BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 62 (66), Numărul 4, 2016
Secția
CONSTRUCȚII. ARHITECTURĂ

INFLUENCE OF SOLUBLE SALTS CRYSTALLIZATION ON THE PHYSICAL CHARACTERISTICS OF MASONRY CERAMIC ELEMENTS

BY

DIANA- ANDREEA CLIM (PEGESCU- CLIM)*, LIVIU GROLL and LIVIA- INGRID DIACONU

“Gheorghe Asachi” Technical University of Iași,
Faculty of Civil Engineering and Building Services,

Received: November 28, 2016
Accepted for publication: December 26, 2016

Abstract. Moisture represents the main cause for the degradation of historical buildings. In addition to the negative effects moisture has on the construction elements, it also carries soluble salts from the soil or from the materials it passes through the capillary pores, thus fostering the acceleration of the degradation processes. The main objective of this research is to establish the influence of soluble salts crystallization in the pores of construction materials on their physical characteristics.

Keywords: crystallization; soluble salts; moisture; physical characteristics; masonry ceramic elements.

1. Introduction

The presence of moisture in the construction elements has a significance role in their degradation, a fact proven especially with old buildings, where the used construction materials has high open porosity and have been subjected to the action of climatic factors for a long period. Ceramic elements for masonry

*Corresponding author: *e-mail:* dianaclim@yahoo.com

are extremely sensitive to water action because of the nature of their constituents (Frattari *et al*., 2005) and their dimensions, respectively because of the pore distribution in the material. The factors that influence the modification of physical characteristics of ceramic elements, because of water action, are porosity, permeability to vapours, water absorption capacity and the presence of soluble salts (Niculiță & Liviu Groll, 2007). As a result of the pressure exercised by salt crystallisation in the pores of the material, there are micro-cracks in its frame, thus accelerating the degradation process. The crystallisation pressure is the pressure which must be borne by the material matrix to prevent the growth of salt crystals in the pores (Seiger & Armussen, 2008). This mechanism is very aggressive and, combined with the effect of freeye- thaw, it has a devastating impact on the structure of construction materials. The presence of these salts is a result of either water in the soil which transports them through the material capillary pores, or of the constituents of construction elements. Very frequent are chlorides, especially sodium chloride and magnesium, calcium or sodium sulphates (Frattari *et al*., 2005).

In the field literature, the influence of salts crystallised in the materials pores on their physical characteristics and mechanical resistances (Foraboschi & Vanin, 2014; Cobîrzan & Balog 2013) is presented unclearly and ambiguously. Researchers draw attention especially on the anaesthetic character of efflorescence (salt crystallisation on the surface of the material) and neglect the destructive effects of the apparition of under-efflorescence (Gentilini *et al*., 2012) (Fig. 1 – salt crystallisation in the material pores). Numerous studies underline the modification of the physical characteristics of construction materials because of the action of the salts, but they do not precisely state the variations produced and the parameters influencing them. For this purpose, we have carried out an experimental study which has as objective to establish the influence of soluble salts crystallisation on the physical characteristics of masonry elements.

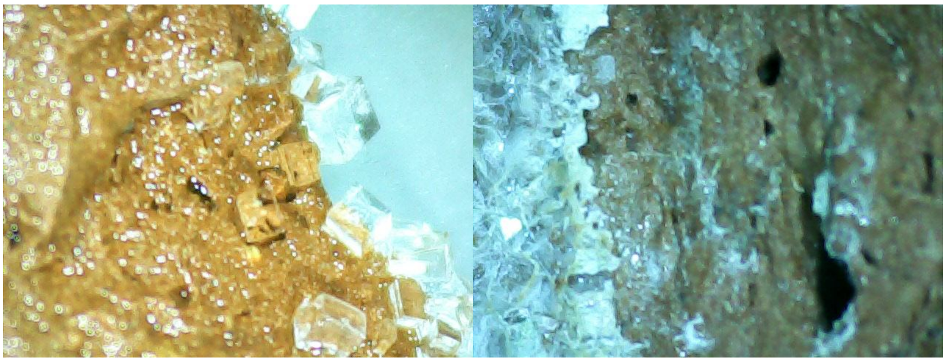
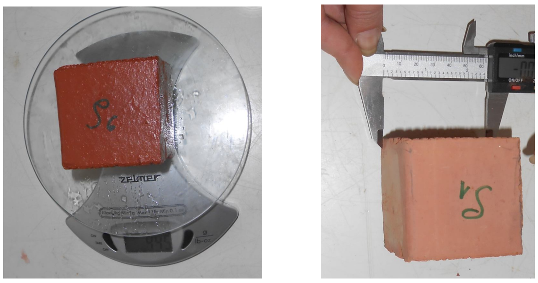


Fig. 1 – Crystallization of salts in the material pores – microscopic image x 20.

