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## Damage to Polymer Coating on Facing Brick Surface in Operated Buildings

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### Abstract

The article describes the main reasons of efflorescence on the facing brick surface coated with polymer that leads to its delamination in operated buildings. To reduce efflorescence moisture, infiltration in the masonry should be reduced, the rate of which depends on the capillary porous structure of bricks. To control the porosity, building ceramic is suggested to be modified with multi-walled carbon nanotubes dispersions of Graphistrength CW 2-45, which enhances the structure of adobe, improves its sintering, increases the structure uniformity of ceramic fragments and efflorescence resistance. Ceramic matrix of the modified samples before and after firing has a dense and uniform microstructure with the minimum of deep interconnected pores. Adding carbon nanotubes in the amount of 0,001 % from the formed mass provides the modification of the ceramic matrix and improves its physical and mechanical properties by 30-35 %.

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**Keywords:** efflorescence; ceramic bricks; polymer coating; multi-walled carbon nanotubes; nanomodification

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## 1. Introduction

Studying efflorescence processes on brick facades of the buildings under construction and the operated ones as well as its prevention has always been important in the construction industry. Currently, the focus of attention is on efflorescence on ceramic brick coated with thermoplastic polymer paint, where efflorescence not only spoils its appearance, but can also lead to the damage to polymer coating.

Efflorescence on brickwork appears depending on the salt content in both brick and mortar and the environmental parameters, including humidity, temperature, and chemical composition [1]. The intensity of efflorescence can also be associated with the pore size and their volume in ceramics, because the migration of soluble salts is due to its capillary porous structure. It is known [2] that, the pore diameter being 30–400 nm, the equilibrium moisture content reaches its maximum in the range of the pore size above 300 nm. Also, the capillary effect intensifies, the pore size increasing. At the same time, the structure with the pores in the range of 30–300 nm increases the specific surface area, which provides longer diffusion path of water with dissolved salts due to the forced rounding of the pore structure [3]. As a result, the concentration of dissolved salts on brick surface is minimized, which prevents efflorescence formation. Researchers [4] show that the increased migration of solutions through brickwork is associated with large pores with the diameter exceeding 1 micron. Thus, the directed change of the porous brick structure decreasing the number of large pores reduces efflorescence on masonry surface.

One of the ways to modify the ceramic matrix is using various admixtures, including nanoparticles [5, 6]. In the scientific literature, there is evidence that adding carbon nanotubes improves ceramics sintering and increases its structure uniformity [7, 8, 9]. Furthermore, some authors have proved that carbon nanotubes limit the grain growth during sintering, contributing to the formation of a fine-grained ceramic matrix [10, 11].

This article describes the main reasons of efflorescence on the polymer coating of ceramic brick and also offers the solution. It is assumed that modifying building ceramics with the dispersions of Graphistrength CW 2-45 multi-walled carbon nanotubes (MWCNTs) enhances the sintering behavior of fragments and the uniformity of the ceramic matrix structure.

## 2. Materials and methods

### 2.1. Preparing samples

The study focuses on the masonry from M125 facing brick with polyester-based polymer coating. This coating is applied by spraying powder paint on the fired brick surface in a heat chamber.

To study the effect of MWCNTs on the properties and structure of building ceramics a ceramic batch similar to the industrial mix was used. The batch consists of 70 % of low-melting clay containing 13,33–16,10 % of aluminum and titanium oxides, and 30 % of quartz sand. The nano-admixture used is Graphistrength CW 2-45 MWCNTs (Arkema, France), the average diameter being 10–15 nm and the length of 10–15  $\mu\text{m}$ . For the uniform distribution of nanoparticles, two types of aqueous MWCNT dispersions were produced in a high speed homogenizer: dispersion 1 was not exposed to ultrasonic treatment; dispersion 2 was put through sonication. The dispersity analysis conducted with CILAS 1090 Liquid instrument showed that after 21 days of storage the average particle diameter in dispersion 1 is 2,53 microns, and in dispersion 2 - 0,65 microns. MWCNTs were added to the batch in the amount of 0,001 % and 0,009 % from the clay mass with water for moistening up to 21,85 – 22,85 % mixing water content. The molded samples were dried at  $20 \pm 5$  °C for 2 days and at 105 °C for 1 day in a chamber drier. After drying, the samples were fired with the isothermal time of an hour at the maximum firing temperature of 950 °C and 1000 °C.

