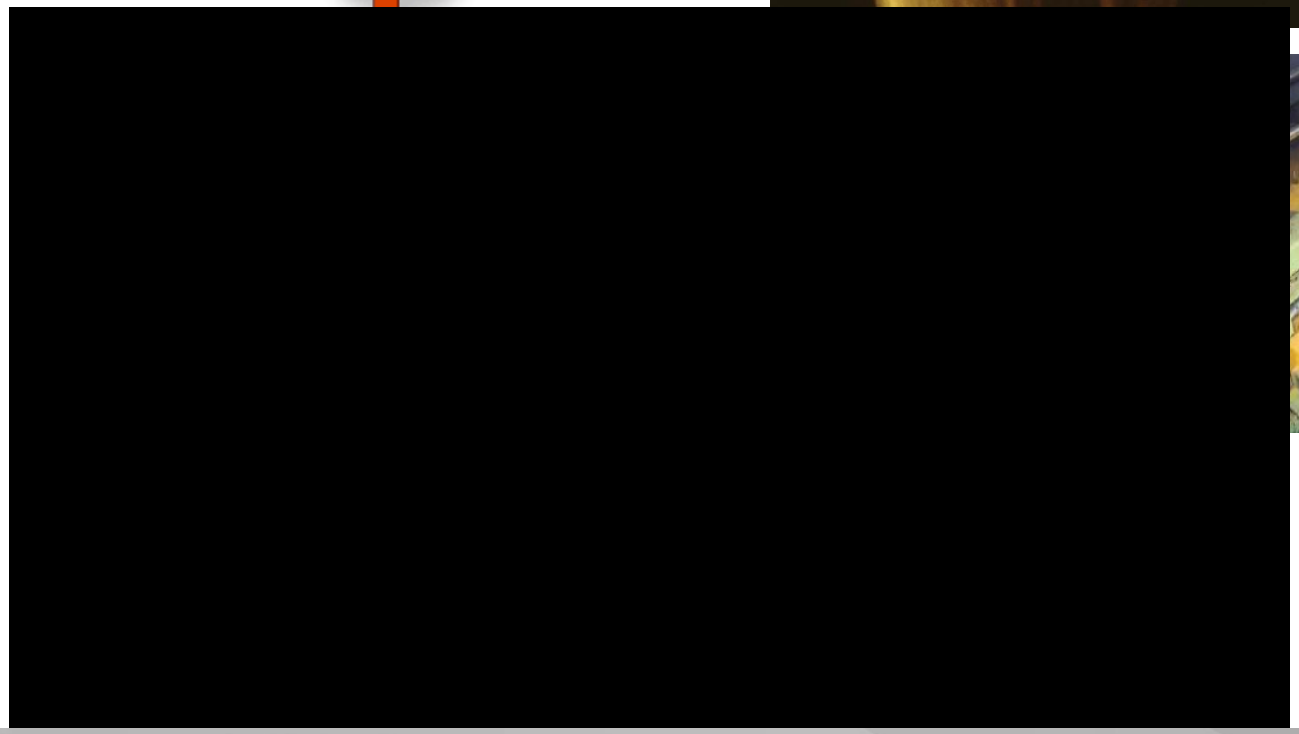
\- **high water absorptivity** (hydrofobization)

\- **health risk** (respirators)

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Glass wool manufacture





Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Mineral wool

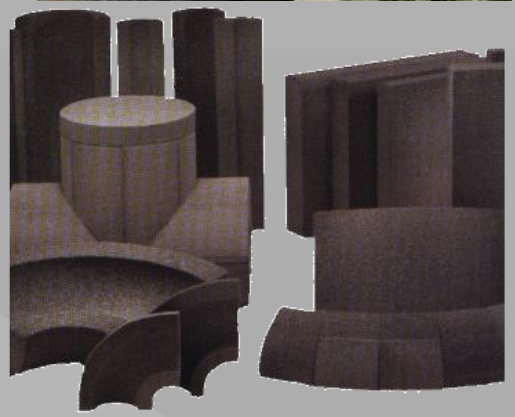
Products

- **boards or slabs** (λ= 0,035-0,045 W.m^{-1}.K^{-1}, ρ_V = 35 – 220 kg.m^{-3})
- **rolls** ($\lambda \cong$ 0,04 W.m^{-1}.K^{-1}, ρ_V= 70 kg.m^{-3})
- **batts, mats** ($\lambda \cong$ 0,04 W.m^{-1}.K^{-1}, ρ_V= 100-120 kg.m^{-3})
- **free wool**
- **in USA spraying on the walls** (with PVAC)

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

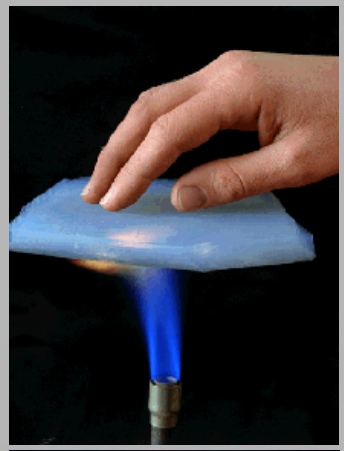
Foam (cellular) glass

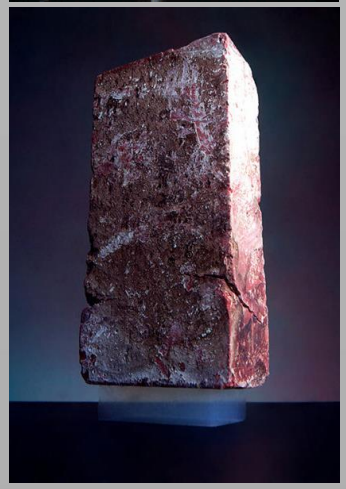
- **crushed glass + coal are heated → glass sintered and gases from coal form pores**
- **$\lambda \approx 0{,}04\ W.m^{-1}.K^{-1}$**
- **$\rho_v = 100 - 150\ kg.m^{-3}$**
- **compressive strength 0,7–1,6 MPa**
- **non-combustible**
- **low absorption** (closed pores)
- **biological and chemical resistant**
- **thermal resistance (**- 260 ºC to + 430 ºC)



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Silica aerogel





- porous material derived from a gel, in which the liquid component of the gel has been replaced with a gas
- a pure silica nanofoam
- λ = 0,004 W.m^{-1}.K^{-1}, ρ_v = 1,9 kg. m^{-3}

Building aerogels

Thicknesses[1]	5 mm 10 mm
Width[1]	1.475 m
Thermal Conductivity[2]	15.0 mW/m-K
Colour	Grey
Euro Fire Performance	C,s1,d0
Water Vapour Transmission	μ ≈ 5

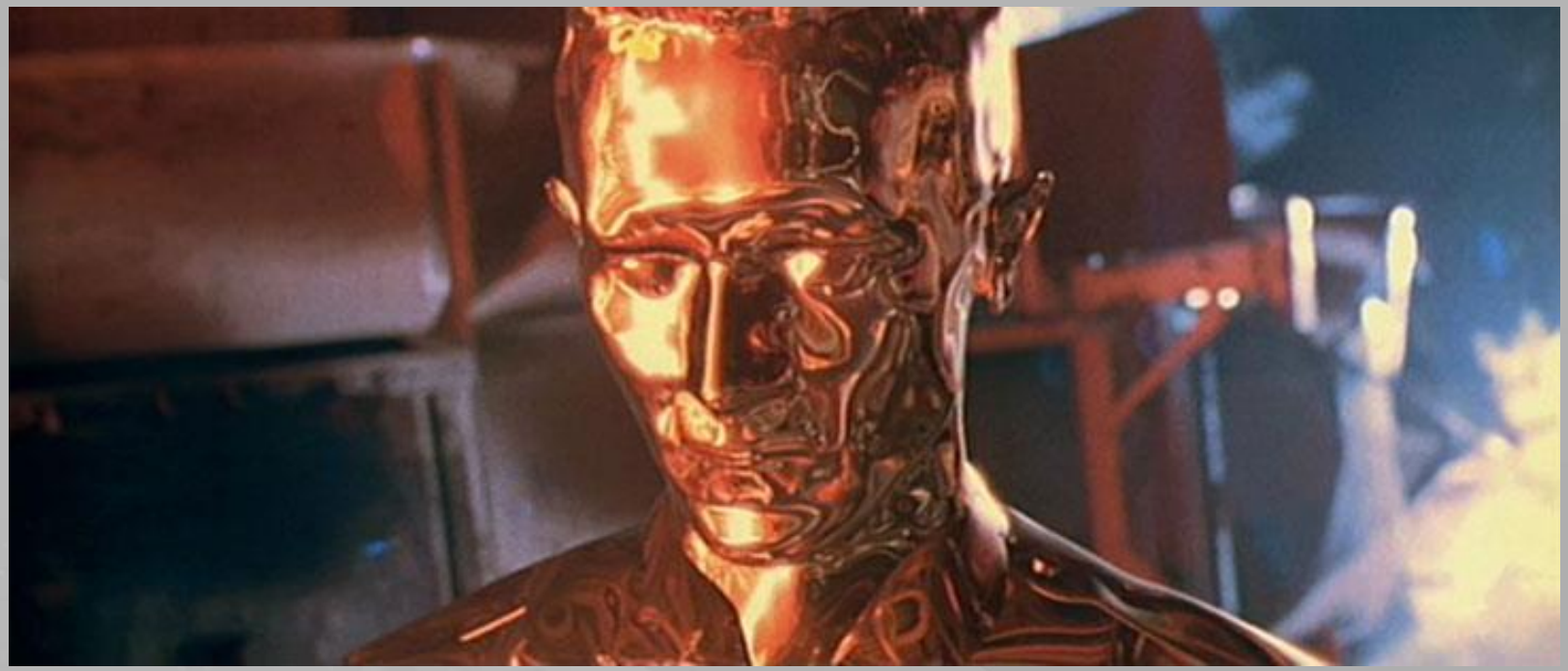
Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

