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FAIR-FACED CONCRETE AND *ANTI-GRAFFITI* PROTECTION

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ABSTRACT

Fair-faced concrete, a design option in public and private buildings, works of art, common structures like bridges and retaing walls, largely built in the twentieth century is susceptible to attacks by *graffiti*. Durability of concrete depends on the composition and characteristics of the surface, whereby it is essential to study the effects of *anti-graffiti* protection systems on concrete durability and to adopt the appropriate methodology in order to preserve the integrity and authenticity of this heritage. Concrete is a porous material sometimes deteriorated over the years. The interactions between the inks and the substrate as well as the removal methods sometimes may deteriorate or alter the concrete surface, especially if it is necessary to repeat the removal process. A*nti-graffiti* products form a protective barrier on the concrete surface, hindering the adhesion of paints or preventing its penetration into the pores of the concrete, which facilitates *graffiti* paint removal. Thus, an experimental program was developed to analyze changes in durability indicators and surface properties related to concrete deterioration. The following possibilities were studied: (i) concrete without protection before and after application of the spray paint, (ii) concrete with protection before and after application of the spray paint and (iii) after paint removal. The concrete durability indicators studied were water absorption by capillarity and immersion and penetration of CO_2. Analysis by stereo binocular microscope, scanning electron microscope and energy dispersive x-ray spectroscopy were performed. The results obtained show that the applied *graffiti*, the *graffiti* protection and the *graffiti* removal affect surface characteristics.

1 INTRODUCTION

The *graffiti* phenomenon has grown in recent years and at any country there is patrimony subjected to the aggressive style of *graffiti* despite the preventive measures that are being implemented [1]. *The pleasure of degrading, breaking of the interdict and defiance against the authorities are roughly the determinants of the writer* [2]. Fair-faced concrete, a design option in public and private buildings, works of art, common structures like bridges and retaing walls, largely built in the twentieth century, is susceptible to *graffiti* paint. Durability of concrete depends mainly on the composition and properties of the surface layer that protect the steel reinforcement against corrosion. Durability of concrete structures is an important factor to be attained with regard to the long term behavior and life cycle cost of concrete structures [3]. The movement of gases, liquids and ions through concrete depends on the permeation properties of concrete surface. Water inside large voids of the order of >50 nm, referred as macropores, behaves as free water and plays an important role in the durability of concrete [4]. Capillary voids larger than 50 nm are detrimental to strength and impermeability of concrete. Concrete is a porous hydrophilic material and paints are absorbed through the pores. The interactions between the inks and the substrate and the removal methods cause a progressive deterioration of concrete surface (Fig. 1). Removal by mechanical processes can cause surface wear and micro cracks which increase permeability, providing the penetration of aggressive ions and consequently the chemical deterioration of concrete. Removing *graffiti* through a chemical product may increase the porosity of concrete, making the material more vulnerable to abrasion and erosion. Stains may appear on the concrete surface as a result of solvent penetration [5] [6].

Fig. 1. Fair-faced concrete with *graffiti*, Bridge of *Canal do Boco*, *Ílhavo* (2014).

Products for protection against *graffiti* have been developed to form a protective layer on concrete surface by lowering the surface energy and difficult *graffiti* paint adherence, facilitating paint removal or preventing their penetration into the pores. Contrariwise, the protective coating must have good adhesion to the concrete surface [7][8].Due to its hydrophobic and oleophobic properties, *anti-graffiti* protection act as a barrier between the environment and the concrete surface, preventing or delaying the penetration of harmful substances [9]. The higher the durability the lower the water absorption capacity, the carbonation degree and the permeability to chloride [10][11]. The protection product must have high permeability to water vapor, low permeability to carbon dioxide and water and good adhesion to the substrate. It must also cover the pore as a transparent film not changing the color on which they are applied, displaying good crack bridging ability and good resistance to alkalis in order to ensure concrete protection simultaneously from *graffiti* and environment [12][13]. So, it is essential to improve the current knowledge of the interactions between *anti-graffiti* protection and *graffiti* paint removal on fair-faced concrete and to contribute to the integrity and authenticity of this very important heritage [14].

