Faculty of Civil Engineering
WARSAW UNIVERSITY OF TECHNOLOGY

Building Materials

Laboratory exercises

Masonry products

Author:
Ewelina Górecka, MSc

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1. The aim of the laboratory

The aim of this exercise is to carry out laboratory tests and calculations of chosen masonry products indicated by the Tutor and assessment of its suitability for use in construction.

2. Background

2.1. Definitions

Masonry - a construction material made of masonry elements arranged in a specified way and connected with each other with a masonry mortar, in which the steel reinforcement (typically rebar) can be placed.

Masonry unit– performed component intended for use in masonry construction.

Unreinforced masonry – masonry without reinforcement or with reinforcement ignored in the calculations.

Reinforced masonry – masonry with reinforcement included in the calculations.

Group of masonry units – masonry units with a similar the percentage amount of holes and orientation of holes in the units when laid and similar wall thickness.

Masonry mortar – mixture of inorganic binder, aggregate and water, including additives, admixtures, if required.

Reinforcing steel – use plain steel for reinforcement of masonry structures in accordance with PN-B_03264.

Hole – formed void which may or may not pass completely through a masonry unit

Coordination dimension – dimension resulting from dimensional coordination, to which corresponds the dimension of the masonry element including joint allowances taking into account dimensional deviations

Nominal dimension– dimension of a masonry element determined for the production of an element the actual dimension of which is within the limits of permissible dimensional deviations

Actual size – size of a masonry unit as measured

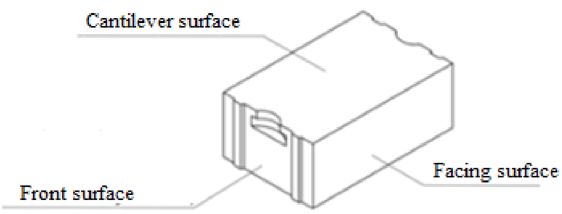


Fig. 1 Masonry surfaces according to PN-EN 771

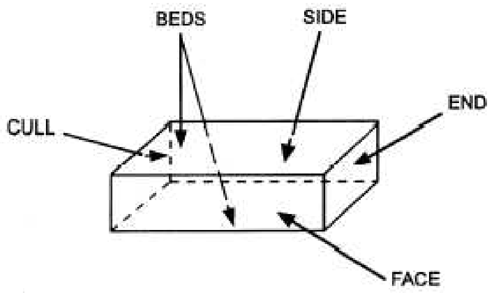


Fig. 2 Names of brick surfaces

2.2. Introduction

2.2.1. Types of masonry elements

The term masonry element replaced the previously used terms, such as e.g. brick, block, block, etc., which are now used as trade names. Today, we distinguish types of masonry elements, which are classified according to the material from which they were created.

Clay masonry units- masonry unit made from clay or other argillaceous materials with or without sand, fuel or other additives fires at a sufficiently high temperature to achieve a ceramic bond.

LD unit – clay masonry unit with a low gross dry density for use in protected masonry

HD unit – clay masonry unit for unprotected masonry as well as clay masonry unit with a high gross dry density for use in protected masonry

