



# Building Materials

## BM01

### Lecture 1



# Václav Kočí



Department of Materials Engineering and  
Chemistry

<https://k123.fsv.cvut.cz/en/>

E-mail: [vaclav.koci@fsv.cvut.cz](mailto:vaclav.koci@fsv.cvut.cz)

A328 (consultations: upon request individually)



# Building Materials

123BM01

2+2

Lectures

Seminars

*Friday*

08.00(?) – 09.40

A229

*Friday*

10.00 – 11.50

A336



# Information about the course

<https://k123.fsv.cvut.cz/en/building-materials/>

Accessible at:

- <https://www.fsv.cvut.cz/index.php>

Departments → K123 → Department Pages  
(<https://k123.fsv.cvut.cz/en/>)



# Literature

- **Lectures**

- After each lecture on subject page
- Somayaji, S.: Civil engineering materials. 2nd ed. - Prentice Hall, 2001
- Soutsos M., Domone, P.: Construction Materials. Their Nature And Behaviour, Taylor & Francis Group; 2017, ISBN 9781498741101.
- Haimei Zhang: Building Materials in Civil Engineering. Woodhead Publishing 2011, ISBN 978-1-84569-955-0

- **Seminars:**

- <https://k123.fsv.cvut.cz/en/building-materials/>

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# Building materials



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# Building material?





# Building Material

- any material which is used for a construction purposes







# Classification of the materials

- **according the chemical composition**
  - **organic** (carbon as the basic element: timber , plastics, asphalt, bitumen, plastics etc.)
  - **inorganic** (siliceous materials (silica), calcareous materials (calcium compounds), argillaceous materials (e.g. clay), metals (elements - iron, copper, and alloys)
- **according occurrence:**
  - **naturally occurring** - stones, timber, some metals
  - **manufactured materials** - plastics, concrete, mortars





# Classification of the materials

- according their use:
  - **basic building materials (blocks)** - stones, bricks
  - **binding materials** - cement (silicaceous), lime (calcareous), clay (argillaceous), bitumen (organic)
  - **finishing materials** - paint, varnish
  - **insulating materials** - rock wool, glass wool, expanded polymers, asphalt etc.



# Material composition of BM

- Stone and aggregates
- Timber, wood-based materials
- Ceramics and glass
- Lime-based materials
- Calcium sulphate-based materials
- Cementitious materials, concrete
- Metals
- Bitumenous materials
- Plastics
- Other materials



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# Which material ?



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# Materials selection

## 1. Analysis of the problem

- type of construction
- performance required
- required service life
- financial limitations/possibilities, maintenance expense