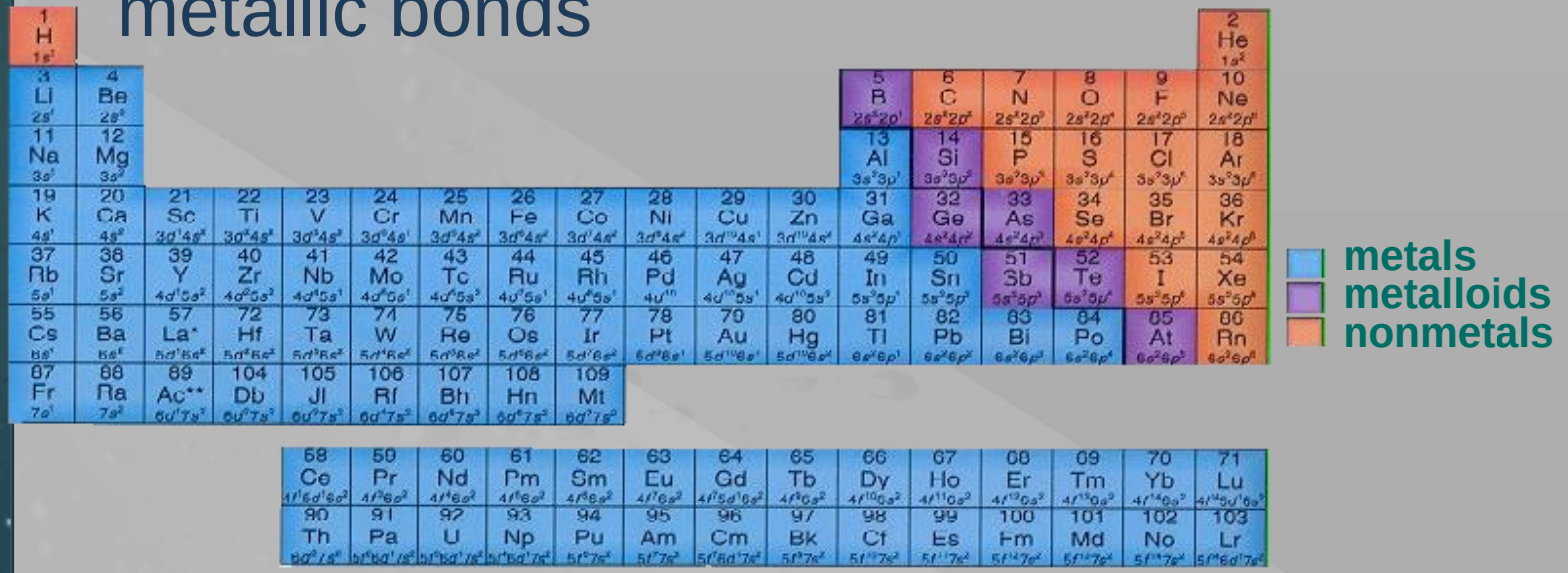
Metals



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Metals

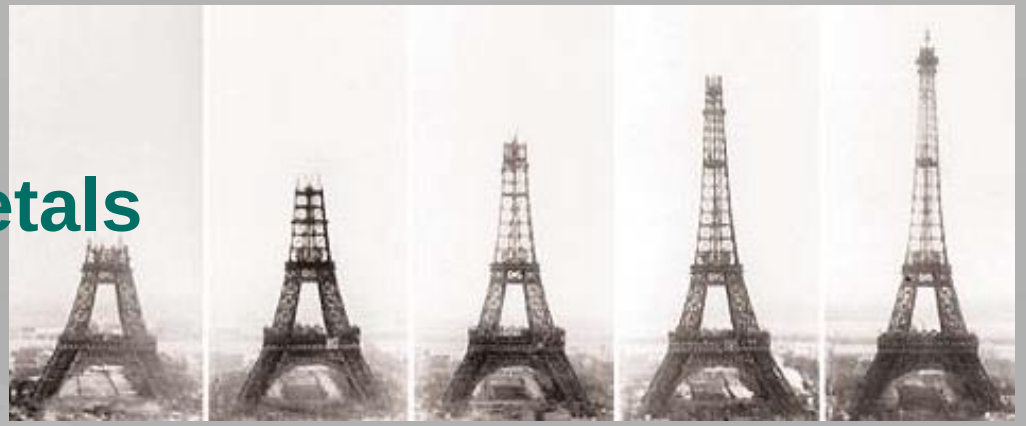
- an element, compound, or alloy that is a good conductor of both electricity and heat
- usually malleable and shiny
- held by electrostatic interactions between the ions and the electron cloud, which are called metallic bonds



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

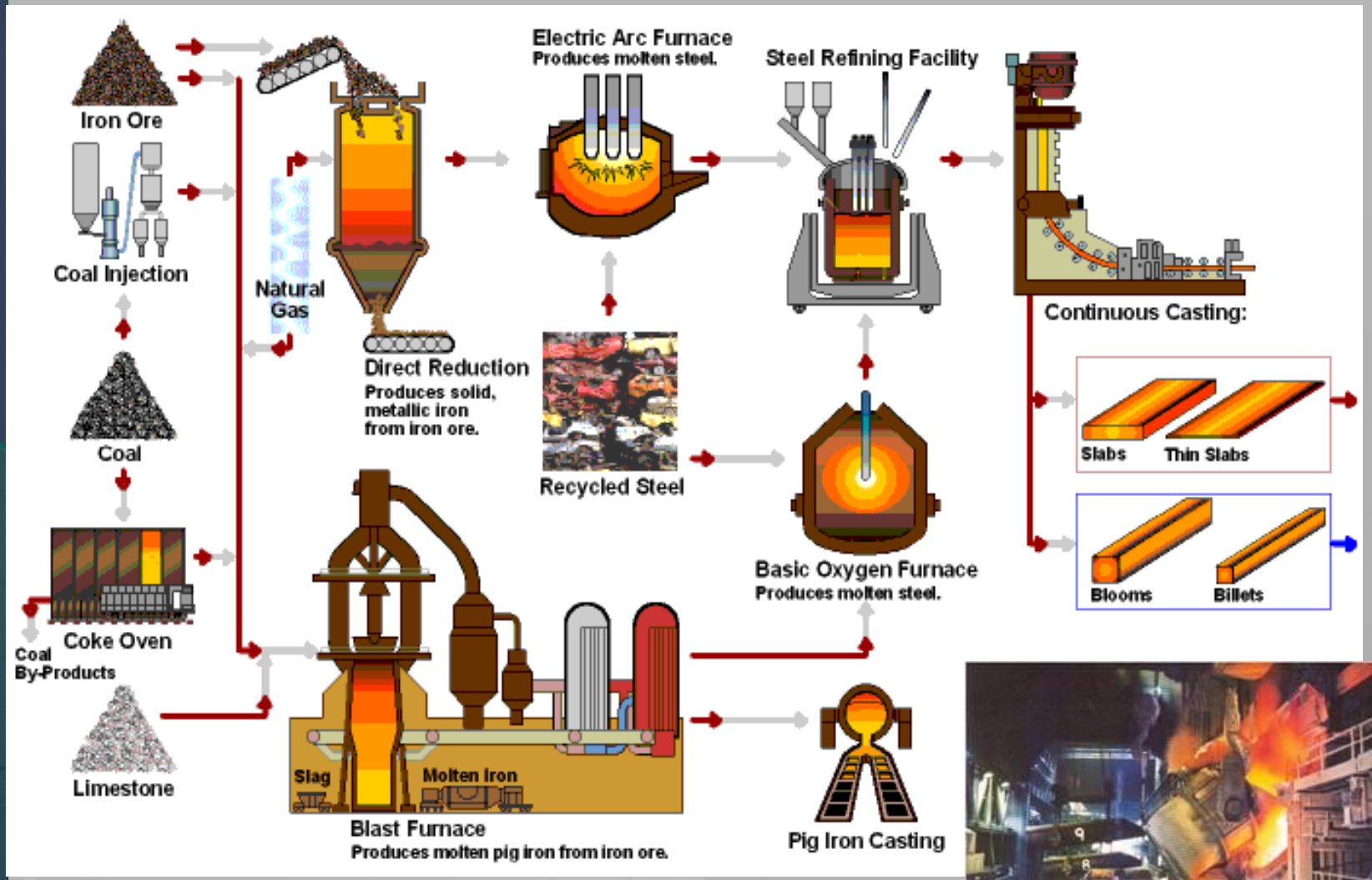
Structural metals

- **ferrous metals**
  - **wrought iron (< 0,1% C)**
  - **cast iron** (white, grey) **(< 5% C)**
  - **steel (< 2% C)**
- **non-ferrous metals**
  - **copper**
  - **zinc**
  - **lead** **+ their alloys**
  - **tin**
  - **aluminum**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel and iron manufacture



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel shaping

- **hot and cold working**
  - rolling – squeezing between rollers
  - extruding – forcing a hot steel through a die
  - drawing – pulling through a die
  - forging – by pressure or blows
  - casting – into moulds

- **heat treatment**
  - normalizing – increasing of uniformity
  - annealing
  - quenching - increasing hardness and strength
  - tempering – reducing of residual stresses, higher ductility

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel composition

- **chemical composition**
  - **carbon steel**
  - **low-alloy steel** (small amount of Mo,Ni,Cr, W, Ti ...)

EN 10025:

Composition limits (max %)						
C	*Si*	*Mn*	*P*	*S*	*N*	*Cu*
0.19		1.5	0.04	0.04	0.014	0.6
0.21		1.6	0.04	0.04	0.014	0.6
0.23	0.6	1.7	0.04	0.04	0.014	0.6
0.23	0.6	1.8	0.04	0.04	0.027	0.6

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel properties

General:

- **density : 7 850kg.m^{-3}**
- **modulus of elasticity:**
  - **tensile and compressive: 210 000 MPa**
  - shear: 85 000 MPa
- **coef. of thermal expansion: 12.10^{-6} K^{-1}**
- specific heat capacity: 0,46 kJ.kg^{-1}.K^{-1}
- Poisson’s ratio: 0,3

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel properties

Dependant on the chemical composition:

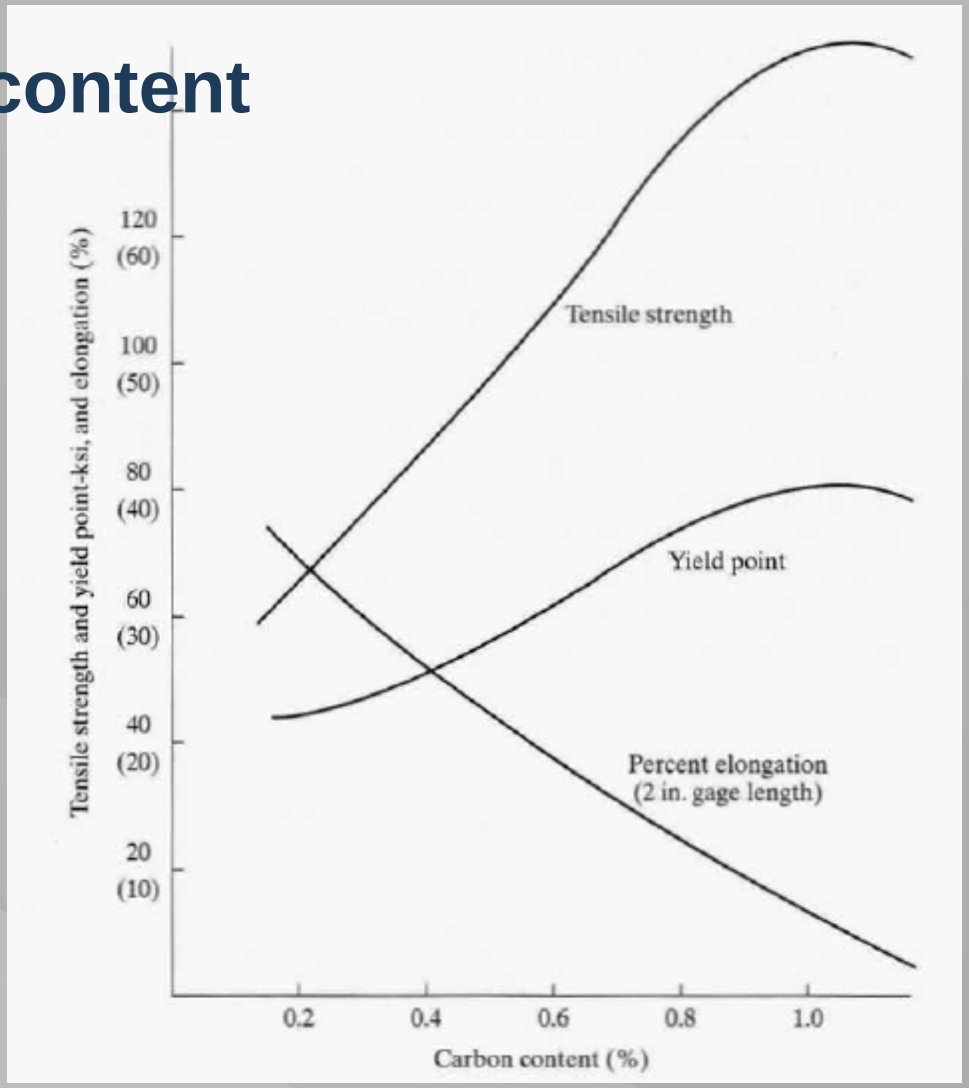
- carbon and alloying elements affect:
  - physical properties (weldability, corrosion)
  - mechanical properties (yield strength. tensile strength, ductility)

Carbon content	**[%]**	**0,1 – 0,15**	**0,5**
Tensile strenght	[MPa]	340 – 450	700 - 850
Yield limit	[MPa]	210 – 280	> 370
Ductility	[%]	≥ 28	10

