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Hydrophobicity – One Target, Several Possibilities

G. Hilbert[1], H.-H. Neumann[2] and E. Wendler[3]
[1]Remmers Fachplanung, Löningen, Germany
[2]Remmers Fachplanung, Löningen, Germany
[3]Munich Conservation Laboratories, Germany

Abstract

Realisation of hydrophobicity – in the field of cultural heritage often a very emotionally held discussion. A bulletin is given on this topic based on a WTA work group under the leadership of Dr. E. Wendler. This bulletin opens the possibility to discuss the subject more rationally in the future.

Beside the primary question “hydrophobicity yes or no”, the state of technology allows multiple possibilities. From impregnation to different forms of a hydrophobic slurry, these possibilities not only differ in their technological characteristics but also in their rating in regard to the Venice Charter – the degree of reversibility of these possibilities is the catchword.

The basis of all discussions must be the characteristics of the individual object. With this paper in the form of case studies, four objects will be presented. In all four cases concerning the substrates limestone, sandstone, brick and historical concrete, the question of hydrophobization was discussed – the answer and the realised concept differ from object to object.

Keywords: hydrophobicity, limestone, brick, sandstone, historical concrete

1 Introduction

"Water is the source of all problems." This opinion was widely held, especially during the 70s and 80s of the last century, in research on the causes of damage through weathering in the field of monument preservation. The result of these often simplistic statements was that the substrate of many objects was treated with a hydrophobizing impregnation agent as the final "crowning" restoration measure. The consequence: Over the course of time, damage was observed on some but not all of the objects treated in this manner (see Figure 1).

Figure 1: Left: A crucifix made of Baumberg sandstone (Münster, Germany). Right: Spalling caused by the impregnation agent that was applied (detail in the illustration on the right)

As a result of the damage observed on several objects, the general endorsement of hydrophobicity made an about-turn to general rejection of this type of measure during the following decades. The Charta of Venice was often cited as an argument against executing water repelling measures. While intensive water repelling measures were carried out in the past on objects when this would not have been necessary, today you see that necessary hydrophobization measures are not carried out on specific objects for purely emotional reasons. Consciously or often unconsciously, it is accepted that a measure can never be perfectly executed and therefore cultural heritage is damaged beyond repair.

Then as well as now, it can also be observed that the destruction of cultural heritage is often provoked by the short-term, profit-oriented sale of protective agents.

This situation can only change by objectively deciding the question of hydrophobicity on the basis of scientific, technical criteria for more and more objects.

As far as possible solutions are concerned, classic hydrophobizing impregnation is not the only answer. As an alternative, a coating can also be applied to reach the goal of preservation. Examples of this in the task field of preserving natural stone are given in [1].

2 WTA code of practice "Hydrophobizing Impregnation of Mineral Building Materials"

The goal of this Code of Practice [2] is to at least considerably minimise the high degree of emotionality when making decisions regarding the subject of "creating water repellency". Work with the Code of Practice in the form of a complex question /answer catalogue leads to a decision based on today's state of knowledge for or against a hydrophobizing impregnation. As an example, sections from the sequential question catalogue are shown in Figure 2.

No.	Question	Yes	No
1	Is the material **highly absorbent** ($w > 5$ kg/m² $h^{0.5}$)?	**7**	**6**
2	Does the material have **low absorbency** ($w < 0.5$ kg/m² $h^{0.5}$)?	**32**	**10**
3	Is the absorbency on the surface clearly less than in deeper zones (compare characteristic values of the material)	**3**	**5**
4	Are there any indications of earlier surface treatments (impregnations, coatings, painting worth preserving)?	**34**	**4**
5	Can the absorbency of the surface be increased by preliminary measures (e.g. cleaning)?	**5**	**34**
7	Is there a risk of **condensation** in interior areas?		
8	Are there any **adjacent materials** on the inside of the room that are **at risk** if there is **moisture** (furnishings, mural paintings, etc.)?	**20**	**9**
9	Are there any **lateral adjacent materials** that are **at risk** if there is **moisture**?	**34**	**10**

Figure 2 a: Examples from the question catalogue based on the WTA Code of Practice

	SOLUTION		
30	A hydrophobizing impregnation makes sense		
31	A hydrophobizing impregnation should never be carried out!!		
32	A hydrophobizing impregnation is not necessary.		
33	A hydrophobizing impregnation will not offer permanent protection against re-infestation with microbes		
34	Further detailed examinations are necessary. If necessary, an expert should be called in		

Figure 2 b: Possible solutions resulting from use of the question catalogue

The question catalogue does not include the alternative possibility for water repellency by applying a water repelling coating. This possibility will be dealt with on a corresponding object example.