Thus, an experimental program was developed in order to analyze the chemical and the microstructural effects of the *anti-graffiti* systems on surface properties and durability indicators related with surface protection against external agents, such as water and *graffiti* paints, covering the following possibilities: (i) concrete without protection before and after application of the *graffiti* paint; (ii) concrete with protection before and after application the *graffiti* paint; (iii) concrete after paint removal.

2. EXPERIMENTAL PROGRAM

2.1. Materials

Concrete. Conventional concrete (CONV) and high performance concrete (HPC) were produced with two calcareous course aggregates with a maximum size of 12 mm and 22 mm and two natural river sands with maximum size of 2mm and 4mm, cement CEM II/A-L 42,5R, fly ash (FA) from a Portuguese electrical power plant, chemical admixtures plasticizer *Sikament® 400 Plus* (P) and a superplasticizer *Viscocrete® 3008* (SP). Cubic (150 mm edge) and cylindrical specimens (150 mm diameter and 300 mm height) were casted, demolded next day and cured for each concrete composition. After demolding, the specimens were kept immersed in water for 7, 14 or 28 days at controlled temperature (21 º C). The compressive strength of the selected concrete compositions was tested on specimens aged at 7, 14 and 28 days. The compressive strength at 28-day of the HPC amounted to 62.8MPa and that of the CONV to 35.6 MPa.

***Graffiti* paint.** The simulation of *graffiti* (G) was performed with a black spray paint (*Ironlak®* product), an acrylic paint with high opacity gloss and very pigmented, used by the writers community to paint over large areas due to its fast drying and complete fixation to the porous surface. Paint was sprayed during 1s with 45 º slop and 15 cm distance from the surface of the concrete specimens.

***Anti-graffiti* systems.** A permanent system (AGS_1) and a sacrificial one (AGS_2), both not changing the color of the concrete surface and practically free of volatile solid compounds had been applied.

AGS_1 is a water-based fluoralkylsiloxane system, density 1.06 and pH 4. Paint removal is performed with a chemical and technical data indicates that it supports some cycles of *graffiti* paint and removal.

AGS_2 is composed of a water-based wax dispersion containing 10-15% of active wax, density 1 and pH 8-9. Removal process is carried out by projecting hot water at 75ºC under a pressure of 90-110 bar. The paint is removed simultaneously with the *anti-graffiti* product.

2.2. Experimental procedures

Observation and analysis by stereo binocular microscope, scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscopy (EDS) were performed to analyze the chemical and the microstructural effect of the *anti-graffiti* systems on surface properties related with protection against external agents, such as water and *graffiti* paints. The penetration depth of the treatments into the concrete surface and their distribution within were studied.

The specimens were prepared from fractured surfaces of concrete, placed and fixed in a cylindrical sample holder with conductive carbon (C-LEIT). After drying, samples were subjected to vacuum and coated with a carbon layer for improved conductivity and reduced electron charge. Subsequently, the samples were characterized by using a high resolution scanning electron microscope Hitachi© model SU-70, Schottky emission (SE), voltage of 500 V a 70 kV with a system of spectral analysis of energy dispersive X-ray (EDS) Bruker© Quantax 400, using an accelerating voltage of 15 keV and timely periods of 60 seconds. The obtained results are the average values of three observations from each specimen and were observed three different specimens from each condition.

3. RESULTS

Observation and analysis by stereo binocular and by SEM/EDS of surfaces of conventional (CONV) and high performance concrete (HPC) indicated that both concretes exhibited identical behavior and very similar superficial chemical characteristics. CONV has a greater tendency to capillary water absorption and penetration of CO_2 than HPC, since the concrete structure is more porous than the HPC [15] [16]. So, it was decided to present results regarding the different conditions for only one type of tested concrete. CONV was the chosen one.

