INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

Surface Protection of Concrete

Influence of the support moisture content in the performance of impregnation products

João Fialho Ribeiro de Sousa Santana

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1. Introduction

Impregnation products are among the various systems currently available for the surface protection of concrete, of which the compounds based on silicates (fluorosilicates and sodium silicate) and the products based on synthetic resins (epoxies and acrylics) are the most common. The mode of action of sodium silicate consists in its reaction with the calcium hydroxide present in the pores of the concrete, forming hydrated calcium silicate, while the synthetic resins harden by chemical reaction inside the pores and capillaries of the concrete, achieving a substantial reduction of the porosity of the concrete and an increase of its superficial resistance with these types of protection. Thus, by its characteristics, the protection with impregnation products is typically used in horizontal surfaces exposed to abrasive wear, such as garages and industrial warehouses.

The literature review conducted within this study revealed that impregnation products have not been sufficiently studied, namely by comparison with other types of superficial protection, such as hydrophobic impregnations. From the few studies carried out, it is worth mentioning the experimental campaign conducted by Lopes [1], who evaluated the influence of the roughness of the support in the performance of two epoxy resins (one solvent based and another water based) and of a product based on silicates, which are the same three products used in the present study. Lopes [1] used specimens of concretes with water/cement (w/c) ratios of 0.40 and 0.70 and with three different types of superficial roughness – (i) without any surface treatment, (ii) subjected to a water jet at 160 bar and (iii) subjected to a needle scaler. The capillary absorption of water, the impact and abrasion resistances, the adhesion to the substrate (by pull-off test) and the depth of penetration were assessed, based on standard EN 1504-2 [2]. Regarding the results of that study, it was possible to conclude that the application of impregnation products introduced improvements in the performance of concrete, for most of the tests performed, and that the support roughness influences their behaviour, but with a positive or negative effect depending on the test in question. It was also observed that the two epoxy resins provided better performance than the silicate based product and that the procedure provided in standard EN 1504-2 [2] did not allow the measurement of the impregnated depth by the products.

Regarding studies of other authors, Ibrahim *et al.* [3] evaluated the performance of a sodium silicate by testing attack due to sulphates, carbonation depth and chloride penetration depth in samples of concrete with w/c ratio of 0.45. Results showed that the product was effective in reducing the concrete's carbonation after five weeks on a carbonation chamber, although the same effectiveness was not obtained in reducing chloride diffusion coefficient and in maintaining compressive strength of concrete immersed in a sulphate solution (330 days).

The Minnesota Department of Transportation [4] evaluated the performance of a sodium silicate and of an aqueous based epoxy resin with regard to chloride penetration in concrete, having concluded that the sodium silicate product does not reduce the penetration of chloride ions (confirming the study of Ibrahim *et al.* [3]). On the other hand, the epoxy resin showed improvements of about 17%, by comparison with non-treated specimens, after 3 years of observations.

Thompson *et al.* [5] tested the abrasion resistance of concrete protected with silicates sealants, with different percentages of solids (37.6% and 38.6%) and dilutions. The test results showed that treated samples obtained better performances, compared with non-treated samples, similarly to the experimental campaign results of Lopes [1].

This paper presents a study whose objective was to evaluate the influence of the moisture content of the concrete support (at the moment of the products application) in the performance of impregnation products applied in concrete with different w/c ratios.

2. Experimental programme

2.1. Objectives and experimental programme

In order to investigate the influence of the moisture content of the concrete substrate at the time of application of impregnation products in their performances, an experimental campaign was conducted based on information present on standard EN 1504-2 [2]. This standard indicates the testing of capillary absorption of water, impact and abrasion resistances, adhesion to the substrate (by pull-off test) and depth of penetration for impregnation products. Samples of concrete with different w/c ratios (0.40 and 0.70) were used, in which the impregnation products previously studied by Lopes [1] were applied, namely two epoxy resins, one solvent based and the other water based, and a silicate based product.

An alternative test was also conducted in order to measure the depth of impregnation of the products, since, as described above, Lopes [1] concluded that the standard EN 1504-2 [2] procedure was ineffective to evaluate this parameter. Thus, it was attempted to quantify this parameter using the addition of a pigment in the products.

Finally, the effect of the amount of silicate based product applied on its performance was tested, having been applied (i) the amount recommended by the manufacturer and (ii) an amount 2.5 higher than that value.

2.2. Materials

2.2.1. Concrete

Concrete slabs with 30 cm x 30 cm x 4 cm were produced with w/c ratios of 0.40 (B1) and 0.70 (B2). Table 1 presents the composition of the used concrete and their compression strength and splitting tensile strength.

In order to ensure a superficial roughness a water jet at 160 bar was applied, for being a common method in works. However, it was found that the abrasive process did not result in a uniform superficial roughness in all slabs, particularly with regard to concrete slabs in concrete B2. The cause may have been related to differences in superficial resistance of the slabs, due to their manufacturing process, with the result that after the application of a pressurized water jet some slabs have been more porous than others.

Table 1 – Concrete compositions and compressive and tensile strengths

Materials	Composition (kg/m^3)	
	B1	**B2**
Coarse aggregate 1 (4-10 mm)	850	600
Coarse aggregate 2 (20 mm)	-	400
Sand	900	900
Cement	455	260
Water	182	182
Compressive strength (MPa)	55.40	27.50
Tensile strength (MPa)	4.10	2.56

Concrete slabs were cut with the use of a diamond saw, resulting in specimens with the dimensions presented on Table 2.