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel – mechanical properties

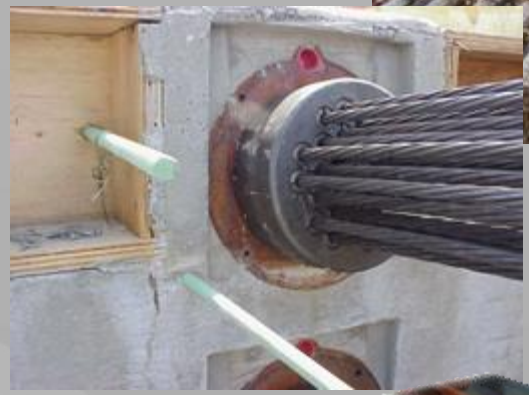
Effect of carbon content

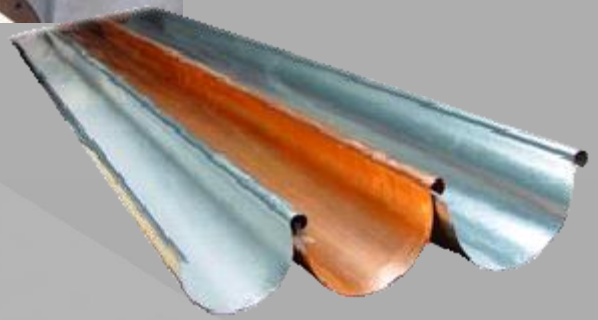


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Steel products

- structural steel
- reinforcing steel
- pre-stressing steel
- rails, piles
- sheets and plates
- wires

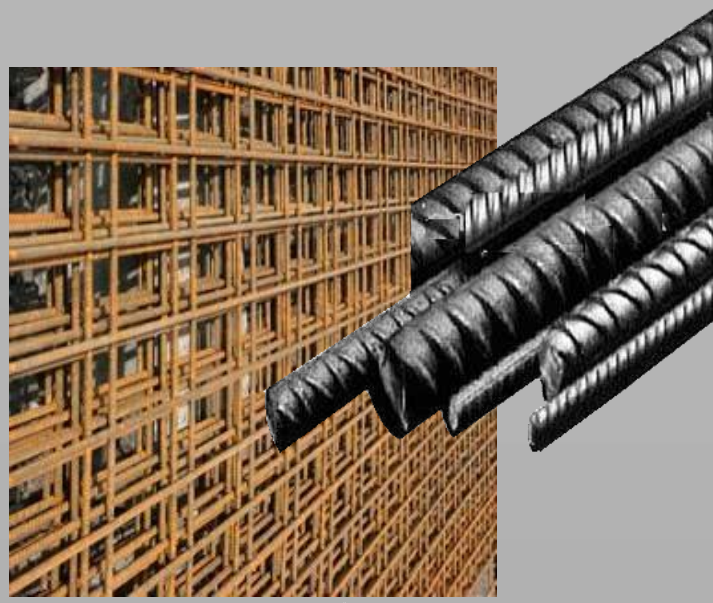


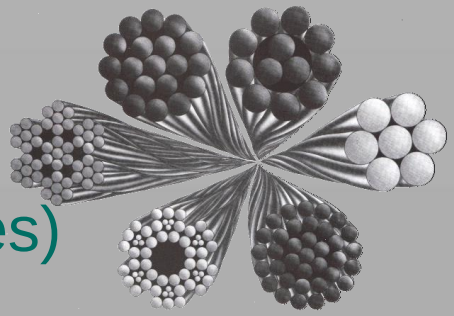


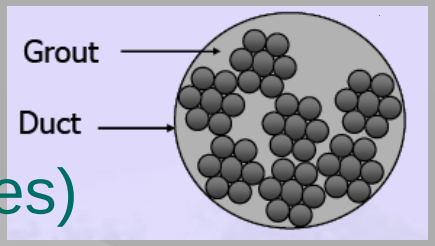
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Reinforcing steel

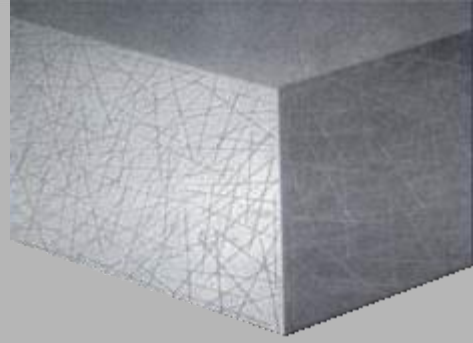
- **rolled and cold-drawn**
- **bars**
- **welded mesh**
- pre-stressing steel
  - **single wires** (Ø 2-7,5 mm, strength up to 2000 MPa)
  - **strands** (a few wires spun together in a helical form)
  - **tendons** (a group of strands or wires)
  - **cables** (a group of tendons)
  - **bars**
  - accessories (wedges, anchors, plates)





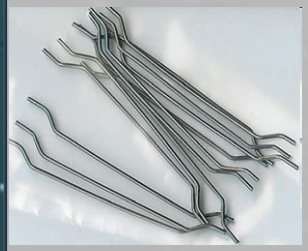


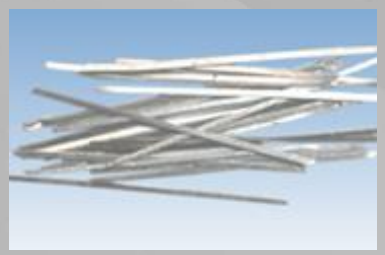
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering



Steel fibres

- **for steel fibre concretes**
  - higher flexural toughness / residual strength, post-crack performance, increased impact and abrasion resistance
- Ø 0,4 –1,1 mm
- length: 12 – 60 mm (straight), 30 – 60 mm (hooked, with flat ends)
- strength: 900-1500 MPa

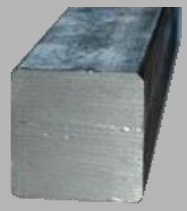


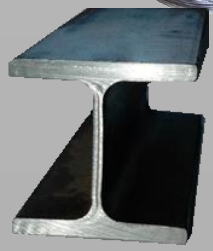


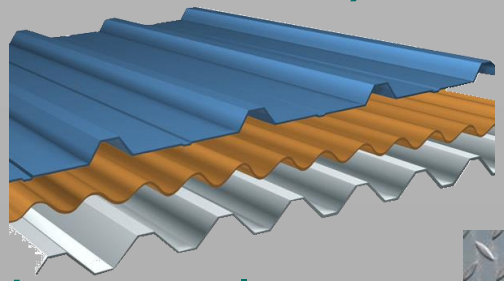
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

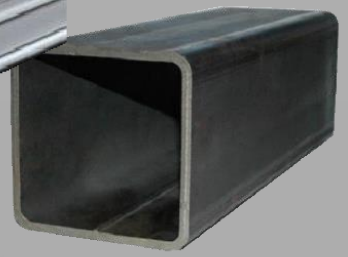
Other steel products

- **long products:**
  - bars, rods and wires, structural shapes (I, L, T, H beams), rails
- **flat products:**
  - plates, hot-rolled and cold-rolled strips and sheets, plates
  - great variety of surface conditions (smooth, corrugated, chequered)
- **pipes**
- **closed thin-walled profiles**









Steel – advantages and disadvantages

+ high strength
+ easy formability
+ good ductility

- corrosion
- high weight
- cost
- behavior in fire
- energy demanding

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Cast iron

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Cast iron

- reheating pig iron and blending it with other materials (limestone)
- compressive strength ~ 1000 MPa
- tensile strength ~ 300- 600 MPa
- **gray iron** (2,7 - 4,2% C)
  - contains graphite flakes
  - weaker and softer
  - ductility 2-20 %
- **white iron** (3,7 %C)
  - contain carbon carbide (Fe_3C)
  - hard and brittle
  - low ductility (< 1 %)

Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Copper Cu and Cu alloys

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

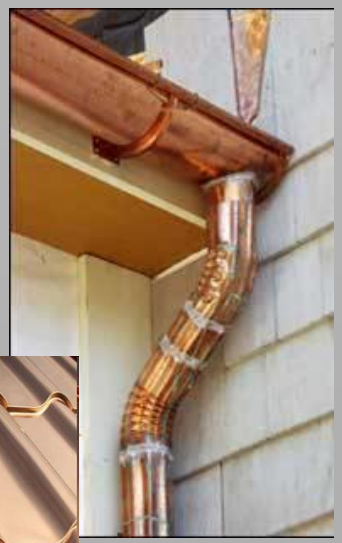
Copper

- reddish-orange color
- does not corrode – green layer of „vedigris“ (copper carbonate)
- high electrical conductivity
- bacteriostatic – tap water pipes
- strenght 200 – 360 MPa (cold-drawn 500 MPa)
- ductility 36 % (cold-drawn 3-6%)

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Copper products

- roofing sheets and shingles
- gutters
- base of bituminous felts (bacteriostatic protection)
- electric wiring
- pipes and fittings
- lightning rods



2014

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Copper alloys

- **brass (Cu + Zn)**
  - **strength 230 - 550 MPa**
  - **plumbing fixtures, door knobs, filler material for soldering, tombak (> 70% Cu),**

- **bronze (Cu + Sn)**
  - **high resistance to corrosion**
  - **mostly decorative uses**
  - Pb bronze, Al bronze

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Zinc Zn

- silvery or gray color
- malleable, castable
- low strength (10 –30 MPa)
- low melting point (415 °C) → zinc plating (galvanizing)
- **titanium zinc alloy**
  (Zn (99,995%) + Cu a Ti)
  – protection against corrosion by layer of $ZnCO_3$

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Zinc - products

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Aluminum Al and Al alloys

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Aluminum

- main Al ore – bauxit
- energy demanding production (electrolysis)

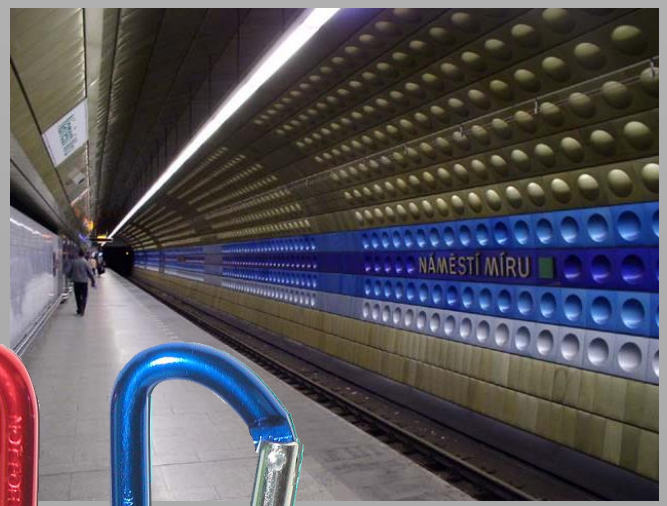
Properties:

- **density: 2650 – 2800 kg.m^{-3}**
- **strengtht: 70 –700 MPa (alloys)**
- ductility: 5 -30 %
- electric conductivity: 65 % of Cu
- does not corrode (Al_2O_3)

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Aluminum alloys

- **alloys with Mn, Cu, Mg, Si, Zn**
  - **– casting alloys**
  - **– wrought alloys** (rolled plates, foils..)
  - – heat-treatable
  - – non-heat-treatable
- surface treatment
  - **– anodizing**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

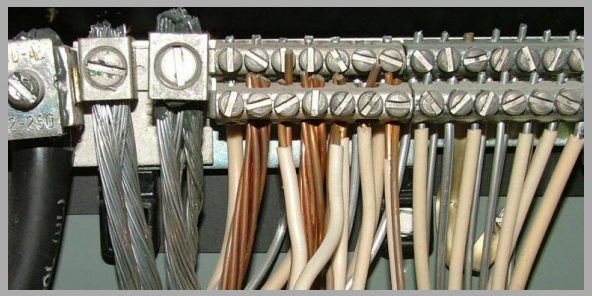
Aluminum + Al alloys - products

- stripes and sheets
  - plain, corrugated, chequered
- extruded profiles
  - hollow (closed, open)
  - solid
- door and windows profiles
- wires
- cables
- pipes
- roofing

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Aluminum + Al alloys

+ corrosion resistant
+ lightweight
+ low maintenance
+ desired properties can be achieved by the appropriate composition



- relatively low strength (pure Al)
- low fatigue strength
- high price
- energy demanding production
- high thermal expansion and creep → loosening of the electrical connections

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Lead Pb

- grey
- density : 11 340 kg.m^{-3}
- thermal conductivity: 35 W.m^{-1}.K^{-1}

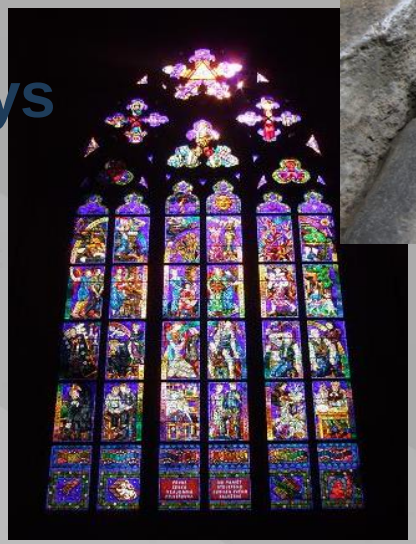
\+ malleable
\+ high resistance to corrosion

\- poisonous
\- low strength: 12 - 20 MPa
\- soft

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Lead - products

- **sheets**
  - t.0,5 –6 mm
- **pipes**
  - Ø 7 –320 mm
  - wall t. 1,5 –20 mm
- **part of solders, pewters, fusible alloys**
- **radiation shields**
- glazing bar for stained glass



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Gold Au

+ weather resistance
+ chemical resistance
+ density: 19 300 $kg.m^{-3}$
+ high malleability and ductility

- soft (3 Mohs)
- price!!!