### 2.2. Analysis methods

The macrostructure of the samples was studied with AM4113ZT Dino-Lite Pro Polarizer USB-microscope. The microstructure analysis was conducted with PHENOM G2 Pure and Quanta 250 (FEI Company) scanning electron microscopes. IR spectra were obtained using SpektrumOne, a Fourier transform infrared spectrometer in the frequency range of  $4000\text{--}400\text{ cm}^{-1}$ .

### 3. Results

#### 3.1. Research findings

Figure 1 shows typical damage to polymeric layer observed in the areas of prolonged exposure of the brickwork on the bows to water. Damage to polymeric coating is caused by efflorescence appearing on the layer boundary with the ceramic surface (Fig. 1 b). Water flushes out the soluble salts from brickwork which migrate to wall surface through the pores of brick and then crystallize on it.

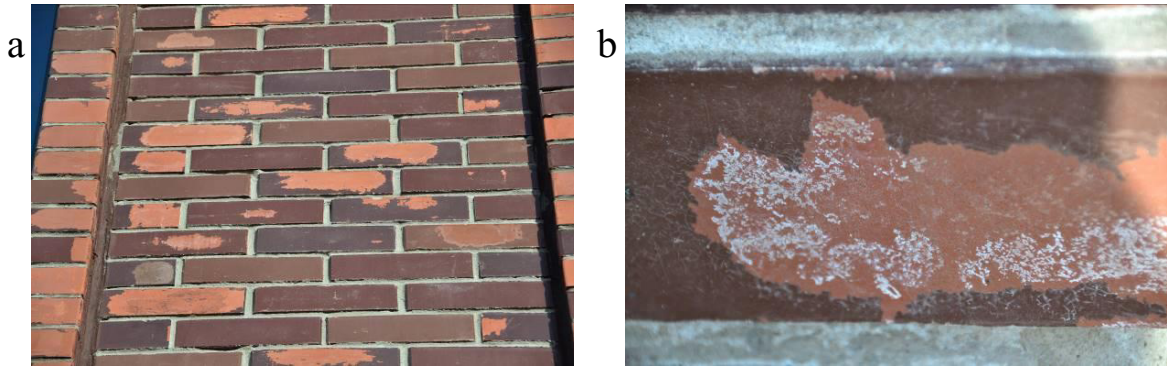


Fig. 1. General view of damage to brickwork on building facade:  
(a) delamination of polymer coating on masonry surface, (b) scaling of polymer coating resulting from salt crystallization

The pictures of macro- and microstructure of the masonry surface show the presence of micropores of 15-20 microns filled with crystallizing salts (Fig. 2).

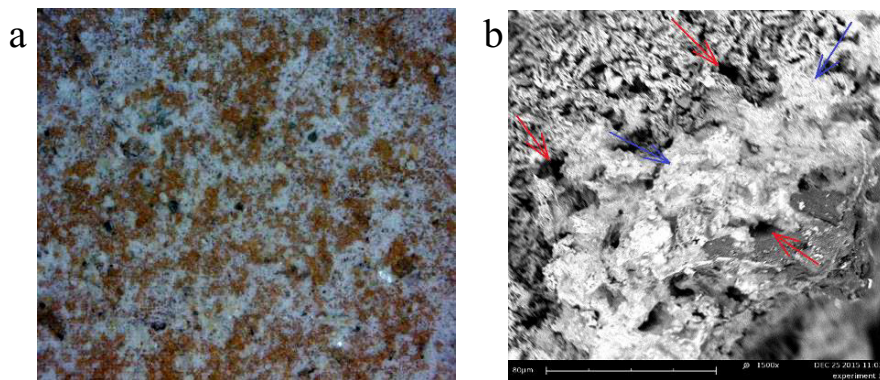


Fig. 2. Microstructure of brick surface with efflorescence: (a) at 200X magnification,  
(b) at 2500X magnification (red arrows pointing at pores, blue arrows showing crystallizing salts)

The potential sources of soluble salts [12] are ceramic brick and mortar with plasticizing and antifreeze admixtures. In order to find the source and composition of efflorescence, IR spectral analysis was conducted of the efflorescence samples from the brick surface (Fig. 3) and the aqueous extracts from ground brick samples dried at the temperature of 105 °C.