Table 2 – Specimens geometry

Test	Dimensions
Capillary absorption of water (**AB**)	Length: 22 cm; Width: 7 cm; Height: 4 cm
Impact resistance (**I**)	Length: 22 cm; Width: 7 cm; Height: 4 cm
Abrasion resistance (**AS**)	Length: 11 cm; Width: 11 cm; Height: 1.5 cm
Adhesion to the support (**P**)	Length: 30 cm; Width: 15 cm; Height: 4 cm

Note that the corners of specimens for the abrasion resistance test (AS) were cut, so that they were compatible with the Taber abraser used.

2.2.2. Impregnation products

The selected products consisted of two epoxy resins (one solvent based and the other water based) and a silicate based product, the same that were studied by Lopes [1]. To deeper the knowledge about their characteristics, their densities were determined in laboratory (procedure based on EN ISO 2811-1 [6]), having additionally used information present in Lopes [1] about the non-volatile matter content and the molecular identification of the products. The procedure for the determination of non-volatile matter content was based on EN ISO 3251 [7] and the molecular identification was conducted by means of Fourier infrared spectrophotometer (FTIR). The referred characteristics of the products are present in Table3.

Table 3 – Characterization of tested products

Product	Density (g/ml)	Non-volatile matter content (%) [1]	Molecular identification [1]	
			Component A	Component B
Solvent based epoxy (**A**)	0.996	62.42	Aromatic amine	Epoxide polymer (bisphenol A and epichlorohydrin)
Water based epoxy (**B**)	1.074	52.00	Epoxide polymer (bisphenol A and epichlorohydrin)	Aromatic amine
Silicate based product (**C**)	1.080	35.04	Acrylic polymer and silicates	

2.3. Moisture content stabilization

To stabilize the moisture content of the specimens the indications present in standard EN 13579 [8] were followed, with the procedure specified in the referred standard having been adapted in order to adjust it to the present study.

The first stage consisted in the mass characterization of the specimens, having been obtained their saturated and dry masses by estimation, from the results of a previous study made in a representative sample of each size type of specimens. In that previous study, saturated mass of the specimens was obtained by immersion in water containers, having been subsequently dried in an oven at 105 ^{o}C during 7 days for dried mass obtainment, as the standard EN 13579 [8] stipulates. Mass variations observed in both procedures were registered, having been possible to extrapolate the values in question to the test specimens, since it was made an initial weighting to all specimens before proceeding to the saturation of the referred representative sample.

A conversion was made of the measure of moisture content (present in the standard EN 13579 [8]), expressed in percentage by weight, to a measure representing the percentage of voids filled with water. Thus, a moisture content of 100% of voids filled with water would correspond to the saturated surface dry moisture content (% by weight), while a moisture content of 0% of voids with water would correspond to a specimen in dry oven condition. Note that this measure conversion is a result of observing that specimens with different sizes showed different saturated surface dry moisture content, forcing the need to use a measure that expressed equally the moisture content of specimens with different dimensions.

For the present study three classes of moisture content were selected, expressed as a function of percentage of voids filled with water: 50% (H1), 75% (H2) and 100% (H3). The procedures for stabilizing the moisture content of the specimens were adjusted to the necessity of gaining or losing moisture in order to meet the values above. Thereby, the specimens of saturated category (H3) were placed in containers with water until their masses stabilized. For the remaining specimens, those that needed to lose weight, to achieve the intended moisture content, were placed in an oven at $60^{o}C$ or in a conditioned room at $21\pm2^{o}C$ and $60\pm10\%$, depending on the value to lose. Oppositely, the specimens with moisture content below the intended were immersed in water or placed in a sealed chamber containing water containers (in order to create an environment with high moisture content), again depending on the value of mass needed to be achieved.

Finally, it is stated that after obtaining the intended mass of each specimen, a measurement of the surface moisture content was made with a *Protimeter* moisture meter.

2.4. Products application

The last procedure for the preparation of the test specimens was the products application, having been applied the maximum quantities recommended by the manufacturers. It is noted that the values of the amount of products to apply were adjusted to their real density, obtained in laboratory.

For the product C it was also made an application 2.5 times higher than the maximum amount recommended by the manufacturer (variant CC), which permitted to evaluate the influence of the applied amount of this product in its performance.

In Table4 are present the quantities applied of each product.

Table 4 – Selected application amount of the products for the tests

A	B	C	Variant CC
250 g/m^2	250 g/m^2	214 g/m^2	540 g/m^2

The products application was made after the moisture content stabilization of the test specimens, with the use of a brush.

After the products application, all specimens were kept in a conditioned room to ensure their drying in a controlled environment.

2.5. Assessment tests of the performance of the products

2.5.1. Capillary absorption of water

This test was based on the standard EN 1062-3 [9], having been weighed the specimens after 10min, 30min, 1h, 2h, 3h, 6h, 24h, 30h, 48h, 72h and then every two days until attaining saturation.

