Building materials

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Building Materials

BM01

Lecture 1

Building materials

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Václav Kočí

Department of Materials Engineering and Chemistry

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A328 (consultations: upon request individually)

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123BM01

2+2

Lectures

Friday

08.00(?) – 08.40

A229

Seminars

Friday

10.00 – 11.50

A336

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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/)

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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 material?

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Building Material

- any material which is used for a construction purposes

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Classification of the materials

- **according the chemical composition**
  - **organic** (**carbon** as the basic element: timber , plastics, asphalt, bitumen, plastics etc.)
  - **inorganic** (silicaceous 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

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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
- Cementitous 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 (performance required, useful life required, allowable cost, maintenance expense…)
2. Comparison of available materials or products with the criteria of step 1
3. Design or selection of type of material, size, shape, finish, method of preserving, method of fastening in place

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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

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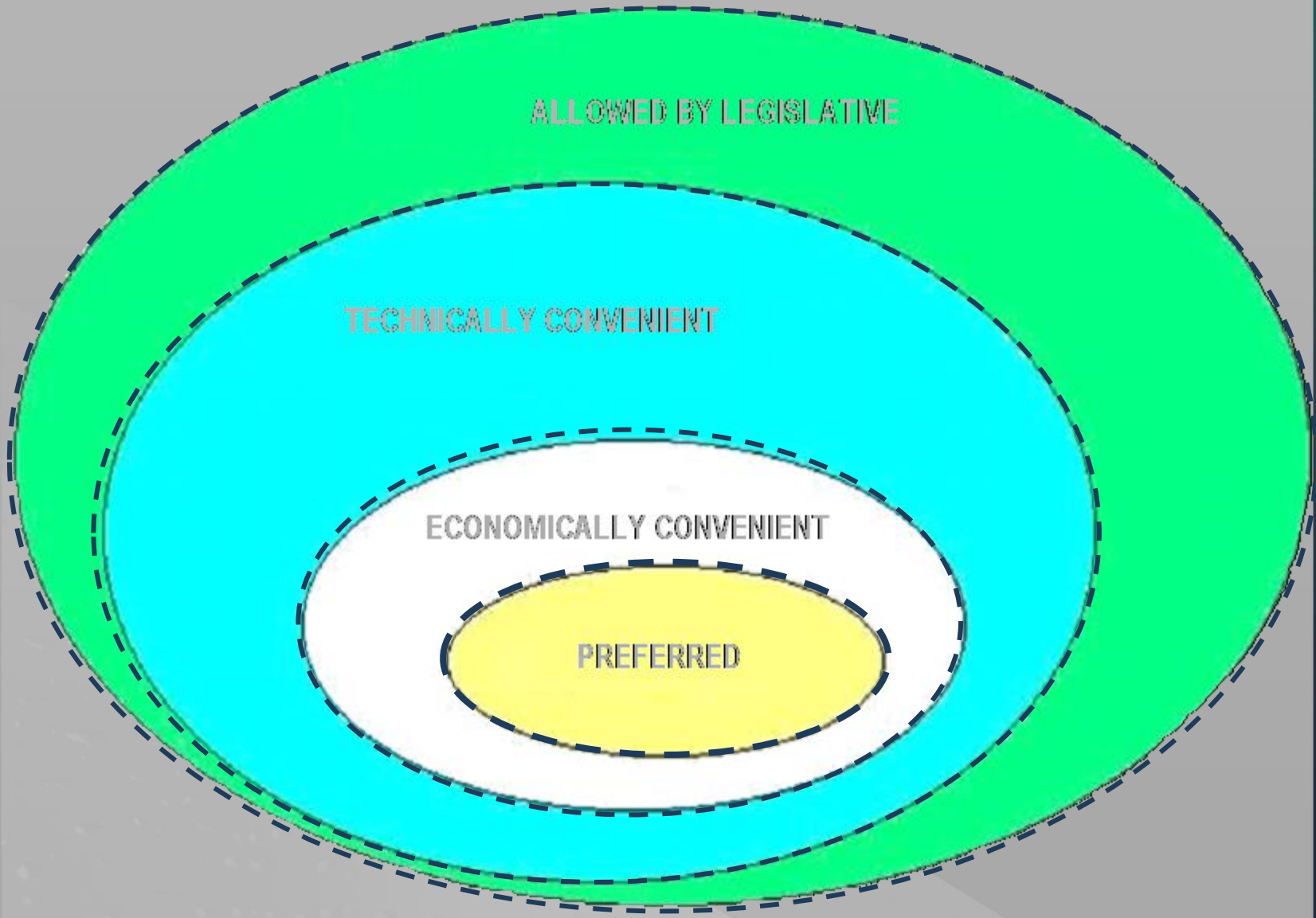
Materials selection



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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

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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

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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

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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

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CPR 305/2011

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

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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

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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

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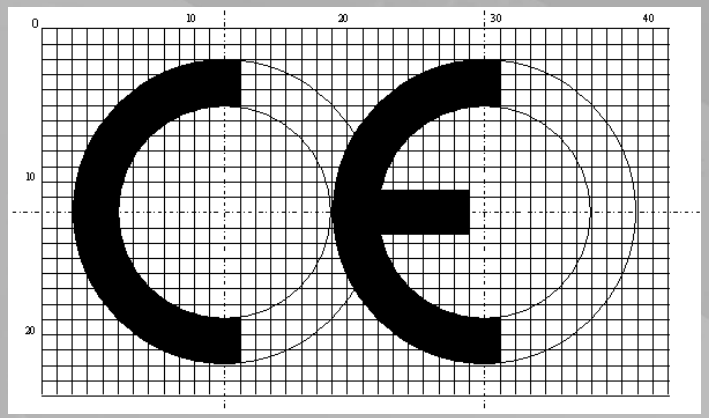
The CE marking

- 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)



https://audiovisual.ec.europa.eu/en/video/I-088654

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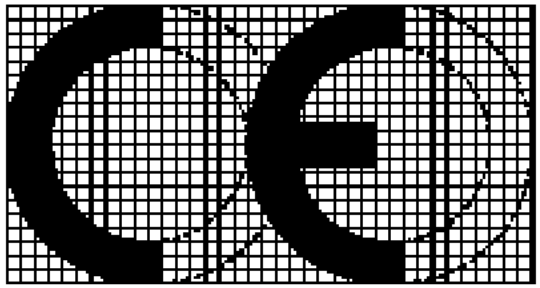
Example of CE marking