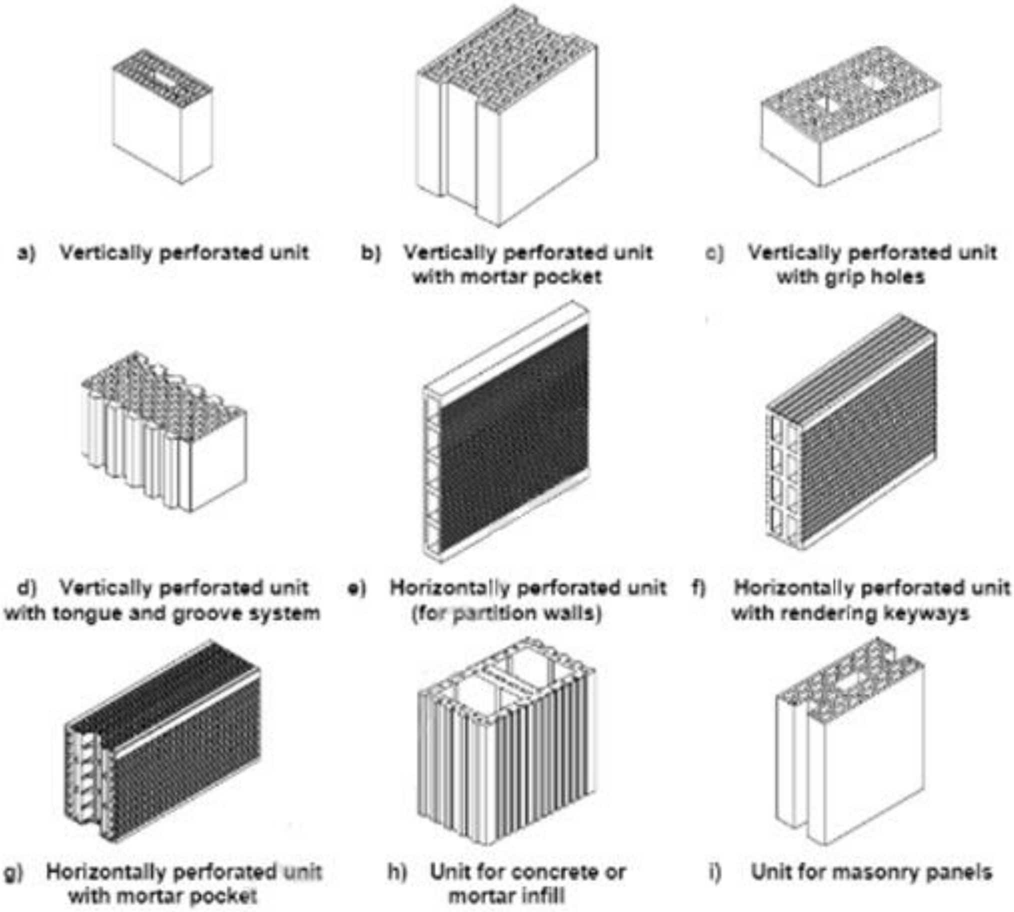
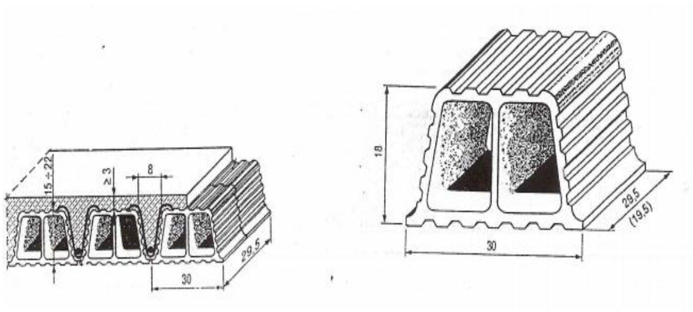
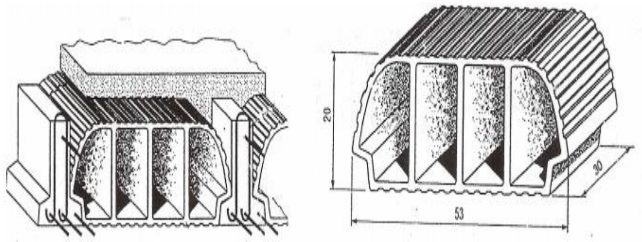


Fig. 3 Examples of LD units (PN-EN 771-1:2011)

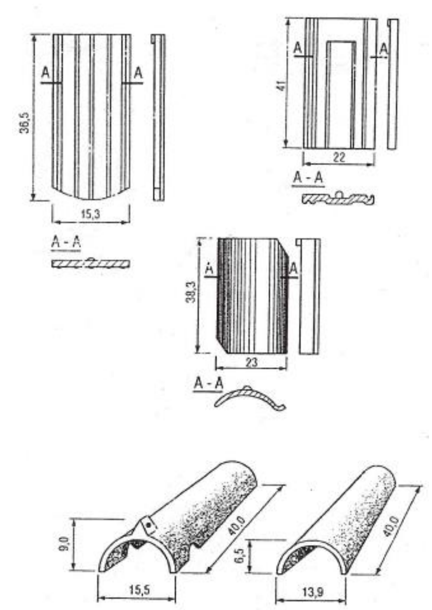


Floor Ackerman's block

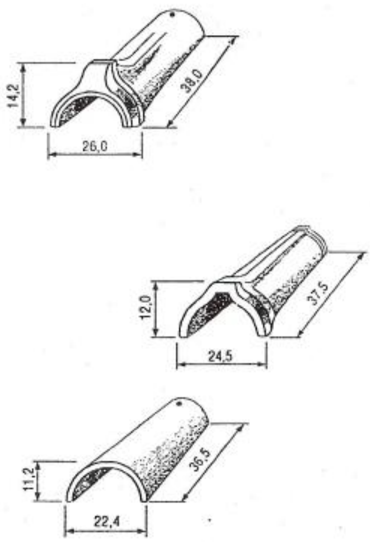


Structural floor tiles DZ3

Fig. 4 Examples of ceramic ceiling elements



Roof tiles



Shapeds

Fig.5 Examples of ceramic roof elements

Calcium silicate masonry units - are produced from sand and silica, which is mixed with hydrated lime and other elements. The no-slump mixture is then pressed into modular-sized molds and cured in an autoclave.

