Water Repellent Treatment of Building Materials
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Hygrothermal Calculations Applied to Water-Repellent Surfaces – Validation and Application –

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Abstract

The moisture balance of natural stone materials is definitely one of the most important aspects of damage mechanisms. Besides constructive measures of rain protection, which should of course be preferred, another possibility to decrease the moisture content is the application of water-repellent agents. It must be noted in mind, however, that treating the stone with such agents always also reduces the possible drying rate. In order to quantify these effects, measurements and calculations were performed on a water-repellent sandstone. The comparison of measured and calculated results makes obvious, that the drying rate is markably decreased by application of a water repellent agent. The calculation shows that it is an important demand on the water repellent agent to increase the vapour resistance at a maximum with 25 %. If a fast drying out of the wall is required, constructive measures for rain protection are much more effective. The calculated results also show that a water repellent surface zone does not induce the risk of water accumulation due to interior moisture load, even if they are higher than normally.

Keywords: drying, damage mechanisms, numerical simulation

1 Defining the problem

The moisture balance of natural stone materials is definitely one of the most important aspects of damage mechanisms. Besides constructive measures of rain protection, which should be of course preferred, another possibility to decrease the moisture content is the application of water-repellent agents. It must be noted in mind, however, that treating the stone with such agents always also reduces the possible drying rate. The impregnation of stone material will reduce its open porosity and in consequence increase its water vapour resistance. Additionally by this impregnation the liquid moisture transport will be stopped partially or totally, which is in fact the real and desired effect of water repellence, but this involves also the liquid transport from inside the wall to its surface. In order to quantify these effects on the moisture balance of a facade, measurements and calculations are performed on a water repellent sandstone.

2 Measurements

On walls of a building in-situ measurements of moisture profiles and its time depending changes is at present practically impossible. Therefore at the Fraunhofer Institute for Building Physics in Holzkirchen a test facility was built up, which enables to expose a wall section to natural weathering while the inner climate can be controlled in an appropriate way. The experiments were carried out on prisms of Cottaer sandstone 25 cm in length, sealed on the flanks to ensure one-dimensional conditions and having a sectional area of 5 x 5 cm^2. For the determination of the drying behaviour the prisms, which were already impregnated on the front side, are saturated from the back and subsequently installed in the west wall of the test facility. From the moment of installation the solar radiation, the outside air temperature, the relative humidity and the driving rain were measured continuously. The moisture uptake and release of the natural stone prisms under the conditions described above was recorded by regular weighing. In addition the moisture profiles in the prisms were recorded at specific intervals using a nuclear magnetic resonance equipment developed especially for this purpose [1]. The investigations were performed over a period of one year.

The measured course of the water content of one specimen, which is impregnated to a depth of about 10 mm and saturated whith water, is shown in figure 1 for the whole period of one year. Figure 2 shows the water content profiles determined at distinct points in time. The water content is decreasing continuously, since - because of the impregnated surface - no water uptake due to driving rain occurs. Nevertheless in spite of the summer conditions (April to September) it needs about 6 months to loose half of the water content. After a period of one year the water content has reached 5 % by volume, which is four times the sorption water content at 80 % R.H. The measured profiles show no markable gradients in a depth above 3 cm, which means that there exists a really effective capillary transport.

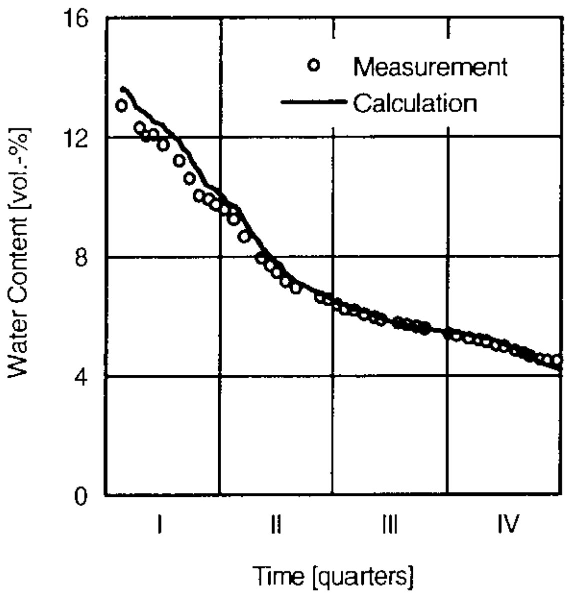

Figure 1: Measured and calculated course of the water content of a specimen made of Cottaer Sandstone exposed to natural climate over a period of one year. Before its exposition the specimen, which is treated with a water repellent agent to depth of 10 mm, was saturated with water.