The specimens' water transmissibility coefficient correspondent to the first 24 hours (w_{24}) was calculated using the measured values during the test, having been compared the results of the treated specimens with the non-treated specimens, which allowed calculating the reduction (R) verified on that coefficient. The used equation, indicated on standard EN 1062-3 [9], is shown below.

$$w_{24} = \frac{\Delta m_{24}}{A \times \sqrt{24}}, \text{ in kg/m}^2\text{.h}^{1/2} \qquad \textbf{(1)}$$

2.5.2. Impact resistance

This test was carried out in order to evaluate the influence of the products application in concrete's resistance to impact. The test, based on standard ISO 6272-1 [10], was performed by dropping a mass (with a sphere of 20 mm at the end) of 1973.28 g.

The standard EN 1504-2 [2] indicates three possible classes for the impact energy, having been selected class II (Nm) so that the results were in accordance with the experimental campaign of Lopes [1].

The drop height of the mass was calculated based on the equation of the gravitational potential energy, which is shown below:

$$E_p = m \times g \times h \qquad \textbf{(2)}$$

in which,

- E_p – gravitational potencial energy (Nm);
- m – mass;
- g – acceleration on gravity;
- h – height.

Thus, the height of fall of the mass to make up the 10 Nm was 51.7 cm.

For the evaluation of the performance of the different variants, a metallic scale was used to measure the diameter of the impacts (in three different directions).

2.5.3. Abrasion resistance

The abrasion resistance test was performed based on the indications present in standard EN ISO 5470-1 [11], having been complemented with some specifications provided by standard EN 1504-2 [2]. According to this last standard, masses of 1 kg were attached on each of the Taber abraser's arms and abrasive wheels H22 were used in this test.

Regarding the number of cycles of this test, standard EN 1504-2 [2] refers that it must be carried out 1000 cycles of abrasive wear in each specimen. However, since after 200 cycles it was verified that in most specimens the treated surface had disappeared, a test with just 400 cycles was chosen, because the remaining cycles would correspond to the evaluation of non-treated concrete's abrasion resistance.

With the measured values, reductions of mass loss in the various cycles were calculated by comparison of the treated specimens with the non-treated.

2.5.4. Adhesion to the support – by pull-off test

The pull-off test was based on standard EN 1542 [12]. Four drills, with 50 mm of diameter and 15 mm of depth were performed per specimen. This way, metallic dollies with the same diameter were used.

During the tests, type of failures and the corresponding load were recorded, having converted this last parameter for tensile bond strength according the equation below:

$$\sigma = \frac{F_{máx}}{A_{dolly}} \tag{3}$$

in which,

- σ – tensile bond strength in MPa;
- $F_{máx}$ – maximum load registered;
- A_{dolly} – dolly's diameter.

2.5.5. Depth of penetration

This test was carried out according the standard EN 1504-2 [2], having been fractured the specimens from the capillary absorption test in two halves. After that, the fractured surfaces were sprayed with water in order to identify a separation of a dry zone (impregnated depth) and other wet.

Additionally, since Lopes [1] refers that the procedure described above has proven to be ineffective in assessing depth of penetration of impregnation products, it was carried out an alternative test using the addition of a red pigment to the products. Therefore, the products were mixed with a pigment soluble in water (KVK Aquadisperse FG – EP (04/87)) and applied (Figure 1) in remains of the two types of concrete slabs (7 cm x 7 cm x 4 cm), performing a total of six samples (two for each product). The amount of products applied coincided with the maximums recommended by the manufacturers (Table 4).

Subsequently, the samples were fractured in two halves, and the measurement of the impregnated depth was performed using a crack comparator.

Figure 1 – Appearance of a sample in concrete B1 after the application of product B mixed with the pigment

3. Results and discussion

In the following sections the results obtained in the various tests will be summarized. The samples identified as O are the control specimens, *i.e.* without any impregnation of product applied.

3.1. Capillary absorption of water

The curves obtained with the weighing carried out during the test of capillary absorption of water are presented in Figures 2 to 9, while the values of the reduction of water transmission (R), by comparison of the treated samples with the non-treated, are presented in Figures 10 and 11.

It can be observed that the application of impregnation products in the B1 concrete caused reductions above 80% in the coefficient of water transmission, while in the more porous concrete (B2) the reductions observed were clearly lower, due to the inability of these impregnation products in filling efficiently the pores and seal them. However, especially with regard to the specimens in concrete B2, the high dispersion of results is notorious, thus a rigorous analysis proved difficult to be performed. The dispersion was due to the influence of low uniformity of surface roughness of the specimens, with this difference having been observed during the preparation of the samples, after the abrasive process by water jet (Section 2.2.1).

Regarding the performance of the products, it was observed that the two epoxy resins (products A and B) showed a better performance than the product based in silicates (C), being this higher efficiency related to the natural tendency of the epoxy resins in forming film in the concrete surface, making more difficult the penetration of external agents.

In what concerns the influence of the moisture content of the support in the performance of the impregnation products, it was found that these products when applied in concrete B1 did not show significant differences in their behavior, due to the general stagnation of the products in the surface, because of the low porosity of the support. However, it is noted that the products B and C obtained better performance with the humidity H3, possibly due to the fact of the products tending to be retained in the surface when the support is saturated.

