Long-term Performance Evaluation Of External Renderings On Autoclaved Aerated Concrete Wall

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Summary: The use of external renderings and surface treatments mainly aims to improve the weather resistance of external walls. The influence of agents present within the microenvironment, particularly moisture, causes degradation of external walls and thus reduces their performance over time. In order to study the long-term effects on rendered autoclaved aerated concrete (AAC) walls, an experimental building has been built. The microenvironment parameters have been continuously measured and laboratory tests and analysis have been carried out on sample cores taken each year from test panels mounted on the experimental building. In this paper, the long-term performance of external renderings is evaluated based on the comparison of test results of the capillary water absorption of sample cores and the microenvironment measurements. The first results obtained after a two-year exposure period indicate that inorganic renderings have improved their initial moisture performance while the performance of organic renderings remained about the same.

Keywords: AAC, external rendering, long-term performance, moisture.

1 INTRODUCTION

Rendered AAC is one of the alternative wall construction types to external walls with insulation systems. Because of the low thermal conductivity of AAC, additional insulation may not be required depending on the climate where the construction is built and on the use of the building. In addition to energy savings during use, it could also save material and reduce work during the construction phase. Moreover, complex moisture problems of multi-layered walls can be avoided by minimising the number of layers. However, as for other wall types, protection of AAC against outdoor conditions, particularly rain, plays an important role for the service life. The durability and service life of rendered AAC walls depends on factors such as characteristics of the building materials forming the wall components, design and the application (workmanship) level, environmental factors and maintenance conditions (ISO 15686-1). Most factors can be controlled, however the exposure environment remains as an important factor, which should be primarily considered in performance assessment. Different coatings and external rendering systems are applied to improve resistance to environmental factors. In fact, performance of these surface coatings and renderings determines the long-term performance of the whole wall component.

In order to study the actual in-service performance of rendered AAC walls, an international research programme, EUREKA-project DurAAC E 2116 (Kus & Nygren 2000), has been initiated at the Centre for Built Environment in Gävle, Sweden. The long-term effects of different rendering systems on AAC are investigated by long-term moisture monitoring at the test cabin and by periodical laboratory tests as well as analysis of sample cores taken from the test cabin every year over a five-year period. The measuring (exposure) programme started in June 1999. In this paper, different rendering systems on AAC are evaluated, based on the comparison of test results of the capillary water absorption of sample cores and the data obtained from the continuous electrical measurements of moisture at the test cabin.

2 EXPERIMENTAL

2.1 Materials

Un-reinforced AAC panels with dry density 423 kg/m^3 and measuring 600 mm × 1200 mm × 150 mm were used as substrates for the rendering systems tested. The rendering work of the test panels was performed indoors by a skilled building contractor under controlled conditions. In this way, the experimental set-up would be repeatable and the performance of the test panels would be comparable. The applications of renderings and water repellants followed the manufacturer's instructions. After a

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curing period of approximately three months, rendered test panels (Fig. 1 and 2) were installed to the long sides of the test cabin facing north-east and south-west, respectively. There are 12 test panels on each of the two facades including uncoated and un-rendered AAC as control sample panels, System 1. The joints between the test panels themselves and the wall were insulated and sealed. The systems tested involve inorganic and organic renderings as well as their modifications with water repellants. The compositions of the six rendering systems, which are studied in this paper, are summarised in Table 1 below.