## 2. Comparison of available materials or products



# Materials selection

**Step 1:** Material specifications - definition of the desired parameters



**knowledge of the properties**

**Step 2:** Comparison and evaluation of available materials



**knowledge of the alternatives**

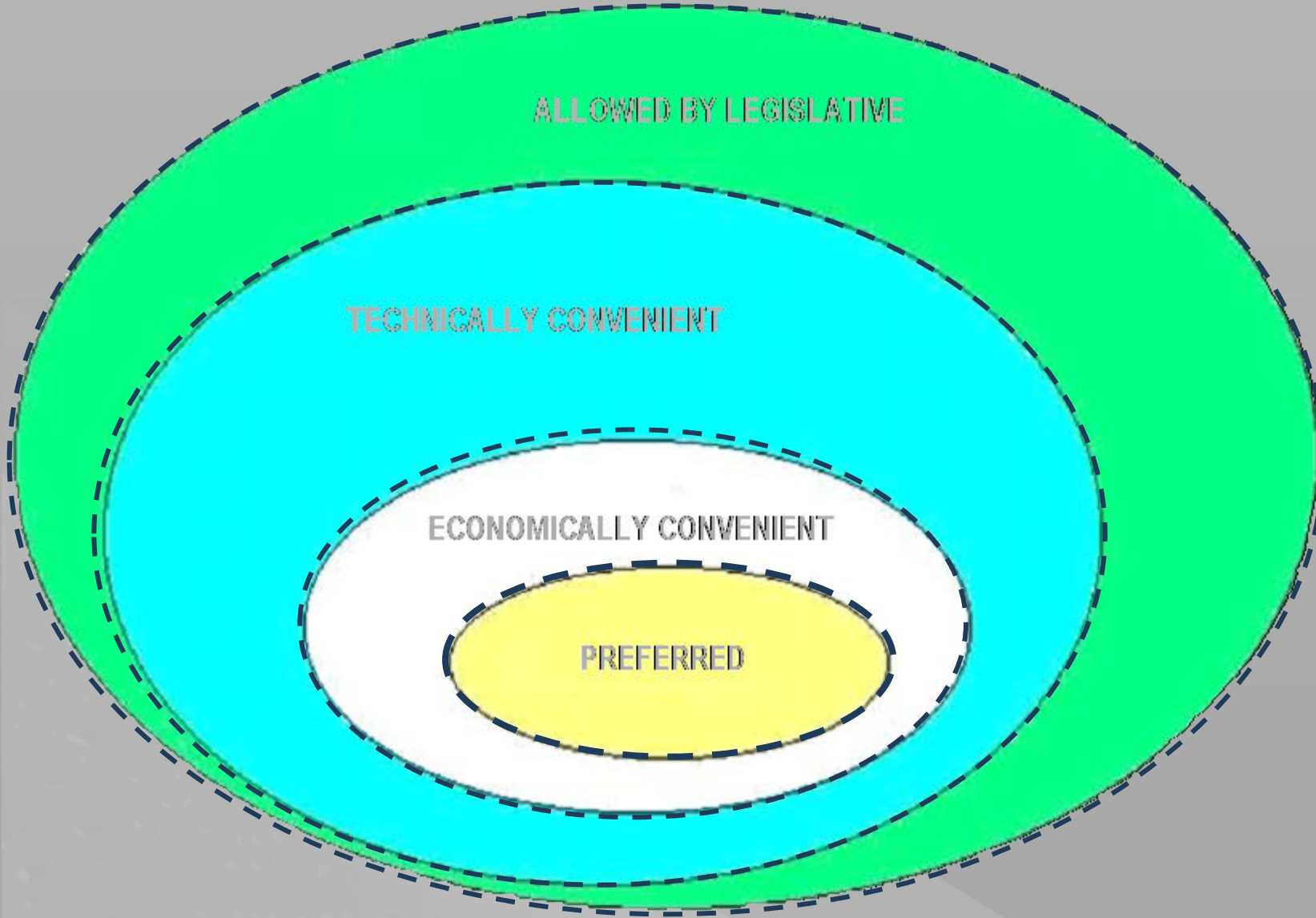


**right choice**





# Materials selection





# Legal requirements

## in EU: Construction Products Regulation (CPR/CPD)

- REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 **laying down harmonised conditions for the marketing of construction products** and repealing Council Directive 89/106/EEC
- **designed to simplify and clarify the existing framework for the placing on the market of construction products**
- **defines 7 essential functional requirements** on the constructions



# Essential functional requirements

The materials and products must satisfy the following essential requirements:

- **mechanical resistance and stability**
- **safety in case of fire**
- **hygiene, health and the environment**
- **safety in use**
- **protection against noise**
- **energy economy and heat retention**
- **sustainable use of natural resources**

for an economically reasonable working life



# 1. Mechanical Resistance and Stability

The construction works must be designed and built in such a way that the loadings that are liable to act on it during its constructions and use will not lead to any of the following:

- collapse of the whole or part of the work
- major deformations to an inadmissible degree
- damage to other parts of the works or to fittings or installed equipment as a result of major deformation of the load-bearing construction
- damage by an event to an extent disproportionate to the original cause



## 2. Safety in case of fire

The construction works must be designed and built in such a way that in the event of an outbreak of fire:

- the load-bearing capacity of the construction can be assumed for a specific period of time
- the generation and spread of fire and smoke within the works are limited
- the spread of fire to neighboring construction works is limited
- occupants can leave the works or be rescued by other means
- the safety of rescue teams is taken into consideration



### 3. Hygiene, health and the environment

The construction work must be designed and built in such a way that it will not be a threat to the hygiene or health of the occupants or neighbours, in particular as a result of any of the following:

- the giving-off of toxic gas
- the emissions of dangerous substances into indoor or outdoor air
- the emission of dangerous radiation
- the release of dangerous substances into ground water, marine waters, surface waters or soil and drinking water
- faulty discharge of waste water, emission of flue gases or faulty disposal of solid or liquid waste
- dampness in parts of the construction works or on surfaces within the construction works



## 4. Safety and accessibility in use

## 5. Protection against noise

The construction works must be designed and built in such a way that:

- they do not present **unacceptable risks of accidents** in service or in operation such as slipping, falling, collision, burns, electrocution, injury from explosion. Accessibility and use for disabled persons has to be taken into consideration.

- **noise** perceived by the occupants or people nearby **is kept** to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions





## 6. Energy economy and heat retention

The construction works and their heating, cooling, lighting and ventilation installations must be designed and built in such a way:

- that the amount of energy they require in use shall be low, when account is taken of the occupants and of the climatic conditions of the location.
- construction works must also be energy-efficient, using as little energy as possible during their construction and dismantling



## 7. Sustainable use of natural resources

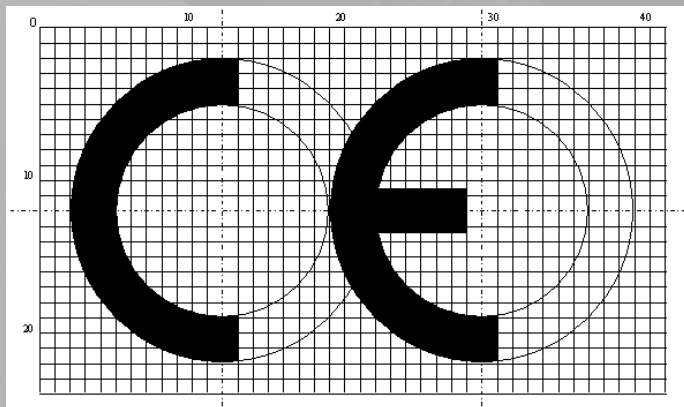
The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

- **reuse or recyclability** of the construction works, their materials and parts after demolition
- **durability** of the construction works
- use of **environmentally compatible** raw and secondary **materials** in the construction works