In concrete B2 it is only possible to conclude that product A (solvent based resin) worsen its performance with the increase of moisture content, suggesting that the mixture of this product with water can be prejudicial to its performance in reducing capillary absorption of water. On the other hand, products B and C showed the same tendency in improving their performance with the saturated support, due to product retention on the surface. In this concrete it is still observable that some specimens treated with product C showed water transmission coefficients higher than that of untreated concrete, being the most likely cause the disparity between the surface roughness of the specimens.

Finally, regarding the effect of the amount of product C applied in its performance, and unlike what would be expected, there was no improvement with the increase of the amount of product applied, being the explanation related with the moisture content of the specimens of variants C and CC at the moment of the test. Since the application of the product in specimens C occurred after the one on specimens CC, the first remained less time in a conditioned room until the execution of the test and, therefore, lost less moisture content than the last ones. This led to the results of specimens CC, which having lower moisture content at the moment of the test, were affected by higher capillary suction capacity.

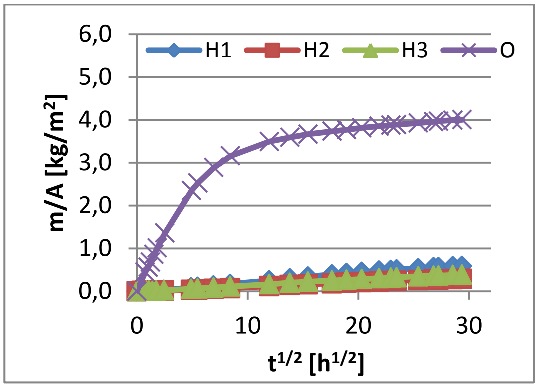

Figure 2 – Speed of water transmission of B1A

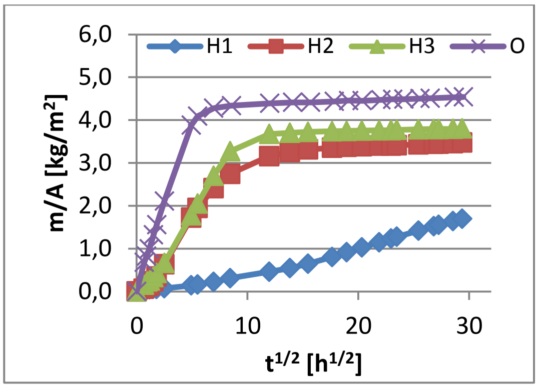

Figure 3 – Speed of water transmission of B2A

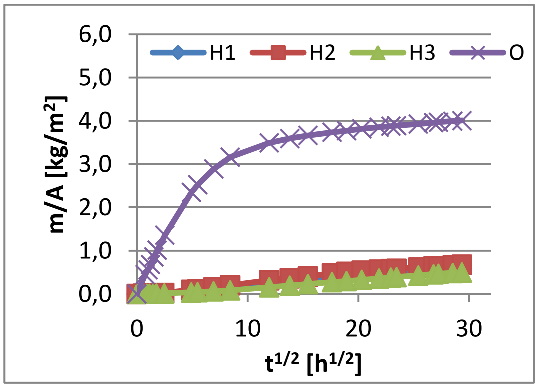

Figure 4 – Speed of water transmission of B1B

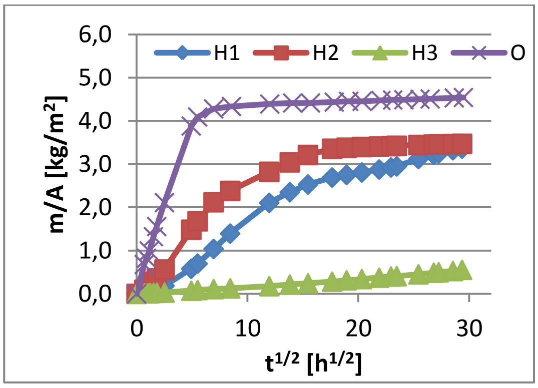

Figure 5 – Speed of water transmission of B2B

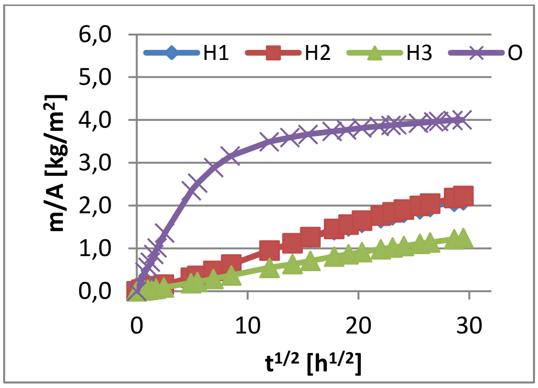

Figure 6 – Speed of water transmission of B1C

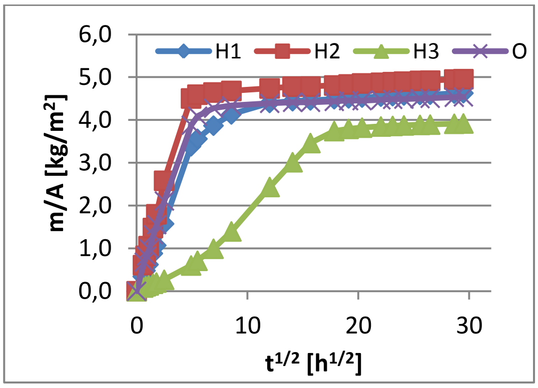

Figure 7 – Speed of water transmission of B2C

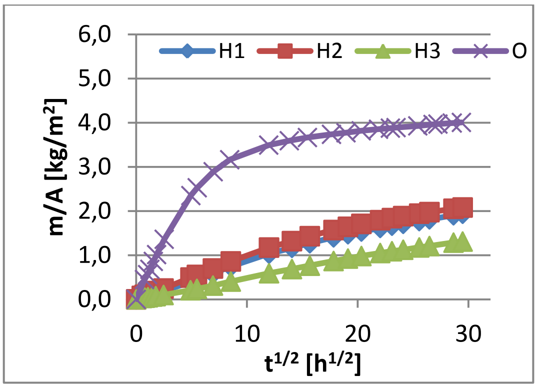

Figure 8 – Speed of water transmission of B1CC

