ELEMENTS OF

BUILDING MATERIALS ENGINEERING

Branches of civil engineering

CE area	Scope
Overground structure	
Building engineering	Houses
	Public buildings: schools, hospitals, theaters, railway stations… …
	Engineer structures: bridges, viaducts, dams
Sanitary systems	Sanitary fittings, sewage treatment plants …
Industrial	Factories, stores…
Agricultural	Outbuildings and buildings for livestock…
Sacred	Churches, cloisters …
Defensive	Military installations
Ground structure	
Communication	Roads, highways, railroads …
Underground structure	
Communication	Tunnels, subway, underground passes …
Defensive	Shelters

Relative share of building materials in EU-construction industry (2000)

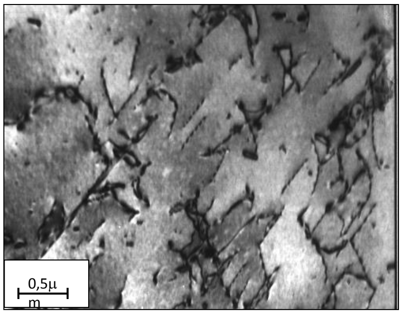
Construction material	Consumption (tons)	Ratio (%)
Concrete and cement based	503 000 000	71
Tiles and bricks	73 000 000	10
Timber	54 000 000	7
Iron and steel	24 000 000	3
Stone, quarry	16 000 000	2
Asphalt and bitumen	16 000 000	2
Polymers	6 850 000	0,97
Flat glass	5 200 000	0,73
Mineral wool	2 000 000	0,3
Copper	1 300 000	0,2
Aluminium	900 000	0,1

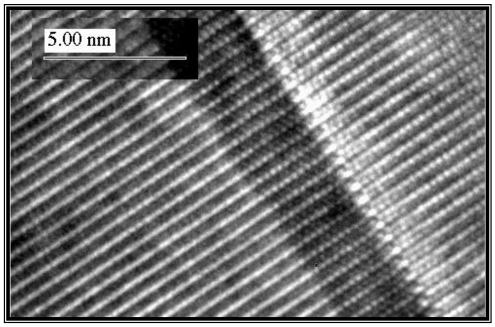
Building materials or their compounds

Homogeneous systems
(one phase)
Eg. glasses, crystals

Non-homogeneous systems
(multi-phase)
eg. colloids, composites

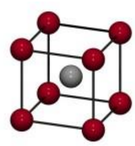
Atomic structure of metals

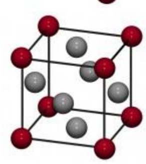


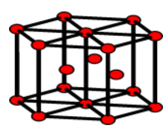


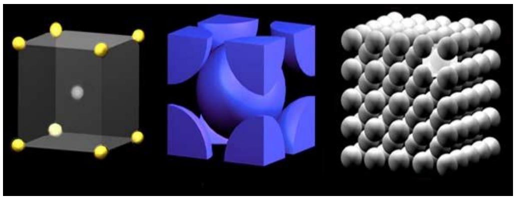
Transmission Electron Microscope

- ❑ there are 14 different types of crystal unit cell structures or lattices are found in nature.
- ❑ most metals and many other solids have unit cell structures described as:
  - body center cubic (bcc),
  - face centered cubic (fcc)
  - Hexagonal Close Packed (hcp).

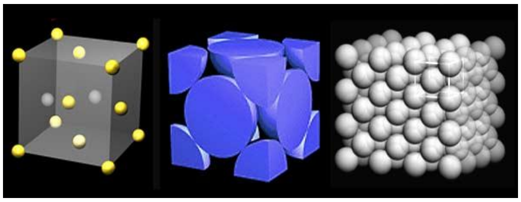




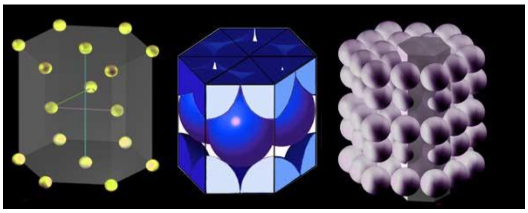




sodium, potassium, chromium, barium, vanadium, alpha-iron and tungsten

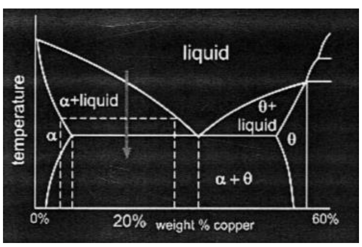


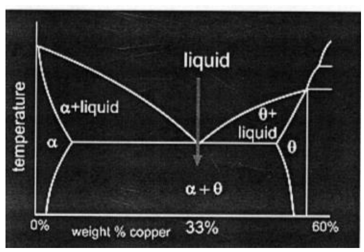
aluminum, copper, lead, nickel, silver

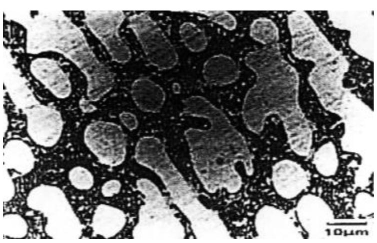


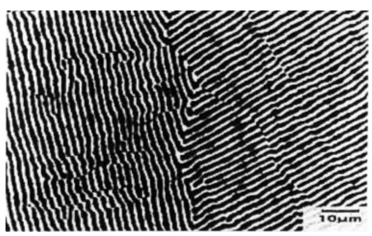
beryllium, cadmium, magnesium, titanium, zinc and zirconium

Alloys microstructure vs. composition









Steel: alloy Fe – Fe_3C

after rolling

after heat treatment

0,4%C

0,8%C

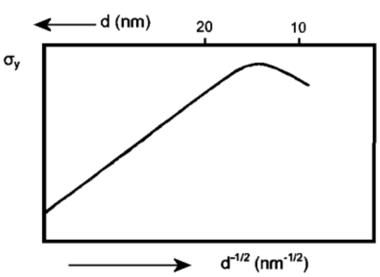
Basic relation: properties - microstructure

Hall-Petch relationship

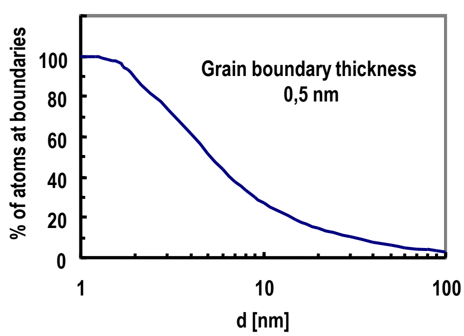
d - grain size

σ_y – yeld stress

$$\sigma_y = \sigma_0 + k \cdot d^{-\frac{1}{2}}$$



Large area of grain boundaries



What is a composite?

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other.

Mechanics of Composite Materials, Second Edition, 2006 by Taylor & Francis Group, LLC

What is a composite?

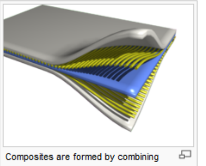
WIKIPEDIA
The Free Encyclopedia

Composite material

From Wikipedia, the free encyclopedia

For the specific carbon and glass fiber based composite materials often referred to loosely as 'composites', see Fiber-reinforced polymer.

Composite materials (also called **composition materials** or shortened to **composites**) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.



Composites are formed by combining materials together to form an overall structure that is better than the individual components

Typical engineered composite materials include:

- Composite building materials such as cements, concrete
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites
- Ceramic Composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and counter tops. The most advanced examples perform routinely on spacecraft in demanding environments.

Two main constituent (phase):

- ***REINFORCING PHASE***

and the one in which it is embedded is called the

- ***MATRIX***

The reinforcing phase material may be in the form of fibers, particles, or flakes.

The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc.