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Gold - products

- very thin gold leafs
  - t. 0,1 μm

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Gold in buildings

- decorative purposes

The Harmandir Sahib
Amritsar, India

St. Michael's Monastery
Kiev, Ukraine

Dome of the Rock
Jerusalem, Izrael

Building materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood

- a hard, fibrous tissue found in many trees
- an organic material
- a natural composite of cellulose fibers (which are strong in tension) embedded in a matrix of lignin which resists compression

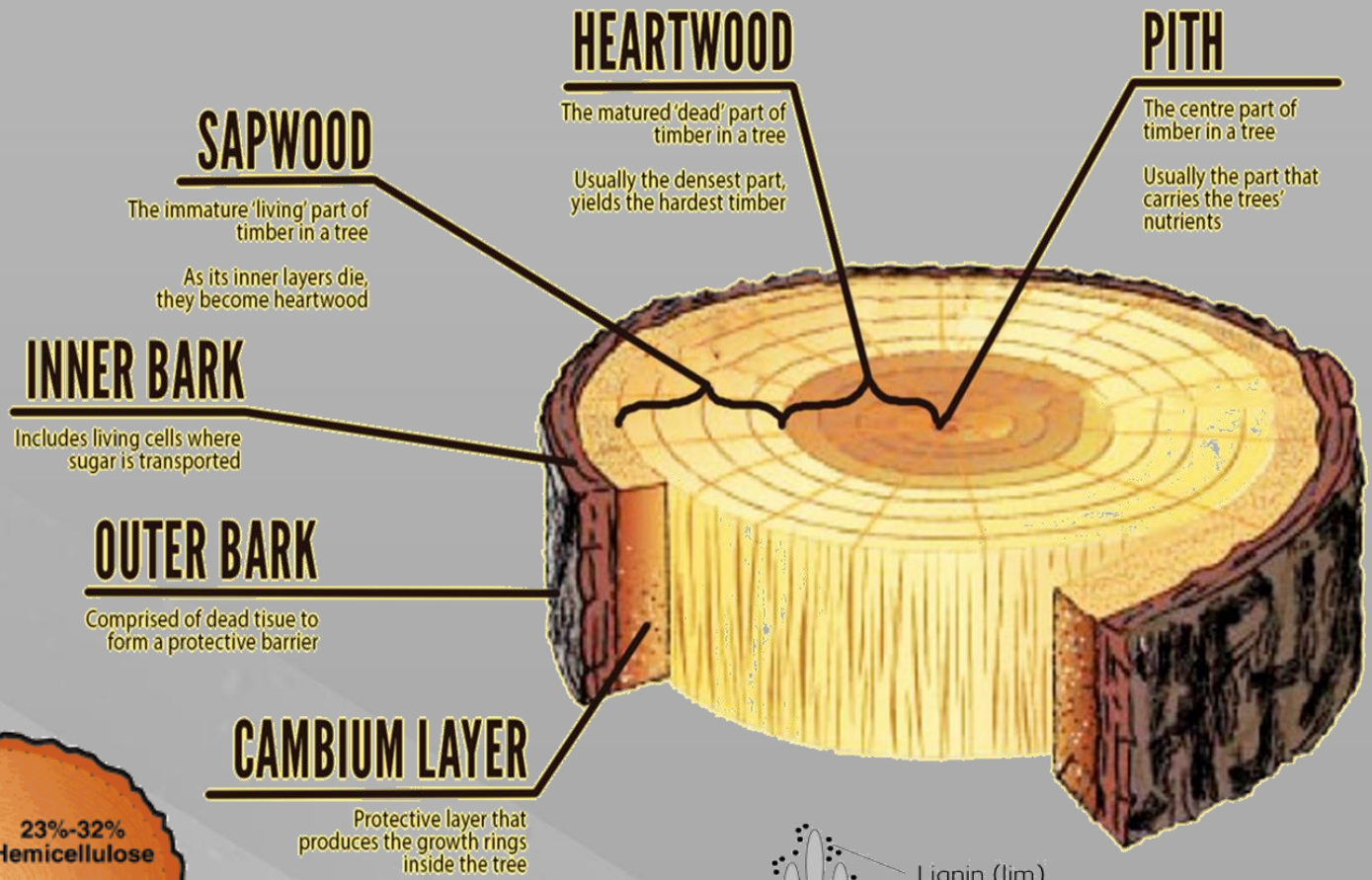
Terminology (EN 844-1, 2)

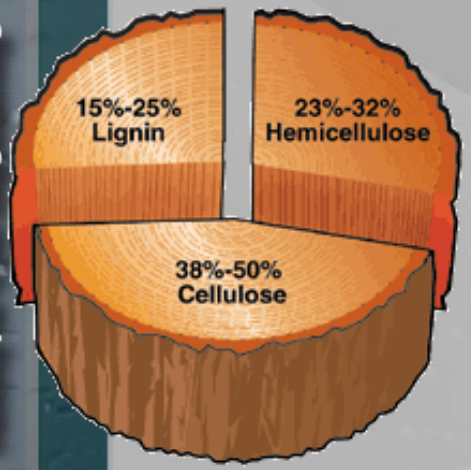
- **wood:** lignocellulosic substance between the pith and bark of a tree or shrub
- **timber**: wood in the form of standing or felled trees or the product of these after conversion
- **round timber**: felled tree cross-cut at the top, with all branches removed, that may or may not have been further cross-cut, generally excluding firewood
- **sawn timber:** timber section produced by the lengthwise sawing or chipping of logs or solid wood of larger dimensions and possible crosscutting and/or further machining to obtain a certain accuracy

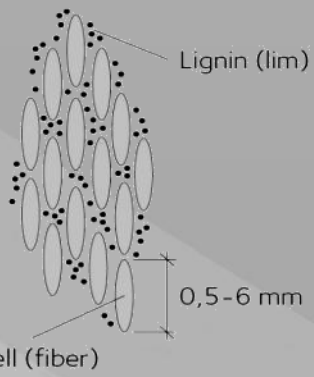
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood structure and composition







Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood - properties

- **color**
  - the darker, the better durability (more resins and tannins)

- **density**: ≅ **1500 kg.m^{-3}**
- **bulk density: 300 - 1200 kg.m^{-3}**

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

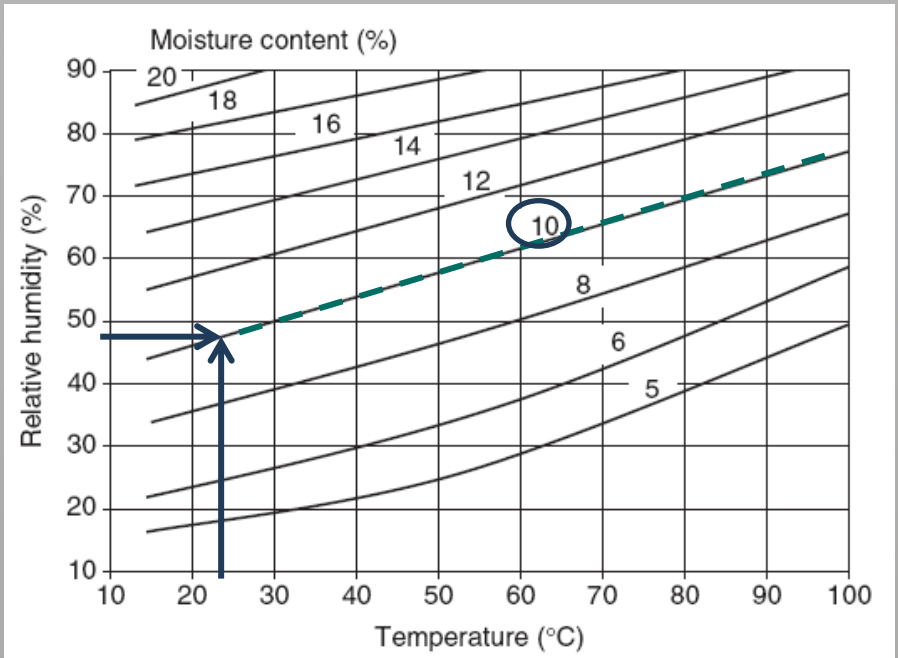
Wood – bulk density

Wood	Bulk density of dry wood	Examples
very light	to 400 kg/m^3	poplar
light	400 - 500 kg/m^3	fir, spruce, pine
moderately heavy	500 - 600 kg/m^3	willow, larch, mahogany
medium heavy	600 - 700 kg/m^3	birch, ash, oak, beech
heavy	700 - 1000 kg/m^3	acacia
very heavy	over 1000 kg/m^3	ebony

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood – moisture

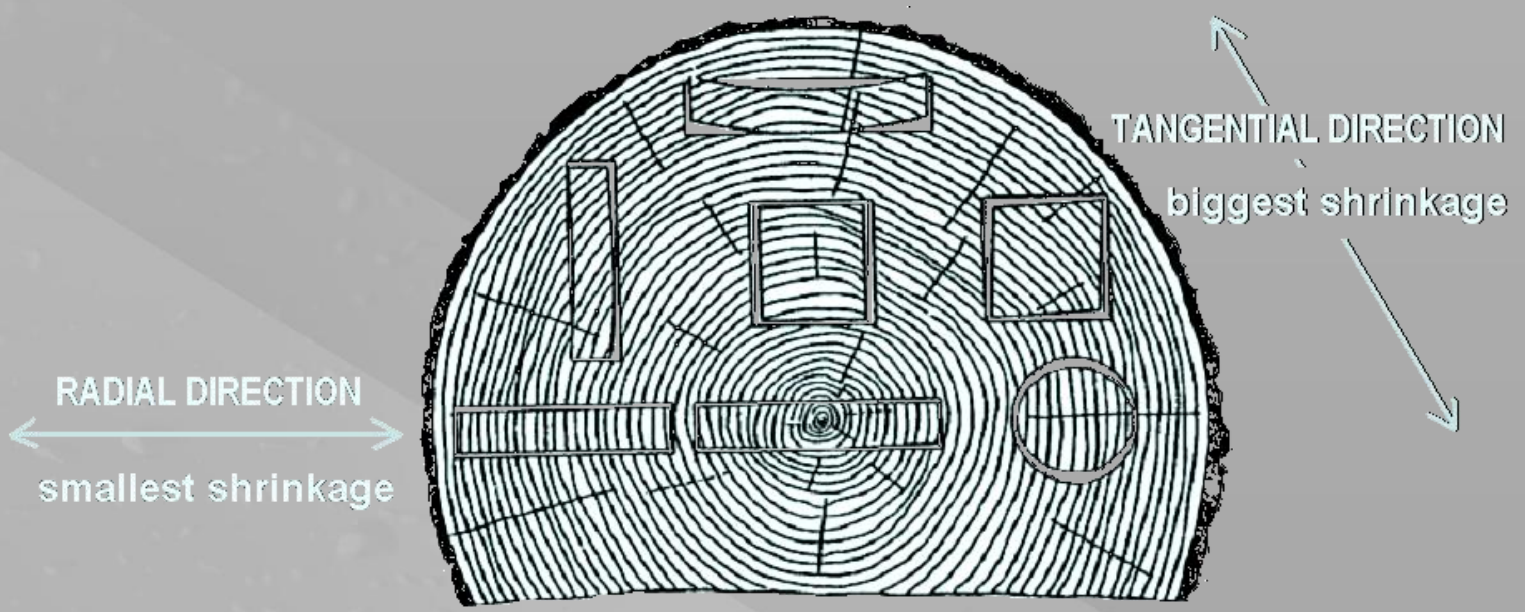
- oven-dry timber
- green timber
  - 40 - 170 %
- **equilibrium moisture content**
  - the vapor pressure within the wood equals the vapor pressure in the ambient space above the wood



