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Assessment of the Type of Paint on Performance of Rendering Mortars

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Abstract: The aim of this work is to determine how the mechanical and physical properties of render mortars, in particular their moisture performance, are affected by the application of paint. In this study, three commercial paints, hydro-pliolite-based paint, acrylic paint and silicate paint, were applied as coating layers on render mortars formulated with different binders. The choice of the binders used (hydrated lime, natural hydraulic lime and cement) was related to the functional requirements that the renders have to fulfil according to the type of buildings where they are applied (i.e., new or old buildings). Firstly, the hardness and surface cohesion of the different painted and unpainted renders were analysed in order to investigate the effect of the type of paint on the mechanical strength of the render surface. The influence of the paints on the moisture behaviour of the renders was then investigated using the water capillarity test, the water vapour permeability test and the drying test. The results show that all the paints studied can cause a significant change in the behaviour of the renders in terms of moisture transport phenomena. Nevertheless, it can be concluded that acrylic paint has the greatest resistance to water absorption, but it is also the paint with the higher resistance to water vapour diffusion. Hydro pliolite paint was found to be adequate from the point of view of reducing moisture accumulation and is the most recommended for old buildings with hydrated lime or hydraulic lime-based renders.

Keywords: paint; moisture; render; natural hydraulic lime; hydrated lime; surface mechanical strength

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1. Introduction

Construction techniques and materials have evolved over time, and with them have come changes in the materials used to coat the exterior walls of buildings and to protect them from the elements. What has not changed, however, and continues to be one of the major causes of nonstructural anomalies in buildings around the world, is the action of moisture. The presence of water in its various states is a constant challenge to constructive solutions, as it inevitably causes premature material degradation and increases the costs associated with building maintenance and repair [1–3]. It is well known that high levels of moisture in constructive solutions lead to a loss of adhesion between materials (mainly due to the ingress of aggressive ions, which are entrained with the absorption of water and promote the degradation of materials), as well as to the growth of microorganisms and an increase in thermal conductivity.

As an exterior finish, paint plays a significant role in the water behaviour of the exterior wall. It is therefore necessary to understand how the most common paints on the market affect the performance of render mortars. The painting of the exterior walls of buildings is an ancient tradition, initially using inorganic paints [4]. With the industrial revolution, artisanal production (using rudimentary processes for grinding natural pigments and dispersing them in the binder) was replaced by automated processes that allowed better control of the quality of paint formulations. Later, with the development of the chemical industry, the first paints based on polymer and copolymer binders, both natural and synthetic, began to appear in paint formulations [4,5].

There is a tendency to think of painting buildings as just a decorative finish. However, in addition to decoration, paint can provide other features. Some of the characteristics that paints can take on are substrate protection, environmental hygiene, signage, thermal comfort, light control and even the psychological influence that colours can have on people [6]. At present, the market offers a wide range of paints and colours with different finishes (textured, smooth, glossy, matt, etc.) and a variety of properties and functionalities adapted to the different purposes for which they are used [4].

Notwithstanding, rendering mortars have the function of protecting the wall, smoothing the masonry for the application of other coatings, promoting waterproofing and improving the aesthetic appearance of buildings. In order to fulfil these functions, rendering mortars must meet certain functional requirements, which vary depending on whether the building is new or historic [7]. Renders are usually coated with a thin layer of paint, which can significantly alter the performance of the render, particularly in relation to its moisture behaviour. A review of the literature clearly shows that there are only a few studies on the surface mechanical strength and moisture behaviour of rendering mortars, especially those based on hydrated lime and natural hydraulic lime (which are the most suitable for the conservation and rehabilitation of old buildings) [8–12].

The aim of this work is to evaluate the characteristics of three types of paints (hydropliolite-based paint, acrylic paint and silicate paint, which are the most used in the Portuguese construction market) applied on different types of substrates/renders, based on three binders, cement, natural hydraulic lime and hydrated lime. To this end, an experimental campaign was carried out in order to be able to draw conclusions on the influence of the different types of paint on the capillarity to water, the permeability to water vapour, the hardness and surface cohesion and the drying of the different render mortars.

2. Materials and Compositions

2.1. Materials

Three different renders were prepared using cement (CEMII/B-L 32.5), natural hydraulic lime (NHL5) and hydrated lime (CL90-S) produced in Portugal according to EN 197-1 [13] and EN 459-2 [14], respectively.

In the preparation of the render mortars, river siliceous sand was used as an aggregate with a volumetric composition of 1:3 (binder:sand). The particle size distribution curve of the aggregate is shown in Figure 1. The hydrated-lime-based render that was used was a predosed commercialised by Fradical®. The loose bulk density of each component was determined according to EN 1097-3:1998 [15], the values of which are as follows: sand = 1.520 g/cm^3; cement = 0.976 g/cm^3 and natural hydraulic lime = 0.794 g/cm^3.

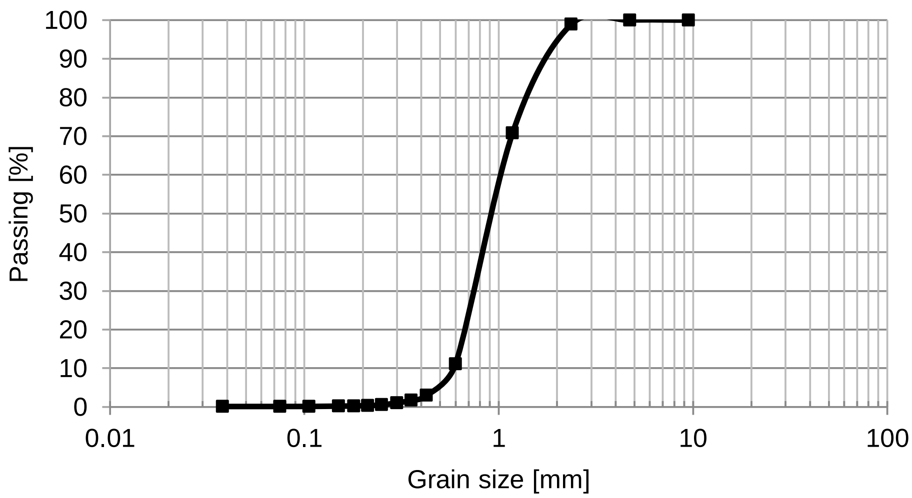


Figure 1. Aggregate particle size distribution curve.

In this study, three paints were investigated, namely hydro-pliolite®-based paint (HP); an acrylic-based paint (AC) and a silicate-emulsion-based paint (SC). No primer was used in the application of HP paint, which was applied in three coats as recommended by the manufacturer. The HP was diluted with 10% water for the first coat and only 5% for the second coat, with an interval of 6 h between coats. The AC paint did not require a primer, so the first coat was diluted with 10% water and the second coat was applied 4 h later (already diluted with only 5% water). For the SC paint, it was necessary to apply a primer of the same nature, diluted 1:1 with water. After 8 h of drying, the first coat of paint was applied, and after 12 h of drying, the second coat, also diluted with 5% water, was applied.