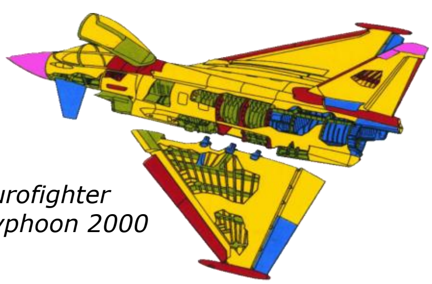
To receive better or extra properties in comparison to properties of particular phases

↓

Adventages of composites:

- Prediction and design of material properties
- Possibility to obtain properties impossible to obtain for classic materials eg. steel

Source of development in composites: military, plane and car industry



Eurofighter Typhoon 2000

- Carbon composites (40%)
- Al-Li alloys (20%)
- Al. Alloys (18%)
- FRP (10%)
- Ti (12%)

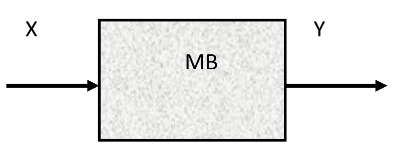
Composites offer several advantages over conventional materials: improved strength, stiffness, fatigue and impact resistance, thermal conductivity, corrosion resistance, etc

Specific modulus: E / ρ

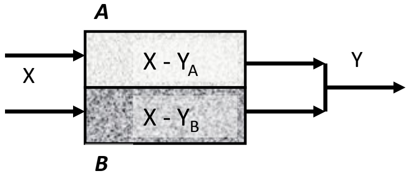
Specific strength: R / ρ

modulus/strength to weight ratio

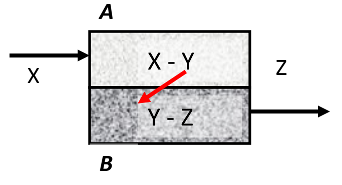
Composites properties:



Additive properties



Synergic properties



eg. Young modulus

Specific mechanical properties vs. material types

Material Units	Specific gravity	Young's modulus (GPa)	Ultimate strength (MPa)	Specific modulus (GPa-m3 /kg)	Specific strength (MPa-m3 /kg)
Graphite fiber	1.8	230	2067	0.1278	1.148
Aramid fiber	1.4	124	1379	0.0885	0.985
Glass fiber	2.5	85	1550	0.0340	0.620
Unidirectional graphite/epoxy	1.6	181	1500	0.1131	0.938
Unidirectional glass/epoxy	1.8	38	1062	0.0214	0.590
Cross-ply graphite/epoxy	1.6	95	373	0.0600	0.233
Cross-ply glass/epoxy	1.8	23	88	0.0131	0.049
Quasi-isotropic graphite/epoxy	1.6	69	276	0.0435	0.173
Quasi-isotropic glass/epoxy	1.8	19	73	0.0105	0.041
Steel	7.8	207	648	0.0265	0.083
Aluminum	2.6	69	276	0.0265	0.106

Application of FRP in building industry

CFRP sheets combined with bonded steel plates

Application of FRP in building industry

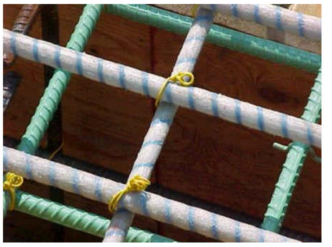


Application of FRP in building industry

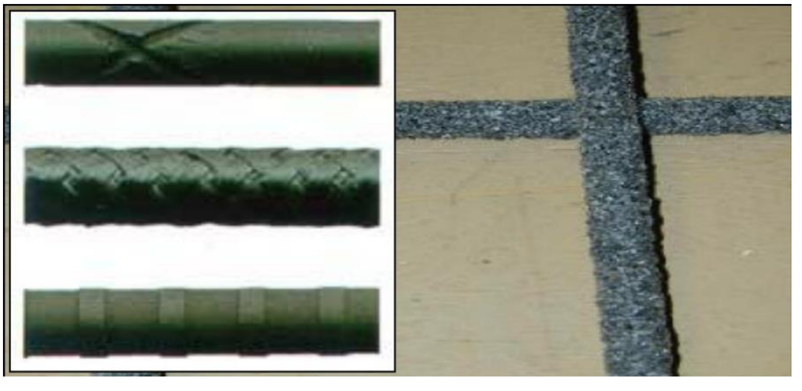
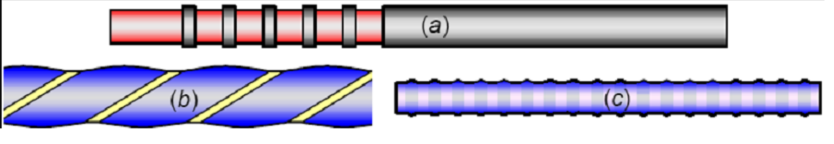

St. Waudru, Frameries, Masonry vault, strengthened with aramid fibres

Photo. D. Van Gemert

Non-ferrous reinfrocement systems for concrete

Adhesion do concrete!

Light-transmitting concrete

+

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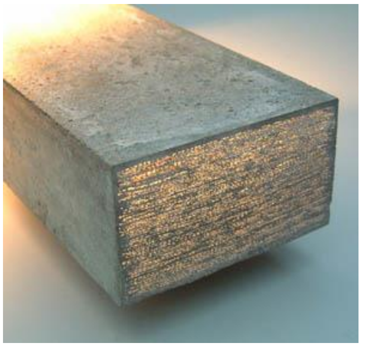


concrete

Fiber optics

Light-transmitting concrete

Light-transmitting concrete - examples

Europe Gate
Komarom, Węgry, 2004

Museum Cella Septichora
Pecs, Węgry, 2006

Light-transmitting concrete - examples


	LiTraCon	Ordinary concrete
density(kg/m^3)	2100 – 2400	2000-2600
Compr. Strength (MPa)	32-49	30-50*

Mineral polymer mortar

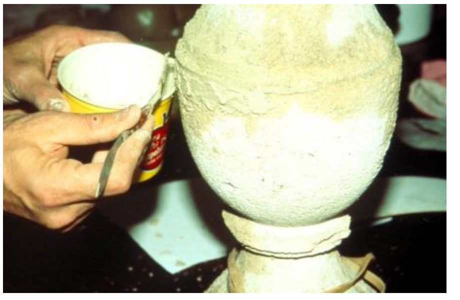
$$n\,(MeO + MeCl_2 + H_2O) = (–Me–O–Me–O–)_n + n\,HCl$$

$$n\,(ZnO + ZnCl_2 + H_2O) = (–Zn–O–Zn–O–)_n + n\,HCl$$

$$2HCl + CaCO_3 = CaCl_2 + H_2CO_3 = CaCl_2 + H_2O + CO_2 \uparrow$$

Mineral polymer mortar

Facade repair by stone replacement



Re-shaping with usual stone-cutter's tools

BUILDING MATERIALS ENGINEERING

Formal Aspects of Building Materials Application

Essential requirements for construction products
Construction Products Directive CPD 89/106/EEC

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and the environment
   - dangerous substances
   - global environment impact
4. Safety in use
5. Protection against noise
6. Energy economy and heat retention

par. 5 clause 1 pt. 1 of Building Law

Building […] have to be designed and built […] ensuring:

1) compliance with fundamental requirements relevant to:
   a) security of construction,
   b) fire security,
   c) use security,
   d) right Health and Safety conditions and environmental protection,
   e) protection against noise and vibration,
   f) economic use of energy and right heat insulation of building partitions.

„Law of building products”

Definitions

<u>Conformity declaration</u>: declaration, at producer's exclusive responsibility, on building product to be according to the polish standard or technical approbation.

<u>Building mark:</u> reserved mark providing guarantee of appropriate level of reliance, what means, that building product is accordant with polish standard or technical approbation.

„Law of building products”, cont.

Definitions

<u>Introduction of building product:</u> first product delivery to user, consumer or supplier by producer or importer.

<u>European technical approbation:</u> positive technical opinion on building product fitness for intended purpose, dependent on compliance with basic requirements in building, issued in accordance with EU requirements

„Law of building products", cont.