- 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**

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1. Experience

Personal

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Shared experience

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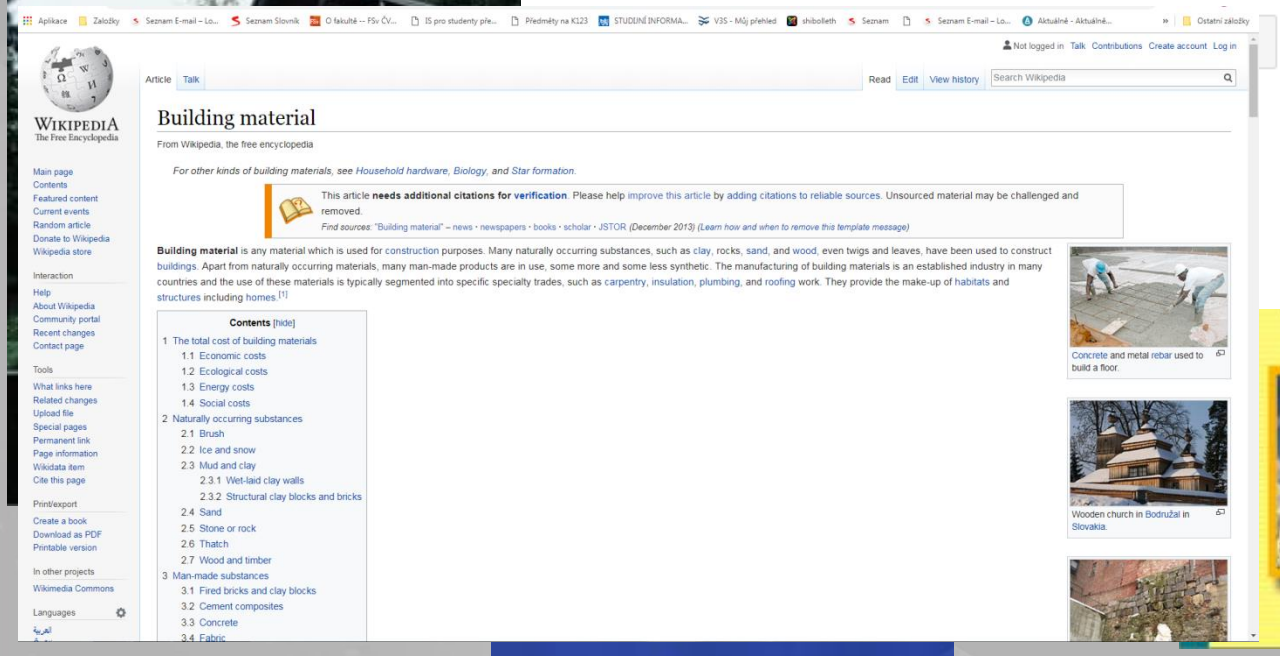
Indirect experience

2. Technical data

Google

Building Materials



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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))

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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**

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Types of standards

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

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Terminological standard

- **EN 12670** Natural stone - Terminology

Scope:

This European Standard **defines the recommended terminology** covering scientific, and technical terms, test methods, products, and the classification of Natural Stones.

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Product standard

- **EN 771- 4:** Specification for masonry units - Part 4: Autoclaved aerated concrete masonry units

Scope:

This European Standard **specifies the characteristics and performance requirements** of autoclaved aerated concrete (AAC) masonry units

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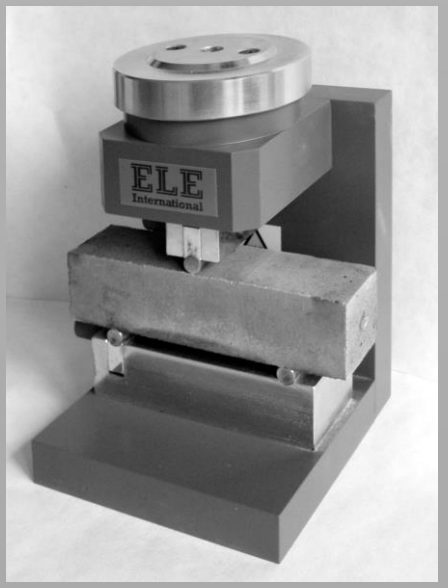
Testing standard

- **EN 196-1** Methods of testing cement - Part 1: Determination of strength



Scope:

This document describes **the method for the determination** of the compressive and, optionally, the flexural strength of cement mortar.

