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## Evaluation of the Efficiency of the Hydrophobic Surface Treatment for Bricks Using Neutron Imaging

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### ABSTRACT

Capillary water absorption in building materials should be minimized because water carries chemical compounds that cause degradation. The effect of the adhesive covering on capillary water absorption in four different types of masonry bricks was investigated using neutron radiography. Only one sample revealed the creation of two layers of the coat to protect bricks against water infiltration. Water is absorbed into the gap between the two layers by capillary action. The progress of the water front between the two layers is proportional to the square root of the absorption time. The capillary penetration coefficient is 3.25 times faster than that of the identical type of sample in the bulk. Between the two layers, the amount of water absorbed is half of what is in the bulk of the sample. The coat is incapable of repelling water ingress in some samples. The coat is effective on some surfaces but not recommended on others.

### INTRODUCTION

Capillary water absorption measurement in porous media, such as constructions and building materials, is necessary and critical in a wide variety of study fields, including civil engineering. Water containing hazardous chemicals such as chloride ions is the primary cause of a variety of degradation mechanisms in porous building materials [1]. Due to the strong capillary forces, ground water can permeate vast distances inside brick walls. Hydration and crystallisation are two processes that take place on the surface of the walls as a result of the presence of water-soluble salts. These processes result in the disintegration of masonry structures, the creation of salt efflorescence, and the dampening and salting of them [1]. Hydrolysis of the binding matrix and the growth of microorganisms contribute to and accelerate the degradation of cement-based materials [2,3]. Other deterioration mechanisms such as acid attack, sulphate attack, chloride attack, and carbonation may occur in the presence of water, resulting in probable reinforcing steel corrosion. Cracks [4,5] occur as a result of shrinkage

caused by drying processes [3, 6,7]. The freeze/thaw cycles may result in an increase in the width of cracks [8-10]. Steel corrosion is accelerated by the existence of cracks because they provide direct flow channels for water carrying dissolved and toxic chemicals. As a result, capillary water movement through these materials must be limited and/or prevented.

Hydrophobic surface treatment of building materials is an effective method for reducing the amount of moisture that is absorbed by them [3,11,12].

Neutron radiography (NR) is a technique that involves recording a neutron beam with an appropriate detector (CCD camera) after it has been absorbed and scattered (attenuated) by the object being studied. NR is an excellent non-destructive method for measuring water absorption in porous media because thermal neutrons are strongly scattered by water due to the large scattering cross-section of hydrogen atoms. Water absorption in a variety of construction materials has been studied using NR [3,11, 13-15].

Numerous research have been carried out to determine the effectiveness of various compounds in controlling water absorption in porous building materials [3,4,5,16-23]. However, most of this research are concentrated on cement-based materials, such as mortars and concretes [3]. For brick samples, just a few works were carried out. Using neutron radiography, Nemeč et al. [11] studied the impregnation of several hydrophobic substances in clay bricks. NR was used to determine the penetration depth and distribution of polymer consolidants in ancient glazed tiles, a porous bioclastic limestone, and a porous sandstone in order to determine impregnation effectiveness [24,25]. Thus, additional research is required to determine the influence of hydrophobic surface treatment chemicals on the water absorption of various types of bricks.

A polymeric waterproofing slurry — an adhesive coat — is available commercially in Egypt. It is used to protect concrete construction surfaces from chloride penetration ions. There are no studies on the use of that coat to protect bricks from water infiltration, particularly when using NR.

The purpose of this study is to determine the capillary water infiltration rate into four different types of bricks coated with a polymeric waterproofing slurry. The neutron radiography (NR) station installed on the 14th beam line of the IBR-2 reactor at the Joint Institute of Nuclear Research, JINR, Dubna, Russia, was used for this study.

## EXPERIMENTAL

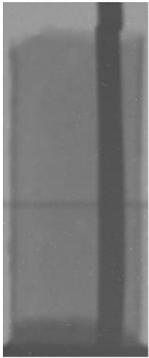
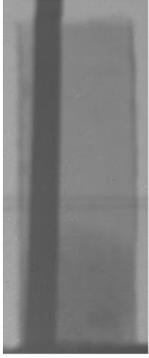
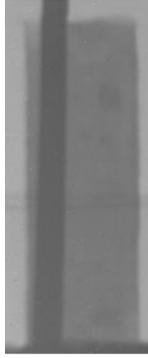
The NR tests were performed at the Joint Institute for Nuclear Research (JINR), Dubna, Russia, utilising the NR station installed on the 14<sup>th</sup> beam line of the pulsed reactor IBR-2 [26]. The NR station is characterized with the following parameters: 1) the thermal neutron flux at the position of the sample is  $5.5 \times 10^6$  n/cm<sup>2</sup>/s<sup>-1</sup>, 2) the detector system consists of a <sup>6</sup>LiF/<sup>6</sup>ZnS scintillation screen and CCD camera, and 3) the spatial image resolution (on average) is 300 μm.

