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The change in selected properties of ceramic materials obtained from ceramic brick treated by the sulphate and chloride ions

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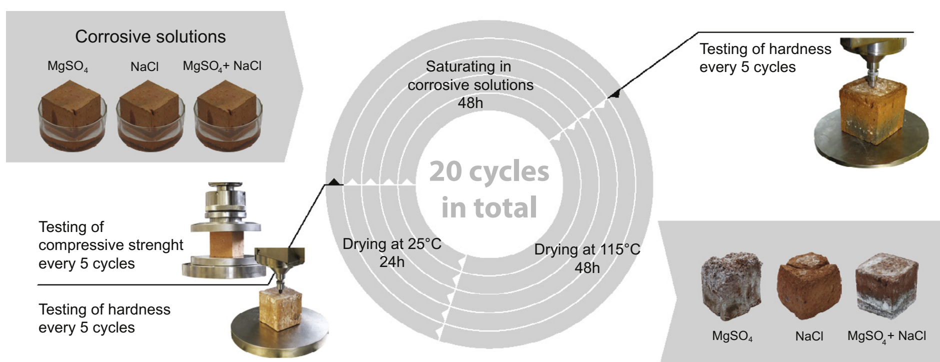
HIGHLIGHTS

- The change of the mechanical properties of the ordinary bricks containing the sulphate and chloride ions.
- The compressive strength of the ordinary bricks contaminated by the sulphate and chloride ions.
- The surface hardness of the ordinary bricks contaminated by the sulphate and chloride ions in the dry and saturated state.
- The impact of the sulphate and chloride ions on the softening of the ceramic brick.

GRAPHICAL ABSTRACT



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ABSTRACT

Long-term use of bricks in different conditions, particularly in the contact with moisture, results in the accumulation of various substances and compounds, which over time causes a change of the performance in the negative direction. Therefore, the studies have been undertaken, which the goal was to determine the effect of the presence of the sulphate and chloride ions on the compressive strength and the surface hardness of the ceramic bricks. The studies have been conducted on the samples cut out from the ceramic bricks, that have been exposed to the corrosive solution of magnesium sulphate, sodium chloride and a solution containing both of these salts, simultaneously. The obtained results indicate that the presence of these ions in the body of ceramic bricks provokes a change of the surface hardness and the compressive strength.

1. Introduction

A ceramic brick is a popular and widely used building material. With success, it has been and is still used in the residential and industrial construction. It is considered as a material with a very great number of useful properties such as the compressive strength or the high resistance to the external environment [1]. The mineral composition of raw materials, the oxide composition and the texture of the burnt ceramic body, resulting from physical and chemical changes occurring during the burning process, determine the durability of the bricks [2–4].

Its lifetime under different conditions, especially in the contact with moisture, promotes changes in the body, which over time trigger a gradual loss of bricks performance. The most examined, destructive factor in lowering usability is a cyclical effect of negative temperatures in the contact with moisture [5–7].

Note also the problem of the effects of the soluble salts in the acid rain or the land that by capillarity are placed on the ceramic body and transported in it [8,9]. In this way, the harmful

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substances may migrate to a height of a few to several meters, especially in the buildings that do not have a horizontal waterproofing or their walls are not protected from the rain [8–12]. This issue is extremely important for the protection of the historic buildings and structures, and their revitalization [10,13].

The extreme example of the degradation of the ceramic bricks, under the influence of the aggressive external environment, are the ceramic liners in the industrial chimneys, which are subjected of decade to the direct impact of the aggressive ingredients contained in the fumes. Long-term life leads to the accumulation of the sulphate, chloride and nitrate ions in the lining of the ceramic bricks [14,15]. Ongoing studies have confirmed negative effects of these compounds on the properties of this material [16–19].

Therefore, the studies have been undertaken which goal was to determine the effect of soluble salts of sulphate and chloride to change the mechanical properties of the body of the ceramic brick. The changes in the surface hardness and the compressive strength changes of the bricks, exposed to corrosive environment containing the sulphate and chloride ions, were determined. The analysis of the results was performed on the base on a comparison of the results of the ceramic uncorroded body (reference material) and the body of ceramic contaminated by the sulphate and chloride ions.