3 Examples of objects

3.1 Limestone – Mohammed Mosque / Baku-Azerbaijan

Located in the centre of the million inhabitant city Baku is the core of the old city which is on the UNESCO Cultural Heritage list. Most of the facades in this part of the city from the Middle Ages, also called "Icheri Sheher", are made of Tertiärien limestone which is characterised by extremely coarse pores (see Figure 3).

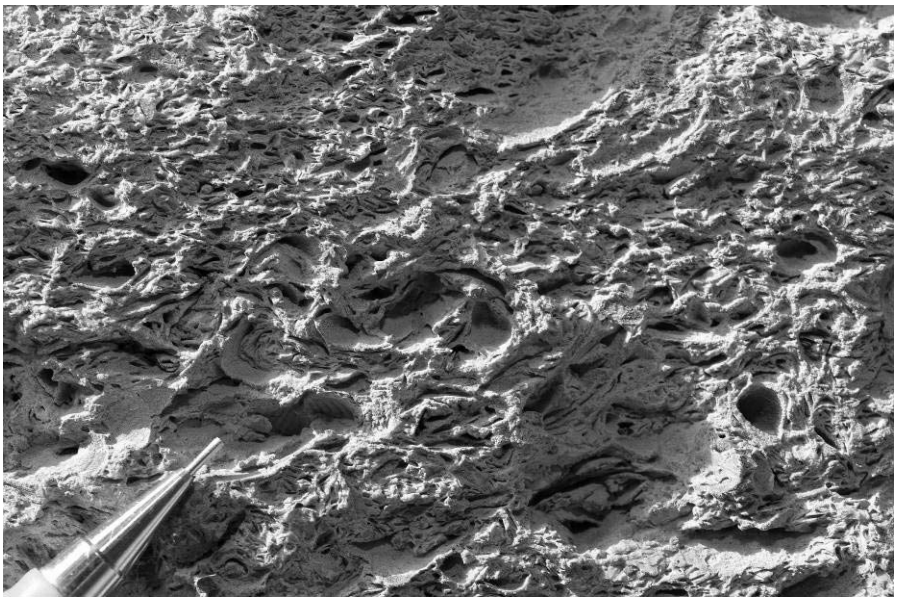

Figure 3: The coarse porosity characteristics of the Azerbaijan limestone with its funnel-shaped pore entrance radii is documented on a millimetre scale

Along with extremely coarse porosity of the substrate, which cannot be bridged by a hydrophobizing impregnation, clearly noticeable, harmful salt loads from the nearby Caspian Sea and the nesting habits of thousands of pigeons decisively speak against a hydrophobizing measure. However, the main argument against this lies at a different level: Along with a significant degree of wind erosion as the cause of the damage on the facade (Baku = the city of winds), there are structural defects that lead to strong local action of water. This cannot be remedied by applying an impregnation agent. Just the opposite, water repelling treatment without a solution for the structural problems would only cause damage in the future.

Bottom line: In the case of the Mohammed Mosque shown in the restored state in Figure 4, there were a number of reasons that spoke against water repelling treatment of the substrate in general and in particular against the application of a hydrophobizing impregnation agent.

Figure 4: A balustrade area of the Mohammed Mosque which had been strengthened in a very complicated, negative pressure procedure

3.2 Sandstone – The Great Colonade / Potsdam

The starting point of considerations concerning moisture protection for a sandstone surface was planning the work for dealing with a sandstone surface that was clearly in the process of converting to gypsum. From a macroscopic as well as a microscopic view (Figure 5), you can see that some areas of the surface have become extremely "vitrified" by the gypsum and thus completely densified. In between are island-like areas with highly absorbent sandstone which form a secondary surface.

The dynamic damage process that is in progress today is at least partly due to heavy moisture behind the crust of gypsum.

