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AN APPLICATION OF ULTRASOUNDS TO ASSESSMENT OF HARMFUL SALTS ACCUMULATION IN THE BODY OF TRADITIONAL CERAMICS

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Abstract: *The long-term utilisation of the ceramic bricks in different conditions, particularly in the presence of moisture, induces the progressive changes, which over time can initiate a gradual loss of performance. This process is related to, inter alia, the collection in the texture of ceramic bricks the salts, derived from the external environment, which may crystallize in the pores of the material. Furthermore, they can form corrosion products in the reaction with the components of the shard. The presence of both enables the loss of performance of the material. Therefore, the studies were undertaken aimed at determining the ability of the various salts to accumulate in the shard of an ordinary ceramic bricks. The accumulation was evaluated on the basis of the mass change and measurements of the ultrasonic pulse velocity.*

Keywords: Ceramic brick, Accumulation of salts, Ultrasound.

1. Introduction

As a result of capillary of water, a porous texture of the ceramic brick is subjected to full saturation. This process often occurs in the walls of old buildings. Along the water, salts dissolved in it penetrate into the material (Hall and Hoff, 2009). Many of them, including salts of sulphate and chloride are not neutral to the sustainability of the brick body. The presence of salts in the ceramic brick changes its physical and mechanical properties. The porous texture promotes accumulation of corrosion products, and the crystallized salts with time of operation (Stryszewska and Wodnicka, 2013). Obviously, the intensity and speed of this process depends on the type and aggressiveness of the external environment and the output characteristics of the ceramic body (phase composition and pore structure).

The article presents the results of laboratory tests, which concerned the ability of accumulation of chloride and sulphate salts in the body of an ordinary brick. This process was monitored by measuring the mass change of tested samples and the determination of changes in the ultrasonic pulse velocity in the ceramic body, in which the porous texture gradually increases the amount of crystallized salts (Runkiewicz and Rodzik, 1990; Lewińska-Romicka, 2001; Hager, 2011).

2. Tested Materials

To the study, ceramic samples, cut out of a brick sized 235 x 115 x 70 mm, were selected. The tested ceramic material was characterized by the following properties (Kańka & Stryszewska, 2013):

- compressive strength 69.5 [MPa],
- actual density 2.68 [g/cm^3],
- bulk density 1.83 [g/cm^3],
- total porosity 31.6 [%],
- open porosity 26.2 [%],
- closed porosity 5.4 [%],
- mass absorption 14.3 [%].

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The mass variation and measurements of ultrasonic pulse velocity in the material were performed on cylindrical samples with a diameter of 75 mm and a height of 70 mm (thickness of the brick).

3. Research Methods

From a batch of manufactured products, undamaged bricks were chosen, from which adequate, cylindrical samples were cutout. After drying to a constant mass, the prepared samples were exposed to corrosion in solutions:

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

The corrosive exposure was carried out periodically. For two days, the tested pieces were immersed in corrosive solutions to ½ of the amount of the sample. At this time, as a result of the capillary action, the samples underwent saturation throughout their whole height. Then, the samples saturated with the corrosive solutions, were dried for two consecutive days at a temperature of 115°C. The article presents the results of a study involving 36 cycles of corrosive exposure performed on 5 samples in each environment.

As diagnostic features for determining the ability of accumulation of particular salts and corrosion products, formed in the ceramic body. The mass of corroded elements and the change of ultrasonic pulse velocity, measured a height of the cylinder, were tested. This method is based on the physical relationship between propagation of ultrasonic pulse velocity in the material and this material properties. In this case, the relationship between the ultrasonic pulse velocity and the density of material, that is a ceramic body. Tests were performed with a defectoscope Pundit Plus equipped with cylindrical probes with a frequency of 54 kHz. During the measurement, the probes (emitter and receiver) were placed opposite each other. To ensure the proper transmission of ultrasonic waves between the heads and the audited samples a coupling agent in was used.

The aim of the study was to determine the characteristic of changes in ultrasonic pulse velocity through the ceramic material, as a result of successive variations in the texture, during the cyclic exposure to corrosion. The particles of the medium begin to vibrate and transmit the part of their energy to the neighboring ones. Transferring of this energy is the essence of elastic wave motion and the speed of the transfer is the essence of the measurement. The potential impact of the geometry of the tested piece on the speed of propagation of the wave was eliminated by testing samples of the same shape.

