EVALUATION OF THE LONG-TERM PERFORMANCE OF WATER REPELLANTS ON RENDERED AUTOCLAVED AERATED CONCRETE

Performance of water repellants

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Abstract

External wall surfaces made of porous materials are known to be susceptible to the effects of wind-driven rain. Water repellants have become widely used to mitigate the apparent problems arising from rain deposition on such wall types. Although manufacturers claim that water repellants perform adequately for extended periods of time, there are still apparent premature failures that occur within a few years of application. To date, various kinds of water repellants have been developed but limited research has been carried out particularly on the long-term field exposure testing from which the real effect of climate on the properties of water repellants can be assessed. This study aims to investigate the long-term performance and durability of water repellants on rendered autoclaved aerated concrete (AAC) by physical and chemical analysis of fresh, naturally and artificially weathered samples. Six sample blocks of AAC were used; one uncoated and untreated as control block and five rendered blocks, one of which was untreated, two treated with silicone, one painted with a styrene-acrylate paint, and one covered with expanded ePTFE membrane employed as the ideal coating. A preliminary test was done for selection of the paint for sealing the sides of the samples against water and vapour ingress. Continuous monitoring of moisture contents and temperatures of naturally exposed samples is also included in the study. WETCORR sensors and nail electrodes are used to measure surface and bulk moisture contents, respectively. This paper focuses on the preparation of test blocks and moisture monitoring and presents the first results derived from field measurements. The results indicate that the experimental set-up works as planned and it is expected that an assessment of the service life of water repellants based on moisture monitoring will be possible after the samples are exposed to longer periods.

Keywords: Autoclaved aerated concrete, field exposure, long-term performance, moisture monitoring, water repellants, WETCORR

1 Introduction

Water repellants are increasingly used for protection of porous mineral building materials subjected to prolonged wetting by driving rain. Although their performance has been confirmed by research, there are still questions on their long-term durability and service life. Existing research on performance of surface treatments is mostly focused on concrete structures and the protection of historical buildings built of stone, brick and wood, and is based primarily on short-term laboratory testing.

In order to evaluate the long-term performance of water-repellent treatments on porous mineral building materials, a long-term field exposure and a short-term accelerated test programme have been initiated at the Royal Institute of Technology (Sweden), Centre for Built Environment. The research work includes continuous monitoring of moisture, which is considered as the major factor in determining durability of porous building materials, and physical and chemical analysis of fresh, naturally and artificially aged samples.

For the surface finishing coatings, AAC and mineral rendering were chosen as substrates being representative of porous building materials. AAC has an extensive use both in residential and industrial construction due to its thermal properties, that lead to energy savings by lowering heating costs and indirectly preventing air pollution. In order to get higher performance, AAC walls are rendered mostly with lime-cement mineral rendering.

Sample specimens used in this work include water-repellent treated and painted, rendered AAC blocks, in addition to reference blocks. Test blocks measuring 400 mm × 300 mm × 150 mm were used for continuous monitoring of moisture and temperature. To investigate the real effect of atmospheric agents on water-repellent properties and to observe the degradation process, an additional group of test samples measuring 130 mm × 130 mm × 150 mm have also been naturally exposed. These specimens will subsequently be used in a laboratory analysis at specific intervals. Short-term accelerated ageing tests will involve exposure to UV (and water) followed by freeze-thaw cycling. The analysis of microstructure and the surface treatments will be undertaken using microscopic (thin sections and SEM) and spectroscopic methods (FTIR).

The present work focuses on the preparation of test blocks and monitoring of surface and bulk moisture contents of the test samples.

2 Durability of rendered AAC walls with and without water repellants

Performance of external walls is greatly affected by weathering elements, thus durability and service life of the wall component vary according to the severity of exposure. The use of surface finishing coatings mainly aims to minimise and delay the deteriorating effects of the atmosphere, maintaining an aesthetically pleasing appearance. By sacrificing themselves, surface coatings extend the life of the substrate and therefore play a major role in the long-term performance and service life of the entire wall system.