3.1. Observation of concrete surface by stereo binocular

On concrete surface with permanent *anti-graffiti* protection AGS_1, due to hydrophobicity and oleophobicity properties of the protective product, spray paint do not stick to the surface in a uniform manner, forming droplets (Fig. 2a). On concrete with sacrificial *anti-graffiti* protection, spray paint adheres to the AGS_2 film without the formation of distinct droplets (Fig.2 b).

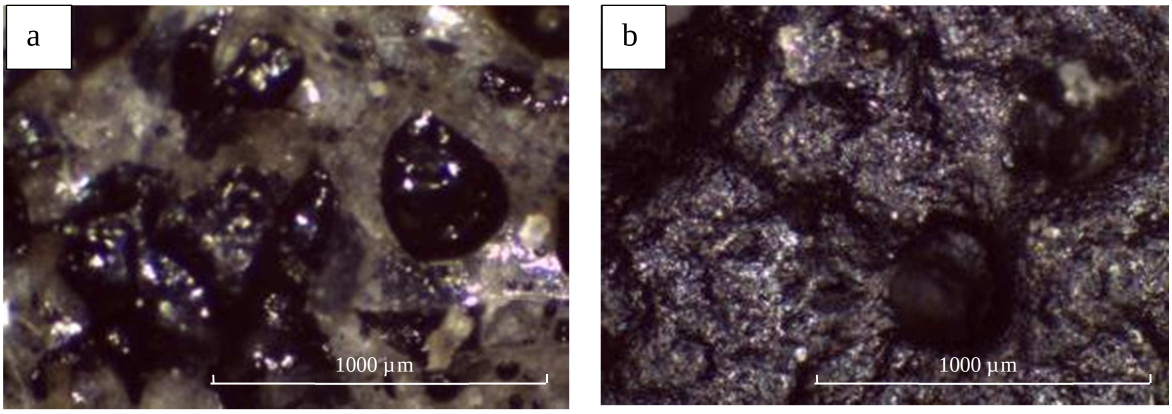

Fig.2. Observation by stereo binocular of concrete surface with (a) AGS_1 and (b) AGS_2 after sprayed with black paint.

After paint removal, concrete surface with permanent *anti-graffiti* protection remains with identical hydrophobicity and oleophobicity as before being sprayed with the paint. This *anti-graffiti* product remains on the concrete surface after ink removal. On concrete with sacrificial protection, ink and product protection film are removed at the same time. However, concrete pores and cracks are filled with black spray paint, being impossible the ink removal without damaging the microstructure of the concrete surface. It was also identified some cracks and macro pores partially covered by a film because the protective product does not have the capacity to coat those macropores and cracks (Figure 3a e 3b).

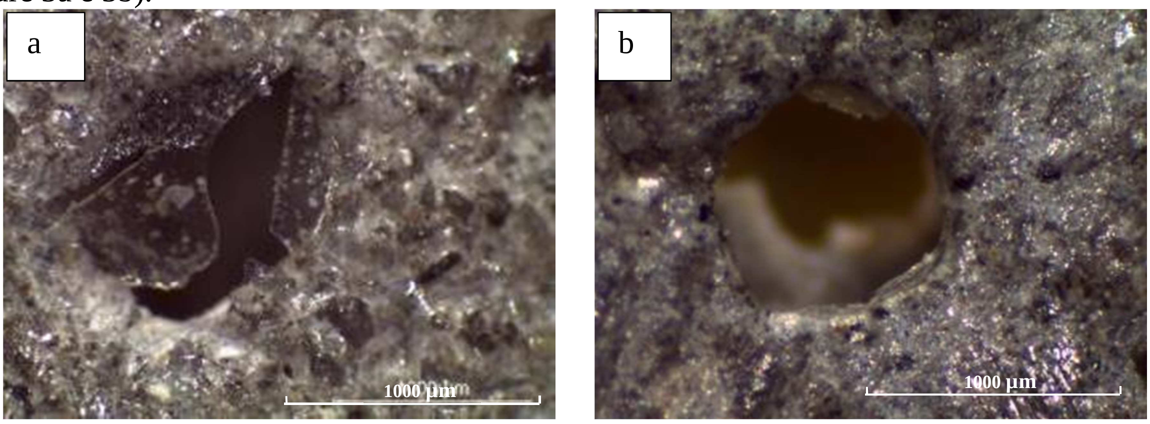

Fig. 3. Observation by stereo binocular of pores on concrete surface with (a) AGS_1 and (b) AGS_2 protection.

