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Mixed coating mortars using tire rubber: performance in the face of water

Morteros mixtos de revestimiento con caucho de neumáticos: comportamiento frente al agua

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Abstract

This paper evaluated the behavioural performance to coating mortar water with rubberized tyres. #0.60 mm and #1.19 mm grain sizes have been used with the incorporation of 10 and 20% (in volume), replacing the small units. The methodology has elapsed with capillary and drying tests; humidification and drying procedures with mass control, infrared thermography and measurement of humidity. The results indicated that in capillarity and drying the trace A20F (#0.60 mm particle size and incorporation of 20%) had have a low absorption rate and helped in the process of water disposal. In the humidification and drying process, both active as well as passive, the rubber possibly blocks the pores of mass, for the grain traits size #0.60 mm (A10F and primarily A20F) have proven easy to lose water, suggesting that the majority of water absorbed would be concentrated on the surface part of the composite.

Keywords: *Mortar; dry; permeability; infrared thermography; thermal analysis.*

Resumen

El trabajo evaluó el rendimiento frente al comportamiento del agua de los morteros de revestimiento con la incorporación de caucho de neumáticos. Se utilizaron granulometrías de #0.60 mm y #1.19 mm, con niveles de incorporación de 10% y 20% (en volumen), reemplazando el agregado fino. La metodología consistió en pruebas de capilaridad; secado; procedimientos de humidificación y secado con control de masa, termografía infrarroja y medición de humedad. Los resultados indicaron que en capilaridad y secado, la dosificación A20F (granulometría #0.60 mm y 20% de incorporación) mostró una tasa de absorción reducida contribuyendo a la eliminación de agua. En el proceso de humidificación y secado, tanto activo como pasivo, posiblemente el caucho bloqueó los poros de la masa, ya que las dosificaciones con granulometría #0.60 mm (A10F y principalmente A20F) demostraron perder agua, lo que indica que la mayor parte del agua absorbida se concentraría en la superficie del compuesto.

Palabras claves: Mortero; secado; permeabilidade; espectroscopía infrarroja; análisis térmico.

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1. Introduction

Water, in the form of both humidity and in its direct contact with the facade coatings, is one of the agents with the highest impact on building degradation. It can be associated with problems related to electrochemical corrosion, chemical decay, staining and discoloration of building finishes, swelling volume changes, shrinking, expanding, cracks and crevices (Straube, 2002). Linking these factors, it is understood that conventional mortars have established studies and valid results for their water usage behaviour; conversely, production of non-conventional materials used in the cement matrixes is still inconclusive.

Given this context, the unserviceable study material for unconventional incorporation in coating mortars will be tire rubber, originating from the mechanical retreating process. This procedure, since it feeds the transport sector, will generate waste from scraping and its destination is much discussed doggedly seeking alternatives to prevent their environmental impact with their disposal.

In addition to the quantity of material generated, its proper disposal deserves attention, for it naturally requires a great deal of time to degrade, potentially causing serious environmental problems if not carefully discarded, such as proliferation of diseases, fire hazard due to its high calorific value and the release of extremely health-damaging gases. For those reasons, its effect on the environment has become the focus of studies to pursue similar applications in other sectors (Silva et al., 2019).

More precisely, when dealing with rubber incorporation in coating mortars, which can be observed along with the investigations on this subject, it presents, as one of its advantages, the issues related to reducing building overload, due to the low density of rubber (Corinaldesi et al., 2011). Another advantage found is the increase in tenacity and the ability to absorb shock energy (Shu and Huang, 2014). As a drawback, an unfavourable interaction with cementitious matrix can therefore be cited for its hydrophobic features, resulting in poor compliance in between its particles and cement slurry. This is because rubber is made out of low surface energy organic polymers, causing an unbalanced hydrophobic hydrophilic interaction (Mundo et al., 2018).

Thus, focusing on this low-energy surface-matter trait, it is understood there that, no matter however low the adhesion to the portfolio is, it may consequently, inhibit water absorption in composites providing benefits, if you assume that since it has a lower water absorption, this may result in a longer durability of cementitious matrix. This lifetime can be either exemplified in cases of its application in deepfreeze and defrosting places, for its self-cleaning capacity, and painting and graffiti resistance (Weisheit et al., 2016). In this regard (Mundo et al., 2018) have presented possibilities of this type of rubber to offer advantages for coating mortar, but they've noted that still needs further work for its application.

