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INVESTIGATIONS OF THE MOISTURE AND CONCENTRATION DEPENDING TRANSPORT OF DETERIORATING SALTS IN MASONRY MATERIALS

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Abstract

In the case of revitalisation of salt contaminated buildings the desalination by poultices is one of the most gentle and effective treatments. The salt reducing processes of this method are based on specific initiated gradients e.g. moisture or ion concentration gradients. The causes of processes used for the desalination are the same causes of processes which leads to the distribution of moisture and salt. To describe and calculate the processes as realistic as possible it is necessary to determine some characteristic complex material properties. So for this work experimental investigations had been done on the determination of a phase-change function for multi-phase system (water(liquid, vapour)-salt (liquid, solid)).

Key Words

Moisture transport, salt transport, masonry materials

1 Introduction

The climatic conditions and the moisture content of the building have a major influence on the destruction of buildings caused by deteriorating salts. The moisture controls the processes of crystallisation and solution of salts. It also provokes the solving of ions from the building material. In addition to those destructive aspects the moisture controls different kinds of the transport processes. These transport processes influenced by changing climatic and boundary conditions can lead to a further distribution of the deteriorating salts. The basic transport processes which may occur in this context are the advective moisture transport and the ion diffusion.

On the other hand these transport processes can be utilised for desalination of affected buildings. One kind of desalination is the reduction of the salt content by the application of bentonite-cellulose-sand poultices. This method is a very gentle but effective treatment and therefore chosen for these investigations. For this kind of desalination procedure it is necessary to know that there is at least a minimum moisture content needed to make the transport of salts possible. So the moisture content has a major

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influence either on the destructive or revitalising transport processes in building materials. Therefore investigations had been done into the influence of the moisture depending transport of salt ions and salt solution in porous building materials. By choosing different masonry materials and pore solutions the characteristic influence of the materials and the complex interaction became more visible.

2 Experimental investigations and Results

For this work there had been done two different kinds of laboratory investigations. The first one was a desalination by poultice application. It should show the effectiveness of desalination processes in relation to the duration of application. The second experimental investigation were made into the distinction of liquid and vapour moisture transport. The differentation of those two parts is particularly necessary for calculation and simulation of moisture transport but also for the case of salt transport.

2.1 Desalination by poultice application

The experimental conditions were chosen close to the situation in practice. The cylindrical specimen (diameter: 5 cm) were made out of fine grained sandstone (sandstone 4) with a length of 30 cm. They had been homogeneous penetrated with 0,5 M Na_2SO_4 solution. For the desalination a bentonit-celluose-sand poultice (thickness: ~2cm) had been applied Fig. 1. All surfaces except the side of the poultice had been covered.

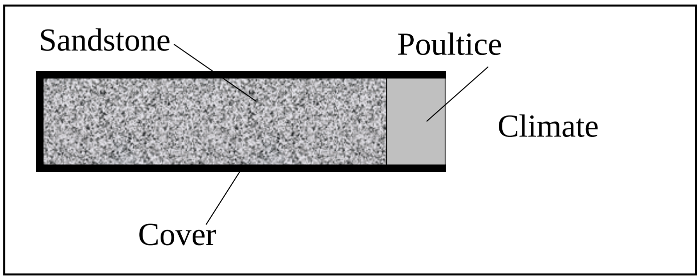

Fig 1: Experimental arrangement

This realised a one dimensional transport. The climatic conditions were chosen with 65% relative humidity and 23 °C. After different periods of desalination the content of salt and water had been determined. And therefore the concentration of the pore solution could be determined and is given in Fig. 2.

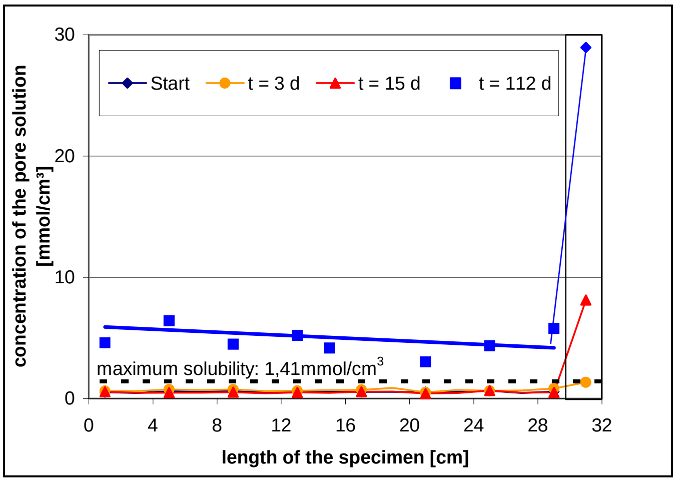

Fig. 2: Concentration of the pore solution of the sandstone 4 and the poultice

Considering Fig. 2 it is obvious that until 15 days of desalination the transport of the salt is done by advection. The concentration of the pore solution of the sandstone obviously doesn´t change. Between 15 and 112 days the concentration of the pore solution of the sandstone rises extremely. This proves the decrease of the liquid moisture transport. Fig. 3 shows the remaining moisture and salt content in the sandstone at different points of time. It can be easily seen that moisture transport still takes place whereas the salt transport significantly decreases.

