NDT DAMAGE DIAGNOSIS ON SANDSTONE – Case Study of Gelnhausen, Germany

Christoph Franzen*; Thomas Löther*; Michael Auras** and Enno Steindlberger**
*Institut für Diagnostik und Konservierung an Denkmalen in Sachsen und Sachsen-Anhalt e. V., Arbeitsstelle Dresden, Schloßplatz 1, D-01067 Dresden, www.idk-info.de, franzen@idk-info.de
**Institut für Steinkonservierung e.V., Große Langgasse 29, D-55116 Mainz, www.ifs-mainz.de

Abstract:

The Kaiserpfalz in Gelnhausen, Germany, was built in Romanesque period in sandstone. The widely known palatinate castle was chosen as study case to prove low impact and non destructive techniques for the state evaluation of historic natural stone building material. The locally quarried middle grained sandstone has a bright red colour. On several masonry blocks and architectural elements formation of subsurface detachment is a serious problem. To detect and locate the damaged areas two non-destructive testing procedures were applied and compared. IR-thermography was applied in active and passive procedure. Additionally acoustical investigation was conducted by discreet dragging a metal ball over the surface of the stone and interpreting the sound. Results were drawn into a mapping. The results were transferred to photographs and compared to the mapping. The outcome of the study presents interesting results of the diagnosis of invisible damage at risk on historical building stone.

Keywords: IR-Thermography (IRT), damage diagnosis, historical building stone, non destructive testing (NDT)

Introduction

Large parts of our cultural heritage worldwide consist out of natural stone material. Within historic building material, sandstones have a major importance. Exposed to the environment the building stone suffers alteration and deterioration occurs. The issue of conservation of the cultural heritage starts by detection of the processes and the damage. Not all deterioration patterns are visible to the naked eye. Subsurface detachment may lead to spontaneous detachment or scaling of large parts of the original surface. To avoid the risks of such major losses knowledge about the place and size of detached parts is indispensable. Detection of detached stone surface areas is possible in several ways. Percussion is one of the widely used techniques for investigation of such defects. Acoustical investigation is either performed with fingers or with adequate tools. Ultrasonic and georadar are other techniques to investigate subsurface stone detachments and voids. All those techniques are non destructive (NDT), however they are based on mechanical contact to the stone material. IR-thermography (IRT) is a contactless non destructive testing method which has become to an excellent damage diagnosis tool in recent years (Avedelidis and Moropoulou 2004, Bison et. al 1996).

Material and Methods

Study case: Kaiserpfalz in Gelnhausen
The Kaiserpfalz in Gelnhausen, Germany, dated on 1170, Romanesque period, attracts attention due to its dimensions and richness of architectural ornaments (Fig.1). Such high level ornaments, which are to be seen on Palace and Chapel, are solely comparable to stone artworks of cathedrals

of this time. The widely known palatinate castle was chosen as study case to prove different low impact and non destructive techniques for the state evaluation of historic natural stone building material.

Figure 1: Study case site of Kaiserpfalz Gelnhausen, Germany.

Sandstone

The Kaiserpfalz is build out of a middle grained sandstone with a bright red colour. The material was used as regular square stones in blocks to a length to 0.8 m and for all high level architectural elements. The locally quarried sandstone belongs to the lower Triassic lithostratigraphy of the Buntsandstein, about 250 Ma. The typical red bed sedimentary colour derives from ferric hydroxide randomly distributed in the material and in thin section detectable as thin layers on the quartz grains. On several masonry blocks and architectural elements formation of subsurface detachment is a serious challenge.

Testing methods

All objects with a temperature above 0 K irradiate electromagnetic radiation in the band of infrared. By measuring the intensity of the radiation the temperature of an object can be detected contactless. Measurements were conducted by VARIOSCAN 3021 ST-camera (InfraTec). The camera detects radiation between 8 and 12 µm wavelengths. Data processing was conducted with IRBIS-professional 2.2.

