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Anti-*graffiti* products for porous surfaces. An overview

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SUMMARY: Graffiti are a current problem especially in highly urbanised cities. Since graffiti removal is expensive and not particularly effective in porous substrates such as mortar and stone, the use of an anti-graffiti treatment can facilitate removal. To protect the surface of materials there are anti-graffiti coatings that prevent the penetration of ink into the substrates and make the substrate water and oil repellent, facilitating their removal. So the anti-graffiti coatings also act as a superficial hydrophobic treatment, since they prevent water penetration. These products can be classified as sacrificial, permanent and semi-permanent. This paper presents a critical analysis of the literature available on graffiti removal and anti-graffiti coatings, in order to determine their suitability for various porous substrate materials. Following this study, an experimental work with the aim of evaluating the performance of four different anti-graffiti coatings will be developed.

KEY-WORDS: Porous surfaces, anti-graffiti, literature review

INTRODUCTION

The presence of *graffiti* in buildings facades is a problem that affects many buildings in urban areas and needs some attention. According to the Portuguese Language Dictionary of Porto Editora, the term *graffiti* is derived from the Italian *graffiare* that corresponds to the first plural person of *graffito*, which means "inscribe in a hard surface".

Graffiti, as a form of artistic or revolutionary expression, have existed for thousands of years. Paintings found in ancient Egyptian monuments and on the walls of the city of Pompeii are examples of *graffiti* made by ancient civilizations [1,2].

Nonetheless, *graffiti* have undergone several changes throughout their history, not only in their visual appearance and types of inks used but also on the type of motivation in its origin. *Graffiti* as they are known today, emerged in the 1970s in New York, within the African American and Latin American destitute communities as a form of individual expression, through custom signatures combining nicknames and street numbers [1-3]. However, this is the type of *graffiti* that is considered vandalism by the majority of citizens, as it does not convey a message to the observers, but serves only as a means of communication between the *writers* [3]. This type of manifestation is found in several buildings such as schools, private residences, train stations, trains and street furniture including traffic lights and garbage bins.

On the other hand, in the last decades, a new *graffiti* type emerged: artistic *graffiti* (Fig. 1). The purpose of these *graffiti* is far beyond the desire of defacing walls and urban furniture, being considered art when they stand out in terms of talent and creativity [3]. The production of a mural involves a lot of imagination and dedication.

Figure 1. *Graffiti* located in: Avenida Fontes Pereira de Melo (left) and Av. Conselheiro Fernando de Sousa, Lisboa (right)

On the other hand, illegal *graffiti*, which is not considered art by the general public, denigrate the image of the buildings. *Graffiti* removal is very expensive. It is estimated that in Berlin about 25 thousand cans are spent per day for making *graffiti*. *Graffiti* removal has a great economic impact; for example, the German railway company, Deutsche Bahn AG, indicates that it spends hundreds of thousands of euros in *graffiti* removal [4,5]. Only in 2010, the Portuguese railway company, CP, spent 304,000 euros in cleaning *graffiti* from the train wagons.

The aim of this paper is to present a critical analysis of available literature about *graffiti* removal techniques and anti-*graffiti* products present in the national and international market, in order to relate their suitability for various substrate materials, in particular the most porous substrates such as some types of stone and mortar. This is part of an experimental study that is being implemented to evaluate the performance of four anti-graffiti products: two sacrificial products (one organosiloxane and a coating with SiO_2 nanoparticles) and two permanent products (a product based on silane chemistry and an aqueous emulsion of nanostructured silicon-based molecules).

GRAFFITI REMOVAL TECHNIQUES

Graffiti removal is an expensive process that sometimes is found to be only partially effective. The use of inadequate cleaning methods may damage coatings materials. The high costs associated with *graffiti* removal and their great aesthetic impacts in buildings justify that new preventive and curative methods are being developed to solve this problem [5]. 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 execution of *graffiti* [6,7].

On the other hand, the use of anti-*graffiti* coatings can work very well, since it facilitates the cleaning of *graffiti*, assuming an important role in the conservation of buildings and contributing to an increased durability of the materials. These anti-*graffiti* coatings are a protective barrier against *graffiti* and facilitate *graffiti* removal by generating a water- and oil-repellent surface that prevents the intrusion of paints on roughened surface of coating materials.

