PERFORMANCE OF SILANE IMPREGNATION FOR EXPOSED BRICK MASONRY

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ABSTRACT

Elevated moisture due to driving rain impact on unrendered brick walls can lead to frost damage or accelerated decay of the exposed facade. Additionally, in the case of monolithic exterior walls which are often encountered in historic buildings a high water content reduces the already low thermal resistance of the wall thus leading to poor hygienic indoor conditions. Since the appearance of the facade should in general remain unaltered for aesthetically reasons, the only measure to improve the moisture protection and thermal quality of brick masonry is the impregnation with water repellent agents possibly combined with an interior insulation.

In field tests the effect of silane impregnation on the moisture behaviour of exposed brick masonry with and without cracks was examined in comparison with untreated as well as with sheltered facades. In all cases the impregnation of exposed wall elements with elevated moisture led to a drying process which resulted in low water contents, similar to the moisture conditions of sheltered facades. The drying of the impregnated wall elements with a thickness of 24 cm takes about one year. Since monolithic brick walls of historic buildings are mostly thicker, complementary heat and moisture transport calculations were carried out for representative walls. Depending on the interior finish of such brick walls the drying time after impregnation ranges from 2 ½ to almost 7 years. Thereby the thermal resistance can increase by up to 50 % so that the minimum insulation requirements for hygienic indoor conditions are generally met. Additional interior insulation should be applied only after the end of the drying process in order to avoid a slow down of the drying rate and the risk of frost damage.

1 INTRODUCTION

Single layer brick walls of old buildings often lack sufficient protection against driving rain and may thus show elevated moisture contents, especially on the weather side. This further reduces the mostly low thermal resistance of these walls which may in some cases even fall below the minimum heat insulation required for hygienic reasons. Additionally, an elevated moisture content entails the danger of frost damage close to the facade. Installing an interior heat insulation, e.g. to increase thermal comfort, aggravates this danger, since the drying-out of the wall is impeded, and its temperature reduced. Prerequisite for a better thermal quality and a better protection against moisture of these walls is therefore an increased rain protection. In the case of unrendered masonry which should retain its appearance for aesthetical reasons, the only way to improve rain protection is repointing the facade and treating it with water repellent agents.

In this paper the performance of silane impregnations examined in a field test are reported and the consequences of such a treatment for the hygrothermal behaviour of single layer brick walls are analysed by experimentally verified heat and moisture transport calculations. The drying time of a representative wall after impregnation with and without simultaneous installation of an interior insulation is investigated as well as the consequences of insulating the wall without treating the facade.

2 EXPERIMENTAL AND CALCULATIVE INVESTIGATIONS

It has been shown in [1] that a combination of field tests and heat and moisture transport calculations can enhance the interpretation and transferability of experimental results concerning the hygrothermal behaviour of building components. If the measured and calculated results for a certain construction element correspond well, it can be assumed that the dominant factors for the hygrothermal behaviour of the considered construction are correctly implemented in the calculation model. This means, however, that further conclusions can be drawn by a calculative study without additional costly and time consuming field test.

2.1 EXPERIMENTAL SET-UP

In a test hall which is conditioned during wintertime to 20 °C and 50 % r.h. masonry elements with a surface of 60x60 cm^2 and a thickness of 24 cm have been exposed with one side facing to the west resp. to the east [2]. The west facade of the hall faces a plain without any obstructions. The amount of driving rain hitting the facade varies between about 400 to 500 l/m^2 a year. The east facade is sheltered by a overhanging roof, so that hardly any rain water hits it.