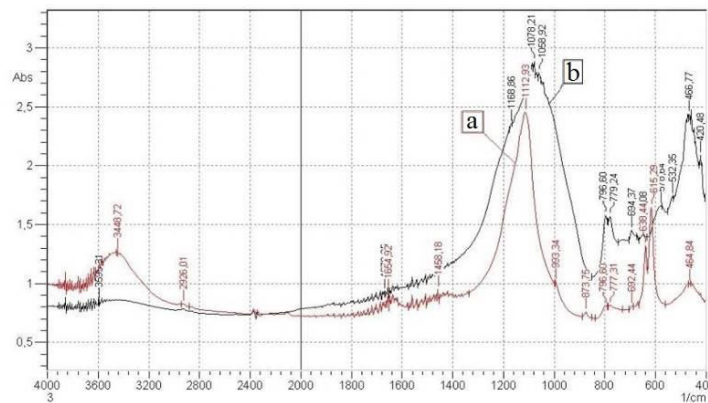


Fig. 5. IR spectrum of aqueous extracts from ground brick from plant (a), control IR spectrum of sodium sulfate (b)

The aqueous extract from ground brick (Fig. 5) has no traces of sodium sulfate or calcium carbonate. The main absorption line in the spectrum of  $\nu = 1078 \text{ cm}^{-1}$  corresponds to the group  $-\text{Si-O-Si}-$  typical for silicon oxide in ceramics.

The IR spectral analysis of the plasticizing admixture Azolit-TR (Fig. 6) used in the masonry mortar shows the presence of sodium sulfate ( $\nu = 1117 \text{ cm}^{-1}$ ). The solubility of sodium sulfate is 19.2 g/l, therefore, its solution can easily migrate into the brickwork and form efflorescence later.

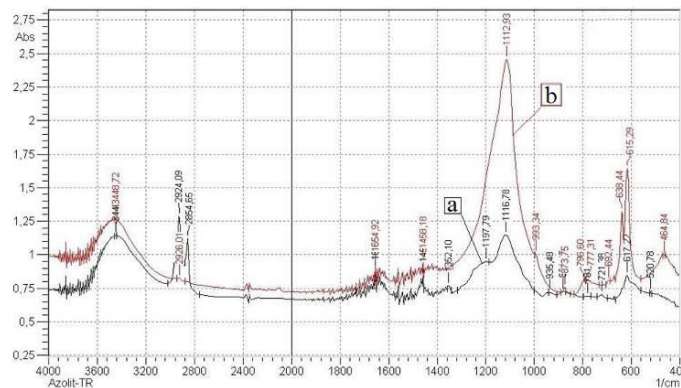


Fig. 6. IR spectrum of Azolit-TR plasticizing admixture (a), control IR spectrum of sodium sulfate (b)

Thus, the source of calcium carbonate and sodium sulfate salts is masonry mortar with plasticizing admixtures containing sodium salts.

Moisture saturation of brick and migration of salts are provided by ceramic capillary porous structure. The migration of salts starts at the brick humidity of more than 6 %. Salt formation on the masonry surface is accompanied by a significant increase in their volume, when passing into crystalline hydrates, and crystallization pressure. For example, thenardite ( $\text{Na}_2\text{SO}_4$ ) passing into mirabilite ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ) increases in volume by 311 % [13, 14]. This process is facilitated by the increased ambient humidity exceeding 70 % at the temperature above 20 °C [15].

### 3.2. Research findings on MWCNTs influence on ceramic structure

Adding MWCNTs to ceramics was assumed to reduce the pore volume and change their shape and size, increasing the reserve porosity, which, in its turn, reduces efflorescence on brick surfaces.

Density measurements of the control and modified samples showed that MWCNTs in the amount of 0,001 % to 0,009 % can affect the density of the ceramic matrix after both drying and firing (Fig. 7).