Figure 1. Test panels

Figure 2. Test panels from the inside

Table 1. Rendering Systems

System No	*AAC Surface Impregnation*	*Primer*	*Undercoat*	*Final Coat*	*Thickness (mm)*
5	-	Lime/white cement/dolomite 10/90/350	-	Lime/white cement/white dolomite 50/50/450	5-7
6	-	System No 5 *with silicon additive*	-	System No 5 *with silicon additive*	5-7
7	-	Lime/white cement/dolomite 10/90/350	Lime/cement/ dolomite-sand 50/50/650	Hydraulic lime/ lime/dolomite	10-12
9	Silane-siloxane emulsion	Acrylic/dolomite-calcite *with silicon additive*	-	Pure acrylic copolymer/dolomite-calcite	<1
11	Silane-siloxane emulsion	-	-	Silicon resin	<1
12	-	-	Cement/polymer/lime stone-plastic fibres	Cement/polymer/lime stone-plastic fibres	3-4

2.2 Measurements

Measurements taken can be grouped as continuous field measurements, periodical field measurements, and laboratory tests and analysis of material properties and over time. The programme will run for at least five years.

2.2.1 Continuous Microenvironment Measurements

Continuous field measurements are carried out at five-minute intervals and hourly averages are registered. The parameters monitored are:

- Surface and bulk moisture of the materials
- Surface and bulk temperature of the materials
- Indoor and outdoor air temperature
- Indoor and outdoor relative humidity
- Driving rain
- Ultraviolet radiation.

Moisture content of the test panels exposed at the test cabin have been monitored since the start of the exposure programme. Wetcorr sensors and resistance-type nail electrodes are used to measure both the surface moisture and the bulk moisture of the material. Resistance is measured by epoxy coated nail electrode pairs placed at seven different depths (in the rendering and in the AAC) in addition to temperature measurements with copper-constantan-type thermocouples at the same depths. The

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moisture sensors and thermocouples are connected to the terminals of five multiplexers controlled by two dataloggers. The resistance measured between the two electrodes together with the temperature, both in the AAC material and in the thick rendering, was converted to moisture content by means of a calibration procedure (Kus & Norberg 2001). Since the moisture performance of AAC is directly related to the effectiveness of the rendering system, the assessment is based on the electrical measurements of moisture made in the AAC.

2.2.2 Capillary Water Absorption Test

Once a year, three sample cores were drilled (with water) from each panel of the test cabin. The diameter of each core was 90-95 mm and the thickness approximately 150 mm (AAC and rendering system). The samples were then conditioned at 20 °C and 65 % relative humidity. After drying in the oven at 65 °C, surfaces of the samples, except for the exposed surface, were sealed with wax. The samples were immersed, exposed faces down into 1-3 mm of distilled water and were then weighed at various time intervals. For the initial test three samples were tested, whilst only one was tested after the first year of exposure and two after the second year.

3 RESULTS AND DISCUSSION

3.1 Microenvironment Measurements

The weather conditions at the north-east facade for the selected periods are summarised in Table 2. These conditions should be taken into consideration in order to make a better assessment of the rendering systems. For example, the total amount of driving rain is much higher during the periods in the first two years compared to the amount during the period in the last year. However, the average relative humidity is the highest during the period in year 2000 while the highest average temperature is found during the period in year 2001.

Table 2. Microenvironment measurements at the north-east facade

	unit	*5-12 Aug 1999*	*29 Jun-6 Jul 2000*	*20-27 Aug 2001*
Air Temperature (average)	°C	14,7	14,7	17,8
RH (average)	%	74	83	77
Driving rain (total amount)	kg/m^2/h	9,1	9,9	1,6

In Figures 3-5, air temperatures, relative humidity and the driving rain monitored on the north-east facade are shown for selected periods. The indoor air temperature is kept at minimum of 15 °C through the year. Because the south-west facade is subjected to sunlight over longer periods, the test panels demonstrate relatively low moisture contents and therefore are not included in this paper. In order to get the most significant effects, the most rainy and humid weather conditions were selected. The ageing process for different rendering systems can be analysed from initial data and data obtained at yearly intervals.