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ČSN 1213

1947

ČSN 1213—1947 691.54:666.94

ČESKOSLOVENSKÁ SPOLEČNOST NORMALISAČNÍ

PRAHA I, DŮM INŽENÝRŮ

ČESKOSLOVENSKÉ NORMY

CEMENT

PORTLANDSKÝ, ŽELEZOPORTLANDSKÝ, VYSOKOPECNÍ A HLINITANOVÝ

II. revidované vydání

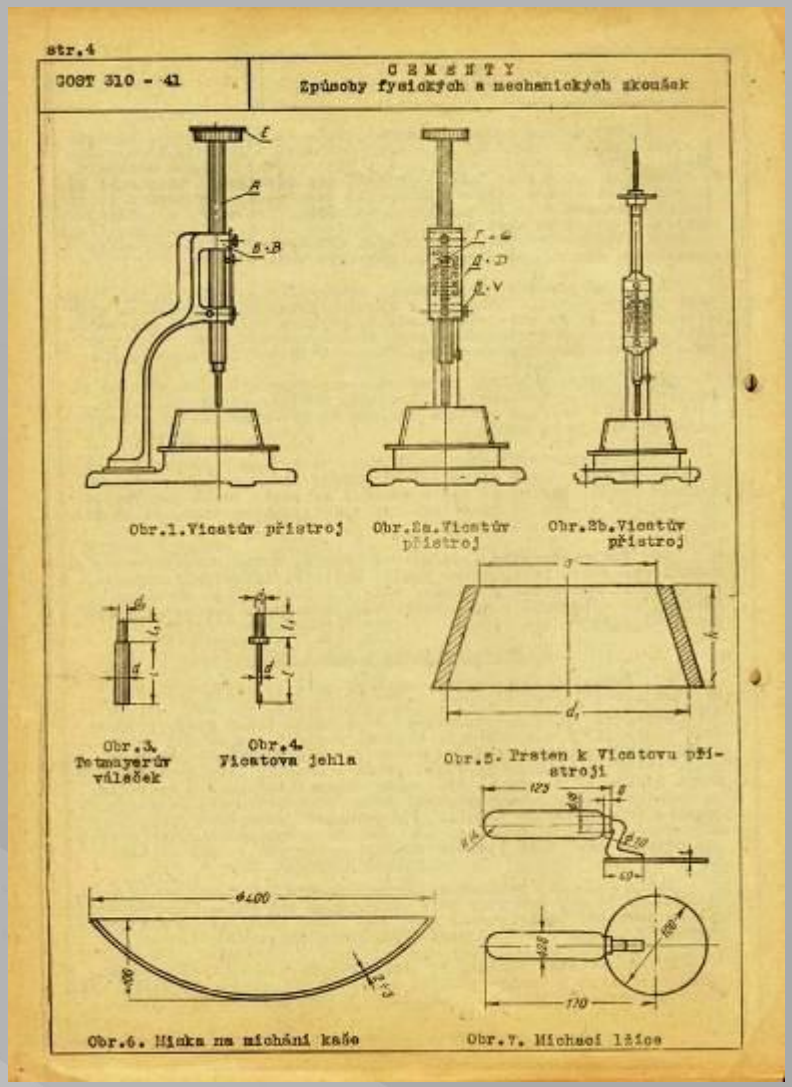
ЦЕМЕНТ

CEMENT • CIMENT

VYDALO PRŮMYSLOVÉ VYDAVATELSTVÍ V PRAZE

Duben 1951

Od 1. 4. 1951 jednotná cena norem, snížená o 50%



str. 4

GOST 310 - 41 | CEMENTY Způsoby fysických a mechanických zkoušek

Obr. 1. Vicatův přístroj

Obr. 2a. Vicatův přístroj

Obr. 2b. Vicatův přístroj

Obr. 3. Tetmayerův váleček

Obr. 4. Vicatova jehla

Obr. 5. Prsten k Vicatovu přístroji

Obr. 6. Mísa na míchání kaše

Obr. 7. Míchací lžíce

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EN 196-3 2017

EUROPEAN STANDARD **EN 196-3**

NORME EUROPÉENNE

EUROPÄISCHE NORM February 2005

ICS 91.100.10 Supersedes EN 196-3:1994

English version

Methods of testing cement - Part 3: Determination of setting times and soundness

Méthodes d'essais des ciments - Partie 3: Détermination des temps de prise et de la stabilité

Prüfverfahren für Zement - Teil 3: Bestimmung der Erstarrungszeiten und der Raumbeständigkeit

This European Standard was approved by CEN on 29 December 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

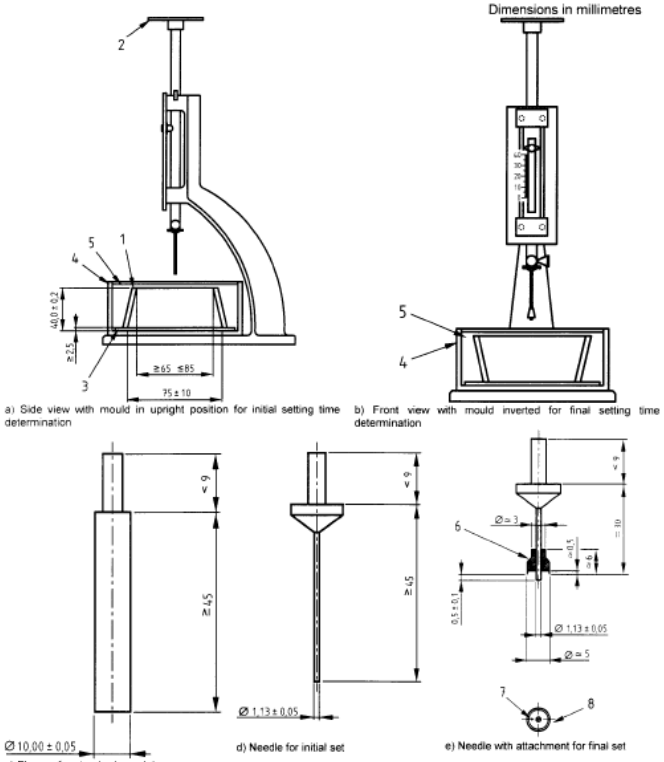
This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Dimensions in millimetres



a) Side view with mould in upright position for initial setting time determination

b) Front view with mould inverted for final setting time determination

c) Plunger for standard consistence

d) Needle for initial set

e) Needle with attachment for final set

Key

1 Mould
2 Correcting weights
3 Base plate
4 Container
5 Water
6 Air vent (Ø ≈ 1,5)
7 Air vent
8 View from below needle with attachment for determining final setting time

Figure 1 – Typical manual Vicat apparatus for detemination of standard consistence and setting time

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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

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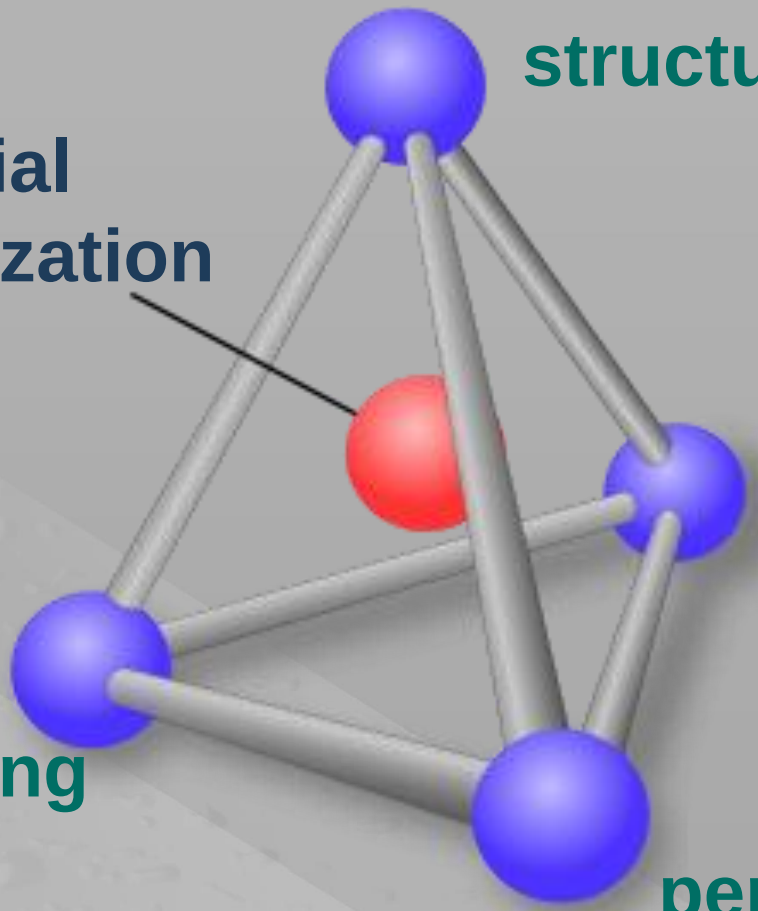
Material Engineering