2.2. Renders Compositions

The renders were prepared by mechanical mixing according to the recommendations of EN 1015-2:1998/A1:2006 [16]. The water/binder ratios were determined by the flow table test in order to obtain renders with a flow consistency of around 170 mm, which was carried out based on EN 1015-3 [17]. The composition of the renders is shown in Table 1.

Table 1. Render mix identification, composition and flow table consistency.

Design Label	Binder	Water/Binder (-)	Consistency (mm)
CEM	Cement	0.604	168 ± 5
NHL	Natural hydraulic lime	0.961	172 ± 1
CL	Hydrated lime	-	169 ± 2

The experimental tests were performed on 36 square samples measuring 15 × 15 cm^2. The renders under study were applied to a ceramic support (2 cm thick) in order to simulate a render applied to a brick masonry support (Figure 2).

(**a**) (**b**) (**c**) (**d**)

Figure 2. Stages of execution of the samples: (**a**) assembly of ceramic bases for the execution of samples; (**b**) application of hydrated lime render on the ceramic support; (**c**) samples in the drying process; (**d**) application of paint.

3. Test Methods and Results

Several properties were determined according to the procedures described in this section. The characterisation tests were carried out at 28 days of age and the samples were stored at a temperature of 20 ± 2 °C and a relative humidity of 50 ± 5% until characterisation.

3.1. Surface Hardness

The surface hardness test was carried out following ASTM D22240 [18] using a hardness Shore A durometer with readings to within 0.5 units of hardness (Figure 3). The durometer measures the resistance to penetration of a metal pin on the sample surface. In this study, 12 measurements were taken at different points on each sample. The test results can be found in Figure 4.

Figure 3. Surface hardness test with Shore A durometer.

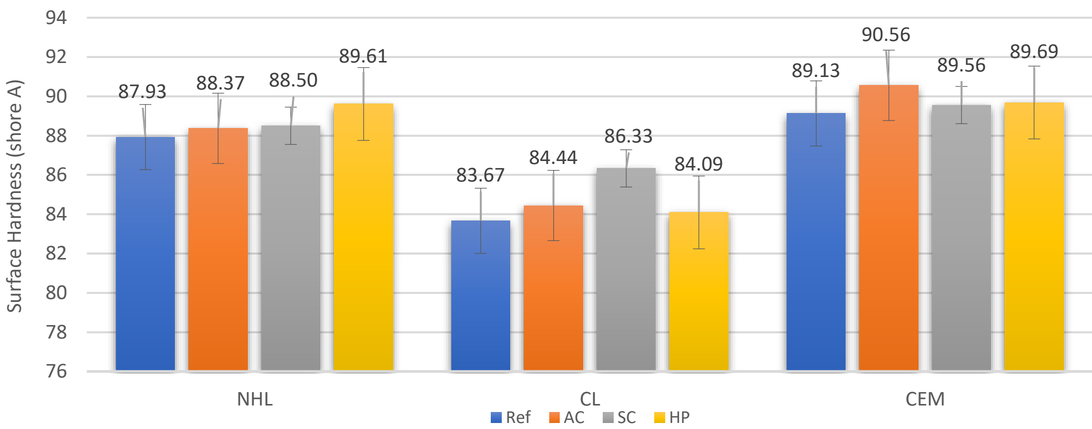


Figure 4. Surface hardness values.

From Figure 4, it can be concluded that the render with the highest surface hardness value is the cement-based render, followed by the natural hydraulic lime render. The hydrated lime render has the lowest surface hardness.

The unpainted renders (ref) are those with lower surface hardness values than the painted ones, although the difference is small. The type of paint used does not have a significant influence on the surface hardness, but it can be said that the simple fact of having a paint coating adds some surface hardness. However, several factors can affect this hardness, such as leaching of the binder, cracking, etc. In this sense, any generalisation of these results should be made with caution.

3.2. Surface Cohesion

The surface cohesion was measured based on the procedure described in another study [19]. The procedure is as follows: several pieces of scotch tape (Tesa® scotch tape 64014) were cut to 50×50 mm^2 in size and their weight was recorded. The tape was then glued to the surface of the render sample, free of imperfections and dried. A 1.5 kg weight was placed on the sample for 5 min. A layer of neoprene was placed between the weight and the tape to allow the load to be distributed over the entire surface of the tape. After 5 min, the weight was removed and the scotch tape was peeled off the render surface at an angle of 90°. In total, 10 repetitions/measurements were performed for each render sample. The difference in mass of the scotch tape was measured on a scale with a sensitivity of 0.0001 g.

The results of the loss of surface cohesion obtained by the renders and corresponding paints studied are shown in Figure 5. These values were obtained by averaging the results of the three samples tested for each paint and render combination.

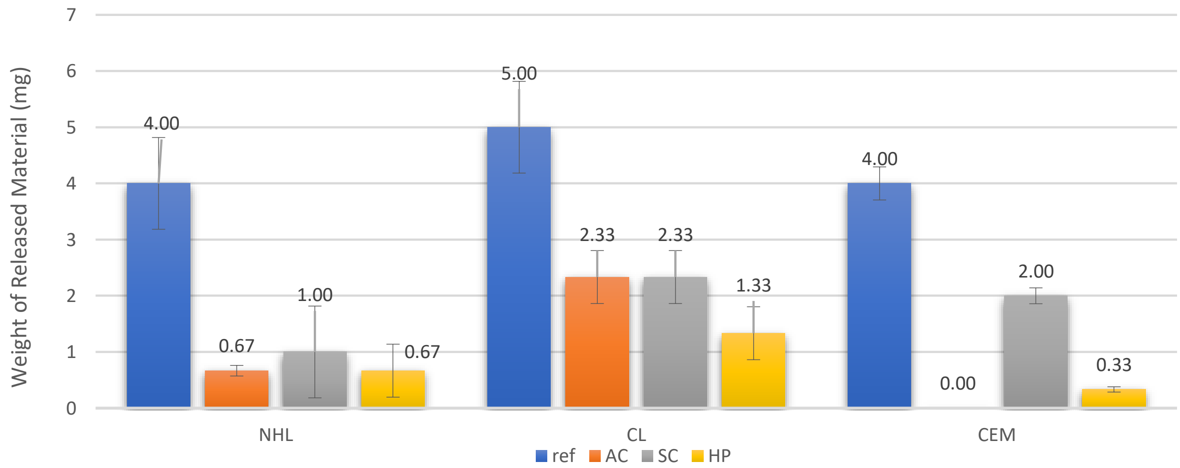


Figure 5. Loss of surface cohesion.

From Figure 5, it is possible to see that the hydrated lime render has the highest values of mass loss (lower of cohesion), which is in line with the surface hardness results. On the other hand, both the natural hydraulic lime render and the cement render show very similar behaviour, with values in the same order of magnitude. The unpainted samples (ref), unlike the painted ones, are the most susceptible to loss of cohesion. Moreover, the samples painted with hydro-pliolite-based paint present the best results in this test. These results may be due to the fact that hydro-pliolite-based paints have a greater adhesive capacity than traditional emulsion paints (due to their drying mechanism), which gives greater cohesion to the substrate.

