

# Performance of hydrophobic products in ETICS

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Extended Abstract

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## 1 Introduction

In the last decades, the construction industry has faced a growing interest in the optimization of the energy efficiency associated to the buildings environment, according also to new EU regulations [1]. In this context, External Thermal Insulation Composite Systems (ETICS) have been extensively applied, as they allow to significantly improve the thermal performance and energetic efficiency of buildings, both in new and retrofitted buildings [2].

However, ETICS can present several anomalies (*e.g.* stains, cracks, biological colonization, etc.), due to their constant exposure to weathering agents, which compromise their energy efficiency and durability. The main decay agent is generally water, which can trigger physical-mechanical-chemical degradation and also enhance biological growth [2, 3]. For this reason, the application of protective coatings with hydrophobic properties, which reduce the wettability and water absorption from the surface, can minimize the appearance of anomalies and increases the durability of the system.

Water repellents can be classified, depending on their mechanism of action and on their composition, as film-formers or penetrant products. The film formers can act in distinct modes, either as a coating, developing a continuous film on the surface (*i.e.* paints and vanishes), or pore blocker, penetrating into the substrate and react with the free salts in mineral building materials and thus filling the superficial pores [4, 5]. Penetrant products penetrate the structure of the superficial pores and create and hydrophobic film in their walls [4]. The main difference between film former and penetrant products is situated in their capability to allow the passage of water vapor. The application of penetrants generally do not alter the porous network, so the passage of water vapor is mostly unaffected. In the case of film formers and pore blocker products, which fill up pores, water vapor permeability is significantly conditioned [5].

The comprehension of the effect of water-repellent protection on a porous substrate is a critical task, since the change in water vapor permeability and the change in drying kinetics can contribute to speed up the material degradation process [6]. In fact, the effectiveness of the water-repellent product depends not only on its chemical properties, but also on the physical features of the treated substrate [7, 8].

The durability of the treatment, *i.e.* the long-term effectiveness, is another important aspect in the selection of the protection product. The durability of these products can be affected by a number of factors, namely, weathering, UV radiation, extreme pH conditions or pollutants [3, 8].

Several studies have been carried out mostly on stone, concrete and ceramic materials (e.g. [5], [6], [9] [10]), and to a lesser extent on mortars (e.g. [3, 11]) and ETICS (e.g. [4, 7]). Among the studies carried out, only few evaluate the performance of film formers (paints and varnishes), focusing mostly on the performance evaluations of penetrant products.

This study aims to contribute to the knowledge of film former hydrophobic protection products applied on ETICS systems, in order to increase its durability, minimize the appearance of anomalies and optimize its thermal performance. The performance of three different commercial paints (two based on acrylic and one based on siloxane) applied on ETICS was analysed, with the aim of assessing the compatibility, effectiveness, and durability of these hydrophobic products. The moisture transport properties (water absorption by capillarity, water permeability under low pressure with Karsten tubes, drying kinetics, water vapor permeability, contact angle measurement) and susceptibility to mold development were assessed through laboratory tests on treated and untreated specimens. The durability of the treatments was also tested, through artificial aging tests (freeze-thaw and heat-cold cycles).

## 2 Materials and methods

### 2.1 Materials

The ETICS specimens considered in this study are composed of EPS insulation board, a finishing render with a cement-base coat and an acrylic-based top coat with hydrophobic properties and incorporation of TiO<sub>2</sub> nanoparticles. The protection products used were three commercial paints. Table 1 provides the description, chemical composition and number of coats for each paint studied.

The application of the products was made by brush and according to the manufacturers' recommendations. Two layers of product were applied, being the second coat applied orthogonally to the first. The drying time between coats was at least 24 h, to guarantee the complete evaporation of the aqueous solvent.