3.2. Chemical and microstructural characterization by SEM/EDS

***Graffiti* paint and *anti-graffiti* systems.** Observation and analysis by SEM/EDS indicate that the main chemical components of black spray paint are carbon (C) and oxygen (O) with average values of, respectively, 71 and 22 wt.%.

Permanent *anti-graffiti* protection main elements in the primer are carbon (C), fluorine (F) and oxygen (O) with average values of, respectively, 46, 32 and 21 wt.%. Permanent *anti-graffiti* product (AGS_1) is mainly made of carbon (C), fluorine (F) and oxygen (O) with average values of, respectively, 23, 57 and 10 wt.%. The gel remover is composed by carbon (C), oxygen (O) and silicon (Si) with average values of, respectively, 18, 48 and 34 wt.%. The main elements of the sacrificial *anti-graffiti* protection product (AGS_2) are carbon (C) and oxygen (O) with average values of, respectively, 79 and 19 wt. %.

Concrete surface without *anti-graffiti* protection. SEM/EDS observation and analysis indicate that the main chemical components are calcium (Ca), oxygen (O) and carbon (C), with average values of, respectively, 25, 46 and 18 wt. %. On the samples observed, pores of the surface have diameters in the range of 10 – 600 μm, occasionally reaching values of about 1mm.

Concrete surface with permanent *anti-graffiti* protection. Observation and analysis by SEM/EDS showed that the main elements are fluorine (F), carbon (C) and oxygen (O) with average values of, respectively, 43, 32 and 14 wt.%. On the samples observed, macropores of the surface have diameters in the range of 59 - 258μm. After spray paint application, SEM/EDS identified some surface areas with higher percentage of carbon (C) and a lower percentage of fluorine (F), as well as other areas with a higher percentage of fluorine (F) and a lower percentage of carbon (C). Cross-section and chemical mapping of concrete surface with AGS_1 protection and spray paint was observed on various samples. The *anti-graffiti* product impregnates the pore system and forms a protective hydrophobic and oleophobic layer on the concrete surface (Fig. 4).