Silicate masonry elements are mainly produced from a mixture of lime and natural silica materials (sand, ground or unground gravel or stone, or a mixture of them) compacted and permanently bound by the action of aromatic steam under pressure.

Fig. 6 Calcium silicate masonry units

Agregate concrete masonry units - A masonry element made of cement binder, aggregates and water, which may contain admixtures and additives as well as coloring pigments, as well as other materials contained in them or added successively in the process of producing the element.

Fig. 7 Aggregate concrete masonry unit

Autoclaved aerated concrete masonry units - Masonry element made of a hydraulic binder such as cement and / or lime bonded to a fine silica material, a pore-forming material and water.

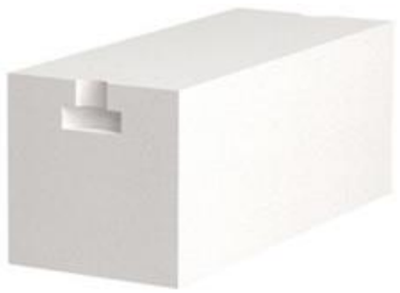


Fig. 8 Autoclaved aerated concrete masonry unit

- **Manufactured stone masonry units**
- **Natural stone masonry unit**

Due to the geometric parameters of the masonry units, a distinction is made:

- Solid elements and with hole volume> 25% and ≤ 25%
- Elements with vertical hollows with the volume of holes > 25% i ≤ 55%
- Elements with vertical hollows with the volume of holes > 25% i ≤ 70%
- Elements with horizontal hollows with the volume of holes > 25 % i ≤ 70 %

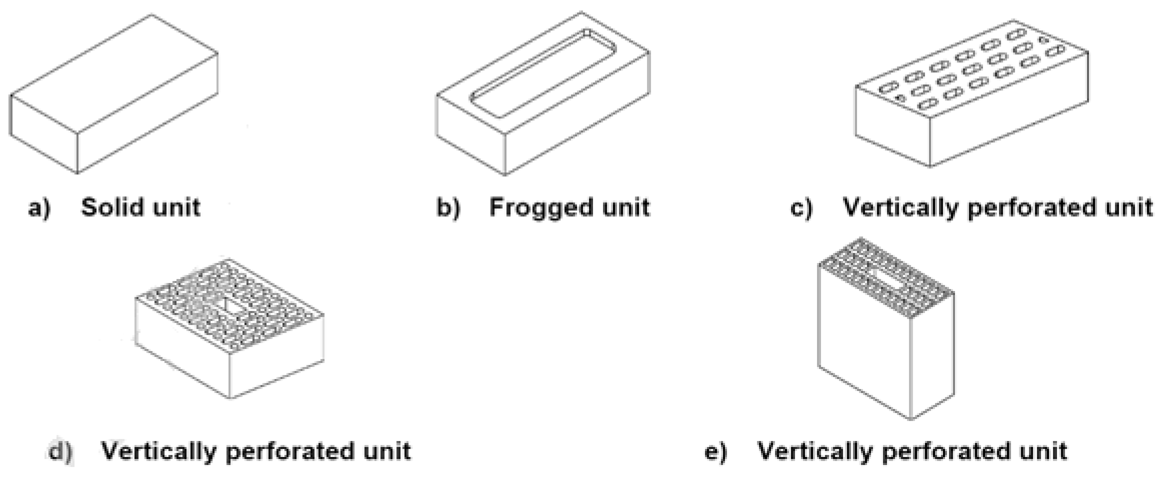


Fig. 9 Examples of HD units (PN-EN 771-1:2011)

2.2.2. Requirements defining particular groups of masonry units made of ceramic material, silicate and cellular concrete are given in the table below.