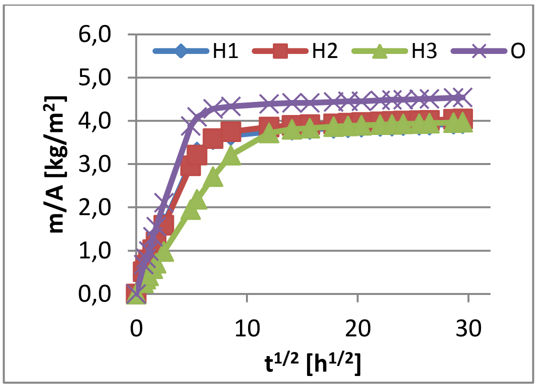

Figure 9 – Speed of water transmission of B2CC

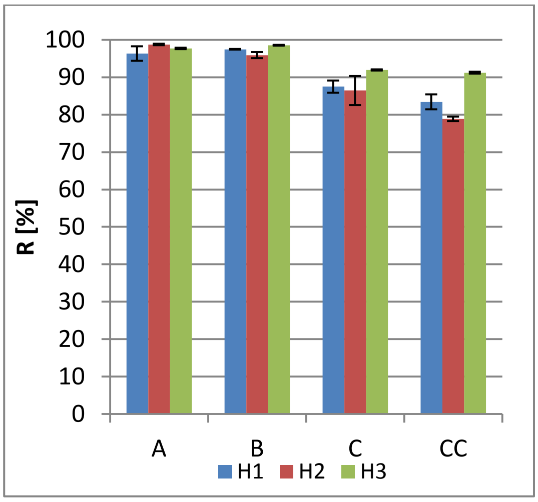

Figure 10 – Results of reduction of the water transmission coefficient of the studied variants in concrete B1

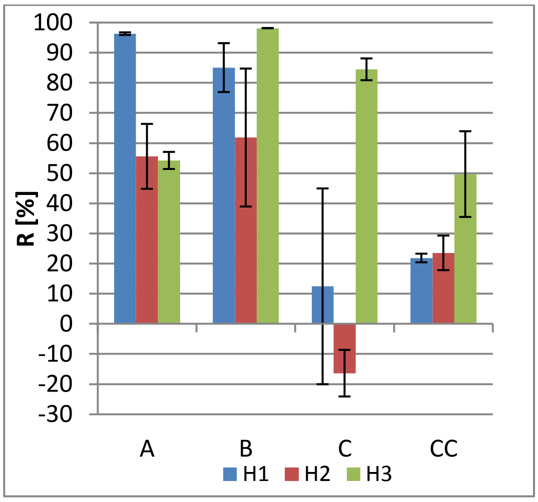

Figure 11 – Results of reduction of the water transmission coefficient of the studied variants in concrete B2

3.2. Impact resistance

In the course of this test it was found that the specimens were fracturing with the realization of impacts. However, since the measurements of the diameters were carried out immediately after each impact and that the fractures occurred in places where the impact had previously undertaken, the results were not affected by this factor.

Thus, by the results of the diameter of the impacts sites, presented in Figures 12 and 13, it was verified that the application of the products did not have a positive effect in the impact resistance of the two concretes. However, the results may be affected by the deformation capacity of the products, taking into account the tendency of epoxy resins in forming film in the concrete's surface. By analyzing the results of the two resins (products A and B) in the two concretes it is possible to see that the treated variants in concrete B2 showed a better performance when compared with the control specimens (O), than the treated variants in concrete B1, which may be due to the higher penetration of the products in the concrete more porous. Therefore, the cavities formed by the impacts depended less on the deformation capacity of the products.

In what concerns the influence of the moisture content of the support in the performance of the products, due to the results obtained and their dispersion, it is not possible to identify a tendency in their behavior.

Finally, regarding the effect of the amount of product C applied in its performance, it was found out that the increased amount applied improved the performance of this product, having decreased the diameter of the impacts.