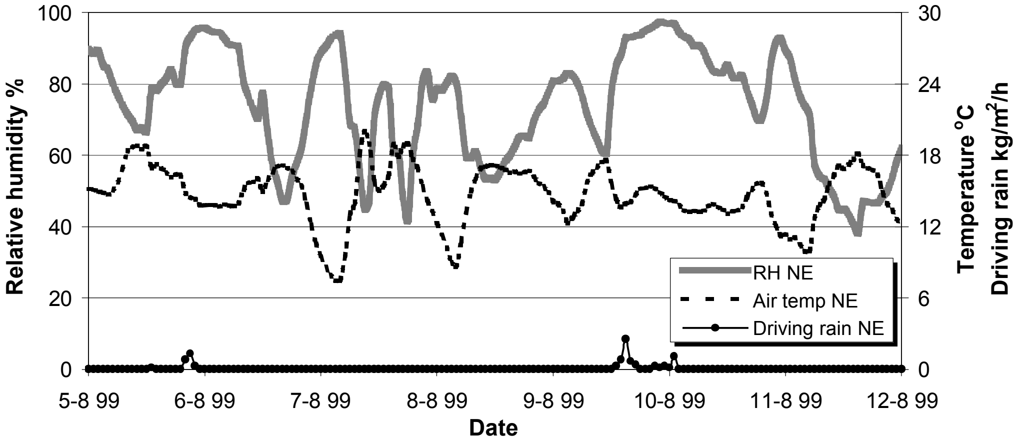

Figure 3. Microenvironment measurements: NE facade: 1999

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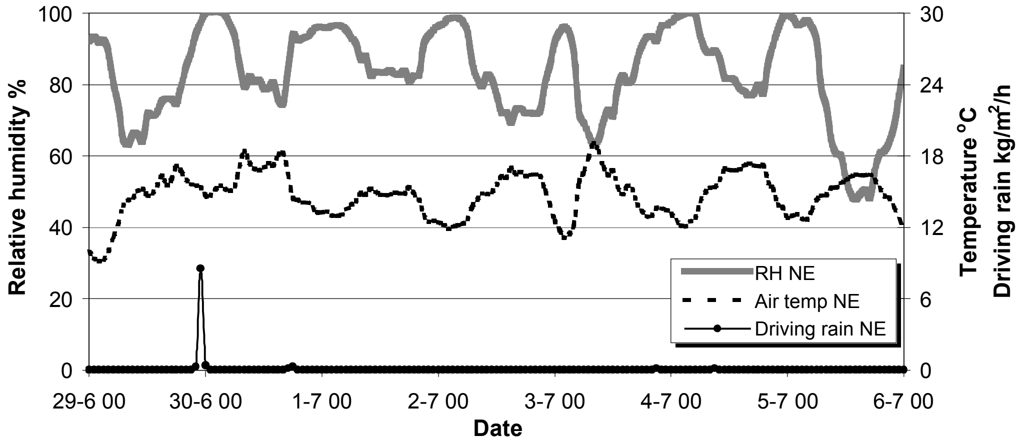

