Desalination of the painted vault ribs of the Franciscan monastery church of Zeitz

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Abstract

The former Franciscan monastery church was mentioned for the first time in 1266 and is located on the periphery of the old town of Zeitz, Saxony-Anhalt, Germany. After several decades of neglect, the building was in the acute danger of collapse. In the 1990s parts of the roof collapsed and the groin vaults of the church were exposed to bad weather conditions.

Along with the structural problems, the structurally damaging salts, principally magnesium sulfate, were regarded as the main cause of damage to the historical substance of the building. In many areas, the painting on the ashlar blocks and mortar was already lost or in acute danger of loss due to salt degradation.

After making a map of the damages and prior testing, the ribs and the vault stones were extensively desalinated by cyclical sprinkling in order to ensure a contact-free treatment.

In this case, the sprinkling proved to be both an economical procedure for a sustained salt reduction.

Keywords: sulfates, desalination, sprinkling method, painted surfaces

1 Introduction

The city of Zeitz is located in the Burgenland (which roughly means “land of castles”) in the state of Saxony-Anhalt, where most of the German UNESCO World Heritage Sites are located. Zeitz, first mentioned under the name of Cici in the Synod of Ravenna in 967, as well as the region were of great historical significance. The town was at times the main fortress of the March of Zeitz and a bishop’s residence.

The city is situated along the river Weiße Elster, in the middle of the triangle of the federal states Saxony-Anhalt, Thuringia in the south, and Saxony in the east (Fig 1b). While the cathedral and fortress were built in the valley, the medieval town was erected on a hill above. The former Franciscan monastery church of St. Francisco, Antonius and Clara was mentioned for the first time in 1266. The church is located on the north-western periphery of the old town hill (Fig. 1, b and c).

1.1 The Franciscan monastery church

The Franciscan Gothic church is 61 meters long and is one of the biggest hall churches in Germany. The long extended vault consists of 11 vault bays and a semicircular choir built in the thirteenth century. The vault was built in the fifteenth century. The gussets were painted with floral decoration. The ribs were painted with simple stone imitation of red ashlars with white joints. The building was used by the Reformation movement of the sixteenth century, and the Reformation leader Martin Luther (1483-1546) gave a speech here.

After several decades of neglect, the building was in acute danger of collapse.

In the 1990s parts of the roof collapsed and the groin vaults of the church were exposed to bad weather conditions that caused water infiltration and much damage (Fig. 2a).

Along with the structural problems, the structurally damaging salts were regarded as the main cause of damage to the historical substance of the building. These were principally magnesium sulfate. Possibly, the building stones and mortar are the source of the salts.

1.2 Geological setting and rock material

The church was constructed out of dolomite bound sandstone that was used throughout this region and that often shows alveolar weathering as a result of salt weathering, as has been also found in buildings in the neighbouring state of Saxony [1].

Hirschwald mentions quarries near Kretschau and Kuhndorf that could be former medieval quarries (Figure 1b) [2]. Other bigger quartzite bound formations can be found in the north-eastern region of Bösau and near

Profen and Elsterstrebnitz, where according to Pietzsch, sandstone formation with a quarry height of up to 5 meters can be found (Fig. 1b) [3]. Younger identified numerous quarries around the town like in Droysig-Hassel, Schkauditz, Haynsburg, Kleinporthen and Pölzig (Fig. 1b) [4].