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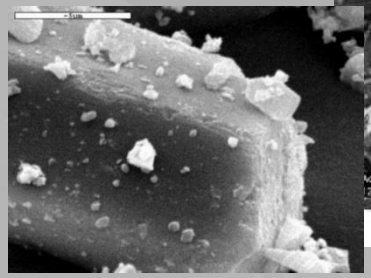
$CaSO_4 \cdot 1/2H_2O$
Gypsum

α- gypsum

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

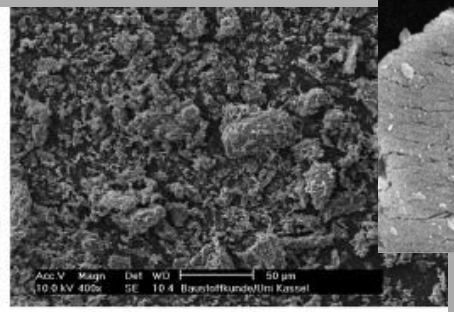


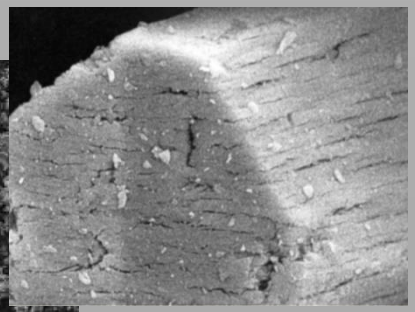
SEM picture of α-hemihydrate

- properties:
  - higher strength
  - less mixing water

β- gypsum

- dry production
  - 120 – 180°C





SEM picture of β-hemihydrate

- properties:
  - lower strength
  - more mixing water

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Building materials

Structure
&
Properties

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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

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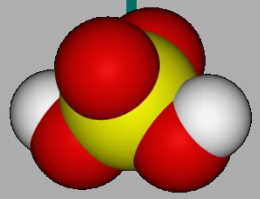
Substance

chemical individual

mixture

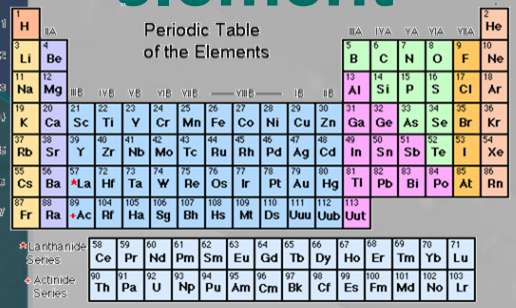
element

compound



heterogenous

homogenous



gaseous mixture

liquid solution

solid solution

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Chemical purity

- the degree to which a substance is undiluted or unmixed with extraneous material, typically expressed as a percentage (%)
- for technical uses the purity 90 % is usually sufficient
- highest achieved purity Si - **99,9999999 %**

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Grades of Chemicals

ACS Grade

• **S**uitable for use in many laboratory and analytical applications

Reagent Grade (R/G)

• Can be used in all scientific areas where quality is critical. Quantitative analysis in QA environments. Research laboratories. Producing primary standards (buffers, volumetric solutions)

Laboratory Grade (L/G)

• Excellent for teaching and educational labs, not pure enough for food, drug or medicinal use. Often used for general lab work where an analytical reagent is not required.

Technical Grade

• Used in low grade applications and/or qualitative testing. Often supplied in bulk for industrial or commercial applications.

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State (phase) of materials

- gaseous
- liquid
- solid

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Gases

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

$$P.V = n . R . T$$

where *n* … the amount of substance of gas [mol]
R … the ideal gas constant (8.314 $J \cdot K^{-1} \cdot mol^{-1}$)
T … an absolute temperature [Kelvin]

Air density ≅ 1 kg/m³

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Liquids

- **lower density than solids**
- **molecules are close, but movable**
- **able to flow** (irreversible deformation)
- **mostly miscible**
- **non-elastic**

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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)

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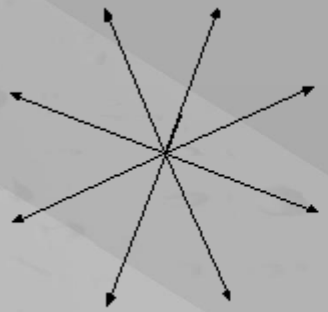
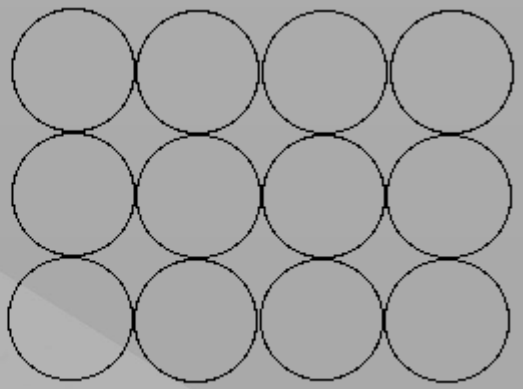
Isotropy

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



Isotropic



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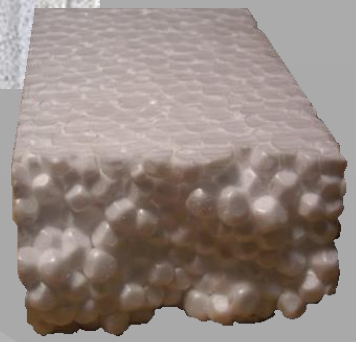
Isotropic materials