The masonry in the wall elements is made of solid brick (format: 24x11,5x5 cm^3) and lime-cement mortar. The mortar gaps have a thickness of ca. 15 mm. At some elements artificial cracks were introduced with a thin wire while the mortar was still soft, which led to cracks of up to 1 mm in thickness between the mortar and the brick. After exposing the wall elements to the natural climate in Holzkirchen the water content was monitored by weighing the elements about once a month. Due to unusually dry weather in the beginning of the observation period the elements facing west were sprayed by a lawn sprinkler in the end of May 1993 in order to obtain a representative water content. Five days later half of the wall elements were treated with a silane impregnation while the other half of the elements remained untreated. The impregnation was applied twice with the aid of a paint brush making the surface soaking wet. The total amount of agent taken up by the masonry was about 0,3 kg/m^2. After the treatment the moisture behaviour of the wall elements was registered by discontinuous weighing for a period of more than one year.

2.2 HEAT AND MOISTURE TRANSPORT CALCULATIONS

The calculations are done with the PC-program WUFI, a one-dimensional version of the calculation model described in [3]. Although this model has been validated by comparison with experimental results several times a verification of the calculations for this case is necessary because the material parameters of the masonry have to be approximated from standard material properties since detailed laboratory tests are beyond the scope of the investigation. As boundary conditions for the comparison the measured meteorological data, temperature, relative humidity, driving rain and solar radiation of the test period are used in form of hourly mean values. The initial moisture taken for this calculation is the measured water content after the spray-wetting of the wall elements assuming a uniform distribution. The effect of the water repellent impregnation is simulated by a non water-absorbing surface and an additional surface diffusion resistance of 0,2 m which was measured by way of a wet-cup test.

The thickness of the examined wall elements is not representative for single layer brick walls found in old buildings which are mostly at least 40 cm thick. The same holds for the precipitation load in Holzkirchen which is classified in driving rain group III according to [4]. Unrendered brick walls cannot bear such a high load and are therefore uncommon in areas classified group III. In order to determine the effects of properly done silane impregnations on a representative exterior wall, the following calculations are carried out on a 40 cm thick unrendered brick wall with an interior plaster or interior polystyrene insulation. The outdoor boundary conditions are taken from an average year in Holzkirchen were the driving rain load has been reduced to half of the measured amount. The interior temperature and relative humidity are approximated by sine waves with mean values of 22 °C and 50 % relative humidity and amplitudes of 2 K and 10 % R.H., respectively. The maximum values are reached in July.

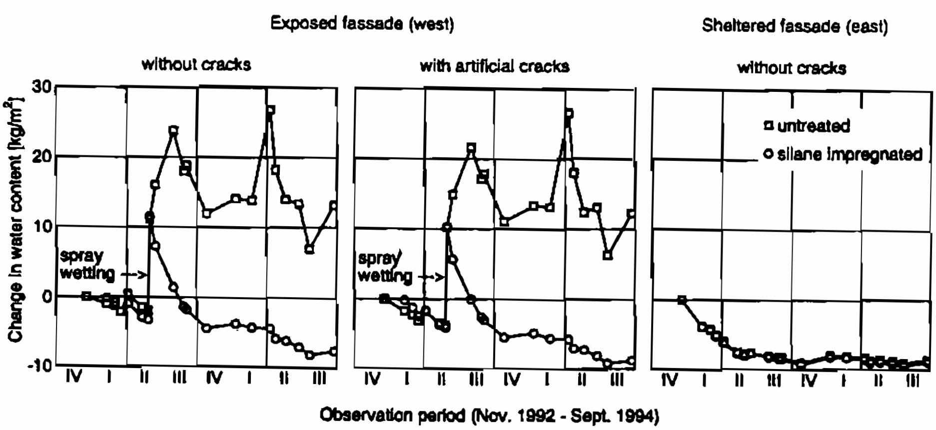
In contrast to [5] where the initial moisture profile in the wall was derived from the measured distribution in a rendered brick wall, the initial conditions here are taken to be equal to the yearly mean moisture profile over the cross-section of the considered wall which is determined by calculating over several years applying the same meteorological data until no changes from one year to another are observed anymore. From that distribution the drying-out behaviour of the wall after the impregnation resp. after impregnation and simultaneous interior insulation with expanded polystyrene slabs (50 mm thick) is calculated.