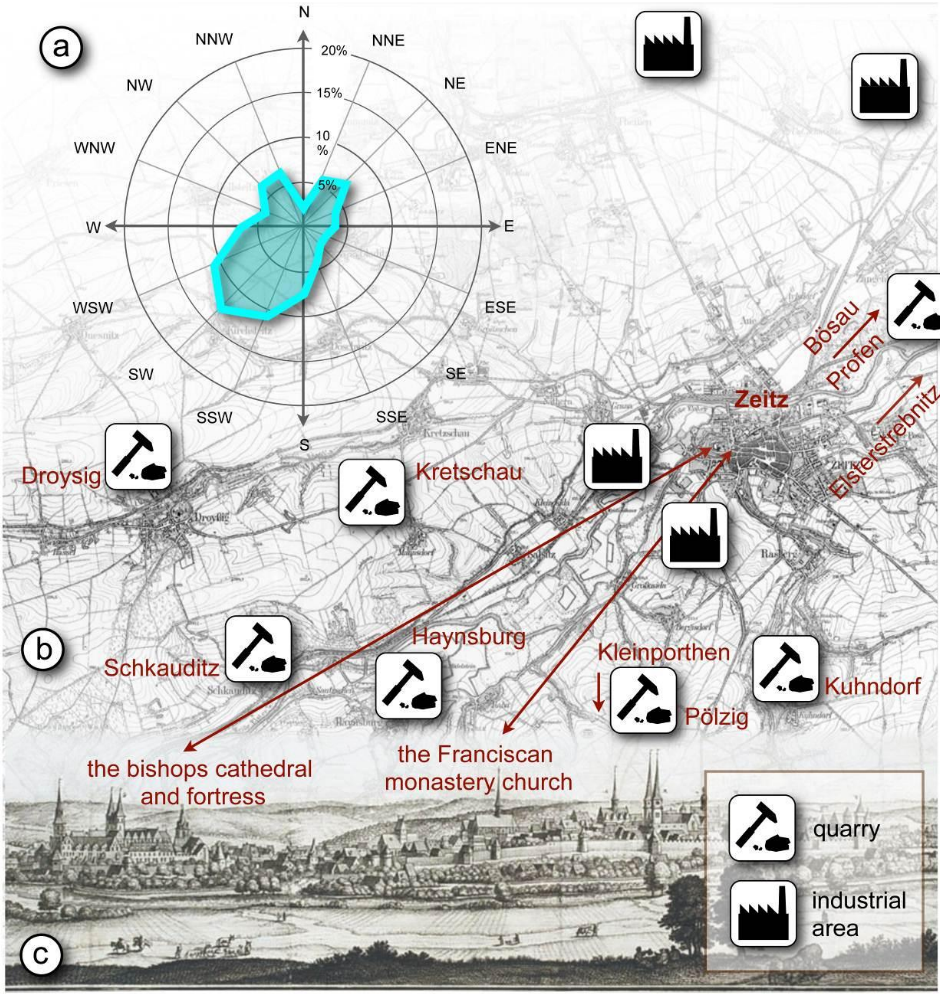

Figure 1: a) the main wind and rain directions in percent (www.windfinder.com). b) Zeitz and its environs around 1912 with location of quarries and industrial areas. c) Lithograph of the medieval city of Zeitz from the "Topographia Germaniae" by Matthäus Merian (1593-1650), showing the outstanding historical buildings and topography.

Sandstone can also be found on the monastery hill itself, but only thin layers.

The sandstone of Zeitz mostly has a yellow colour. Besides these varieties, which clearly dominate the stone architecture of the town, greyish to greenish types are also present. These colours are due to high concentrations of feldspar, mica and clayish substances.

The rock material has a low porosity that varies between 3 and 15 % with a dominance of micropores, and contains a homogeneous fine to middle grain size with a clearly visible layered structure. The Zeitz sandstone has a dolomite cementation that varies between 13 and 76 % volume. Due to the high amount of dolomite cement, the density reaches 2.72 g/cm^3. As a consequence of the high density and low porosity with an averaged value of around 5 % the stone has a low water uptake rate (averaged 0.8 [kg/m$^2\sqrt{}$ t]). The water uptake rate varies as much as 46% with the bedding direction. Compressive strength, 100 N/cm^2, is quite high comparable to other sandstones.

1.2.1 Environmental impacts and geographical setting

During the industrial revolution Zeitz became one of the main centres for charcoal extraction and coal briquette production, starting in 1800 and continuing up to the 1990s. Today the last existing historical briquette factory in Europe, “Hermannschacht”, is declared as monument and can be visited in the industrial area of Zeitz. Especially the processing of lignite produces a high content of sulfur within industrial pollution. From 1865 to 1905 charcoal production in Zeitz increased from more than one million square meters to more than six million a year [5]. The briquette production factories were located near the mining areas west of the town. The monastery complex is located at the western end of the city mountain (Figures 1b & 1c). The main wind and rain direction with 13.4 % is the southwest, followed by the west-southwest with 11.6 %, and the south-southwest with 10.9 % (Fig 1a). Consequently, sulfur pollutants were transported continuously in the direction of the historical city over a period of nearly two hundred years. The impact can be seen today on several historical buildings such as the Michaelis Church, which exhibits dramatic forms of alveolar weathering on the western and south-western side of the building (Fig. 2b).