Different surface coatings require different maintenance and repair periods depending on their properties and effects on the facade. Indeed, the service life of the external walls depends directly on the extent to which those intervals of maintenance are kept.

Due to being directly in contact with atmospheric agents, such as rain, solar radiation, temperature and wind, surface coatings may fail prematurely. This in turn will lead to deterioration and damages in the wall structure unless remedial action is taken. Among the atmospheric agents, moisture plays the major role in premature deterioration (Kus and Kalmar 1998). Thus the moisture storage of a wall can be a potential indicator of long-term performance for a given construction type and location. The amount and duration of moisture in the wall structure can be regarded as the two most important characteristics for assessing the long-term effects.

Field inspections on rendered AAC walls show that organic external renderings degrade faster than inorganic systems (Nygren 1998). Being vapour-tight to some extent and greatly affected by UV radiation and thermal variations, organic external coatings degrade relatively fast compared with inorganic ones. During the desorption period, the transport rate outwards of water vapour is higher in an inorganic system. It takes a longer time for organic coatings to dry out, due to their lower vapour permeability. Therefore, organic coatings may contribute to insufficient drying of the wall which can potentially lead to increased deterioration. The adhesion of the coating to the substrate is also weakened by excessive moisture, which accelerates the ageing process. Another reason for the observed differences between these coatings is that the organic external renderings inspected were not maintained as frequently as prescribed.

On the other hand inorganic external renderings treated with water repellants perform much better owing to their hydrophobic effects (Kus and Kalmar 1998). By reducing the ingress of water, water repellants are expected to minimise and delay the degradation mechanisms related to rainwater. As they are highly protected from the UV radiation by penetrating the substrate, a long durability is achieved compared to other surface coatings. The effectiveness and durability are affected greatly by the properties of the substrate, such as surface porosity and moisture content, and the amount and the uniform permeation of the water-repellent material applied (McGettigan 1992).

3 Experimental

3.1 Test specimens

Six sample blocks measuring 400 mm × 300 mm × 150 mm were used for continuous monitoring of moisture and temperature, including uncoated and untreated AAC as the control sample block. AAC blocks, 150 mm thick and density 450 kg/m^3, were employed as substrate to the coating systems tested. Four samples were coated with three layers of lime-cement rendering for a total thickness of 12 mm, one of which was untreated, one treated with a water repellant at the surface, one coated with styrene-acrylate paint, and one covered with expanded ePTFE membrane (GORE-TEX®) employed as an ideal top coating. The sixth sample was coated with three layers of lime-cement rendering containing water-repellent additive, having a total thickness of 12 mm. The AAC blocks were obtained from Yxhult AB. The renderings were obtained from Optiroc AB and Yxhult AB. The representative samples of water repellants in powder and liquid form were obtained from Wacker-Chemie. The styrene-acrylate paint was selected among the paints commonly used for mineral substrates in order to compare the effectiveness of water repellants and was obtained from Snöland Fasad AB. In Table 1, the coating systems are summarised according to their corresponding codes.

The side faces of the sample blocks were then sealed with four layers of epoxy paint, except the surface to be exposed. Consequently moisture absorption and desorption through the coatings could be controlled.

Table 1: Test blocks

Code	Substrate	Render	Top coating
O	AAC	-	-
B1	AAC	Lime-cement	Silane-siloxane emulsion
B2	AAC	Lime-cement	-
C2	AAC	Lime-cement	(Expanded) ePTFE membrane
C3	AAC	Lime-cement	Styrene-acrylate paint
G2	AAC	Lime-cement with silicone resin additive	-

3.2 Pretest for selection of the tightening material

A preliminary test was first carried out in order to obtain the best material for sealing the sides of the test blocks, which should also be durable to outdoor conditions during the whole exposure period. AAC test pieces measuring 50 mm × 50 mm × 75 mm were completely coated with seven different types of waterproof coatings with 3 - 5 layers by painting and immersion. The coatings were stearine, aluminium primer, silicone rubber and alkyd, epoxy, polyurethane and ePTFE paints. They were left to dry completely for several days before the tests. Water and vapour ingress were tested. The samples were first put in the climate cabinet at 95%RH and 20°C, and weighed periodically during 30 days. Afterwards, they were completely immersed in water and weighed periodically during 10 days. Epoxy paint proved to be the best among the conventional coatings used in this experiment. The results from this study are given in Fig.1 and Fig.2.