3 RESULTS

3.1 PERFORMANCE OF SILANE IMPREGNATION IN THE FIELD TEST

The course of the change in water content of the exposed wall elements during the observation period is shown in Fig. 1. Prior to the silane impregnation, which was applied beginning of June 1993 shortly after the spray wetting of the west facing elements, the moisture changes of the west facing elements are very similar. After the impregnation, however, the untreated masonry elements are becoming increasingly wet until they reach some dynamic equilibrium whereas the silane impregnated masonry elements dry out continuously. As expected the drying-out process is faster in summer than in winter. There appears to be no influence of the cracks on the moisture behaviour of the masonry since the changes in water content with and without cracks between the bricks and the mortar are almost equal for the treated resp. the untreated wall elements. The east facing sheltered wall elements show no difference in the moisture behaviour of the treated and untreated masonry. The slight increase in material moisture during winter time due to vapour diffusion from the inside and a higher relative humidity outside is equal in both cases. That means that the silane impregnation has only a minor effect on the vapour diffusion and sorption behaviour of the masonry.

FIG.1
Moisture behaviour of the exposed masonry elements over a period of almost two years.
The roman numbers indicate the quarters of a year.
The impregnation of the exterior surface of the elements was done shortly after the spray wetting.



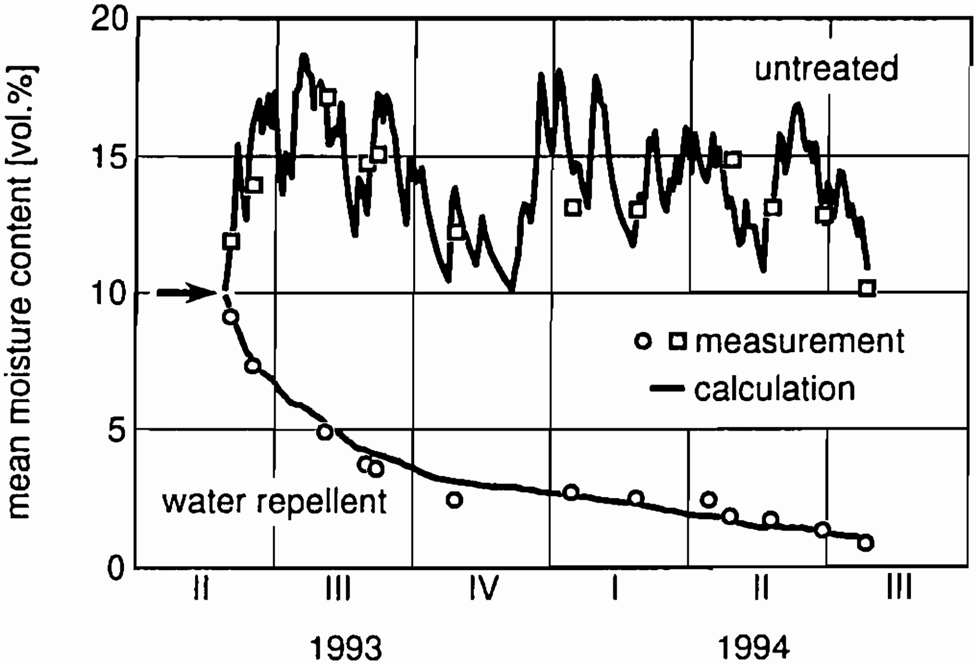
3.2 COMPARISON OF CALCULATION AND EXPERIMENT

The calculated and measured courses of the mean water content of an impregnated and an untreated west facing wall element after the artificial wetting are compared in Fig. 2. The agreement between the calculation results and the measurements is very good which means that the approximated material parameters are sufficiently accurate in order to get realistic calculation results. It also shows that rain water penetration of the impregnated facade must be very low because the measured water content hardly deviates from the calculated course where zero water absorption is assumed.

FIG.2

Comparison of the calculated and the measured variation in water content of 24 cm thick brick masonry under natural conditions.

