Faculty of Civil Engineering

WARSAW UNIVERSITY OF TECHNOLOGY

**Building Materials**

Laboratory exercises

# Testing of chosen mechanical properties of building materials

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# 1. Purpose of the exercise

The aim of the exercise is to perform laboratory tests and calculate chosen mechanical properties of building material.

# 2. Basic information

## 2.1. Basic definitions

**Flexural strength** – the maximum value of the stress that the tested material can withstand during the bend test;

**Compressive strength** – the maximum value of the compressive stress that the tested material can withstand during the test;

**Impact resistance** the ability of the material to carry short-term variable dynamic loads;

**Hardness** – material resistance to local plastic deformations, applied on a small surface of the test sample as a result of pressing so called indenter, which is a harder material;

**Abrasion resistance** – resistance of the material to mechanical damage caused by the action of the abrasive agent;

**Elasticity** –the ability of a material to assume its original form after removing the external force, under the influence of which the material sample changes its shape;

**Plasticity** – plasticity is the ability of a material to remain deformed after removing the forces that caused these deformations (without destruction);

**Brittleness** – the material susceptibility to sudden failure under load, without noticeable deformations prior to material failure;

**Slurry** – the mixture of a binder (cement, gypsum, calcium) and water;

**Mortar** – the mixture of at least one binder, fine aggregate and water, and eventually mineral additives or admixtures;

**Concrete** – the material created from the mixture of cement, fine and coarse aggregate, water and eventually mineral additives or admixtures or fibers, which gains its properties in in result of cement hydration;

## 2.2. Introduction

Properties of construction products depend on properties of materials they have been made of, and thus the selection of materials should be performed on the basis of knowledge on their properties. Properties of building materials may be divided into:

- Physical properties;
- Chemical properties;

- **Mechanical properties.**

Mechanical properties are related to the reaction of the material to loading or deformation that destroys its structure. The load value can be constant, or it can change continuously. On the other hand, materials can be loaded or deformed at low or high temperature, in the medium of the surrounding air or in the medium of other gases or liquids.

The mechanical properties depend on the internal structure of the material (Fig. 1), its physical properties, temperature, direction of the force, etc. (Fig. 2).

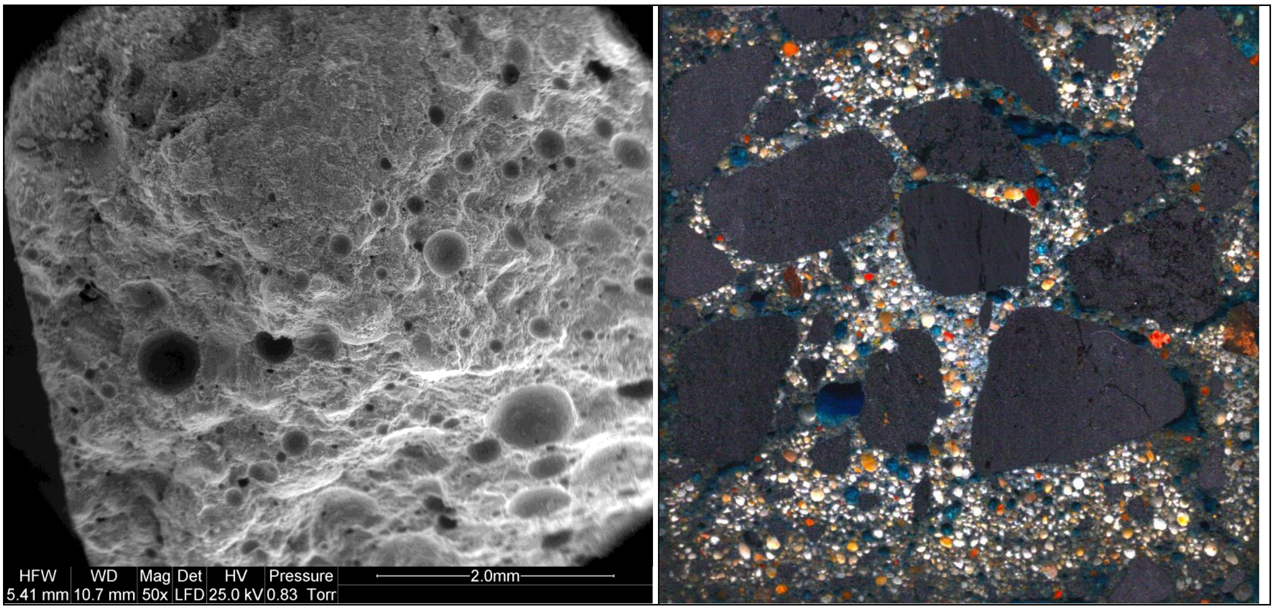


*Fig.1. Microstructure image of the magnetite concrete registered by SEM (on the left) and computer scanner (on the right)*

The reaction of the material to the loading conditions presented is elastic or plastic deformation and cracking (Fig. 2).