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood shrinkage and swelling

- **EN 844 – 4** : decrease in dimension of a piece of timber due to reduction of moisture (**shrinkage**) and vice-versa (**swelling**)



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood – other properties

- **thermal conductivity**: (resin wood , moisture content 15 %):
  - $\lambda \parallel$ to grain $\cong 0{,}25\ W.m^{-1}.K^{-1}$
  - $\lambda \perp$ to grain $\cong 0{,}075\ W.m^{-1}.K^{-1}$
- **thermal expansion** – relatively small
- **electric conductivity**: in the dry state good insulator, conductivity increases significantly with increasing moisture content
- **acoustic properties**

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

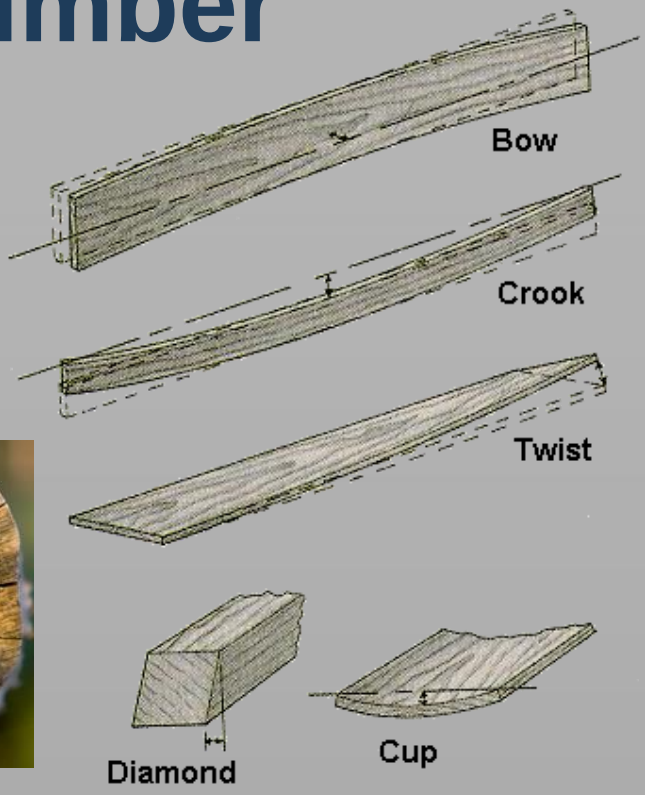
Wood natural durability

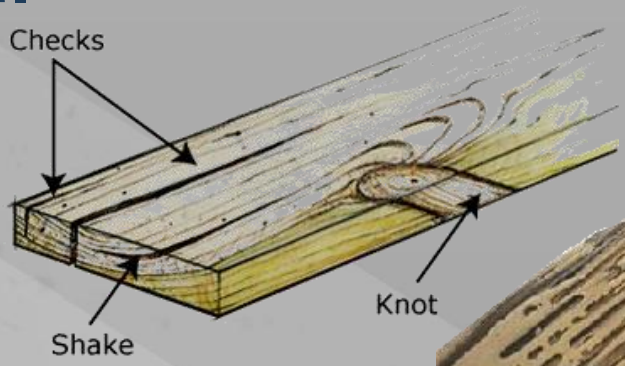
- the degree of resistance to deterioration by the biological, chemical, mechanical and physical wood-destroying agents
- depends on conditions and species
  - **moisture**, temperature
  - worst in variable conditions (esp. at partial contact with ground)

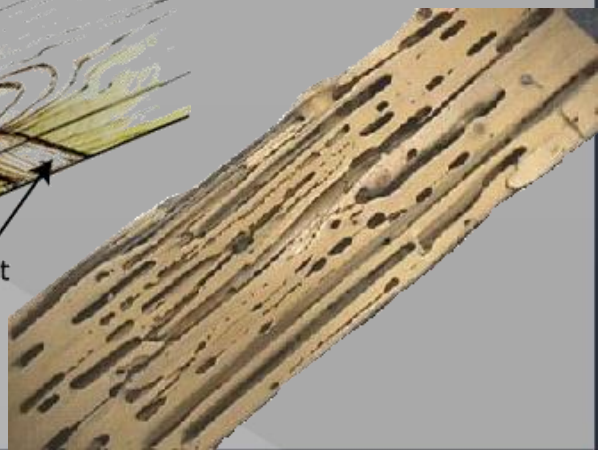
Defects in timber

= anything that effects the structural integrity or appearance of timber

- **natural d.**
- **woodworking d.**
- **warping**
- **fungal, insect d.**





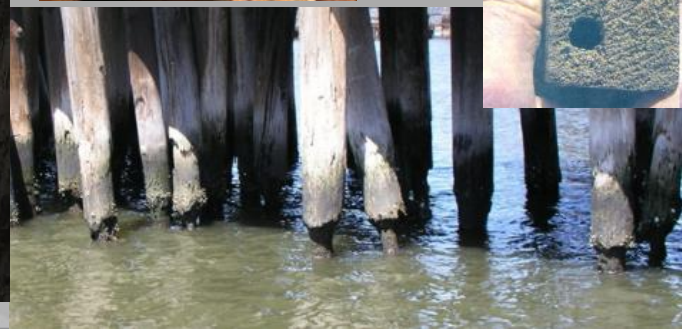


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood destroying organisms

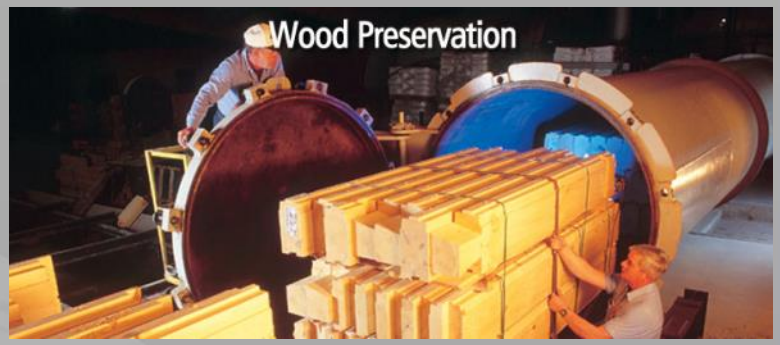
- **fungi**
  - wood decay f.
  - wood staining f.
- **insects**
  - **powderpost beetles** (Anobii, Lyctidae)
  - carpenter ants
- **termites**
- **marina borers**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Timber protection

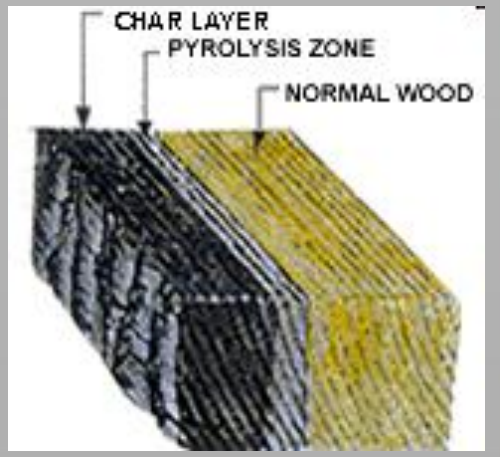
- **against weather (UV radiation), wood destroying organisms and fire**
- **structural (non-chemical)**
  - appropriate species
  - optimized shape
  - protection against moisture
  - decrease of humidity
- **chemical**
  - spraying, painting, soaking, submerging vacuum/pressure treatment



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

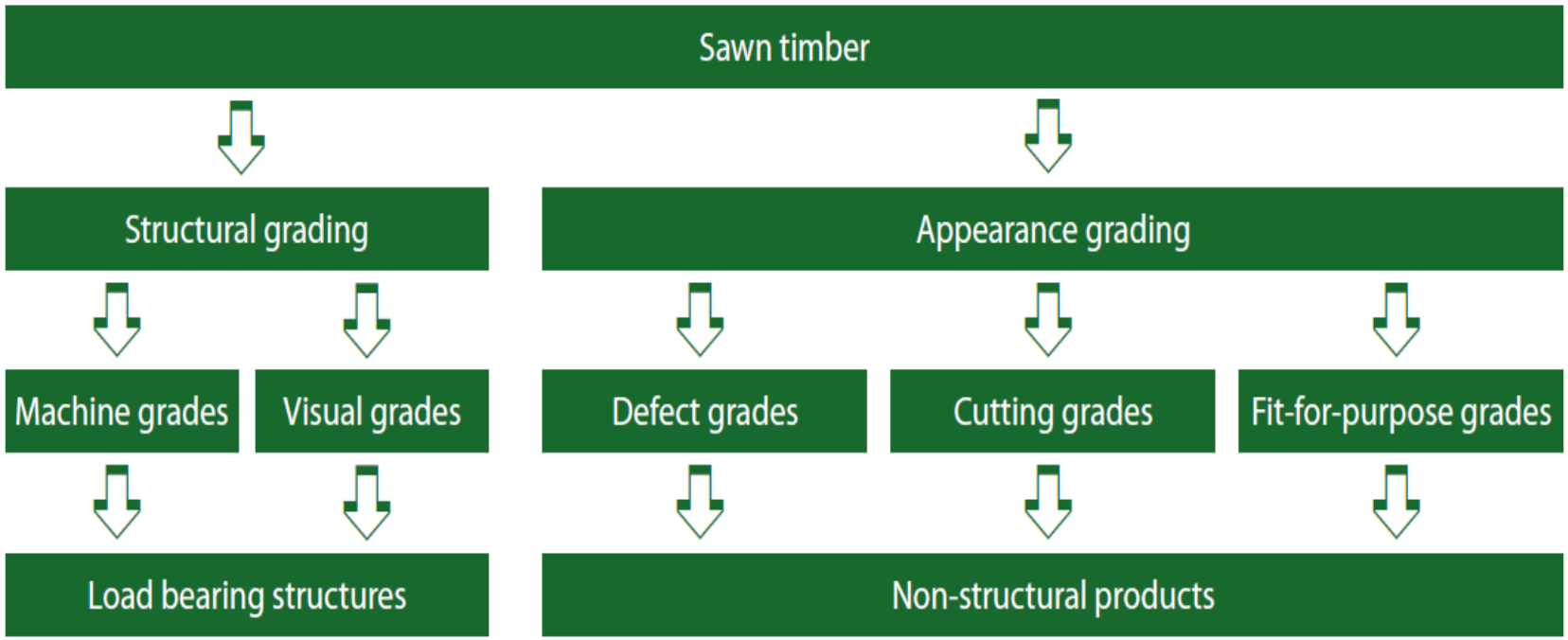
Behavior of wood in the fire

- combustible, but performs very well in fire
- the carbonized layer protects the inner parts of wood against further destruction from fire
- **fire protection**
  - **plaster (20-30 mm)**
  - **ammonium salts**
  - **intumescent paints**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Timber grading



- **knot size & frequency**
- **splits, cracks, checks**
- **colour, grain uniformity**
- **shape** (cup, bow, spring, twist)

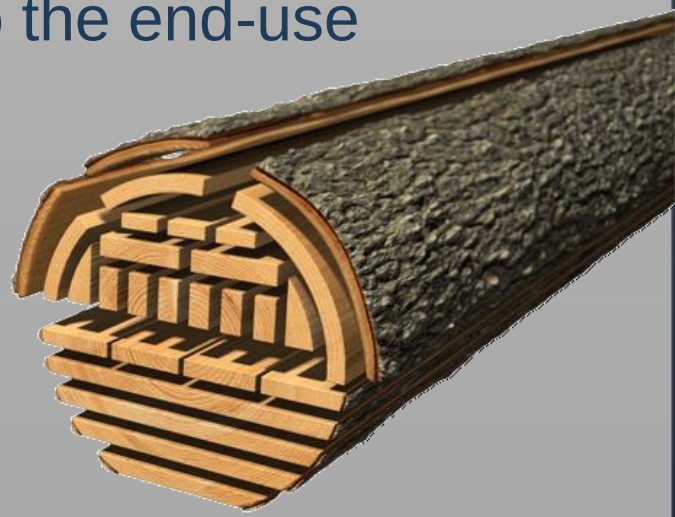
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Structural grading

- **strength and stiffness**
- **visual strength grading**
  - visible defects
  - grader's experience and
- **machine strength grading**
  - deflection-controlled bending tests.