Graffiti removal should be performed as soon as possible, so as to discourage future attacks and guarantee that the paints do not overlap and combine chemically with the air pollution making it more difficult to clean [2, 6, 8, 9]. Non-permeable and non-porous materials, such as steel, glass and glazed tile, can be easily cleaned with chemicals. However, cleaning *graffiti* from porous materials is more complex and, in most situations, multiple cleaning cycles are necessary [2,10].

Most of the *graffiti* are made with aerosol spray paint (polyurethane, lacquers, and enamels) and permanent felt-tip markers due to its fast and easy application.

Graffiti made with permanent felt-tip marker are the most difficult to remove, since the ink contained in these markers is very fluid (high percentage of solvent) and can easily fill the pores of the surface while penetrating to a significant depth into the substrate [8]. For this reason, it is very important that cleaning be performed as quickly as possible to avoid complete drying of the ink in the surface. Otherwise, the ink dries and hardens, making its removal more difficult.

Graffiti made with aerosol spray paint on porous materials are also difficult to remove. However, the paint is sprayed against the surface and therefore it does not penetrate as deep into the substrate so it is less affected. Nevertheless, the drying time of these inks is very short, especially on roughened surfaces, reducing the probability of effectively removing the *graffiti* paint while the ink is still fresh [6,8].

There are various removal techniques, which should be chosen according to the type of *graffiti* and surface. The most frequently used methods are mechanical and chemical removal. However, these procedures may severely damage some materials [9-12]. *Graffiti* removal with a laser is another method, which has recently been studied, since in certain materials it allows a less aggressive process, compared to chemical or mechanical removal. Table 1 summarizes the main cleaning methods used.

Chemical cleaning combined with the use of a hot water-jet is very useful. Sometimes, for nonporous materials, after the application of the chemical, it is enough to wash the surface with a cloth dampened with hot water [2]. However, the pressure of the water jet greatly influences the cleaning process, since much higher pressures may damage the surface of certain materials. On the other hand, the use of cleaning chemicals is the most widely used method.

Table 1. *Graffiti* removal techniques [2,8,10-14].

Removal techniques	Description
Mechanical removal	Dry or wet abrasive blasting • Dry abrasive blasting: sandblasting, dolomite powder, alumina oxide, ground-walnut shells, sodium bicarbonate (baking soda); • Hot or cold pressure water jet cleaning, with or without chemical additives; • Abrasive blasting with water; • Abrasive methods (disc abrasion).
Chemical removal	Detergents, paint removers (based on methylene dichloride), organic solvents, alkaline products (caustic soda) and paint strippers. These products are available in the market with different consistency (liquid solutions, gels). Washing with a hot water high-pressure jet often complements this technique.
Removal with *laser*	The most studied and tested lasers are CO_2 *lasers*, Nd: YAG *laser* and *laser* diode high power (HPDL). Laser can be an alternative to other methods because it exhibits high cleaning efficiency per unit area, it is localized and selective, and does not require mechanical contact. However, this technique does not allow the cleaning of inks that exhibit high reflectance such as silver and gold.

To solve problems that sometimes arise from the use of chemical or mechanical methods, several studies have been made to analyse the method of *graffiti* removal with *laser*. However, in addition to the effectiveness and viability of this method depending on many factors, such as the roughness and porosity of the surface, the moisture content, the physical properties of the surface, the colour and thickness of *graffiti* and the various parameters of lasers, such as the intensity and wavelength, this technique can cause fractures and craters in materials, due to the sudden temperature increase of the surface [11-14].

In summary, it appears that methods of cleaning are not fully effective for porous materials. Nonetheless, finding a solution to the problem of cleaning and protection of the porous materials proves to be very important in Portugal, since the vast majority of buildings are rendered. i.e., coated with mortars. The difficulty of removing *graffiti* on walls coated with painted renders, using chemical cleaning, is compounded by the modification of the physical characteristics of the material. In addition to the recovery of the original paint of the render being almost impossible after applying a chemical remover, the subsequent use water jet to wash the surface can also damage the render.

ANTI-*GRAFFITI* PRODUCTS

Anti-*graffiti* products consist in a protective barrier that prevents contact between the ink of the *graffiti* and the substrate facilitating the removal of *graffiti.* Anti-*graffiti* coatings can be classified into three categories: sacrificial, semi-permanent and permanent [7,10,15].

