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Durability Testing of Water Repellents on Rendered Autoclaved Aerated Concrete

H. Kus
KTH Research School, Centre for Built Environment, University of Gävle, Sweden

Abstract

The paper presents the preliminary results of a research work investigating the long-term performance, deterioration processes and ageing characteristics of rendered autoclaved aerated concrete with and without silicon-based water repellents. Performance assessment is based on long-term moisture monitoring of samples exposed to natural weathering as well as capillary water absorption and drying tests in the laboratory. Data obtained both from site monitoring and laboratory tests show similarities in moisture characteristics of the samples. The results obtained so far show that performance decline of water repellents is still negligible both after three-year outdoor weathering and 1000-hour artificial weathering to UV and water. In the long-term, natural weathering is more effective in deteriorating the water repellent than the artificial weathering tested. While the initial findings are promising, further weathering tests are necessary in order to give a more reliable estimate of the durability of water repellents.

1 Introduction

Silicon-based water repellents are increasingly used as a preventive or remedial measure against the problems associated with excessive moisture content, particularly as a result of rain penetration. Because of their hydrophobic properties, silicon-based water repellents are considered to prolong the service life of external walls by preventing or minimising water ingress into the wall structure and thus delaying its deterioration. However, the long-term performance and durability of water repellents on different building materials is not well known. A research project [1] has been initiated to study the long-term performance, deterioration processes and ageing characteristics of rendered autoclaved aerated concrete (AAC) with and without water repellents, based on different testing procedures following the systematic methodology given in the standard ISO 15686-2 [2]. In order to compare the efficiency of various alternatives, two different applications of water repellents (as surface impregnation and as additive in the rendering) and a commonly used acrylic-styrene paint are tested. The samples are then weathered by exposure to natural conditions or artificially in the laboratory [3]. Performance tests and material analysis were carried out initially, during and after weathering. Long-term moisture and temperature monitoring of naturally exposed test blocks are also included in the study [4], the results of which are presented below.

Depending on the deterioration suffered, the performance of building materials and/or components gradually diminishes with time. The principal performance requirements expected from a water-repellent product are, among others, high resistance to water penetration, minimal reduction in vapour transmission and resistance to UV radiation. In this paper, the performance over time and durability of water repellents are evaluated by the capillary water absorption and drying properties of the wall component. These properties are to be subsequently evaluated by contact angle measurements and vapour transmission tests.

In addition, microstructural characterization of both unexposed and exposed samples has been initiated. The effects of ageing are investigated by correlating pore structure and moisture performance of rendered AAC with and without water repellents [5]. The microstructure is studied in thin section by light optical microscopy. The surface characteristics are examined by scanning electron microscopy (SEM) and the chemical constituents are identified by energy dispersive x-ray spectroscopy (EDS). X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) are also to be used.

Table 1: Sample types of test specimens

Code	Substrate	Rendering	Top coating/impregnation
O	AAC	-	-
R	AAC	Lime-Cement	-
P	AAC	Lime-Cement	Styrene-acrylate paint
S1	AAC	Lime-Cement	Silane-siloxane emulsion
S2	AAC	Lime-Cement with silicon resin additive	-

2 Experimental

2.1 Materials

Four different rendering systems applied on AAC were included in this study: a plain rendering that served as reference (R); another to which a silicon-based water repellent was applied (S1); a third which included the water repellent as an additive in the render (S2); and a fourth to which a conventional styrene acrylate top coating was applied (P). A plain AAC block served as the control sample (O). This is summarized in Table 1.

System S1 included a silane-siloxane emulsion (active ingredient 50% by weight) applied to the rendered surface in a 1+6 solution in water by weight. Two coats of the emulsion were applied by brushing onto the pre-wetted rendered surface. The penetration depth of emulsion in the lime-cement rendering was measured to be ~1,5 mm, i.e., the final coat was entirely impregnated as well as part of the undercoat. System S2 included a silicon powder product (active ingredient 50% by weight) added to the dry mix of the rendering in the amount of 0.5% by weight. In both cases, the applications of the water repellents followed the instructions of the manufacturer.