Definitions

<u>Supplier</u>: transactor delivering introduced building product to the other transactor, in the purpose of use in building or subsequent deliver.

Certification of building product

- confirmation of building product properties accordance with polish standard (PN-EN), European standard (EN) or technical approbation (AT), for product made-up by one producer

- if certification is not obligatory for a product, the conformity declaration is required.

Producer issues such a declaration on conformity with document of reference.

Marking of building product

- Common mark

CE

„Law of building products"

Regional building product

WYRÓB REGIONALNY
WOJEWÓDZTWO ....

Traditionally produced on the restricted area building product, verified by well known practice, for local introduction; it could be marked by building mark on producers responsibility.

Regional building product can be established by local building inspection, on application of producer.

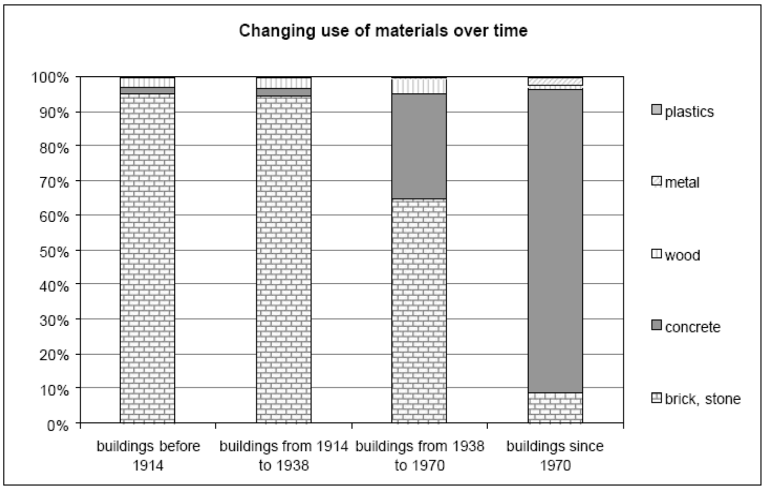
Sustainable development

BUILDING MATERIALS ENGINEERING

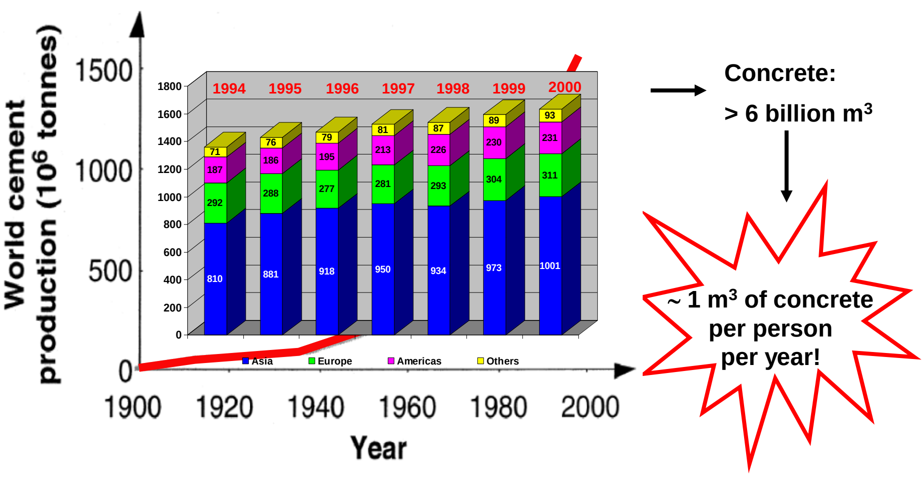
SUSTAINABLE DEVELOPMENT

implies meeting the needs of the present without compromising the ability of future generations to meet their own needs.

G.H. Bruntland, UN, 1987

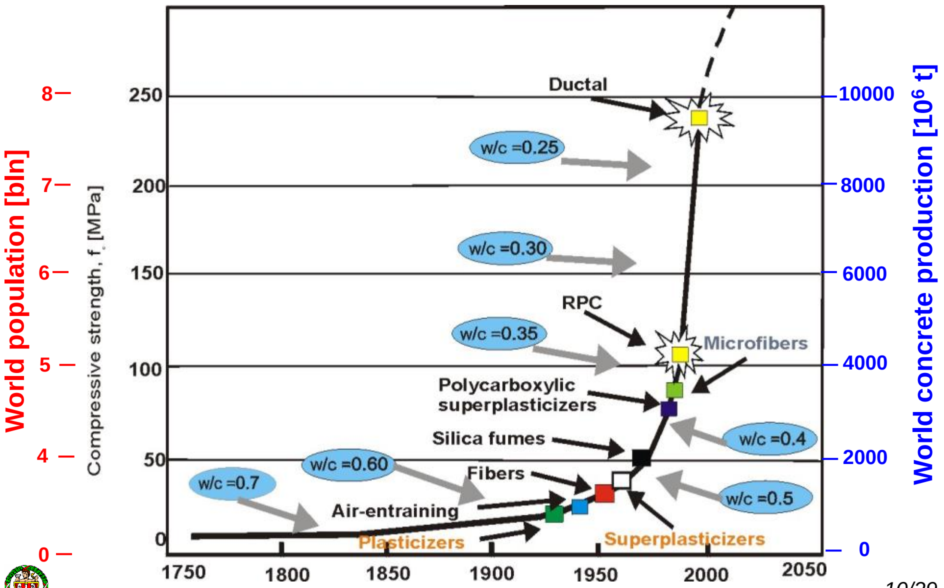


Changing use of materials over time



In less than one century, concrete has become the most widely used construction material over the world

The concrete development curve



Concrete industry is consuming annually:

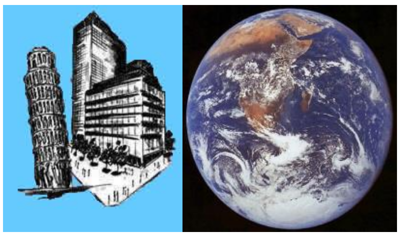
• cement	1.6 bln tonnes
• aggregates	20 bln tonnes
• water	800 mln m³ (0.5 % of total water consumption – irretrievable
• CO_2	7 % of total emitted greenhouse gases (but construction industry 35 %)
• Energy	40 %

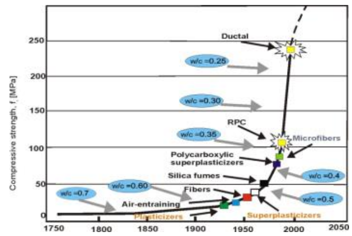
Idea & matter

Sustainable development → Sustainable construction → Sustainable building materials

Leading civilisation material → Concrete

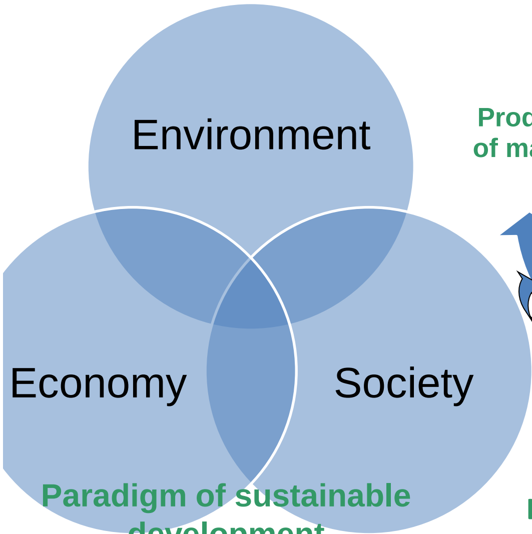
Sustainable building materials ↔ Concrete



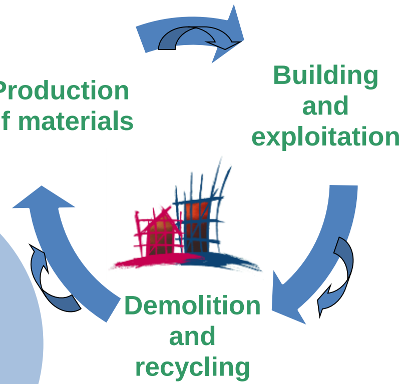


Lead Market Initiative for sustainable construction

Use of resources/Production of pollution and waste	Environmental impact	Sustainability
Faster than natural regeneration	Degradation	None
Equal to regenerative potential	Balance	Steady state
Slower than regenerative potential	Regeneration	**Development**



Paradigm of sustainable development



Life-cycle of the building

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Fundamental research inspiration:

- rationalisation of matter (energy + mass) management,
-construction durability,
- maintenance,
- renovation,
- repairing,
- modernisation & revitalisation,
- service life
- reclaim and reuse,
- recycling,
- health impact,
- environmental impact,

- sustainability measures:
- - calculation methods,
- - prognosis tools,
- - stimulation,
- - prediction.