*Table 1 - Characterization and application information of the studied protection products.*

Designation	H1	H2	H3
<b>Chemical Composition</b>	Acrylic-based paint	Siloxane-based paint	Acrylic-based paint
<b>Physical characteristics</b>	Color: white Density: 1,34 ± 0,05 pH: 8,00 - 9,00	Color: white Density: 1,58 ± 0,05 pH: 8,50 - 10,00	Color: white Density: 1,30± 0,03 pH: 8,00 - 9,00
<b>Number of coats and composition</b>	1 <sup>st</sup> coat: 30 ml of paint + 3 ml of water 2 <sup>nd</sup> coat: 30 ml of paint		

These products also have antibacterial (biocide additive) and self-cleaning (photocatalytic additive, *i.e.* titanium oxide nanoparticles) features.

## 2.2 Experimental methods

To evaluate the performance of the protection products, three specimens of each paint and three specimens for the ETICS system without protection (reference) were tested.

The capillarity water absorption test was carried out according to ETAG 004 [12]. The water absorption curves and the capillary water absorption coefficient were determined. The capillary water absorption coefficient is calculated according to equation 1.

$$Cc = \frac{M_2 - M_1}{A \times (\sqrt{0,05})} \quad (1)$$

Where  $Cc$  is the capillary water absorption coefficient ( $\text{kg}/\text{m}^2\text{h}^{0.5}$ );  $M_1$  is the specimen mass at the beginning of the test (kg);  $M_2$  is the specimen mass after 3 min (0,05 h) (kg) and  $A$  is the immersed base area ( $\text{m}^2$ ).

The drying test was performed according to *EN 16322* [13] and was carried out sequentially at the end of the capillary water absorption tests. The test assesses the performance of the specimens through the drying rate in the step I (DR1) ( $\text{kg}/\text{m}^2\text{h}$ ), the drying rate in the step II (DR2) ( $\text{kg}/\text{m}^2\text{h}^{0.5}$ ), and the drying index. The drying index is determined according to equation 2 [7].

$$DI = \frac{\int_{t_0}^{t_f} f\left(\frac{M_x - M_1}{M_1}\right) dt}{\left(\frac{M_3 - M_1}{M_1}\right) \times t_f} \quad (2)$$

Where  $M_x$  is the specimen mass registered during the drying process (g);  $M_1$  is the specimen mass in dry state (g);  $M_3$  is the specimen mass at the beginning of the test (g);  $t_f$  is the ending time of the drying process (h).

The water absorption at low pressure with the *Karsten* tube followed the test No. II.4 of RILEM [14] for 24 h and the coefficient of water absorption for 60 min is determined according to equation 3.

$$C_{abs}^{60min} = \frac{A_{bp} \times 10^{-3}}{A_{contact} \times 10^{-4} \times \sqrt{1}} \quad (3)$$

where,  $C_{abs}^{60min}$  is the coefficient of water absorption for 60 min ( $\text{kg}/\text{m}^2\text{h}^{0.5}$ );  $A_{bp}$  is the water mass absorbed after 60 min (g);  $A_{contact}$  is the contact area of the tube with the surface (assumed to be 5,7  $\text{cm}^2$ ).

The contact angles were measured by sessile drop technique, *i.e. Axisymmetric Drop Shape Analysis*. This test is based in the variation of the interface free energy (area/water drop). The test is carried out by dropping with a micropipette  $4 \pm 0.4 \mu\text{l}$  of water on the specimen. The contact angle is measured according to equation 4 (using MATLAB).

$$\theta = 2 \arctan\left(\frac{2 \times hm}{am}\right) \quad (4)$$

where,  $hm$  is the height and  $am$  the diameter of the microdrop, respectively. The final result is obtained by calculating the mean value of several static contact angle measurements.

