Bulletin of the *Transilvania* University of Braşov • Vol. 10 (59) Special Issue No. 1 - 2017
Series I: Engineering Sciences

EFFECTS OF SOLUBLE SALTS CRYSTALLIZATION ON THE MECHANICAL CHARACTERISTICS OF CERAMIC MASONRY ELEMENTS

D. CLIM (PEGESCU-CLIM)[1] **L. DIACONU**[1]

Abstract: *Soluble salts crystallization in the pores of ceramic elements for masonry induces significant modifications of their physical and mechanical characteristics. Although the mechanism of the degradation of construction elements caused by salt crystallisation is common with most all buildings, the phenomenon has not been thoroughly studied. The paper contributes to the investigation and diagnosis of historical buildings both by determining the degradation mechanisms and by underlining their effects on construction materials. The aim of the study is to determine by means of scientific methods the influence of the crystallisation phenomenon on the compressive strength of ceramic elements.*

Key words: *crystallization, soluble salts, ceramic elements, masonry, degradation mechanism.*

1. Introduction

In the long run, society has understood the importance of the conservation of the built patrimony, thus identifying the need for the investigation, diagnosing, rehabilitating and monitoring of old buildings. Most of the built edifices are seriously affected by humidity, especially ascending [1]. The degradations caused by this phenomenon are multiple, from esthetic degradation, such as exfoliations, plaster expulsion, degradation of ornaments, to mechanical degradation which can cause diminishment of the resistance characteristics, corrosion of the reinforcements, contraction of elements section etc. [2].

One controversial degradation mechanism is the one caused by soluble salts present in the pores of construction materials. Specialized literature treats this degradation mechanism ambiguously and superficially, focusing on the ugly character of the degradation caused by soluble salts on construction materials, an effect known as efflorescence. In addition to unaesthetic aspect caused by them on the parameters of old constructions, the soluble salts content has a negative influence on the mechanical performances of construction elements. These modifications appear after numerous salts hydration dehydration cycles, when stains are not so obvious anymore and change their colour from white, into colours similar to the materials they form on. [3] The crystallization of saline solutions in the capillaries of construction materials represents an

[1] "Gheorghe Asachi" Technical University of Iaşi, Faculty of Civil Engineering and Building Services

important degradation mechanism. Because of the pressure exercised by crystallization, micro-cracks can appear in the element matrix, which can lead to significant modifications of the resistance characteristics [4].

The degradation processes which are based on chemical actions have effects regarding both aesthetic characteristics and mechanical ones. Studies have shown that when construction elements (ceramic elements connected with mortar) reach saturation humidity, mechanical resistances diminish by approximately 50 %, and salt crystallization phenomena have a major impact on the structural performances of construction elements [5].

The main aim of the paper is to determine the influence of soluble salts crystallization in the pores of ceramic elements on the mechanical characteristics, as many historical buildings affected by humidity are made of full brick masonry.

2. Description of the Building

The experimental study was carried out on 18 test samples extracted from the ceramic elements for masonry with a side of 63 mm. The test samples were dried at constant mass in the drying chamber ventilated at +105°C ± 5°C, then they were distributed as follows:

- three test samples to be immersed in sodium chloride solution, with a concentration of 10%;
- three test samples for the sodium chloride solution of 20% concentration;
- three test samples for the sodium chloride solution of 30% concentration (Figure 1);
- three test samples for the calcium chloride solution of 30% concentration (Figure 2);
- three test samples for a mixture of sodium chloride solution of 5% concentration and calcium chloride concentration of 5% concentration;
- the last three were saved as reference samples (Figure 3). All test samples were measures and weighed and the initial data was recorded.

The building belonging to the Municipal Theatre from Turda city and subjected to the analysis was built between 1901 and 1904, having different destinations at the beginning, later becoming a theatre, respectively the municipal theatre of the city.

The partial building was built on an existing basement of another building, constructed in 19th century.

The height of the building is about 6.58m (B+GF+attic), respectively 12.98 m (B+GF+2nd floor+attic) (Figure 1).

Fig. 1. *(a) ceramic test samples; (b) ceramic test samples prepared to be immersed in sodium chloride solution*

Fig. 2. *Ceramic test samples prepared to be immersed in calcium chloride solution 30%*

Fig. 3. *Reference ceramic test samples*

Then, five recipients were prepared as follows:

- three recipients with sodium chloride solution, with concentrations of 10%, 20 %, respectively 30%;
- one recipient with calcium chloride, of 30% concentration;
- one recipient with a mixture of calcium chloride solution of 5% concentration and calcium 5%.