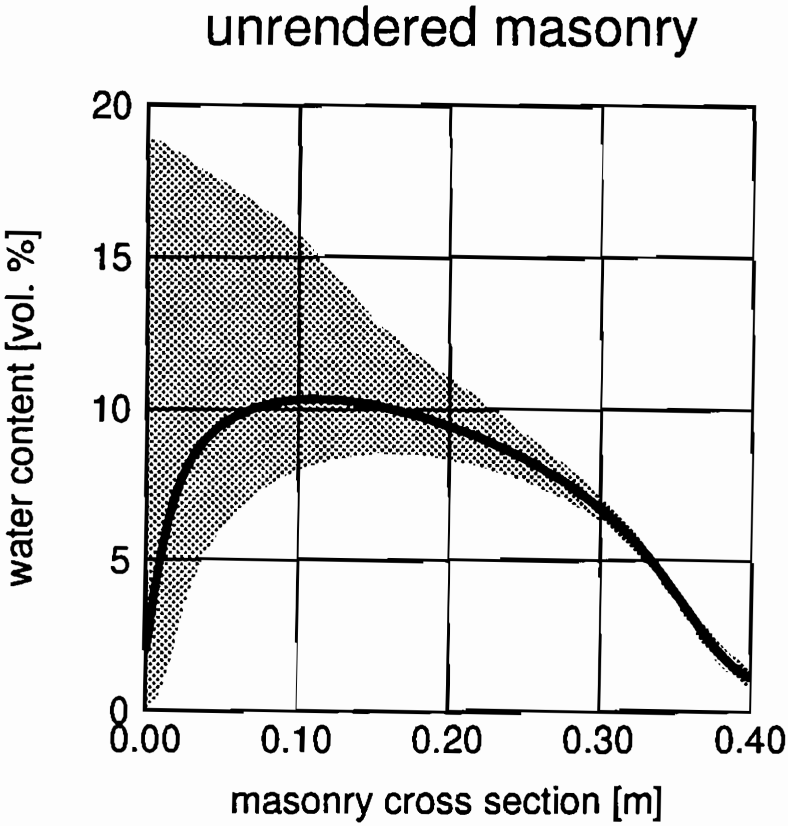
The initial water content (marked with an arrow) was reached by artificial spray wetting of the facade elements.



3.3 MOISTURE BEHAVIOUR OF A REPRESENTATIVE WALL

The annual mean moisture profile (solid line) and the annual variation range (hatched area) of a 40 cm thick untreated brick wall is shown in Fig. 3. The exterior surface shows the highest variation in water content but the annual mean water content there is rather low. Towards the interior of the wall the variations are decreasing rapidly whereas the mean water content increases steeply to a peak about 10 cm below the exterior surface before it decreases again down to the indoor sorption equilibrium. It is obvious that the average moisturé over the cross section of the wall is too high to guarantee the hygienic minimum heat insulation. Therefore an additional interior insulation would be required if the rain protection of the wall is not improved. The effect of such an insulation on the moisture situation in the masonry is shown in Fig. 4. Because the 50 cm thick polystyrene insulation slabs drastically diminish the evaporation to the inside while reducing the overall temperature of the wall in winter time the water content in the wall reaches much higher values than in the non insulated case. Since this can entail serious frost damages such a measure cannot be recommended.

FIG.3
Annual mean profile (solid line) and annual variation range (hatched area) of the water content in the masonry of an unrendered single layer brick wall.



This leaves the alternative to taçkle the improvement of the rain protection by impregnation first or at the same time as the installation of the interior insulation. Starting in October from the annual mean moisture profile in Fig. 3 the drying courses of the impregnated masonry with and without interior insulation are plotted in Fig. 5. While the uninsulated wall dries within 2 ½ years below the practical moisture content of 1,5 Vol.-% it takes almost

7 years until the insulated wall reaches this value. Apart from the lower temperature in the wall this can again be explained by the hampered evaporation to the inside which even increases the water content below the insulation by capillary redistribution as can be deduced from the moisture profiles in Fig. 6. The increase in moisture in the masonry beneath the interior insulation shortly after its installation and the subsequent slow drying could lead to hidden mould problems in this region.