The water vapor permeability was performed according ETAG 004 [12]. This test considers the diffusion resistance of the water vapor coefficient ( $\mu$ ) (equation 6) and the diffusion-equivalent air-layer thickness ( $S_d$ ) (m) (equation 6) [15].

$$\Delta = \frac{m}{A \times \Delta_p} \quad (5)$$

$$\mu = \frac{1,94 \times 10^{-10}}{\Delta \times e} \quad (6)$$

$$S_d = \mu \times e \quad (7)$$

Where,  $\Delta$  is water permeance ( $\text{kg}/\text{m}^2 \cdot \text{s} \cdot \text{Pa}$ );  $m$  is the slope of the linear relationship between weight change and time ( $\text{kg}/\text{s}$ );  $A$  is the specimens area ( $\text{m}^2$ );  $\Delta_p$  is the difference between the outdoor and indoor vapor pressure (assumed to be 1395 Pa) and  $e$  is the thickness of the specimen (m).

The biological growth test was carried out according to a methodology adapted from American Standards *ASTM D 5590-17* (2017) [16] e *ASTM C 1338-19* (2019) [17] and previously validated by Parracha et al. [18]. Two fungal species (spore suspensions of *Aspergillus niger* and *Penicillium funiculosum*), applied together, were used in this study.

The durability of the treatment was also tested, through artificial aging test with freeze-thaw and heat-cold cycles. This test was adapted from *EN 1015-21* [19] and Table 2 provide the description of cycles conditions. Eight cycles of each type were performed.

Table 2 - Accelerated aging test – Cycles conditions.

Heat-cold cycles	Freeze-thaw cycles	time
Heating-Infrared lamps (T = 60 ± 2°C)	Sprinkler system (water at T = 20 ± 1 °C)	8 h ± 5 min
Stabilization (T=20 ± 2 °C e HR=65 ±5%)	Stabilization (T=20 ± 2°C e HR=65 ± 5%)	30 min ± 2 min
Freeze (T = -15 ± 1 °C)	Freeze (T = -15 ± 1 °C)	15h ± 15 min
Stabilization (T=20 ± 2 °C e HR=65 ±5%)	Stabilization (T=20 ± 2 °C e HR=65 ±5%)	30 min ± 2min

### 3 Results and discussion

#### 3.1 Capillary Water Absorption and Water Absorption with Karsten tubes

Results obtained for capillary absorption and absorption with Karsten tubes are presented in Figure 1 and Table 3. The results showed that the hydrophobic protection products decrease the capillarity water absorption coefficient ( $C_c$ ) of 25 – 35% for all protections (Table 3), being H3 (acrylic-based) the less water absorbent treatment (Figure 1). In Figure 1, it can be observed that for all specimens (treated and untreated), after 1 h of testing, the water absorption is less than 1  $\text{kg}/\text{m}^2$ , as required by ETAG 004 [12].

Accelerated artificial aging reduced water absorption by capillarity in all systems, including the ETICS system without protection (55%  $C_c$  decrease, compared to unaged specimens (Table 3)). One of the possible causes for the reduction of capillary water absorption after aging with hygrothermal cycles may be the leaching of some particles from the ETICS finishing layer due to freeze thaw cycles, particularly for specimens, where detached particles were observed on the surface (Figure 1Figure 2b). Another possible hypothesis is related to the reduction of the porosity of the base layer of the ETICS system as

a result of an evolution in the hydration reactions of the cement, as an effect of the cycles of exposure to water.

For treated specimens, the main cause can be the reduction of capillary suction, resulting from the expansion of capillary pores as a consequence of micro-cracking (Figure 3d, e and f). However, these protected systems may also have been partially leached. Even after artificial aging, the specimens protected with hydrophobic products continue to repel water more than aged unprotected specimens. The system with application of H3 showed, as in the initial performance, the highest reduction in the absorption of capillary water.

In the low pressure water absorption test with Karsten tubes, the H1 and H3 products (both acrylic based) reduced the water absorption with a reduction of the coefficient at 60 min up to 67%, standing out (according to capillarity) H3. In this same test, the H2 product present lower values when compared to the other protection products, with water absorption values similar to those of the unprotected system.