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



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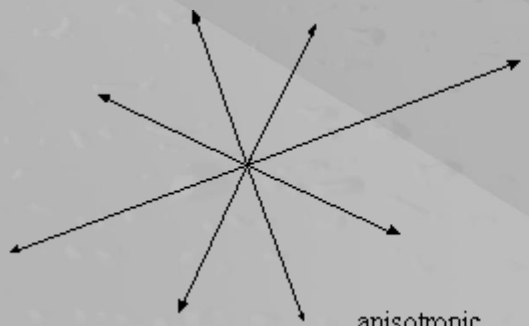
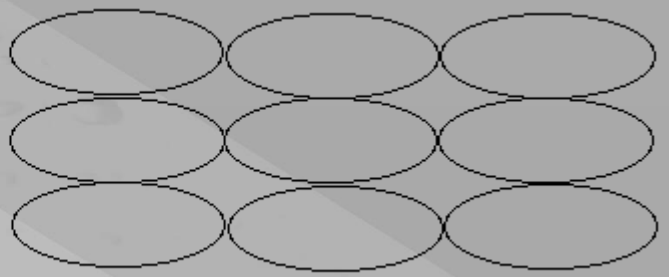
Anisotropy

- **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



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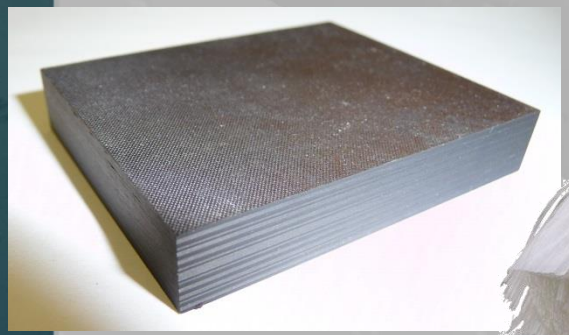
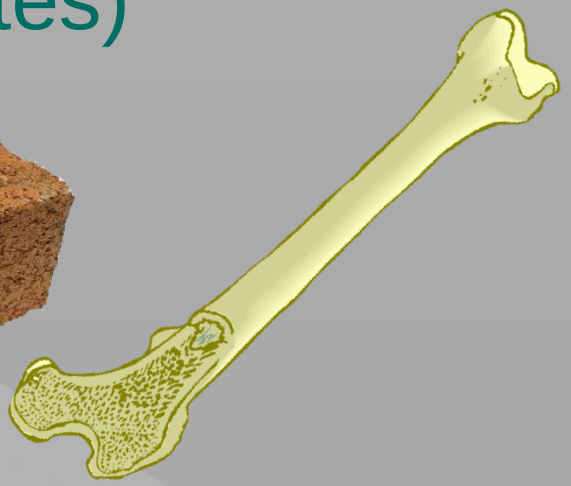
Anisotropic materials

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





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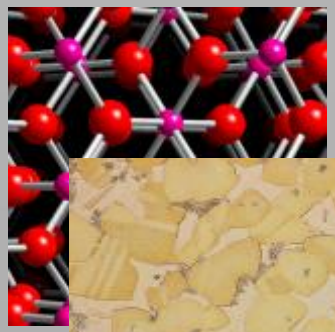
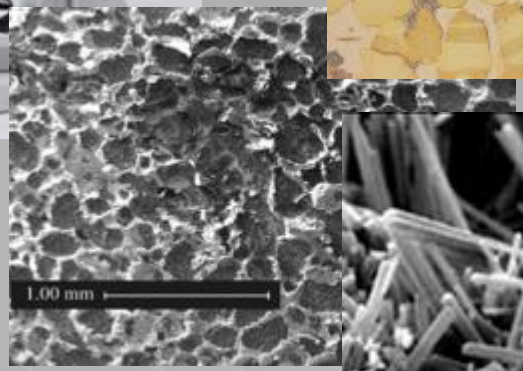
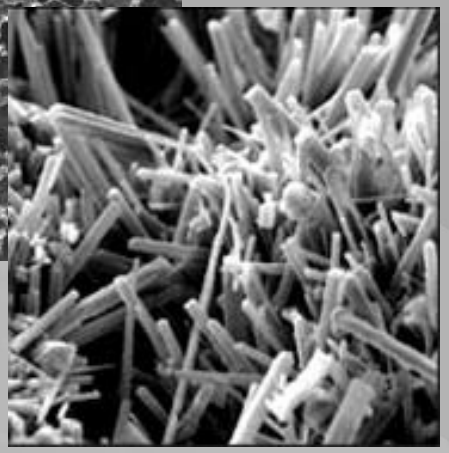
Structure

- microstructure
- macrostrukture







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Structure of solids

- crystal materials

- amorphous mat.

- heterogeneous mat.
  - porous
  - granular
  - composites

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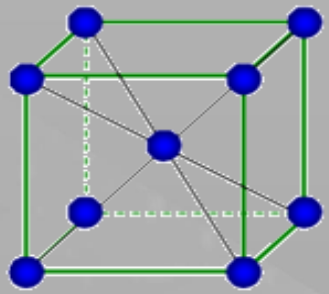
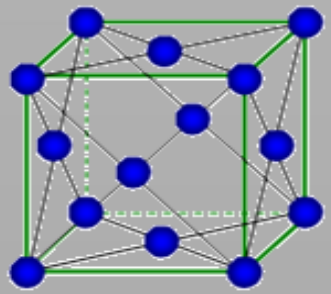
Crystal materials

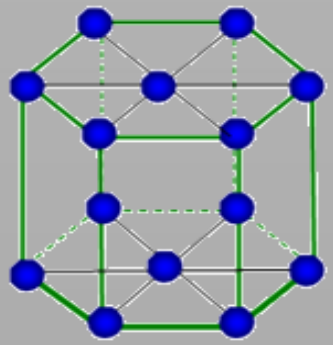
- the atoms are packed in regular, repeating, three-dimensional form
- most energy favorable