# The CE marking

- a passport to free circulation.
- not a quality mark, merely a statement that the product complies with the applicable legislation
- it indicates that the product conforms to an harmonized European Standard (hEN) or an European Technical Approval (ETA)

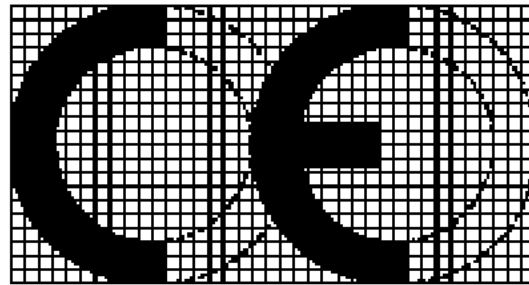






# Example of CE marking

- stone slabs for external paving



**AnyCo Ltd**, P.O. Box 21, B-1050

Year:03

Reference standard : EN 1341 : 2001

Product: Natural stone slabs for external paving  
(pedestrian and vehicular use)

Characteristics:	Declared values
Flexural strength	3,6 MPa
Flexural strength (after frost test)	3,2 MPa
Slip resistance	45
Abrasion resistance	22 mm

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# Materials selection

According to:

1. **experience** (personal, shared)
2. **technical data** (published, standardized)
3. **physical and chemical studies** (relationship between structure and properties) - **materials engineering**



# 1. Experience

## Personal





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# Shared experience



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# Indirect experience

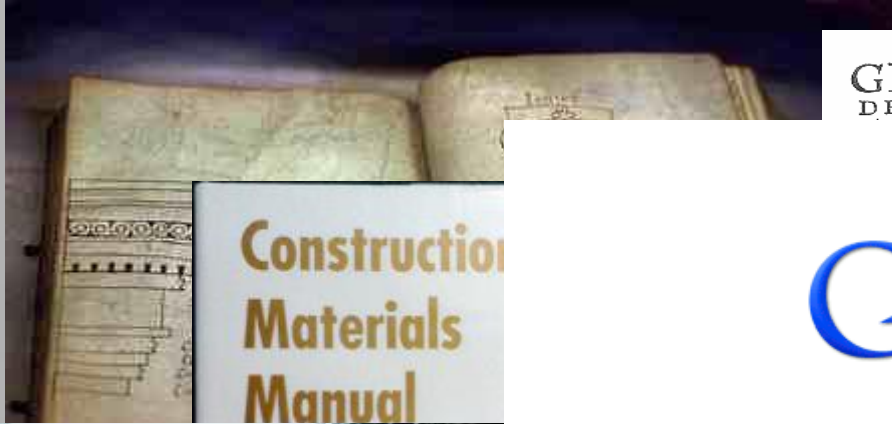


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# 2. Technical data



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Building Materials

WIKIPEDIA The Free Encyclopedia

Building material

From Wikipedia, the free encyclopedia

*For other kinds of building materials, see Household hardware, Biology, and Star formation.*

This article **needs additional citations for verification**. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.

**Building material** is any material which is used for construction purposes. Many naturally occurring substances, such as clay, rocks, sand, and wood, even twigs and leaves, have been used to construct buildings. Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacturing of building materials is an established industry in many countries and the use of these materials is typically segmented into specific speciality trades, such as carpentry, insulation, plumbing, and roofing work. They provide the make-up of habitats and structures including homes.<sup>[1]</sup>

**Contents** [hide]

- The total cost of building materials
  - Economic costs
  - Ecological costs
  - Energy costs
  - Social costs
- Naturally occurring substances
  - Brush
  - Ice and snow
  - Mud and clay
    - Wet-laid clay walls
    - Structural clay blocks and bricks
  - Sand
  - Stone or rock
  - Thatch
  - Wood and timber
- Man-made substances
  - Fired bricks and clay blocks
  - Cement composites
  - Concrete
  - Fabric



Concrete and metal rebar used to build a floor.



Wooden church in Bodružal in Slovakia.





# Technical standards

- a publication that provides **rules, guidelines or characteristics** for activities or their results, for common and repeated use
- **explicit set of requirements to be satisfied by a material, product, or service**
- may be developed by any of various kinds of organizations – international, regional, national (e.g. International Organization for Standardization (ISO), European Committee for Standardization (CEN), British Standards Institution (BSI) )





# European Standard EN

- a standard that has been adopted by one of the three recognized European Standardisation Organisations (ESOs): CEN, CENELEC or ETSI
- produced by all interested parties through a transparent, open and consensus based process
- the European Commission requests the ESOs to develop and adopt European Standards, by means of 'standardisation mandates'. Those European Standards developed in response to a mandate are called **harmonised Standards**



# Types of standards

- terminological
- for testing
- for products
- safety regulations
- quality control