After aging, the  $C^{60}$  were also much lower than those obtained for the initial performance for all systems, with most significant reduction for H3 (93.3%). However, this trend was not maintained throughout the test, with absorption values higher than those obtained before aging, particularly for surfaces with H1 and H3 (both acrylic based) and for the unprotected system, which may indicate some loss of effectiveness in protecting the coating water with aging (Figure 1b).

As a matter of a fact, the mechanisms of water penetration in the system by capillarity and by Karsten pipes are different. The entry of water under pressure is associated with larger pores, when compared to capillary pores (1 to 10  $\mu\text{m}$ ) [20], which might indicate an expansion of the pores present on the surfaces (occlusion-destruction of capillary pores and increase of non-capillary pores). For the system with H2 protection product (based on siloxane), the absorption values were always lower during the test (Figure 1b) (with few pores, more microcracks being observed on this surface - Figure 3d).

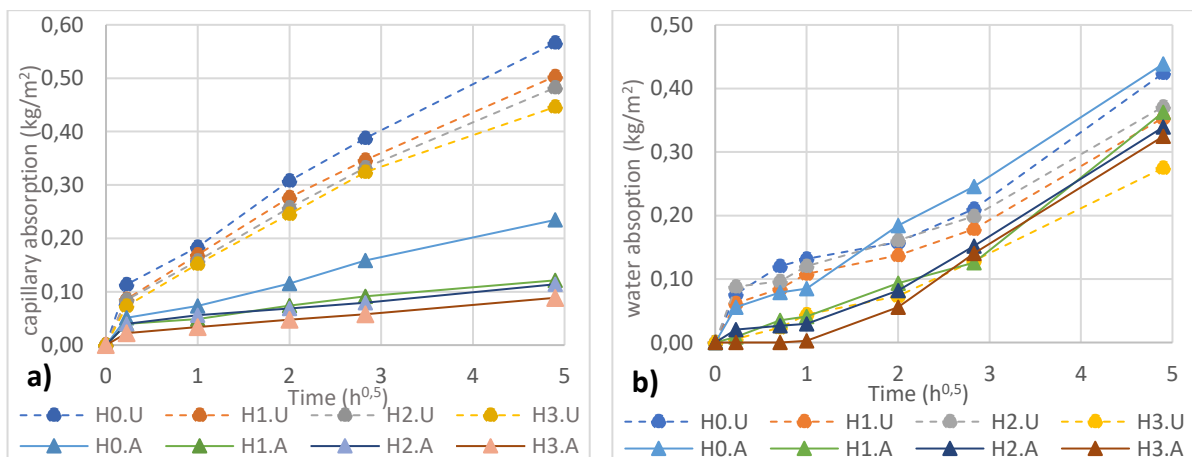


Figure 1 - a) Evolution of the capillary water absorption; b) Evolution of the absorption with Karsten pipe, in unaged (U) and aged specimens (A). H0 is the reference; H1 and H3 are acrylic-based paints and H2 siloxane-based paint.

### 3.2 Contact Angle

With the application of a water-repellent protection system, a reduction in water absorption and an increase in the contact angle on the protected surface ( $> 90^\circ$ ) is expected [6]. However, in the present

study, despite a reduction in water absorption both by capillarity and under low pressure, an increase in the contact angle of up to 54.3% was observed with the application of H2 and H3 products and a 32.7% reduction with the application of H1 (Table 3). One of the possible causes for the decrease in the angle of contact on the surface with H1 is related to the chemical composition of the product. H1 paint (100% acrylic dispersion) is a generic product with no special features, it is not specified that it has water repellent properties in its technical data sheet. This product might contain a higher amount of non-polymeric additives, such as fillers or pigments, if compared to H2 and H3, conferring hydrophilic properties to the substrate, which can explain the decrease of the contact angle and increase of the surface wettability.

Additionally, acrylic products can be functionalized using several monomers with specific characteristics [21]. Thus, it is possible to create acrylic (co)polymers with hydrophilic or hydrophobic properties [11].

