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The Drying Behaviour of Building Materials Treated with Anti-graffiti

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Abstract

Anti-graffiti coatings are often used to protect facades against unwanted graffiti. Despite the fact that anti-graffiti are widely used, their effect on the drying behaviour of the materials is not well known. Recommendations on their application as well as product documentation generally only considers their water vapour permeability without taking into account that the drying behaviour of a material is largely governed by liquid water transport.

The paper reports the findings of a research on six types of anti-graffiti coatings (permanent and sacrificial, water repellent and not) applied to two substrate materials (fired-clay brick and calcium silicate brick). The effect of the anti-graffiti coatings on the drying behaviour of these materials is evaluated by means of drying tests performed at different RH. The drying behaviour of the same material impregnated with different types of water repellent products is given for comparison. The obtained results are analyzed as a function of product composition and the properties of the substrate materials, such as porosity and pore size distribution. The possible consequences of the application of the tested anti-graffiti coatings on common damage processes, such as frost and salt crystallization, are discussed.

Keywords: anti-graffiti coatings, drying behaviour

1 Introduction

Anti-graffiti coatings are used to protect facades against unwanted graffiti. They have the aim of limiting or avoiding the penetration of the graffiti into the substrate, thus making graffiti removal easier.

Anti-graffiti coatings can be grouped into three distinct categories [1]:

a) Permanent coatings: these coatings are generally based on epoxy or polyurethane resins. Graffiti can be removed (with solvents) without the loss of properties, performance or appearance of the coating itself. These coatings have a service life of about 10 years and can be re-applied only after an adequate pre-treatment, i.e., sand blasting or laser cleaning, of the wall to eliminate the residue of the old anti-graffiti coating.

b) Sacrificial coatings: are mostly based on poly-acrylates, polymer waxes, biopolymers (polysaccharides) or combinations of these. When cleaning graffiti, the anti-graffiti layer and the graffiti are removed together by the use of (warm) water. After the removal, the coating has to be re-applied. The solubility in water limits the service life of a sacrificial coating to about 3 years. They have good transparency and do not alter the aesthetical appearance of the treated material.

c) Semi-permanent coatings: These systems can be of two types: (i) a combination of a permanent base layer and a sacrificial top-layer: or, (ii) a semi-permanent one-layer coating. In the first case the properties of the two layers are the same as described in a) and b). In the case of ii), during graffiti removal with an organic solvent the oleophobic, i.e., hydrophilic, part is removed, while the hydrophobic part is maintained. After the removal of graffiti a new layer of coating should be applied. These systems do not usually alter the aesthetical aspect of the treated substrate and have a service life of about 10 years.

Within each of the categories, a distinction can be made between film forming (e.g. polyurethane based products) and not film forming (e.g. polysaccharide based products) coatings.

Depending on its chemical composition, an anti-graffiti coating can have a minor or major influence on the drying behaviour of the material coated with it. In spite of the fact that drying of a material is a combination of both liquid water and vapour transport, recommendations related to anti-graffiti coatings generally consider only water vapour transport [2]. It can be expected that anti-graffiti coatings having water repellent properties or forming a water-tight film on the surface may strongly reduce the moisture transport by hindering the liquid water transport. Drying will therefore take longer, even if the product has a minimum effect on the water vapour transport. This may enhance some processes such as salt decay, frost damage and biological growth. Moisture and salt related damage processes are in particular to be considered in case of ancient buildings and monuments.

This study investigated the effect of anti-graffiti coatings on the drying behaviour of treated material. Drying tests were performed on two common building materials (a fired-clay brick and a calcium silicate brick, i.e. sand-lime brick) treated with a selection of six types of anti-graffiti coatings. The effect of the anti-graffiti coatings on the drying behaviour was evaluated and compared with the effect of water repellent products applied to the same substrates. At the end of the drying test the specimens treated with anti-graffiti were cut and their surfaces and cross sections observed by optical microscopy.

2 Materials and methods

2.1 Anti-graffiti coatings and water repellents

Six anti-graffiti coatings were selected, including sacrificial, semi-permanent and permanent systems. The most relevant properties of the products are summarized in Table 1.