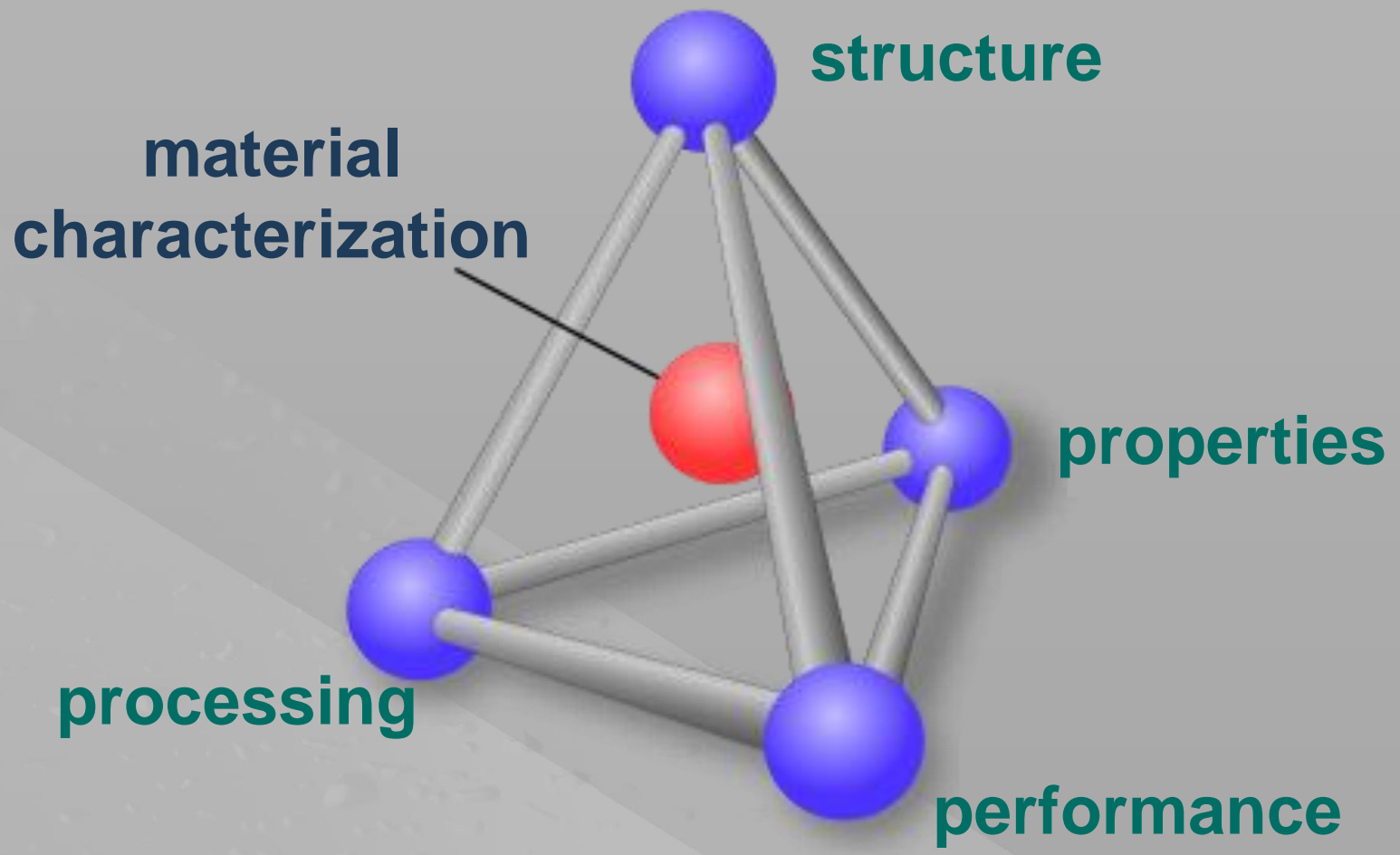


# 3. Materials engineering

- all of the useful **properties** of a material are related to its **structure** (at all levels - which atoms are present, how the atoms are joined, and how groups of atoms are arranged throughout the material)
- this structure and the resulting properties, are controlled by the **processing** of the material



# Materials Engineering



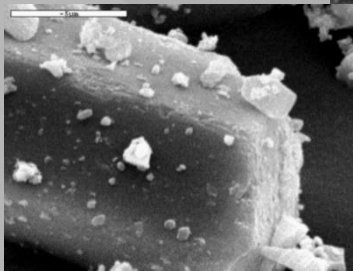


# Materials Engineering

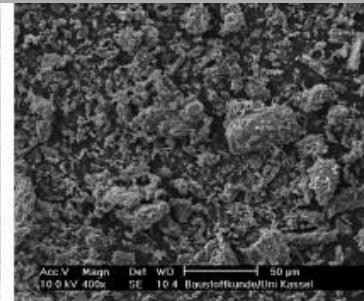
## $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ Gypsum

### $\alpha$ - gypsum

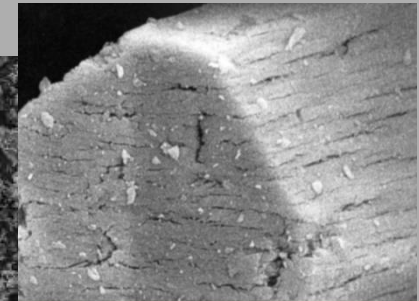
- wet production:
  - 130 °C
  - pressure 0,4 - 0,5 MPa
- structure:



SEM picture of  $\alpha$ -hemihydrate



SEM picture of  $\beta$ -hemihydrate



### properties:

- higher strength
- less mixing water

### $\beta$ - gypsum

- dry production
  - 120 – 180°C

### properties:

- lower strength
- more mixing water

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# Structure & Properties



# Composition of Building Materials

- Practically each **real** material (substance) is a mixture, which consists from components
- Component is constituted by the atoms or molecules (= element or compound)
- Properties of the materials depends on the type, amount and mutual interaction of the components