On the other hand, an increase in the contact angle was observed after the application of H2 and H3, however, the contact angles did not achieve the hydrophobicity threshold (90°). The reduced contact angles can be explained by the chemical composition of the polymer (particularly for H1 and H3, acrylic-based) [5], or by inclusion of significant percentages of TiO<sub>2</sub> for self-cleaning purposes [22] (up to 25% in volume) which generally provides hydrophilic properties; furthermore, the binder content and the amount of additives added to the paint [23, 24] can also increase wetting.

After aging, the contact angle increases for all specimens (according to the reductions observed in previous tests) (Table 3). However, as in the initial performance of the products, lower contact angle values were observed for the protection products H1 and H3 (acrylic based) after aging, if compared to those of the unprotected system (25.4% and 12.2%, respectively), despite lower absorption values both by capillarity and with Karsten tubes. It should be said that contact angle > 90° (*i.e.* hydrophobic surface) is observed only in the case of the aged H2 specimen (Table 3) however, it is not the surface that has lower water absorptions by capillarity.

Thus, it is concluded that there is no clear linear relation between the contact angle and the water absorption of a surface, particularly when using this type of multifunctional protection products (paints) with complex formulation. It is worth noting the competitive effect among the polymeric component with hydrophobic properties and the titanium dioxide nanoparticles with hydrophilic (photocatalytic) features.

*Table 3 - Average results and relative standard deviation of the capillarity water absorption coefficient (Cc), of the water absorption coefficient under pressure ( $C_{abs}^{60min}$ ) and contact angle of protected and unprotected specimens, prior and after artificial aging test.*

System	Before Artificial Aging			After Artificial Aging		
	Cc (kg/m <sup>2</sup> h <sup>0.5</sup> )	$C_{abs}^{60min}$ (kg/m <sup>2</sup> h <sup>0.5</sup> )	Contact angle (°)	Cc (kg/m <sup>2</sup> h <sup>0.5</sup> )	$C_{abs}^{60min}$ (kg/m <sup>2</sup> h <sup>0.5</sup> )	Contact angle (°)
Reference	0,51 ± 0,04	0,13 ± 0,04	54	0,23 ± 0,05	0,09 ± 0,03	85
H1	0,38 ± 0,04	0,11 ± 0,05	37	0,18 ± 0,05	0,04 ± 0,04	64
H2	0,38 ± 0,03	0,12 ± 0,02	84	0,18 ± 0,02	0,03 ± 0,03	111
H3	0,33 ± 0,03	0,04 ± 0,03	63	0,10 ± 0,01	0,01 ± 0,01	75

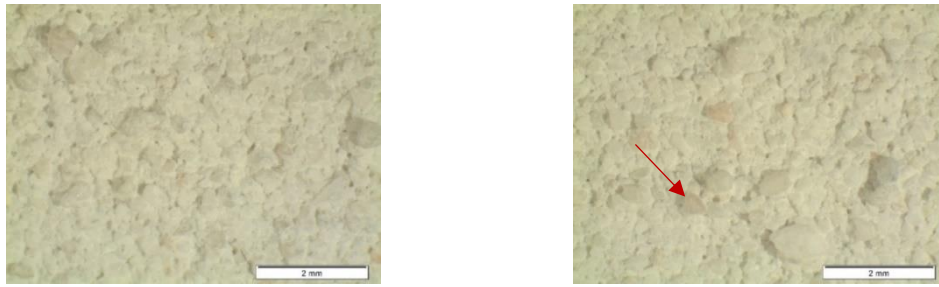


Figure 2 - ETICS system untreated. a) before artificial aging; b) After artificial aging. The arrow indicates the loose particles