Figure 4. Microenvironment measurements: NE facade: 2000

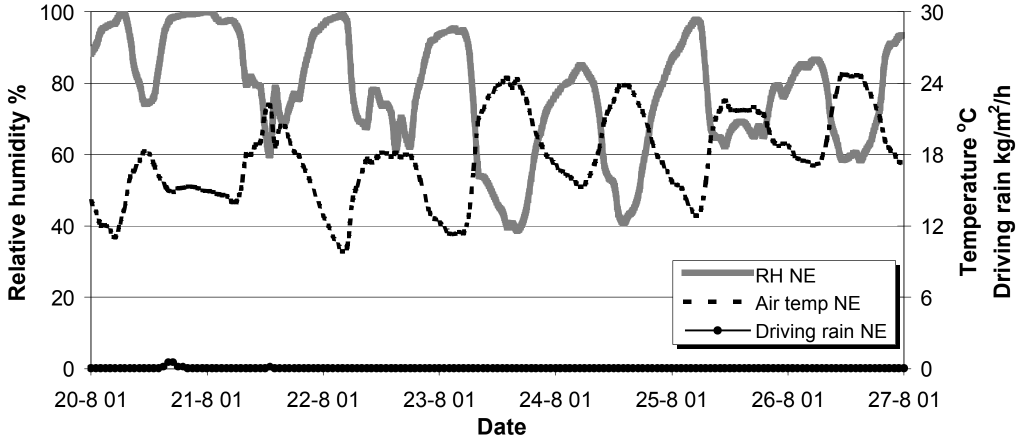

Figure 5. Microenvironment measurements: NE facade: 2001

3.2 Continuous Moisture Measurements

The average moisture content from one-week data measured at two different depths in the AAC is displayed in Figures 6 and 7. The moisture performance of lime-cement rendering systems, *Systems 5* and *7*, differs most from the other systems. The moisture content in these systems with inorganic renderings is higher than the control panel (plain AAC), *System 1* (Fig. 6). The only impairment over time, although rather small, appears for *System 6*. The performance of both *Systems 9* and *11* seems unchanged during the whole exposure period. The high moisture content of *Systems 5* and *7* at 25 mm depth in the AAC (Fig. 7) probably depends on the intensity of the driving rain and the high relative humidity during this period.

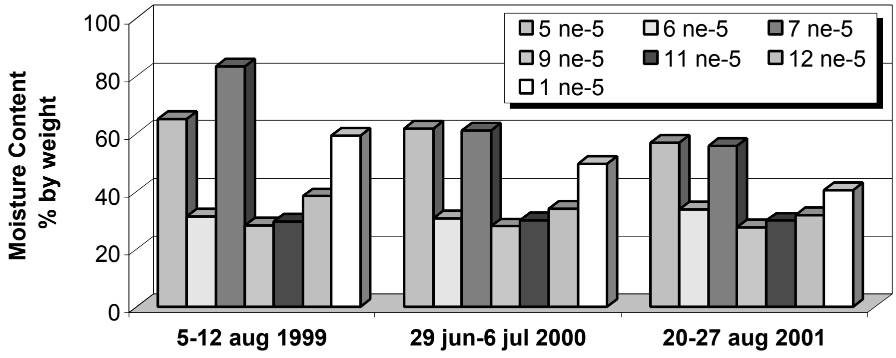

Figure 6. Average moisture content at 5 mm depth

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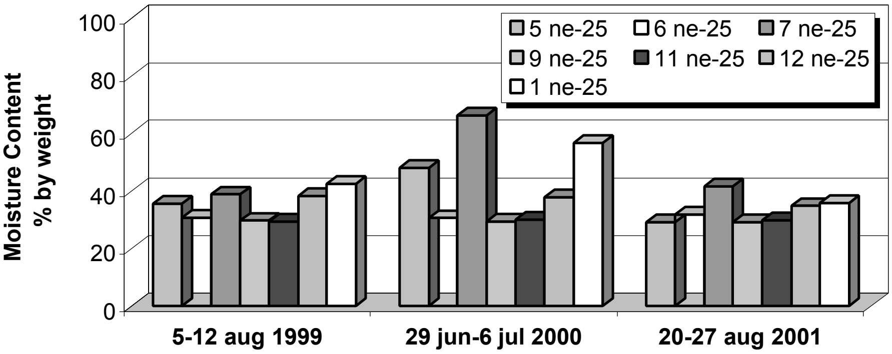

