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Effect of hydrophobisation on durability related properties of ceramic brick

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HIGHLIGHTS

- The hydrophobisation of materials determines their resultant physical properties.
- The good adherence of polysiloxanes gel to mineral compounds of the brick was confirmed.
- The frost and salt resistance of the bricks intensively increases after impregnation with organic solvents.
- The fine-molecular alkyl-alkoxy-silane compounds ensure the highest resistance of ceramic bricks.

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ABSTRACT

The article describes the issues of resistance hydrophobised ceramic bricks. The purpose of the research was to evaluate the possibility to apply organosilicone based hydrophobising preparations for impregnation of ceramic building materials. Within the experiment the efficiency of three preparations which differed in hydrolytic polycondensation grade, viscosity and product concentration was checked main factors influencing the final effect of the hydrophobising procedure. The capillary-porous structure of bricks makes them sensitive to water influence. Therefore, a detailed analysis of heat parameters in relation to moisture was required. The following laboratory tests were performed: the basic physical properties, water flow due to capillary forces, water permeability, contact angle and surface free energy, thermal conductivity, resistance to salt crystallization, frost resistance, silicon resin distribution in the micro-structure of a ceramic bricks. The moisture changes influence on thermal conductivity coefficient in non-impregnated and hydrophobised bricks were analysed and verified. The analysis of moisture parameters and moisture transport was executed using a constant monitoring time domain reflectometry (TDR) method. The fine molecule compounds of alkyl-alkoxy-silanes provide the highest resistance of ceramic brick.

1. Introduction

In the buildings exposed to the effect of moisture, the accelerated processes of materials and equipment destruction may occur. They may lead to the biological and chemical corrosion and thus an increase of exploitation costs [1]. Together with the natural processes of moisture sorption and desorption occurring during the building exploitation, the properties of applied materials also influence the moisture performance of the envelopes [2]. Too much moisture has a negative effect on people's health. This is the reason for the overestimated heat consumption due to an increase of thermal conductivity of external envelopes [3–7]. Frost damage due to cyclic water freezing/ice thawing in the pores of building materials, is one of the main reasons expose durability of the materials [8]. An increase of moisture also causes changes of indoor microclimate and a decrease of heat-moisture comfort which may cause diseases of respiratory track, infections and allergies [1,9–12]. In rooms with normal humidity, water condensation is mainly caused by improper thermal insulation of the partitions and the presence of thermal bridges and quoins [6,7,13]. Physical and chemical properties not only affect the quality of air, heat comfort, energy consumption but also the resistance of building materials [14,15].

In recent years, the interest in application of hydrophobising preparations has increased considerably. This is evidenced by an increase of consumption of hydrophobising preparations, introduction of new hydrophobising products, and the research about the hydrophobisation efficiency [1,9,12,16–21]. Hydrophobisation is acceptable on new constructions if the application of the materials

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is done just after construction. The main purpose of hydrophobising is to increase the boundary surface tension between water and the impregnated material, to the greatest possible difference. The greater the difference, the less water-wettable the material is [9,18]. A hydrophobic layer should be impermeable to water but to allow the evaporation of water contained in the material. Hydrophobisation on the ceramic wall provides additional problems if there are large pores, gaps, bad pointing, cracks, salt in the construction. In such cases, water might penetrate behind the impregnation layer and the result of hydrophobisation could be worse than the original wall.

Nowadays, organosilicone compounds based on monomers, polymers and the oligomers are frequently applied for hydrophobisation [1,19,22–24]. Silanes, siloxanes and silicone resins do not differ in the activity, but in the structure and the particle size. The molecular weight of silanes is about 178, siloxanes about 500, and polysiloxanes about 2500 [25]. The particle size of organosilicone compounds affects the depth and the speed of penetration into the material structure. The largest particles have silicone resins which are about 100 times larger than the particles of siloxanes [22]. The pore diameters decide on the possibility of a chemical compound adsorption and the size of a critical particle [13].

The efficiency of brick hydrophobisation using the high volatile organic compounds (VOC) content emulsion was analysed in the paper [23]. The material from the same brickyard was studied in this article, but from the brick coming from another batch. The SFE of the impregnated bricks was 4.5–5.2 times smaller than in the case of the non-hydrophobised samples. The biggest contact angles of liquids and top hydrophobicity were obtained for methyl silicone resin. The water vapour permeability was in the range of $3–13 \cdot 10^{-12}$ kg/m s Pa and depends on the ceramic micro-structure, particularly volume, size and specific surface of the pores.

The work was not performed aging research of the hydrophobisation agents applied to a ceramic brick. Hydrophobisation durability is not too high and is evaluated for about ten years. In situ tests conducted by the Polish researchers on the historical building proved good quality of the surfaces impregnated with silica-organic agents within fifteen year of exploitation. On the other hand, foreign investigations show that the minimal durability period of water proof impregnation is up to three years [26]. Accordingly, the hydrophobisation treatment must be repeated every few years.