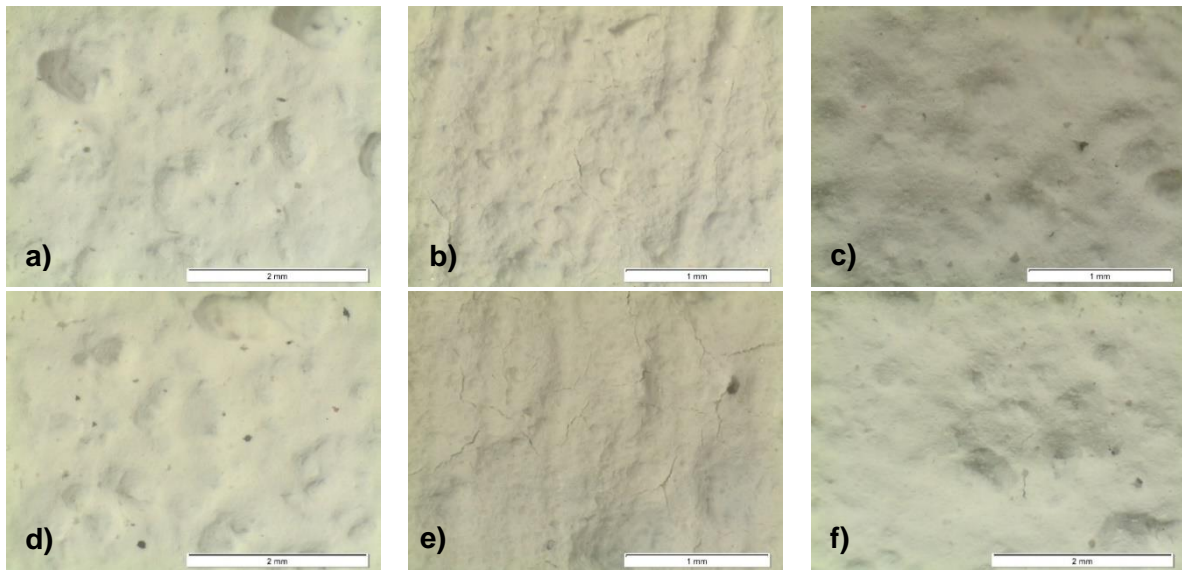


Figure 3 - Treated Specimens. A) H1 before aging; b) H2 before aging; c) H3 before aging; d) H1 after aging; e) H2 after aging; f) H3 after aging.

### 3.3 Drying test

Concerning the drying kinetics, the (acrylic-based) products H1 and H3, despite absorbing less water, delay the drying rate, with an increase in the drying index (DI) of the ETICS system of 99 and 124%, respectively (Table 4). H2 (based on siloxane) was the only one that decreased the drying resistance of ETICS, with an improvement of 12.4% in the DI. In fact, product H2 had the lower negative effects on drying rates (DR1 and DR2), keeping drying kinetics in the 2<sup>nd</sup> step of drying (DR2) practically unchanged, whereas the acrylic-based treatments (H1, H3) have a higher impact (higher delay, especially in the case of H3 - 70%) (Table 4).

After aging, the same trend observed in the previous tests was observed, supporting the hypothesis of a change in porosity with the aging cycles (justified also by the lower amount of water absorbed). The aging effect was more evident in the drying rate 2 (DR2), corresponding to the transport of water in the vapor phase. The unprotected system suffered a reduction in DR2 of 71.1% and the protected systems (H1, H2 e H3) suffered a reduction in the order of 80%. Product H3 continues to be the one that induced a higher delay of the drying of the substrate, while H1 and H2 present insignificant variations in drying resistance (DI) (Table 4).