In order to have a comparison standard to evaluate the effect of anti-graffiti on the drying behaviour, some specimens were treated with two water repellent products:

- solvent based water repellent: an oligomeric alkylalkoxysiloxane in an aliphatic solvent
- water based water repellent: an alkylalkoxysilane emulsion in water

Two building materials commonly used in The Netherlands were selected as substrates: a fired-clay brick (FCB) and a calcium silicate brick (CSB). These substrates were also chosen because they are largely different in colour; surface smoothness, an important parameter for the aesthetical influence of the anti-graffiti coating; and, in pore size distribution, the most relevant parameter determining the liquid water transport behaviour. Their total porosity and the pore size distribution were measured by means of Mercury Intrusion Porosimeter (Autopore IV/9500 by Micromeritics) (Figure 1). During testing it was found that the outer surface of the CSB had been treated during production with a water repellent. The penetration depth of the water repellent, measured by wetting a broken cross section of the CSB, was found to be limited to the outer 2 mm.

Table 1: Properties of the selected anti-graffiti coatings

Composition	Type	Layers	Solvent	Film forming	µd* [m]
Wax based	Sacrificial	2	no	No	0.050
Polysaccharides	Sacrificial	2	no	No	0.024
Acrylic	Sacrificial	2	no	Yes	0.200
Acrylic (+ siloxane)	Semi-perm.	2	no	Yes	0.200
Polyurethane	Permanent	3	water	Yes	0.950
Acrylic + polyureth.	Permanent	2	no	Yes	0.575

* relative water vapour diffusion resistance [3]. This value expresses the thickness of the air layer having a water vapour resistance equal to that of the product layer thickness.

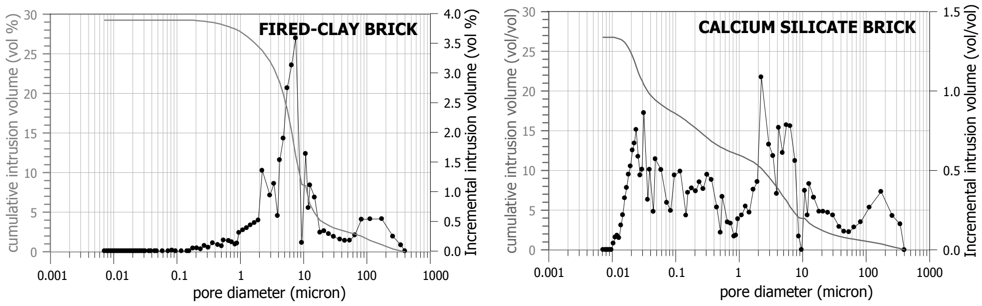

Figure 1: Pore size distribution of fired-clay brick (left) and calcium silicate brick (right)

2.2 Procedure

The specimens consisted in a half brick having a size of approximately 110 x 50 x 100 mm^3 in the case of the FCB; and of 120 x 70 x 100 mm^3 for the CSB. Before the application of the products, the specimens were coated with epoxy resin on the lateral sides, dried in the oven at 105°C to constant weight and then conditioned at room temperature for one day. The anti-graffiti coatings were applied with a roller to the upper, external surface of the specimen.

The water repellents were applied by brush at approximately 1 l/m^2. For each combination of material/treatment/climatic condition, 3 specimens were used; not treated specimens were used as reference (see Table 2).

All the specimens were then conditioned for 2 weeks at 20 °C / 50% RH. After this, they were immersed with their bottom, untreated surface in water until saturation. In the case of polysaccharide, it was taken care that the upper, treated surface was not wetted to avoid swelling and dissolution of the anti-graffiti product. Once saturated, the bottom of the specimens which had been in contact with the water was sealed with tape, to ensure unidirectional drying through the treated surface. The specimens were stored to dry at two different climatic conditions: 20°C / 80% RH and 20°C / 50% RH. The first condition reproduces the average RH of the air in The Netherlands; the second condition allows the study of the drying behaviour of slow drying materials (like the calcium silicate brick) in a reasonable period of time.