Figure 7. Average moisture content at 25 mm depth

3.2.1 At 5 mm depth from the AAC surface

The rendering systems modified with water repellants, *Systems 6*, *9* and *11*, and the fibre reinforced cement-polymer rendering, *System 12*, had relatively low moisture contents compared to the lime-cement rendering systems, *Systems 5* and *7* (Fig. 8-10). Initial measurements indicate that both thin and thick lime-cement rendering systems, *Systems 5* and *7*, absorbed about the same amounts, however, the absorption rate of *System 7* was lower, probably because of the thickness of the rendering which is thicker than that of *System 5* (Fig. 8). Also, it took longer for *System 7* to dry out and it absorbed moisture later and the moisture content remained higher than that of *System 5* when the second wave of driving rain occured (Fig. 8). After the first and second year of exposure, thick lime-cement rendering, *System 7*, absorbed less than the thin lime-cement rendering, *System 5*, however, demonstrated almost the same rate of drying (Fig. 9-10). When the duration of driving rain was very long, the lime-cement rendering containing silicon additive, *System 6*, and the fibre reinforced cement-polymer rendering, *System 12*, began to absorb small amounts of moisture. This is clearly seen, particularly after the second driving rain period (Fig. 8). This implies that the effectiveness of water repellent additives decreases when they are exposed to longer periods of driving rain.