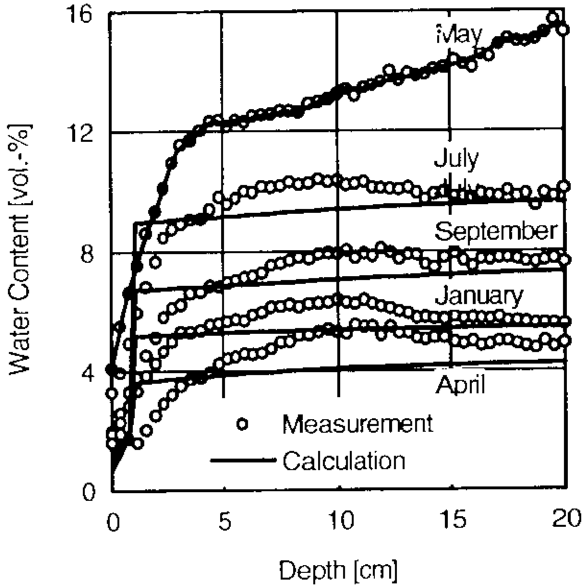

Figure 2: Measured and calculated water content profiles of the specimen at different time points.

3 Validation of the calculation

With the computer program WUFI, which is developed for the calculation of the simultaneous heat and moisture transport [2], the drying behaviour of the prism described above was simulated using the material properties determined on untreated stone material. The effect of impregnation is introduced by a capillary inactive layer with a thickness of 10 mm, which has an increased vapour resistance. The vapour resistance of this layer has been determined by iterative raising its vapour resistance number until the calculated course of the water content shows the best agreement to the measured (see picture 1, straight line). This yields to an increase of the vapour resistance number from 15 to 18,5, which means an increase of about 25 %. With this, the calculated water content profiles also show a good correspondence to the measured ones. The deviation in the first centimetres are caused by the fact, that in reality the material properties are changing continuously from the hyrophobed zone to the untreated material, which is not considered in order to simplificate the calculation.

4 Calculations

The good agreement between calculated and measured results permits the assumption, that calculations with other boundary conditions also reflects the real moisture behaviour. To show the influence of different effects resulted by the impregnation (increase of the diffusion resistance and loss of the liquid moisture transport) further calculations have been conducted. Figure 3 shows the course of the water content without any increase of the diffusion resistance due to the impregnation (doted line). The comparison to the measured course shows, that a diffusion resistance of the impregnated zone raised by "only" 25 % yields to a markable slowing down of the drying process. But the effect of the change of the liquid transport is much more striking. With an untreated wall without driving rain (which means a constructive rain protection) the drying process is accelerated extremely (straight line). In the beginning the water content decreases rapidly with the effect that after only three months one fifth of the initial water content is

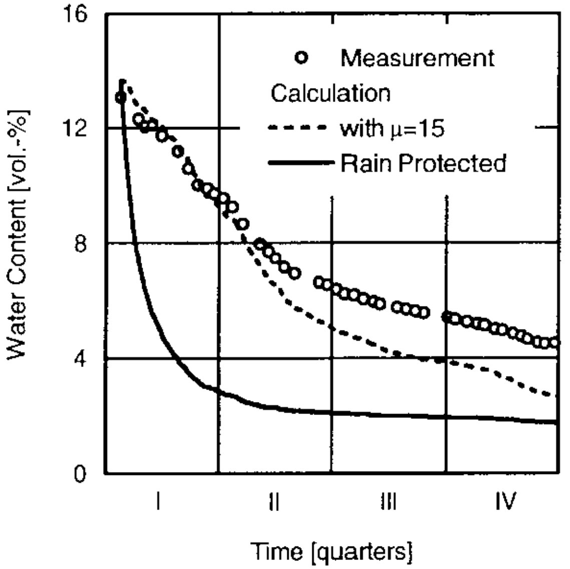

Figure 3: Comparison of the measured course of the water content with calculated courses for a hydrophobing measure without rising the vapour resistance (dotted line) and for a non-treated but rain protected facade (straight line).

reached. The further drying, which is governed by diffusion processes, is much slower.