In order to obtain a better assessment of the actual performance, all test samples used in this research were cut from a wall made of AAC (density of 450 kg/m^3) panels measuring 2.40m×1.20m×0.15m. The wall was constructed indoors by a skilled building contractor who also applied the rendering. One part of the wall was rendered with three layers of lime-cement mortar having a total thickness of 12-mm. The mix for the scratch coat, i.e., the first render coating, was 10:90:350 (w/w) of lime:cement:sand, while for the undercoat it was 50:50:650. The final coat had the mix 50:50:450 w/w of lime:white cement:crushed white dolomite. A second part of the wall (corresponding to samples S2) was rendered in the same way and thickness but with the addition of a water repellent, a silicone powder additive, to all three rendering mixes. After the rendering was completed, the wall was covered with a plastic film and kept wet for three days.

Subsequently to the approximate 3-month curing period at indoor conditions, samples were cut from both parts of the rendered AAC wall. Some specimens from the first part were then treated with either the water repellent (S1) or the paint (P), others were left untreated (R).

For each system R, P, S1 and S2 and for the control O, one larger sample (40 cm×30 cm×15 cm) for moisture and temperature monitoring as well as three smaller samples (13 cm×13 cm ×15 cm) were cut for natural exposure on the test rack, while two samples (6.5 cm ×15 cm ×9 cm) were cut for artificial exposure. The sides and rear faces for all the samples were sealed with four layers for epoxy paint, leaving only the exposed face uncovered.

The mean value of the contact angle from preliminary measurements made on the unexposed surfaces of samples from systems S1 and S2 were found to be approximately 100º in both cases, while for those of system P the angle was lower [6].

2.2 Weathering

2.2.1 Natural Weathering

To expose the samples to natural weathering they were set on a 45º metal rack facing south (Figure 1) where they are subject to direct rainfall and ultraviolet radiation. Since the inclination of the test rack accelerates photodegradation rates, the field exposure arrangement may be considered as a naturally “accelerated” weathering test. The weather conditions at the exposure site are being monitored in close proximity to the test rack. The programme started in September 1998 and will continue for at least five years in order to subject samples to a wide range of weather conditions.

Two of the three smaller sets of samples were removed after 6 and 18-month exposure for laboratory tests and analysis. The third sample will be taken down for analysis after 36-month exposure, while the larger samples still on the rack will remain for at total of 60-months exposure. At that time they also will be taken down for laboratory tests and analysis.

2.2.2 Artificial Exposure

Two samples of each system as well as of the control were subjected to artificial weathering. This consisted in continuous light and intermittent water-spray exposure. A filtered xenon-arc lamp type apparatus (Figure 2) was used. The testing programme was operated in accordance with the test procedure described in the standard ASTM G 26-96 [7]. Each cycle consists of 102 minutes of light followed by 18 minutes of light and water spray. The spectral irradiance level is 0.35 $W/m^2/nm$ at 340 nm. The samples are to be aged for a total of 2000 h (~ 12 weeks) in the weathering chamber.

Every 500-h two samples of each type are taken out of the chamber for testing. One is used for capillary water absorption and drying, while specimens of the other