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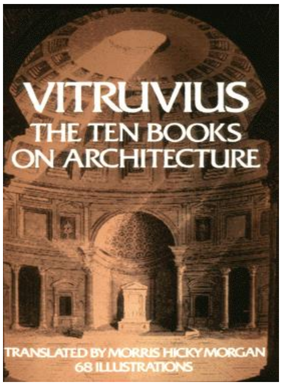
20-10 b.Chr.



- **durability**
- **benefit**
- **beauty**

1990-2010

durability

- **bearing & stability**
- **fire safety**
- **safety of using**
- **hygiene, health, environmental protection**
- **vibration and noise protection**
- **energy saving; heat insulation**
- **sustainable construction**

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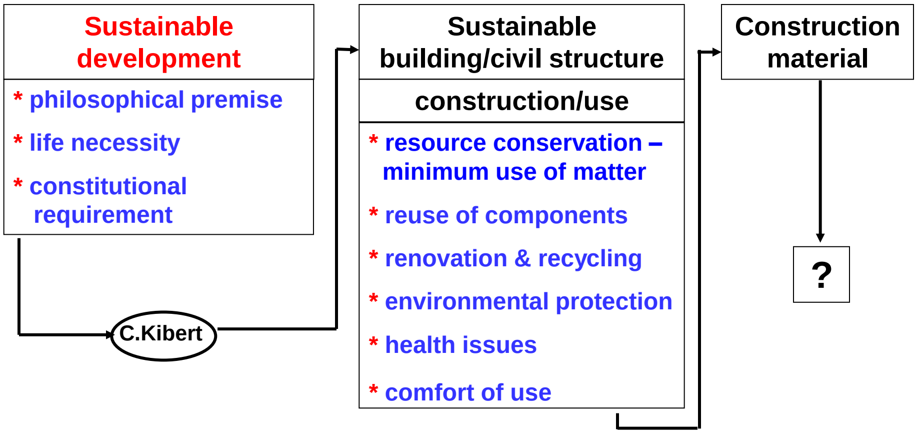
Developments in the research areas concerning construction materials

Development factors (International Concrete, 1998	Principal requirements (ER 89/106/EEC)	Sustainable Building, factors according to:		Research areas
		C.J.Kibert, 1999	Sustainable Building Code, 2006	
sustainable development environmental impact energy saving reduced costs of erection, maintenance, dismantling and recycling use of highly-suitable materials; optimisation of structural solutions big and growing share of repairs and modernisation in construction works design focused on the utility of the building/civil structure	structural safety: load-bearing capacity and stability fire safety hygiene, health and environment safety of use protection against noise and vibration energy-saving properties and thermal insulation	minimum quantity of materials used (resource conservation) maximum re-use of components possibility to renovate components or materials environmental protection health comfort of use	demand for energy and emission of CO_2 water use (dm^3/person/day) effect of used materials and products on the environment evacuation of surface runoff waste management minimised pollution health and comfort construction process and building management ecology	performance criteria of construction materials methods of suitability assessment modification of materials and new material solutions material performance in service conditions – matching materials with structures recycling of construction materials; use of waste material

Material factors in the sustainable development of construction

20/29



Performance concept – Well Defined Properties Product

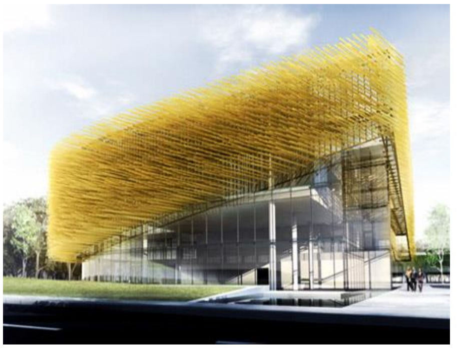
US Code, 1925:

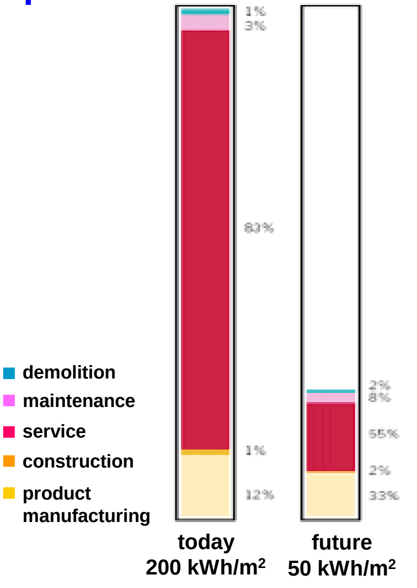
Whenever possible, requirements should be stated in terms of performance, based upon test results for service conditions, rather than in dimensions, detailed methods or specific materials. Otherwise new materials, or new assemblies of common materials, which would meet construction demands satisfactorily and economically , might be restricted from use, thus obstructing progress in the industry.

Examples of new research topics:

- energy factors

passive building





courtesy K.Adelberth
Lund University

Energy consumption (annually)

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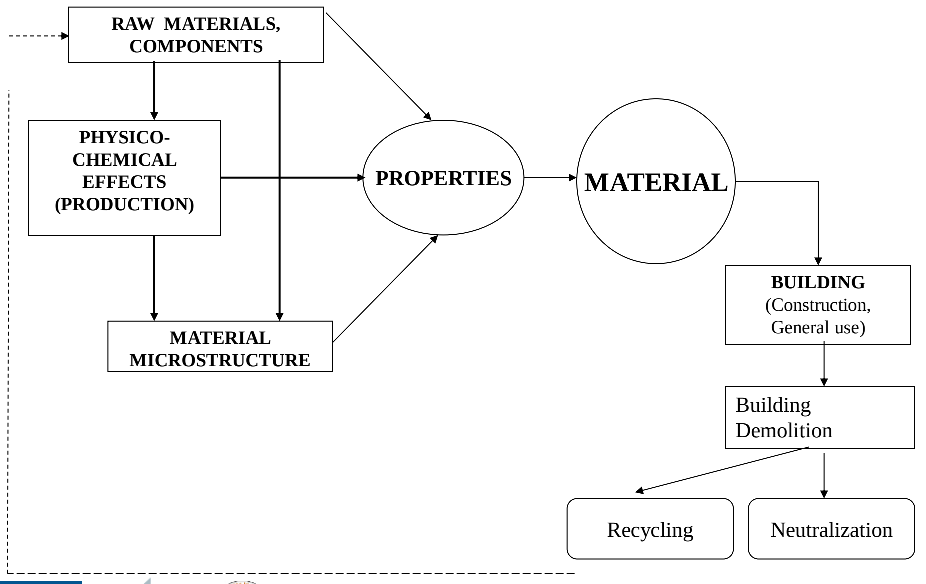
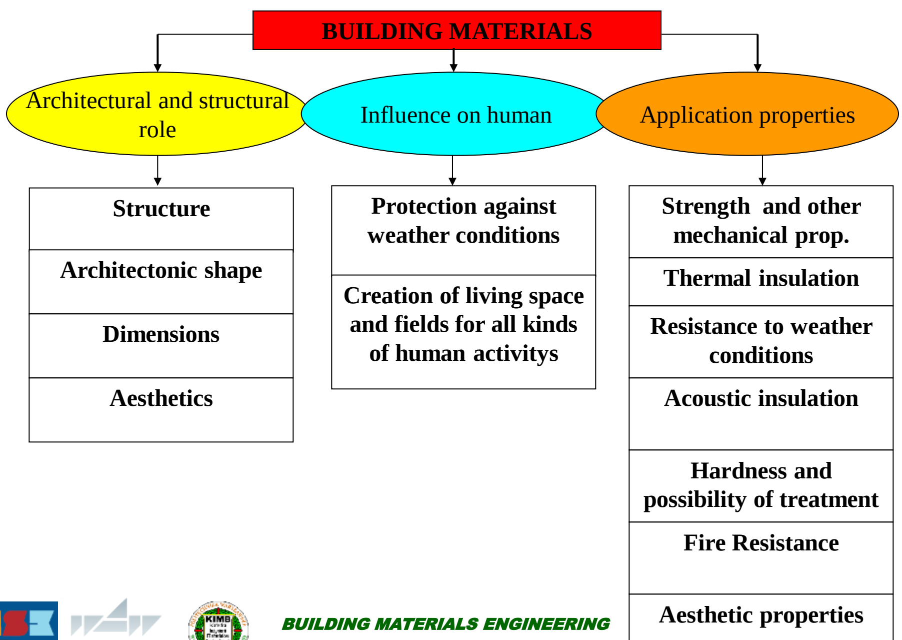
Technical properties of BUILDING MATERIALS