The question, whether as commonly assumed after the application of a water repellent agent behind the hydrophobic zone an accumulation of moisture occurs due to moisture produced inside the building by the users, can also be answered with a calculation. A west-oriented wall built up with Cottaer Sandstone and with a thickness of 50 cm is chosen. The climatic data which serve as boundary conditions are derived from measured hourly Holzkirchen weather data of 1991. The year 1991 represents typical conditions for the Holzkirchen area (in front of the Alps, 680 m a.m.s.l.). The mean temperature of this year agrees with the long-term mean. According investigations from Künzel [3,4] for Holzkirchen the indoor climate can be approximated with a sinus function with a relative humidity of 50 ± 10 % for medium humidity load with its maximum on the 15th of August. The indoor temperatures varies from 20 °C with its maximum on the 3rd of June. The water repellent agent will be applied to the wall, when due to an exposition

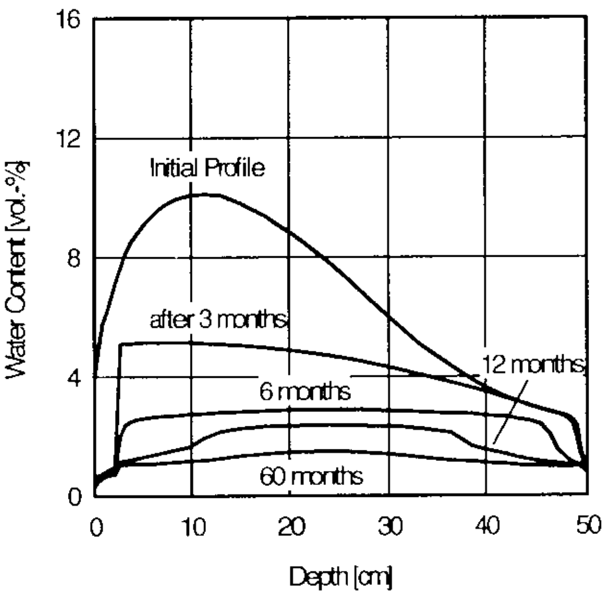

Figure 4: Calculated water content profiles of a wall made of Cottaer Sandstone at different time points after applying the water repellent agent. For this calculation a medium internal moisture load was assumed.

for several years a dynamic equilibrium state with high moisture content is reached. The moisture profile of this point of time serve as the initial moisture profile for the calculation of the moisture balance of the treated wall. Figure 4 shows the water profiles at different time points after the application of the water repellent agent. After three months the wall has lost more than one third of its initial moisture content and after 6 months two third of it. During the next four years the wall is drying to a medium water content of about 1.5 % by volume.

A second calculation has been conducted to see, whether extreme internal moisture loads may cause a moisture accumulation behind the hyrophobic zone. For this an internal climate is chosen with a variation of the relative humidity from 60 % in winter time to 80 % in summer time. With these extreme boundary conditions the wall is drying continuously too but a bit slower (see fig. 5). In winter time at the inner side of the wall a rise of the water content can be observed, which is caused by surface condensation. Even with this example no rise of the water content can be observed behind the outer surface.

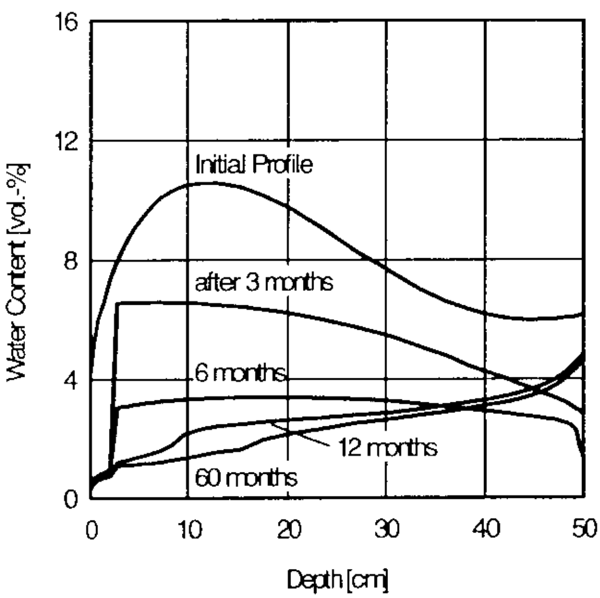

Figure 5: Calculated water content of a wall made of Cottaer Sandstone at different time points after applying the water repellent agent. For this calculation an extreme internal moisture load was assumed, which cause in winter surface condensation.

5 Practical consequences

The comparison of measured and calculated results makes obvious, that the drying rate is markably decreased by application of a water repellent agent. The calculation shows that it is an important demand on the water repellent agent to increase the vapour resistance at a maximum with 25 %. If a fast drying out of the wall is required, constructive measures for rain protection are much more effective. The calculated results also show that a water repellent surface zone does not induce the risk of water accumulation due to interior moisture load, even if they are higher than normally. But nevertheless, before the decision to use a water repellent agent it is of major importance to know all sources for the wetting of the wall. If beside the driving rain other important inputs for water exists, thus as raising damp, damaged mortar joints or defective rain water drainage, the uses of water repellent agent can in fact worsen the moisture balance of the building.

Acknowledgement

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