FIG.4
Annual mean profile (solid line) and annual variation range (hatched area) of the water content in the masonry of an unrendered single layer brick wall with 50 mm of interior polystyrene insulation.

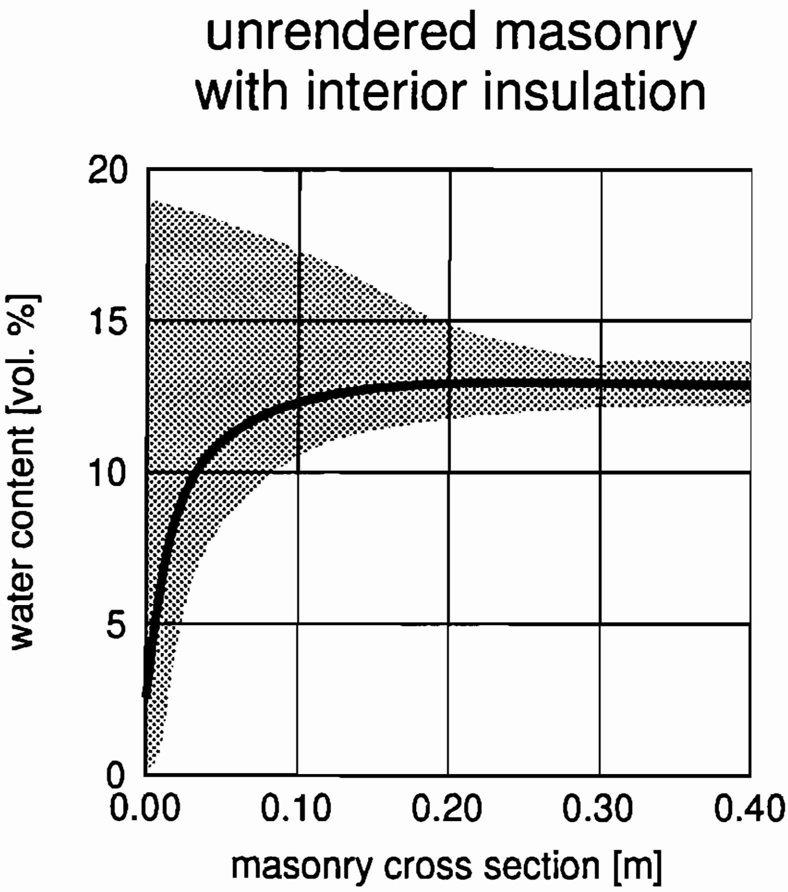


FIG.5

Course of the mean water content in the wall after application of an effective impregnation and in one case simultaneous insulation (broken line). Without insulation the practical moisture content for brick walls (1,5 Vol.-%) is reached after 2½ years. With interior insulation it takes almost 7 years.