3.3. Dry Abrasion Resistance

The dry abrasion resistance of the renders was determined based on ASTM C1803-20 [20]. The procedure consisted of quantifying the weight loss of render samples after 20 rotations of a circular polyethylene brush, applied to the sample surface. The results obtained are presented in Figure 6. These values are the outcome of the average of the results of the three samples tested for each paint and render combination, with two measurements taken on the surface of each sample.

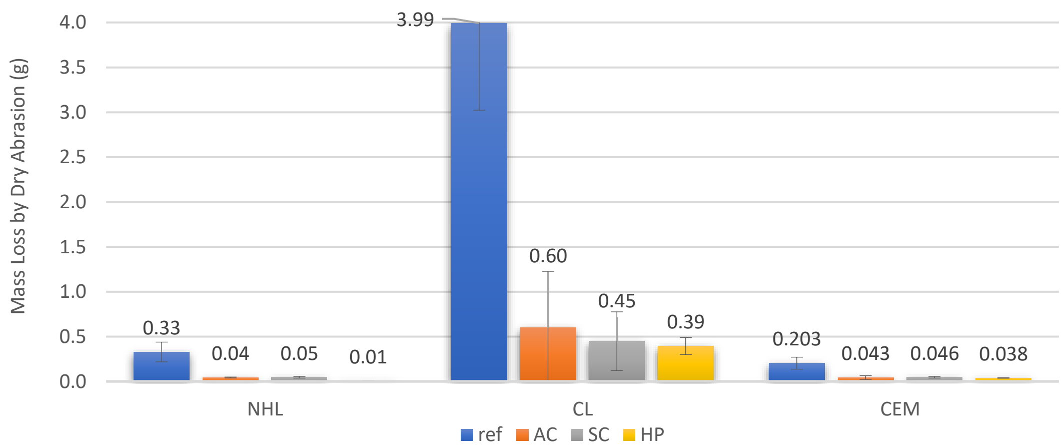


Figure 6. Mass loss through the dry abrasion resistance test.

The average mass loss due to dry abrasion obtained for the hydrated lime render was the highest when compared to the other two renders. The trend observed in the two previous tests was confirmed again, with the hydraulic lime and cement renders showing values of the same order of magnitude, but with the cement renders having slightly lower mass loss values. The lower mass loss of the painted samples confirms the importance of applying a coat of paint, of whatever type, to improve the abrasion resistance of the render.

3.4. Water Absorption by Capillarity

The test of water absorption by capillarity was performed based on EN 1015-18:2002 [21]. Water absorption by capillarity can be expressed graphically as the amount of mass absorbed per unit area in contact with water as a function of the square root of the test time (Figure 7).

(**a**) (**b**) (**c**)

Figure 7. Water absorption test by capillarity: (**a**) test box; (**b**) placing the samples in the box with the painted base in contact with the water; (**c**) weighing of the samples.

From the water absorption curves, the capillary water absorption coefficients (CC) can be determined. The CC were determined by the slope of the initial linear section of the capillary water absorption curve. It was, therefore, necessary to adjust, on a case-by-case basis, the point at which the trend line best fits the initial absorption section, as was the case in previous studies [22–24]. In several cases, the first 10 min of the test were also considered to determine the CC, as the absorption at this initial moment is quite significant and should not be neglected. Figure 8 shows the CC values obtained from the average of the results of the three samples tested for each combination of paint and render.

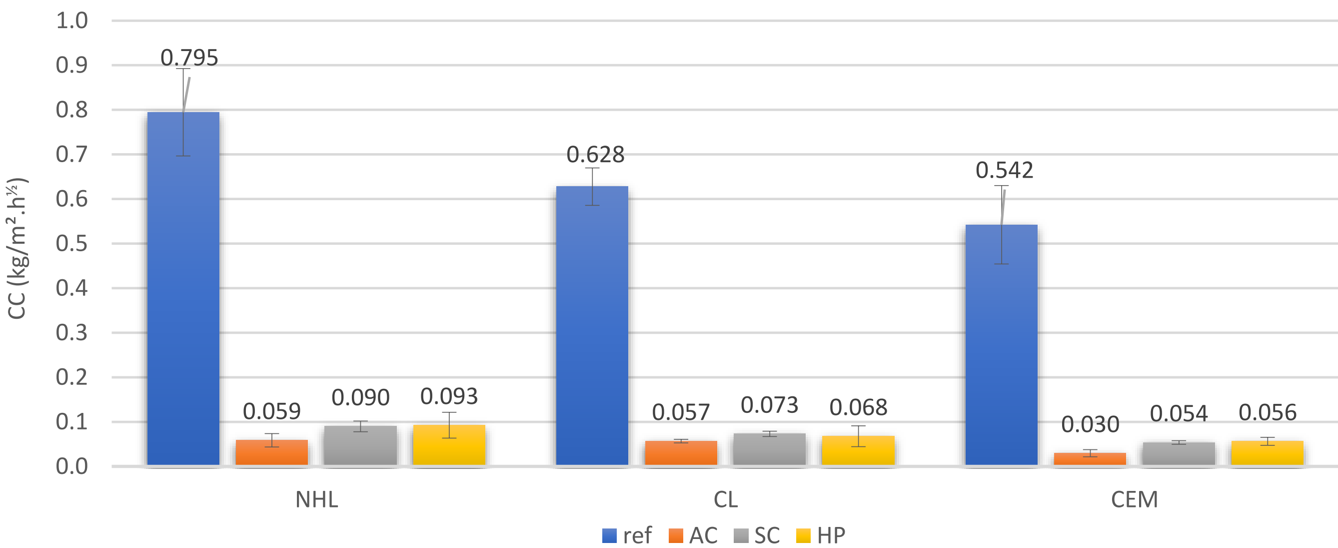


Figure 8. Coefficients of capillary water absorption.

The natural hydraulic lime render was the one that absorbed the most water, although we would expect this behaviour from the hydrated lime render since the literature points out that it is the most porous of the renders studied [25]. The explanation for this may be the fact that this hydrated lime render contains marble powder in its composition, which has the characteristics of a filler and, consequently, reduces the porosity. Comparing the three types of renders analysed, the cement render is the one with the lowest CC, unlike the natural hydraulic lime render. From the results obtained (Figure 8), it is easy to see that the paint coatings greatly reduce the capillary absorption of the renders, with an average reduction of 93%, 89% and 89% for acrylic, silicate and hydro pliolite paints, respectively.

3.5. Drying Test

The drying test was performed based on RILEM specification, test no. II.5 [26]. The same samples were used as in the capillary test but under slightly different environmental conditions. The tests were carried out in a conditioned room at 20 ± 3 °C and 65 ± 5% RH (Figure 9). The drying curve was plotted with time on the abscissa and water content on the ordinate and was used to calculate the drying index (*DI*), which is calculated through Equation (1):

$$DI = \frac{\int_0^{t_i} f(w) \times dt}{w_0 \times t_i}, \quad (1)$$

where $f(w)$ reflects the variation over time of the water content w (%), w_0 (%) is the water content at the beginning of the test (t = 0) and t_i (h) is the total duration of the test.

(a) **(b)**

Figure 9. Drying test: (**a**) samples arranged during the test; (**b**) waterproofing of samples for unilateral drying.