BUILDING MATERIALS ENGINEERING

Lifecycle of building material





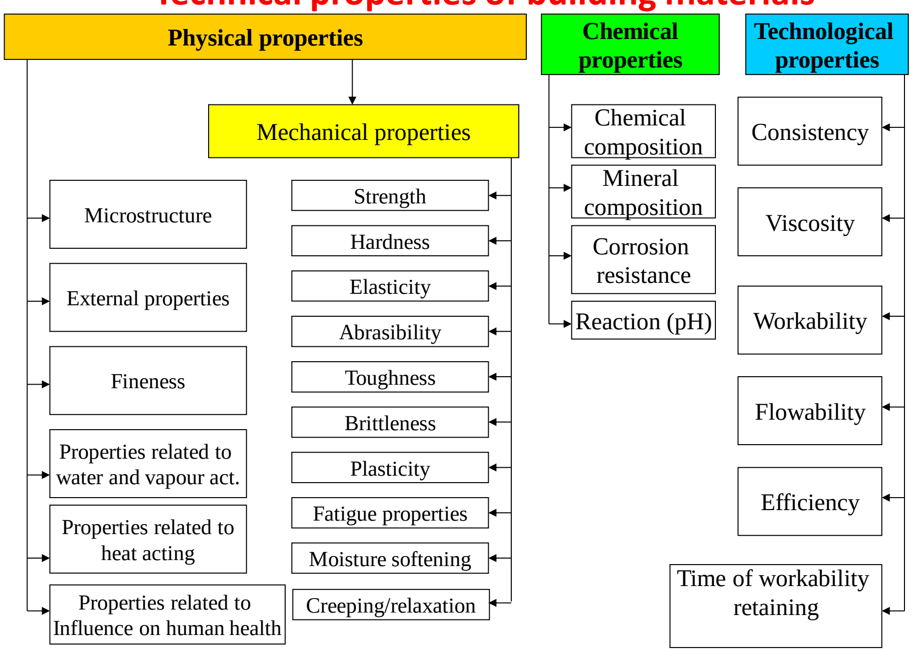
Technical properties of building materials

Material's reaction on different kinds of loads (*or influences*):

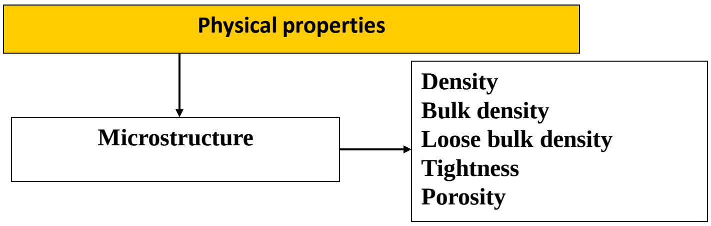
- **physical,**
- **mechanical,**
- **chemical,**
- **biological.**

Material's behavior under different conditions and actions – e.g. mechanical loads, changes and gradients of temperature, freezing water, precipitations, aggressive fluids and vapours.

Technical properties of building materials



Technical properties of building materials



Density

Definition:

Weight of volume unit of material without pores in material

Unit:

[g/cm^3, kg/m^3]

BUILDING MATERIALS ENGINEERING

Bulk density (apparent density)

Definition:

Weight of volume unit of material (including pores). Mass and volume ratio.

Unit:

[g/cm^3]

BUILDING MATERIALS ENGINEERING

Loose bulk density

Definition:

Weight of volume unit of loose poured powder material.

unit:

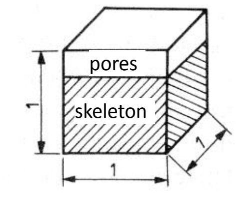
[g/cm^3]

Tightness

Definition:

Ration of bulk density (ρ_p) and density (ρ)

formula: $S_z = \rho_p / \rho \leq 1$



Unitless:

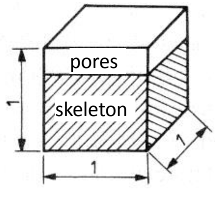
[1]

Porosity (air content)

Definition:

Percent of free space in material (by volume).

Formula: $p = (1 - S_z) \times 100$



Unit:

[%]

Technical properties of building materials

Physical properties

- **Microstructure** → Density; Bulk density; Loose bulk density; Tightness; Porosity
- **External properties** → •Dimensions; •Shape correctness; •Dimensions stability; •Defects
- **Fineness** → •Gradation; •Specific surface

BUILDING MATERIALS ENGINEERING

GRADATION

Definition:

Percentage content of grains of each particular fraction in granular material

Grain, oversize grain, undersize grain

Unit:[%]

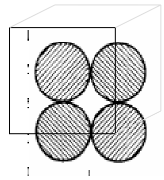
BUILDING MATERIALS ENGINEERING

Specific Surface

definition:

Ratio of surface (sum of particles surfaces) and mass.

Measured for granular materials



Unit:[cm^2/g, m^2/kg,]

Technical Properties of Building Materials

Physical properties

- **Microstructure** → Density, Bulk density, Loose bulk density, Tightness, Porosity
- **External properties** → •Dimensions •Shape correctness •Dimensions stability •Defects
- **Fineness** → •Grading •Specific surface
- **Properties related to water and vapor action** → •Absorptivity •Permeability •Hygroscopic •Capillarity •Vapor permeability •Frost resistance

Absorptivity

Definition:

Capability of material to absorbe water and retain it in the material - maximum water content in volume or weight.

Formulas: $n_{weight} = [(m_n - m_s)/m_s] \times 100$

$n_{volume} = [(m_n - m_s)/(V x \rho_w)] \times 100$

Unit: [%]

$\rho_w = 1\ g/cm^3$

Humidity (moisture content)

Definition:

Momentary water (liquid or vapor) content in the material

Formula: $w = [(m_w - m_s)/m_s] \times 100$

Unit: [%]

Permeability

definition:

Material capability to be infiltrate by the specific water pressure

Unit: [no permeability under specified pressure (1),

velocity (cm/s),

depth of penetration (mm)]

Permeability

Bituminous hydroinsulation products

Asphalt materials	Permeability not allowed under pressure of	
	Water column of height [cm]	during [h]
Asphalt coating emulsion	50	24
Roofing paper felt	50-100	100
Roofing fabric felt	100	150
Roofing aluminum foil felt	150	120

Hygroscopic

definition:

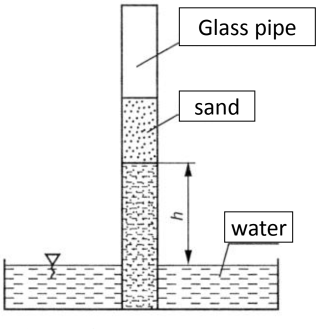
Capability of material to absorb moisture from the surrounding air.