2. The test materials and the corrosive environment

The study was performed on the samples with dimensions of 65 × 65 × 65 mm, cut out from a burnt ceramic brick. The properties physico-mechanical and chemical and phase composition of the studied materials are show in Tables 1 and 2.

The dried and weighed samples were exposed to the corrosive environment of the solution:

- magnesium sulphate, wherein the concentration of SO_4^{2-} was 50 g/dm^3,
- sodium chloride, wherein the concentration of Cl^- was 50 g/dm^3,
- magnesium sulphate and sodium chloride, wherein the ions concentration of SO_4^{2-} was 25 g/dm^3 and the ions concentration of Cl^- was 25 g/dm^3.

Selection of the corrosive environment was based on the results of the composition of corrosion product of chimney liner and concrete thermal insulation in industrial chimneys [17].

The corrosive exposure was conducted periodically. Over 2 days, the test pieces were immersed in the corrosive solutions to half of their height. At this time, as a result of capillary action, the sample underwent the saturation over their entire height. Then, the samples, saturated by the corrosive solutions, were dried for two consecutive days at 115 °C and cooled down at 20 °C for 24 h. The article presents the results after the full 5, 10, 15 and 20 cycles of the corrosive exposure. As a benchmark, the research results on samples of "reference" were set i.e. not exposed on the corrosion.

As the diagnostic features, determining the impact of the sulphate and chloride ions on mechanical properties of ceramic bricks, the compressive strength test and the hardness test, were selected [20].

3. The research methodology

3.1. The compressive strength test

The compressive strength test was performed in a universal testing machine Zwick 1200. The load was applied parallel to the forming element. The load speed was 1 MPa/s. The compressive strength test was performed on the dried samples, after each subsequent exposure of 5 cycles. The obtained results were the average of 15 determinations. Fig. 1 shows a method of testing the compressive strength.

Table 1
Properties physico-mechanical of ceramic materials brick.

Properties		
Compressive strength	69.5	[MPa]
Density	2.68	[g/cm^3]
Bulk density	1.83	[g/cm^3]
Water absorption by weight	14.3	[%]
Total porosity	31.6	[%]
Open porosity	26.2	[%]
Close porosity	5.4	[%]

Table 2
Chemical and phase composition of ceramic materials.

Parameter	[%]	Phase	[%]
Ignition losses	1.47	Quarz	59.0
SiO_2	64.8	Albite	7.0
Al_2O_3	16.0	Microcline	16.0
Fe_2O_3	5.74	Calcite	2.4
CaO	2.58	Montmorillonit	7.0
MgO	3.45		
K_2O	3.95		
MnO	0.13		
TiO_2	0.74		
P_2O_5	0.11		
SO_3	0.18		
Na_2O	0.53		
Cr_2O_3	<0.10		
ZrO_2	<0.10		

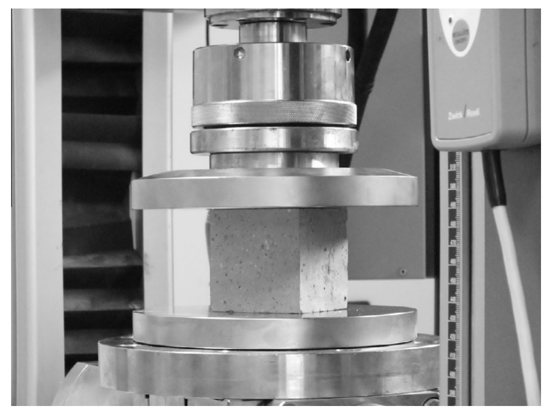

Fig. 1. The compressive strength test.

Fig. 2. The hardness test.

3.2. The surface hardness test

The surface hardness test was performed in a universal testing machine Zwick Z100 equipped with a Rockwell indenter with the diamond cone. The indenter entered into the test pieces at a constant speed of 1 mm/min. After entering the indenter to a predetermined