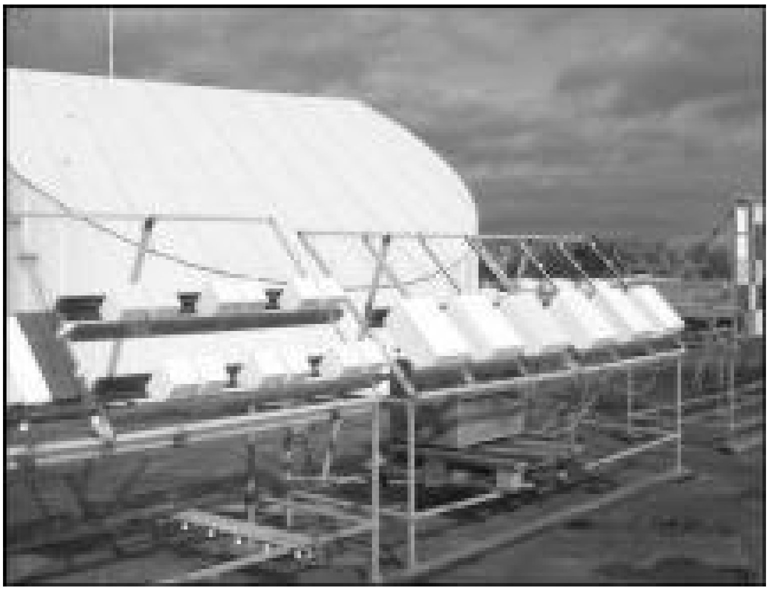

Figure 1: Exposure rack for natural weathering

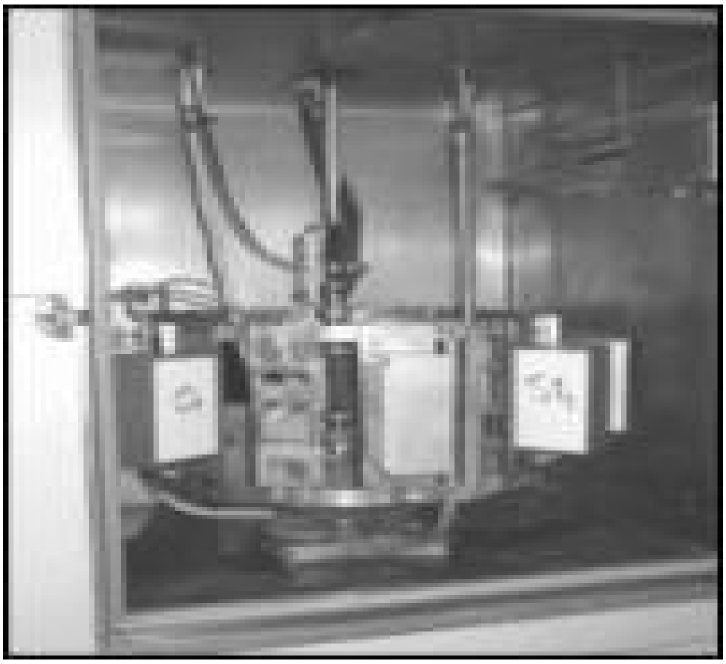

Figure 2: Artificial weathering chamber

one are cut every 500-h to be used for microscopy examination. All the exposed surfaces were white in colour before exposure and no significant change was observed after 1000-h exposure.

2.3 Measurements

2.3.1 Capillary Water Absorption Test

Since the samples were wet after exposure they were first dried at 40ºC to constant weight before the capillary absorption test was performed. For this, the samples were immersed, exposed face down, some 1-3mm deep into the water. The samples were then weighed at various time intervals. The naturally weathered samples were weighed for four weeks, the artificially weathered samples for only one week.

2.3.2 Drying Curves

Once the capillary water absorption test reached maximum water absorption, the samples were immediately put to dry in the laboratory where the temperature ranges from 20°C to 24°C and the relative humidity between 30% and 40%. The naturally weathered samples were weighed at various time intervals for 28 weeks, those artificially weathered for only four weeks so that they could be returned to the chamber for further weathering.

2.3.3 Continuous Moisture Measurements

The moisture of the test blocks on the outdoor weathering rack was monitored from the beginning of the exposure programme. Wetcorr sensors [8] and resistance type nail electrodes were used to measure the surface moisture and the moisture content in the material, respectively. Resistance is measured by epoxy coated nail electrode pairs placed at five different depths (in the rendering and in the AAC) in addition to temperature measurements with copper-constantan-type thermocouples at the same depths. The moisture sensors and thermocouples are connected to the terminals of two multiplexers controlled by a datalogger. The sensors are scanned at five-minute intervals and the averages of resistance and temperature are stored every hour. The electrical measurements of moisture carried out both in the AAC material and in the thick rendering were calibrated and the resistance measured between the two electrodes together with the temperature were converted to absolute moisture content [4].

3 Results and Discussion

3.1 Capillary Water Absorption

The course of capillary water absorption for the treated samples, weathered both naturally and artificially, are shown in Figures 3 and 4, respectively.

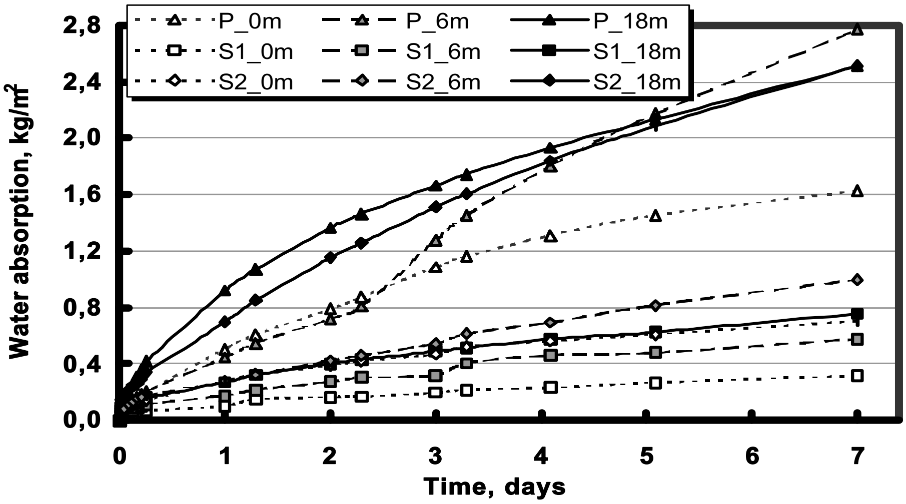

Figure 3: Capillary water absorption curves for treated samples, before and after the indicated time-span of natural weathering