Unit: [%]

Capillarity

definition:

Ability of material to draw water along capillars.



Formula: K = h / t

unit: [m/s]

Frost resistance

Definition:

Resistance to destruction in water saturated material subjected for the cyclic freezing and thawing action.

Unit: [# of cycles]

BUILDING MATERIALS ENGINEERING

Physical properties

Physical properties, cont.

Properties related to heat action

- **Heat capacity**
- **Heat conductivity**
- **Thermal expansion**
- **Fireproofness**
- **Fire resistance**
- **Combustibility**

BUILDING MATERIALS ENGINEERING

Heat Capacity

Definition:

ability of a material to store heat as it changes its temperature

formula: $Q = c \cdot m \cdot (t_1 - t_2)$

$Q = dQ/dt$

where: c – specific heat of material

unit: [J]

Specific heat (c)

for selected building materials

material	Specific heat [kJ/kg·K]
Water	4,18
Air	1,0
Wood	2,4 ÷ 2,7
Ceramic, concrete	0,75 ÷ 0,92
Aluminium	0,92
Steel	0,46
Glass	0,72
Polyethene	2,3
Polyamide	1,67

Heat (thermal) conductivity

Definition:

Ability of material to transmit heat,

-property depends on the temperature gradient between opposite surfaces of material

Unit: [W/(m·K)]

Coefficient of Thermal Conduction (λ)

Definition:

Density of heat stream passing by thru the layer of material [W/m^2], when temperature change (Δt) on the thickness of material (d) is 1K/m

Unit: [W/(m·K)]

Coefficient of thermal conduction (λ)

Material	λ for dry material [W/(m·K]
Styrofoam	0,037 ÷ 0,045
Fiberboard	0,058 ÷ 0,069
Pine wood	0,163 ÷ 0,300
Cellular concrete	0,140 ÷ 0,275
Brick wall	0,756
Glass	0,95 ÷ 1,05
Normal concrete	1,22 ÷ 1,50
Granite	3,20 ÷ 3,50
Steel	58,00

BUILDING MATERIALS ENGINEERING

Thermal expantion

definition:

Changes in material dimensions along with temperature changes

formula: $\alpha = \Delta l / l \cdot \Delta t$

Unit: [1/^{o}C]

BUILDING MATERIALS ENGINEERING

Coefficient of linear thermal expansion (α)

Material	α [1/°C]
Stone, ceramic and wood along the grain	$(0,3 \div 0,9) \cdot 10^{-5}$
glass	$(0,87 \div 0,9) \cdot 10^{-5}$
Cement concrete and steel	$(1,0 \div 1,1) \cdot 10^{-5}$
Aluminum	$2,4 \cdot 10^{-5}$

Fireproofness

definition:

Material's ability to resist (not change shape and not change major properties) a long term high temperature influence.

Unit: [classes: depends on temperature]

Fireproofness

Clasification:

- <u>fireproof material</u>,

  stabile in temperature > 1580°C (e.g. fireclay),

- <u>hardly fusible material</u> ,

  stabile in temperature 1350 ÷ 1580°C,

- <u>easily fusible material,</u>

  not stabile in temperature > 1350°C,

Fire resistance

Definition:

No destruction of material during fire: measured in classes related to the time in which material could resist destructive influence of fire

Fire

Uncontrolled process of fire extension

Destructive influence of fire can affect changes of: structure, strength properties, shape etc.

COMBUSTIBILITY

Ability of catching fire and burn

Combustibility is classified on the basis of tests in testing furnace.

Cylindrical specimen placed in furnace with wall temperature of 825°C; signs of combustion has to be observe (increase of temperature in furnace, flame, loose of mass).

COMBUSTIBILITY

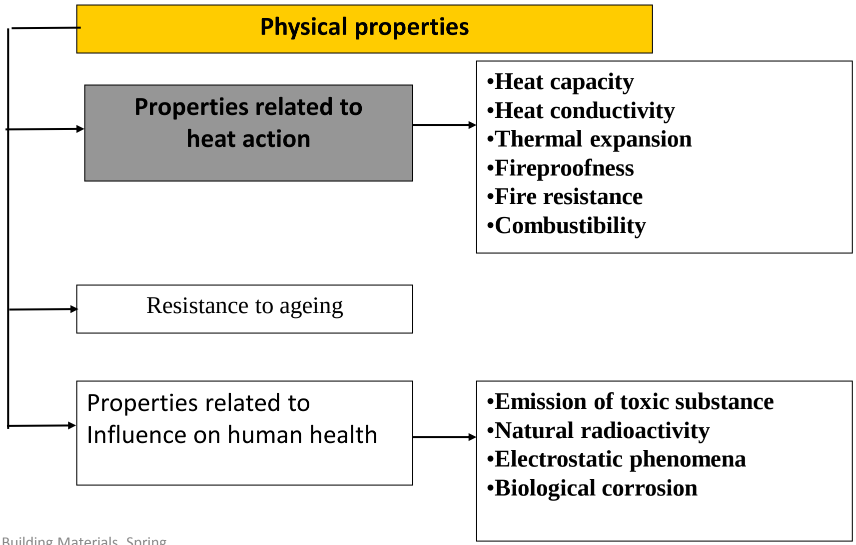
CLASSIFICATION:

Not combustible materials: not burn under flame or high temperature (glass, ceramic, stone) action.

Hardly combustible materials: – burn hardly under flame or high temperature (smolder and carbonization) action. Not support combustion without source of flame (fire protected timber).

Easly combustible materials: - burn easly under flame or high temperature action. Support burning without external source of flame (wood).

Physical Properties of Building Materials



Natural Radioactivity

Content of radioactive elements

S_K = concentration of potassium ^{40}K;

S_{Ra} = concentration of radium ^{226}Ra;

S_{Th} = concentrations of thor ^{232}Th;

1 Bequerel: one self induce nuclear change in isotop during one second time period

Unit: Bq/kg (Bequerels/kg)

BUILDING MATERIALS ENGINEERING

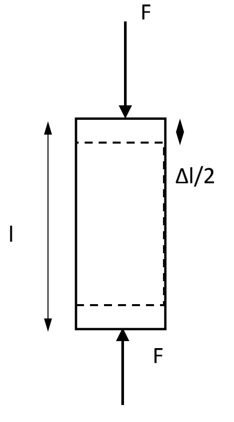
MECHANICAL PROPERTIES

MECHANICAL PROPERTIES

<u>Strength</u>

- **Compressive**
- **Tensile**
- **Bending**
- **Shearing**
- **Torsional**

Strength



Definition:

Materials ability to resist strains

$\varepsilon = \Delta l / l$

Formula: $\sigma = F/A$

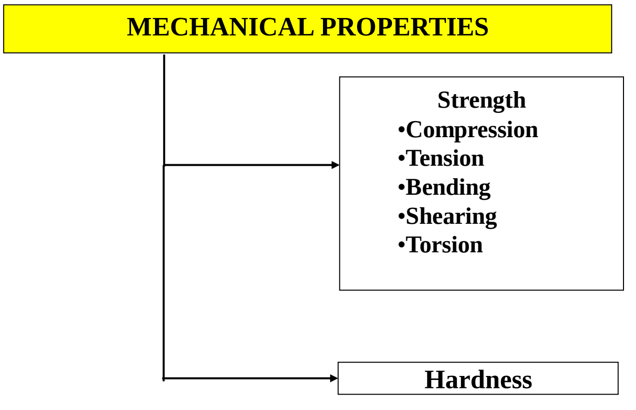
Unit: [Pa= N/m^2]

Unit: [MPa = N/mm^2] what is psi?

