Construction and Building Materials 107 (2016) 157–164

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Study of the effect of three anti-*graffiti* products on the physical properties of different substrates

A. Moura [a], I. Flores-Colen [b,*], J. de Brito [b]

[a] Civil Engineering, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[b] CERis – ICIST, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

HIGHLIGHTS

- Experimental study of the anti-*graffiti* products performance.
- Study of three commercial anti-*graffiti* products (sacrificial and permanent).
- Study of the effect on physical properties of stone and mortar porous substrates.
- Variations on colour and water absorption and drying.

ARTICLE INFO

Article history:
Received 14 July 2015
Received in revised form 8 December 2015
Accepted 22 December 2015
Available online 11 January 2016

Keywords:
Anti-*graffiti* products
Performance
Stone
Painted mortar
Unpainted mortar
Physical properties
Colour

ABSTRACT

To protect the surface of materials from the effects of *graffiti* paints, there are anti-*graffiti* products that prevent the penetration of these paints into the pore system of the substrates, making the substrates water- and oil-repellent, thus facilitating their removal. This paper presents a comparative study of three commercial anti-*graffiti* products (two sacrificial and one permanent) applied on three substrates, in order to evaluate the changes caused by these products on the physical properties of the substrates. Thus, the anti-*graffiti* products were applied on a Portuguese limestone and on painted and unpainted lime-based mortars. The experimental work was focused on various laboratory tests such as open porosity, capillary water absorption, water absorption under low pressure, water vapour permeability, drying behaviour and colour variations. The results have shown that these products introduced variations on the physical performance of the substrates, especially the water absorption, drying behaviour and water vapour permeability.

1. Introduction

Graffiti in facades is a problem that affects many buildings in urban areas and needs some special attention. *Graffiti* removal is an expensive process that sometimes is not totally effective, especially on porous substrates because the penetration of the pigments is usually deep [1–4]. On the other hand, the use of inadequate cleaning methods may damage the facades coating's materials. The high costs associated with *graffiti* removal and their great aesthetic impacts on buildings justify that new preventive and curative methods are developed to solve this problem. Using physical barriers (compatible with the aesthetics of the building) that prevent access to the facades of buildings, as well as placing fences or vegetation, such as shrubs, are good strategies, but do not preclude the application of *graffiti* [5,6].

On the other hand, the use of anti-*graffiti* products can be a solution, since it helps the cleaning of *graffiti*, assuming an important role in the conservation of buildings and contributing to an increased durability of the materials [1,5,7]. These anti-*graffiti* products are a protective barrier against *graffiti* and enable *graffiti* removal by generating a water- and oil-repellent surface that prevents the intrusion of water and paints on roughened surface of coating materials [1,3,5,7,8].

However, these products are often applied without a previous scientific knowledge of their effects on the physical properties of the substrates. This study intends to evaluate the effect of the application of three commercial anti-*graffiti* products on three substrates (stone, mortar and painted mortar), in order to determine their suitability for the protection of porous materials, currently used on buildings facades.

* Corresponding author.
E-mail addresses: ana.r.moura@ist.utl.pt (A. Moura), ines.flores.colen@tecnico.ulisboa.pt (I. Flores-Colen), jb@civil.ist.utl.pt (J. de Brito).

http://dx.doi.org/10.1016/j.conbuildmat.2015.12.181
0950-0618/

2. Literature review

Anti-*graffiti* products consist of a protective barrier that prevents contact between the paint of the *graffiti* and the substrate facilitating the removal of *graffiti* [1,6,7].

These anti-*graffiti* products can be classified into three categories: sacrificial, semi-permanent and permanent [2,4,5]. The sacrificial products are eliminated during the cleaning process together with the *graffiti* paint, and have to be reapplied after the removal process [5,7–9]. Semi-permanent products can be applied in several layers, but are also eliminated after a few cleaning cycles (two or three) [5,7]. The permanent anti-*graffiti* products are not dissolved with the products used to clean the *graffiti* and therefore can withstand repeated cleaning cycles (usually up to ten) [7–10].

For years, the most widely used anti-*graffiti* products were waxes or micro-waxes (sacrificial product type) and polyurethanes (permanent product type). However, polyurethanes change the colour of material surfaces and form a barrier to the passage of water vapour [2,7]. The reduction of the water vapour permeability of the substrate can lead to the accumulation of liquid water contributing to the substrate's deterioration. For this reason, polyurethane-based anti-*graffiti* products are not suitable for porous materials, since they have a relatively low durability and, in some cases, may even damage the substrate. Another disadvantage is their low resistance to UV light, e.g. long sun exposure causes yellowing of the product changing the colour of the coating [6,10]. On the other hand, it appears that the use of products based on waxes or silicones in aqueous base, although limited, does not reduce the water vapour permeability as much as the polyurethanes do, and for that reason they are more suitable for historic masonry and continue to be more often used [3,8]. However, when exposed to UV radiation, it seems that anti-*graffiti* products based on waxes have a limited durability and silicones lose their hydrophobic capacity [3,5].