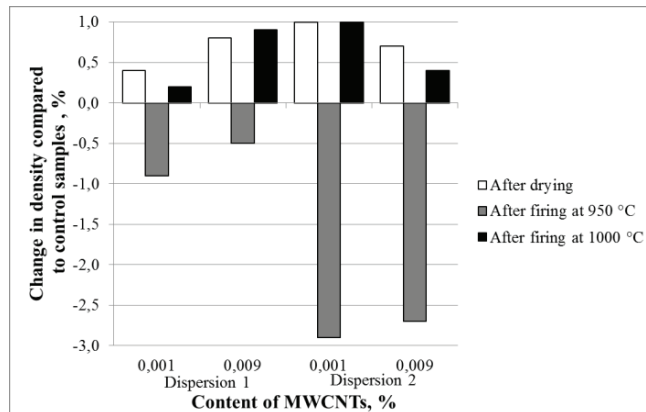


Fig. 7. Change in density of ceramic samples, MWCNTs dispersion used

The greatest increase in density after drying compared to the control sample can be observed in the samples containing 0,009 % of MWCNTs. After firing at the temperature of 950 °C all samples with MWCNTs have lower density compared to the control one. After firing at 1000 °C their density increases compared to the density of the sample without MWCNTs. In this case, maximum density is typical for the sample with 0,001 % of MWCNTs.

Testing samples for compressive strength (Fig. 8) shows that after drying the greatest strength increase of adobe is  $\approx 55$  %, MWCNTs being added in the amount of 0,009 %. This composition has its maximum strength after firing at 950 °C, while other compounds at the given temperature, on the contrary, have less strength parameters. After firing at 1000 °C, dispersions 1 and 2 with 0,001 % MWCNTs increase their compressive strength by 32 % and 28 % correspondingly compared to the control composition. Such significant differences in the strength properties of the compositions with 0,009 % MWCNTs (dispersion 1 and dispersion 2) are due to the fact that nanotubes in dispersion 2 are better dispersed with ultrasound, while the excess volume of added nanotube works as impurity influencing the mechanical characteristics.

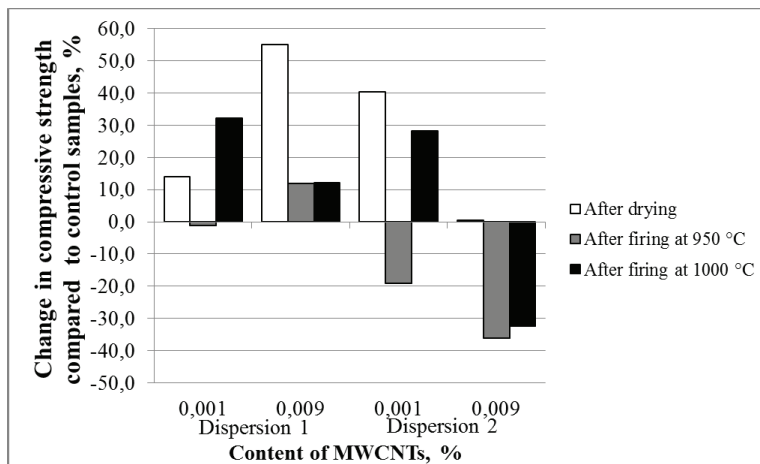


Fig. 8. Change in compressive strength of ceramic samples, MWCNTs dispersion used

The changes in the structural parameters of porosity of ceramic (total open porosity, effective porosity, pore

reserve), MWCNTs being added, are given for the samples fired at 1000 °C (Fig. 9).

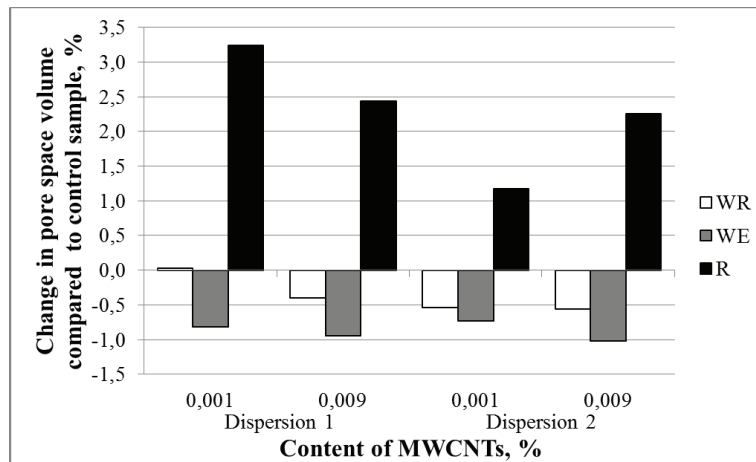


Fig. 9. Change in pore space volume of samples fired at 1000 °C, MWCNTs dispersion used: WR – total open porosity; WE – effective porosity; R – pore reserve