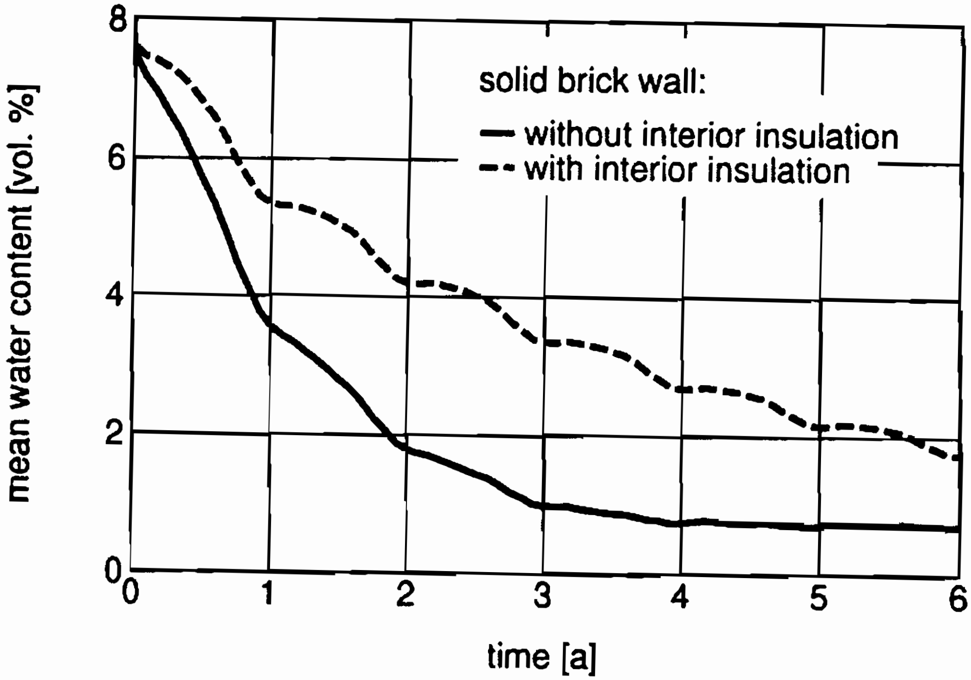
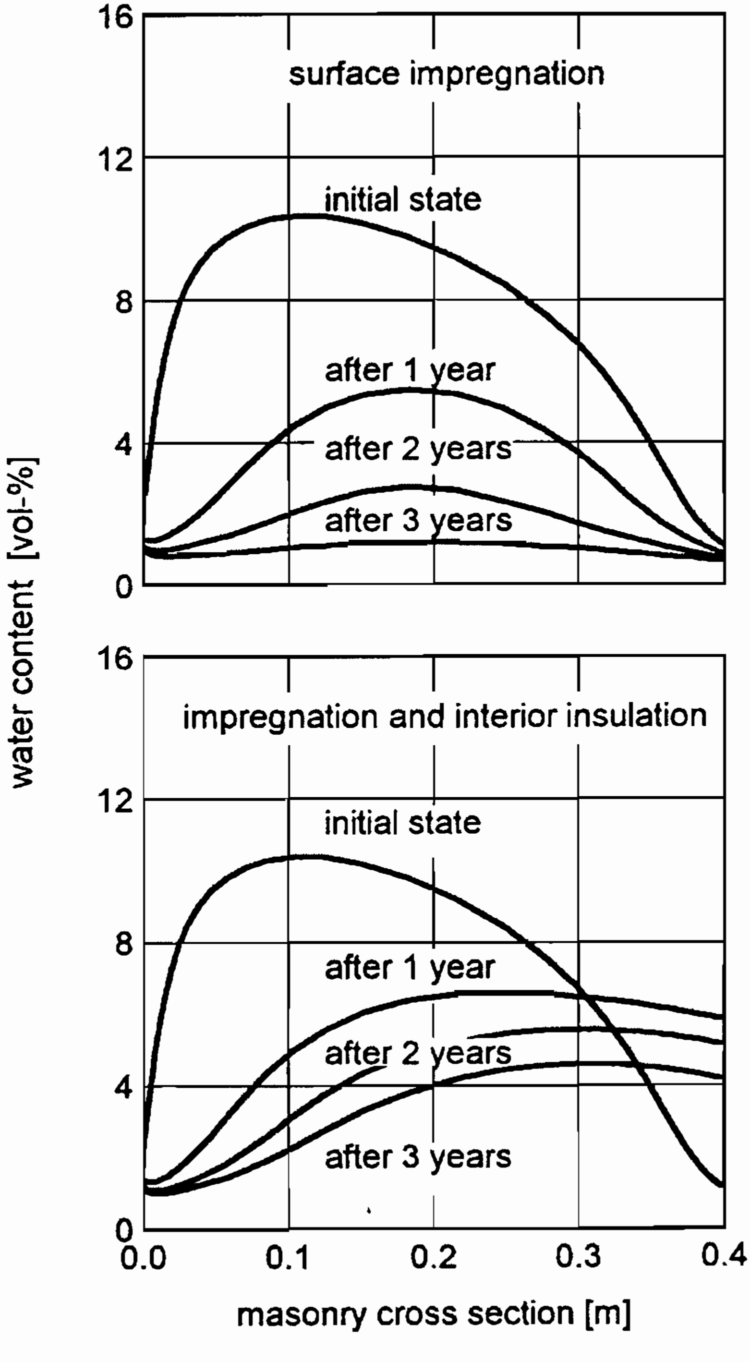