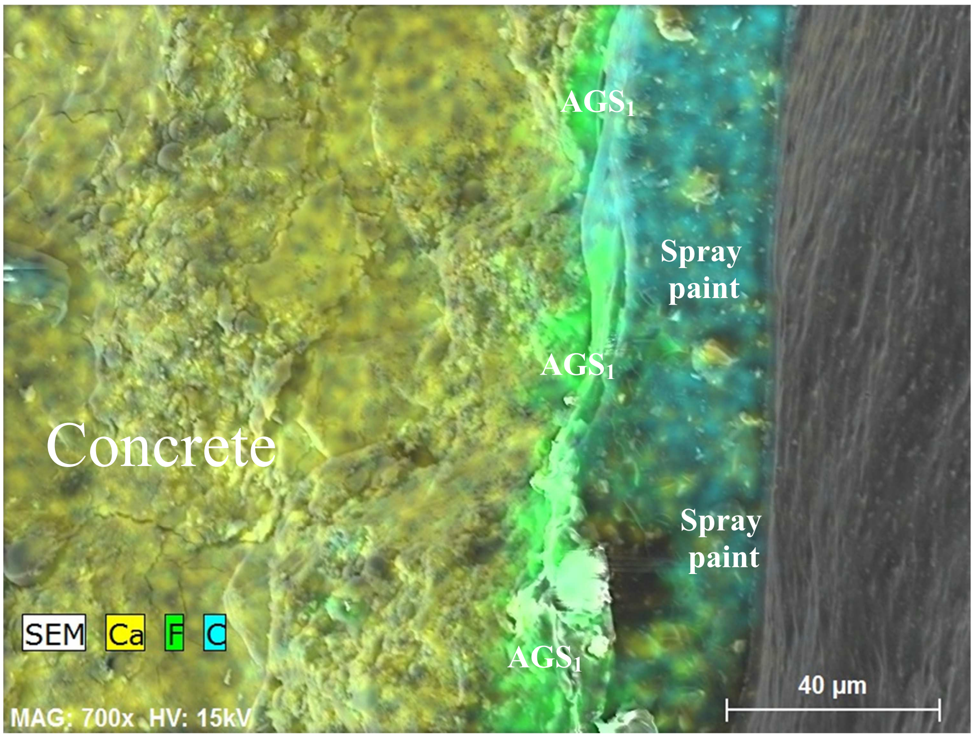

Fig. 4. SEM image of cross-section and chemical mapping of concrete surface with permanent protection (AGS_1), sprayed with black spray paint (magnification 700 x).

After spray paint removal, SEM/EDS observation and analysis confirmed the presence of the same elements fluorine (F), carbon (C) and oxygen (O), with average values of, respectively, 45, 31 and 13 wt. %. These values and proportions are similar to those obtained in the concrete with AGS_1 protection. It seems that permanent *anti-graffiti* protection remained on concrete surface for at least one removal cycle. The surface showed identical chemical characteristics to those of the concrete surface with permanent *anti-graffiti* protection, as no relevant changes were observed excluding pores filled with ink.

Concrete surface with sacrificial *anti-graffiti* protection. Observation and analysis by SEM/EDS showed that the main elements presented are carbon (C) and oxygen (O), with average values of, respectively, 80 and 19 wt. %. These are the same main components of either AGS_2 or spray paint. On the samples observed, macropores of the surface have diameters in the range of 80-288μm.

After spray paint application, observation and analysis by SEM/EDS showed that the main components are the elements carbon (C) and oxygen (O) with average values of, respectively, 68 and 21 wt. %. Cross-section and chemical mapping by SEM/EDS of concrete surface with the sacrificial *anti-graffiti* protection AGS_2 forms a coating, i.e. a protective homogeneous and continuous film. In this sample (Fig 5) AGS_2 fills a pore with a good adhesion to the substrate, contrariwise to the paint layer that stands out of the protective film due, simultaneously, to poor paint adhesion and experimental conditions.

After projecting hot water at 75ºC under a pressure of 90 - 110 bar, SEM/EDS observation and analysis of the surface showed that the ink was removed simultaneously with the *anti-graffiti* product. Soft water or acid fluids would increase the porosity of concrete, thus making the material more vulnerable [6]. In order to keep surface protected, a new application of the product in the affected area is mandatory. This protective product also doesn't have the capacity to coat the pore surface, do not preventing the penetration of ink into some macropores. If removal is perfect, some main chemical elements obtained by SEM/EDS must be present in identical proportion in concrete surface without any protection. Observation and analysis by SEM/EDS of concrete surface after paint removal is important for the reapplication of a new AGS_2 layer, avoiding overlapping of the product and contributing to their correct application.