4. Results and Analysis

Measurements of the mass and velocity of propagation of the ultrasonic pulse were performed after each full cycle that is after two days of saturation and two days of drying at 115 °C. The obtained results are the average values of 5 samples and they are shown in Figs. 1-3.

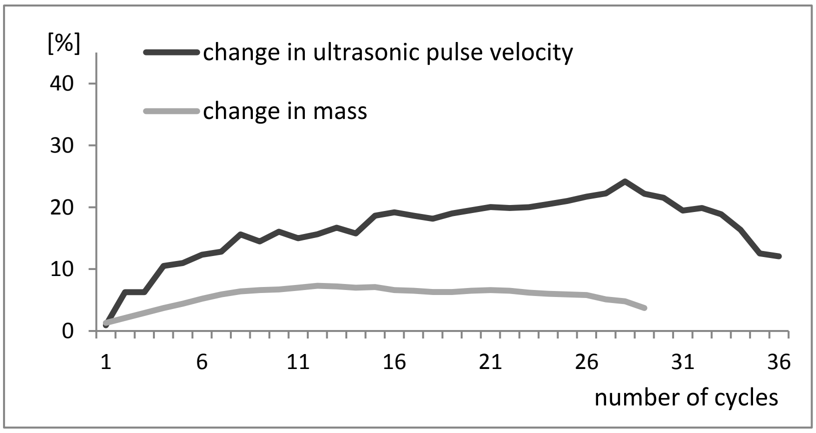

Fig. 1: Changes in mass and ultrasonic pulse velocity of body of the ceramic brick exposed to the of $MgSO_4$ environment.

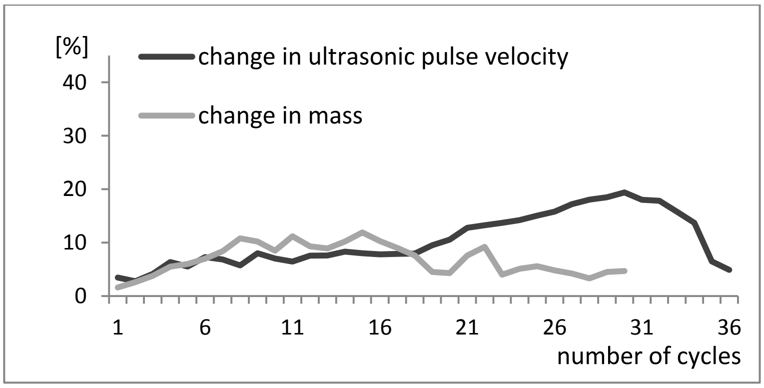

Fig. 2: Changes in mass and ultrasonic pulse velocity of body of the ceramic brick exposed to the of NaCl environment.

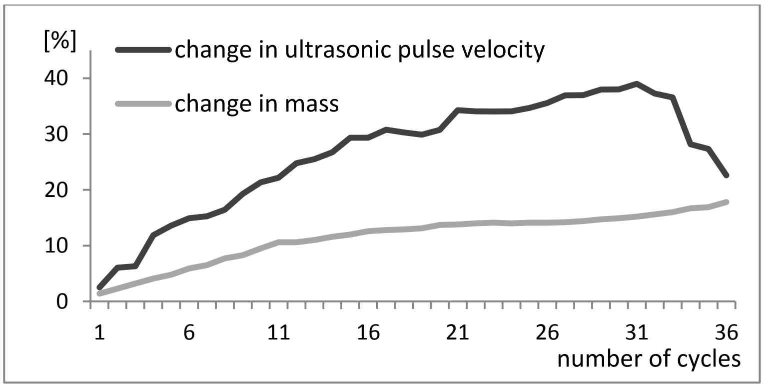

Fig. 3: Changes in mass and ultrasonic pulse velocity of body of the ceramic brick exposed to the of MgSO4 + NaCl environment.

In the initial period of corrosive exposure in all environments, obtained results reflect directly the weight of the salt, which crystallized in the material. However, in the long term, mass result was the outcome of two processes, the weight increase associated with the salts crystallization and the loss, as a effect of destruction of the tested piece. The corossive exposure has caused exfoliation, delamination of materials and formation of cracks.