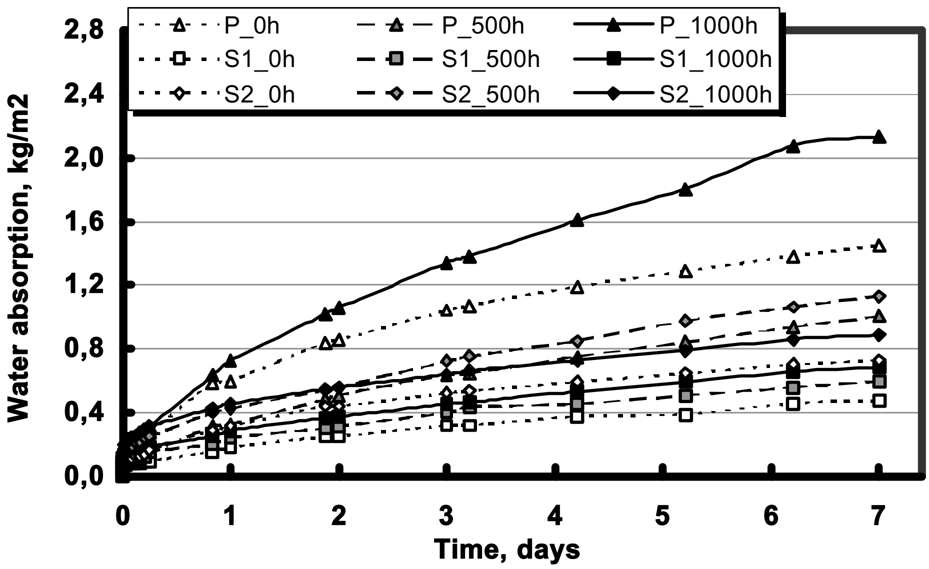

Figure 4: Capillary water absorption curves for treated samples after the indicated time-span of artificial weathering

In general, samples treated with water repellents (S1 and S2) absorb less water than those coated with the styrene-acrylate paint (P), both before and after weathering. The surface application of the water repellent (S1) was the most effective in resisting both natural and artificial weathering. On the other hand, the samples where the water repellent was added into the render (S2) suffered a far greater increase of water absorption after natural weathering than after artificial ageing (the greatest change was observed after 500-h) than the other two types of samples, as can be clearly seen in Figure 3. This appears to indicate that other atmospheric agents, not included in the artificial weathering programme, have a greater influence on the deterioration of this treatment.

Figures 5 and 6 show the change in capillary water absorption coefficients at 24 hours (A_{24}) after natural and artificial weathering, respectively. Although the values increase over time, all samples are still water repellent according to the definition given in the standard DIN 18550 [9]. The behaviour of the styrene-acrylate painted sample (P) is similar after 6 months' natural and 500-hour artificial weathering. Although the capillary water absorption coefficient decreases initially after exposure, it increases significantly after weathering, both natural and artificial, for longer periods of time. For longer exposure times, the natural weathering conditions at the site are more effective than those tested in the chamber in deteriorating the products tested

3.2 Drying curves

The drying curves - after the capillary water absorption test - for samples weathered both naturally and artificially are shown in Figures 7 and 8, respectively. All samples displayed a similar decrease in relative moisture loss after an 18-month.