Wood products
Sawn timber

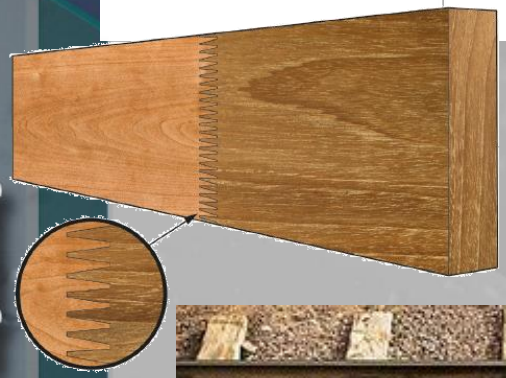
- **EN 844-3**: Timber section produced by the lengthwise sawing or chipping of logs or solid wood of larger dimensions and possible crosscutting and/or further machining to obtain a certain accuracy that has been dried to the end-use moisture content
  - square edged
  - unedged



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood products

Product	Application	Common sizes
Sawn timber	Small structural framing, studs and joists, general carcassing, door panels, joinery	Length: up to 5.4m Width: 25-75mm Depth: up to 250mm
Finger-jointed softwood	Floor and roof joists, ceilings, loadbearing studs, cladding support, prefabricated multi-span 'cassette floors', laminations for glulam members	Length: up to 20m Width: 38-75mm Depth: up to 250mm
'Massive' or cross laminated timber (CLT)	Floor slabs, roofs, beams, columns, load bearing walls, shear walls	Length: up to 20m Thickness: 50-300mm Width: up to 4800

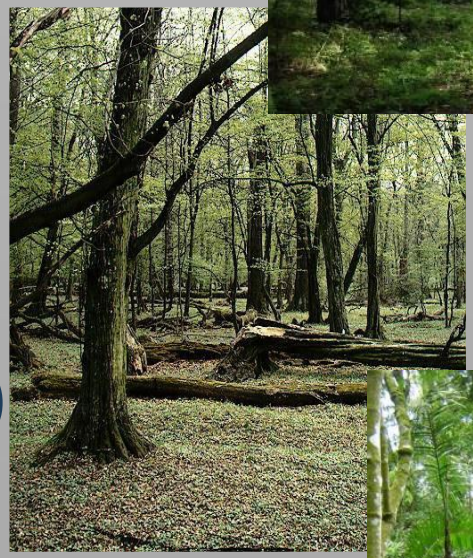


Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Wood species

- **softwood** (coniferous)
  - lower strength
  - lower durability
  - cheaper (quick growth)
- **hardwood** (deciduous)
- **exotic**



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Softwood

- **Spruce** *(Picea)*
  - **good workability, low shrinkage, durable in the dry conditions**
  - **cheap, not suitable to exterior**
  - roofs, formwork, furniture
- **Fir** *(Abies)*
  - **similar to spruce, high durability in water, good splitting** (shingles)
- **Larch** *(Larix)*
  - **higher strength, good durability**
  - use in exterior and at higher demands
- **Pine** *(Pinus)*
  - **a lot of resin, strong, not elastic**
  - windows, doors, beams, floors

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Hardwood

- **Beech** *(Fagus)*
  - **hard and string, high shrinkage, craks, durable in dry conditions and under water**
  - veneers, bend furniture, plywood, floors
- **Oak** *(Quercus)*
  - **hard, heavy, strong, high durability**
  - floors, timber frames, veneers, cork
- **Cherry** *(Prunus)*
  - **strong, hard, tough, distinct grain, high shrinkage**
- **Birch** *(Betula)*
- **Walnut** *(Juglans)*
- **Poplar** *(Populus)*
  - saunas

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Exotic woods

- different properties
- usually durable in exterior
- ecology?

Species

- teak
- mahogany
- ebony
- azobe
- massaranduba
- bangirai

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Solid wood

+ lightweight
+ easy workability
+ easy connecting
+ high strength
+ renewable
+ appearance

- moisture volume changes
- lower durability
- not homogenous properties
- combustibility
- biodegradability

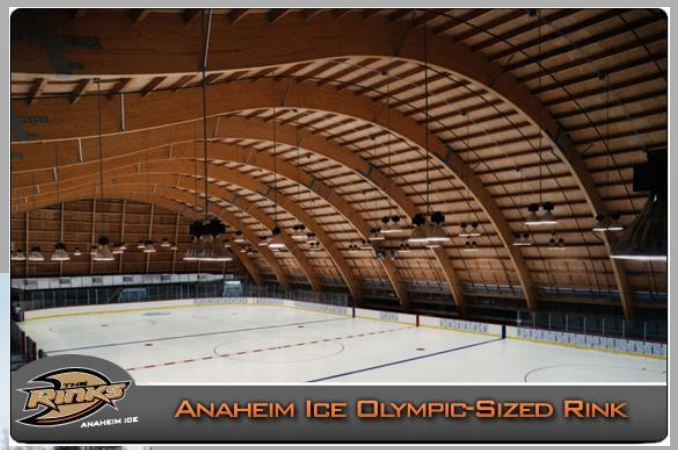
Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

Engineered wood
(wood based materials)

- wood products, which are manufactured by binding the strands, particles, fibers, or veneers of wood together with adhesives, to form composite materials



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

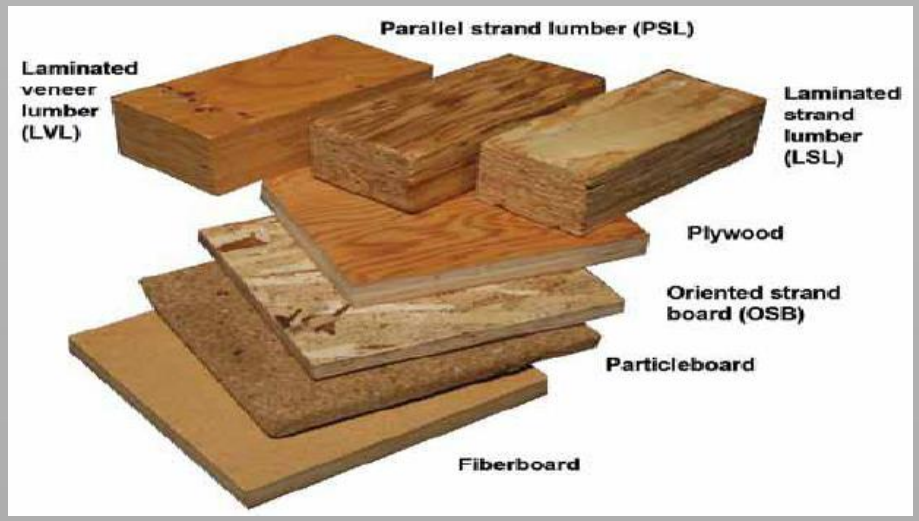
Engineered wood

- exclusion of defects
- more efficient use than wood (use of small pieces of wood)
- mostly very low bulk density (about 500 $kg.m^{-3}$) at high strength
- easy workability and connecting
- volume stability
- better fire and biological resistance
- precise design specifications

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Engineered wood

- boards
  - plywood
  - laminated
  - fiberboard
  - particleboard
  - OSB

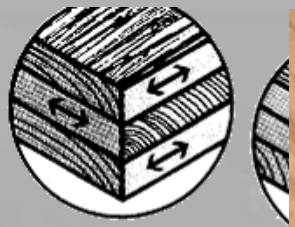


- glued laminated timber (glulam)
- laminated veneer lumber
- parallel strand lumber, laminated strand lumber, oriented strand lumber
- modified wood

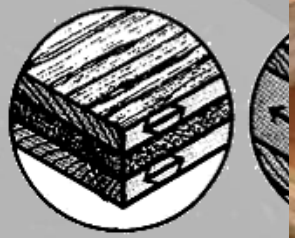
Plywood

- veneer plywood, wood core boards (block board, laminboard), composite plywood

veneer plywood



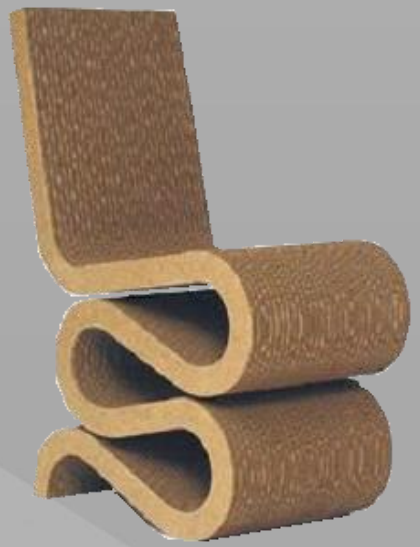
composite plywood



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Fibreboards

- panel material with a nominal thickness of 1,5 mm or greater, manufactured from lignocellulosic fibres with application of heat and/or pressure
- the bond is derived:
  - either from the felting of the fibres and their inherent adhesive properties
  - or from a synthetic adhesive added to the fibres



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Particle board

- wood-based panel manufactured under pressure and heat from particles of wood (wood flakes, chips, shavings, saw-dust, wafers, strands and similar) and/or other lignocellulosic material in particle form (flax shives, hemp shives, bagasse fragments and similar) with the addition of an adhesive
- usually 3 layers

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

OSB – oriented strand boards

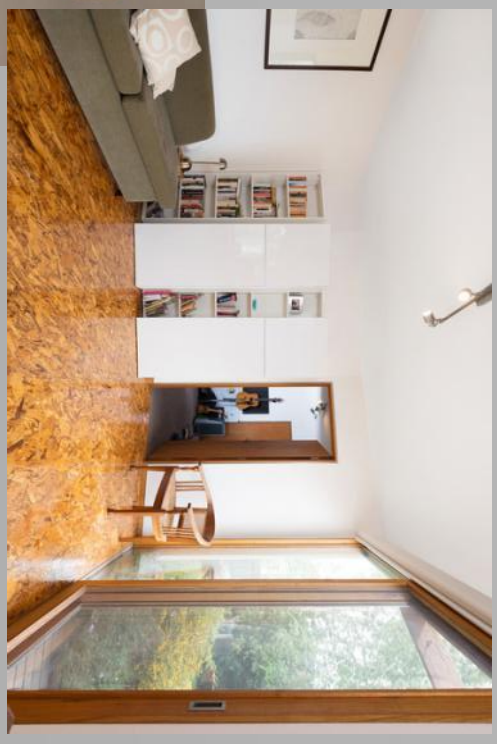
- multi-layered board made from strands of wood of a predetermined shape and thickness together with a binder
- the strands in the external layer are aligned and parallel to the board length or width; the strands in the center layer or layers can be randomly oriented, or aligned, generally at rights angles to the strands of the external layer

Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

OSB



Cement bonded particleboard

- wood-based panel material manufactured under pressure, based on wood or other vegetable particles bound with hydraulic cement and possibly containing additives
  - **wood wool boards** (magnesite binder)
    - $\rho_V < 400$ kg.m^{-3}
    - thermal. noise insulation
  - **wood-cement chipboard**
    - ρ_V 400 – 800 kg.m^{-3}
    - „lost formwork“
  - cement-bonded **particleboards**
    - $\rho_V > 800$ kg.m^{-3}
    - fire resistant, strong