# State (phase) of materials

- **gaseous**
- **liquid**
- **solid**





# Gases

- **lowest density** ( cca 1000x lower than density of solids and liquids)
- **large distance between molecules**
- **ideal gas law**



$$P \cdot V = n \cdot R \cdot T$$

where  $n \dots$  the amount of substance of gas [mol]

$R \dots$  the ideal gas constant ( $8.314 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$ )

$T \dots$  an absolute temperature [Kelvin]

**Air density  $\cong 1 \text{ kg/m}^3$**



# Liquids

- lower density than solids
- molecules are close, but movable
- able to flow (irreversible deformation)
- mostly miscible  
(=mixable, fully dissolved when mixed)
- non-elastic





# Solids

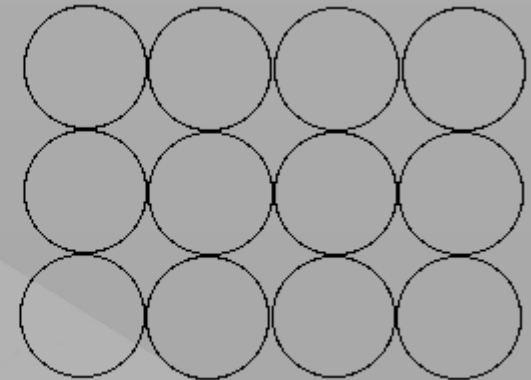
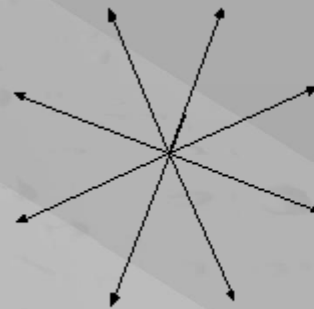
- the particles (ions, atoms or molecules) are closely packed together
- the forces between particles are strong → the particles cannot move freely but can only vibrate
- a solid has a **stable, definite shape**, and a definite volume
- change their shape only by force (breaking, cutting)
  - **isotropic**
  - **anisotropic** (orthotropic)





# Isotropy

- uniformity in all orientation
- from the Greek *iso* (equal) and *tropos* (direction)
- **having identical values of a property in all directions**

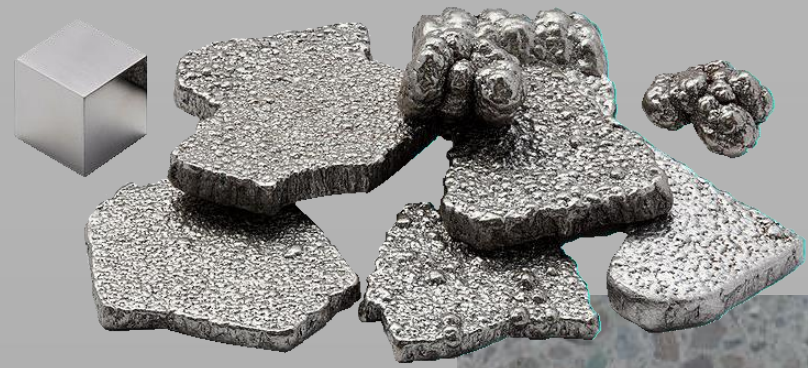


Isotropic



# Isotropic materials

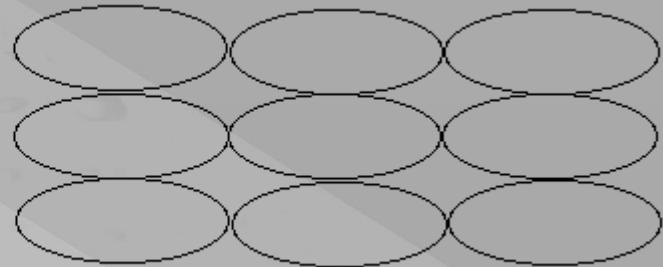
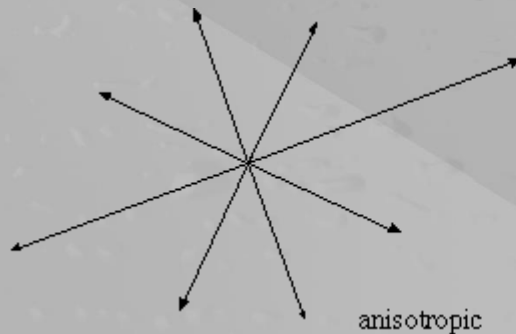
- metals
- concrete
- aerated concrete (AAC)
- polystyrene (EPS)
- ceramic
- rubber





# Anisotropy

- the property of being directionally dependent
- a difference in a material's properties, when measured along different axes
- most materials exhibit anisotropic behavior
- if the different materials properties are in orthogonal directions - **orthotropy**