At the end of the drying test an indication of the effect of the anti-graffiti coating on the substrate/water contact angle was obtained by observing the shape of a water drop on the surface of the specimens. The surface and the cross section of the specimens were studied by means of optical microscopy and Polarized Fluorescent Microscopy (PFM) to investigate the thickness and adherence of the anti-graffiti layer.

Table 2: Specimens and testing matrix.

substrate	Treatment	Drying conditions	No. of specimens
FCB	Untreated	20°C 50%RH / 20°C 80%RH	3 for each drying condition
	6 anti-graffiti	20°C 50%RH / 20°C 80%RH	3 for each anti-graffiti and drying condition
	2 water repell.	20°C 50%RH	3 for each water repell.
CSB	untreated	20°C 50%RH	3
	6 anti-graffiti	20°C 50%RH	3 for each anti-graffiti

3 Results

3.1 Drying behaviour

The drying behaviour at 50% RH of FCB and CSB is reported in Figures 2 and 3 respectively. The drying behaviour of the FCB at 80% RH is illustrated in Figure 4.

3.1.1 Reference materials

For the case of the untreated specimens, the FCB dries faster than the CSB. The slower drying for the CSB can be attributed to both the presence of the water repellent layer applied on production to the brick, and to its smaller pores compared with the FCB. From the abrupt change in the slope of the drying curve of the FCB, it can be deducted that drying occurs in two distinct phases: a 1st phase where drying is controlled by liquid water transport, followed by a 2nd phase where drying occurs mainly through water vapour transport. A porous material treated with a water repellent does not allow liquid moisture transport to the surface and therefore no abrupt change should appear in the slope of the drying curve [4]. This was expected for the case of the CSB, however, a minor change in slope was observed, as shown in Figure 3, indicating that the water repellent layer was not completely effective and some liquid moisture transport is still possible.

As expected, the drying at 80% RH is much slower than at 50%RH, and the drying behaviour of the untreated FCB is similar to the one of the untreated FCB but with a lesser change in the slope at the higher humidity.