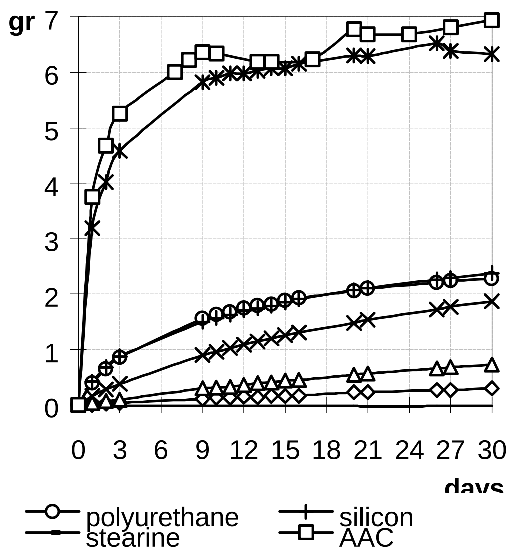

Fig. 1 : Vapour uptake

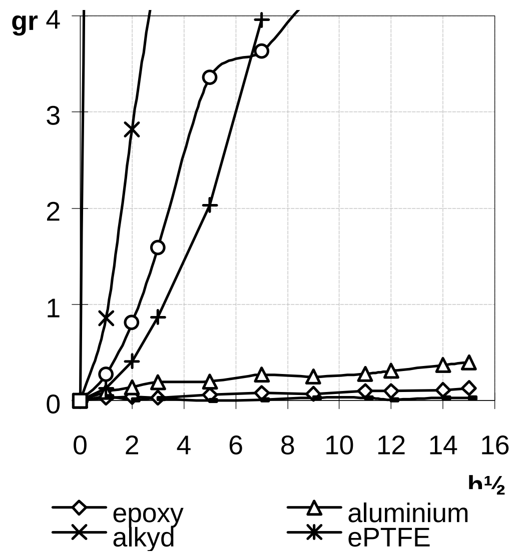

Fig. 2 : Water uptake

3.3 Moisture and temperature measurement set-up

3.3.1 Moisture sensors

WETCORR sensors (Norberg 1993) are used for measuring time of wetness (TOW) at the exposed surfaces, while epoxy coated nail electrode pairs are used for measuring moisture content inside the blocks.

Two WETCORR sensors were mounted on the exposed surface of two blocks, by gluing with epoxy resin. Nail electrodes (26 pairs) were driven into five different depths from the back of the blocks. The moisture sensors were arranged as shown in Table 2. The nail electrode pairs were placed approximately 12 mm apart. The joints at the back surface were then sealed with epoxy resin so that any leakage was prevented. The connections of the nails to the cables leading to recording devices were also sealed with silicone.

3.3.2 Thermocouples

To measure the temperature, copper-constantan-type thermocouples were used. Two thermocouples were mounted on the exposed surface of the blocks with WETCORR sensors, positioned approximately 50 mm beside the sensor and 55 mm from the bottom. The wire at the surface was glued with epoxy resin and painted white, the same colour as all block surfaces, in order to avoid any inaccurate measurement due to different radiation heat exchange. Twelve thermocouples were inserted into the blocks at the same depths as the moisture sensors, from the back (Table 2). The joints at the back surfaces were sealed. In addition to surface and inner temperatures, air temperature was also measured by one thermocouple kept in a self-ventilated radiation shield.