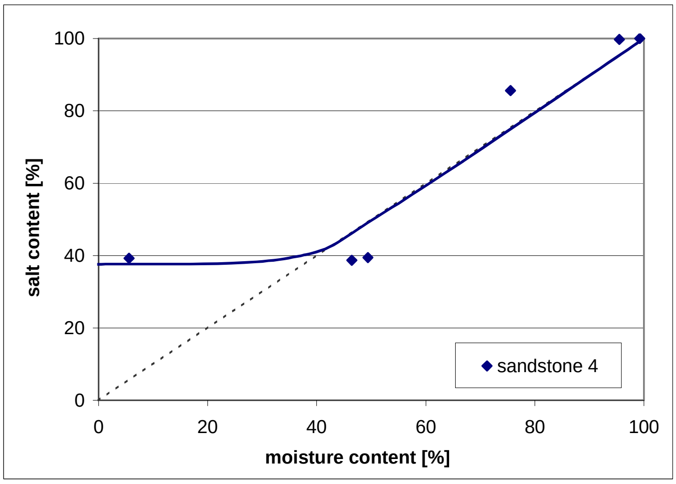

Fig. 3: Reduction of the moisture and salt content in the sandstone by desalination

Fig. 3 shows the reduction of the moisture and salt content during a desalination process. This behaviour implies the increase in vapour moisture transport beginning from a certain point of time and moisture content in the material. It shows that the material still dries out but no salts are transported anymore. For closer examinations of the vapour and liquid moisture transport and the salt transport the following experimental investigations had been realised.

2.2 Further Investigation on ion and water transport

To get more detailed information about the dominance of different transport processes being part of drying processes different drying experiments were performed. Different parameters were varied: climatic conditions (humidity), building materials, pore solution and salt solution.

2.2.1 Separation of gaseous and liquid transport of water

Those drying experiment were made with cylindrical specimen penetration either with water or salt solution. They got covered on all side besides the one front side. This front side got exposed to the climatic conditions. The transport processes were realised as one-dimensional and isotherm. The plotting of the loss of water against the square root of time is shown for Sandstone 1 in Fig 4.

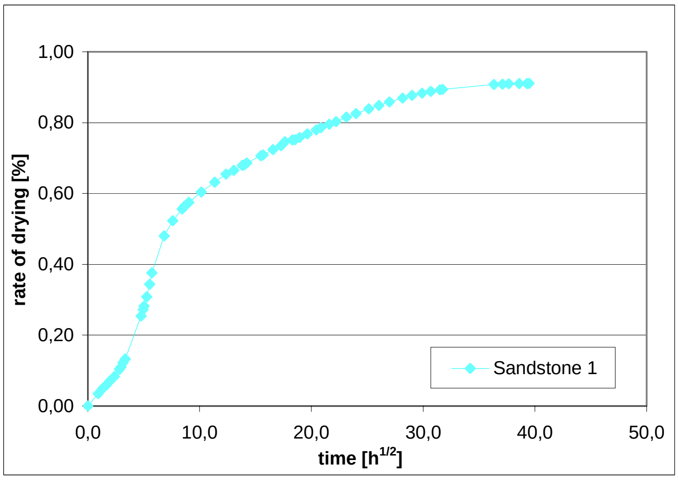

Fig. 4: Drying process of a sandstone 1

The plot shows the four different periods in drying process. All periods can be characterised approximately by a linear form with a different gradients denoting different speeds of drying. The explanation is that those periods are dominated by different transport mechanism. Period I is characterised by reaching a constant evaporation at the front side and provoking the capillary transport. Period II is dominated by the advective transport while Period III is characterised by an increase in vapour moisture transport. In period IV the moisture transport is dominated by the vapour phase. Those different periods are schematically shown in Fig. 5.