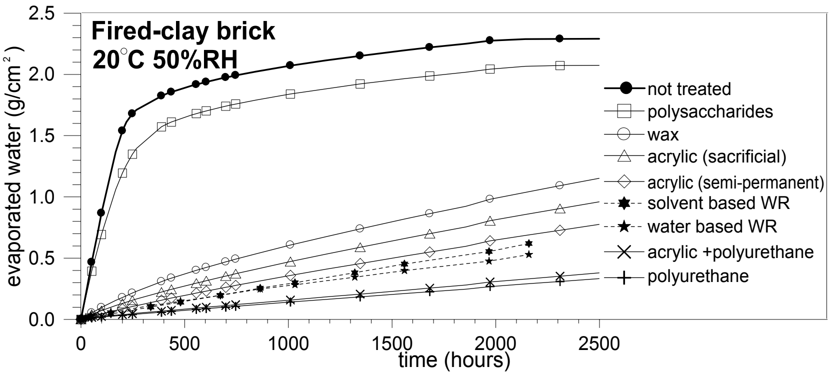

Figure 2: Drying behaviour at 20°C 50% RH of fired-clay brick

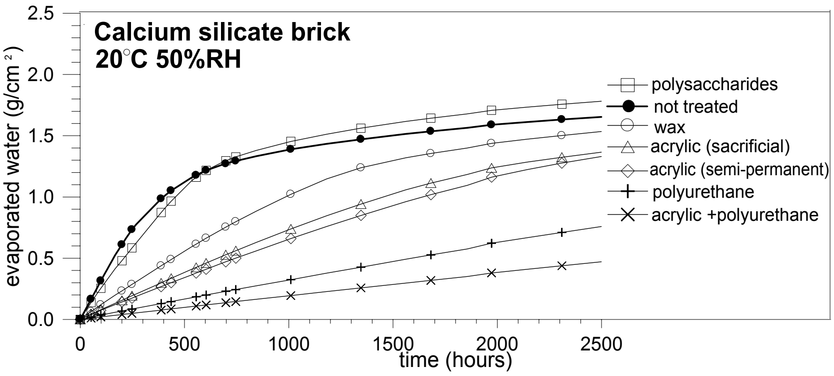

Figure 3: Drying behaviour at 20°C 50% RH of calcium silicate brick

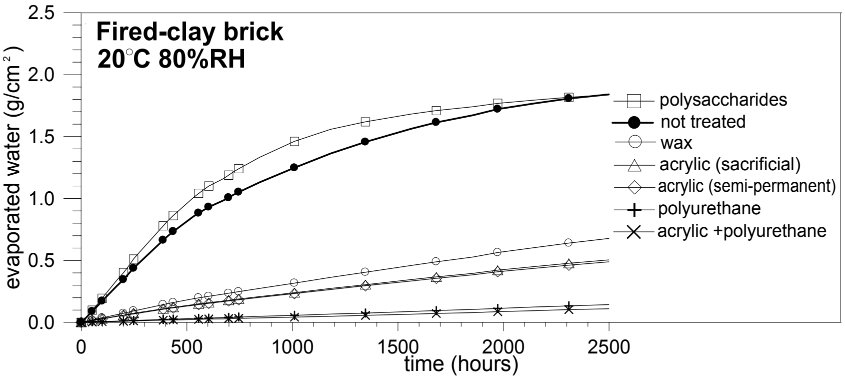

Figure 4: Drying behaviour at 20°C 80% RH of fired-clay brick

3.1.2 Materials treated with anti-graffiti coatings and water repellents

The effect of the anti-graffiti coatings on drying is clearly visible, both at 50% and at 80% RH. On the basis of the effect on the drying behaviour three "classes" of anti-graffiti can be differentiated:

Anti-graffiti that do not affect the drying rate of the substrate: the polysaccharide belongs to this group. The drying behaviour of FCB and CSB treated with polysaccharide is similar to the one for the untreated materials.

Anti-graffiti that reduce the drying rate: wax and acrylic products (sacrificial and permanent) belong to this category. These products significantly reduce but do not completely stop liquid water transport: in fact a change in the slope is still visible in the drying curves.

Anti-graffiti that strongly reduce the drying rate: polyurethane coatings, alone or in combination with an acrylic primer, belong to this category. Due to the presence of a film on the surface of the treated material, liquid water transport is stopped and drying can occur only through water vapour diffusion, as shown by the constant drying rate. In the case of the CSB the drying reduction for the 3-layer polyurethane coating is less than for the combination acrylic primer and polyurethane. In the case of the FCB no relevant differences between the two anti-graffiti coatings can be observed.

It is interesting to notice that a few tents of mm layer of anti-graffiti has a comparable, or even larger, hindering effect on drying than several mm impregnation with a water repellent (Fig. 2).

In general, there is correspondence between the water vapour diffusion data (see Table 1) and the drying behaviour measured on the treated FCB and CSB bricks: low water vapour diffusion resistance values correspond to a lesser blocking effect on the drying (Figure 5). However, the drying test gives more information than the simple water vapour diffusion resistance value, since it takes into account both water phases and their transport mechanism as well as the influence of the material properties. In fact it has been observed that the properties of the material on which the anti-graffiti coatings are applied play an important role. The blocking effect of anti-graffiti coatings on the drying behaviour is more pronounced for the FCB than for the CSB. This can be explained by the fact that these products, excepting the polysaccharides, limit the liquid moisture transport, therefore they have a large impact on the first phase of the drying. As can be seen by the drying of the reference specimens, the first phase of the drying is more important for the FCB than for the CSB (the FCB looses 60% of the initial moisture content in the first phase, while the CSB only 30%), therefore the effect of these products on the drying will be more relevant for materials with a faster drying rate than for slow drying materials.