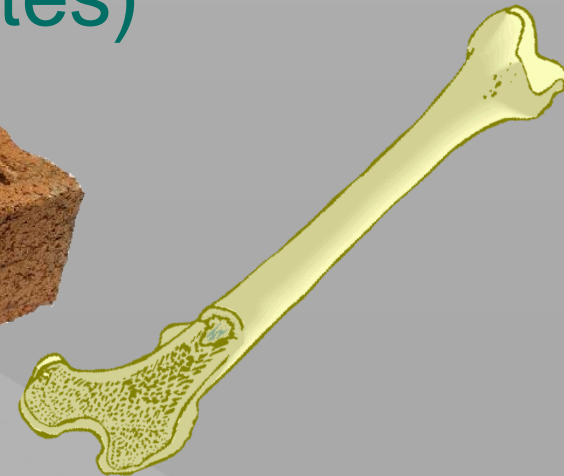
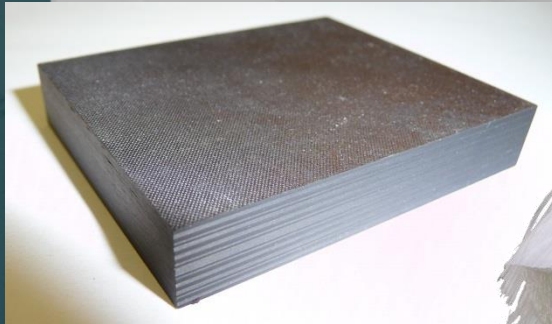






# Anisotropic materials

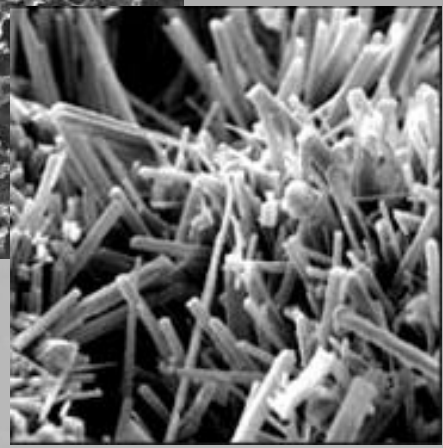
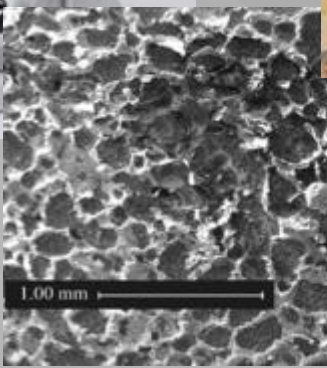
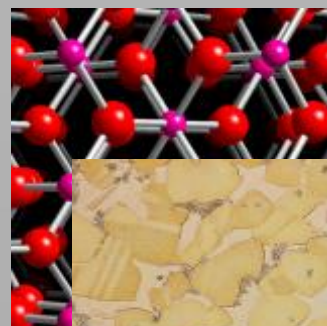
- wood
- wood-based materials
- perforated brick
- bones
- some composites (laminates)





# Structure

- microstructure
- macrostructure





# Structure of solids

- crystal materials



- amorphous mat.



- heterogeneous mat.

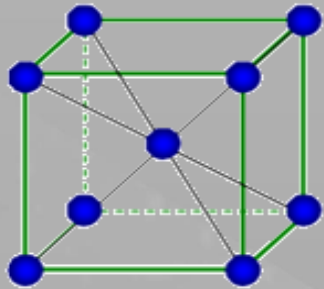


- porous
- granular
- composites

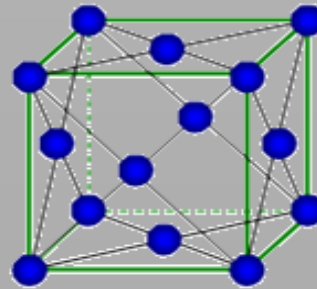


# Crystal materials

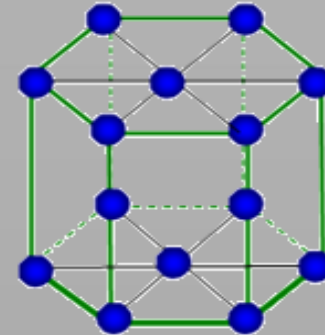
- the atoms are packed in regular, repeating, three-dimensional form
- most energy favorable



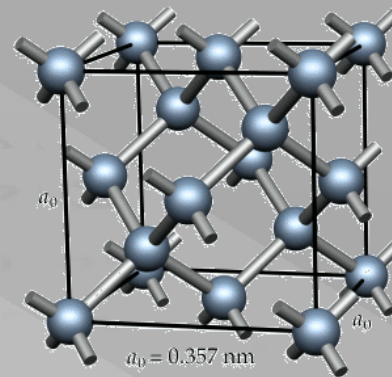
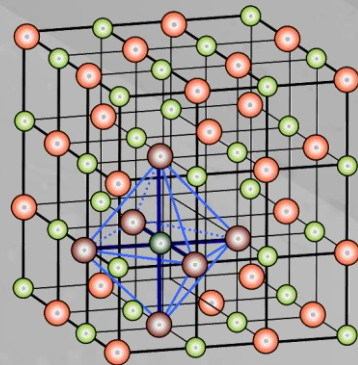
Fe, V, Nb, Cr