For the reasons set out above, this paper is aimed at carrying out a survey about performance of water behaviour of mixed mortar coating incorporated with two tire rubber sizes #0.60 mm and #1.19 mm, and peer-reviewed under the partial replacement aspect of sand in volume levels of 10 and 20%.

2. Materials and Methods

CP II Z-32 cement was used, tested based on ABNT NBR 11578: 1997, with 3 g/cm of absolute mass, mass density of 0.95 g/cm³, 5000 cm/g blaine and final hardening times of 195 min and 270 min with compression resistance at 7 and 28 days of 28 and 33 MPa, respectively. The hydrated lime used as CH – III, with 21 g/cm³ absolute mass, 0,9 g/cm³ mass density, sieves of 0.6 and 0.075 mm, 0.35 and 13%, respectively. 87% of water retention rate was tested by ABNT NBR 16605: 2017, ABNT NBR NM 45: 2006, ABNT NBR 9289: 2000 and ABNT NBR 9290: 1996 standards, and respectively. We have used natural fine sand, characterized by ABNT NBR NM 52: 2003, ABNT NBR NM 45: 2006, ABNT NBR 9775: 2011, ABNT NBR NM 46: 2003, and ABNT NBR NM 248: 2003 standards. It resulted in 2.62 g/cm³ specific mass gravity, 1.61 g/cm³ mass per unit, 0.052% moisture content and 0.20% powder material, top featured and fine module were of 06 mm and 1.36, respectively. We have used free of contamination, cleaning potable water mixtures. The tire rubber from truck tire retreats has been selected and characterized in different granulometric ranges to pass through #1.19 mm e #0.60 mm mesh sieves opening, henceforth referred to as thick and thin as respectively. Based on ABNT NBR NM 45: 2006, Archimedes' Theorem and ABNT NBR NM 248: 2006 the value for specific gravity 1.15 g/cm³, its 0.39 g/cm³ mass per unit for thick rubber and 0.32 g/cm³ for fine rubber. Also, a granulometric curve showed in (Figure 1), and its correspondents. The dosage element volume of dry materials was (cement: whitewash: sand) 1:1:5, equal to mass-scale line 1:0.86:7.67, with 1.05 water agglomerate. The added percentages were of 10% and 20% rubber in place of the small units, given its low specific mass, physical traits and based on references studies (Aliabo et al., 2015; Angelin et al., 2015). The trial plan was formed by implementing five-

ply mixed mortar, one being the reference line – a comparative parameter so-called AREF – two of them using 10% and 20% fine rubber, denominated A10F and A20F accordingly, and two with 10% and 20% thick rubber called A10G and A20G, respectively. A total of five samples per dosage have been produced, justified by both their making with dimensions 30 x 20 x 7 cm (larger than the conventional ones) according to (Ferreira, 2016), as for the testing techniques employed, it is designed to simulate coating mortars. Densification mechanical properties of composite method was applied through a vibrating table.

