X-RAY DIAGNOSIS APPLIED TO STUDY SALT MIGRATION IN IMPREGNATED STRUCTURAL ELEMENTS

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1 INTRODUCTION

Many damages on porous building materials result from increased salt contents. The decay of the material is caused by processes, like for instance solution, crystallisation and hydration, as well as hygroscopic or osmotic effects. The processes of salt action can be found at the building mostly in combination. Normally the salts are identified and quantitative analyses are done by using destroying methods [Sne83, Web85, Web88].
For assessing the possibility of applying water repellent systems it is necessary to estimate the kind and the amount of existing salts.
An exact numeric capture of the transport processes of salt solutions in porous media is difficult because of the complex relationship and interaction between the parameters. A complete control of the results is difficult, because the removal of material makes a repetition of examination results impossible.

2 EXAMINATION AIMS

The presented method is a modelling one. This method allows a two dimensional examination of salt contributions in mineral building materials. It enables one to simulate the different situations of moistening or drying at the same specimen. The examination of the concentration distributions is a quantitative one.

Several sandstone varieties were used. The specimens were treated partly with water repellent systems so that some areas were not influenced. The partial Treatment simulates faults while applying the water repellent agents or a decrease of effectiveness.

The changes in the salt concentration after moistening and drying behind the hydrophobic and the non-treated areas were of a higher interest.

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3 PRINCIPLES

A specimen with a thickness of 1 cm was subjected to an X-ray treatment. The X-ray equipment employed is normally used in the human medical practice.[2] The salt in the building material was simulated by a contrast medium. When radiation passes through the specimen, the contrast medium attenuates the X-ray more than the sandstone. An exact two-dimensional localisation of contrast medium content is possible.

Organic contrast media, used in medical practice, are not suitable because their properties are different from salts normally acting in building materials (for example solubility, crystallisation, molecular dimensions and viscosity). Iodine at the ends of the organic chains is the real contrasting element in all organic contrast media.

To connect the contrasting properties and the behaviour of salts, existing in porous building materials, inorganic iodine compounds (here sodium iodide - NaI) were used. The high solubility enables one to bring high salt amounts into the material in a short time.

FIGURE 1
Scheme of the used specimens

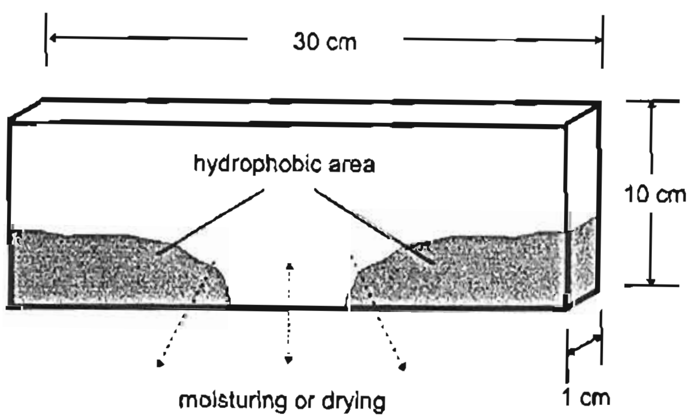

Figure 1 shows a scheme of the specimen. Areas and edges, which did not take part in the solution transport processes, were waterproofed. The specimens were treated with a solution of sodium iodide. The salt contents of the

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2 Examinations werecarried out in the Public Hospital Hamburg-Harburg, Department of clinical Radiolofy, Priv.-Doz.Dr.Groß-Fengels.

solution and the marginal settings (existing salt content, direction of salt transport, etc.) can be changed in wide areas. Comparison specimens with a known salt content were used for quantitative analysis.

4 RESULTS

4.1 X-RAY-DIAGNOSTICS

The following X-ray-figures are results of changing several marginal settings. The intensity of the lightning is a measurement of the concentration of contrasting material or of salt content at any point of the specimen.

FIGURE 2
Posta sandstone, area-salted

FIGURE 3
Posta sandstone, after watering for 30 min.

FIGURE 4
Posta sandstone after drying for 11 days at 40°C

A Posta sandstone is shown in Figure 2, where the whole specimen was treated with a solution of sodium iodide. It is visible that the salt concentration is not well distributed not even in the initial condition, which is caused by the textures or stratification natural stones often show.

This specimen was watered for 30 minutes (see Figure 3). Even though nearly the complete specimen was wet, the penetration depth of the salt solution was only among 3 and 4 cm [LHA94]. The velocity of capillary transport was higher than the solution velocity.