Glued laminated timber (glulam)

- structural member formed by bonding together timber laminations with their grain running essentially parallel
- horizontal and vertical

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

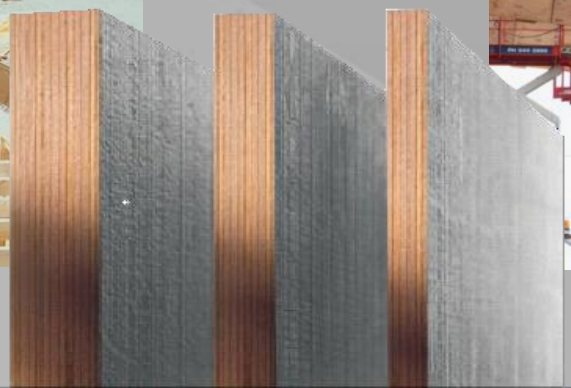
Glulam

Advantages:

- in less loaded parts the worse wood can be used
- reduces the overall amount of wood (about 20 %)
- increased strength (fewer natural defects)
- dimensional stability
- chemical resistance
- large section sizes and long lengths
- very good fire resistance (slow charing - 0,5-0,7 mm/min)

Laminated veneer lumber (LVL)

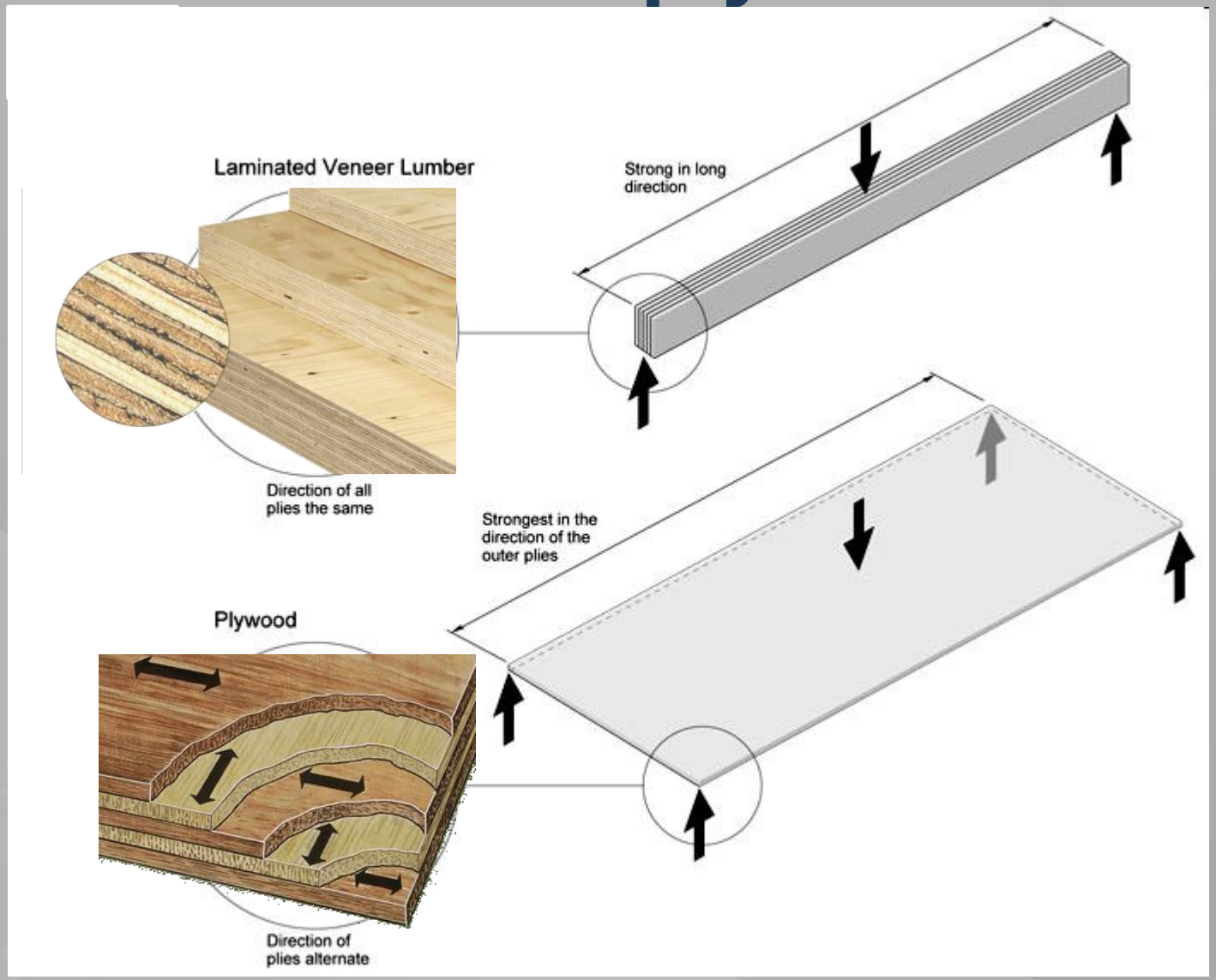
- layered composite of wood veneers with fibers principally in the same direction
- veneers t. 2,5 - 6 mm, min. 5 plies
- manufacture at higher temperature and pressure



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

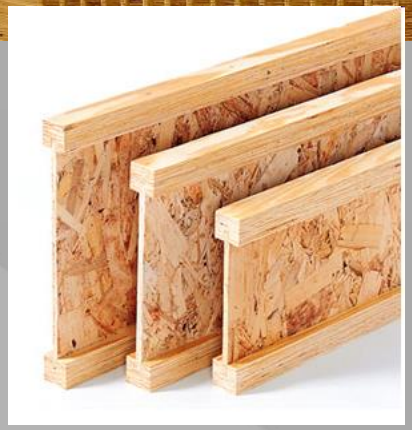
LVL x plywood



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

LVL

- bending strength ≈ 50 MPa
- average modulus of elasticity ≈ 14 000 MPa.
- high dimensional stability
  - no shrinkage
  - no warping
- structural framing
- roof timbers
- beams and headers
- flange material for I-joists



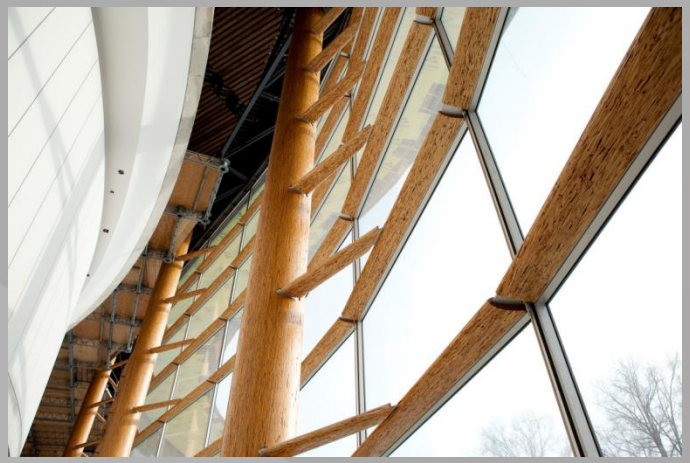
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

LVL

Metropol Parasol, Sevilla

Parallel strand lumber - PSL

- Parallam
- clipped veneer strands (width 20 – 30 mm, length to 2400 mm)
- strands laid in parallel alignment and bonded with adhesive under pressure
- sometimes hardening by microwaves.



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

PSL

- mechanical properties similar to concrete
- dimensions: h. 300 - 500 mm, w.~300 mm,
- length limited only by the transport possibilities (~ 20m)
- dimensional stability
- less prone to shrinking, warping, bowing, cupping and splitting

Structural products

- I joists
- web joists

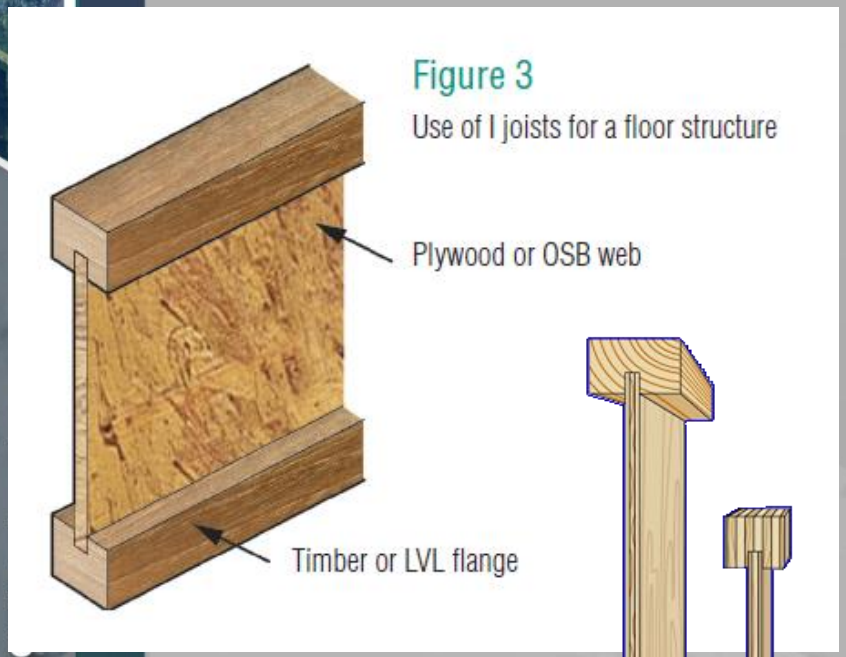


Figure 3
Use of I joists for a floor structure

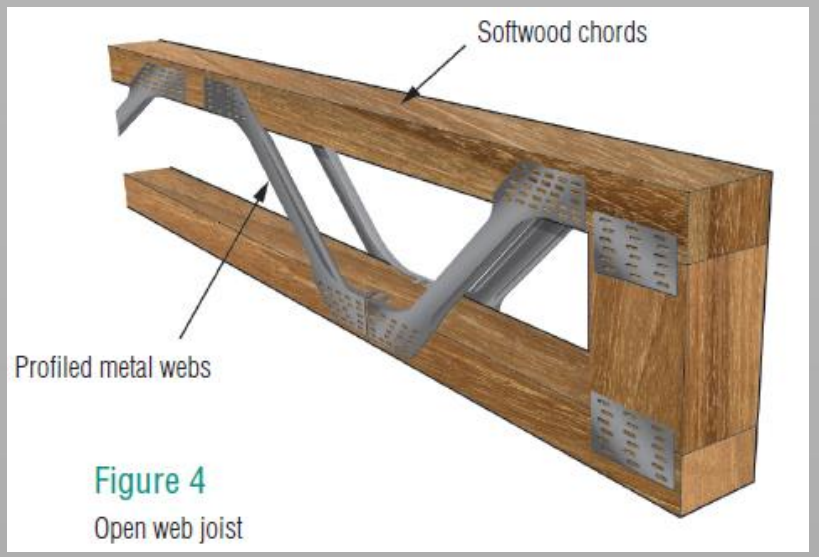


Figure 4
Open web joist

Department of Materials Engineering and Chemistry
Faculty of

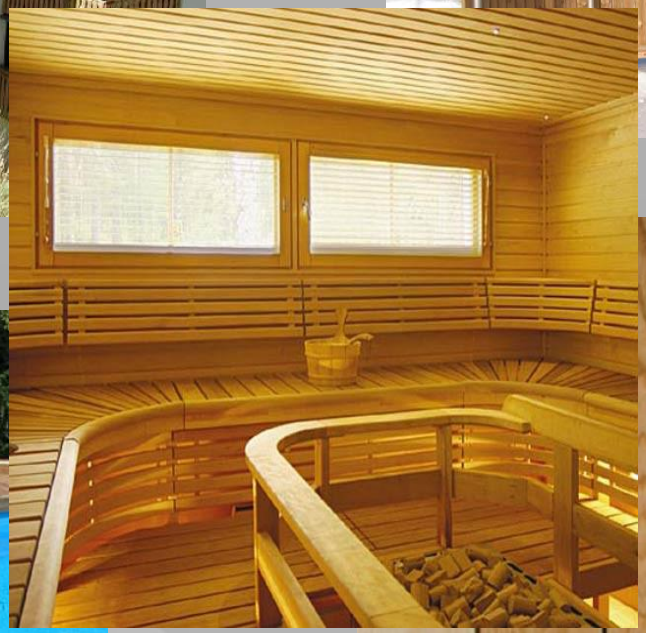
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Modified wood