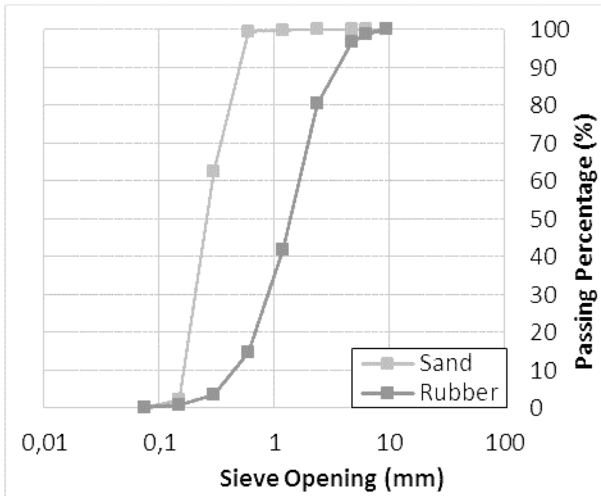

***Figure 1**. Granulometric distribution of sand and tire rubber*

The composites were being kept for maturation for 21 days in a humid chamber. Subsequently, they were taken into a greenhouse (temperature of 105°C) around the clock. Afterwards, they were put into a silica container in an attempt to avoid the absorption of humidity around it by the samples during intervals, all of which aged ≥ 28 days. The tests for analysis were: capillarity test on the basis of ABNT NBR 9779: 2012; drying process (Penacho, 2012); non-standardised mass-controlled system of humidification and drying test; infrared thermography and measurement of surface humidity, in which several procedures resulted from work (Ferreira, 2016). Two cases have been addressed in the analysis: passive (natural drying) and active (using two 500W infrared heat lamps). Pre-established mass control tests were conducted at all times, also thermography experiment and measurement of the surface humidity to analyse the takes-up of composites within one-minute water exposure,1 hour and 24 hours, and further drying test monitoring within 48 hours for the passive process and 3 hours for the active case. Like that, the evaluation results for mass control took into account the amount of absorbing water (by comparing the original weighing and right after the exposure to water) and water loss (by comparing the first weighing and the last weighing after water contact). Next, a thermographic test was carried out with FLIR E40 thermal imaging camera, which had previously been subjected empirically to emissivity calibration of analysed composites (Avdelis and Moropoulou, 2004), reaching out a value of 0.93 m and located 0.70 m away from the specimens whilst testing. The test results showed the thermographic images (thermograms) that had undergone through software Flir Tools+ processed and calculated the averages of superficial temperature from each image. The gauging of surface humidity was held by using digital humidimeter and the procedure progressed in ways that each predetermined period, right after weighing and thermogramming, 24 composite areas from an auxiliary braid on the specimen surfaces with a permanent pen, were rated by the humidimeter. The results were edited in Excel software for the elaboration of the samples surface humidity graphs at times of trial.

3. Results and Discussion

3.1. Water absorptance by capillarity

(Figure 2) shows the results in the capillary absorbance test and also that the integration of tire rubber has reduced water intake, as well as slowing down the speed at which water runs through the mortar, whereas the highest rate of incorporation (20%) has led to substantial mortar improvements. The explanations for the results may be tied to the increase in air level in the composite when incorporating unconventional material, and to the fact that the rubber has low water absorption, thus obstructing the water flow through the capillary path, even if its incorporation causes

dissatisfactory mass compaction and therefore greater porosity, (Angelin et al., 2015). Furthermore, as (Nakakura and Cincotto, 2004) have presented, the existence of interconnected or unrelated pores, beyond the diameter difference, may influence on permeability, implying that they will be higher if there are also significant amounts of pores in the matrix, and to ensure that they are interconnected while contributing to the flux. If the porosity is discontinuous, even if it is high, it is unlikely to have a high level of capillarity absorption, the so-called closed porosity. In the light of the results obtained, one can assume that the increased percentage of rubber has led to more pores. Yet, they did not deliver a capillarity flow as continuous as for the sample reference, or that the incorporation of rubber has reduced the fine mass content (since fine units have been partly replaced by rubber) causing an increased radius of capillarity by the hydrophobic action of rubberized material.