Three cubes each were positioned on supports in each recipient and solution was added up to ¼ of the height of the test samples. These were left in the solution for 24 h, after which the level of the solution was completed to ½ of the height of the test samples. After other 24h, the solution level was completed until it exceeds the height of the test samples by 2 cm. This procedure of progressive immersion ensures the replacement of air in the material pores with calcium chloride solution, thus ensuring sample saturation.

The samples were left in the solution for 48 h, in laboratory conditions, then they were removed, the surplus of solution was removed with a damp cloth and the mass of the samples in saturated state was recorded (Fig. 4). The test samples were then dried at constant mass in the drying chamber ventilated at the temperature of +105°C ± 5°C, for 24 h. After the mass of the samples in dried state was recorded, they were left to cool down in the lab, after which the immersion procedure was repeated. 8 complete drying – saturation cycles were performed, comprising 9 drying stages and 8 saturation stages.

Fig. 4. *Ceramic test samples prepared for mass determination*

After the final mass of the test samples was recorded in dried state (Figure 5), compressive strength was determined (Figure 6).

Fig. 5. *Ceramic test samples after drying*

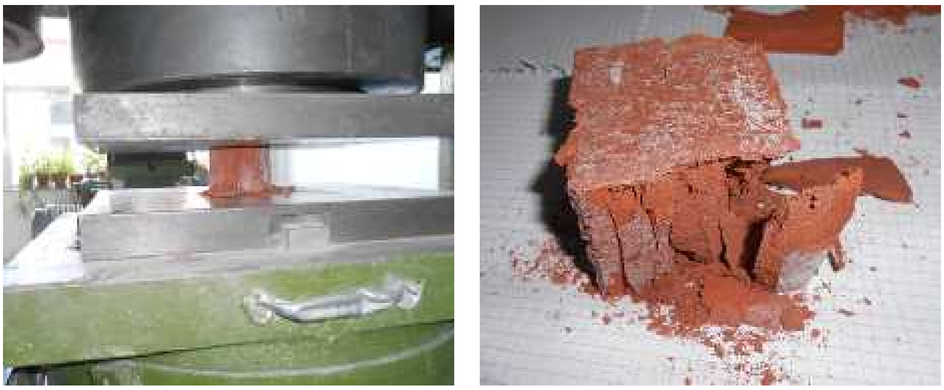

Fig. 6. *Ceramic test sample (left) during the determination of compressive strength and (right) after determination*

3. Results

3.1. Variation of the Test Samples Mass During the Saturation – Drying Cycles

A linear ascending variation of the mass of the test samples subjected to the saturation – drying cycles is observed. This is caused by the crystallisation of soluble salts in the material pores, from one cycle to the other, reducing their dimensions.

Thus, the final average mass of the samples:

- of the sodium chloride solution of 10% concentration increases by 12.66% (Figure 7);
- of the sodium chloride solution of 20% concentration increases by 18.52% (Figure 8);
- of the sodium chloride solution of 30% concentration increases by 23.01% (Figure 9);
- of the calcium chloride solution of 30% concentration increases by 13.87% (Figure 10);
- of the calcium chloride solution of 5% concentration and sodium chloride solution of 5% concentration increases by 9.97 % (Figure 11).

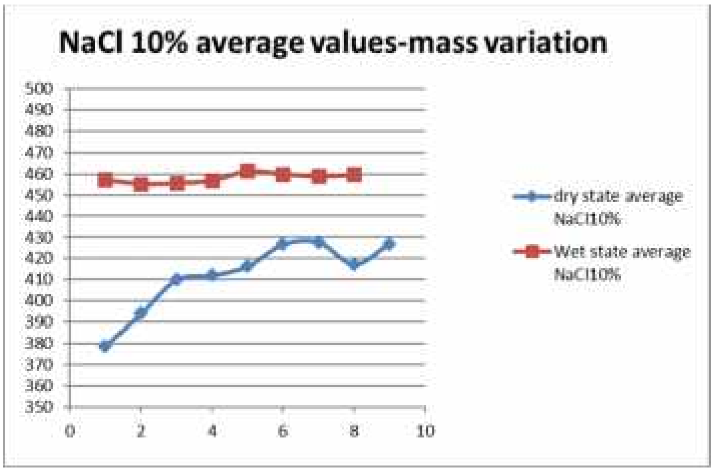

Fig. 7. *Average mass variation of samples immersed in sodium chloride solution 10*