Figure 10 shows the drying curves for the various combinations of render and paint type. The curves presented are the average value of the results obtained on three specimens of each combination.

The analysis of the comparative curves of the different unpainted renders (Figure 10d) allows us to conclude that the cement and natural hydraulic lime renders have similar behaviour, although the slope of the initial straight line of the natural hydraulic lime render is slightly steeper, indicating a longer initial drying time. It should be noted that although the cement render has a lower water absorption by capillarity, the painted samples of this render have a higher water content at the end of the test than the unpainted sample (Figure 10c). This situation may indicate a more difficult drying process, i.e., a higher drying index (DI). Nevertheless, the water absorption behaviour of the samples with silicate paint is closer to that of the unpainted samples. For a better analysis of the paint effects on drying kinetics, Figure 11 shows the results obtained for the DI of the different solutions.

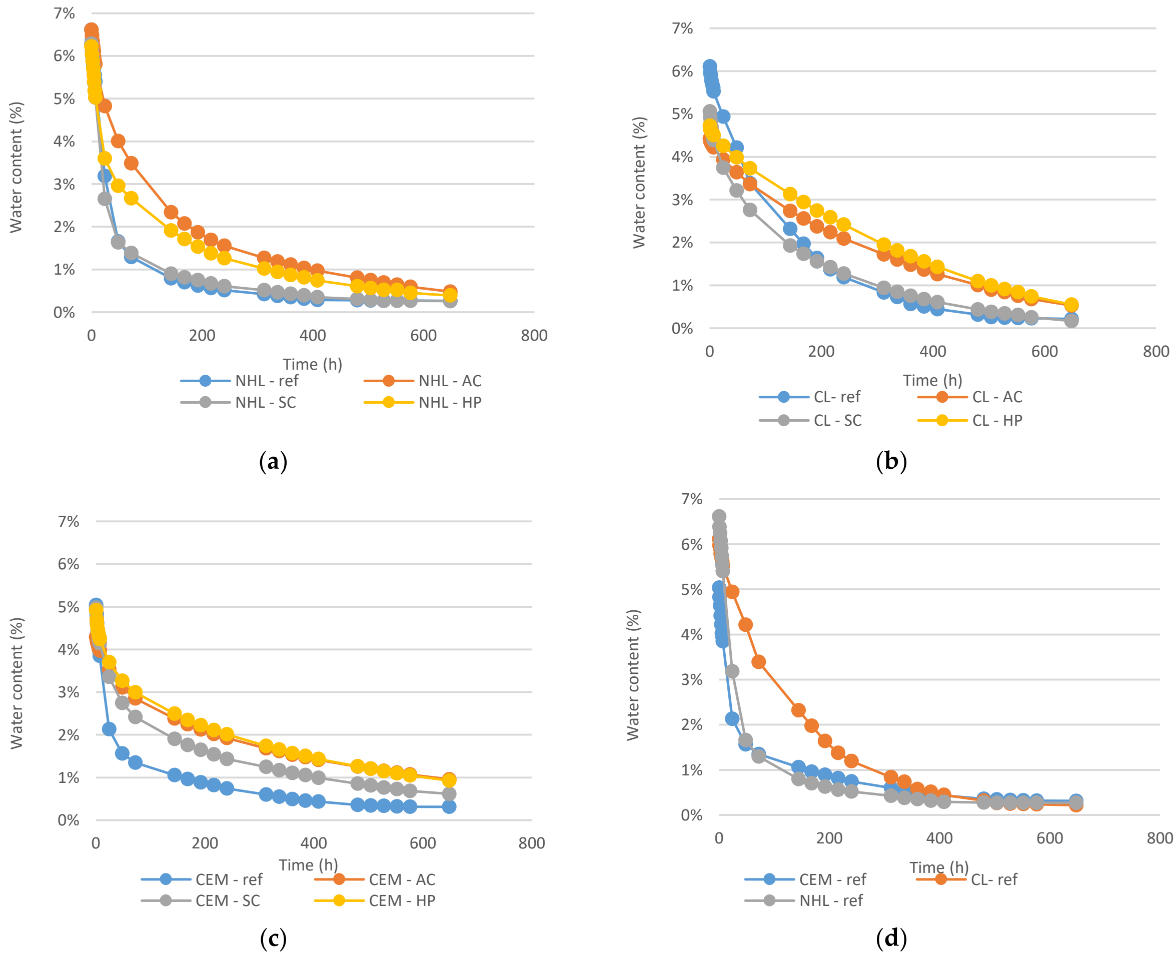


Figure 10. Drying curves resulting from the capillary test: (**a**) curves related to the NHL render; (**b**) curves related to CL render; (**c**) curves related to CEM render; (**d**) comparative curves of different renders without paint.

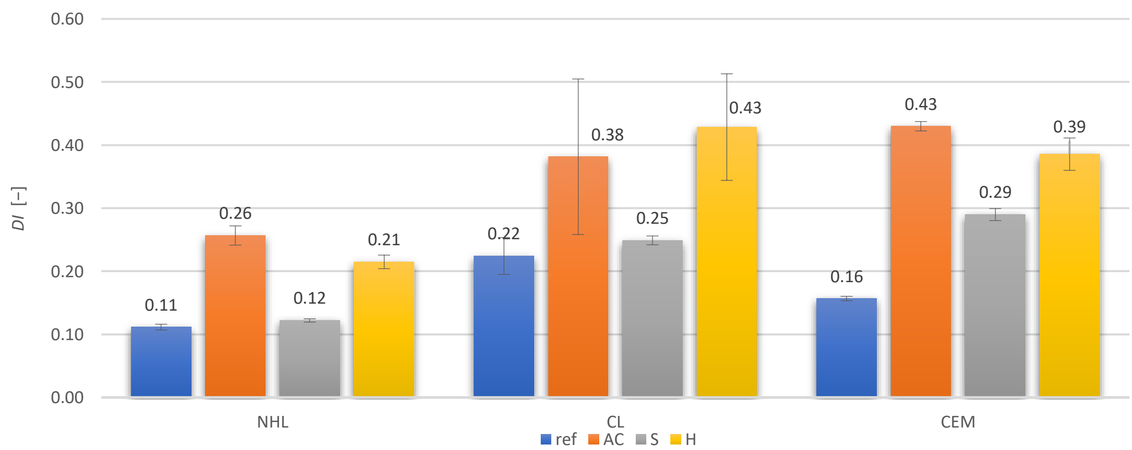


Figure 11. Drying index values.

Acrylic paint has the highest drying index values, except when applied over hydrated lime render. In fact, these results are to be expected, as these paints are known for their low water vapour permeability, which results in poorer and slower drying kinetics. The samples with silicate paint, on the other hand, show that the silicate paint does not compromise drying, with a performance close to that of the unpainted render. This fact confirms the low water content observed in the silicate samples at the end of the capillarity test.

3.6. Absorption of Water under Pressure

The behaviour of the test specimens under the combined action of rain and wind was analysed. The Karsten tube technique was used for this purpose (Figure 12). The test was carried out by calculating the amount of water absorbed per contact surface as a function of time (60 min) in accordance with standard EN 16302:2013 [27]. These results were obtained using the aforementioned Karsten tube technique, where the sealant used to ensure the tightness of the tube was plasticine.