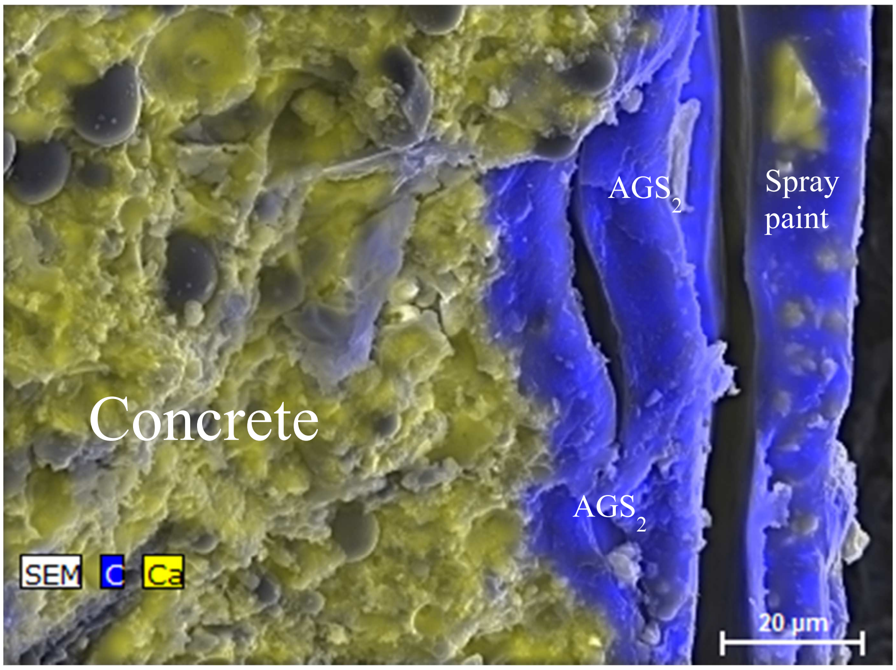

Fig.5. SEM image of cross-section and chemical mapping of concrete surface with sacrificial protection (AGS_2), sprayed with black spray paint (magnification 1.00K).

3.3. Influence on durability indicators

Chemical and microstructural characterization by SEM/EDS allows understanding the influence of concrete surface properties, with *anti-graffiti* protection and after paint removal, on durability indicators. Effects of the *anti-graffiti* systems on concrete durability were investigated and the tests performed include: water absorption by capillarity and immersion and penetration of CO_2. The CONV has a greater tendency to capillary water absorption and penetration of CO_2 than HPC, since the concrete structure is more porous than the HPC. Detailed information can be obtained in [15] [16].

As discussed in [15] [16], when the *anti-graffiti* protection, permanent and sacrificial, is applied in a concrete surface, water absorption by capillarity and by immersion inside the concrete decreases significantly but doesn´t prevents the entry of some water by the macropores without *anti-graffiti* protection film. Paint sprayed on the concrete surface, without protection or with *anti-graffiti* protection, also decreases water absorption. After paint removal, the *anti-graffiti* permanent protection remains on surface at least for one removing cycle. Analysis by SEM/EDS confirmed the presence of the main chemical elements fluorine (F), carbon (C) and oxygen (O). Indeed, water absorption before applying the spray paint and after paint removal has identical values. On concrete surface with *anti-graffiti* sacrificial protection, SEM/EDS analysis indicates the same chemical elements of concrete without any *anti-graffiti* protection. Water absorption after paint removal is similar to concrete without *anti-graffiti* protection. Sometimes, the removal process is not completed and the sacrificial product remains in substrate. In this case the *anti-graffiti* product removal remained unfinished and water absorption has an inferior value. The removal process must be careful because the elevated temperature, water pressure and chemical products may increase porosity, making concrete surface more vulnerable. The *anti-graffiti* protection does not prevent CO_2 penetration but decreases the depth of carbonation for the same exposure time, with a lower value for sacrificial protection. Paint sprayed on the concrete surface, without protection or with *anti-graffiti* protection, also decreases the penetration of CO_2. Contrary, ink removal increases the tendency for CO_2 to penetrate to similar levels to those seen in concrete without protection, which means that in this case, the removal process may have not modified the porous structure of the surface concrete.

4. CONCLUSIONS

Chemical and microstructural characterization of concrete surface properties by SEM/EDS is very useful to access its influence on transport processes inside concrete in relation to concrete durability. These a*nti-graffiti* systems, both permanent (AGS_1) and sacrificial (AGS_2), do not alter concrete surface aesthetic and facilitate removal of *graffiti* paint; also improve the durability of the concrete surface, reducing water permeability and carbon dioxide penetration and facilitating ink removal. The permanent and sacrificial *anti-graffiti* protection impregnates pores of concrete surface with a good adhesion. However, the *anti-graffiti* protection does not prevent penetration of the ink inside some macropores. Pores will appear with paint and masks when removing *graffiti* paint and it will be impossible to remove paint completely without damaging concrete surface structure.