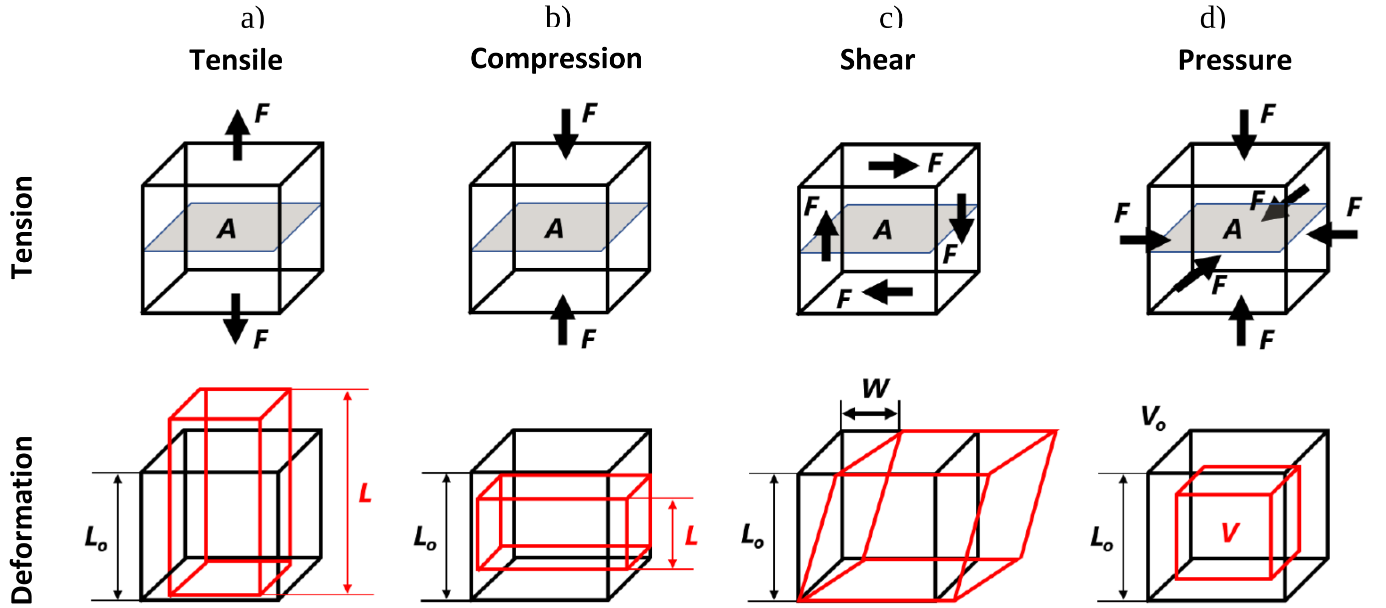


*Fig.2. The type of deformation for different types of loading*

# 3. Tests to perform

## 3.1. Flexural strength

### 3.1.1. Materials and equipment

- Michelis tool
- Samples of gypsum slurry or cement mortar
- Caliper or ruler

### 3.1.2. Performing the test

The bending strength test of construction binders and mortars is performed by applying a force to the center of a beam with dimensions of 40 mm x 40 mm x 160 mm, which is placed on supports spaced 100 mm from each other (Fig. 3). The load increases continuously and uniformly until the specimen breaks. The bending strength ($R_g$) should be calculated based on the read force destructive to the sample according to the formula:

$$R_g = \frac{M}{W} = \frac{F_g l}{4W} \qquad \left[\frac{\mathrm{N}}{\mathrm{mm}^2} = \mathrm{MPa}\right]$$

where: $M$ – bending moment, $W$ – section strength factor depending on the dimensions of the specimen cross-section (for a square section $W = \frac{b^3}{6}$), $F_g$ – force [N], $l$ – spacing between supports equal to 100 [mm].