Strenght

Material	Compressive strength [MPa]	Tensile strength [MPa]
Granite	**120-280**	**10-20**
Steel	**320-900**	**320-900**
Glass	**350-1000**	**10-80**
Timber (┴ or ‖)	**40-80**	**70-150**
Ceramic	**5-35**	**0,2-2**
Regular concrete	**10-60**	**0,9-6**
Iron cast	**600-1000**	**140-180**

Mechanical properties

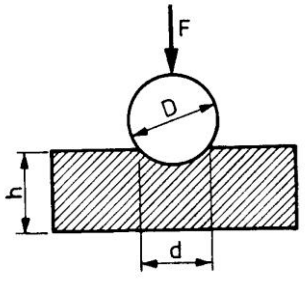


BUILDING MATERIALS ENGINEERING

Hardness

Definition:

Materials resistance to resist residual strains under focused force acting on its surface



HARDNESS Test methods

- Mohs (rocks)
- Janki (wood)
- Rockwell (steel)
- Brinell (steel, plastics)
- Shore (rubber)
- Vickersa (glass)

BUILDING MATERIALS ENGINEERING

HARDNESS

Mohs' scale

Scratching material surface pieces of minerals with kı establishing which one leaves (l — talc, 2 — gypsum, 3 - calcite,

4 — fluorite, 5 — apatite, 6 — orthoclase,

7 — quartz, 8 — topaz, 9 — corundum,

10 — diamond)

- 1, 2: nail,
- 3, 4: coin (copper),
- 5, 6: steel,
- 7: glass

Friedrich Mohs, 1773-1839

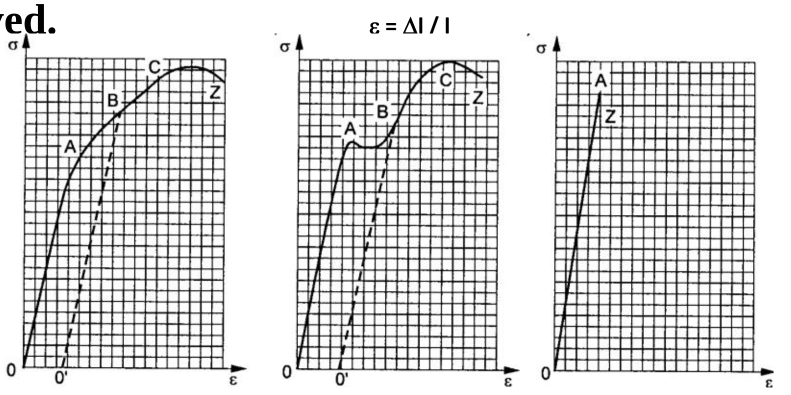
MECHANICAL PROPERTIES

MECHANICAL PROPERTIES

- Strength
  - •Compression
  - •Tension
  - •Bending
  - •Shearing
  - •Torsion
- Hardness
- **Elasticity**

Elasticity

Material ability to deform under stress and return to its original shape when the stress is removed.



Aluminum **Steel** **Glass**

BUILDING MATERIALS ENGINEERING

Elasticity

Material's elasticity is described by mo

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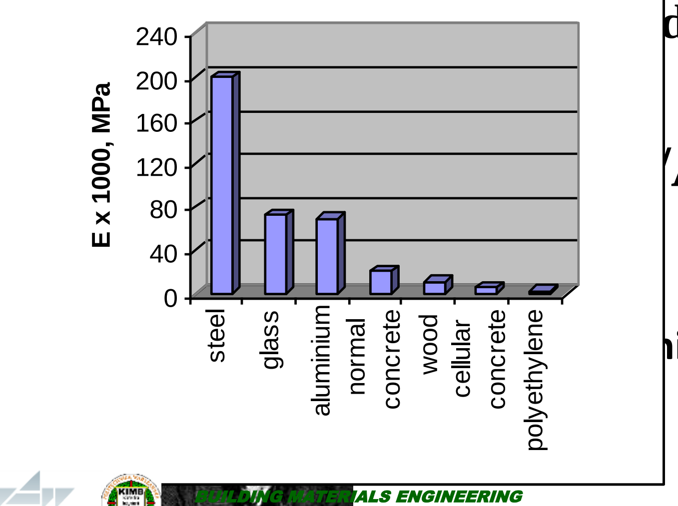
(E)

/A,

it: MPa



Thomas Y

1773-182

BUILDING MATERIALS ENGINEERING

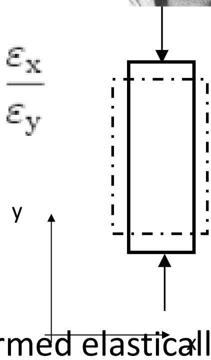
Mr. Simeon Poisson, 1781-1840 =>1811

Poisson's ratio

•Ratio of lateral strain (transverse or normal to axial direction) to axial strain;

•$\varepsilon = \Delta l / l$

$$\nu = -\frac{\varepsilon_{\text{trans}}}{\varepsilon_{\text{axial}}} = -\frac{\varepsilon_x}{\varepsilon_y}$$

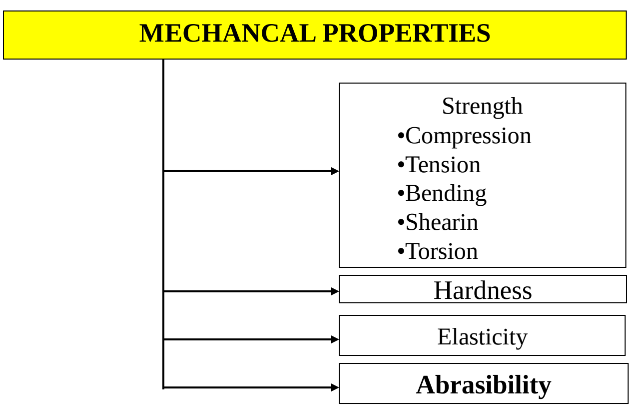


- Cork: close to 0.0
- Most steels: around 0.3
- Rubber: almost 0.5

- A perfectly incompressible material deformed elastically at small strains would have a Poisson's ratio of exactly 0.5

BUILDING MATERIALS ENGINEERING

MECHANICAL PROPERTIES



Abrasibility (Grindability)

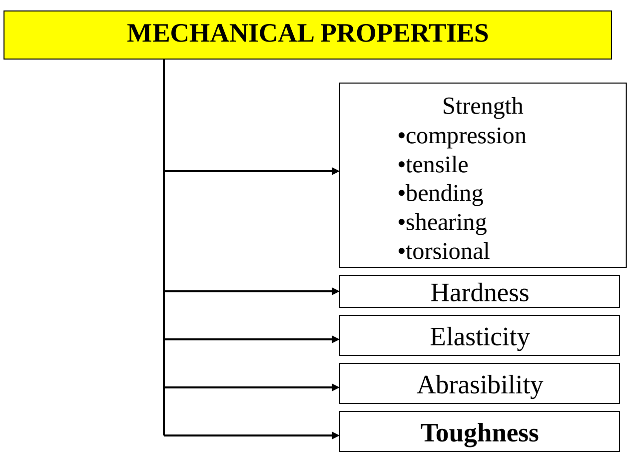
definition:

Material's behavior to resist destructive influence of abrasive forces

Unit: [cm, g, cm^3]

BUILDING MATERIALS ENGINEERING

MECHANICAL PROPERTIES

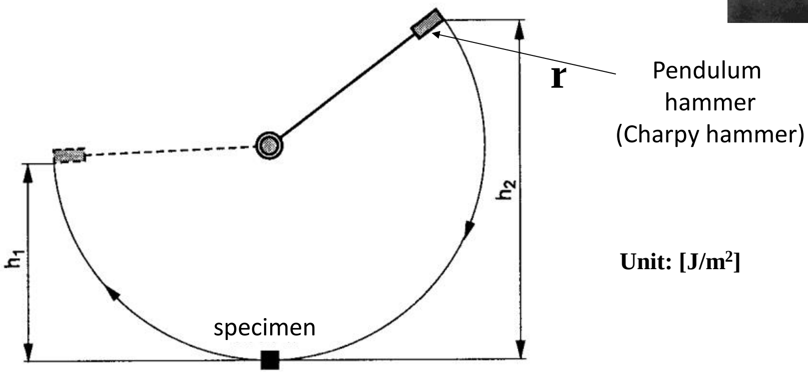


Toughness

Georges Charpy

1865-1945

definition:



Unit: [J/m^2]

(energy to break specimen to specime's cross section)

BUILDING MATERIALS ENGINEERING

MECHANICAL PROPERTIES

MECHANICAL PROPERTIES

- Strength
  - •compression
  - •tensile
  - •bending
  - •shearing
  - •torsional
- Hardness
- Elasticity
- Abrasibility
- Toughness
- **Brittleness**

Brittleness

Definition:

Tensile strength (R_r, f_t) and compressive strength ratio (R_c, f_c).