Table 4 - Results of drying rate in the liquid phase (DR1), drying rate in the vapor phase (DR2), drying index and total variation of mass in the end of test ( $\Delta Tm$ ), in protected and unprotected specimens, before and after artificial aging test

System	Before Artificial Aging				After Artificial Aging			
	DR1 (kg/m <sup>2</sup> .h)	DR2 (kg/m <sup>2</sup> .h <sup>0.5</sup> )	DI	$\Delta Tm$ (%)	DR1 (kg/m <sup>2</sup> .h)	DR2 (kg/m <sup>2</sup> .h <sup>0.5</sup> )	DI	$\Delta Tm$ (%)
Reference	0,062	0,043	0,125	1,26	0,106	0,013	0,193	0,78
H1	0,038	0,035	0,249	2,06	0,051	0,008	0,186	0,33
H2	0,046	0,042	0,110	0,80	0,043	0,008	0,202	0,37
H3	0,031	0,030	0,280	2,32	0,029	0,005	0,250	0,35

### 3.4 Water Vapor Permeability

The results of the water vapor permeability test showed that the water vapor permeability of the system was practically unchanged, with even a slight improvement, with the application of the protection products H1 and H2. The water vapor diffusion resistance coefficient ( $\mu$ ) reduced (up to 4%). With the application of H3, a higher resistance to the diffusion of water vapor (14%) was observed (Table 5).

It is necessary to emphasize that for the average values for H0 (reference, unprotected specimens) (Table 5) only values of two specimens were considered (due an uncontrollable analytical error in a specimen), in contrast to the other products, which were used for calculation three.

The water vapor diffusion resistance coefficient ( $\mu$ ) from thermal insulation (EPS) was also obtained. Results confirm that all the systems fulfill the value recommended by ETAG 004 [12] (diffusion-equivalent air-layer thickness -  $S_d < 2m$ , in the case of systems with EPS as thermal insulation) (Table 5).

After aging, H0 suffered a significant decrease in permeability (80%), in the same way as DR2, confirming the possibility of a reduction in the porosity of the ETICS system. The products H1 and H2 continued to show the most suitable performance in vapor permeability, with a moderate decrease, considering that they protected the system from the damages caused by the aging cycles, maintaining an adequate permeability. The product H3, as in the unaged specimens, showed a higher resistance to vapor diffusion, compared to the unprotected system. The  $S_d$  obtained for H3 after aging exceeds the recommended 2 m and the remaining systems present values very close to 2 m. This indicates that after aging, and particularly for the surface with H3 application, there is a high possibility of interstitial condensations, which can affect the durability of the system.

The better performance in water vapor permeability and drying rate 2 of H2 may result from the differences between polymers (siloxane and acrylic), such as polymer microstructure, crosslink density and morphology. [25]. Additionally, other characteristics of the paints, such as the binder content, the size and the geometry of the pigment, have an influence on the permeability of the protective films [26].

Topçuoğlu et al. [26] found that the permeability of water-based acrylic paints, containing different levels of binder, decreased dramatically with increasing binder content.



Concerning the contact angle results, due to the complex paint formulation, the choice of the type of binder, the type and amount of additives and pigments, as well as their distribution in the paint film created on the substrate, is difficult to attribute a unique cause for the difference in performance observed among the three analyzed water repellent products.

### 3.5 Susceptibility to mold development

The results show that, during the 4 weeks of tests, no development was observed for any of the systems, with or without protection, being the classification assigned equal to zero for all specimens in all phases of the test. Also after aging, there was no growth of microorganisms on the protected surfaces, only in one of the unprotected specimens there was a extremely low growth. Thus, it is considered that the biocides added to the protective coatings and to the finish of the ETICS system are sufficient to prevent biological growth, and are not completely leached from the substrate after artificial aging.

The addition of TiO<sub>2</sub> in the paint formulations and in the finishing layer of the ETICS system may also be associated with the prevention of biological growth; in fact, titanium dioxide nanoparticles, when exposed also to low irradiation (2.5 W/m<sup>2</sup>), therefore also in an indoor environment, can form free radicals, that can penetrate the cellular membranes of biocolonizers, inhibiting the growth of algae or fungi [27].

Table 5 - Results of the water vapor permeability test, in protected and unprotected specimens, before and after artificial aging.