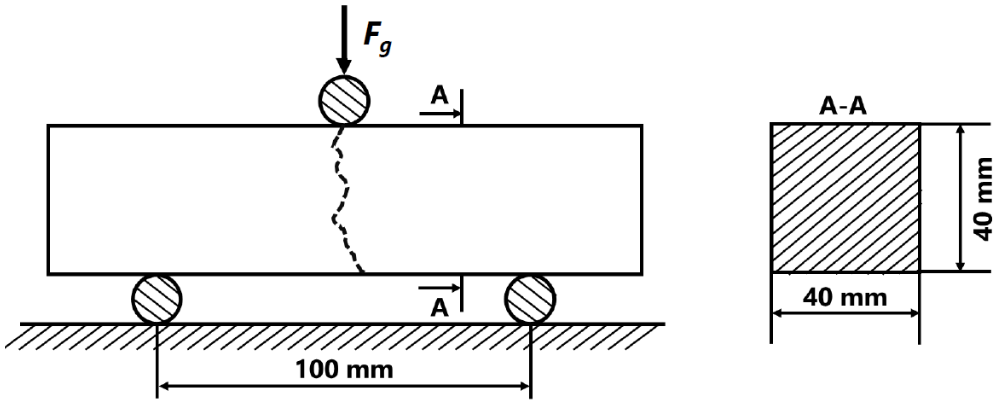


*Fig.3. Bending strength test acc. to EN 1015-11*

## 3.2. Compressive strength

### 3.2.1. Materials and equipment

- Hydraulic press
- Steel pads
- Samples of gypsum slurry or cement mortar
- Caliper or ruler

### 3.2.2. Performing the test

The compressive strength of construction binders and mortars is determined on the halves of beams obtained after a bending test by applying a compressive force to through steel pads with dimensions of 40 x 40 $mm^2$ (Fig.4). The samples are compressed to failure and the compressive strength ($R_c$) is calculated from the formula:

$$R_c = \frac{F_c}{1600} \qquad \left[\frac{\mathrm{N}}{\mathrm{mm}^2} = \mathrm{MPa}\right]$$

where: $F_c$ – compressive strength destroying the sample [N], 1600 – surface area subjected to compression (the surface of steel pad).

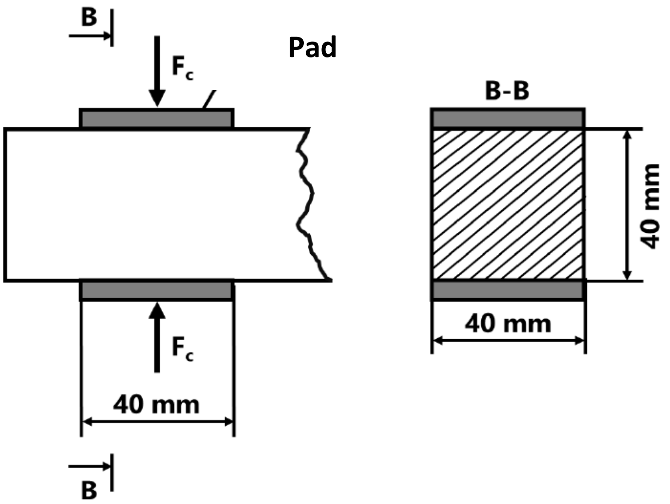


*Fig.4. Compressive strength test of mortars acc. to EN 1015-11*

## 3.3. Impact resistance

### 3.3.1. Materials and equipment

- Charpy hammer
- Wood samples
- Caliper or ruler

### 3.3.2. Performing the test

The wood sample (Fig.5) with a specified cross-sectional area is placed on the buttresses, the scale is zeroed and the pendulum lock is released (Fig.6). After hitting the sample, the pendulum will swing at an angle depending on the work done to break it. The result is read off the scale in kGm and the impact strength is calculated using the relation:

$$U = \frac{A}{a * b} * 9{,}81 \qquad \left[\frac{\mathrm{J}}{\mathrm{cm}^2}\right]$$

where: $A$ – the work used to break a sample [kGm], $a$, $b$ – cross section dimensions of sample [cm]