FIG.6
Moisture profiles in the masonry at the beginning and 1-3 years after facade impregnation (top) as well as simultaneous impregnation and insulation (bottom).



4 DISCUSSION OF THE RESULTS AND CONCLUSION

The field test show that silane impregnations if properly done can repel rain water to such an extent that a complete dry-out of the masonry is possible. The question is whether the experience from rather small test elements even with artificial cracks which were impregnated by experts can be translated into the application on a real building. It seams possible that an inappropriate impregnation can even increase the moisture and hence the danger of frost damages as stated in [6]. The quality of workmanship and the preparation of the facade for example by repointing it appear to be of major importance. If the quality conditions are met, the silane impregnation can be considered as an effective rain protection. Small cracks of up to 1 mm wide do not affect the rain protection if they are thoroughly impregnated under the condition that the wall is sufficiently airtight, e.g. through a plaster on the inside. A similar result for cracks up to 0,5 mm has been obtained by laboratory simulations in [7]. The drying time of the masonry even after an effective impregnation should not be underestimated. It is recommendable to install an interior insulation some time after the excessive moisture in the masonry has dried out in order to avoid a moisture accumulation beneath the insulation. Finally, it should be noted that a high accumulation of salt in the brickwork may impede its drying-out or even prevent it altogether [8]. Under these circumstances, impregnation measures may fail to have the desired effect. If the moisture in the wall is not due to rain but to rising damp, an impregnation may even worsen the situation.

5 LITERATURE

[1] Künzel, H.M. and Krus, M.: Beurteilung des Feuchteverhaltens von Natursteinfassaden durch Kombination von rechnerischen und experimentellen Untersuchungsmethoden. Bauinstandsetzen 1 (1995), H. 1, S. 5-19.

[2] Riedl, G. und Kießl, K.: Untersuchungen zum Feuchteverhalten von Ziegelmauerwerk mit unterschiedlichen Imprägnier- und Beschichtungssystemen unter natürlicher Bewitterung. Report of the Fraunhofer-Institut für Bauphysik FtB-31/1994.

[3] Künzel, H.M.: Simultaneous Heat and Moisture transport in Building Components. ISBN 3-8167-4103-7. IRB-Verlag, Stuttgart 1995.

[4] DIN 4108, Teil 3: Wärmesçhutz im Hochbau. Klimabedingter Feuchteschutz. August 1981.

[5] Künzel, H.M. and Kießl, K.: Hydrophobing historical facades for rain protection and thermal quality purposes. Proceedings of the International Symposium on Moisture Problems in Building Walls. Porto, 11.-13. Sept. 1995.

[6] Franke, L. und Bentrup, H.: Schädigung von Mauerwerksbauten durch Umwelteinflüsse; Beurteilung und Instandsetzung. Bauphysik 13 (1991), H. 5, S. 187-195.

[7] Franke, L. und Bentrup, H.: Einfluß von Rissen auf die Schlagregensicherheit von hydrophobiertem Mauerwerk und Prüfung der Hydrophobierbarkeit. Bautenschutz + Bausanierung 14 (1991), H. 6, S. 98-101 und H. 7, S. 177-121.

[8] Künzel, H.: Trocknungsblockade durch Mauerversalzung. Bautenschutz + Bausanierung 14 (1991), H. 4, S. 63-66.