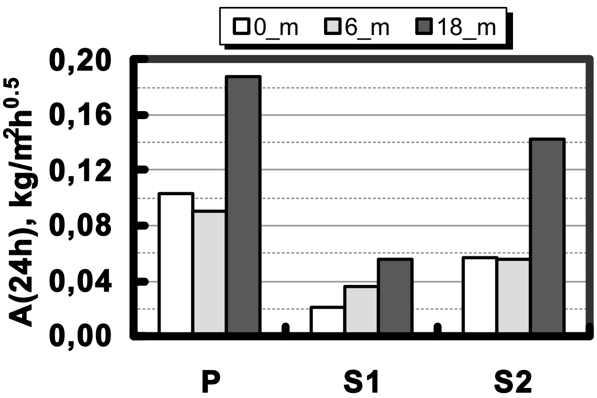

Figure 5: A_{24} for natural weathering

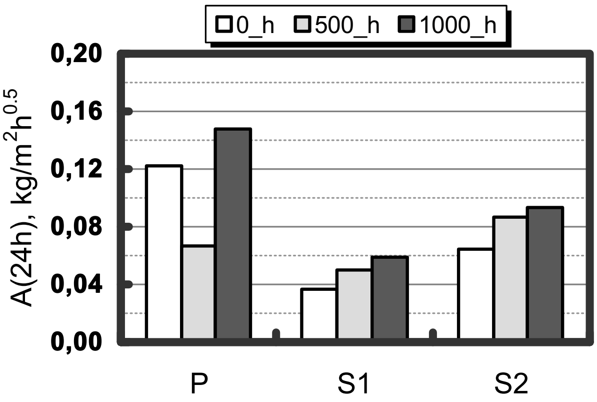

Figure 6: A_{24} for artificial ageing

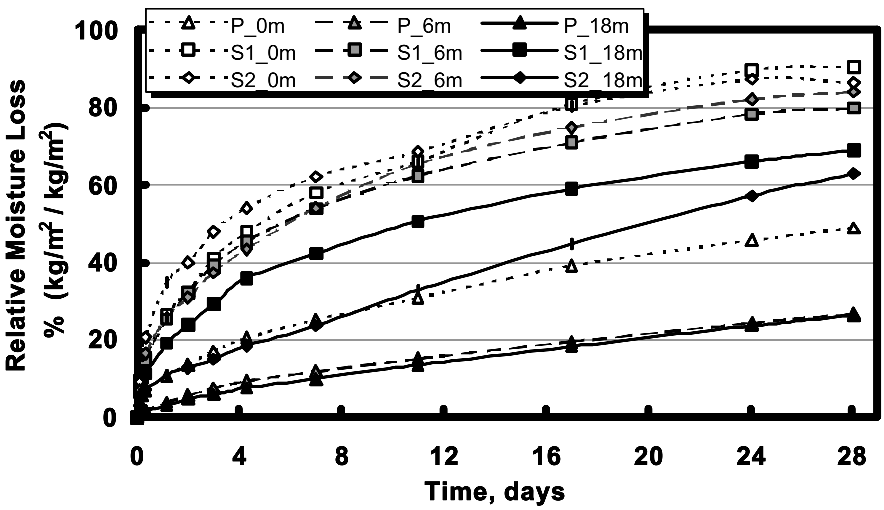

Figure 7: Drying curves for treated samples before and after the indicated time-span of natural weathering

exposure as compared to the unweathered samples, i.e., they dried slower. For the sample with the surface applied water repellent (S1), the moisture loss decreased about 10% after six months and about 20% after 18 months of natural weathering as compared to the unweathered sample. This same change in moisture loss was shown by the styrene-acrylate painted sample (P), while the sample with water

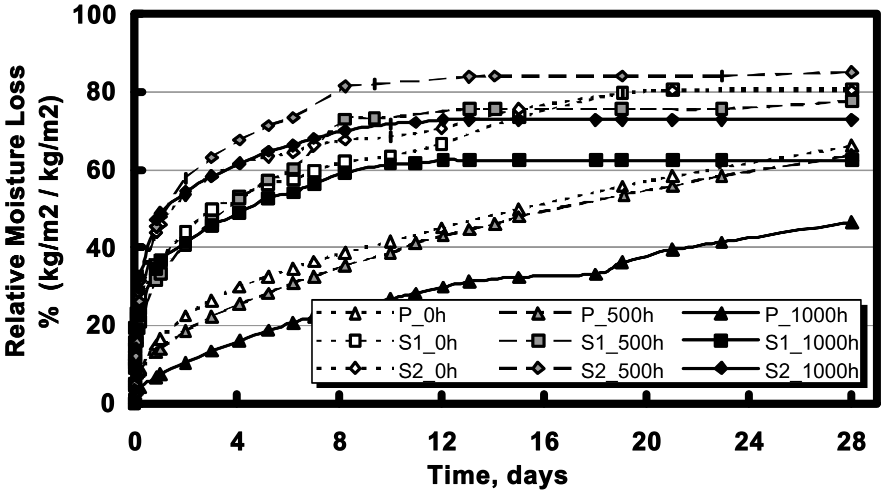

Figure 8: Drying curves for treated samples after the indicated time-span of artificial Wattierung

repellent render (S2) showed a decrease of abour 25%. For these last two samples (P and S2), short-term exposure (6 months) had negligible effect.