When drying these specimens at relative humidity of 50 %, a transportation process directed to evaporation area took place but no salt concentration was found. Probably this effect is based on the hygroscopic properties of the salt, starting below 50 % relative humidity [GOR94].

The drying velocity was increased by drying at 40°C and at a relative humidity of 10 %. The detected transport to the evaporation area is clearly visible in Figure 4. In these areas a concentration can be estimated, especially in the not treated areas in the middle of the specimen because the best conditions for evaporation are existing in these areas.

These examinations were carried out also with an Obernkirchen sandstone which has a water absorbency that is considerable less than the absorbency of the Posta variety used before. This property can be seen in the less penetration depth of the water repellent agent that is only about some millimetres. It is visible as a dark zone at the bottom of the following figures.

This specimen was treated from the backside with a solution of sodium iodide (see Figure 5). A nearly equally distributed solution was adjusted after a 7 day storage because of the hygroscopic effects already mentioned (see Figure 6).

The watering time was increased up to 90 minutes but a high penetration depth could not be reached (see Figure 8). Although the visible penetration depth of salt was about 5 mm, the real penetration depth of the solution during water absorption was about 4 cm. After one day the concentration peaks were reduced because the solution spread out in all directions. A considerable transport to the evaporation area was not found.

FIGURE 5
Obernkirchen sandstone, treated with solution from backside

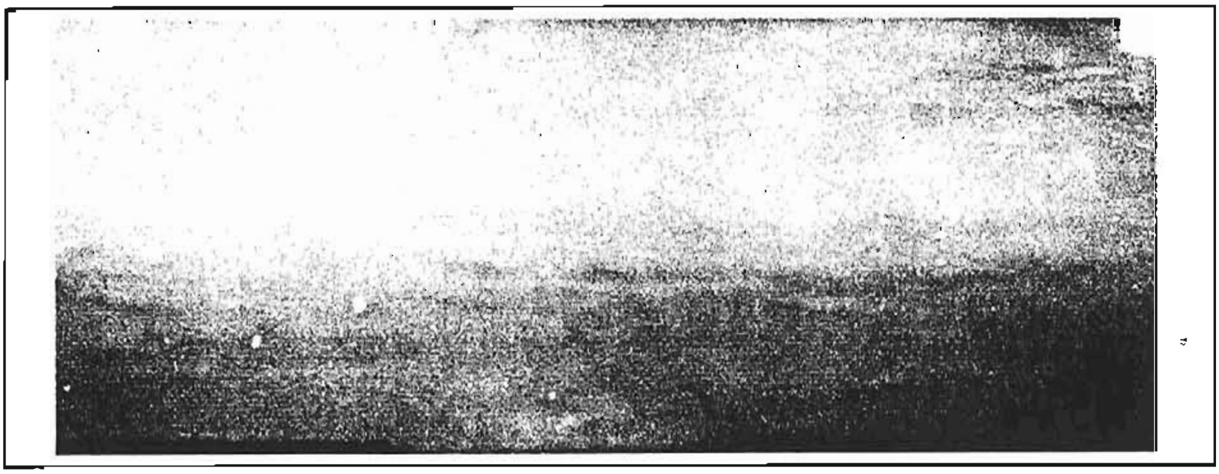


FIGURE 6
Obernkirchen sandstone, distributed solution

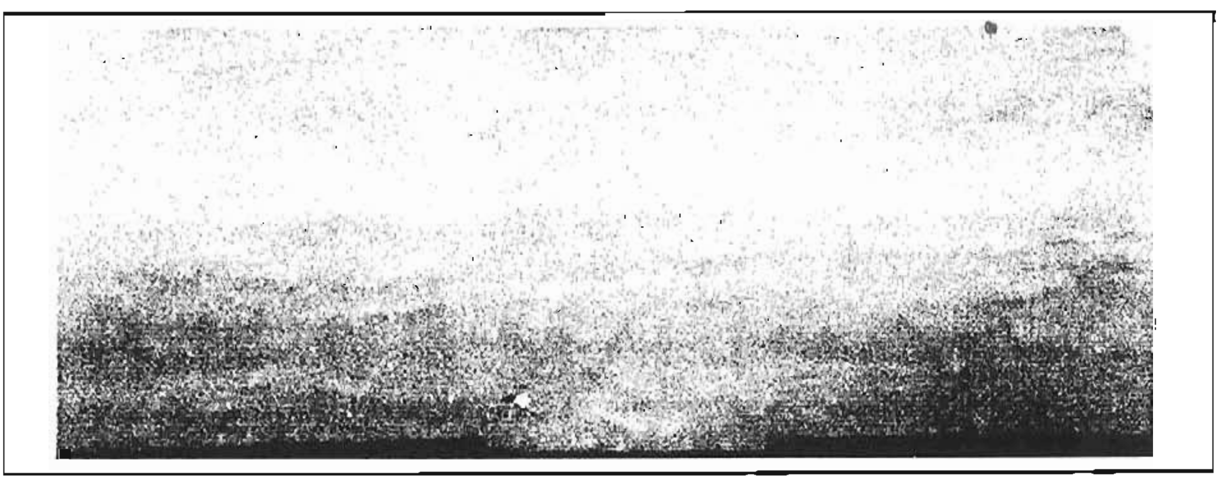
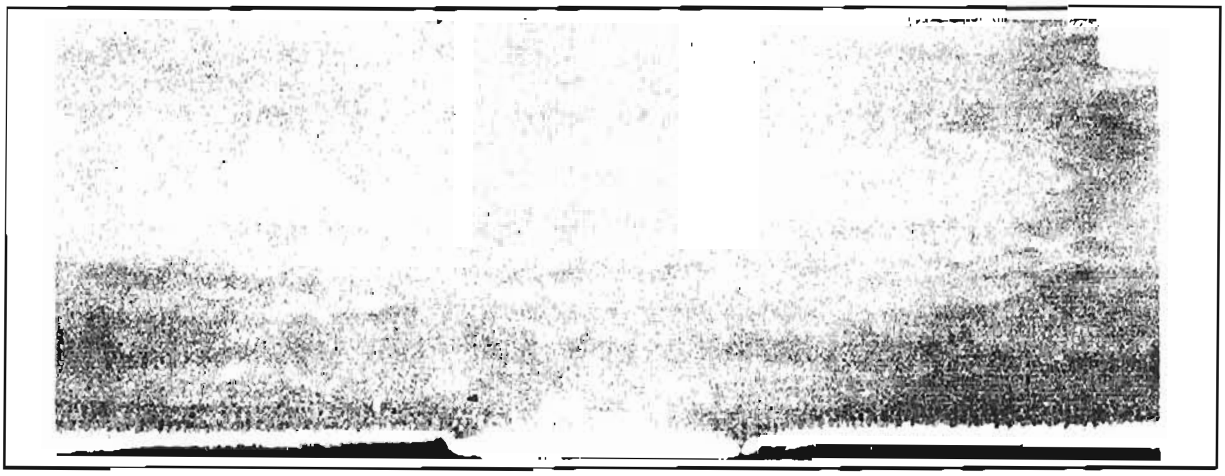


FIGURE 7
Obernkirchen sandstone after watering for 90 min.

FIGURE 8
Obernkirchen sandstone after drying at 40°C for 8 days



A visible concentration at the evaporation area took place at the non-treated area as well as behind the hydrophobic areas after drying at 40°C for 8 days. The capillary travel is interrupted in these areas and diffusive transport was determined.
It should be mentioned that the specimens which are shown in Figure 2 to Figure 4 (Posta sandstone) and Figure 5 to Figure 8 (Obernkirchen sandstone) are the same. A removal by destroying material was not necessary.