Hydrophobisation ceramic walls is expensive, so the select of effective preparations should be based on a detailed laboratory tests. The aim of the research was to evaluate the resistance of ceramic bricks hydrophobised organosilicone compounds.

2. Materials and methods

2.1. Material details

2.1.1. Brick

The main objective of the research was a ceramic brick. Determination of physical parameters was conducted according to EN 1936: 2010. Within the research the following parameters were determined: density, apparent density, total and open porosity. Three samples were used for the study. The following results were obtained: density $\rho = 2.45$ g/cm^3, apparent density $\rho_a = 1.59$ g/cm^3, open porosity $P_o = 23.77\%$, total porosity $P = 34.57\%$.

2.1.2. Hydrophobising preparations

The following hydrophobising preparations were selected: A – water-based solution of methyl silicone resin in the potassium hydroxide, B – organic solvent based methyl silicone resin, C – organic solvent based alkyl-alkoxy-silanes oligomer. The non-hydrophobised bricks were described as S.

Hydrophobic effect of ceramic brick depends on the structure of organosilicone compounds, viscosity, active substance concentration and the surface tension/solvent viscosity ratio. There were applied the preparations of well-known producers, that differed in type of the solvent, viscosity, concentration, for the reason that they are the main factors influencing the final hydrophobisation result.

Alkyl-alkoxy-silanes are reactive compounds of silicone and organic nonpolar functional groups, $R–Si–(OR')_3$. Efficiency of hydrophobisation is determined by the chemical composition of the monomers: alkoxy groups (OR') controlling the reactivity of the compounds and alkyl groups (R) which define the hydrophobic performance of the impregnated material.

Properties of the applied preparations used in the research were shown in Table 1. Viscosity was determined by the measurement of solutions flow time. Surface tension was measured by the method of fluid rising in the capillary. The research was executed in room temperature of 22.5 °C. Six measurements were performed for each characteristic.

The lowest viscosity factor value η was observed in the A preparation, characterised by the lowest concentration of active substances. This is water-based solution of A preparation. On the other hand, the maximal viscosity, almost 250% greater than A was observed in the case of methyl silicone resin in the mineral spirit (agent C). The highest value of a ratio between the surface tension and the viscosity was observed for A preparation diluted in water, and the lowest one-organic microparticular C preparation. The analysis of preparation concentration and the number of layers was not conducted. These factors influence the preparation ability to penetrate and thus the efficiency of hydrophobisation. Own research proved that this rule was not always true. Some preparations were not raised by capillary forces in porous materials, especially macromolecular siloxanes in stones with small pores [9].

Brick were hydrophobised according to instruction provided by the producers – double spreading of the preparation with a brush. A preparation was diluted in the following proportion 1:6. Other hydrophobising preparations with organic solvents were not diluted. Then all the hydrophobised bricks have been seasoned in laboratory conditions for 7 days to control the process of hydrolytic polycondensation of hydrophobic coatings.

2.2. Experimental methods

2.2.1. Determination of capillary rise

Determination of capillary rise is based on measuring the mass increase of the water in the capillaries. Time domain reflectometry (TDR) is a method of determining the dielectric permittivity. It is a parameter which depends on the moisture of the porous material, and allows evaluation of the saturation medium. The TDR has been developed and used to measure soil moisture for three decades [27–29]. There is also adopted for moisture evaluation of building materials for several years [30,31]. The TDR consists in determining the velocity of electromagnetic pulse and interpretation of results based on physical or empirical calibration [27,32–34].

The following equipment was applied for the test: a multi-channel TDR multimeter, TDR probes designed to measure the moisture of the hard porous materials, a PC to control a multi-meter, the experiment monitoring and data acquisition. The length of measuring rods is 100 mm, the diameter is 4 mm and the spacing of rods is 25 mm. Calibration of the sensor was carried out on the basis of gravimetric research on brick samples with dimensions: 50 × 50 × 150 mm. The samples were cut from the bricks and openings were drilled to install measuring rods of the TDR sensors.

Table 1
Basic characteristics of hydrophobising preparations.

Type of agent	Viscosity			Surface tension			Apparent density			Surface tension/viscosity ratio
	Mean (mPa s)	Standard deviation (mPa s)	Coefficient of variation (%)	Mean (mN/m)	Standard deviation (mN/m)	Coefficient of variation (%)	Mean (g/cm^3)	Standard deviation (g/cm^3)	Coefficient of variation (%)	Mean
A	1.10	0.20	10.10	67.92	0.84	1.2	1.26	0.11	8.8	61.73
B	1.48	0.13	8.22	23.11	0.12	0.5	0.80	0.09	10.7	15.65
C	2.85	0.16	6.11	24.30	0.37	1.5	0.82	0.07	8.6	8.54