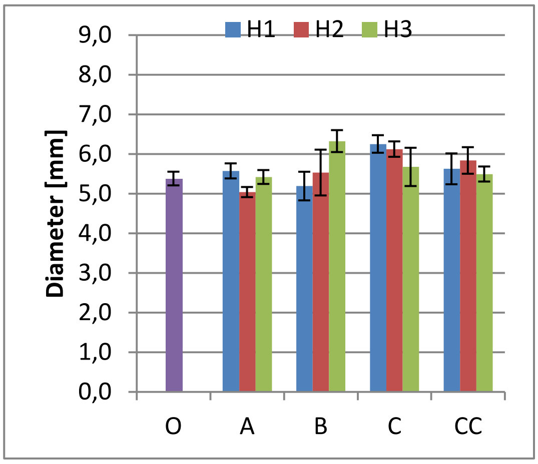

Figure 12 – Comparison of the diameters obtained in the studied variants in concrete B1

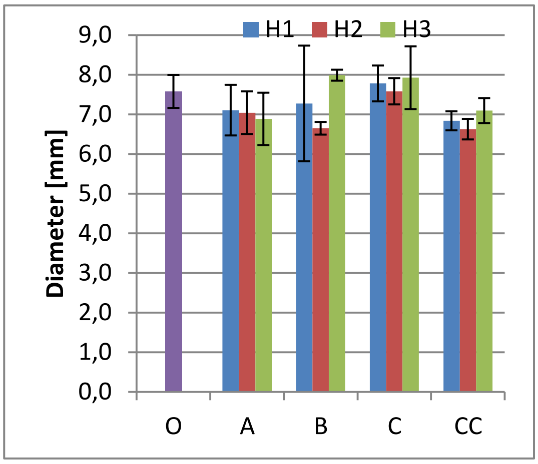

Figure 13 – Comparison of the diameters obtained in the studied variants in concrete B2

3.3. Abrasion resistance

The results of the reduction of mass loss obtained in this test are shown in Figures 14 and 15, having been concluded that, as in the test of capillary absorption of water, the difference of surface roughness in the specimens was related with the dispersion of the results.

In what concerns the products' performance, it was found out that the protection conferred by the application of the epoxy resins (products A and B) is superior than that offered by the product based in silicates (C), which may be, as in the capillary absorption of water test, consequence of the film formation of these products in the concrete's surface.

Regarding the influence of the moisture content in the performance of the products, it was verified that the product A presented a tendency to improve its behavior with the increase of the moisture content, possibly due to the fact that the presence of water in the pores hinder the penetration of the product, forcing it to be retained in the surface. It is further noted that the water present in the support does not seem to influence the characteristics of the mechanical resistance of this product, in contrast with what was observed in the test of capillary absorption of water, in which the transport properties of the film were adversely affected.

Product B was not influenced by the variation of the moisture content of the support at the moment of the application of the product, showing only a slight improvement in the saturated variety, possibly due to retention of product in the surface.

According to the results of the concrete B1, product C showed the lowest performance in the humidity H3, which may be due to the fact that the product was retained in the surface of the concrete when the pores were filled with water. Unlike epoxies, for not being a product that naturally forms film, its presence in the concrete's surface may be ineffective in abrasion resistance.

Finally, regarding the effect of the amount of product C applied in its performance, it was found out that the increased amount applied is beneficial to its performance in both concretes, pointing out that in concrete B2 a substantial improvement is achieved in abrasion resistance in the categories of humidity H1 and H2.

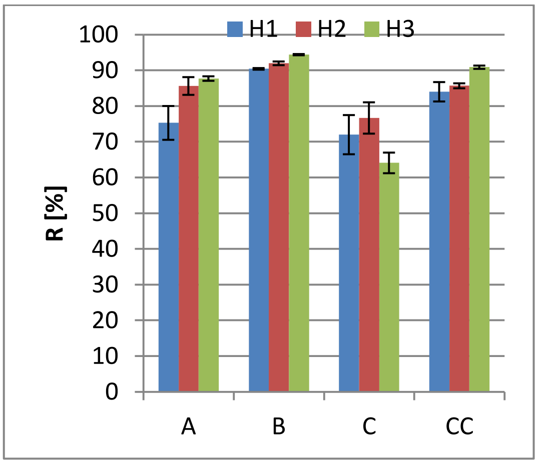

Figure 14 – Reduction of mass loss in the specimens of concrete B1

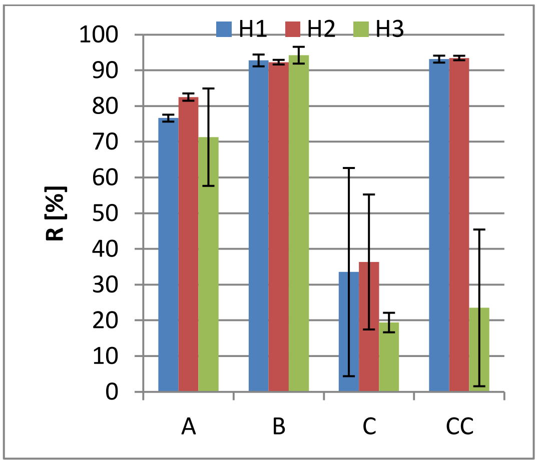

Figure 15 – Reduction of mass loss in the specimens of concrete B2

3.3.1. Adhesion to the support – by pull-off test

For a correct interpretation of the results, the different types of failure that may occur in this test are first listed as follows:

- A – cohesion failure in the concrete substrate;
- A/B – adhesion failure between the substrate and the product layer;
- B – cohesion failure in the product layer;
- Y – cohesion failure in the adhesive layer;
- A/Y – adhesion failure between the substrate and the adhesive layer(applicable only in untreated specimens);
- Y/Z – adhesion failure between the adhesive layer and the dolly.