For active IRT additional energy is supplied to the area of investigation. By detection of the temperature development on the surface area it is possible to locate anomalies below the surface (Avedelidis, Moropoulou 2004). Thermal activation was proceeded by a 3000 W heater which was placed normal to the surface similar to the procedure suggested by Grinzato (2004) and brought into standard practice for investigation of mural paintings by Franzen et al (2007).

IR-thermography was applied in passive and active procedure. The digitally logged pictures of IRT were analysed and interpreted in the office, damages areas hatched and transferred to photographs. Those results were compared to the traditional mapping.
Besides, additional acoustical investigation was conducted by discreet dragging a metal ball over the surface of the stone and interpreting the sound. The most used method in restoration practice for investigation of subsurface defects is based on percussion with different tools (Drdácký, Lesák 2006). Here the “Lehrberger-Kugel”, a resonance sound detector developed for Cultural Heritage investigation was used (Lehrberger and Gillhuber 2007). Results were also drawn into a mapping.

Results and discussion

The sandstone Base No 3 shows in some parts pits looking like an enlargement of the natural porosity (Fig.2). On the upper roll moulding of the base a blistering was observed, following the stone deterioration terminology recommended by Vergès-Belmin et. al (2008). Active IRT (Fig. 3) showed that the detachment is traceable and does not exceed the visible damaged area. The thermogram is given as difference-temperature; solely the temperature difference to the temperature distribution at the start of the investigation is shown. This neglects temperature irregularity present at the beginning of the investigation. Interpretation of the thermogram is made difficult due to the three-dimensional structure of the part investigated. Overhanging slim parts heat up faster than massive parts

Figure 2: Base No 3 (right).

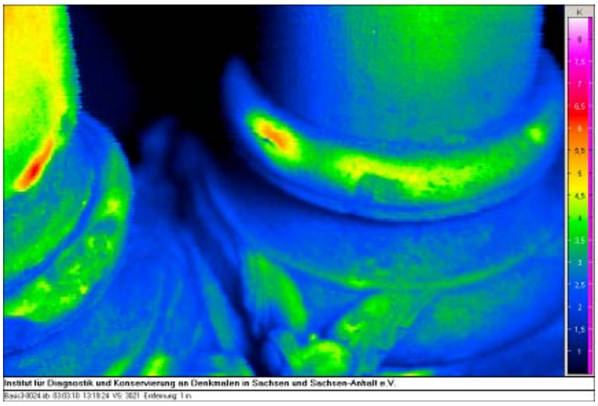

Figure 3: Active IRT on Base No 3.

On pillar No. 5 (Fig. 4) active IRT was conducted. The pillar shows differential erosion and alveolisation in its lower parts. Previous typical damage investigation assumed subsurface detachments in the middle part of the pillar. This part was taken for specified investigations. Heater was placed normal to the central part of the pillar at a distance of 1.3 m for 300 s. Every 5 s IR-thermogram was captured. The total measurement sequence covered the activation and the cooling phase of the area investigated (Fig. 5, 6). Also here interpretation was done on the difference-temperature-thermograms.

Figure 4: Pillar 5 (left), previous damage mapping, suspicion of subsurface detachment areas.

From both investigation phases, activation and cooling, thermograms were taken as basis for interpretation. Thermal anomalies were interpreted as detachment areas and hatched. In comparison to the previous damage mapping (Fig. 4) the IRT damage detection yields high correlation to the detachment area on the right hand side of the pictures (Fig. 5, 6). On the left hand side, divided by the vertical crack, a subsurface detachment was detected, which was not detected before.

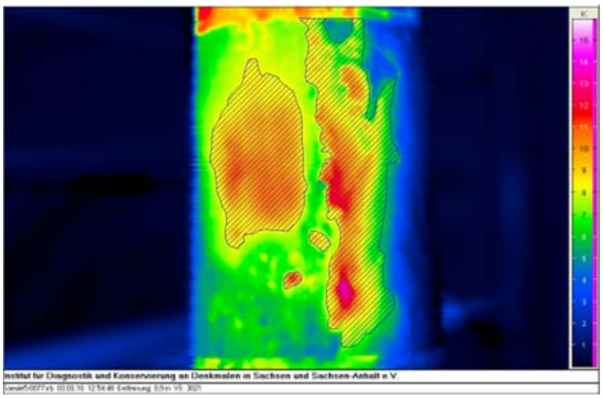

Figure 5: Thermogram of the end of heating sequence, detached areas are hatched.