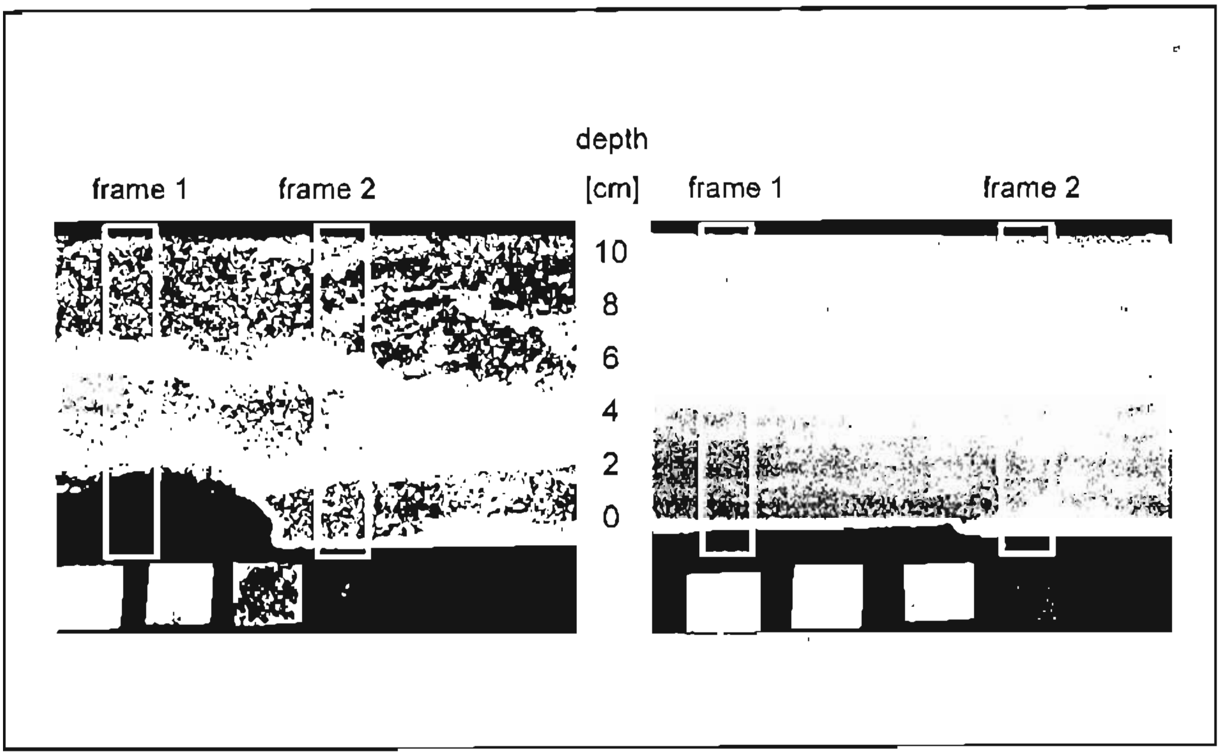
4.2 CONCENTRATION DISTRIBUTION

After proving the possibility of qualitative analyses, the quantitative distribution of sodium iodide is of great interest. The use of comparison specimens with a known salt content realised this intention. The analysis was carried out with the help of digital picture analysing systems. Examples of salt distributions after drying the specimens are given in Figure 9 and Figure 10. These figures show details of Figure 4 and 8.

The comparison specimens with known salt content are shown in the following figures at the bottom.

FIGURE 9
Posta sandstone with comparison specimen, after drying, detail

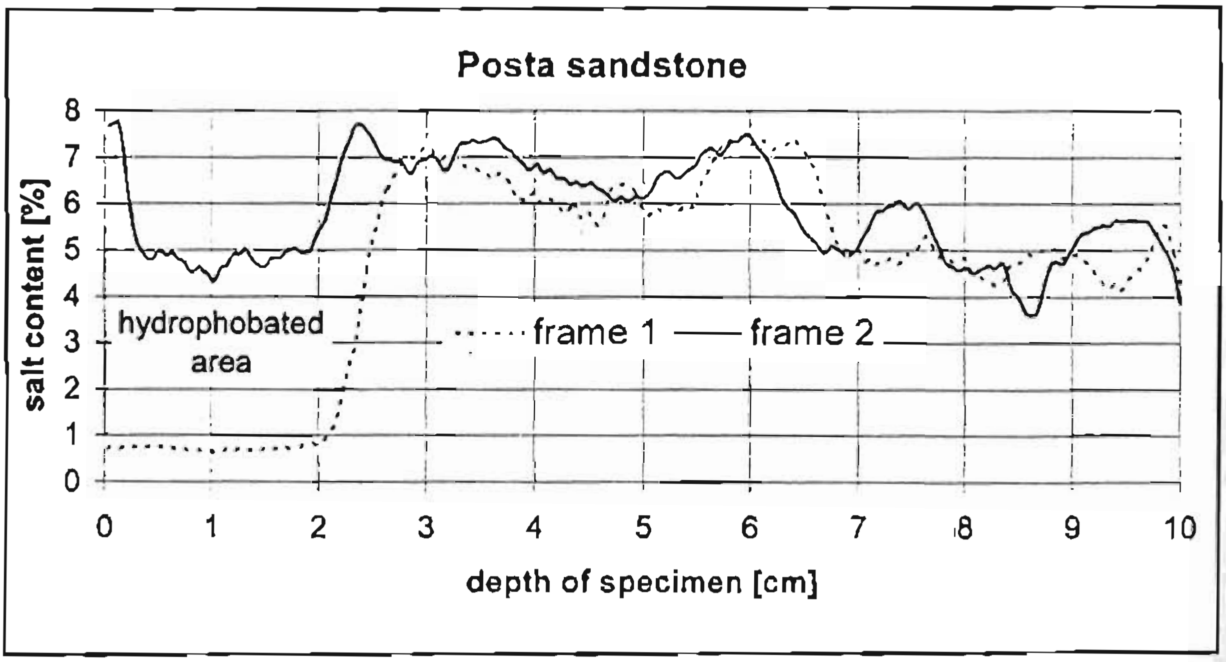
FIGURE 10
Oberkirchen sandstone with comparison specimen, after drying, detail



By analysing the grayscale, the salt concentration can be determined in every-part of the picture. This means that line profiles can be madeout as well as area profiles.