Sacrificial coatings are eliminated during the cleaning process together with the *graffiti* paint, and have to be reapplied. These products are based on waxes, micro-wax, acrylates and polysaccharides. These coatings are most commonly transparent and their removal is relatively easy because in most cases, the use of a water jet is sufficient [8,10,16,17]. Semi-permanent products are typically based on polymers, acrylics or epoxies and can be applied in several layers, but are also eliminated after a few cleaning cycles (two or three) [10]. The removal of *graffiti* is performed by applying a *graffiti* removal product followed by washing with water. Semi-permanent products are transparent too, but as mentioned, are removed after a few cycles of cleaning the substrate again exposed [10,15,17]. Permanent products are normally acrylic-siloxane copolymers, polyurethanes and silicones and are not eliminated during the removal of *graffiti*. This type of anti-*graffiti* coating is not dissolved with the products used to clean the graffiti and therefore has a longer service life [10,17]. Even though they are more expensive, these protections have greater durability. *Graffiti* removal is usually performed with chemicals or with hot water jet only [10, 17].

For years, the most sold anti-*graffiti* products were waxes or micro-waxes coatings (sacrificial) and polyurethane coatings (permanent). However, polyurethanes change the colour of material surfaces and form a barrier to the passage of water vapour [2, 9]. Reduction of the substrate water vapour permeability can lead to the accumulation of liquid water contributing to its deterioration. For this reason, polyurethane-based anti-*graffiti* coatings 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: the long sun exposure provokes its yellowing 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 (sacrificial product), although limited, does not reduce the permeability to water vapour as much as the permanent products do, and for that reason they are more suitable for historic masonry [6, 8] and for this reason, they continue to be more used.

Stone is the material that has been most studied regarding the prevention and removal of *graffiti*, since the buildings with historical interest are mostly constructed or coated in stone. Granite, marble, limestone, and sandstone are the stones most studied [18,19,20-22].

Although there are some quite porous stones (e.g., travertine and *moleanos*), mortar presents and even higher porosity and therefore, the application of some anti-*graffiti* coatings such as polyurethanes that can block the passage of water vapour through pores are not recommended for mortars or renders regardless of their durability [23].

Colour and brightness are also important properties that should be evaluated. Some anti-*graffiti* products may lead to changes in these parameters for surfaces of certain materials. In historical buildings this problem should be avoided. Sacrificial products, in particular waxes, produce smaller changes in colour and brightness of the surface compared with polyurethanes [20].

Some polysaccharides or products based on silicones are sacrificial and have shown a good performance. Their application has some advantages: they do not change the natural appearance of the surfaces as the permanent products do, they are permeable to water vapour and their application can be carried out immediately after the removal of *graffiti*, even when the surface is still wet [8].

Some anti-*graffiti* coatings found on the market are based on silicone. These products have been used due to their high hydrophobic capacity, good adhesion to the substrate, high durability and good resistance to weathering and chemicals [24].

Silanes (simpler monomeric silicon bonded to alkyl and alkoxy groups) and siloxanes (oligomeric compounds based on 3 to 7 repeating Si-O units), are often used as water-repellent products, but are also found in the market as anti-*graffiti* products due to their ability to adhere to porous materials [20, 24].

Recently, newer products have been synthesized based on fluorinated compounds as reported in several studies related to their effectiveness as anti-*graffiti* coatings [4,9,18]. The presence of fluorine in anti-*graffiti* coatings has been studied not only because it works as a water-repellent but also as an oil-repellent. Its inclusion in anti-*graffiti* products also gives anti-encroaching properties and higher resistance to stain formation and the development of microorganisms and algae, facilitating the cleaning process [4,18,19].

Fluorinated polymers provide anti-*graffiti* protection by their low surface energy, high resistance to solar and UV radiation, permeability to water vapour, and an increased durability of the coatings. Thus, it is possible to obtain permanent anti-*graffiti* protection with high resistance to several cleaning cycles [10]. The low energy surface obtained with fluorinated polymers may significantly reduce the cost of removal, since *graffiti* can be removed by using simpler methods and less aggressive cleaning agents from an environmental point of view [5]. Furthermore, the high resistance to weathering, light and heat (up to 450 ºC) given by the strong bond C-F is a characteristic provided by the addition of fluorine in the anti-*graffiti* products [10].