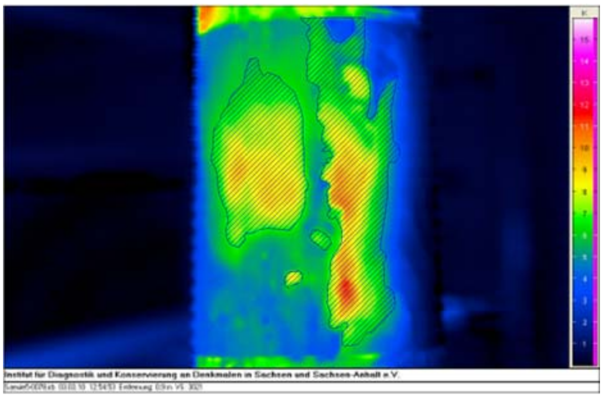

Figure 6: Thermogram during the sequence, detached areas are hatched.

Figure 7: Results of IRT mapping drawn into the photograph.

On the eastern pylon passive IRT was proceeded. From investigation with the acoustic Lehrberger Kugel detachments at the sandstone squares was known. In Fig. 8 these areas are given in red colour. IRT was proceeded when the sun was shining on the masonry. Areas of detachment were clearly visible due to temperature anomalies on the surface (Fig. 9). These results were transcripted into the foto (Fig. 8). The challenges in consistency between the two procedures have to be discussed.

Figure 8: Eastern pylon with damage of resonance sound detector (red) and damage detection by IRT (hatched blue).

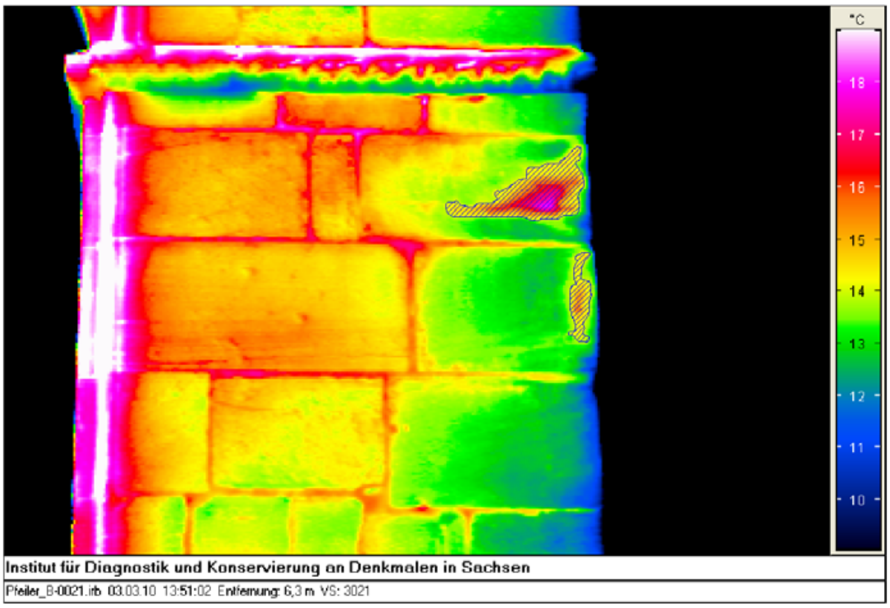

Figure 9: Passive IRT on eastern pylon, damage areas hatched.

Conclusion

Infrared thermography is to date the most interesting technique for the detection and evaluation of subsurface detachment of historical sandstone. Major advantages IRT measurement are that they are not only non destructive but even contactless and yield two dimensional results which can easily transferred into a damage mapping.

Acknowledgements

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