Table 2: The arrangement of sensors and thermocouples in test blocks, distances from the back of AAC (thickness of AAC blocks 150 mm and rendering 12 mm)

Sample	Surface	160 mm	156 mm	152 mm	148 mm	123 mm	78 mm
O					O-4 O-4T	O-5 O-5T	O-6 O-6T
B1	B1-W B1-T	B1-1 B1-1T	B1-2	B1-3	B1-4	B1-5	
B2	B2-W B2-T	B2-1 B2-1T	B2-2 B2-2T	B2-3 B2-3T	B2-4 B2-4T	B2-5 B2-5T	
C2		C2-1 C2-1T	C2-2	C2-3			
C3		C3-1 C3-1T	C3-2	C3-3	C3-4	C3-5	
G2		G2-1 G2-1T	G2-2	G2-3	G2-4	G2-5	

W: WETCORR sensor, T : Thermocouple

3.3.3 Multiplexer-datalogger

The moisture sensors and thermocouples were connected to the terminals of two multiplexers controlled by a datalogger from Campbell Scientific Inc. The sensors are scanned at five-minute intervals and the averages of resistance and temperature are stored every hour. For convenience and safety reasons the data are automatically retrieved every day and stored on a VAX computer for further processing on a PC.

The recording devices were placed in an insulated box under the test rack with a box temperature regulated to 25 °C by miniature heaters. In this way the equipment is kept in a stationary environment independent of atmospheric conditions.

3.4 Orientation and exposure period

Test blocks are exposed on a 45° metal rack facing south, on the roof of the KTH-Built Environment building in Gävle (Fig. 3). In this case, the field study may be considered as a naturally accelerated ageing test.

The weather conditions at the exposure area have been monitored in close proximity to the test rack and the yearly averages according to data from 1997 are as follows:

- temperature, cold season : max. 16,9 °C min. - 15,6 °C (October-March)
- temperature, warm season : max. 29,6 °C min. - 4,8 °C (April-September)
- relative humidity : 74 %
- total rainfall : 605 mm
- wind direction and speed : (44 %) S – 2,6 m/s
- UV-radiation : 138 MJ/m^2/year

The exposure programme started on 25 September 1998 and will run for at least 18 months in order to subject samples to a wide range of weather conditions.

Fig. 3 : Test samples on the rack

3.5 Presentation of data

Temperatures in ^{o}C and the logarithmic values of resistances between 1-10000 k are presented in Fig. 4 and Fig. 5 below.

4 Results and discussion

The results obtained after one month show that sample B2, the untreated rendered AAC block, has the highest level of moisture content. Moisture reaches even to the deepest point measured, which is approximately 40 mm from the exposed surface. The moisture fluctuation near the surface is, as might be expected, greater than at larger depths. Fig. 4 presents the measurement results from sample B2 for a selected period.

Sample G2, the block with water repellant as additive, shows almost no capillary absorption whereas sample B1, the block with water repellant as surface treatment, displays some capillary absorption near the surface area. The amount of moisture for B1-1, is very small and constant, which may be a result of inaccurate measurement. The precise reason for this anomaly is not known at the time of writing. Measurement results from sample B1 for a selected period are presented in Fig. 5.

Sample C2, the ideal block that was covered with ePTFE membrane and, as expected, has not absorbed any water at all.

The control sample O, the untreated and uncoated AAC block, has a capillary absorption reaching almost to the middle of the block. However, the moisture content level seems to be less than the one in rendered AAC, i.e. B2. This can be explained by the pore structure of the rendering system and the AAC substrate, respectively.

Sample C3, the styrene-acrylate painted block, has a capillary absorption only reaching to some parts of the rendering. The AAC substrate is almost dry.

Since the calibration of measurements is not yet completed, the results can only be compared for similar samples at specific depths. The absolute moisture contents will be calculated after calibration of each pair of electrodes.