Figure 12. Absorption of water using the Karsten tube technique.

Figure 13, which corresponds to water absorption curves for the various paint and render studied, presents the mean values of three samples per render/paint combination.

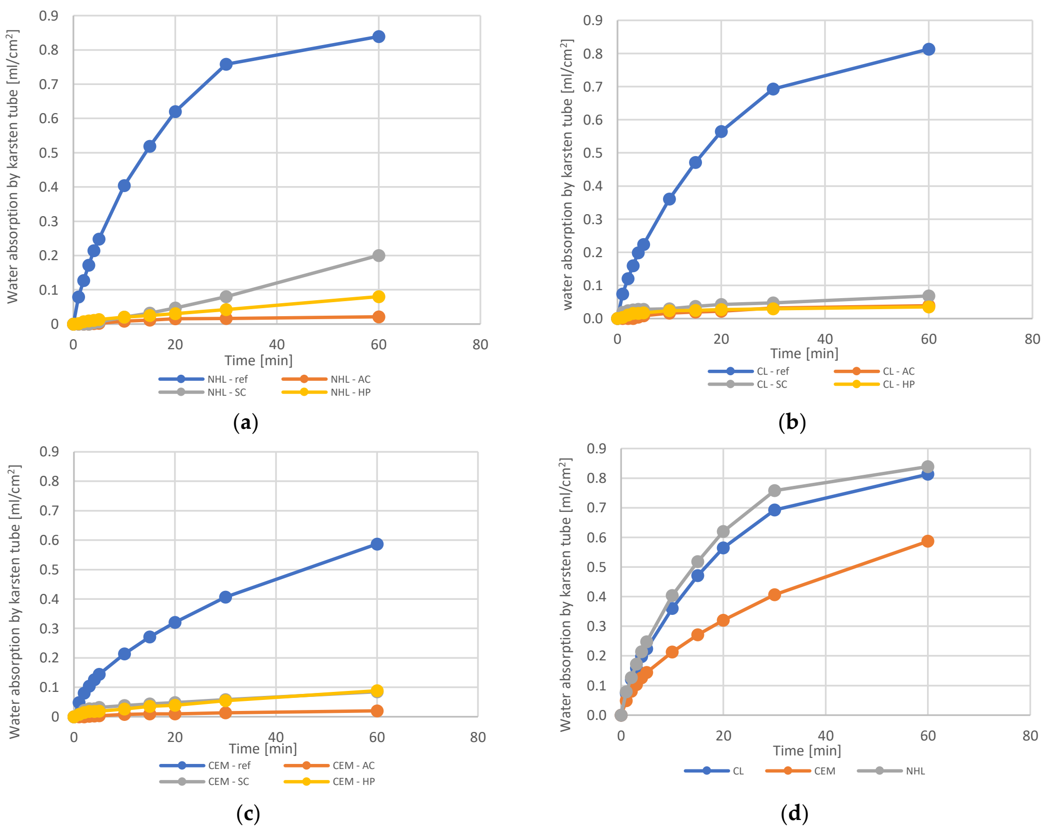


Figure 13. Water absorption curves for Karsten tubes: (**a**) curves related to NHL render; (**b**) curves related to CL render; (**c**) curves related to CEM render; (**d**) comparative curves of different renders without paint.

As shown in Figure 13d, the cement render absorbs much less water than the hydrated lime or natural hydraulic lime renders. In this test, none of the unpainted samples of cement render had completely absorbed the 4 mL of water after 60 min, which was observed in all the unpainted samples of the two lime-based renders. This is probably to be justified by the porous structure of the cement render, which is more compact than the other two binders [28,29]. Observing the results, it can be seen that the curve of the cement render has a less pronounced slope, indicating a lower absorption coefficient.

Figure 14 shows a comparative graph of the absorption coefficients for the different systems is presented. Irrespective of the type of render, the absorption coefficient and the amount of water absorbed by the substrate are drastically reduced on painted samples compared to unpainted ones. On average, the coefficient of water absorption under pressure in the painted samples is reduced by 97%, 84% and 88%, respectively, for acrylic, silicate and hydro pliolite paints compared to the unpainted samples.

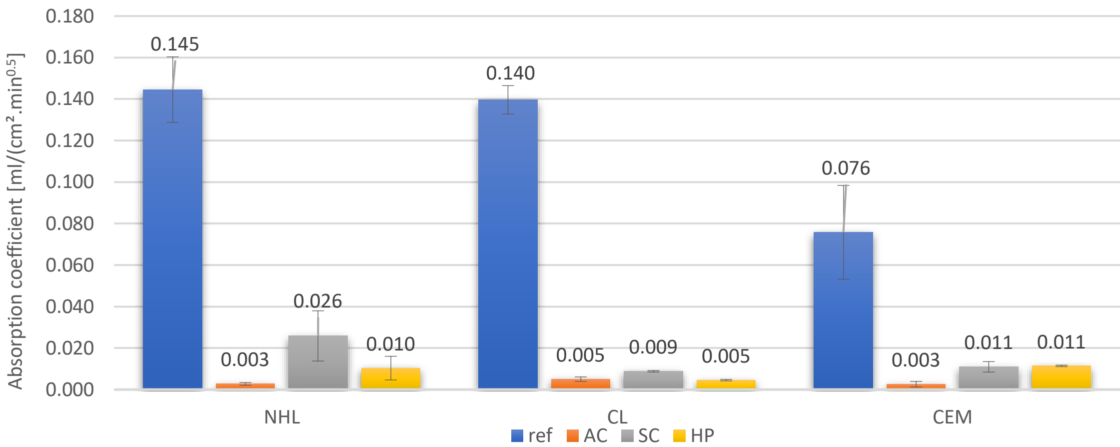


Figure 14. Low-pressure water absorption coefficient values.

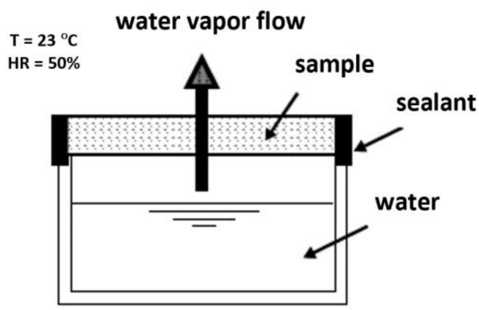
3.7. Water Vapour Permeability

The water vapour permeability test was performed according to the standard EN 1015-19 [30] using the wet capsule method but with slight changes in the size of the samples. The samples prepared for this study have dimensions of 15 × 15 cm^2 and, therefore, plastic boxes with dimensions of 20 × 20 × 10 cm^3 had to be used. Inside the boxes, 800 mL of water was poured and cotton was placed to prevent the movement of water when the boxes were moved for weighing. Finally, the boxes were closed and resealed to create a saturated environment inside (Figure 15). The results of the vapour permeability test are expressed in terms of the diffusion equivalent air layer thickness (S_d), see Equation (2), which is given in meters (m)

$$S_d = \frac{P_{ar \times A \times \Delta P}}{G}, \quad (2)$$

where *Par* is the diffusion coefficient for water vapour in air at atmospheric pressure (1.95×10^{-10} kg·m^{-1}·s^{-1}·Pa^{-1}), A (m^2) is the test area of the sample, ΔP (Pa) is the vapour pressure differential between the top and bottom surfaces of the sample and G (kg/s) is the rate of water vapour flow across the sample in steady-state conditions.