2. Research Methodology

The experimental study was carried out on nine 63 mm assay-samples extracted from the masonry ceramic elements. The samples were dried at constant mass (in accordance with SR EN 772:2005) in a drying cabinet ventilated at +105°C ± 5°C, then three assay-samples were distributed for the calcium chloride solution with a 10% concentration, other three samples were distributed for the calcium chloride solution with a 20% concentration, and the remaining three assay-samples were kept as reference samples. All samples were measured and weighed, and the initial data was registered (Fig. 2 *a*).



a *b*

Fig. 2 – Measuring and weighing of the specimens.

Then two containers with calcium chloride solution were prepared (Fig. 2 *b*), of 10% and 20% concentration, respectively. Three tubes for each were positioned on supports, in each container, and solution was added up to ¼ of the assay-samples height. These were left in the solution for 24 h, and then the solution was raised to the level of ½ the assay-samples height. After another 24 h, the level of the solution was raised until it exceeds the samples height by 2 cm (Fig. 3). This procedure of progressive immersion ensures air replacement in the material's pores with calcium chloride solution, thus ensuring sample saturation.

a *b*

Fig. 3 – *a* – Calcium chloride, *b* – assay-samples in calcium chloride solution.

The assay-samples were left in the solution for 48 h, in laboratory conditions. After that, they were taken out, the surplus was removed by wiping with a moist cloth and the samples' mass in saturated state was weighed. Then, the assay-samples were dried at constant mass in a drying cabinet ventilated at +105°C ± 5°C for 24 h (Fig. 4). After the samples' mass in dried state was registered, they were left to cool in the laboratory and then the immersion procedure was restarted. 8 complete drying-saturation cycles, comprising 9 drying stages and 8 stages of saturation in calcium chloride solution, were carried out.

Fig. 4 – Ventilated drying cabinet.

After the final mass of the assay-samples in dry state was registered, the following physical characteristics were determined: apparent density, apparent porosity, and water absorption.

Apparent density represents mass per unit of apparent volume, after drying at constant mass (SR EN 772-13:2005), and it is determined with:

$$\rho_{g,u} = \frac{m_{\text{dry},u}}{V_{g,u}} \times 10^6, \ [\text{kg/mm}^3], \tag{1)}$$

where: $m_{\text{dry},u}$ is the element mass, in dry state, in grams; $V_{g,u}$ – apparent volume, [mm^3]; $\rho_{g,u}$ – sample density, in dry state, [kg/m^3].

Apparent porosity represents the pore volume in relation to the apparent volume of the assay-sample (Babor & Plian, 2009), and it is determined with:

$$n_a = \frac{m_s - m_u}{\rho_1} \cdot \frac{1}{V_a} \times 100, \ [\%], \tag{2}$$

where: m_s is the element mass, in wet state, [g]; m_u – element mass, in dry state, [g]; V_a – apparent volume, [mm^3]; ρ_1 – liquid density, [kg/cm^3].

Water absorption capacity of the masonry ceramic elements and it is determined in accordance with SR EN 771-1:2003/Annex C. The assay-samples, dried at constant mass and cooled at ambient temperature, are introduced in a water tank, on supports, taking into account the fact that all sides of the samples must be in contact with the water. After 20 h, the samples are taken out, wiped with a moist cloth to remove water surplus and are weighed. The water absorption capacity is determined with eq. (3), with a precision of 1%:

$$w_m = \frac{m_w - m_d}{m_d} \times 100,\ [\%], \tag{3}$$

where: m_w is the element mass, in wet state, [g]; m_d – element mass, in dry state, [g]; w_m – water absorbtion capacity.

3. Results

3.1. Variation of Assay-Samples' Mass During the Saturation-Drying Cycles

Research noticed a linear variation, in ascendant direction, of the mass of the assay-samples subjected to the saturation-drying cycles (Fig. 5). This is a