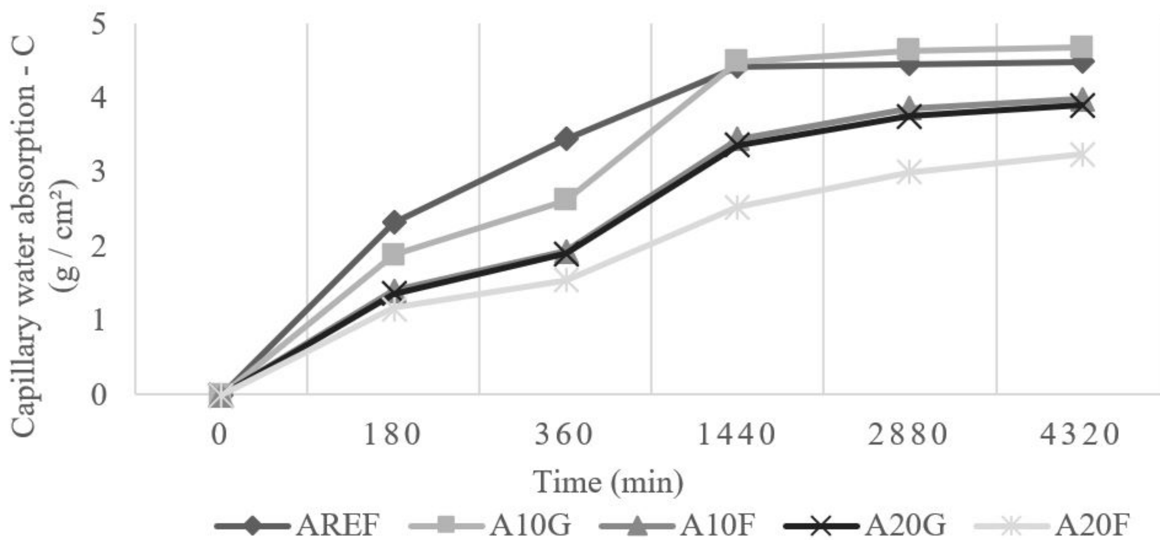

Figure 2. *Graph of water absorption by capillarity (g/cm²).*

3.2. Drying test

From (Figure 3) we can analyse the percentage data of evaporated water, taking into account the value of the initial mass of each piece of evidence relating to the end of the capillary test and the corresponding weight during drying time. The experiment has shown that thin rubber composites yielded more satisfying results if you consider that a higher evaporation percentage for coating mortar will benefit and prevent any pathological outbreak in the system. For thick rubber traits, the highest drying rate was obtained by the highest percentage of rubber incorporation (Avdelis and Moropoulou, 2004) and all traces analysed had dried up quicker than the reference trace (AREF). If we combine the capillarity and drying tests together, it can be said that the two traits that most absorbed water (AREF e A10G) were the ones that lost the least in the drying test. The inverse could also be seen since A20F have had the lowest capillary absorption and the highest drying rate. This way, it is understood that the traits lagging behind capillary absorption were the ones supposedly presented as closed pores and/or of dimensions that would not allow water to ise

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in the material. Then, perhaps the composites with the poorest water sources have largely dried out for being less humid inside and more in the outside.