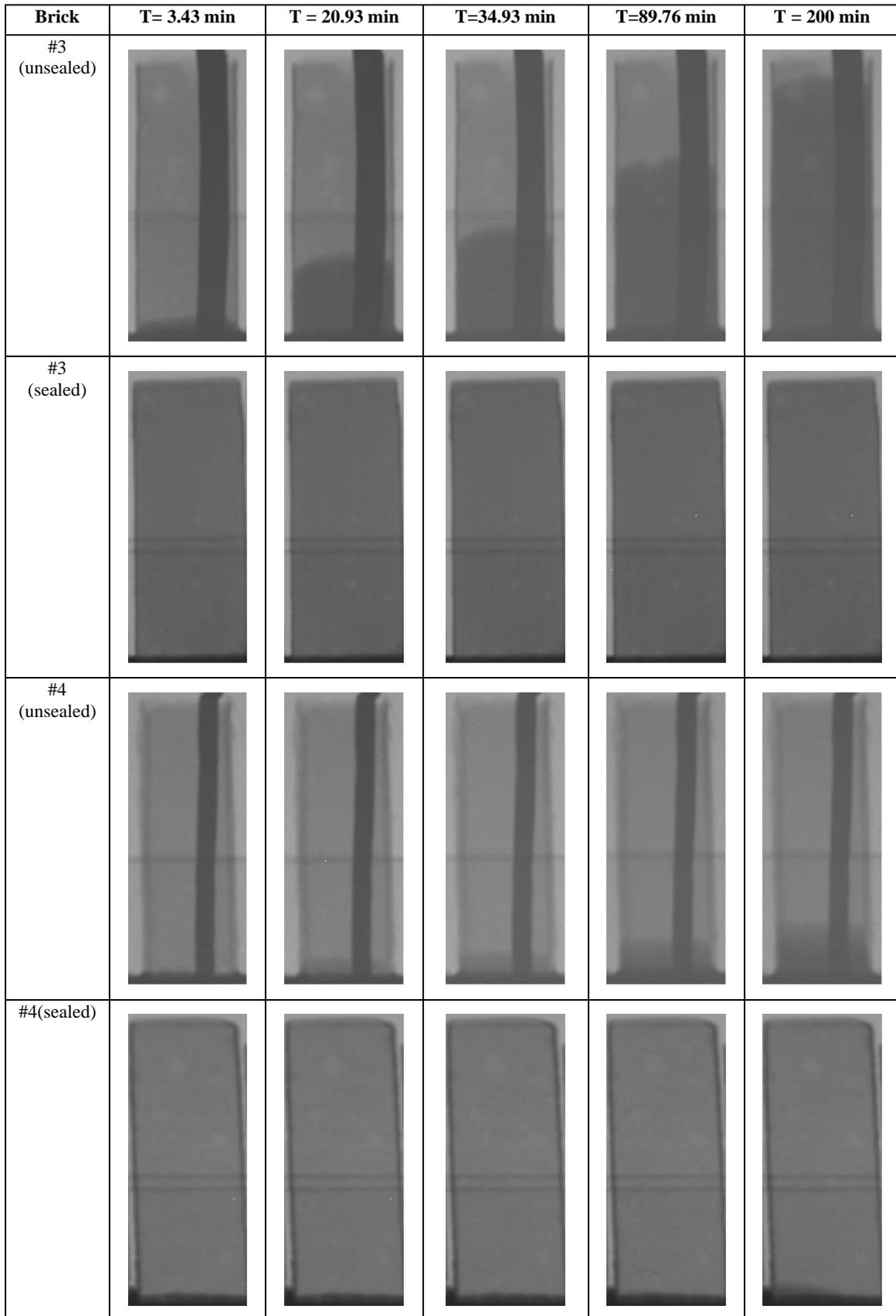
NR was utilised to perform capillary water absorption tests on four types of brick samples. These samples are brick #1, #2, #3 and #4. The dimensions of these samples (thickness x width x length) are: 2 cm x 3.3 cm x 9 cm, 2 cm x 3.3 cm x 9.5 cm, 1.65 cm x 3 cm x 9.5 cm, and 2.4 cm x 2.4 cm x 10 cm, respectively. After several days of drying in a 105°C oven, the samples were dry. The samples under examination were previously investigated in [27]. These samples were