For example, water-based fluoroalkylsilanes are especially suitable to modify the surface of mineral materials such as concrete and have the potential to protect from *graffiti* as well as reducing chloride migration into the substrate thus deceasing reinforcement corrosion [5].

Water-repellency is imparted by the fluorine atoms, the distribution of the fluorinated groups in the polymer chains and their orientation on the surface. The low energy of surface that fluorine gives to these coatings prevents their wetting, since most of the polymers are characterized by a surface tension lower than of the water [5, 25]. Several studies indicate that the higher the concentration of fluorine, the lower the surface energy [10]. However, this is valid up to a given amount of fluorine; if it increases the improvement in anti-*graffiti* properties is not significant, and in addition, a problem may arise: the impossibility of reapplication.

Similarly, anti-*graffiti* products based on water-borne silicone, are also known to confer low surface energy coatings. Thus, to apply a second layer of the product, it may be necessary to wet the surface, which in this case is not possible due to adhesion problems. However, the reapplication is required since after several cycles of cleaning the anti-*graffiti* coating loses some properties [5, 25].

Newer technologies have been developed that allow changing the surface microstructure of the material in order to improve their resistance to *graffiti*. It is the case of the inclusion of nanoparticles in anti-*graffiti* products. The development of coatings incorporating nanoparticles have shown that there are many properties that can be improved with this technology, including: corrosion preventive coatings, improved self-cleaning capacity, antibacterial coatings, develop-ment of anti-glare glasses, more resistant paints and also anti-*graffiti* coatings [26]. The use of nanosilica, for example, has been included in products based on organic polymers. Its combination improves some of the properties of the coatings in particular the hardness, chemical and thermal stability, UV resistance and transparency [10, 27].

Finally, the need to find anti-*graffiti* solutions effective for inorganic porous materials is clear. Therefore, new products have emerged in the international market to improve some properties. Table 2 presents a comparison between various anti-*graffiti* products, in terms of their main properties, such as permeability to water vapour, changes in colour, water-repellence, durability and weathering resistance.

Table 2. Comparison between four anti-*graffiti* products [9, 10, 19, 20, 21].

	Waxes	Polyurethanes	Fluorinated polymers	Products with nano-particles of silica
Water vapour permeability	-	--	+	+
Colour change	++	++	+*	+*
Hydrophobicity	+	++	++	++
Durability	--	--	+	++
Resistance to weathering	--	--	+	+
Suitability of application in porous materials	Little suitable	Unsuitable	Suitable	Suitable

Caption: -- reduces significantly - reduces + satisfactory ++ increases
* Colour changes not visible to the human eye

CONCLUSIONS

Graffiti removal is a very expensive curative measure and, therefore, it is important to establish plans for prevention and maintenance of buildings, as well as developing new products to keep the materials protected from eventual attack.

The cleaning methods currently used for *graffiti* removal have not proved to be fully effective in porous materials such as renders. Their high porosity allows *graffiti* paint to attain a significant depth in the material, making the action of chemicals or laser problematic. Therefore, the use of anti-*graffiti* protection promises to be very important since it prevents the penetration of the ink into the substrate, facilitating the removal of *graffiti*.

To protect the surface of materials there are anti-*graffiti* coatings that prevent the penetration of ink into the substrates and make them water- and oil-repellent, facilitating the removal. These products can be classified as sacrificial, permanent and semi-permanent.

In the national market the use of polyurethanes (permanent) and waxes (sacrificial) has not had good results. Waxes to not influence the water vapour permeability of the substrate and therefore they are more frequently applied. However, the maintenance associated with the sacrificial products is intense and costly and therefore new products in the international market have tried to solve this and other problems.

The introduction of fluorine and nanoparticles of silica in the composition of these anti-*graffiti* coatings has led to good results. While fluorine provides a water- and oil-repellent protection, nanoparticles of silica increment the resistance to UV radiation and weathering, significantly increasing the durability of coatings. In addition, these products do not prevent the natural flow of water vapour between the substrate and the environment, making it more suitable for porous materials such as renders.

Based on the available studies, it appears that most of the current products marketed in Portugal are not the most suitable for porous surfaces. In this way, more studies should be carried out to improve the performance of existing products as well as to study the performance of more innovative ones.

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