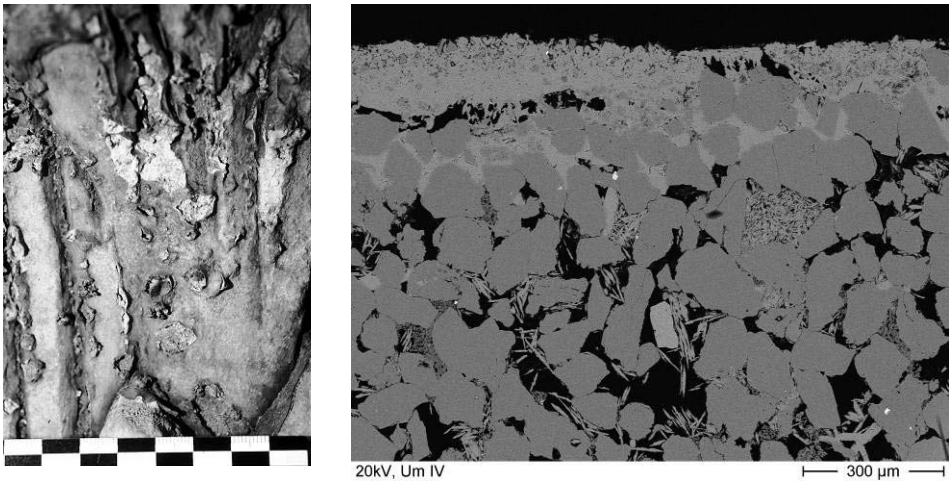

Figure 5: Left: Pustule-like spalling on the historic, limestone decorated with coloured paint which has completely converted to gypsum. Right: The secondary electron photograph taken by the scanning electron microscope documents the gypsum crust that lies on the inside as well as the outside, covering the remaining pore spaces. (Source of photograph: MPA Bremen, SCHLÜTTER)

The original goal was to loosen the detected gypsum crust sufficiently so that the absorption capacity of the two different surface areas described would be at least somewhat more similar. This goal could not be reached without destroying the original surface (coloured paint decoration, marks from working) – the crust of gypsum was too closely interlocked with the remaining structure.

So the only way to coordinate the two strongly differing absorption capacities so that they are more similar is to create a water repelling effect everywhere. Since experience has shown that the substrate (Cotta sandstone from the surrounding of Dresden) will react to a hydrophobizing impregnation by increasing the degree of hygroscopic swelling, the application of a water repelling coating was the only solution in this case. If required, this measure can be executed so that it imitates the natural stone –e.g. as executed around 10 years ago on the Constance Minster/Lake Constance on the top of the spire.

Bottom line: To reduce the speed of the weathering process now in progress, creating water repellency is indispensable. However, the specific conditions of this object do not allow the application of a hydrophobizing impregnation agent. With this in mind, the application of a hydrophobic coating that is reversible is the best solution for the problem. This can be executing in various forms that differ in appearance.

3.3 Clinker – School building / Hamburg

The historically protected facade shown in Figure 6 is made of a hard, not very absorbent clinker brick. At the time an inquiry was received concerning a hydrophobizing impregnation, the facade had just been restored by replacing the pointing.

Figure 6: Typical architecture of buildings made of peat moss fired clinker in the Hamburg area. The practically non-absorbent, very hard clinker is typical

To be able to make further definitive statements concerning the object, the following was carried out:

a. Trial surfaces using different hydrophobizing impregnation agents were set up.

b. After the agents had reacted, the effect of the hydrophobizing impregnation agents were examined on the trial surfaces, using a test tube developed by Karsten for evaluation.

The results the examinations and the following report given to the owner of the building was surprising to many of those involved – an impregnation agent was not the solution for the problem shown in Figure 7.

Figure 7: Damage caused by moisture in an interior area of the school building shown in Ill. 6 – the extent of the damage indicates the magnitude of the quantity of moisture penetrating into the building

Further examinations showed that the damage was caused by faulty execution of the new pointing that had recently been carried out. Viewed under a microscope, lateral detachment was observed in many places, taking the form of sheet-like capillaries between the clinker and joint mortar. Their dimensions were so large – similar to the Azerbaijan limestone – that a hydrophobizing impregnation could not remedy the problem. Similar to the case in Baku, the execution of hydrophobizing measures on the object in Hamburg would only cause damage in the future.