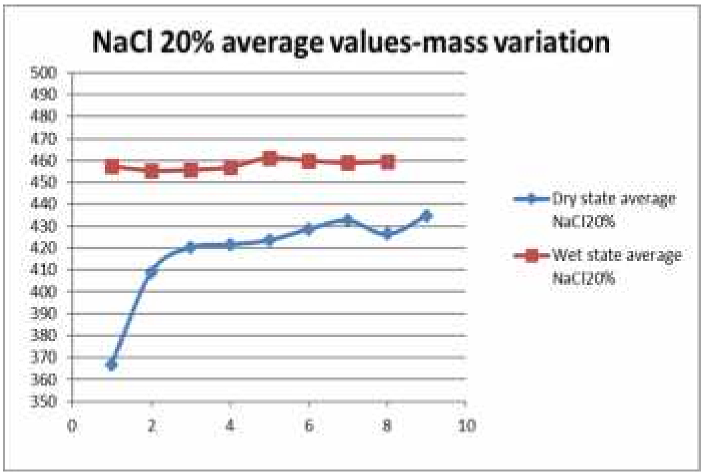

Fig. 8. *Average mass variation of samples immersed in sodium chloride solution 20%*

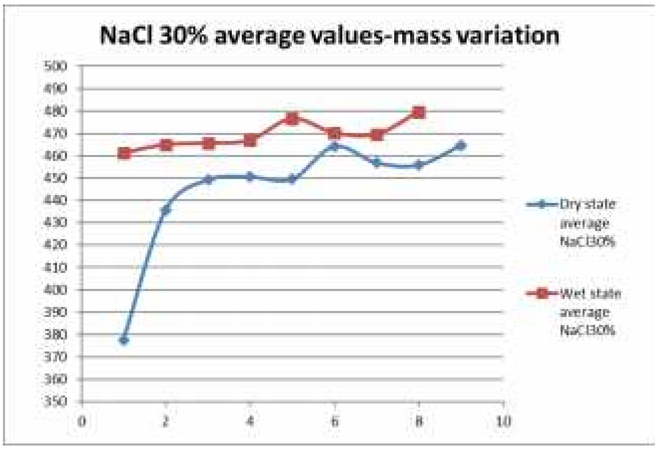

Fig. 9. *Average mass variation of samples immersed in sodium chloride solution 30%.*

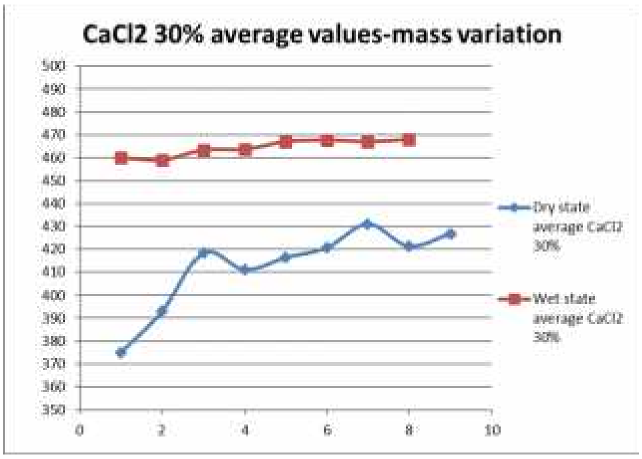

Fig. 10. *Average mass variation of samples immersed in calcium chloride solution 30%.*

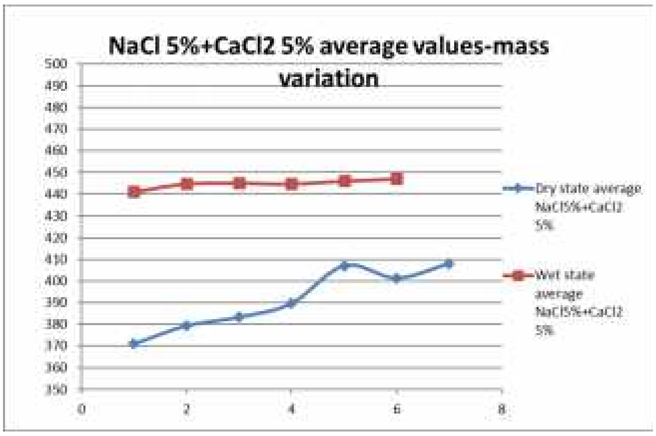

Fig. 11. *Average mass variation of samples immersed in calcium chloride solution 5% and sodium chloride 5%.*