It is noted that results with adhesive failures (type Y and Y/Z) greater than 10% were not considered, with the exception of specimen B1CH3P-1, for having presented results above the referred limit in all tests. In that case it was only considered the result with the lowest percentage of failure by the adhesive layer (20%), for having less interference of this factor in the reading of the load at failure and because the remaining three tests were very similar (all with 40% of adhesive failure).

Figures 16 and 17 show the tensile bond strength obtained in the specimens of concrete B1 and B2, respectively, while Figures 18 and 19 present the average percentage of each type of failure that occurred in specimens of concrete B1 and B2, respectively.

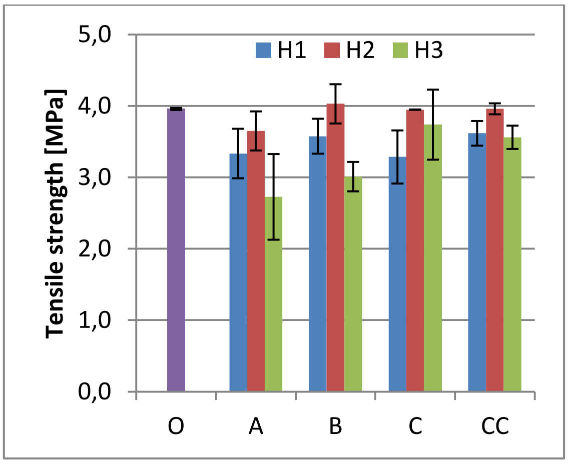

Figure 16 – Results of the tensile bond strength in the variants of the concrete B1

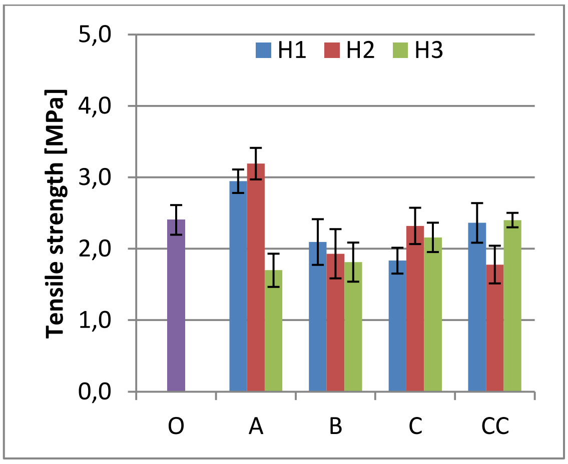

Figure 17 – Results of the tensile bond strength in the variants of the concrete B2

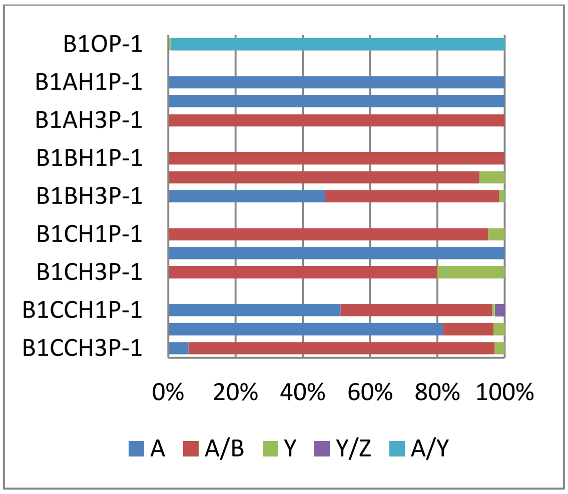

Figure 18 – Types of failure in the variants of the concrete B1

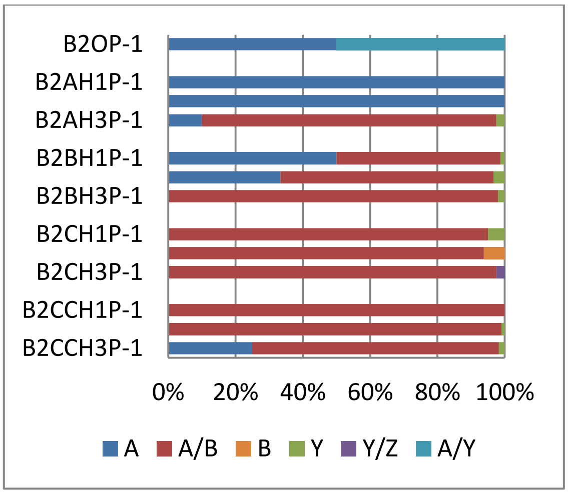

Figure 19 – Types of failure in the variants of the concrete B2

For the product A, in both concretes, it can only be concluded that the tensile bond strength decreased with the category of humidity H3, since the failures of the other two categories occurred completely by the concrete substrate (type A), only indicating that tensile bond strength of the product in those is higher than the measured values. This behavior indicates that the product did not penetrate properly with the saturated support, as would be expected.

In what concerns product B, it was also verified that the worst results of adhesion were obtained in humidity H3, suggesting a less effective penetration. Furthermore, in the concrete B1 there was an improvement of the adhesion to the support with the intermediate category of humidity (H2), which indicates that, for being a water base product, the presence of water may favor the chemical reaction with the concrete. For the concrete B2, the failure types (high percentage of type A) of categories of humidity H1 and H2 do not permit the comparison of the results in question.