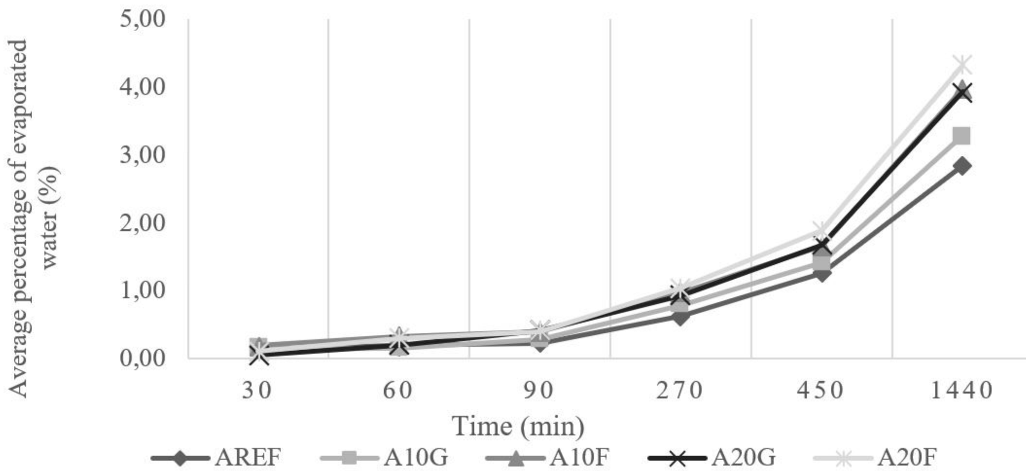

Figure 3. *Graph of the percentage of water evaporated by the drying test.*

3.3. Humidification and drying procedures

3.3.1. Mass control

(Figure 4) displays a chart listing the mass gain results obtained from the active and passive process, for each minute, 1-hour and 24 hours of contact with water. It shall be understood that rubber-substituted composites are trendy to take longer to retain water against the reference trace. These results can be cross-checked against (Mundo et al., 2018), who, by analysing the time of water penetration in conventional mortars and mortars with rubber sand replacement, have shown that non-added rubber traits has a nearly immediate absorption of water droplets, resulting in a much higher percentage of drop absorption as opposed to composites with 50% incorporation. Mortars with 100% replacement were the least water absorber for the same time interval. In relation to loss in mass, (Figure 5) reports 1 minute, 1 hour and 24 hours contact with water for both active and passive drying procedures. It states that for 1 minute in contact with water the leakage differences are negligible for the analyses, since all the samples lost more than 98% of water, they had absorbed in. One-hour tests are more accurate, for they display the defaults of standard mortar, being the most water-absorbing trait with minimum loss during passive and active testing. For the 24-hour trial, A20G absorbed more water, but lost a smaller percentage of its humidity. Relating to these factors, considering that the ideal behaviour for mortars facing water is to absorb less water and to release it more constantly. Consequently, in the mass control test, equating gains and losses, 10 and 20% of rubber composites of #0.6 mm particle size have achieved favourable characteristics for lower absorption and also a more efficient drying. These capillarity and drying tests results are identical to those previously obtained.

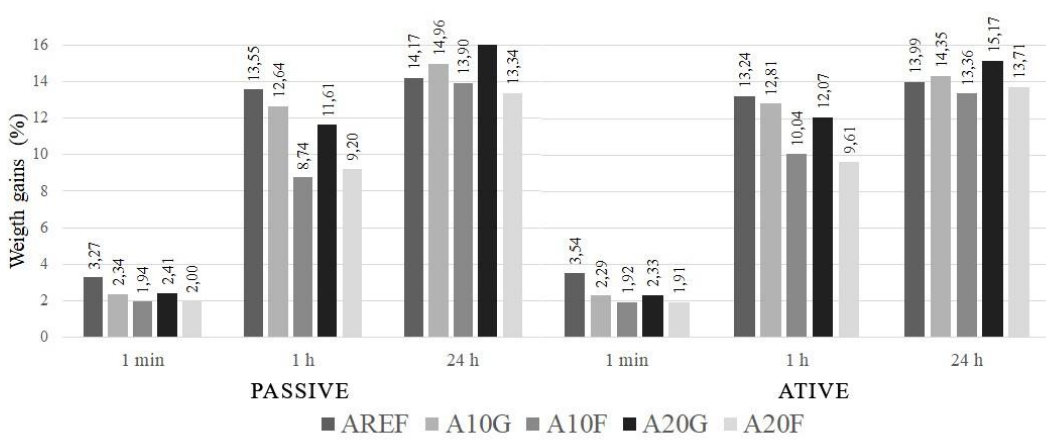

***Figure 4**. Weight gains in the passive and active humidification and drying process.*

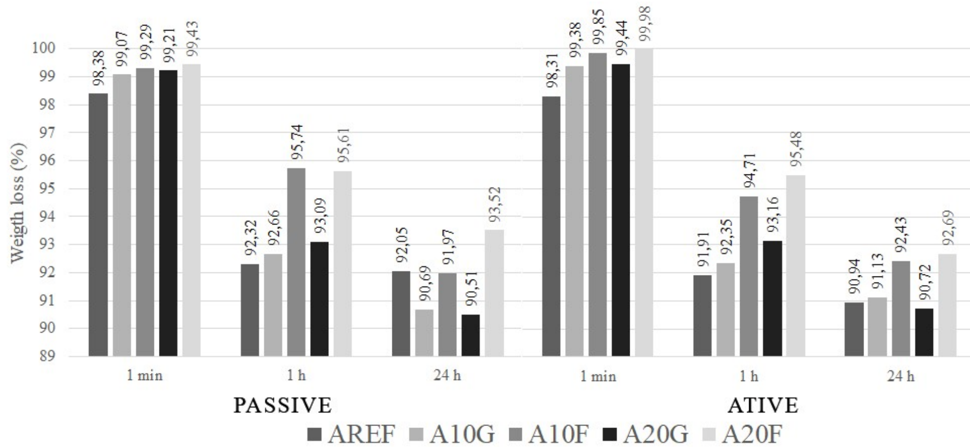

***Figure 5**. Weight losses in the passive and active humidification and drying process.*

3.3.2. Thermographic test

By analyzing the 1 minute, 1 hour and 24 hours thermographic results for humidification and passive drying procedure, it seems that the thermo analysis of drying process can be carried out, as long as every thermogram has been examined during the trial period, for they obtain similar pattern when drying all traces of those passive tests. Thereafter, it was possible to approximately define them through visual analysis drying time of the samples. Once the surface color variation of gradients become negligible, showing color bleeding, briefly, the sample body could be considered almost dry. This feature is shown in (Figure 6), which gives the full result of the passive test for A20F reference body and it shows that prior to water contact the thermograms were homogenized with surface temperature and the drying process. After submersion, the specimen have dropped temperature on their extremities getting more homogeneous as the test progressed, signaling this way, earlier water loss from the edges, a feature also revealed by (Barreira and Freitas, 2005) who have exhibited the complexity of drying analysis on account of temperature and humidity of body samples may vary only a little on the passive approach.