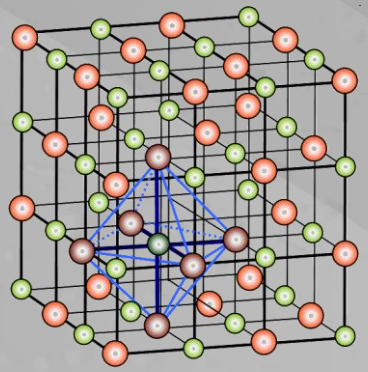
Fe, V, Nb, Cr

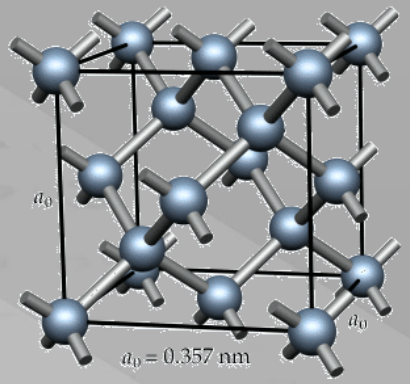


Al, Ni, Ag, Cu, Au



Ti, Zn, Mg, Cd





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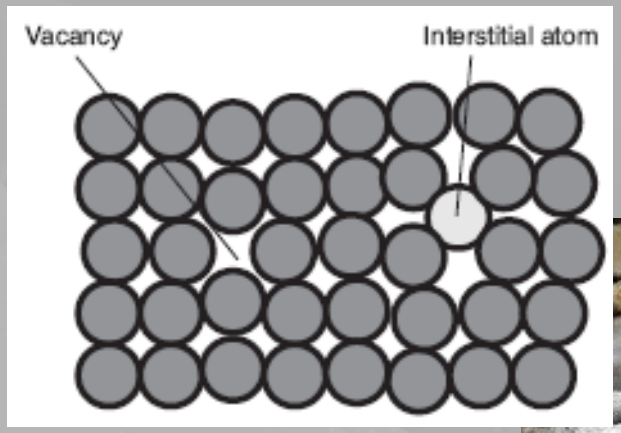
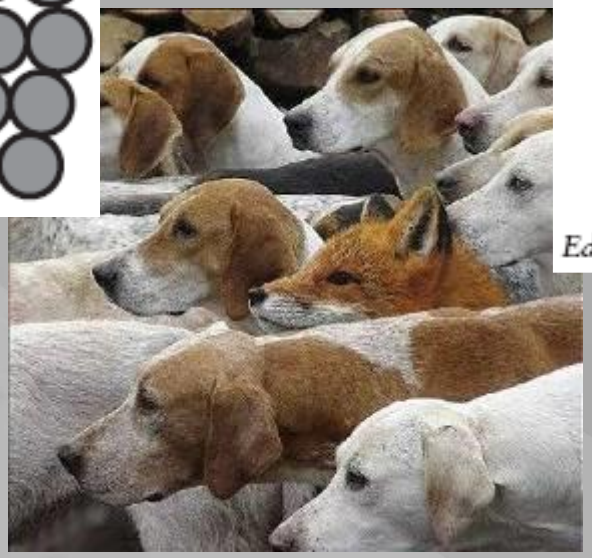
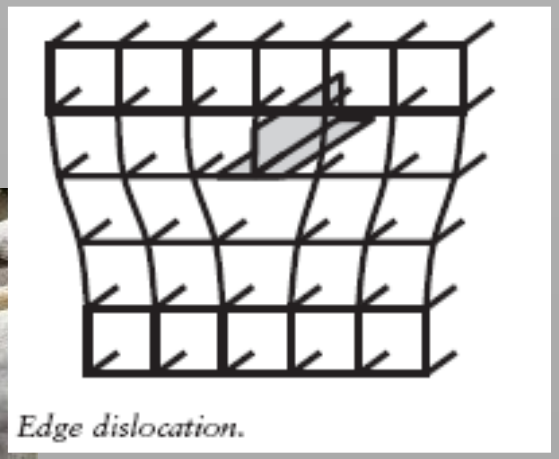
Imperfections and impurities

- 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







Edge dislocation.

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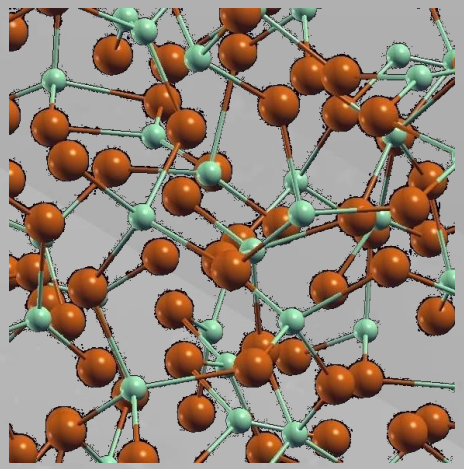
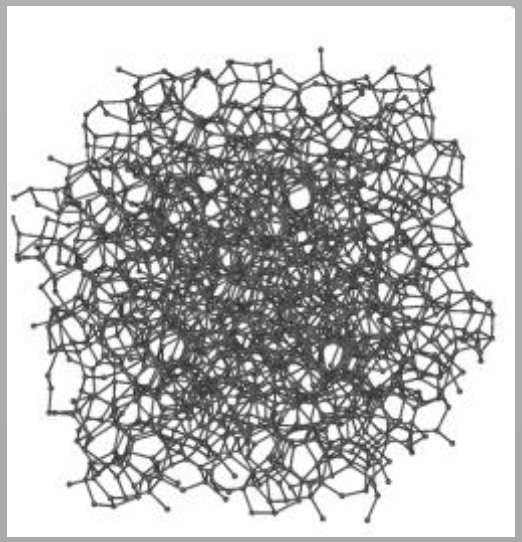
Amorphous materials

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





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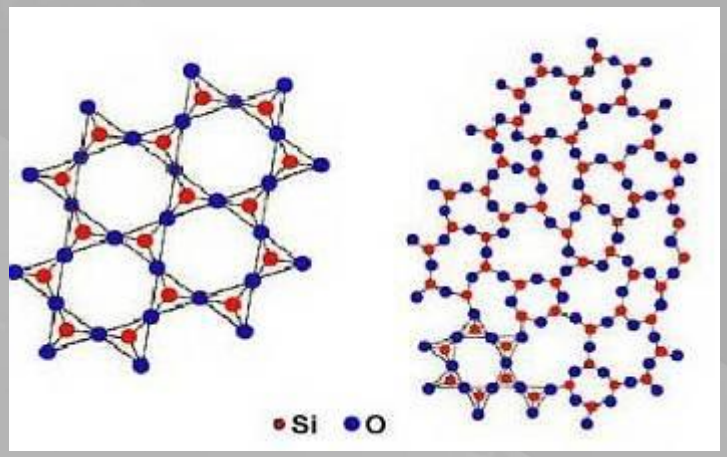
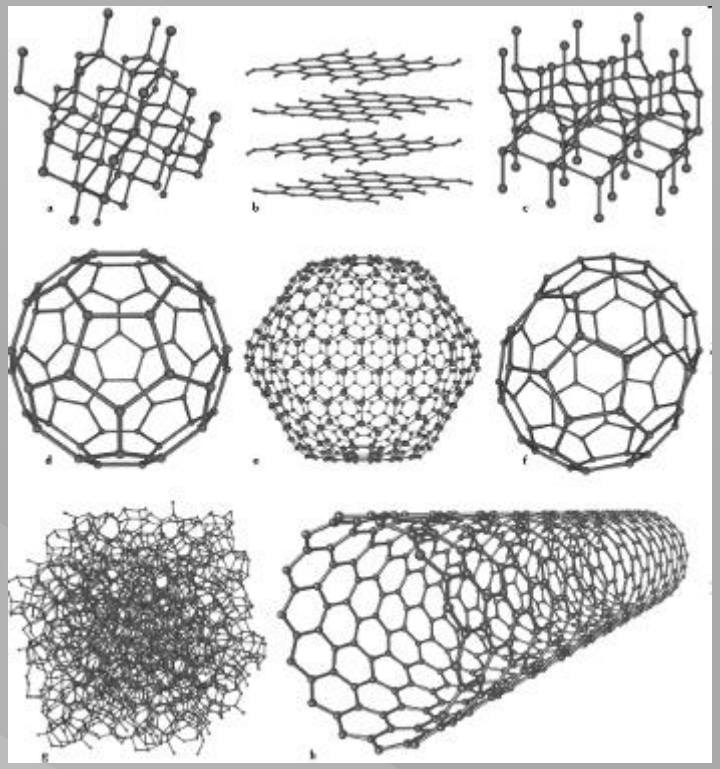
Amorphous materials