2 Salt and weathering forms

In the case of historical buildings in Zeitz, the industrial pollution in combination with the binding material of the sandstone and lime mortar creates a dangerous salt with a high potential for damage: magnesium sulfate. The salt can result in extensive salt weathering in historical monuments as well if dolomite cemented stone or mortar and gypsum mortars are present [6-8]. The system of magnesium sulfate is already well investigated and described (www.salzwiki.de). It consists in three stable crystalline phases in the terrestrial atmosphere with a different number of water molecules bound within the crystalline structure: epsomite ($MgSO_4•7H_2O$), hexahydrite ($MgSO_4•6H_2O$) and kieserite ($MgSO_4•1H_2O$) [9]. At least 8 identified metastable crystalline phases with 1 to 12 water molecules can form by hydration or dehydration of the stable salts according to the relative humidity and temperature [10]. The damage potential of magnesium sulfate can be traced back to the stress generated by crystallization and hydration. The main stress is induced by salt crystallization of epsomite and hexahydrite precipitated from solution [11].

Salt weathering in Zeitz is characterized by alveolar weathering (Fig 2a). The ashlars of the vault ribs show different weathering forms, such as sanding, flaking and the out weathering of clayish components (Fig. 2b-d).

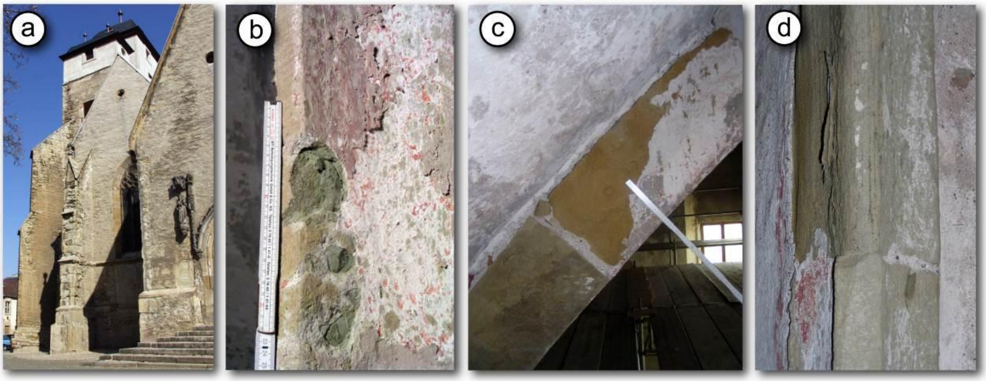

Figure 2: a) At the south-western side of the Michaelis Church, effected by the main wind and rain direction, alveolar back weathering can be found. b) Weathering of clayish material and flaking of painting. c) Back-weathering of single ashlars of the vault ribs. d) Lamination parallel to the bedding.

2.1 Method of desalination

In the 2000s preservation and restoration of the church vault were carried out and a desalination in the painted ribs, main arch, and abutments was performed.

In many areas, the painting on the ashlar and mortar was already lost or in acute danger of loss due to salt degradation (Fig. 2b, 3b).

Figure 3: a) The church before conservation. b) An exemplary mapping of damages of the ribs of vault no. 9. c) The church during conservation. In the front the first restored vaults are visible.

After making a map of the damages (Fig. 3b) and prior testing on loose material of the stone surface, the ribs and the vault stones were extensively desalinated. The desalination technique by cyclical sprinkling (rinsing method) was used, in order to ensure a contact-free treatment. A similar technique was used successfully for the desalination of brick architecture in Venice [12] and to desalinate the salt contaminated tafoni on a tomb facade in Petra, Jordan [13]. For smaller objects like tomb stones the sprinkling method also produces good results [14]. If there are fragile wall paintings, contact-free methods such as sprinkling, as employed at the Neues Museum in Berlin [15], or flushing for partial salt-reduction, as used for the Tiepolo frescos in the residential castle in Würzburg [16], are especially suitable.

2.2 Evaluation of the method

Each treatment in conservation or restoration, with the exception of preventive conservation, induces stress to the object. By cleaning, removing unsuitable materials, as well as in desalination a minimum of original substance will be lost.

As a conservator, one has to evaluate the risks and benefits of each method and choose the one that promises the best results and generates the least damage.

In case of the vault ribs, in general the use of the poultice-method would also be an option. The execution parameters of the poultice-method depend on the condition of the object, the climatic conditions, the type of salt and the depth of contamination. With respect to the stone material of the vault ribs and its pore structure, a lot of fine aggregate, such as kaolinite, would have to be used in the poultice to create a pore size distribution dominated by micropores. Once the humidity of the poultice has migrated into the pore system of the stone, these micropores are necessary to create a capillary flow of humidity back into the poultice [17-19].

In case of fragile layers of paint, desalination by poultices can cause damage to the original substance. The problem occurs mostly when removing the poultice after drying. Often the poultice sticks to the original substance by forming a solid bond, especially if the poultice consists of a high amount of clayish material, as would be necessary in this case study. Therefore largely contact-free methods were considered as promising the best results. The chosen sprinkling method was first tested by desalination of one rib. A good efficacy was assessed and no serious damage to the painting could be observed.