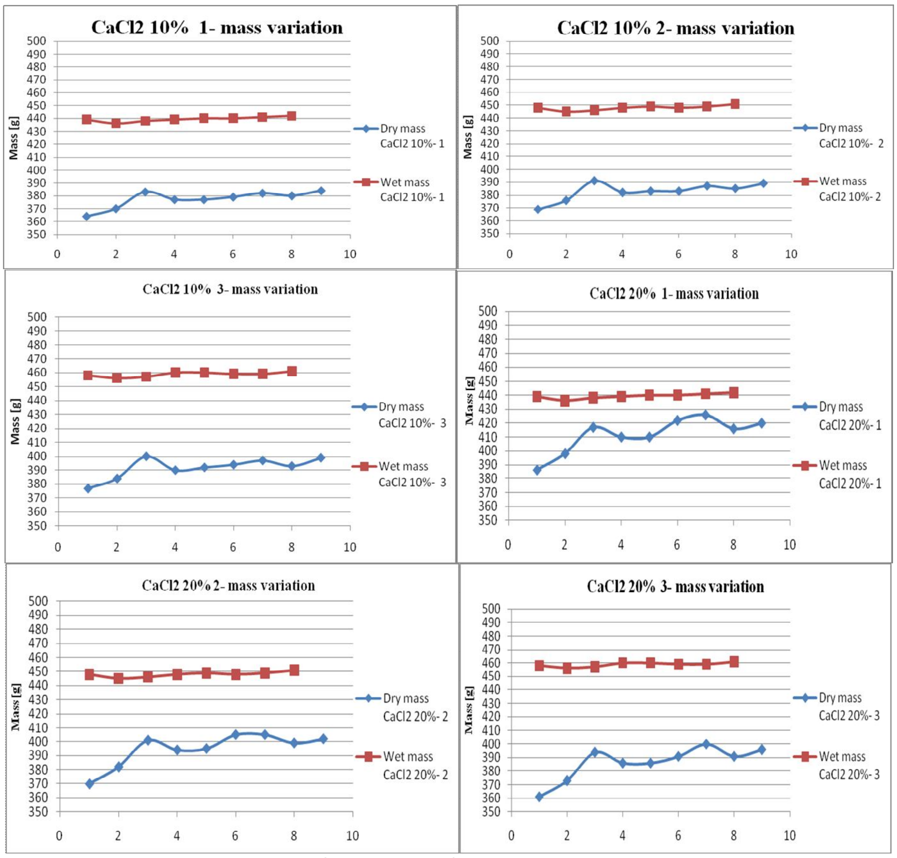


Fig. 5 – Variation of the mass of the assay-samples subjected to calcium chloride solution crystallisation cycles.

result of soluble salts crystallisation in the materials pores, part of the crystallised solution remaining in the pores from one cycle to the other and reducing their dimensions. Thus, the final average mass of the samples in the 10 % concentration solution rises by 5.58 %, and that of the samples in the 20 % concentration solution rises by 9.04 %.

3.2. Apparent Density

There is a 2.81 % increase of the average apparent density for the samples immersed in 10 % concentration calcium chloride solution and an increase of 9.94 % for the assay-samples immersed in 20 % concentration calcium chloride solution, as compared to the reference assay-samples (Fig. 6).

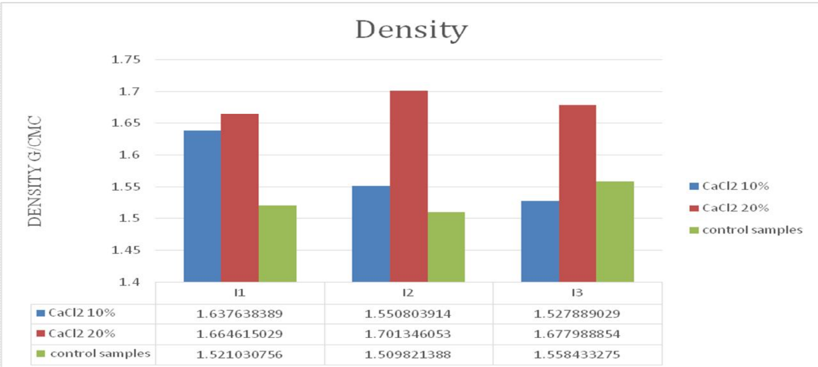


Fig. 6 – Apparent density.

3.3. Apparent Porosity

After the data was analysed, there was an average decrease of 18,37 % of the apparent porosity for the samples immersed in 10 % concentration calcium chloride solution, respectively 33.80 % for the ones in 20 % concentration calcium chloride solution (Fig. 7).

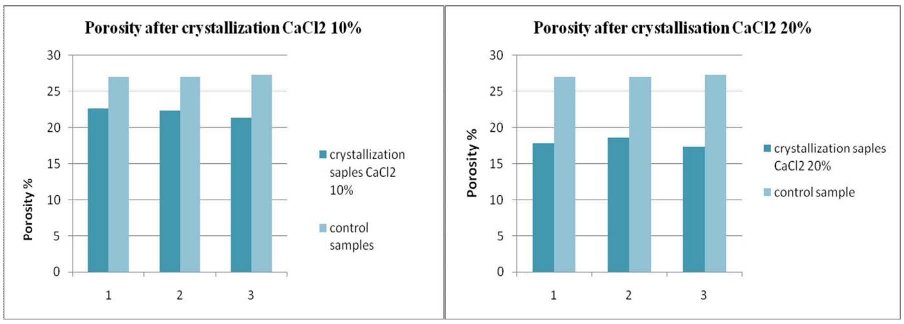


Fig. 7 – Apparent porosity.