Table 1 Requirements specifying particular groups masonry elements

<table>
<tr><td rowspan="3">Parameter</td><td rowspan="3">The material of the masonry unit</td><td colspan="7">Group of masonry units</td></tr>
<tr><td rowspan="2">Group 1</td><td colspan="2">Group 2</td><td colspan="2">Group 3</td><td colspan="2">Group 4</td></tr>
<tr><td colspan="4">Vertical hollowing</td><td colspan="2">Horizontal hollowing</td></tr>
<tr><td rowspan="3">Volume of all holes
(% of gross volume)</td><td>ceramics</td><td rowspan="3">≤25</td><td colspan="2">> 25; < 55</td><td colspan="2">> 25; < 70</td><td colspan="2">> 25; < 70</td></tr>
<tr><td>calcium silicate masonry units</td><td colspan="2">> 25; ≤ 55</td><td colspan="2">does not apply</td><td colspan="2">does not apply</td></tr>
<tr><td>concrete [b)]</td><td colspan="2">> 25; ≤ 60</td><td colspan="2">> 25; ≤ 70</td><td colspan="2">> 25; ≤ 50</td></tr>
<tr><td rowspan="3">The volume of one hole
(% of gross volume)</td><td>ceramics</td><td rowspan="3">≤ 12,5</td><td colspan="2">each of the holes (without grip holes) ≤ 2
grip holes up to 12.5 in total</td><td colspan="2">each of the holes (without grip holes) ≤ 2
grip holes up to 12.5 in total</td><td colspan="2">each of the holes ≤ 30</td></tr>
<tr><td>calcium silicate masonry units</td><td colspan="2">each of the holes (without grip holes) ≤ 15
grip holes up to 30 in total</td><td colspan="2">does not apply</td><td colspan="2">does not apply</td></tr>
<tr><td>concrete [b)]</td><td colspan="2">each of the holes (without grip holes) ≤ 30
grip holes up to 30 in total</td><td colspan="2">each of the holes (without grip holes) ≤ 30
grip holes up to 30 in total</td><td colspan="2">each of the holes ≤ 25</td></tr>
<tr><td rowspan="4">Declared thickness of the inner and outer wall (mm)</td><td></td><td rowspan="4">no requirements</td><td>inner</td><td>outer</td><td>inner</td><td>outer</td><td>inner</td><td>outer</td></tr>
<tr><td>ceramics</td><td>≥ 5</td><td>≥ 8</td><td>≥ 3</td><td>≥ 6</td><td>≥ 5</td><td>≥ 6</td></tr>
<tr><td>calcium silicate masonry units</td><td>> 5</td><td>> 10</td><td colspan="2">does not apply</td><td colspan="2">does not apply</td></tr>
<tr><td>concrete [b)]</td><td>≥ 15</td><td>≥ 18</td><td>≥ 15</td><td>≥ 15</td><td>≥ 20</td><td>≥ 20</td></tr>
<tr><td rowspan="3">Declared equivalent thickness of walls (% of gross width)</td><td>ceramics</td><td rowspan="3">no requirements</td><td colspan="2">≥ 16</td><td colspan="2">≥ 12</td><td colspan="2">≥ 12</td></tr>
<tr><td>calcium silicate masonry units</td><td colspan="2">≥ 20</td><td colspan="2">does not apply</td><td colspan="2">does not apply</td></tr>
<tr><td>concrete [b)]</td><td colspan="2">≥ 18</td><td colspan="2">≥ 15</td><td colspan="2">≥ 45</td></tr>
<tr><td colspan="9">a) The equivalent thickness is the sum of the inner and outer wall thicknesses measured horizontally in the right direction.
b) In the case of conical or chamber holes, the average thickness of the internal and external walls is taken.</td></tr>
</table>

Masonry units shall be classified as Category I or Category II units as appropriate to the production control. Category I includes elements with the declared compressive strength with the probability that the occurrence of lower strength is ≤ 5%. Category II are elements that do not meet the standards of Category I.