In most cases, salt-contaminated areas already show back-weathering and surface loss, as was also the case on the vault ribs. The goal of the sprinkling method is to target the strongly stressed zones and to keep moisture movement at a minimum, reducing thereby that salts get concentrated on the stone surface by capillary transport, diffusion and subsequent drying. Their crystallization can cause damage in the near surface zone of the porous material, a risk that has to be kept in mind.

2.3 The treatment

In the following, the step-by-step procedure for the ensuing treatment is described.

For the desalination of the vault ribs their position as well as their form was helpful. The upper area of the contaminated zone was sprinkled with a spray head; subsequently the water flowed down the ribs. As sprinkling water normal tap water with a defined conductivity (because of the lime content) was used (Fig 4b). At the beginning of the procedure the water is predominantly absorbed by the porous stone surface through capillary forces. Water absorption is dependent upon the transport properties of the material. These are controlled by the pore space properties, such as porosity and pore radii distribution, and are a time-dependent process [20]. In the case of the treated sandstone vault ribs, salt contamination was analyzed from drill cuttings obtained in the first two centimetres of the stone in relevant amounts. The salt contaminated zone was sprinkled for washing and moisture penetration during a period of ten minutes, in accordance with the determined infiltration rates for the Zeitz sandstone variety. At the lower end of the treated area a drain gutter was constructed from clay, so that the eluate can be funnelled into a sample container. Excess water not absorbed by the stone was collected in five-liter amounts and checked for electrical conductivity (mS/cm) (Fig. 5a). The correlation between the electrical conductivity and the real content of soluble substances within the eluate was calculated by evaporation of different samples consisting of 1-liter eluate in a drying oven and weighing. After a treatment of about 10 minutes, the sprinkling was terminated and a drying period of at least two days followed. After every sprinkling cycle, a break of ca. 48 hours was observed in order to initiate the drying procedure, which leads to the concentration of salts in the near-surface area of the stone. A complete drying out of the stone material did not take place and salt efflorescence could not be observed. Over a period of one month, a total of up to seven sprinkling cycles was completed.

At the end of the sprinkling cycles a compress was applied to the treated area and the stone could dry out completely within one week. The poultice was made out of sand, bentonite and cellulose in a proportion by volume of 2 : 1 : 1.

3 Results

The highest values of electrical conductivity were relate to the first measurement in the course of a respective sprinkling treatment by washing away the high salt concentration from the surface (Fig. 4b). Compared with the first dataset, the second values showed a decrease ranging between 30 and 50% after sprinkling. A continuous decrease in the electrical conductivity occurred in the following measurements. The last conductivity value was about one-fourth of the initial sprinkling cycle value.

The highest amount of about half a kilo of salt was extracted from a central pillar integrated in the western facade (Fig. 4c). This facade was heavily weathered due to its orientation and topographic position on the edge of the city hill (Fig. 1c). From the contaminated areas of the ribs and main arches of the vault of the bays 1-5, merely 350 g of dissolved substances were extracted whereas a total of ca. 2.5 kg from 209 stones of the ribs and main arches of the bay 6 to the choir.

In general, it might be possible that also other salts were removed by sprinkling that show a slightly different electric conductivity and therefore another mass content of solvent goods. Therefore the total amount from all measurements of almost 3.4 kg extracted salts should thus be regarded as an approximate value.

The results confirmed the intensity of weathering of the vault, which in the mentioned 6 vault bays displayed the most damage in the vault plaster and painting as well. In this area also the biggest damages could be observed in the roof of the church.