Since waxes and polyurethanes have a limited durability and may induce a substantial decrease in water vapour permeability, other products such as fluoroalkylsiloxane and organic–inorganic hybrid products [7–12] have been studied. These products have demonstrated a good performance in porous materials due to their capacity to generate a low surface energy preventing the absorption of water and paint and to allow water vapour diffusion [7,8,11]. The fluorinated polymers increase the resistance to solar and UV radiation; they also increase the chemical, thermal and photochemical stability and, consequently, improved the coatings' durability [7,8,24]. On the other hand, the development of coatings incorporating nanoparticles and organic–inorganic hybrid products has shown that there are many properties that can be improved with this advanced technology, including: corrosion preventive coatings, self-cleaning capacity, antibacterial coatings, development of anti-glare glasses, more resistant paints and also anti-*graffiti* coatings [12,13]. The inclusion of nanosilica in products based on organic polymers improves some of the properties of the anti-*graffiti* products such as the hardness, chemical and thermal stability, UV resistance and transparency [7,12,13].

The effects of the anti-*graffiti* products have been mostly investigated in stone [8,20–23]. However, there are only a few studies in the literature related to porous materials, such as mortar and painted mortar [6–8]. In addition, *graffiti* removal from mortar is quite difficult due to the high porosity property of this substrate.

This study intends to evaluate the effect changes induced by the application of three anti-*graffiti* (two sacrificial and one permanent) products in different substrates (limestone, painted and unpainted mortar), in terms of their physical properties (water repellence, water vapour permeability, drying behaviour, open porosity and colour).

3. Experimental programme

3.1. Materials

3.1.1. Anti-graffiti products

In this experimental work, three commercial anti-*graffiti* were studied: two sacrificial products and one permanent product. The chemical characteristics of the products are shown in Table 1. According to the technical sheets, these products can be applied on porous materials.

3.1.2. Substrates

The anti-*graffiti* products were applied on three substrates: Portuguese calcareous stone (*Moleanos* limestone), lime-based mortar without and with silicate-based paint.

Moleanos is a beige limestone characterised by its 8.3–9.4% open porosity. The mortar studied consists of a pre-dosed lime-based mortar made with air lime, hydraulic binder, fillers, synthetic fibres and the specific adjuvants. This mortar is characterised by a very high open porosity (between 38% and 45%) and a low bulk density (between 1000 kg/m^3 and 1200 kg/m^3). These values were determined through laboratory tests.

To paint the mortar samples, a silicate-based paint was used. According the technical sheet, this is a mineral paint based on an inorganic binder (potassium silicate) pigmented with rutile titanium dioxide and inert fillers that is suitable for mineral substrates such as cement or lime base mortars.

3.2. Samples preparations

For the experimental work three types of samples were used. The prismatic samples (80 × 40 × 40 mm) were used in the porosity and capillary water absorption tests. Three prismatic samples were tested per substrate and type of anti-*graffiti* and three untreated samples per substrate.

For the water vapour permeability and drying behaviour tests, disk-shaped samples (diameter = 160 mm and thickness = 20 mm) were used (two samples per substrate and type of anti-*graffiti*) and, finally, the water absorption under low pressure and the colour tests were performed on rectangular stone samples (200 × 200 × 20 mm) and specimens of mortar applied on bricks (300 × 200 × 20 mm). For the water absorption under low pressure four samples were tested per sample (one per anti-*graffiti* product and one untreated sample).

Before the application of the anti-*graffiti* products, the specimens were cleaned with a moist cloth to remove any dirt and then were kept under laboratory conditions until constant weight (25.5 ± 0.5 °C and 44.6 ± 7.8% R.H.). Constant weight was achieved when two consecutive mass measurements, 24 h apart, differed by no more than 0.1% of the sample's mass. Then, the anti-*graffiti* products were applied according to the recommendations in the technical sheets (Table 2). The application of anti-*graffiti* products S_{silox} and P_{fluor} was performed with a brush, while the S_{nano} product was applied by spraying. In the samples used in the porosity test, the anti-*graffiti* products were applied on all sides of the specimens. In the other samples, the anti-*graffiti* products were applied only in one of the sides (the one tested). The number of anti-*graffiti* layers and the drying time between layers adopted were those recommended in the technical sheets. Then the specimens were kept under laboratory conditions for two weeks (23.6 ± 0.9 °C and 60.5 ± 8.5% R.H.).

3.3. Test procedures

Table 2 shows the experimental tests performed on the three substrates treated with the three selected anti-*graffiti* products (S_{silox}, P_{fluor}, S_{nano}). These test procedures were also performed on untreated specimens to use as control samples for comparison purposes.

To assess the colour changes caused on the substrates' surface by the application of anti-*graffiti* products, the colour coordinates were measured using a spectrophotometer (portable spectrophotometer Minolta CM-508i). Twenty-five and nine readings were performed on the stone and mortar specimens, respectively. Each measurement zone had an 8 mm diameter and each data point was the average of five measurements. Colour characterisation tests were carried out with an integrating sphere (diffuse illumination/8° viewing angle) with diffuse illumination

Table 1
Anti-*graffiti* products studied and their chemical characteristics.

Anti-*graffiti*	Type	Chemical characteristics
S_{silox}	Sacrificial	Water-based organosiloxane emulsion with special additives
S_{nano}	Sacrificial	Coating with SiO_2 nanoparticles
P_{fluor}	Permanent	Water-based fluoroalkylsiloxane