3.4. Water Absorption

There was a decrease of the average water absorption by 20.55% for the samples immersed in 10% concentration calcium chloride solution, respectively by 39.75% for the ones in 20% concentration calcium chloride solution (Fig. 8).

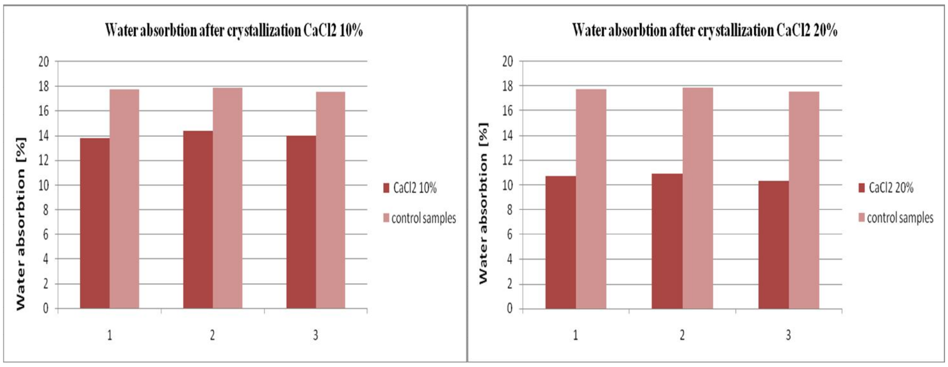


Fig. 8 – Water absorption.

4. Discussions and Conclusions

In accordance with the objectives set in the experimental plan, the research noticed that the presence of soluble salts, especially their crystallisation in the materials pores, has a major influence on the modification of the physical elements of the masonry ceramic loments.

It can be observed that, from one saturation-drying cycles to the other, there is crystallised sodium chloride solution remained in the materials pores, the mass of the assay-samples varying both linear and in an ascendant direction. This phenomenon, although apparently insignificant, can have extremely negative effects because, with the increase of the concentration of the solution, there is an increase of the crystallising solution, thus fostering cracks in the material matrix.

Another aspect worth mentioning is the significant decrease of the water absorption. This aspect could be favourable to construction materials, but, once the water absorption capacity decreases, vapour permeability also decreases, thus fostering condensation.

In conclusion, in accordance with the data obtained in the experiment, the soluble salts crystallisation phenomenon influences significantly the physical characteristics of masonry ceramic elements. Future studies will establish whether the presence of soluble salts has a positive or a negative impact on the mechanical characteristics of ceramic elements.

REFERENCES

Babor D., Plian D., *Încercarea materialelor de construcție*, Vol. **I**, Edit. Karro, Iaşi, 2009.

Cobîrzan N., Balog A., *Analysis of Rendering Mortars Decaz Due to Salt Attack*, J. of Appl. Engng. Sci., **3**, *16*, 21-26 (2013).

Foraboschi P., Vanin A., *Experimental Investigation on Bricks From Historical Venetian Buildings Subjected to Moisture and Salt Crzstallization*, Engineering Failure Analysis, **45**, 4291-4306 (2014).

Frattari A., Albatici R., Brumaru M., Palacean S., *Umiditatea în elementele de zidarie* – Modul de curs nr. 2, Universitatea Tehnică, Cluj- Napoca, 2005.

Gentilini C., Franyoni E., Bandini S., Nobile L., *Effect of Salt Cristalisation on the Shear Behavoir of Masonrz Walls: An Experimental Study*, Construction and Building Materials, **37**, 181-189 (2012).

Niculiță M., Groll L., *Consolidarea clădirilor de patrimoniu*, Edit. Societații Academice "Matei- Teiu Botez", Iaşi, 2007.

Seiger M., Armussen S., *Crystallization of Sodium Sulfate Phasses in Porous Materials: The Phase Diagram Na_2SO_4-H_2O and the Generation of Strss*, Geochimica et Cosmochimica Acta, **72**, 185-203 (2008).

* * * SR EN 771-1:2003/Anexa C.

* * * SR EN 772-13:2005.

INFLUENȚA CRISTALIZĂRII SĂRURILOR SOLUBILE ASUPRA CARACTERISTICILOR FIZICE ALE ELEMENTELOR CERAMICE PENTRU ZIDĂRIE

(Rezumat)

Umiditatea reprezintă principala cauză a degradării clădirilor istorice. Pe lângă efectele negative pe care prezența umidității le are asupra elementelor de construcție, aceasta transportă săruri solubile din sol sau din materialele pe care le traversează, prin porii capilari, favorizând astfel accelerarea proceselor de degradare. Obiectivul principal al acestei cercetări este stabilirea influenței cristalizării sărurilor solubile, în porii materialelor de construcție, asupra caracteristicilor fizice ale acestora.