Here profiles were carried out inside the frames which are shown in Figures 9 and 10. The corresponding concentration distributions are shown in Figures 11 and 12. A profile was made out from the bottom to the top, or from outside to inside of the specimens. The dimensions were given. The average of every horizontal pixel-line was determined.

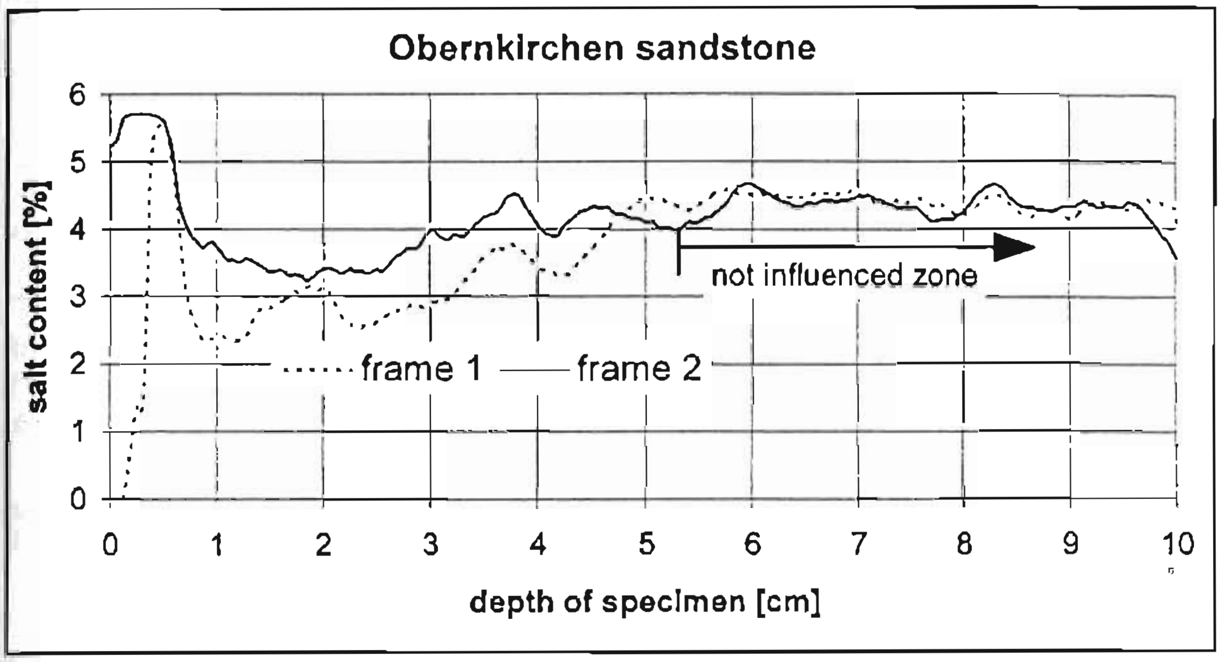
FIGURE 11
Salt distribution, posta sandstone, relating to Figure 9



In Figure 11 the area treated with water repellent agents is well to be seen. The salt content of the first 3 centimetres was transported to the evaporation area after drying the specimen. The variations of the salt content between 3 and 6 cm or between 6 and 10 cm were an effect of the texture and the stratification of this sandstone variety.

FIGURE 12

Salt distribution, Obernkirchen sandstone, relating to Figure 10



In Figure 12 a zone is visible that did not take part in the salt transport process when drying the specimen.

The differences in the concentration distribution are significant in hydrophobic and in the non-treated area. Some salt concentrations were near saturation. This was also an effect of the high salt amounts the specimens were "treated".

5 SUMMARY

A procedure was developed which allows one to model a complete two-dimensional distribution of salt in porous mineral building materials. The main advantage of the proceeding is that the salt distribution can be determined at the same specimen after some changes in marginal settings and that there is no necessity of destroying material.

It is possible to simulate several conditions. Varieties in the material, the salt content, the transport direction or the examination of constructive features can be determined. It is even possible to determine the salt distribution after several processes of moistening or watering and drying without destroying the specimen.

It should be pointed out that this procedure is a modelling one for understanding events and effects of salt transport and salt deterioration at buildings. During this research project it is strived for a transfer on real conditions at buildings.

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