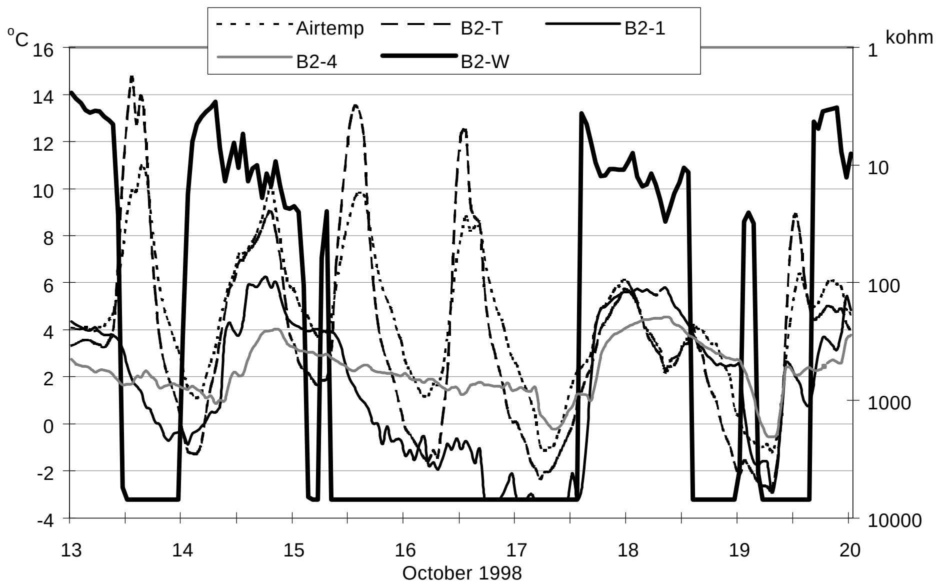

Fig. 4 : Air temperature and surface temperature, surface and bulk moisture measurement results of sample B2 for a selected period

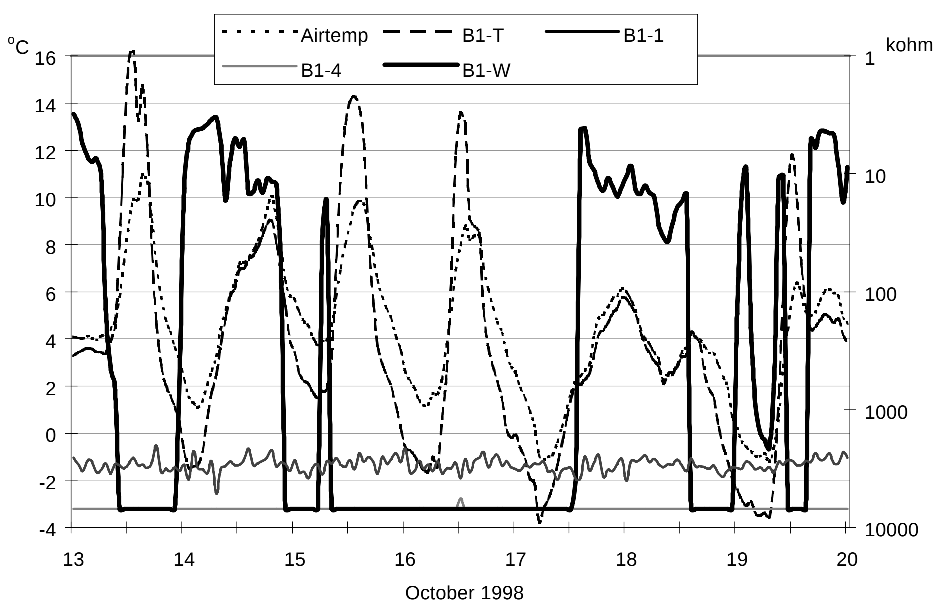

Fig. 5 : Air temperature and surface temperature, surface and bulk moisture measurement results of sample B1 for a selected period

5 Conclusion

The results obtained so far show that the field measurement set-up is working properly. However, it is too early to draw any conclusion for the assessment of the service life of water repellants based on the moisture measurements, whereas this should be possible to accomplish after a longer exposure time. It will also be likely to obtain information on the effects of water repellants on the freeze-thaw deterioration of the wall samples.

In this research work

- moisture characteristics,
- long-term performance and service life evaluation and
- degradation processes and ageing characteristics

of porous building materials with and without surface coatings are investigated. Future aspects of this study will also include the development of ageing procedures and accelerated test methods to be applied on smaller samples. Comparison of the results from the natural and artificial ageing tests will give information on how to design short-term test methods for evaluating renderings containing water repellants.

6 Acknowledgements

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7 References

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