The duration of the test varied according to the type of render, taking into account its microstructure. The more permeable the render is, the quicker it reached a steady state and the end of the test. In this regard, the natural hydraulic lime render had a test duration of 15 days, the hydrated lime render had a duration of 18 days and, finally, the cement render had a duration of 23 days. Even within the same render, the different paints also influenced the duration of the test, as some took longer to reach a steady state than others. In general, the samples painted with acrylic paint took the longest to reach this regime.



(**a**)

(**b**)

Figure 15. Water vapour permeability test: (**a**) schematic illustration of the capsule; (**b**) capsules inside the climatic chamber.

Figure 16 shows the diffusion equivalent air layer thicknesses for the different combinations studied. It should be noted that the results presented are an average of three samples per paint and plaster tested.

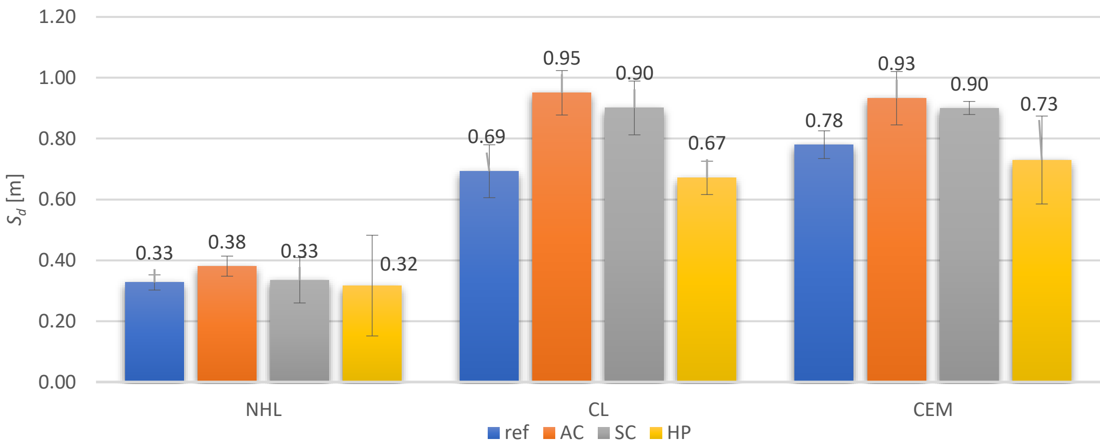


Figure 16. Diffusion equivalent air layer thickness values.

From the results obtained (Figure 16), it can be concluded that the natural hydraulic lime render samples are the ones with the highest permeability to water vapour diffusion, indicating a smaller thickness of the Sd compared to the other two renders. On the other hand, the hydrated lime and cement renders show very similar behaviour in terms of water vapour permeability. This result is consistent with the results of the drying test, in which the natural hydraulic lime render stands out. As shown in the graph, it is easy to understand the difference in permeability imposed by the different paints. The hydro pliolite paint presented superior permeability to water vapour, with practically identical performance to the unpainted samples, which would be an advantage in terms of the drying kinetics of the render, especially in old buildings [12]. The acrylic paint was responsible for the greatest reduction in permeability in all the renders, which allows it to be concluded that it is an obstacle to the passage of water vapour.

4. Discussion

The experimental campaign was designed to study the contribution of the different types of paint to selected render mortars and how they affect their performance. It was possible to establish a relationship between the following test parameters:

- Surface hardness, cohesion and dry abrasion resistance:

When characterising the surface hardness characterisation of the renders, the cement-based render and the natural hydraulic lime render showed a similar surface hardness, resulting in values of the same order of magnitude. These results are in line with the trend of previous studies on render mortars [31,32].

In terms of surface cohesion, the hydraulic-based renders achieved the best results, in agreement with the hardness test results, followed by the render made of hydrated lime. Drdácký et al. [19] studied hydrated lime mortars using the same method and obtained values of surface mass loss higher than those obtained in this study. These results demonstrate that the renders of the present study have good surface cohesion. Furthermore, the differences in surface mass loss between painted and unpainted samples are noteworthy. This result supports the theory that the formation of a film of paint protects and aids the surface cohesion of the render. Moreover, this result was more pronounced in the hydrated-lime-based render, probably due to the presence of larger pores in this render [33], which may also facilitate the fixation of the paints. Nevertheless, this possibility could only be confirmed by demonstrative pore size distribution results. With regard to the loss of surface mass due to erosion, the renders painted with hydro pliolite stand out from the rest with the lowest values. This difference observed is probably due to the greater adhesion of the hydro-pliolite-based paint [4].

- Capillarity coefficient vs. water absorption coefficient under pressure:

The natural hydraulic lime render had the highest water absorption values in both tests, followed by hydrated lime and then cement render. The smaller porometry of the hydraulic lime mortar, as shown by [28,34], may explain the high CC value. Regarding the effect of the paints on water absorption, acrylic paint is the one that reduces the water absorption more significantly, either by capillarity or by low pressure through the Karsten tube. This means that acrylic paints are less water-permeable, such as the one assessed by [35]. On the contrary, the silicate and hydro pliolite paints show higher water absorption values, but with very similar results in both water absorption tests.

It can be said that the results obtained in this work are of the same order of magnitude as those obtained by Brito [10] for silicate paints. The results of CC obtained by Brito [10] for silicate paints vary between 0.06 and 0.43 $kg/m^2{\cdot}h^{\frac{1}{2}}$, and the upper limit is slightly higher than the results obtained in this work, which are between 0.0537 $kg/m^2{\cdot}h^{\frac{1}{2}}$ and 0.0898 $kg/m^2{\cdot}h^{\frac{1}{2}}$, values in line with the author's lower limit. The results obtained by Veiga and Tavares [36] for the same silicate paint (0.81 $kg/m^2{\cdot}h^{\frac{1}{2}}$ to 1.42 $kg/m^2{\cdot}h^{\frac{1}{2}}$) are slightly different from those of this study, being much higher, which may be due to the fact that the samples tested by these authors are quite different from those of the present study.

With regard to the paint based on hydro pliolite, the results of this work are in agreement with those obtained by the author [10], who obtained results between 0.06 $kg/m^2{\cdot}h^{\frac{1}{2}}$ and 0.08 $kg/m^2{\cdot}h^{\frac{1}{2}}$, corresponding to 0.05 $kg/m^2{\cdot}h^{\frac{1}{2}}$ and 0.09 $kg/m^2{\cdot}h^{\frac{1}{2}}$ obtained in this study. Likewise, the results obtained by the author [10] for acrylic paint are in line with those obtained in this work, with a value of 0.07 $kg/m^2{\cdot}h^{\frac{1}{2}}$ compared to the 0.03 $kg/m^2{\cdot}h^{\frac{1}{2}}$ and 0.06 $kg/m^2{\cdot}h^{\frac{1}{2}}$ obtained in the present study. However, for the same paint, Remédios et al. [37] obtained a value of 0.143 $kg/m^2{\cdot}h^{\frac{1}{2}}$, which is not consistent with the results of this work, being much higher. The explanation could be that the render used by the author is slightly different from that used in this work or that the author mentions that one of the samples painted with this paint never stabilised the test, probably due to cracking, which may have influenced the results.