Formula: $k = f_r/f_c$

Unit: [1]

Brittle material: $k \leq \frac{1}{8} (k \leq 0{,}125)$

MECHANICAL PROPERTIES

MECHANICAL PROPERTIES

- **Strength**
  - •compression
  - •tensile
  - •bending
  - •shearing
  - •torsional
- Hardness
- Elasticity
- Abrasibility
- Toughness
- Brittleness
- **Plasticity**

PLASTICITY

Definition:

property of a material to undergo permanent deformation without loosing cohesion.

Clay, metals, asphalts, polymers.

MECHANICAL PROPERTIES

- **Strength**
  - •compression
  - •tensile
  - •bending
  - •shearing
  - •torsional
- Hardness
- Elasticity
- Abrasibility
- Toughness
- Brittleness
- Plasticity
- **Fatigue properties**

BUILDING MATERIALS ENGINEERING

FATIGUE of MATERIAL

progressive and permanent structural damage

that occurs when material is subjected to a cyclic or fluctuating strains

(strains corresponding to the nominal stresses)

nominal stresses have maximum values less than the static yield strength of the material

MECHANICAL PROPERTIES

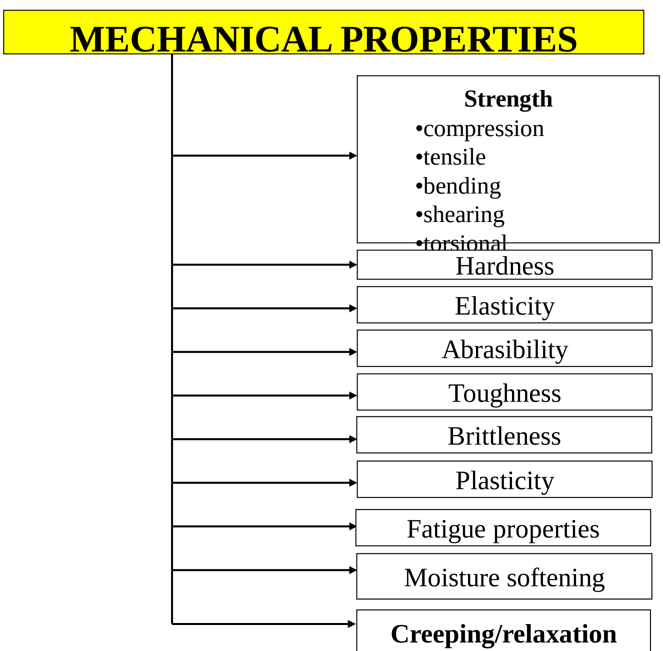
- **Strength**
  - •compression
  - •tensile
  - •bending
  - •shearing
  - •torsional
- Hardness
- Elasticity
- Abrasibility
- Toughness
- Brittleness
- Plasticity
- Fatigue properties
- **Moisture softening**

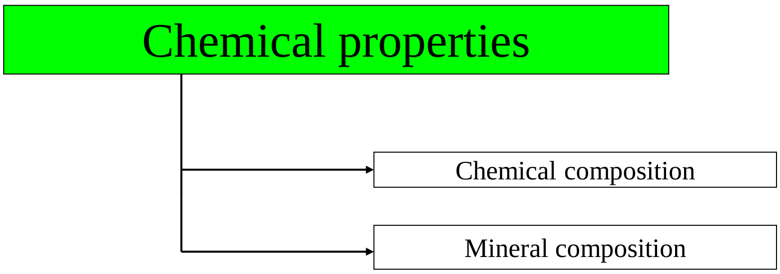
MOISTURE SOFTENING COEFFICIENT

Definition:

Ratio of material compressive strength measured for dry and water saturated specimens.

Unit: [1]





CHEMICAL COMPOSITION

Elements or oxide content in material.

Example: chemical composition of Portland clinker

elemental[%]	oxides [%]
Ca 44 ÷ 49	CaO 62 ÷ 68
O 30 ÷ 38	SiO_2 18 ÷ 25
Si 8 ÷ 12	$A1_20_3$ 4 ÷ 8
Al 2 ÷ 4	Fe_20_3 2 ÷ 4
Fe 1 ÷ 3	
	others:
Others: up to 7	MgO 0,5 ÷ 6
	SO_3 0,8 ÷ 3
	Na_2O +K_2O 0,4 ÷ 3

BUILDING MATERIALS ENGINEERING

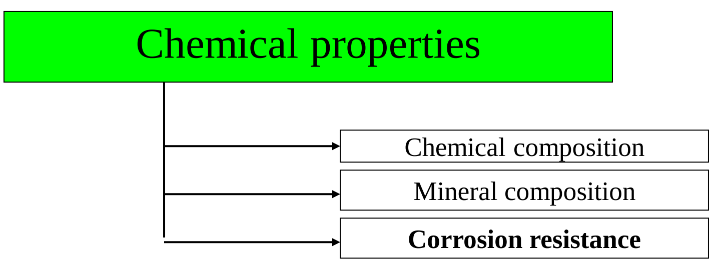
MINERAL COMPOSITION

Polyminerals content in material.

Exmple: mineral composition of Portland clinker

Mineral compounds	content [% by mas.]
$3CaO \cdot SiO_2$ tricalcium silicate (alite)	50-65
$2CaO \cdot SiO_2$ dicalcium silicate (belite)	15-28
$3CaO \cdot A1_2O_3$ tricalcium aluminate	5-15
$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ ferroaluminate (braunmillerite)	5-15
$CaSO_4 \cdot H_2O$ - gypsum or $CaSO_4$ - anhydrite	~5

CHEMICAL PROPERTIES OF BUILDING MATERIALS



Corrosion

Deterioration of essential properties of material due to chemical, physical or chemo-physical reactions in aggressive environment or due to the internal processes in the material (internal corrosion).

Aggressive environment: assembly of external agents which could harmfully influence material structure (and material properties).

Corrosion resistance: material's ability to resist aggressive environment.

BUILDING MATERIALS ENGINEERING

Technological properties

- Consistency
- Viscosity
- Plasticity
- Workability
- Fluidity
- Efficiency
- Time of workability retaining

BUILDING MATERIALS ENGINEERING

Durability: capacity of a product (material), component, system, building or structure to perform the function for which it was designed, for a specified period of time.

Deterioration agents for building materials:

a) External agents

physical, chemical, biological

b) Internal agents

physico-chemical properties of material

c) Indirect agents

defects, errors in: designing, production, construction, application

Durability

a. External agents:

- **physical**: **precipitation, snow, temperature, changes in humidity, frost, pressure and suction of wind, climate,**
- **mechanical**: **static and dynamic loads, vibrations, explosions,**
- **chemical**: **environment,**
- **biological**: **microorganisms (bacteria), moulds, algae, fungus etc.**

Durability

b. Internal agents:

expansion, shrinkage, changes of chemical composition due to interactions of material components

c. Indirect agents:

improper selection of compounds, bad quality of production, improper application.