Al, Ni, Ag, Cu, Au



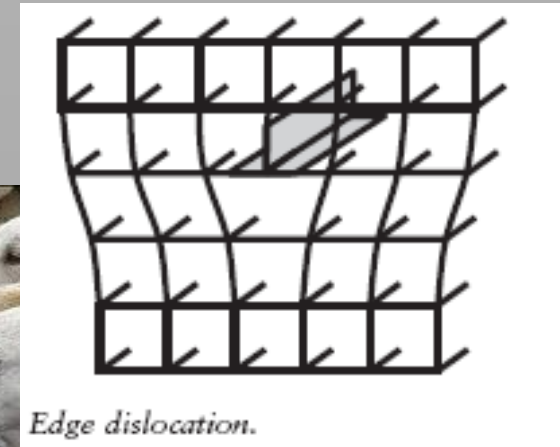
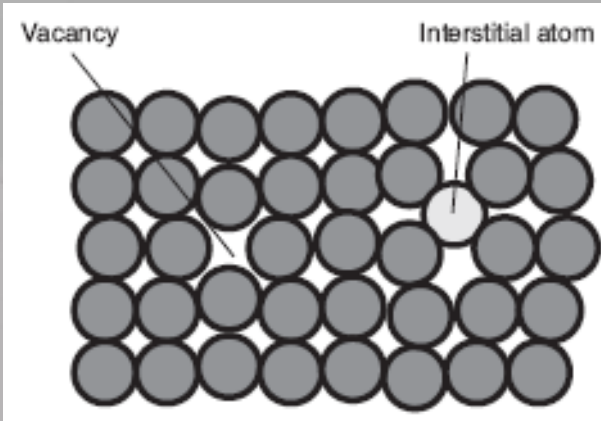
Ti, Zn, Mg, Cd





# Imperfections and impurities

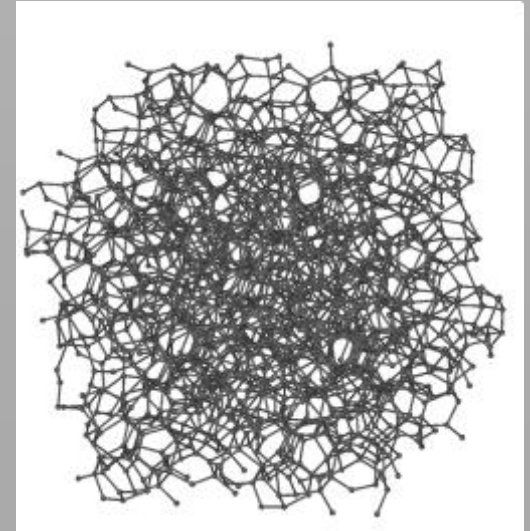
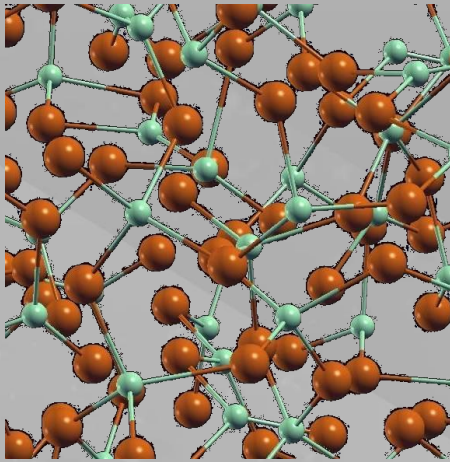
- in practice it is impossible for a perfect and uniform atomic structure to be formed throughout the material
- there will always be a number of imperfections





# Amorphous materials

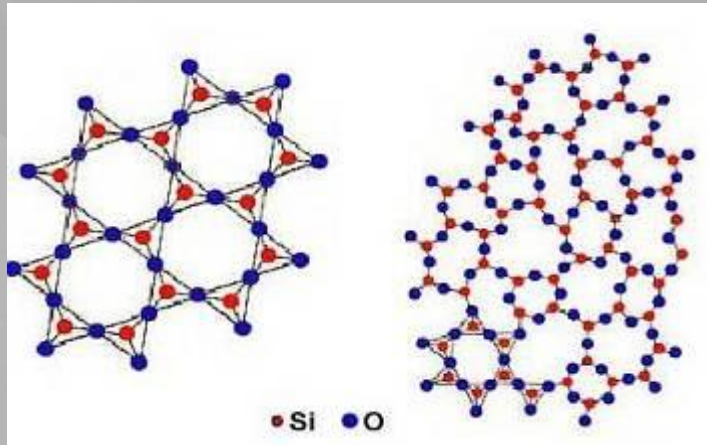
- a solid that lacks the long-range order characteristic of a crystal
- glass, asphalt, wax, resins