- Drying index vs. diffusion equivalent air layer thickness:

Acrylic paint is the one with the highest resistance to water vapour diffusion, which means that it is the paint that hindered the drying process of the render the most. If we compare the results obtained by Brito [10] for the hydro pliolite paint, the obtained Sd values obtained are slightly higher than those obtained in this work (1.80 m vs. 1.16 m and 1.08 m vs. 0.90 m). As can be seen from Figure 16, the hydro pliolite paints have the highest water vapour permeability values, exceeding those of the silicate paints in all renders. The water vapour permeability of the silicate painted renders decreases significantly compared to the unpainted render when applied to hydrated lime and cement renders. In the natural hydraulic lime render, the silicate paint resulted in a permeability similar to that of the unpainted sample. Considering the results obtained, as well as the conclusions of another study on the same type of paint [38], it can be stated that silicate paint should be chosen with caution, as its influence on the vapour permeability and drying kinetics can be different depending on the characteristics of the render. From the results shown in Figures 14 and 16, it can be concluded that not all paints are suitable for use on old buildings when considering the results in terms of water vapour permeability and drying kinetics. Silicate paint, which is considered to be a paint with good water vapour permeability, in this case, as already mentioned, did not give the expected results, approaching the behaviour of the plastic paint. The correlation between the drying index and Sd is shown in Figure 17. The relationship between the two variables is useful to check how the two properties relate to each other. A good correlation between these two parameters was obtained for the painted renders. Of note is the low correlation for the unpainted renders.

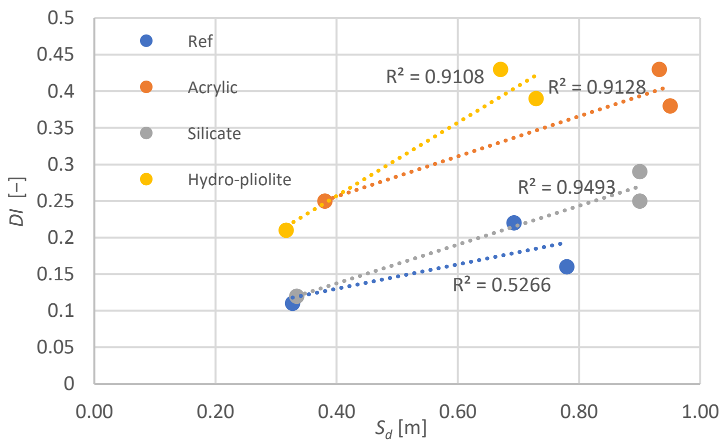


Figure 17. Correlation between the drying index (*DI*) and the equivalent air layer thickness (S_d).

5. Conclusions

Exterior paints and coatings play a key role in the protection of buildings against the agents of deterioration, of which water is the most prevalent. It is therefore essential that the properties of the renders and paints are as appropriate as possible to the conditions in which they will be used. In this study, natural hydraulic lime renders, hydrated lime renders and cement renders without any type of paint were analysed and used as a reference. These renders were painted with three different types of paint (acrylic paint, silicate paint and hydro pliolite paint), which are the most commonly recommended materials for painting the exterior of buildings in Portugal. The aim was to analyse the contribution of these paints to the behaviour of the renders towards water in the liquid and vapour state, as well as some mechanical properties.

The results showed that the surface cohesion of the hydrated-lime-based render was more influenced by the paints than the cement or natural hydraulic lime renders. This result is probably due to the fact that the bond between the matrix and the aggregates is the weakest and, consequently, the aggregating contribution of the paint is more noticeable. It was also observed that the capillary absorption of the render is significantly reduced in the presence of the paint coating. On average, the reduction in absorption was about 90% compared to the reference samples (i.e., unpainted). Regarding the type of render, it can be concluded that acrylic paint offers the greatest resistance to water absorption, but at the same time, it hindered drying the most. Hydro pliolite and silicate paints behave very similarly in terms of water absorption, with the former achieving slightly better results than the latter. From the point of view of water vapour permeability, the results of the hydro pliolite paint are much more suitable for reducing moisture accumulation due to its high water vapour permeability.

Considering the results assessed, it can be said that for new buildings, where the presence of water inside the walls is not an issue, acrylic paint can be an appropriate choice in terms of water absorption by capillarity and drying behaviour. Silicate paint should be chosen with caution, as its influence on water vapour permeability and drying kinetics can be different, depending on the characteristics of the render. In the case of old buildings (natural hydraulic lime or hydrated lime-based renders) with thick masonry walls and high water content in the core, the most suitable paint would be a hydro pliolite paint that promotes good drying kinetics of the wall.

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References

1. Smith, B.M. *Moisture Problems in Historic Masonry Walls: Diagnosis and Treatment*; Department of the Interior, National Park Service, Preservation Assistance Division: Washington, DC, USA, 1986.
2. Massari, G.; Massari, I. *Damp Buildings: Old and New*; ICCROM: Rome, Italy, 1993.
3. Lourenço, P.B.; Luso, E.; Almeida, M.G. Defects and moisture problems in buildings from historical city centres: A case study in Portugal. *Build. Environ.* **2006**, *41*, 223–234. [CrossRef]
4. Stoye, D.; Freitag, W. Paints, Coatings and Solvents. Wiley-VCH Verlag GmbH: Weinheim, Germany, 1998. [CrossRef]
5. Carretti, E.; Dei, L. Physicochemical characterization of acrylic polymeric resins coating porous materials of artistic interest. *Prog. Org. Coat.* **2004**, *49*, 282–289. [CrossRef]
6. Xi, W.; Liu, Y.; Zhao, W.; Hu, R.; Luo, X. Colored radiative cooling: How to balance color display and radiative cooling performance. *Int. J. Therm. Sci.* **2021**, *170*, 107172. [CrossRef]
7. TC 203-RHM (Main author: Caspar Groot). RILEM TC 203-RHM: Repair mortars for historic masonry. *Mater. Struct.* **2012**, *45*, 1277–1285. [CrossRef]
8. Ramos, N.M.M.; Delgado, J.M.P.Q.; Freitas, V.P. Influence of finishing coatings on hygroscopic moisture buffering in building elements. *Constr. Build. Mater.* **2010**, *24*, 2590–2597. [CrossRef]
9. Vares, O.; Ruus, A.; Raamets, J.; Tungel, E. Determination of hygrothermal performance of clay-sand plaster: Influence of covering on sorption and water vapour permeability. *Energy Procedia* **2017**, *132*, 267–272. [CrossRef]
10. Brito, V.; Gonçalves, T.D.; Faria, P. Coatings applied on damp building substrates: Performance and influence on moisture transport. *J. Coat. Technol. Res.* **2011**, *8*, 513–525. [CrossRef]
11. Gonçalves, T.D.; Pel, L.; Rodrigues, J.D. Influence of paints on drying and salt distribution processes in porous building materials. *Constr. Build. Mater.* **2009**, *23*, 2590–2597. [CrossRef]
12. Freitas, V.M. Influence of the vapour permeability of paintings and the hygroscopicity of the internal coating on the hygrothermal behaviour of walls. In Proceedings of the CIBW40 Meeting, Kyoto, Japan, 7–10 October 1997; pp. 256–269.
13. *CEN EN 197-1:2011*; Cement. Part 1: Composition, Specifications and Conformity Criteria for Common Cements. CEN-European Committee for Standardization: Brussels, Belgium, 2011.
14. *CEN. EN459-1:2010*; Building lime. Part 1: Definitions, Specifications and Conformity Criteria. CEN-European Committee for Standardization: Brussels, Belgium, 2010.
15. *CEN. EN 1097-3:1998*; Tests for Mechanical and Physical Properties of Aggregates—Part 3: Determination of Loose Bulk Density and Voids. CEN-European Committee for Standardization: Brussels, Belgium, 1998.
16. *CEN. EN 1015-2:1998/A1:2006*; Methods of Test for Mortar for Masonry—Part 2: Bulk Sampling of Mortars and Preparation of Test Mortars. CEN-European Committee for Standardization: Brussels, Belgium, 2006.