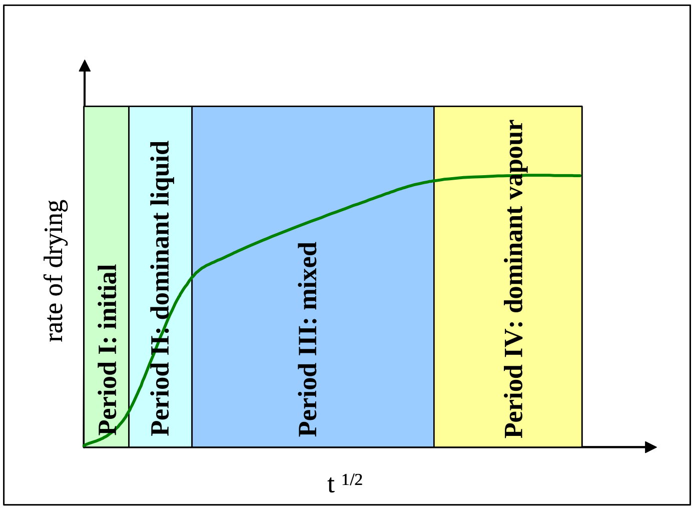

Fig. 5: Schematic form of a drying process of a building material

Between the second and the third period there is the change in the dominance of the transport of moisture by the liquid and vapour phase.
To verify this schematically form it is useful to penetrate the sandstone with a salt solution. This allows to measure the distinction between the liquid and the vapour transport. As long as the salt solution is transported as liquid phase the concentration of the solution doesn't change. By having liquid and vapour moisture transport the concentration of the solution starts to increase. Characterised by the rising of the concentration of the pore solution it is possible to determine indirectly the amount of moisture being transported by vapour. The function to distinguish between the liquid and the vapour transport for three different sandstone is plotted versus the rate of drying in Fig. 6. The sandstone specimens had been penetrated with Na_2SO_4-solution.

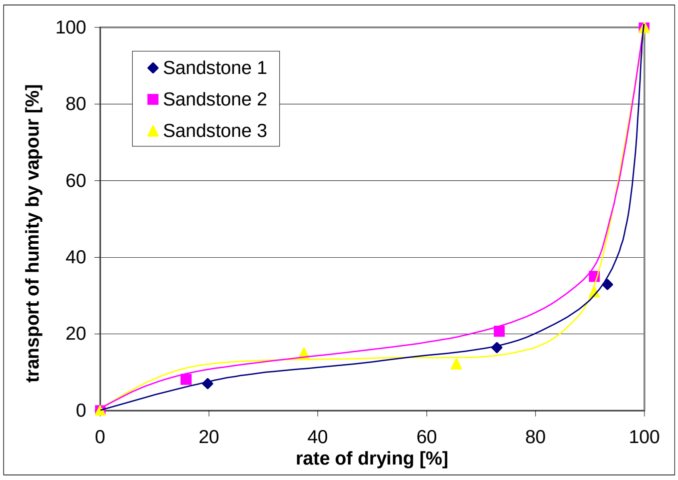

Fig. 6: Separation of vapour and liquid transport during the drying process

By using this dependency as a function it is also possible to determine the amount of crystallisation of salt during the drying process. In order to determine this function for a water penetrated material the influence of the salt can be minimised by choosing a very low concentrated salt solution. Another way is to determine this function for water from the plot in Fig. 5.

2.2.2 Influence of varying parameters on the determination of the phase-change function

To determine the influence of ions in the pore solution the same drying experiment mentioned in 2.2.1 was done. Therefore the specimen of sandstone 3 were penetrated on the one hand with water (W) and on the other hand with 0,5 M Na_2SO_4-solution (S). Another varied parameter was the relative humidity in the surrounding climate. The specimen were either exposed to a climate with 40 % or 60 % relative humidity. The temperature had been kept constant at 23 °C. The results of those experiments are shown in Fig. 7.

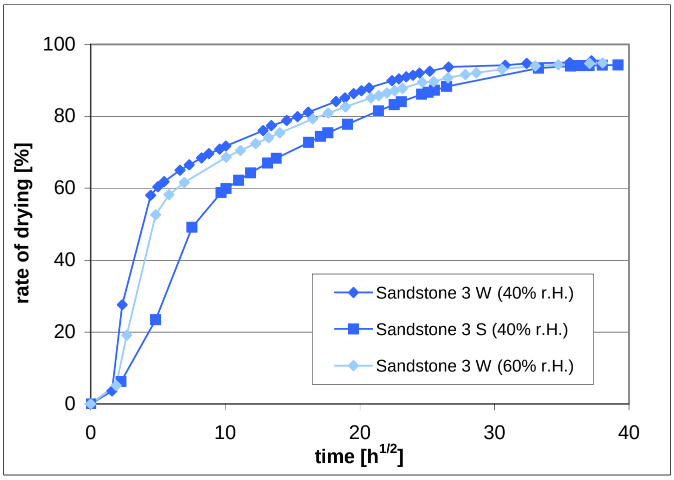

Fig. 7: Influence of salt concentration and climatic conditions on the drying process

In the first case comparing water (W) and salt solution (S) the measurement shows as one major influence that the transport in the second period slows down. The slower advective transport results from the changed characteristics of the pore solution e.g. density, viscosity and wetting angle of contact. By comparing the measurement at two different climates it shows that the two curve are almost parallel caused by a delay of drying in Period I. The drying of the specimen at higher humidity starts slower caused

of the smaller gradient of humidity between the specimen and the climatically conditions. For the following processes the change in humidity is not that significant anymore.

3 Summary

In the case of determining salt transport processes in building materials it is necessary to take different transport processes besides the advective transport into consideration. The experimental investigations of this work showed a possibility to determine a phase-change function for multi-phase systems. Throughout this presented method it is possible to distinguish between vapour and liquid moisture transport. Furthermore it allows to distinguish between dissolved and solid salt by using a pore solution with a defined start concentration.

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