Bottom line: The entrance of moisture into the facade was caused by problems with the mortar used for pointing. The solution for this problem is not "invisible", i.e. in the form of a hydrophobizing impregnation – in fact, hydrophobizing impregnation of the facade is definitely not advisable. The application of a water repelling and crack filling slurry is out of the question for monument preservation reasons. Therefore, the only solution is to renew the pointing in the joints or to buffer the moisture on the inside. For political reasons, the latter solution was selected for solving the problem.

3.4 Historical Concrete–Viewing Tower Rotehornpark / Magdeburg

It is a well-known fact that buildings made of concrete often have problems with corroding reinforcement steel. As a rule, this destruction mechanism can be halted by applying a coating or an impregnation agent to achieve a hydrophobic effect. The impregnation agents applied are usually monomer silane compounds, the molecular design of which is coordinated to the requirements of a dense concrete matrix.

With historical concrete, the situation is often different. In the field of preserving concrete, extremely open-pored structures are found since the structure or water-cement value was often not optimised. An example of this is the viewing tower in Rotehornpark / Magdeburg (see Figure 8).

Figure 8: Arial view of the viewing tower in Rotehornpark / Magdeburg

Built in the years 1926/27 according to plans drafted by Albin Müller for a theatre exhibition, the building material technology on which the structure is based is unique. One of the first concrete frame structures built in Germany, the structure is infilled with "Ambiwinkel" concrete blocks.

"Ambiwinkel" concrete blocks are hand-formed, L-shaped blocks that were made at the building site, using Portland cement as a binder. They were built into the facade in twos, standing opposite each other so that there is a cavity in the middle of the two stones which was then also filled at the building site with a binder/aggregate mix. Steel reinforcement was laid into the cavity filling to increase the structural stability of the construction. A cut cross-section of this construction is shown in Figure 9.

Figure 9: Structural detail of the "Ambiwinkel" block construction

As far as the building material is concerned, the most important technical characteristics of this construction are:

- The "Ambiwinkel" concrete blocks as well as their filling are extremely coarse pored and their structure cannot be compared to "normal" concrete.
- In spite of large pores, the building material is highly absorbent overall which led to the penetration of moisture into the interior of the viewing tower, particularly on the weather side.
- The unit of the building material shown here is completely carbonated – the embedded steel no longer has any protection against corrosion through a high pH value.

Because of these characteristics, the only way to preserve this unique monument is to execute water repelling treatment that is as permanent as possible. Impregnation alone is not sufficient for the structure of this building material – the voids to be bridged are too large for the sole use of a hydrophobizing impregnation agent. For this reason, a concept was implemented, the functionality of which is based on the combined effect of an impregnation agent (deep protection) and a water repelling grout in the form of a silicone resin paint system. The grout was formulated so that it had a translucent effect which gave the coating an optical effect of depth.

In this conjunction, another subject that is of overriding importance as well as object-specific must be dealt with separately. And that is the necessity of maintaining the surfaces of the facades of these objects which have been treated with hydrophobizing agents. In the case of the viewing tower, cracks were observed on the west side of the structure subjected to wind after approx. 4 years. This damage was due to the construction of the tower, not the concept carried out or the materials used. When the object was turned over to its owner after the works had been concluded, he was given a concept for maintenance and had known from the beginning that maintenance work would have to be carried out. Such maintenance work is necessary for all facades that have been hydrophobically treated. The scope and intervals of the measures may differ, depending on the object, but their **absolute necessity** is applicable in general for all of them.

If this is not taken seriously, the probability is high that damage will occur over the medium term. As a rule, the damage is caused by the penetration of water behind the hydrophobized surface because of areas not completely covered by the hydrophobizing system – one of the reasons why hydrophobizing measures have been rejected in general.

Bottom line: The viewing tower in Magdeburg is one example of a monument that could not be preserved without hydrophobizing treatment. Even with the most critical discussion, no other approach will lead to a concept for a permanent solution. The combined use of an impregnation agent and a water repelling grout makes sense for the conditions of this particular object. But the measure will only be effective over the long-term if regular maintenance is carried out – in this case by continuously closing the cracks that form in the west facade caused by the construction.

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