References

[1] Lozano, J.Sebastián. Catálogos nacionales de património de Europa: una visión en conjunto, II Jornadas Europeas de Património Cultural, Madrid, 2001.ISBN 84-7491-642-9.

[2] Levisohn, Cedar. Street Art. Tate Publishing. Eds. 2009.

[3] Kreijger, P.C. (1984). The skin of the concrete. Composition and properties.Materials and Structures, 17275-283(DOI: 10.1007/BF02479083).

[4] Aligizaki, Kalliopi K. Pore Structure of Cement-Based Materials. Testing, interpretation and requirements. Taylor and Francis ® 2006 Kalliopi K. Aligisaki ISBN 0-419-22800-4.

[5] Carmona-Quiroga, P., Martinez-Ramirez, S., Sobrados, I. & Blanco-Varela, M.. Interaction between two *anti-graffiti* treatments and cement mortar (paste). Cement and Concrete Research 40 (2010), pp. 723-730.Matsui, I, Onda, A., Shinozaki, S., Kyo, E., Nagai, K.. (DOI: 10.1016/j.cemconres.2010.01.002).

[6] Metha, P. Kumar, Monteiro, J. M. Microstructure, Properties and Materials. Te MacGraw-Hill Companies, Inc ®2006 (DOI:10.1036/0071462899).

[7] Saidi, Salima, Guittard, Frédéric, Géribaldi, Serge (2001). Polymères contre graffiti. L´ACTUALITÉ CHIMIQUE. Mars (3) 2001, p3-14.
[8] Resende, João Alexandre (2010).Análise dos efeitos de produtos preventivos e corretivos *anti-graffiti* no granito do Porto (2010).Dissertação de Mestrado, Universidade do Minho.
[9] Swamy, R. N., Suryavanshi, A. K. and Tanikawa, S. Protective ability of an acrylic-based surface coating system against chloride and carbonation penetration into concrete. ACI Materials Journal 95 (1998), 101-112 (DOI: 10.14359/355).
[10] Basheer L, Kroop J and Cleland DJ (2001). Assessment of the durability of concrete from its permeation properties: a review. Construction and Building Materials (2001), vol. 15, nº 2-3, pp. 93-103.
[11] Camões, Aires and Costeira, André (2012). Durabilidade de Betões Reforçados com Fibras de Aço. BE-2012-Encontro Nacional de Betão Estrutural. Porto - 24, 25 e 26 de Outubro de 2012.
[12] Hammer, Tor Arne and Plesser, Thale Sofie Wester. Effect of surface treatment on chloride ingress and carbonation in concrete structures-State of the art. COIN Project report 3 (2008).
[13] Stadelmann, V.F. Acrylic and styrene/acrylic polymers. Handbook of coatings for concrete. Whittles Publishing. (2002). Caithness, pp.21-34.
[14] Intervention approaches in the 20^{th} century arquitectural heritage. International Conference CAH 20^{th} C. ISC20C-ICOMOS, Madrid document ISBN: 978-84-8181-505-4 (2011).
[15] E. Neto, A. Souto, A. Camões, A. Begonha and P. Cachim. Effects of *anti-graffiti* protection on concrete durability. 1º Encontro Luso- Brasileiro de Degradação em Estruturas de Concreto Armado. Salvador, Bahia, Brasil, 06 a 09 de agosto de 2014.
[16] E. Neto, A. Souto, A. Camões, A. Begonha and P. Cachim. Effects of *anti-graffiti* protection on concrete durability. Key Engineering Materials 634 (2015), 517–526. (DOI:10.4028/*www.scientific.net*/KEM.634.517).