- **modification** = hydroxyl groups OH replaced by other groups
  - chemical treatment - **acetylation** (H replaced by $COCH_3$)
  - thermal treatment (at higher pressure and temperature the OH groups are removed from wood cells)
- decrease of sorptivity (up to 40%) → reduction of volume changes
- worse mechanical properties
- better resistance against biological attack

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Thermal modified wood



Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Other organic materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Cellulose insulation

- pulp paper + boric acid + borax (for higher resistance against fire and biological attack)
- ρ_V (fine fibers) 30 - 90 kg.m^{-3}
- ρ_V (pellets) 500 kg.m^{-3}
- $\lambda \approx 0{,}04$ W.m^{-1}.K^{-1}
- thermal insulation
  - loose fill (cavities)
  - spray applied

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Cork

- **bark from cork oak**
- **low thermal conductivity** (λ = 0,05 W.m^{-1}.K^{-1})
- **low absorptivity**
- does not support its own combustion and chars only slowly

Use

- **expanded** (autoclaved) **cork**
- **thermal, acoustic insulation**
- **insulation against vibrations**
- **sidings**
- **linoleum** (linseed oil, cork dust, wood flour, mineral fillers)

Straw

- straw bales
- loose
- straw boards
- thaches

Department of Materials Engineering and Chemistry

Faculty of C

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Other vegetable materials

- **reed**
  - roofing
  - insulating boards
- **fibers** (cotton, sisal, coconut coir, flax, hemp…)
  - boards
  - matts
  - loose
- **bamboo**
  - flooring

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Sheep wool

- hygroscopic
- $\lambda \approx 0{,}035 – 0{,}04\ W.m^{-1}.K^{-1}$
- $\rho_v = 12{,}5–25\ kg.m^{-3}$
- flame retardant, self extinguishing
  - fire rating B
- treatment against pests (borax)
  - moth attack
- when wet, smells

Sheep wool utilization

- thermal and acoustic insulations
  - batts
  - roles
  - ropes
  - spraying

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry

Faculty of Civil Engineering

Building materials

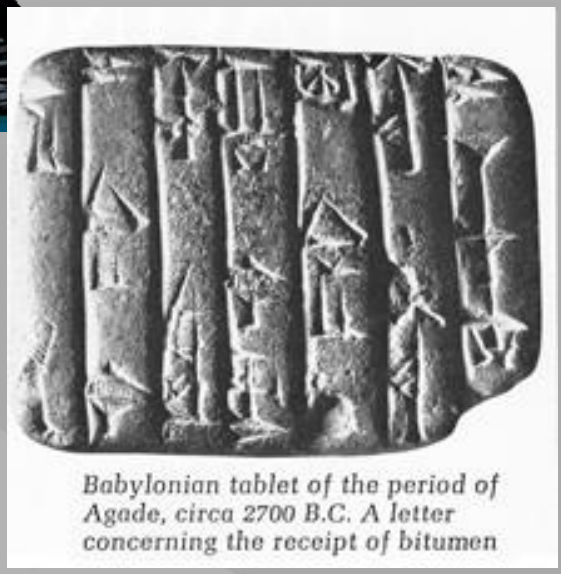
Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Bituminous materials

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Bituminous materials

- an amorphous, black or dark-colored, (solid, semi-solid, or viscous) cementitious substance, composed principally of high molecular weight hydrocarbons
  - **asphalts**
  - **tars**
  - nonvolatile
  - nontoxic
  - soften when heated
  - soluble in carbon disulfide



Babylonian tablet of the period of Agade, circa 2700 B.C. A letter concerning the receipt of bitumen

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Bituminous materials

- **asphalt**
  - natural
  - from petroleum processing
- **tar**
  - do not occur in nature
  - condensates in the processing of coal, petroleum, oil-shale, wood or other organic materials
- pitch
  - formed when a tar is partially distilled so that the volatile constituents have evaporated off from it

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Natural asphalt

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Petroleum asphalts

- refined residue from the fractional distillation of crude oils = **primary asphalt**
  - **oxidised a**. - passing air through asphalt at elevated temperature
    - **less sensitive to thermal changes**
  - **modified a.** - their properties (elasticity, adhesive or cohesive strength) have been modified by the adition of polymer
    - **SBS** (styren-butadien-styren, 7-15%)
      - **higher ductility** (several hundred %)
    - **APP** (atactic polypropylene, 15-35 %)
      - **higher resistance against UV radiation**
      - **better adhesion**

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Asphalt properties

General:

- insoluble in water
- no absorptivity
- density ≈ 1000 $kg.m^{-3}$
- $\lambda \approx 0{,}75\ w.m^{-1}.K^{-1}$
- soluble in organic solvents
- thermal elongation ≈ $600.10^{-6}\ K^{-1}$
- combustible
- ageing by UV radiation and O_2

Influence of modification on properties

Property	Oxidized asphalt	APP modification	SBS modification
softening point °C	ca 95	ca 135	ca 120
breaking point °C	0	-5 to -15	up to -35
elasticity	any	low	high
ductility %	2 to 5	ca 20	over 100

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Asphalts testing

Special tests:

- **penetration**
- **softening point**
- **breaking point**
- **ductility**
- viscosity
- coating ability

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Penetration test

- the depth to which a needle penetrated an asphalt sample under specified conditions of load, time and temperature
- units: 0,1 mm

Softening point test

- **Ring-and-ball method**
- the **softening point** is the temperature at which a material softens beyond some arbitrary softness

heating by 5°C/min

= temperature,

men specimen

(25 mm)

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

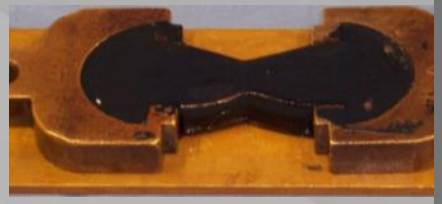
Breaking point test

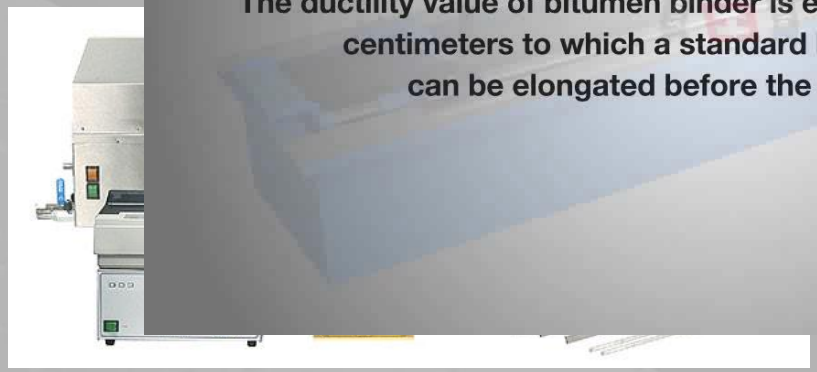
- **Fraass method**
- to determine the temperature bellow which a bitumen tends to break rather than to flow when stressed
  - **breaking point** = the temperature at which the first cracks appear in the coating

Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Ductility test

- stretching a standard-sized briquette of asphalt binder at standard temperature to its breaking point
  - **ductility** = stretched distance in cm at breaking

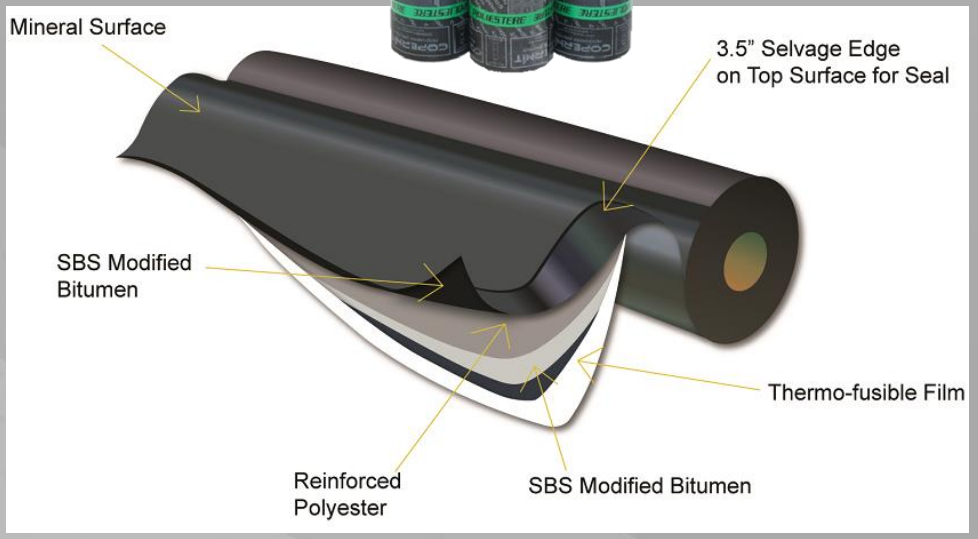




Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Asphalt products

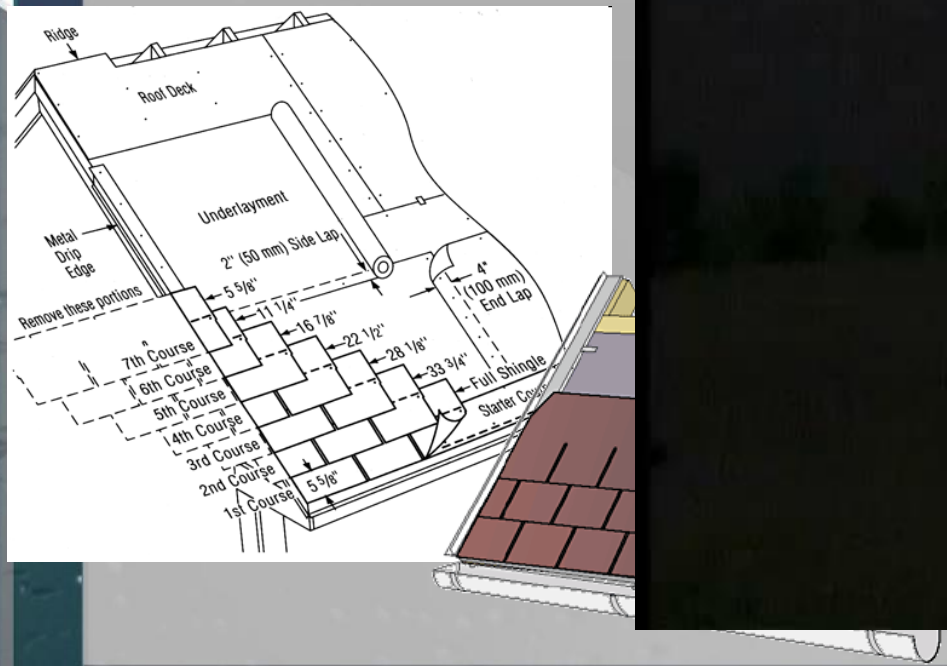
- paints
- mastic
- **asphalt cement**
  - asphalt concrete
- emulsions
- suspensions
- **membranes** (felts)
- roofing



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Asphalt shingles

- roof covering
- cutted from asphalt membranes
- wood roof decking
- fixation by ga



Department of Materials Engineering and Chemistry
Faculty of Civil Engineering

Asphalt shingles - roof

- minimal **roof slope** - 15°
- **square weight** - 9,5 to 14 kg/m^2
- **life expectancy** - 30 to 50 years

\+ lightweight

\+ price

– lower fire resistance

– softening at higher temperatures

– high demands on realization

– shorter durability

– decking under shingles