Since the drying of the 1000-hour artificially weathered samples was ongoing at the time of writing, the results presented for this group (Figure 8) is limited to 14 days. The drying behaviour of the samples is less affected by artificial than by natural weathering. The greatest change was observed for the styrene-acrylate painted sample (P) after 1000 hours of exposure in the weathering chamber.

3.3 Continuous Moisture Measurements

Continuous moisture and temperature measurements at the test rack have been carried out for almost three years. In general, the moisture level increases in seasons with high air humidity or precipitation, and at low temperatures with short periods of sunlight. In Figure 9, the moisture contents in the AAC material at 2-mm depth, as measured from the rendering-AAC interface, is exemplified for a 3-day period. The moisture changes in the AAC are directly related to the effectiveness of the coating system applied to it. In this example, the performance assessment of water repellents is given by the data obtained from the measurements made in the substrate, i.e. the AAC.

So far, no significant changes in moisture contents have been observed for samples treated with a water repellent (S1 and S2). The untreated rendered AAC (R) has high amounts of moisture which change significantly with weather conditions while the acrylic-styrene painted sample (P) displays similar but smaller amounts of and muted variations in moisture content. The lowest moisture content that can

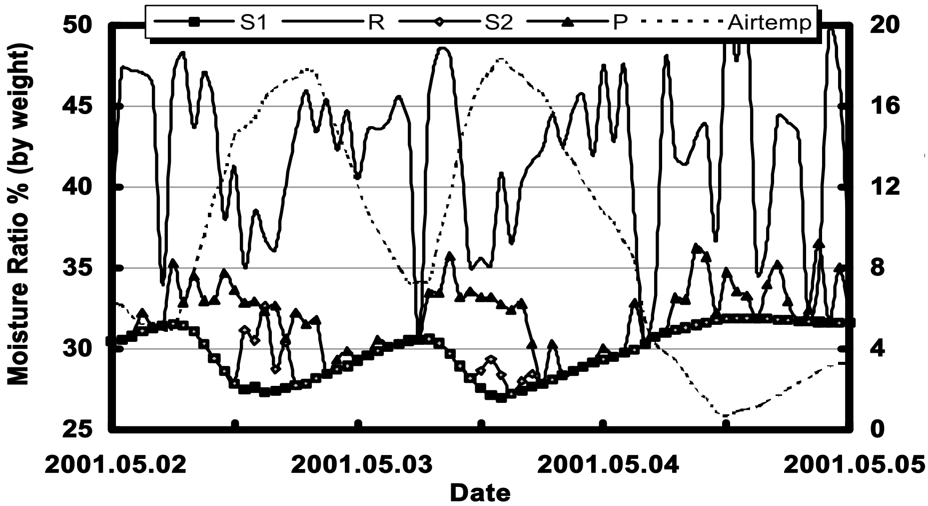

Figure 9: Moisture performance of untreated and treated samples for a 3-day period

be measured with this experimental set-up is appr. 27% (by weight) at 20°C. Because the absorption rates of water repellent applied samples (S1 and S2) are very small, their moisture contents are probably under this detection limit. Thus, only the maximum moisture content which these samples may contain are accurately reflected. However, very small changes have appeared on sample S2 after two years of monitored weathering. A longer exposure time is needed to be able to make more reliable estimations on the durability of these water repellent treatment.

4 Conclusions

The study has advanced towards understanding the deterioration effect of natural and artificial weathering on the performance and durability of silicon-based water repellents. Comparison of the results obtained from natural and artificial weathering will help to determine the relationship between these two different experimental programmes. This, in turn, will allow to design short-term tests simulating the real effects of natural weathering on water repellent treatments applied on or in renders. Determining performance over time and durability of silicon-based water repellents in this way would serve to predict the service life of these treatments faster than by means of natural exposure while maintaining the prediction accuracy. While the initial findings are promising, further research is still necessary on specific topics such as the influence of cracks in water repellent treated renders and the resistance of these treatments during salt crystallization cycles.

5 References

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