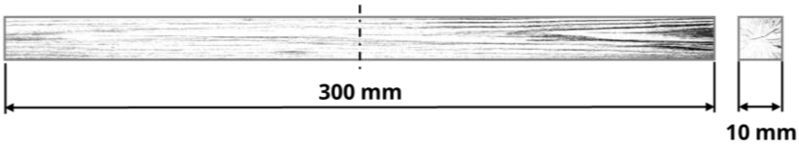


*Fig.5. Wood sample for impact resistance testing*

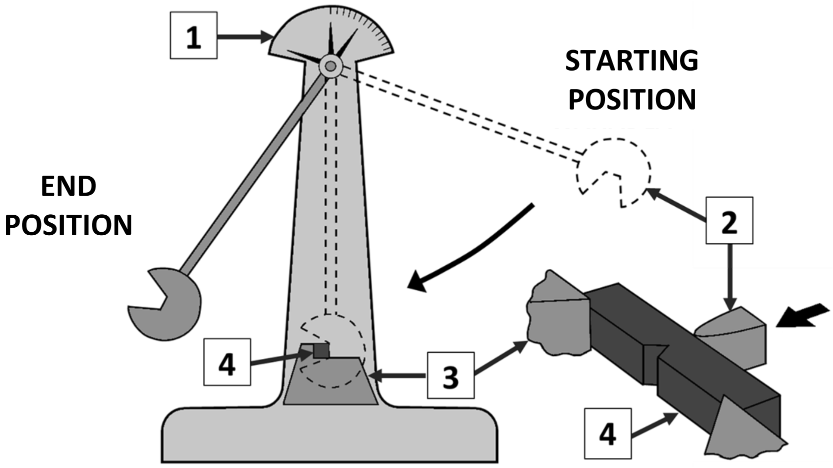


*Fig.6. Impact resistance test using Charpy hammer*

## 3.4. Brinell hardness

### 3.4.1. Materials and equipment

- Brinell hardness tester
- Aluminum samples
- Loupe

### 3.4.2. Performing the test

Brinell hardness testing is one of the static methods in which a hardened steel ball (HBS) or cemented carbide (HBW) is used to load the sample with a constant force of a fixed value, as a result of which the ball is dented into the test material (Fig.7). After removing the load, the diameter of the resulting imprint is measured, and then the hardness is calculated according to the relation:

$$HBW = \frac{0{,}204 * F}{\pi D(D - \sqrt{D^2 - d^2})} \quad \text{[arbitraty units]}$$

where: *F* – loading force of the steel ball; *D* – steel ball diameter [mm]; *d* – diameter of imprint made [mm].

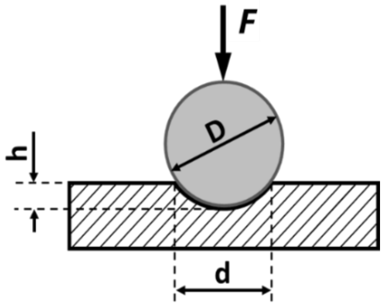

*Fig.7. Brinell hardness test*

# 4. Summary of test results

*Tab.1. Sample table presenting the results of laboratory tests*

| Test | Material/sample | Device / equipment | Data | Calculations and results |
|---|---|---|---|---|
| **Bending strength** $\left[\frac{\mathbf{N}}{\mathbf{mm^2}} = \mathbf{MPa}\right]$ | | Michelis apparatus | $F_g =$<br>$l =$<br>$b =$ | $R_g = \frac{M}{W} = \frac{F_g l}{4W} = \frac{3F_g l}{2b^3}$<br>$R_g = ???$ |
| **Compressive strength** $\left[\frac{\mathbf{N}}{\mathbf{mm^2}} = \mathbf{MPa}\right]$ | | Hydraulic press | $F_{c1} =$<br>$F_{c2} =$<br>$F_{c\,śr} =$ | $R_{C\,śr} = \frac{F_{c\,śr}}{1600}$<br>$R_{C\,śr} = ???$ |
| **Brinell hardness [arbitrary units]** | | Brinell hardness tester | $F =$<br>$D =$<br>$d =$ | $HBW = \frac{0{,}204 * F}{\pi D(D - \sqrt{D^2 - d^2})}$<br>$HBW = ???$ |
| **Impact resistance** $\left[\frac{\mathbf{J}}{\mathbf{cm^2}}\right]$ | | Charpy hammer | $A =$<br>$a$<br>$b =$ | $U = \frac{A}{a * b} * 9{,}81$<br>$U = ???$ |

## 5. Exercise report

The report should include the following points:

I. Subject of research

(basic information about the tested materials/articles)

II. Research results

(the results of tests obtained during laboratory classes presented in tables and elaborated in the manner indicated)

III. Conclusions

(listed findings formulated based on the results obtained)

IV. Literature

(references to the literature used to prepare the report)

## 6. Recommended supplementary literature to the topic

Mamlouk M., Zaniewski J.: Materials for Civil and Construction Engineers