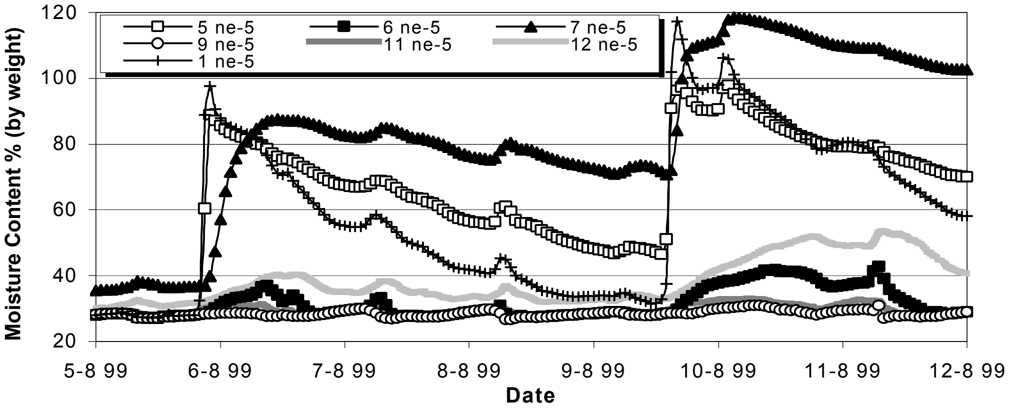

Figure 8. NE facade, 5 mm depth from the AAC surface: 1999

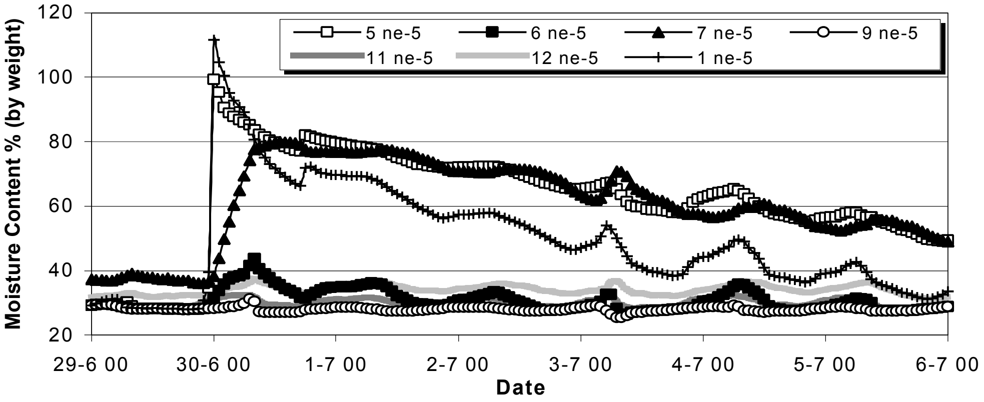

Figure 9. NE facade, 5 mm depth from the AAC surface: 2000

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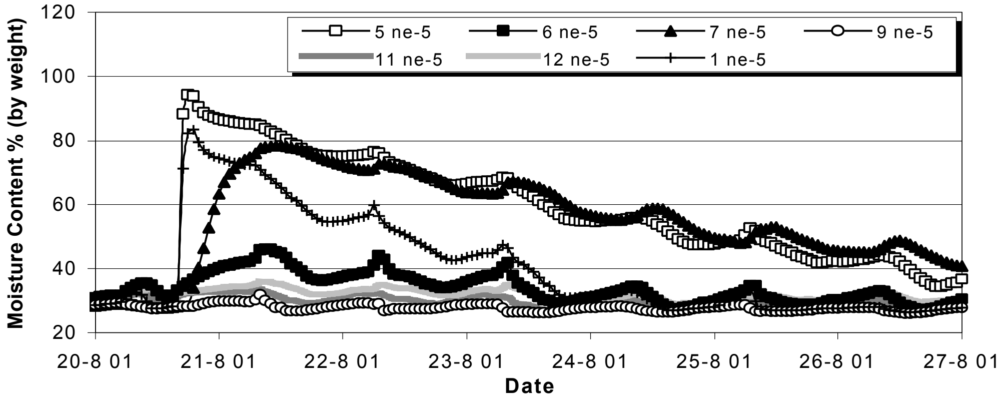

Figure 10. NE facade, 5 mm depth from the AAC surface: 2001

3.2.2 At 25 mm depth from the AAC surface

After approximately one year of exposure, the test panels with inorganic renderings, *Systems 7* and *5*, and the control panel (plain AAC), *System 1*, had the highest moisture contents at 25 mm depth (Fig. 12). This might be due to the intensity of the driving rain during this period which probably propagated the capillary suction inwards.