Pore space reserve is typical for the pores and capillaries hindered from water penetration. Therefore, the higher the pore space reserve is, the lower the rate of migration of water with soluble salts in brick is. The total open porosity of the samples varies from 26,11 to 25,52 %, the effective porosity - from 21,05 to 20,03 %; the reserve porous space - from 19,28 to 22,52 %. Thus, adding MWCNTs increases porous space reserve and reduces the volume of effective porosity.

The positive effect of MWCNTs on the ceramic matrix structure is confirmed by the images of the samples microstructure (Fig. 10).

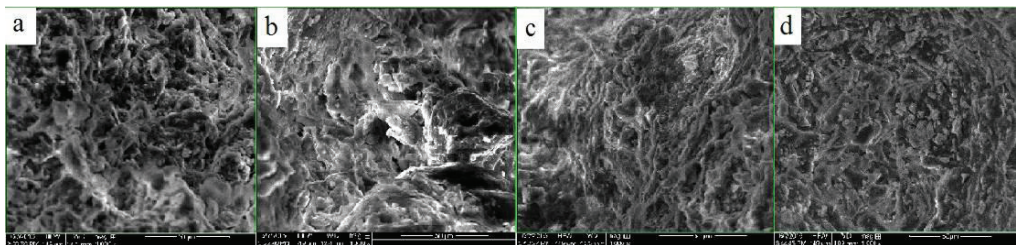


Fig. 10. Microstructure of samples at 1000x magnification:

a – control sample after drying; b – control sample after firing;  
c – sample modified with 0,009 % of MWCNTs after drying; d - sample modified with 0,009 % of MWCNTs after firing

The structure of the modified sample with 0,009 % of MWCNT becomes denser already after drying, the pore number and size being significantly reduced (Fig. 10c). After firing, this sample (Fig. 7d) also has a more uniform structure with a small number of pores compared to the control sample (Fig. 7b). In [16], the authors show that MWCNTs admixture retards the growth of micro-cracks during the drying process of the clay slurry. Thus, the modifying agent as a colloidal solution with negatively charged MWCNTs enhances the stability of clay colloidal mass and increases the mobility of clay colloidal particles, improves the rheological properties of clay slip, which, in its turn, leads to the improved mechanical properties of the dried samples. Due to their good adhesion with clay, MWCNTs provide nanoreinforcing and increasing the mechanical strength of the samples.

#### 4. Conclusion

The main source of efflorescence on the brickwork surface is masonry mortar with plasticizing admixtures containing sodium sulfate and calcium hydroxide formed during the hydration of Portland cement and passing into calcium carbonate. The migration of salts from a solution is due to the capillary porous structure of ceramics. Therefore, the delamination of the polymeric coating on ceramic brick can be caused by the crystallization of the soluble salts coming from masonry mortar to the brick surface under the impervious polymer film.

The offered solution to the delamination of polymer coating caused by crystallizing salts is modifying the brick structure with MWCNTs dispersions. Adding MWCNTs has a positive effect on the structural characteristics of ceramics, increasing its density, reducing the overall porosity and increasing the reserve porosity. The changes in the structure are accompanied by the increased ceramic strength before and after firing. At the same time, the strength of adobe with MWCNTs increases by 55 %, the strength of the samples with MWCNTs after firing at 950 °C is 12 % higher than the control sample strength, after firing at 1000 °C – 32 % higher. The ceramic matrix of the modified samples has fewer deep interconnected pores and is characterized with a uniform and dense microstructure compared to the control composition matrix. The determined differences in the structural parameters of the control and modified samples suggest that the changes in the ceramic structure will assist in decreasing migration of soluble salts in brickwork and reducing damage to polymer film on the surface of brick facades.

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