3.2. Determining compressive strength for ceramic samples subjected to the crystallisation of soluble salts in materials pores

As a result of experimental tests, it was observed that the compression resistances of the ceramic test samples subjected to the crystallisation of soluble salts in the materials pores suffer modifications (Figure 12), as follows:

- for the test samples immersed in sodium chloride solution, 10 % concentration, we noticed an increase of the average value of the compression resistance by 3.95 % of the reference value;
- for the test samples immersed in sodium chloride solution, 20 % concentration, we noticed a decrease of the average value of the compression resistance by 7.07 % of the reference value;
- for the test samples immersed in sodium chloride solution, 30 % concentration, we noticed a decrease of the average value of the compression resistance by 49.01 % of the reference value;
- for the test samples immersed in calcium chloride solution, 30 % concentration, we noticed a decrease of the average value of the compression resistance by 5.73 % of the reference value;
- for the test samples immersed in sodium chloride solution, 5 % concentration and calcium chloride 5 %, we noticed a decrease of the average value of the compression resistance by 10 %, of the reference value.

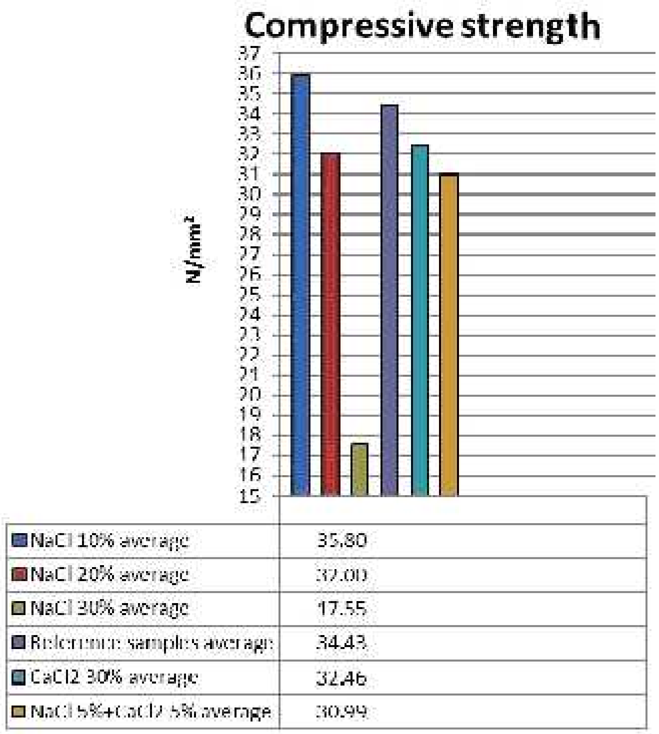

Fig. 12. *Average of values obtained for the compressive strength of ceramic elements*

4. Conclusions

This experiment demonstrates that the salts crystallised in the pores significantly modifies the compressive strength of the ceramic elements for masonry.

The test conclusions are limited, and the results cannot be extrapolated to the on-site situations because with existent buildings the phenomenon of the crystallisation of soluble salts in the materials pores is joined by freeze thaw, material aging, erosion and degradation caused by weather, mixtures of crystallising solutions, some coming from underground water, others from effluent waters or pollution of the environment. Thus, the conditions on site are much more complex than the conditions studied in the laboratory. However, based on the study, new research directions can be created in order to help conceive new solutions and techniques to eliminate humidity adequate for historical buildings.

References

1. Franzoni, E.: *Rising dump removal from historical masonries: A still open challenge*, Construction and Building Materials 54, 2014, pp. 123-136..
2. A. Frattari, R. Albatici, translated by M. Brumaru, S. Palacean, Umiditatea în elementele de zidarie- Modul de curs nr. 2, Universitatea Tehnică din Cluj- Napoca, 2005.
3. Fragata, A., Veiga, M.R., Velosa, A.: *Substitution ventilated render systems for historic masonry: Salt crystalisation tests evaluation*, Construction and Building Materials 102/ 2016, pp. 592-600.
4. Seiger, M., Armussen, S.: *Crystallization of sodium sulfate phasses in porous materials: The phase diagram Na2SO4-H2O and the generation of stress*, Geochimica et Cosmochimica Acta 72/2008, pp. 185-203.
5. Gentilini, C., Franzoni, E., Bandini, S., Nobile, L.: *Effect of salt cristalisation on the shear behavoir of masonry walls: An experimental study*, Construction and Building Materials 37/ 2012, pp. 181-189.