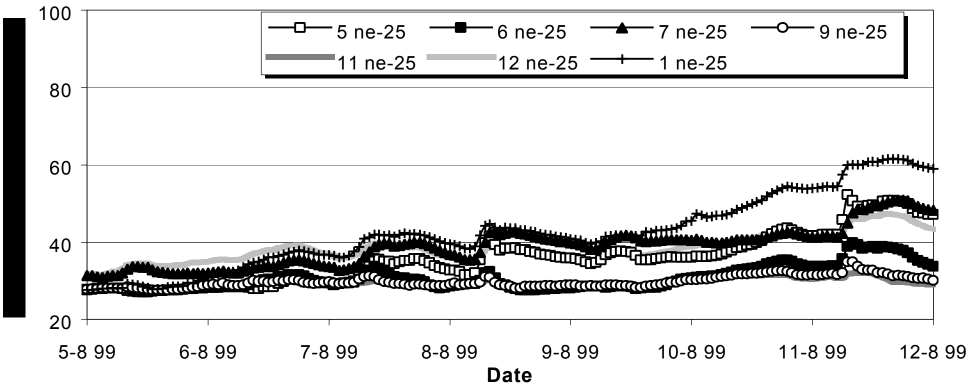

Figure 11. NE facade, 25 mm depth from the AAC surface: 1999

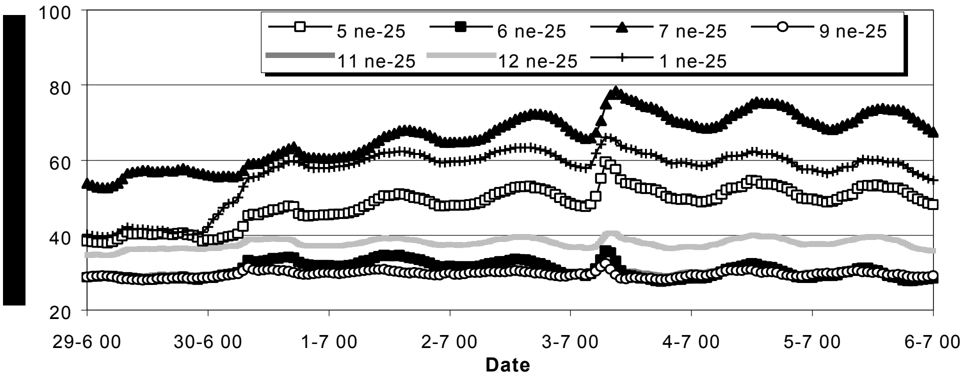

Figure 12. NE facade, 25 mm depth from the AAC surface: 2000

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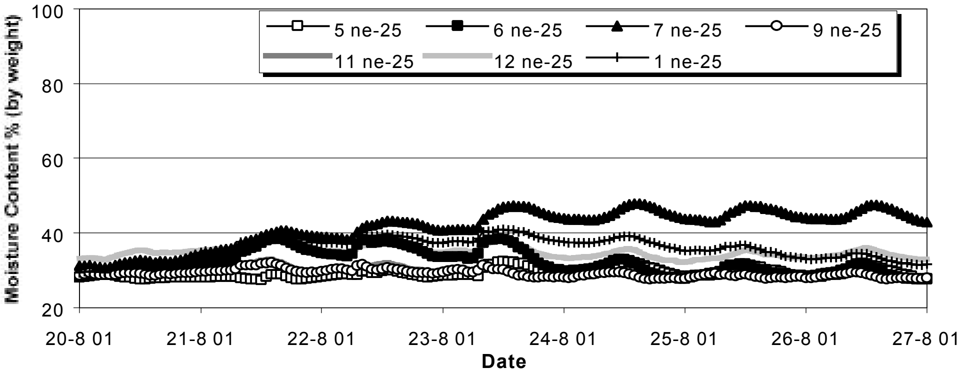

Figure 13. NE facade, 25 mm depth from the AAC surface: 2001

3.3 Capillary Water Absorption

Figures 14-16 demonstrate the capillary water absorption of the sample specimens, initially and over time. In general, the results indicate similar long-term declining tendency in suction properties of the inorganic systems, *Systems 7* and *5*. The fiber reinforced rendering, *System 12*, shows similar moisture behaviour over time, which is also decreasing. *Systems 9* and *11* keep almost the same low absorption levels after the second year of exposure (Fig. 16). The curve for *System 6* confirms its susceptibility to moisture absorption when it is in contact with water for a long duration, however the absorption rate is low compared to the inorganic systems.