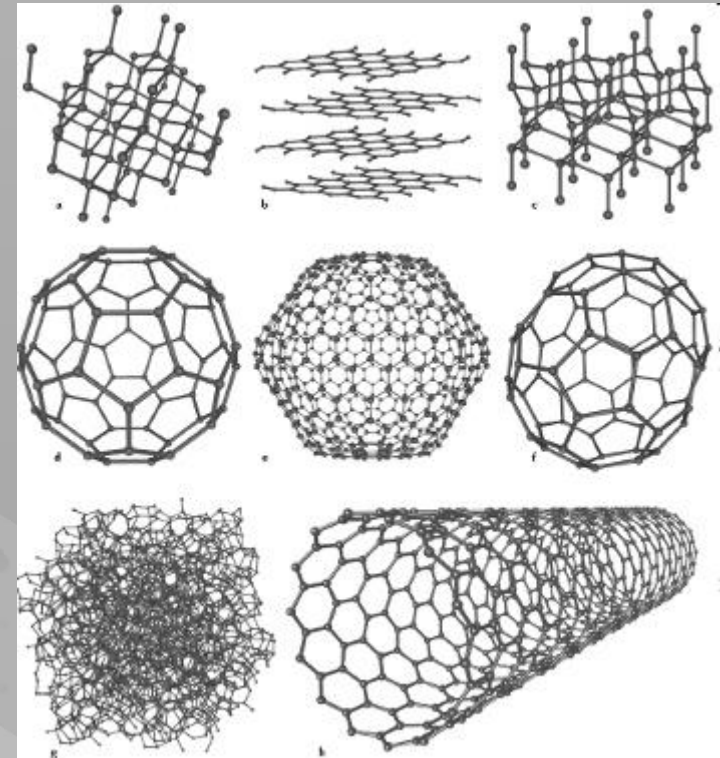
# Amorphous materials

- can crystallize in the course of time
- some substances can have amorphous and crystalline structure (allotropes)



crystal  
 $\text{SiO}_2$  (quartz)

amorphous  
 $\text{SiO}_2$  (glass)





# Heterogeneous materials

- porous materials, granular materials, composites
- **more than one phase**
- **heterogeneity depends on the scale of examination**
- **mostly anisotropic behavior** (can be statistically isotropic)



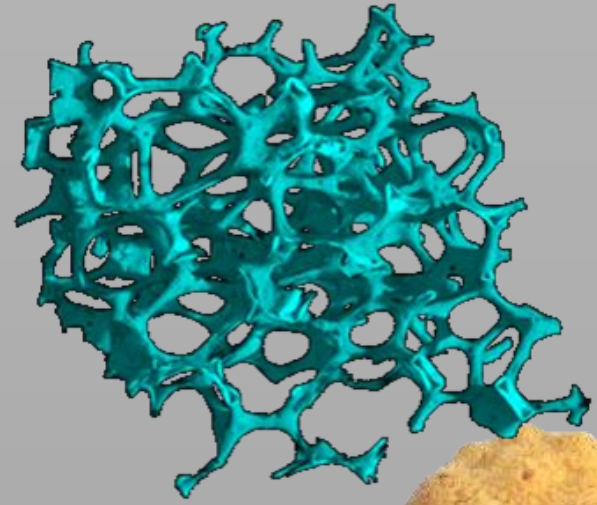


# Porous materials

- closed pores



- open pores





# Granular materials

- a conglomeration of discrete solid, macroscopic particles characterized by a loss of energy whenever the particles interact
- solid phase + voids
- loose





# Composites

- materials made from two or more constituent materials with significantly different properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. The constituents act together **synergically**



SYNERGY  
 $1+1=3$

## Synergy

- the interaction of two or more agents or forces so that their combined effect is greater than the sum of their individual effects.



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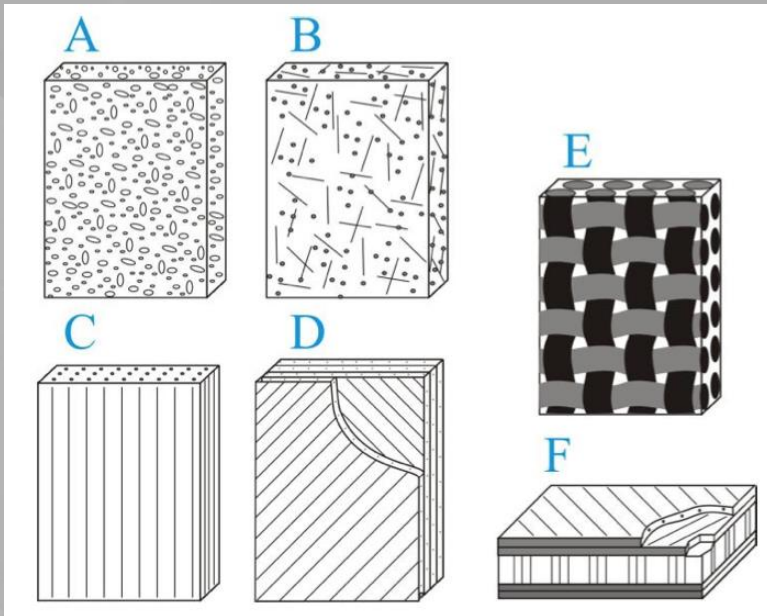


Natural and man-made composites



# Reinforced materials

- reinforcement (strengthening material)
- +  
• binding substance (**MATRIX**)



- A. composites reinforced by particles;
- B. composites reinforced by chopped strands;
- C. unidirectional composites;
- D. laminates;
- E. fabric reinforced plastics;
- F. honeycomb composite structure;



# Reinforced materials

- **particles**
  - filled plastics, concrete
- **short fibers**
  - carbon, glass, metal, natural
- **bars**
  - reinforced concrete
- **continuous fibers, flat layers**
  - laminates, plywood



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# Lectures BM01 - publication

- Each lecture will be published after the performed lecture and will be accessible for one week on the site:

„<https://k123.fsv.cvut.cz/en/building-materials/>“

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