17. *CEN. EN 1015-3:1999*; Methods of Test for Mortar for Masonry—Part 3: Determination of Consistence of Fresh Mortar (by Flow Table). CEN-European Committee for Standardization: Brussels, Belgium, 1999.
18. *ASTM C150*; Standard Specification for Portland Cement. ASTM International: West Conshohocken, PA, USA, 2016.
19. Drdácky´, M.; Lesák, J.; Niedoba, K.; Valach, J. Peeling tests for assessing the cohesion and consolidation characteristics of mortar and render surfaces. *Mater. Struct.* **2015**, *48*, 1947–1963. [CrossRef]
20. *ASTM C1803-20*; Standard Guide for Abrasion Resistance of Mortar Surfaces Using a Rotary Platform Abraser. ASTM International: West Conshohocken, PA, USA, 2020.
21. *CEN. EN 1015-18:2002*; Methods of Test for Mortar for Masonry–Part 18: Determination of Water Absorption Coefficient due to Capillary Action of Hardened Mortar. CEN-European Committee for Standardization: Brussels, Belgium, 2002.
22. Faria, P.; Santos, T.; Aubert, J.-E. Experimental Characterization of an Earth Eco-Efficient Plastering Mortar. *J. Mater. Civ. Eng.* **2016**, *28*, 04015085. [CrossRef]
23. Baltazar, L.G.; Henriques, F.M.A.; Cidade, M.T. Grouts with Improved Durability for Masonry Consolidation: An Experimental Study with Non-Standard Specimens. *Key Eng. Mater.* **2017**, *747*, 480–487.
24. *RILEM TC 25-PEM*; Test No. II.6. Water Absorption Coefficient. Recommended Tests to Measure the Deterioration of Stone and to Assess the Effectiveness of Treatment Methods. U.S. Department of the Interior: Washington, DC, USA, 1980.
25. Guterres, P.C.; Oliveira, L.P. Behaviour of rendering mortar for rehabilitation of buildings subjected to rising damp. *J. Civ. Eng. Archit.* **2017**, *11*, 342–347.
26. *RILEM TC 25-PEM*; Test No. II.5. Evaporation curve. Recommended Tests to Measure the Deterioration of Stone and to Assess the Effectiveness of Treatment Methods. U.S. Department of the Interior: Washington, DC, USA, 1980; Commission RILEM/25.PEM.
27. *CEN. EN 16302*; 2013 Conservation of cultural heritage–Teste methods–Measurement of water absorption by pipe method. CEN-European Committee for Standardization: Brussels, Belgium, 2013.
28. Silva, B.A.; Ferreira Pinto, A.P.; Gomes, A. Natural hydraulic lime versus cement for blended lime mortars for restoration works. *Constr. Build. Mater.* **2015**, *94*, 346–360. [CrossRef]
29. Baltazar, L.G.; Henriques, F.M.A.; Rocha, D.; Cidade, M.T. Experimental characterization of injection grouts incorporating hydrophobic silica fume. *J. Mater. Civ. Eng.* **2017**, *29*, 04017167. [CrossRef]
30. *EN 1015-19:1998/A1:2004*; Methods of Test for Mortar for Masonry-Part 19: Determination of Water Vapour Permeability of Hardened Rendering and Plastering Mortars. CEN-European Committee for Standardization: Brussels, Belgium, 2004.
31. Santos Silva, A.G.; Borsoi, R.; Veiga, A.; Fragata, M.; Tavares, F. Llera, Physico-chemical characterization of the plasters from the church of Santissimo Sacramento in Alcântara, Lisbon. In Proceedings of the 2nd Historic Mortars Conference HMC10 and RILEM 203-RHM Final Workshop, Prague, Czech Republic, 22–24 September 2010.
32. Borsoi, G.; Veiga, R.; Santos Silva, A. Effect of nanostructured lime-based and silica-based products on the consolidation of historical renders. In Proceedings of the 3rd Historic Mortars Conference, Glasgow, UK, 11–14 September 2013.
33. Barbero-Barrera, M.D.M.; Maldonado-Ramos, L.; Van Balen, K.; García-Santos, A.; Neila-González, F.J. Lime Render Layers: An Overview of Their Properties. *J. Cult. Herit.* **2014**, *15*, 326–330. [CrossRef]
34. Silva, B.A.; Ferreira Pinto, A.P.; Gomes, A. Influence of natural hydraulic lime content on the properties of aerial lime-based mortars. *Constr. Build. Mater.* **2014**, *72*, 208–218. [CrossRef]
35. Topçuoglu, Ö.; Altinkaya, S.A.; Balköse, D. Characterization of Waterborne Acrylic Based Paint Films and Measurement of Their Water Vapor Permeabilities. *Prog. Org. Coat.* **2006**, *56*, 269–278. [CrossRef]
36. Veiga, M.R.; Tavares, M. Characteristics of ancient walls requirements for painting coatings conference communication. In Proceedings of the Paint Industry at the Beginning of the 21st Century, Lisbon, Portugal, 22–23 October 2002; Available online: http://conservarcal.lnec.pt/pdfs/RVMT_APTETI.pdf (accessed on 3 February 2020); (In Portuguese).
37. Remédios, N.; Paulina, F. Evaluation of finishing systems for plastering on old buildings (in Portuguese). In Proceedings of the Code2.2.11-Conference: REHABEND 2016—6th Euro-American Congress on Construction, Pathology, Rehabilitation Technology and Heritage Management, Burgos, Spain, 24–27 May 2016.
38. Ferreira Pinto, A.P.; Bernardo, D.; Gomes, A.; Silva, B. Influence of different paint finishes on the water transport characteristics of rendering mortars for old masonry walls. In Proceedings of the Conference: 4th Historic Mortars Conference (HMC 2016), Santorini, Greece, 10–12 October 2016.