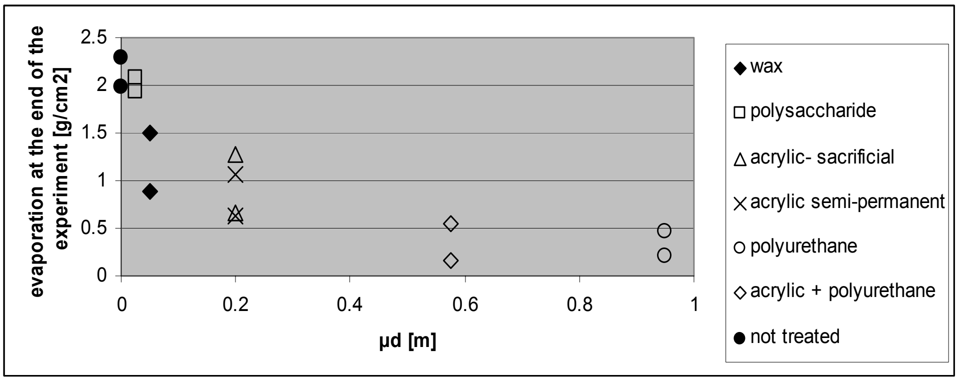

Figure 5: Correlation between the relative water vapour diffusion resistance and the evaporation measured at the end of the drying experiment

3.2 Water drop test

The change in the substrate/water contact angle due to the application of the anti-graffiti has been evaluated by performing the drop test on the FCB. The specimens treated with polysaccharide showed no water repellency: the water drop was immediately absorbed by the brick. On the other hand, the drop remained more or less spherical on the surface of the specimens treated with all the other products.

3.3 Microscopy observations

The microscopy observations of the surface and cross section of the specimens showed that:

- The presence of the anti-graffiti is clearly distinguishable on the surface of the brick. Only in the case of the polysaccharide the amount of anti-graffiti left seems to be very limited.

- The surface retains its opaque appearance for the case of the brick treated by wax, polysaccharide and acrylic anti-graffiti coatings, while it acquires a gloss for the case of the polyurethane and, in minor extent, of the acrylic and polyurethane combination.

- Wax and polysaccharide do not form a film on the surface. The wax shows some penetration in the substrate, up to about 0.5 mm. The other products form a more or less thick film without any penetration depth (Figure 6). The thickness of this layer, observed in cross section, is not homogeneous.

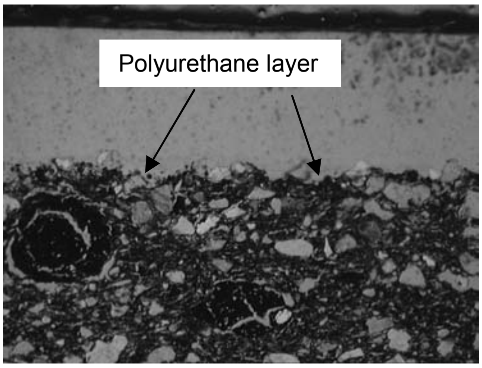

Figure 6: Polarized light photomicrograph of the cross section of a FCB treated with polyurethane

4 Discussion and conclusions

The drying rate of a building material may influence its durability. Materials which retain water for a long time are generally more susceptible to decay. The drying rate of a material, with moisture above its critical moisture content, the content below which capillary water transport is not continuous, depends both on liquid and vapour transport. The first mechanism being far more effective than the second. Therefore, blocking of liquid water transport may have a larger effect on the drying than reducing the water vapour transport. For this reason it is recommended that the effect of a surface treatment should be evaluated by measuring the drying behaviour of treated materials, instead of referring to water vapour transport only, as done by the existing guidelines.

The study has shown that anti-graffiti coatings may strongly reduce the drying rate of a material. Some anti-graffiti coatings cause a comparable or even larger reduction than an in-depth impregnation with a water repellent. The only anti-graffiti coating which has no relevant effect on the drying is the polysaccharide. Wax, acrylic and, in larger extent, polyurethane based products partially or totally block liquid moisture transport, thereby significantly reducing the drying rate. This may have negative effects not only on decay processes affecting high moisture loaded materials (like frost and biological growth) but also on salt damage. The salts, which can be transported only in liquid water and not in vapour, accumulate beneath the treated layer and will eventually cause its detachment.

It is interesting to note that the delaying effect of the anti-graffiti on the drying process is more evident in materials having larger pores and thus a faster drying rate. The physical properties and in particular the pore size distribution of a material should therefore be taken into account when selecting a suitable anti-graffiti coating.

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