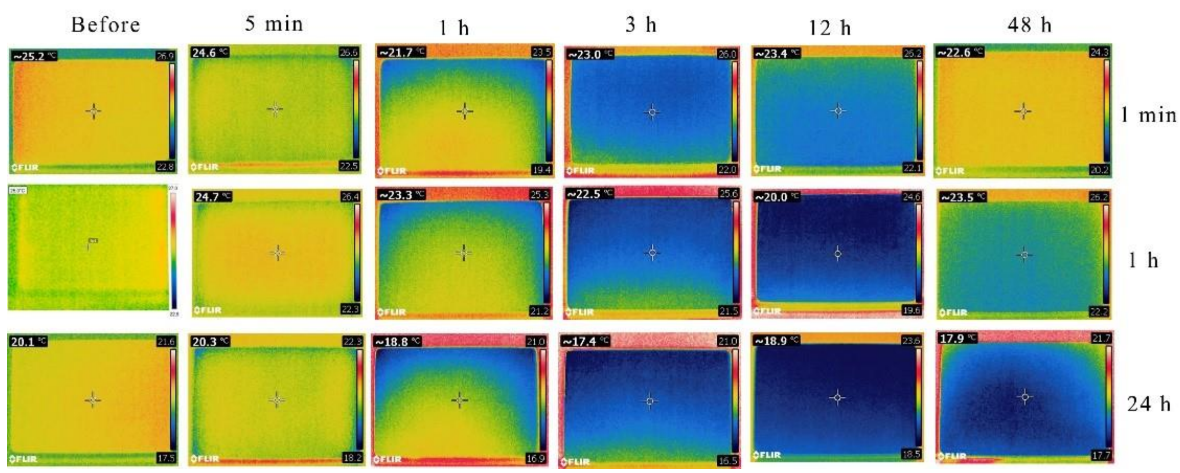

***Figure 6**. Thermographic images of the passive process (A20F).*

Comparing the thermogram of the last 3 tests, it is noted that for 1 minute water contact, the specimen showed a higher temperature than the times of 1h and 24h, as well as a more even surface, which means less surface humidity as the presence of high humidity reduces the test body temperature on the surface (Barreira and Freitas, 2005).
Regarding the active tests, the same piece of evidence (A20F) has shown greater difficulty in identifying the drying process by thermograms alone, even though mass control had quickly showed water loss during the test, it barely changed in the thermographic test, making it difficult to identify humidity loss simply by visual thermogram analysis. This feature has been constant in the 5 trial bodies from the active process. It is hereby understood that the ability to observe potential wet and dry areas occurs due to two physical phenomena within the analyzed area: the evaporative cooling/condensation process in this region with water and an increasing heat storage capacity of the material

(Kirmtat and Krejcar, 2018). Subsequently, the passive process has given a more accurate overview than the active one. In addition to this, it is well known that the outcomes from passive and active trials occur since passive thermography is essentially a qualitative test than simply aims at the visual evaluation of thermograms indicating and locating thermic differentiation, being commonly used in identifying processes, such as heat losses and gains, and thermal building insulation review (Kylili et al., 2014).

The thermographic experiment revealed the possibility of monitoring the average test-body temperatures. From the passive test we get that the average temperatures had not followed a steady pattern while drying, however visually the passive test has provided from drying, which means the average surface temperatures do not relate to the process. For the active (Figure 7), a greater regularity of responses was obtained, as for all average tests, whether within 1 minute, 1 hour or 24 hours into water, the temperatures have varied in line with mass gains and losses. Ergo, the more water the evidence bodies held, the lower the average temperature value manifests and the higher the temperatures stands for the traces with less water within it. This greater thermal regularity found in the active test is made up of artificial sources for a thermal excitation to provide an environment under better control for drying and heat transfer (Garrido et al., 2019).