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



crystal SiO_2 (quartz)

amorphous SiO_2 (glass)



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Heterogeneous materials

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

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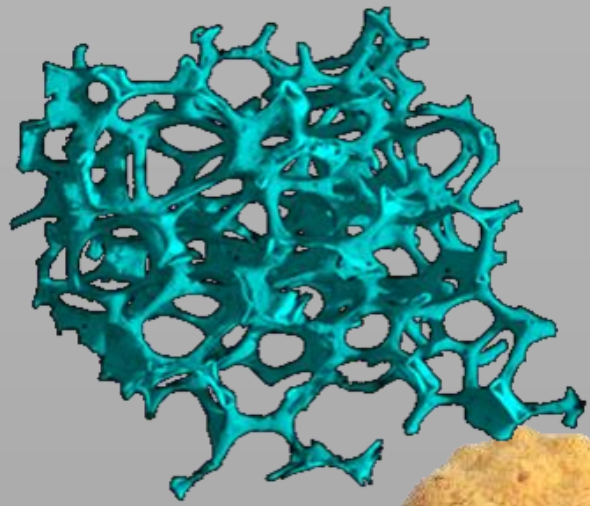
Porous materials

- closed pores

- open pores



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Granular materials

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

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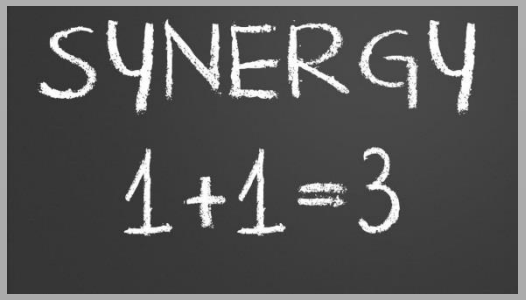
Composites

- 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

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

Natural and man-made composites

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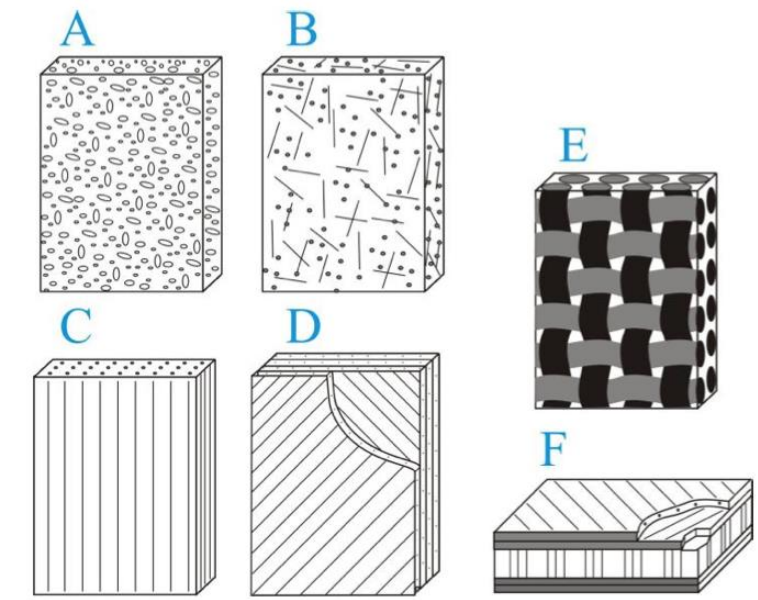
Reinforced materials

- reinforcement (strengthening material)

+

- binding substance (THE 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;

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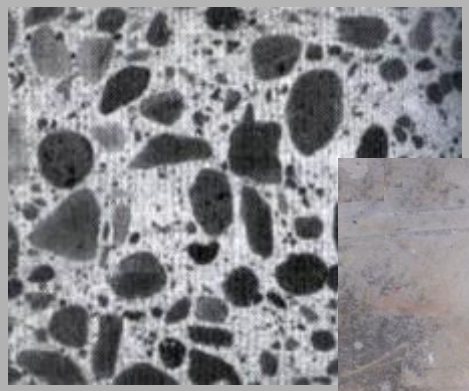
Reinforced materials

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



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Building materials

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Material Testing

- for exact knowledge of the material properties it is necessary to test it

Material testing

- according testing standards
- on appropriate sample

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Principles of material testing

- **defined conditions and methods** of testing (according technical standard)
- the test should **emulate the real situation**
- **the load of the material** is often extreme (to provide some warranty)
- to characterize material sufficiently – **several different tests**

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Test sample

- **representative** (typical example)
- **average** (in the middle of properties)
- **sufficiently large** (for all tests, for repeating of the tests, for auxiliary tests)

Representative sample

- Contains all important structural features

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Sample size

- **differs for different materials:**
  - **steel** – 10^{-3} mm
  - **wood** – tenth of mm
  - **concrete** – min. 100 mm

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Amount of tests

„ One test = no test “

- mostly given by standard
- usually min. 3 - 6 measurements
- statistical evaluation (to minimize measurement errors)

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Sampling

- depends on structure of the material

Solid materials:

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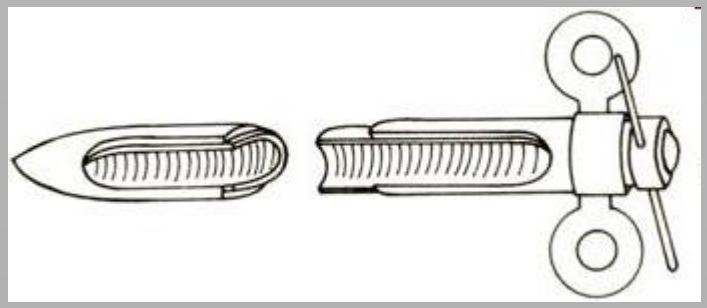
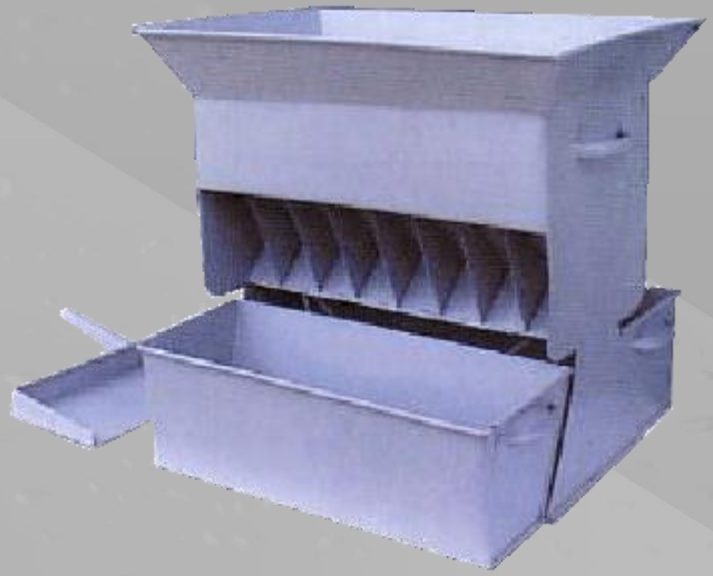
Liquid sampling

Sampling of granular materials



Sampler splitter



Rotary sample divider

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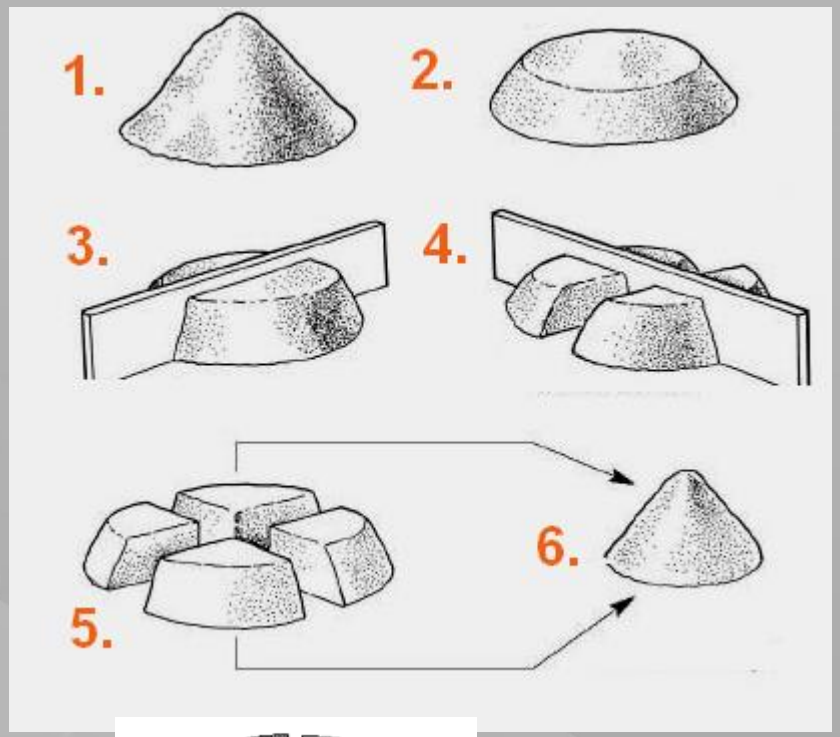
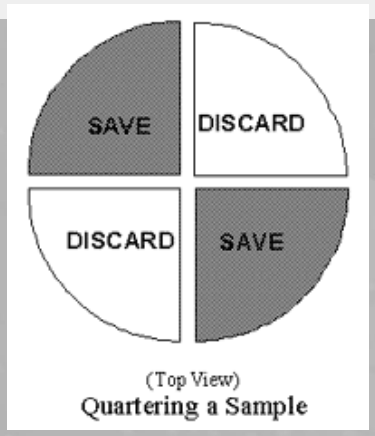
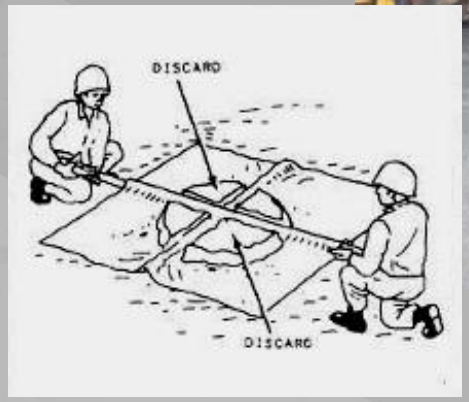
Quartering







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Measurement error

"It is better to be roughly right than precisely wrong." (Alan Greenspan)

- **No measurement is absolutely accurate**

Errors

- **systematic** (mis-calibrated device, staff, method)
- **random** (naturally occurring - minimize by repeating of measurements)

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Accuracy

- **Accuracy** - the validity of measuring procedure, the quality of measuring device and the care at measuring
- **Readability** - the number of significant digits or decimal places
- **Repeatability** (Precision) - ability to show consistent results under the same conditions
- *Even if the person making a measurement is as accurate as humanly possible, limitations imposed by the measuring instrument and the conditions under which the measurement is being made, dictate that the result should not imply greater precision than circumstances warrant.*

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Assuring Quality in the Lab

Can I use a balance with a readability of 1 g to weigh 4g of a substance with an accuracy of 1%?

→ 4 g

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Laboratory conditions

- **composition, temperature, pressure**

Building materials :

– under standard conditions

- air humidity
- temperature
- pressure

Normal laboratory condition:

- temperature: **20 °C ± 5 °C**
- relative air humidity: **55 – 80 %**
- normal pressure

Sample storage and documentation

- sample curing
- unmistakable labelling
- record keeping

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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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