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New Experiences with Tuffaceous Material Treated with Hydrophobic Agents - Consequences of Water Repellent Impregnation for the Surface of Natural Stone

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Abstract

The natural stone of the monastic church St. Vitus in Moenchengladbach was built of different volcanic stone types. The so called Roemer Tuff and basalt are the oldest of them, other tuff stones, such as Weiberner Tuff and Ettringer Tuff were used for restorations after World War II. In the 70‘s, apart from other renovation measures, the facade was treated with a water repellent agent. Since 1995 different examinations of the building took place and proved that for a substantial part of the building the water repellent treatment is still functioning. Water absorption is still very low, about $w < 0.1[kgm^{-2} \cdot h^{-0,5}]$. In different parts of the building—not in contact with the ground—the stone was completely wet. Salt efflorescences can be seen behind the scales. Different sulphates are present showing a distinct concentration gradient from surface to the inner parts of the stone: The concentration increases up to ~10 mm behind the surface, then gradually reduces to average values of a „normal“ tuff. The forming of scales, the distribution of salt and moisture in the stone are typical for a building material with very good water repellent properties, which is strongly wetted through by water penetrating in joints, fissures and defective mouldings.

1 Historical review

The monastery of St. Vitus in the city of Moenchengladbach was founded in the late 10th century. The church was built in different phases, beginning in the 11th century. The western part of the church was erected in the years between 1180 and 1183.

The main material for the masonry and the surface is the tuff from the Eifel region in western Germany - a stone with a very high porosity and water absorption capacity. After important damage during World War II the last phases of the restoration and a final silicone treatment was completed in the 70‘s . (The exact type of the silicone used is not known).

Different new damage, seen in the early 90‘s, called for another renovation campaign. During the pre-examinations, in 1995, the correlation between great part of the damage and the 30-year old treatment became evident.

2 Measurements and Analysis

Water absorption was measured directly on the facade using the method of KARSTEN pipe. About 45 different examinations were carried out on the various types of stone and surface varieties.

The water absorption coefficient calculated from the KARSTEN pipe measurements was confirmed by numerous measurements carried out in the laboratory (according to DIN 52617).

With the aid of a drilling machine a large amount of powder samples were obtained. The samples were collected at increasing depth in 5-mm depth intervals from the surface, so that it was possible to assess changes in concentration of water soluble components in the material. The analysis were carried out after elution in aqua dest., according to the Deutsche Einheitsverfahren using Ion Chromatography.

Examples for the various data obtained from these analysis are shown in diagrams 1 to 3, for water absorption, and in diagrams 4 and 5, for the distribution of water soluble materials in the interior of the stones.

3 Results of the Measurements

3.1 Water absorption coefficient

In most parts of the intact stone surfaces the water absorption coefficient is very low, the surface is strongly water repellent. We found water absorption coefficients of w = 0.11 to 0.51 [$kgm^{-2} \cdot h^{-0,5}$].

Other specimens and KARSTEN pipes gave results of e. g. w = 1.11 – 3.23 [$kgm^{-2} \cdot h^{-0,5}$] which is still very low for a Eifel Tuff, in this case the so called „Roemer Tuff“ since the porosity of this variety is known to be 35 – 45 Vol.-%!

Where surface scales had already detached from the stone, the „normal“ water absorption capacity was found: w = 31.86 – 65.39 [$kgm^{-2}\cdot h^{-0,5}$].

3.2 Moisture Content

Different stones looked quite „wet“, once the surface scales were removed. This was the reason for controlling the content of water in the material. According to the „Darr – Method“, the moisture content (% w/w) and the grade of pore-filling with water (%) in correlation to the porosity was determined.

Directly around the portal and below a moulding, a moisture content of 21.7 to 23.49 % w/w was found, representing a grade of moisturing of 75 to 83 %, i. e. the stone was almost completely wet! These results were found in zones of the facade where a large number of scales also occured.

In all the other parts of this western facade, the moisture content behind the surface was quite high, compared with results from other buildings, showing „only“ values of approximately 5.00 – 7.95 % w/w.

3.3 Concentration of soluble salts

At each of five different locations, six samples were taken at different depths from the surface. The diagrams 1 and 2 show the distribution in sample 10 and 1, respectively. In diagram 3 the average of the analysis of all different samples are shown.

Only sulphate is concentrated in remarkable amounts. Others ions, such as chloride and nitrate, are only found in very low concentrations. The important fact is the distribution of soluble components found in every sample: behind the surface, according to the thickness of the scales, the concentration of salts grows to a maximum at 10 to 15 mm in depth. Then the concentration decreases to an average content of 0.10 – 0.20 %.

4 Results and Conclusions

- In this case the mouldings and the contact between roof and wall were not sufficiently isolated. The joints, filled with a very hard cement mortar, had a lot of fissures and cracks, in other cases the joints were completely open because the mortar had fallen out. This made it possible that liquid water could penetrate – the consequence was a strongly wet material in the zones of entering water.
- The evaporation of water is strongly reduced for the impregnated stones. This results in a high moisture content and the water dissolves particles from the stone and mortar.

- The author is often involved in discussions with people who still are convinced that hydrophobization of surfaces are a guarantee for a „dry wall“! The results show however, that even with only few possibilities for liquid water entering into a porous material, just the opposite is correct. As evaporation is diminished, water penetrates the building material and cannot leave. The consequences are scales on the surface and deterioration up to a depth of 2.5 to 3.5 cm in the case of tuffaceous stones.
- One of the most important roles in this mechanism is the presence of water soluble salts, such as sulphate, chloride and nitrate. They are enriched behind the surface, e.g. behind the water repellent zone and induce scale formation.
- Thus the hydrophobization of buildings constructed with very porous materials is the main reason for the destruction of historical surfaces.
- In spite of assertions to the contrary, a „soft“ transition from the hydrophobized to the „normal“ zone does not exist in these very porous tuffaceous stones. A distinct border line exists with very different physical properties on either side, as shown by the figures and the salt distribution.
- The physical properties of the still attached surface scales which are water repellent have grave consequences for future restorations. The adhesion of water based mortar, e.g. for closing the joints, is strongly reduced and will require the use of mortars with polymer additives. There is no possibility to stop the detachment of scales. Although the church is an important historical monument, a great part of its historical stone surface will be lost.
- In general, it can be said that a water repellent treatment of a facade (or a part of it) may be the right way for a long lasting protection. However, this requires that absolutely no water can penetrate behind the surface by any other way. If this is cannot be ensured for a long time, it is better to leave the building without any water repellent treatment. Once treated, the hydrophobic properties will last for many decades and there is no way to undo this.