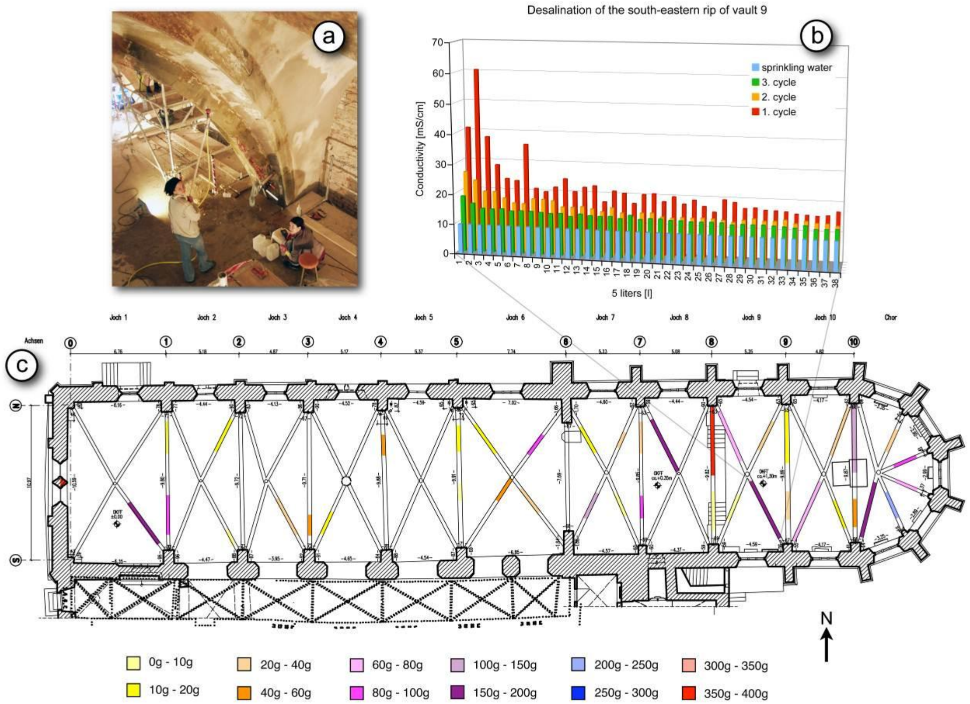

Figure 4: a) The sprinkling method and measurement of the electric conductivity in action. b) Exemplary diagram of a typical desalination treatment by sprinkling of the south-eastern rib of vault no. 9. c) The results of desalination of treated areas of the vault ribs.

3.1 Conservation-Restoration

After desalination, the ashlar of the ribs was conserved by using a fine mortar made from crushed sandstone and lime in order to use the natural pigmentation of the sand as a colour (Fig. 5b). Bigger gaps and missing parts were repaired by dry slaked lime mortar according to the historical technique (Fig. 5c). A reduced application of the mortar was considered in a way that the material only remains in the weathered areas to equalize the surface and to integrate the remainder of the decorative painting (Fig. 5d). Flaking parts of the paint were stabilized by backfilling with a lime suspension and reapplication.

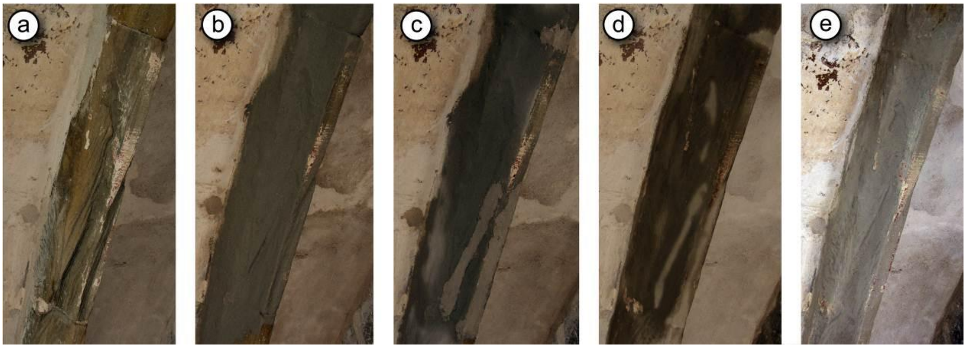

Figure 5: a) Ashlar of a rip after desalination. b) The fine mortar was applied with a brush. c) Bigger gaps were filed with dry slaked mortar. d) After the beginning of hardening, waste mortar was reduced with a wet sponge. E) The ashlar after restoration.

4 Conclusions

By using the described sprinkling technique for desalination, a control of the process was immediately possible by electric conductivity measurements. This allows a calculation of the contamination as well as the planning and application of the whole desalination process.

In this case, the sprinkling method proved to be both an economical procedure for a sustained salt reduction and an extremely gentle method for the partially loose remains of the decorative painting: only one poultice was applied and removed after the desalination by sprinkling and only one month was used to complete the hole procedure of treatment.

Today visitors can experience the church in its restored condition, which serves as a location for cultural events.

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befindlichen, zu gelegentlicher Benutzung erschlossenen und aufgelassenen Steinbrüche, nach Provinzen, Regierungsbezirken und Kreisen geordnet, mit Angabe der Verwendung der betreffenden Gesteine zu älteren Bauwerken und des an ihnen beobachteten Wetterbeständigkeitsgrades des Materials, Bornträger, Berlin 1910.

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