In contrast, ultrasonic pulse velocity has proved the caulking process of the ceramic body, with increasing number of cycles, regardless of the corrosive environment. Despite of the weight decrease of the tested pieces, as a result of flaking or crumbling of the material, the body was undergoing of continuous sealing which was reflected in the recorded increase in ultrasonic pulse velocity. After obtaining the maximum of wave flow velocity, sharp decline was noticed, associated with waves attenuation on the verge of continous medium that was caulked by salts crystallized of the ceramic body, and medium devoided of discontinuity i.e. air-filled crack.

In the environment of magnesium sulphate, the mass measuring change of the samples and measuring of wave velocity, in the initial period of the exposure, i.e. up to the 10^{th} cycle, points to the sealing of the brick body. The continued exposure was connected with a decrease in mass while an increase in the ultrasonic pulse velocity was still observed. The mass loss was due to mechanism of intensive degradation of the upper and outer layers of the tested pieces. On the other hand, the core of samples has been undergone a constant caulking. The maximal increase of the velocity was recorded after 28 cycles and reached 25%.

Characteristics of changes in mass and the velocity of the wave flow for samples exposed in a solution containing only the chloride ions indicates the intensive weight gain during the initial study period, i.e .up to the 10^{th} of cycle. Maximum weight gain of samples reached 12%. The further process of exposure caused a rapid destruction of the material being tested. The characteristic of changes in the mass of samples after the 11^{th} cycle, illustrates the intense process of crushing and flaking of the material, accompanied by a process of accumulation of sodium chloride. In the next cycles of corrosion, the appearance of cracks and subsequent growth of those that had appeared previously, were observed. In this environment, the best results correlation of mass changes and changes in the wave velocity, was detected around the 17th cycle. The sudden increases of weight and velocity changes during this period of the exposure resulted from the intense process of peeling of the surface layers and the formation of small cracks in the deeper layers of the material. This resulted in a loss of continuity of the material at an early stage of the exposure. The maximum pulse velocity reached 20%, and was already registered after the 27th cycle. The further exposure was accompanied by the formation of distinct cleavage planes, the presence of which resulted in a sharp decline in ultrasonic wave velocity and the destruction of corroded elements.

In the environment containing both the chloride and sulphate ions, tested samples of the material in the entire study period were characterized by mass increase. Maximum mass gain reached nearly 20%. The measuring of the wave velocity was carried out simultaneuosly and it indicated that the sample of material corroded in this environment underwent the greatest caulking. Maximal increase of the pulse velocity was recorded after 30 cycles and reached the level of 40%. After this time, there was a decrease associated with the appearance of cracks in the material. In the final step of the exposure, the cracks appeared accompanied by decrease in the wave velocity. However, the material did not crumbleand peel. Thus, both the mass gain and changes in velocity reflected the ability of salts accumulation in the material texture.

5. Conclusions

On the basis of the study it was concluded that:

1. The ability to accumulate the salt in the body, as measured by mass change and the change of an ultrasonic pulse velocity, is clearly dependent on the type of salt.
2. No clear correlation between the results of mass measurement and measure of ultrasonic pulse velocity propagation, in relation to the number of cycles, after which maximum changes of the measured values was noted, is associated with a different mechanism of destruction of the corroded materials. In the case of destruction, which begins at the surface and progresses into the material, initially mass loss is primarly observed. In contrast, no effect on the change in the ultrasonic pulse velocity is noticed. Opposite to the issue, when the destruction depends on the formation of cracks in the entire volume of the material. This results in a decrease in both the mass and wave velocity of a comparable number of cycles of corrosion.
3. Characteristics of ultrasonic pulse velocity through the ceramic body with the passage of the number of cycles can be a basis for the assessment of changes occurring in the material under the influence of the external environment containing the sulphate and chloride ions.
4. Measurements of the ultrasonic pulse velocity is a non-destructive testing, therefore, to know the relationship between the speed of the wave passing through a ceramic brick and its texture can be a valuable source of information on the physical and chemical processes occurring in the material. This is of particular importance for the assessment of the technical condition of historic buildings.

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