3. Laboratory determinations

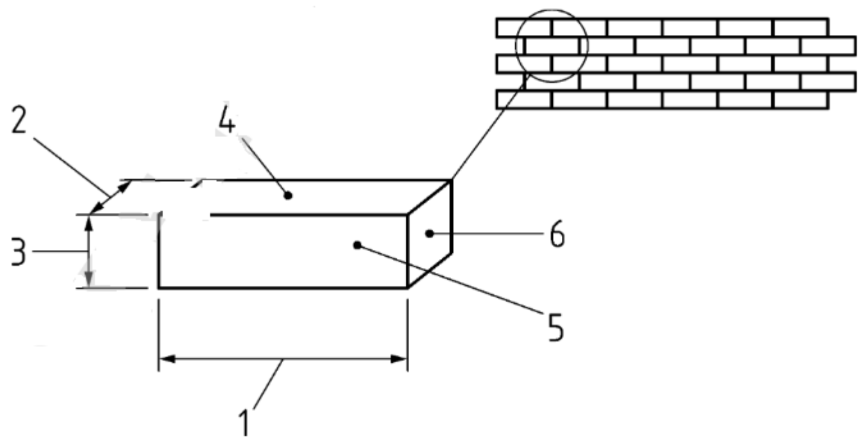
3.1. Assessment of element dimensions

3.1.1. Materials and equipment

- Masonry product,
- Slide caliper or ruler.

3.1.2. Measurement

The determination should be performed on the masonry unit indicated by the Tutor. The dimensions of the masonry element should be declared in mm, in the order: length, width and height, with an accuracy of 0.1 mm. The actual dimensions should be compared with the nominal ones and dimensional deviations should be assessed.



Key

1 Length 3 Height 5 Face

2 Width 4 Bed 6 Header

NOTE This relates to the normal use of the masonry unit in the wall.

Fig. 10 Dimensions and surfaces

3.2. Gross dry density

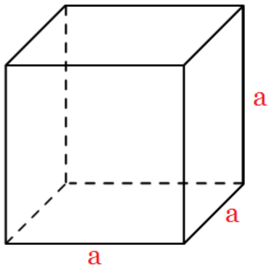
3.2.1. Materials and equipment

- Regular shaped material sample,
- Laboratory scale,
- Slide caliper or ruler.

3.2.2. Measurement

The gross dry density of the masonry element with should be declared in kg/m^3 with an accuracy of 1 kg/m^3. A representative solid, complete unit, i.e. containing no open or cut holes, measuring approximately (100 x100 x100) mm shall be cut from the entire component (sample). After determining the dimensions of the representative samples (point 1), dry the sample to constant weight and determine its mass in kg. To determine the gross density on a dry basis, divide the dry mass m_{dry} (kg) by the total volume V (m^3).

The volume of the cube



$$V = a \cdot a \cdot a, \ (\text{m}^3)$$

Density:

$$\delta = \frac{m_{dry}}{V}, \left(\frac{kg}{m^3}\right)$$

3.3. Compressive strength

3.3.1. Materials and equipment

- A sample of the material in the form of a cube,
- Slide caliper or ruler,
- Hydraulic press.

3.3.2. Measurement

Compressive strength will be determined on one sample for the entire group..

The compressive strength is the highest compressive stress that a sample of the tested material transmits during compressing. Compressive strength (R_c) in MPa (N/mm^2) is calculated according to the formula:

$$R_c = \frac{P_n}{F}$$

key:

P_n – static force destroying the sample, kN

F – area of the compressed surface, cm^2

The test is carried out in strength machines for static tests. The test specimens used are cube-shaped and of a size depending on the type of construction material (fig. 10).

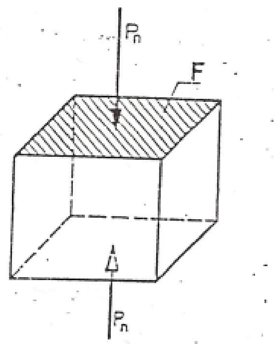


Fig.11 Compressive strength determination scheme

The surface area of the compressed sample should be determined. The specimen is placed centrally on the compression platen of the testing machine. Then an evenly distributed load is applied which increases uniformly until the specimen fails. The value of the destructive force applied to the sample should be recorded. The result should be given in MPa with an accuracy of 0.1 MPa.

3.4. Water absorption

3.4.1. Materials and equipment

- Cubic sample,
- Water cuvette,
- Laboratory scale,
- Slide caliper or ruler.

3.4.2. Measurement

Moisture absorption (also called water absorption) is the ability of a material to absorb moisture from its environment. Water absorption applies to elements intended for use in external building elements with an exposed face surface (maximum water absorption after 10, 30 and 90 minutes - acc. to EN 772-11). Due to the duration of the laboratory, the water absorption is assessed after 10, 30 and 60 minutes.

- Representative samples should be dried to constant mass and their weight determined (g) (here: it is both the dry mass and the mass before saturation),
- Determine the dimensions of the facing surface (length and width in mm),
- Calculate the area of the facing surface,
- Place the sample in a cuvette of water to a depth of 5 mm ± 1 mm,
- Determine the weight of the sample after 10, 30 and 60 minutes.