System	μ EPS	Before Artificial Aging		After Artificial Aging	
		μ ETICS	S <sub>d</sub> of the rendering system (m)	μ ETICS	S <sub>d</sub> of the rendering system (m)
Reference		43,84* ± 0,10	0,35* ± 0,02	80,39 ± 10,25	1,93 ± 0,43
H1	39,07 ± 3,11	43,65 ± 0,12	0,34 ± 0,01	65,14 ± 0,73	1,26 ± 0,02
H2		42,10 ± 2,95	0,26 ± 0,11	73,08 ± 10,48	1,61 ± 0,46
H3		50,04 ± 3,90	0,62 ± 0,18	103,02 ± 20,88	2,86 ± 0,92

\*average value only whit two samples

## 4 Conclusions

In order to increase the durability of ETICS solutions, the present study analyzed the hydrophobic protection provided by three commercial paints (two based on acrylic and one based on siloxane). It was concluded that the hydrophobic protection product H2, based on siloxane, presented a slightly better performance in relation to the other two acrylic-based products. Product H2, despite not having the lower capillary water absorption, showed the lower variation in the drying kinetics of ETICS, before and after aging, as well as the most suitable vapor permeability in the initial performance and didn't significantly alter the permeability of the support after aging. Additionally, in the measurement of the contact angle, product H2 had the best performance, presenting values of contact angle considerably higher than those of acrylic products, reaching the value of 111° after aging, which can classify this product as water-repellent.

The H1 and H3 products, despite consisting of the same (acrylic) polymer, present some notable differences in their performance. Therefore, the performance of this type of products depends not only on the type of polymer used, but also on many other parameters involved with its formulation (e.g. type of pigments used, pigment volume concentration (PVC), types of additives, etc.).

Hygrothermal cycles did not confer negative effects on the water transport properties of the analyzed systems, inducing even lower absorptions and higher contact angles. A slight increase in the water absorption was observed only in the test with Karsten tubes, particularly for the untreated and treated specimens with (acrylic-based) H1 and H3 at 1h and 8h test, respectively. However, after aging, the protection systems continued to show higher water repellency than the untreated ETICS. However, aging cycles significantly affected the drying and vapor permeability of the systems. In vapor permeability, the untreated system showed the worst permeability when compared to treated systems, considering that the protection provided by the products was adequate. Specimens treated with H3 (acrylic base) are the only exception, where the lowest DR2 and the highest resistance to drying (DI) were recorded, before and after accelerated aging. Thus, it is considered that the aging cycles possibly affect the porosity of the ETICS system.

Relating the results of the numerous laboratory tests carried out, it was found that not all tests showed the same sensitivity to characterize the action of hydrophobic protection products. The measurement of the contact angle was one of the parameters had no clear linear correlate with the water absorption tests.

In general, it was found that the hydrophobic protection products studied are suitable for ETICS systems. It was found that the product H2 (based on siloxane) has the most adequate compatibility with ETICS, respecting the drying kinetics and permeability of the system. The H1 product also showed adequate compatibility, being the H3 product the one that causes the higher changes in drying and water vapor permeability of the system. In fact, the H3 protection product is the most impermeable product, both to liquid water and to water vapor.

Interestingly, it is necessary to emphasize that the H1 protection product performed properly as a hydrophobic protection coating in the ETICS system, despite being a generic commercial paint, with no specific water repellent properties, as in the case of the other two studied paints.

In terms of protection durability, all products showed a good performance, maintaining water repellent efficiency after aging; the product H1 and H2 also demonstrated to protect the system, allowing to improve the water vapor permeability with the aging of the solution. However, the loss of water repellent efficiency of these products may be associated with other factors not considered in the present study, such as UV radiation, for example.

For last, it's considered that the present study made a significant contribution to the knowledge of the action mechanisms on these specific water protection solutions, leading to the conclusion that these paints can be applied to ETICS systems in order to increase their durability. However, other studies that complement the present one, should be performed, such as the evaluation of the performance of paints on naturally aged substrates, the effects of UV radiation on the aging of coatings, amongst others.

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