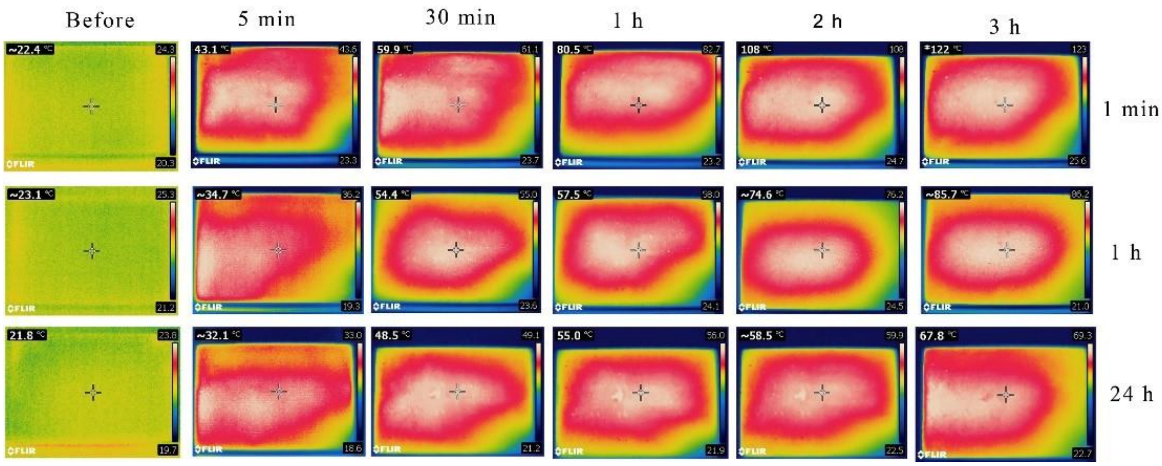

***Figure 7.** Thermographic images of the active process (A20F)*

Levering the results to the theoretical framework (Santos et al., 2019), it is believed that the thermal analysis may be of use in detecting humidity, subject to significant gradient values in between the dry and wet areas. Besides that, such porous material as the mortar coating has a significant wet zone viewing thanks to a larger thermal gradient value from water evaporation, where a non-destructive technique may be envisaged as a complementary tool to other methods mostly in light of its poor detection of surface moisture drying only (Barreira and Freitas, 2005).

3.3.3. Humidity measurement

(Figure 8) and (Figure 9) illustrate the graphical humidity for specimen A20F, respectively in the passive and active process. There is no approximation with thermography images obtained (Figure 6) and (Figure 7), since the surface humidity graphs have failed to report a similar thermography pattern of enabling visualization of the drying process from end to homogenization. The results from both passive and active test methods have already presented these characteristics. In addition to the area charts, the verification of moisture has made the examination of average humidity content of specimens possible. By comparing these data against the mass control, we observe in active testing that, the values of water gains and losses are similar during drying monitoring. This way, the samples with the greatest loss were the ones with the lowest average surface humidity. This link could not be established in passive tests, being possible to state that, with just the humidity measurement test, it would not be viable to draw conclusions from these not correlated findings in thermographic and mass check tests.

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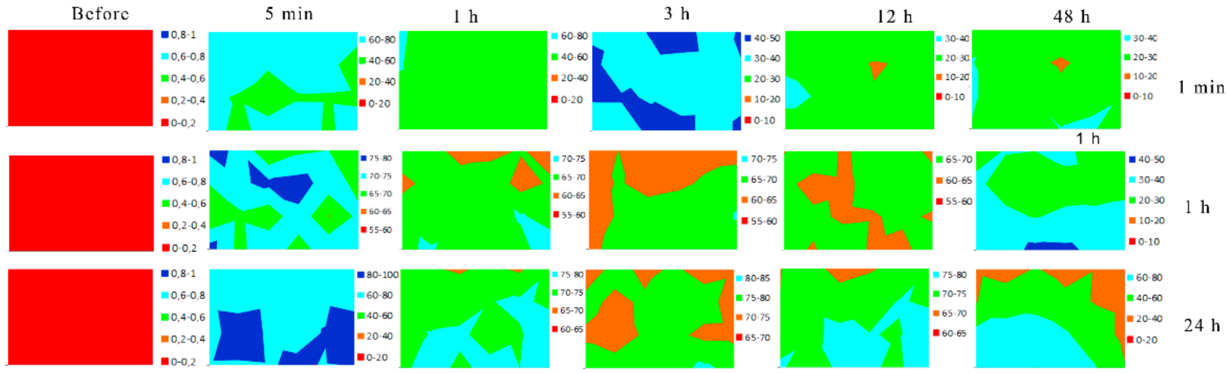