Coefficient of water absorption due to capillary action of autoclaved aerated concrete should be calculated as the average of three measurement results with an accuracy of 1 g/(m^2 * s^{0,5}) from the formula:

$$c_{ws} = \frac{m_{so,s} - m_{dry,s}}{A \cdot \sqrt{t_{so}}} \cdot 10^6 \left(\frac{g}{m^2 \cdot s}\right)$$

key:

$m_{dry,s}$ – the mass of the specimen after drying, (g)

$m_{so,s}$ – the mass of the specimen in grams after soaking for time t, (g)

A – the gross area of the face of the specimen immersed in water, (mm^2)

t_{so} – the time of soaking, (s)

c_{ws} – the coefficient of water absorption due to capillary action, ($g/m^2 \cdot s^{0,5}$)
s – seconds.

3.5. Thermal conductivity

3.5.1. Materials and equipment

- Data given by the Tutor

3.5.2. Measurement

Thermal conductivity is the conductivity of heat through a material as a result of temperature differences between its opposing surfaces. It is determined by the thermal conductivity coefficient λ, which is the amount of heat passing through a surface of 1 m^2 of 1 m thick material in 1 hour, with a temperature difference of both surfaces equal to 1 K.

$$Q = \lambda \frac{F \Delta T t}{g} \qquad \lambda = \frac{Qg}{F \Delta T t}, \; \mathrm{W/(m \cdot K)}$$

gdzie: Q – the amount of heat needed to heat the material by 1K, J,
g – material thickness, m,
ΔT - temperature difference of the partition surface, K,
t – heat flow time, h.

The thermal conductivity coefficient of porous materials increases with increasing density. This is because the higher density of porous materials means that the air pore content in the material has decreased, while the volume proportion of the skeleton (here, the concrete matrix), which has a much higher λ coefficient than air, has increased. The thermal conductivity coefficient also increases as a result of moisture in the material. This is understandable, because the water that has penetrated into the pores of the material conducts heat much better than the air it displaces from the pores. Using a plate apparatus with heat flux density sensors, the thermal conductivity coefficient λ for autoclaved cellular concrete of different densities with different moisture content was investigated. The tables in the laboratory show the results. Tutor will indicate the number of the analysis set.

4. Summary of the measurements

A summary of the measurements results and the calculations performed should be placed in Table 2.

Table 2 Results of physical properties of masonry units

DIMENSIONS AND GROSS DRY DENSITY						
Element symbol	Dimensions			Mass	Gross dry density	Average value of the gross dry density
	length [mm]	width [mm]	height [mm]	[g]	ρ [kg/m^3]	ρ [kg/m^3]
1						
2						
3						

COMPRESSIVE STRENGTH					
Type of material	Dimensions		The area of the compressed surface F [cm^2]	Force P [kN]	Compressive strength R [MPa]
	length [mm]	width [mm]			

WATER ABSORPTION										
Element symbol	Dry mass	Face area dimensions		The mass of the specimen in grams after soaking				The coefficient of water absorption after:		
				before soaking	after 10 min.	after 30 min.	after 60 min.	10 minutes	30 minutes	60 minutes
	[g]	length [mm]	width [mm]	[g]	[g]	[g]	[g]	g/m^2· s^{0,5}	g/m^2· s^{0,5}	g/m^2· s^{0,5}
1										
2										
3										
Average value of coefficient of water absorption c_{ws}, g/m^2· s^{0,5}										

THERMAL CONDUCTIVITY λ
Conclusions……………………………………………………………………………………………… ………………………………………………………………………………………………………

5. The report on the laboratory task

The report on the laboratory task should contain:

I. Subject of the study (basic information about the test material)

II. Test results (results of measurements and calculations made in the laboratory classes)

III. Conclusions

IV. Literature (references to the literature used to prepare the report)

6. Literature

- Mamlouk M., Zaniewski J.: Materials for Civil and Construction Engineers
- PN-EN 771-4+A1:2015-10 *Specification for masonry units -- Part 4: Autoclaved aerated concrete masonry units;*
- PN-EN 771-1+A1:2015-10 *Specification for masonry units -- Part 1: Clay masonry units*;
- PN-EN 771-3+A1:2015-10; *Specification for masonry units -- Part 3: Aggregate concrete masonry units (Dense and lightweight aggregates);*
- PN-EN 771-2+A1:2015-10 *Specification for masonry units -- Part 2: Calcium silicate masonry units.*