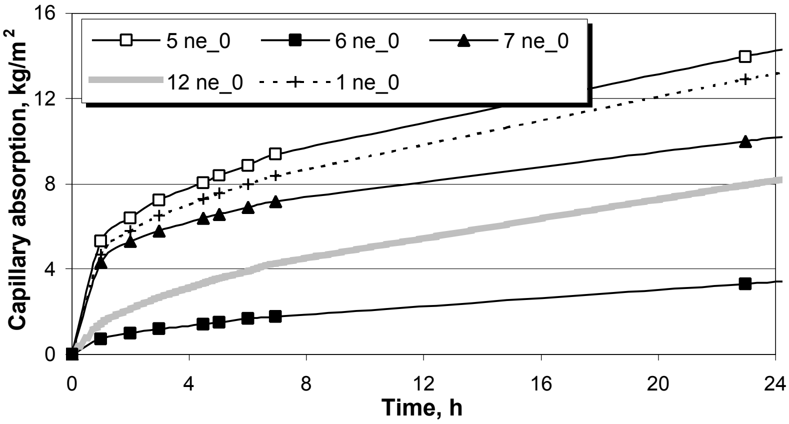

Figure 14. Initial capillary absorption: 1999

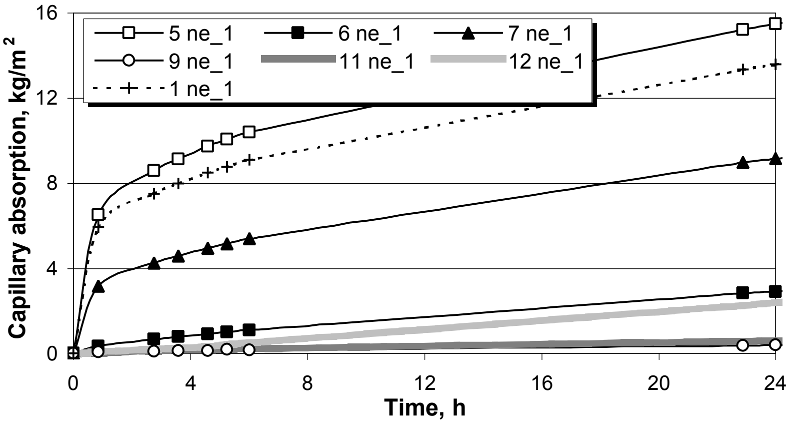

Figure 15. Capillary absorption: 2000

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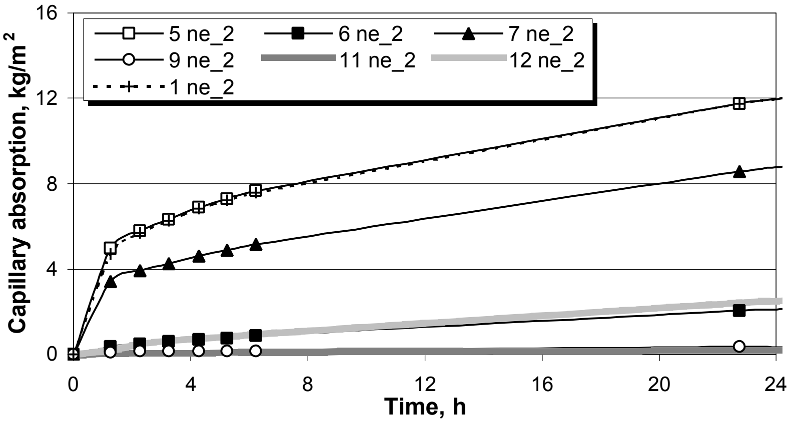

Figure 16. Capillary absorption: 2001

4 CONCLUSIONS

The long-term performance of different external rendering systems on AAC is being investigated within an international research project. The research programme consists of continuous microenvironment measurements and laboratory tests and analysis of initial material properties and material properties over time. Twelve systems including inorganic renderings and organic renderings as well as their modifications with silicon-based water repellants have been investigated. Efficiency of the rendering systems is basically assessed by moisture analysis of naturally exposed test panels mounted on an experimental building. The degradation processes and ageing characteristics are also studied by microstructure analysis of sample cores taken from the experimental building each year over a five-year period.

Among the six systems studied in this paper, *Systems 9* and *11*, the ones with impregnated AAC surface, perform best so far. Due to the hydrophobic effect of silicones, almost no change in moisture content has been observed during the initial two-year exposure period. The moisture content of *System 6*, the thin lime-cement rendering containing silicon additive, only increases after a long duration of driving rain. During long periods of driving rain the moisture content of *System 6* reached up to 80 % by weight. On the other hand, its drying rate was high. Initially, *System 12*, fibre reinforced rendering, was fairly susceptible to driving rain while subsequently improving its performance. *Systems 5* and *7*, the two inorganic systems, demonstrated the highest moisture absorption rates. However, after a short exposure period, the moisture contents of both inorganic systems decreased to some extent. The drying rate of *System 7* was lower compared to that of *System 5.* Faster degradation can be expected for *System 7* due to high moisture content during long periods of time.

First results obtained after a two-year exposure period indicate that inorganic renderings have improved their initial performance while the performance of organic renderings remained about the same. Another preliminary conclusion is the susceptibility of lime-cement renderings containing silicon additive to driving rain of long duration. Overall, the first results from the moisture monitoring give some insight into the actual in-service performance of different rendering systems on AAC. However, data from the two-year exposure period is not sufficient for reliable evaluation of long-term performance. The research programme is to be carried out for at least five years. Hence, it is expected that clearer findings will be made.

5 ACKNOWLEDGEMENTS

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