Figure 8. *Humidity graphs of the passive process – 1 hour contact (A20F).*

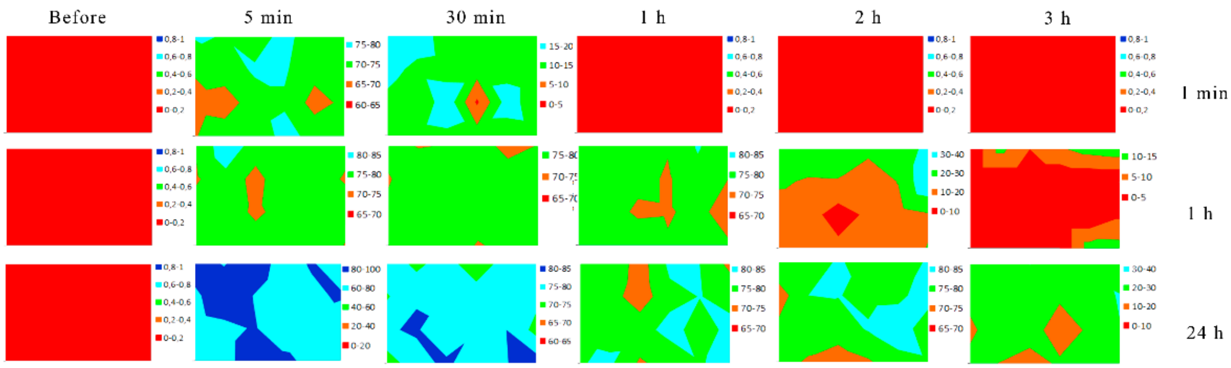

Figure 9. *Humidity graphs of the active process – 1 hour contact (A20F).*

Paralleling the observations taken from capillarity and drying results, all of the above, points to the tendency towards rubber-infused traits to soak up surface water. Since then, the humidity measurement tests exhibit high values, albeit internally, by the thermography and mass control tests and results indicate that no large percentage of water is being stored. This feature is most evident for traces incorporating rubber grain size.

From this point of view, one can assess with the established links that water intake with rubber compounding for tire treads withstands its penetration, particularly if the contact with water is done quickly. (Na and Xi, 2017) also presented that the permeability of rubberized mortars had had low values, since the rubber could block the pores and micropores' paths, given its hydrophobic nature previously explained in this essay. This may possibly relate to the fact that, with a longer water contact, the traces of thick rubber absorbed relatively high amounts of water, since it contains larger areas of internal voids.

4. Conclusions

Within this experimental programme, it will be possible to identify that, in water absorption by capillarity and the drying test, rubber incorporation has decreased the mortar absorbency values, and also reduced water speed along the material. Moreover, fine #0.60mm grain size and the 20% incorporation of content, A20F trace has diminished mortar absorption and contributed to the process of water removal from the composite.

In the humidification and drying process, both in active and passive procedures, the results revealed AREF traits with important gains in mass through absorbency, regardless of the time spent in contact with water. It has also been remarked that such water absorption happens quickly for AREF, streamlining it compared to rubberized traits. So as analyzed in the capillarity test, the rubber might block the pores of mass, hindering water penetration, thereby delaying the absorbance of the material. The two lines with A10F and A20F fine rubber have proven easy to lose water, specifying through surface humidities that most of their water supply would be on the composite, providing much more rapid water loss than the AREF trait.

Here, in view of the tests results and the environmental matter which enables a higher percentage of non-traditional material inputs, it is concluded that A20F would be the most favorable trait for applying coating mortar, (composed of passing granulometry in the #0.6 mm size sieve mesh and with 20% rubber in volume).

5. Acknowledgment

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