The results of the product C in concrete B1 indicate that the best performance was obtained in humidity H2. In concrete B2 it was not possible to observe a similar behavior, possibly due to the fact of specimens of the categories of humidity H2 and H3 being from slabs that were produced with different sand than the others. It is noted that this option was only considered for not being available more material produced with the same sand.

Regarding the effect of the applied amount of product C in its performance, it was found out that, in most of the categories, the increased amount of product applied contributed for a higher adhesion to the support.

3.4. Penetration depth

In this test, performed according to the procedure recommended by standard EN 1504-2 [2], it was not possible to detect the impregnated surface of the specimens, being only possible to observe that the two epoxy resins formed film, which we clearly thicker in specimens in concrete B1, than in those in concrete B2. This difference is related with the fact that the latter concrete is more porous and thereby, facilitates the penetration of the products.

The inefficiency of the procedure indicated in the standard EN 1504-2 [2] may be related with various factors, namely the following: the main objective of the use of impregnation products is the hardening of concrete surfaces and not the substantial reduction of water absorption (which is the case of the hydrophobic products). This fact may be responsible for the impossibility of detecting a delimitation of a dry zone after spraying the fractured surface, for not having a sufficient water repellent effect. On the other hand, the dry zone may be not visible, due to insufficient depth of penetration. Finally, since the color of the products is not distinguishable after the reaction of the products with the concrete, it is difficult to analyse the depth of penetration.

However, with the alternative procedure, in which a red pigment was added to the products, it was possible distinguish the impregnated depth (Figure 20), having registered the values presented in Table 5.

Table 5 – Impregnated depths registered

Product	Penetration Depth (mm)	
	B1	B2
A	0,40	0,65
B	0,10	0,20
C	0,075	2,0

Figure 20 – Impregnated depth on a specimen in concrete B2 with the product A applied

As expected, the products achieved higher penetration depths in the more porous concrete (B2).

4. Conclusions

Based on the results obtained with the experimental campaign, the following main conclusions are drawn:

1. It is noted that the application of the impregnation products tested introduces improvements in the behavior of both concrete, being also noticeable that the two epoxy resins (products A and B) provided the best results in most of the tests. This last fact is related with the intrinsic characteristics to these resins, namely the tendency in forming film in the surface of the concrete, which ensures a more effective barrier between the environment and the concrete.

2. In the test of water capillary absorption it was verified that the saturated condition of the support (H3) contributes to a better performance of the products B and C, for leading to product retention in the surface of the concrete and form a more efficient barrier. Moreover, the increment of humidity of the support may be prejudicial to the transport properties of the film of product A (due to the mixture of water with the solvent base), lowering its performance in this parameter.

3. The impact resistance test was found to be inconclusive, since it was observed that the results were influenced by the deformation capacity of the products, particularly in the specimens treated with the epoxy resins (products A and B), having not been possible to determine the real deformation of the concrete.

4. In what concerns the abrasion resistance test, it was verified that the product B didn’t significantly change its behavior, while the product A improved the reduction of mass loss with the increasing of moisture content of the support, suggesting that this led to a retention of the product in the surface, not having affected its properties of mechanical resistance. In contrast, the product C lowered its performance with the humidity H3, possibly due to the fact that with the saturated support a reaction of the product with the concrete (making it sufficiently resistant) does not occur.

5. Regarding the adhesion of the products to the support, it was found that the products presented tensile bond strength that approaches the tensile strength of the substrate,

with an aggravation of this parameter occurring with the saturated condition of the support, as would be expected. Moreover, it was observed that the product B had its adhesion to the support improved with the intermediate category of humidity (H2), indicating that a presence of a certain moisture content in the support might promote its reaction with the concrete.

6. Generally, the obtained results showed that a saturated support in the moment of the application of the products may be favorable to the performance of the water based epoxy and of the silicate based product in reducing the permeability of concrete to water. Similarly, the abrasion resistance of treated concrete with the epoxy resins can be favored with the saturated condition of the support in the moment of the application of these products. However, the application of impregnation products in saturated concrete is, generally, prejudicial to their adhesion to the support, which may have negative consequences regarding the medium and long-term durability of the system of surface protection of the concrete. On the other hand, the intermediate category of humidity may promote the reaction of the water based epoxy with concrete, leading to a better adhesion of this product to the substrate.

7. The performance of the products, in the majority of the evaluated parameters, when applied in the concrete B1 showed to be less affected by the moisture content of the support in the moment of the application, due to the low porosity of this concrete, which led to the concentration of products in the surface of the specimens, regardless the moisture content (although it has not been possible to quantify the penetration depth of the tested products).

8. The test for the evaluation of penetration depth of the products, performed according to the standard EN 1504-2 [2] proved to be inconclusive, suggesting that the procedure is inadequate to the type of products in question. On the other hand, the alternative procedure tested, with the addition of a pigment to the products, appeared to be feasible, although being necessary to evaluate the chemical influence of the pigment in the products.

9. Regarding the effect of the amount of product C applied in its performance, it was found that the increased amount applied had a positive effect in the protection of the concrete, although this has not been demonstrated in the test of capillary absorption of water. However, for this component of the study, it is noted that the experimental procedure should have been adjusted, by carrying out a new moisture content stabilization of the specimens before the test, which was not possible to carry out given the existing limitations for the execution of this study.

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