divided into two groups. The polymeric waterproofing slurry was applied to the samples' external surfaces (all surfaces). After wetting the samples with distilled water, a stiff brush was used to apply two perpendicular layers of the coat. The samples are then dried for further several days. The polymeric waterproofing slurry was removed from the top and bottom sides of the first group of samples, but not from the second group. During the capillary water absorption experiments, the polymeric waterproofing slurry was utilised as a sealing agent to allow water to flow in one direction and avoid evaporation. Two NR experiments were carried out, one for the first group of samples and another for the second group of the samples. The samples were positioned vertically in both tests and their ends were immersed in a water container. The samples were positioned vertically in both tests and their ends were immersed in a water container. The water level in the container was maintained constant at 3mm above the immersed sample ends. During the moisture absorption process, a large number of NR images were continuously registered. The NR images were acquired with a frame duration of 20 seconds and a 45-second delay between frames. The acquired images were corrected using the ImageJ software by removing the dark current and then normalizing to the image of the incident neutron beam [28]. The results of the first group ( sample 1,3, and 4 ) were discussed in [29].

## RESULTS AND DISCUSSIONS

Fig.1 shows the NR images taken during the capillary water absorption experiments on the two groups of brick samples. As can be seen, coated samples (designated sealed) on all sides with a polymeric waterproofing slurry- second group- do not absorb water. This is readily apparent from the constant darkening of the NR images as the absorption time passes. This indicates that the coat is efficient at preventing the samples from absorbing water. It can be noticed that brick # 4 slightly absorbs water at higher absorption times. For the first group of the samples, the samples 1,2 and 4 which are coated from on all sides except the ends (designated unsealed) absorb water with different rates as discussed in [29]. The water absorption process into sample 2 is completely different from those in the samples 1,3 and 4. The water absorption process in this sample is the fastest and the darkness of the images during the absorption process is the lowest. It means that the amount of water absorbed by sample 2 is smaller than the other samples.

Brick	T= 3.43 min	T = 20.93 min	T=34.93 min	T=89.76 min	T = 200 min
#1 (unsealed)					
#1 (sealed)					
#2 (unsealed)					
#2 (sealed)					



**Fig. (1): Neutron radiography images for brick #1, brick #2, brick #3 and brick #4 samples at different absorption times (T) with and without coat.**

The water content distribution and progress of the water front inside sample 2 were determined using the procedures described in [27,29]. These procedures were used to determine the water content distribution along the direction of water flow,  $x$ , and at an absorption period,  $t$ . The results are shown in Fig.2a. Fig.2b shows the distribution of water content within the same type of sample 2 previously discussed in [27]. As can be seen, the water content inside the sample in this work (Fig.2a) is smaller than that in the prior work [27]—it is around half the value in [27]. In addition, as shown in Fig.3, the progress of the water front during the water absorption process in the current study was compared to that in the previous study [27]. The following equation [29-32] is frequently used to describe the progress of the water front in porous medium, such as bricks:

$$h=kt^{1/2}+a, \quad 1$$

where  $h$  is the height of the liquid front (cm),  $t$  is the absorption time (h), the intercept  $a$  is a correction term which accounts for surface effects and  $k$  is the

capillary penetration coefficient ( $\text{cm}\cdot\text{h}^{-1/2}$ ). The results were fitted using Equation 1. R-squared is 0.99. The fitting parameter  $k$  (capillary penetration coefficient) was determined to be  $9.62 \text{ cm}\cdot\text{h}^{-1/2}$  in this work, however it was found to be  $2.96 \text{ cm}\cdot\text{h}^{-1/2}$  in [27]. It means that the current study's water progress inside the sample is 3.25 times faster than that of [27].

On the basis of these results, it can be concluded that the coat applied produces a thin layer on the external surface of sample 2. Another thick layer, visible to the human eye, surrounds the thin film layer, forming a jacket. Water is absorbed via capillary action in the space between the two layers. This explains why the capillary water flow process inside sample 2 is much faster in the current work than it is in [27].

Using the same coat, a similar effect was found with other porous materials [31]. The coat not only created a jacket around the sample's surface, but also developed a thin layer and/or reacted with the sample's surface [31]. Water spread between the thin film-covered surface and the outer jacket [31].

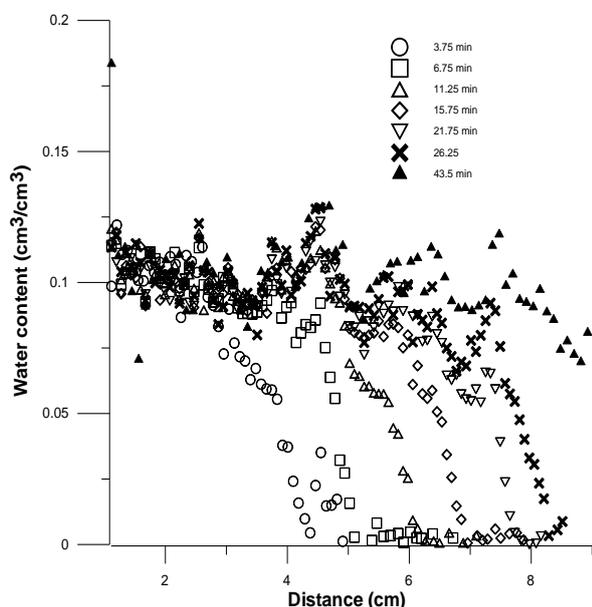


Fig. (2a): Water content distribution inside sample 2 along the water flow direction  $x$ . The legend shows the absorption times.

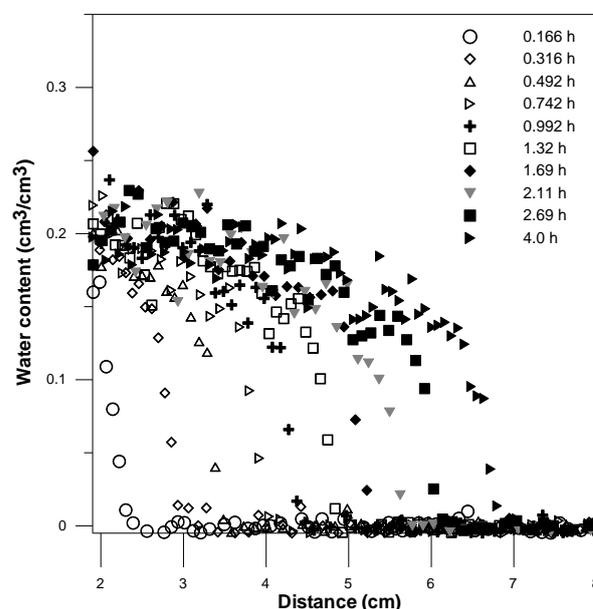
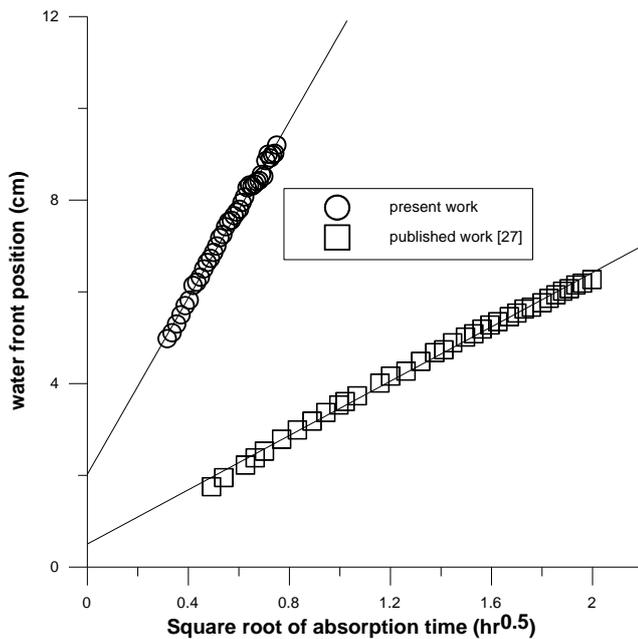


Fig. (2b): Water content distribution inside sample 2 along the water flow direction  $x$  taken from [27]. The legend shows the absorption times.



**Fig. (3): Water front position versus the square root of the absorption time for sample 2 in the present work and the results published in [27].**

According to the results reported in this and another paper [31], the polymeric waterproofing slurry used to protect building components from water ingress should be used carefully. It is incapable of resisting water infiltration in sample 4. Although the formation of two layers is advantageous for protecting a porous sample from water infiltration, this was found for only one sample. This means that the coat is effective on certain surfaces but should not be used on others.

## CONCLUSIONS

Neutron radiography was used to evaluate the hydrophobic treatment of brick samples. In some instances, the polymeric waterproofing slurry is incapable of repelling water ingress. The coat is effective for some surfaces but is not recommended for others. Only one sample revealed the creation of two layers to protect bricks against water infiltration. Water is absorbed into the gap between the two layers by capillary action. During the water absorption process, the progress of the water front between the two layers is proportional to the square root of the absorption time. It is 3.25 times faster than that of the identical type of sample in the bulk. Between the two layers, the amount of water absorbed is half of what is in the bulk of the sample.

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