

## Laser Induced Breakdown Spectroscopy (LIBS) – On-site investigations on a bridge with a mobile LIBS-system

Steven MILLAR<sup>1</sup>, Cassian GOTTLIEB<sup>1</sup>, Gerd WILSCH<sup>1</sup>, Thorsten EICHLER<sup>1</sup>,  
Christian BOHLING<sup>2</sup>, André MOLKENTHIN<sup>3</sup>

<sup>1</sup>BAM, Federal Institute for Materials Research and Testing  
Unter den Eichen 87, 12205 Berlin, Germany

Phone +49-30-8104-4689, Fax: +49-30-8104-1447; e-mail: [steven.millar@bam.de](mailto:steven.millar@bam.de)

<sup>2</sup>SECOPTA GmbH

Ostendstraße 25, 12459 Berlin, Germany

e-mail: [christian.bohling@secopta.de](mailto:christian.bohling@secopta.de)

<sup>3</sup>Specht, Kalleja + Partner GmbH

Keplerstraße 8-10, 10589 Berlin, Germany

e-mail: [molkenthin@skp-ingenieure.com](mailto:molkenthin@skp-ingenieure.com)

### Abstract

LIBS is on the step from a laboratory application to on-site analysis. A validated mobile LIBS-system for on-site application on building materials is under development at BAM in cooperation with industrial partners (system developers and companies), who will use this technique for investigations on building structures like bridges and parking decks. The system is designed to measure the content of harmful species like chlorine, sulfur or alkalis, to give the engineer a tool for the estimation of the condition of concrete structures and for quality assurance during concrete repair work on-site. In these work results of on-site measurements on a chloride contaminated bridge are shown. Further work will focus on providing guidelines to establish LIBS as a standard procedure for chemical investigations of building materials.

**Keywords:** LIBS, chlorides, sulfur, alkalis, corrosion, ASR, chemical analysis

## 1. Introduction

Concrete buildings are designed in consideration of a specific expected lifetime. Usually for reinforced concrete structures in civil engineering as e.g. multi-storey car parks a minimum life time of approximately 50 years is strived for. Environmental factors like weather, location or general exposition can force aging- and damage-processes due to deterioration of concrete and/or reinforcement. The ingress of harmful species like CO<sub>2</sub> or Cl<sup>-</sup> causes corrosion of the embedded reinforcement in the concrete structure. In this case especially older constructions with insufficiently concrete cover are not able to attain the assessed life time. Laser induced breakdown spectroscopy (LIBS) can be applied as a fast and reliable method in order to identify harmful species and their accompanying damage processes. The LIBS method is a combination of material ablation, plasma formation and analysis of emitted radiation by spectroscopic methods. To generate plasma a high energy pulsed Nd:YAG-laser is focused on a surface. The radiation of the plasma is analysed by a spectrograph and in combination with a CCD-camera. As a matter of principle all elements are detectable, even light elements like hydrogen or sodium. The results can be quantified by calibration.

LIBS may be used on gases, liquids or solids. There are a lot of applications in different fields like environmental analysis, pharmaceutical investigation, biomedical investigation, forensic investigation or industrial applications like process control, recycling, sorting and quality control

during manufacturing [2, 3]. At BAM LIBS has been successfully applied for investigations on distribution and transport of different ions in building materials [1,4-6].

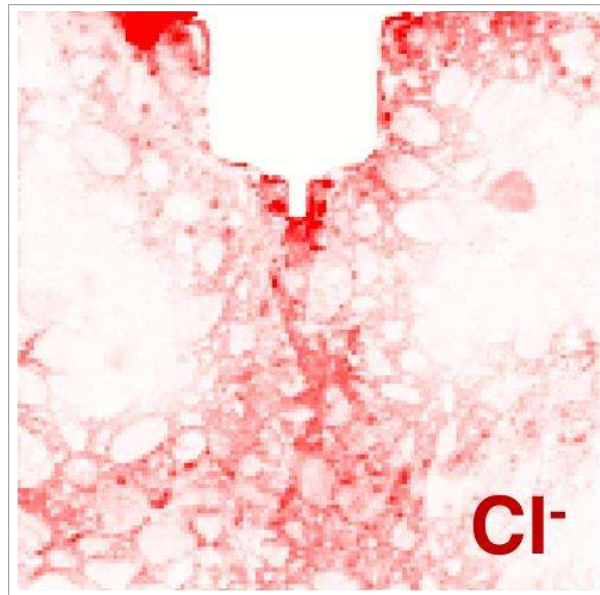


Figure 1. Chloride-ingress at a cracked concrete specimen; crack width = 350  $\mu\text{m}$ ; sample-size = 140 mm  $\times$  140 mm; applied with a NaCl-solution from top; darker red represents a higher chloride content

The challenge of separating aggregates and cement-matrix in studying element distributions of concrete based materials, which is e.g. wet chemical analyzes unfit to do, solves LIBS at BAM with a scanning system. Taking the heterogeneity of concrete into account is necessary and elementary, because the main transport-processes occur in the cement-matrix via pores. In damaged concrete the transport processes can be supported by cracks. With a spatial resolution of 50  $\mu\text{m}$  and the aforementioned scanning technique LIBS is able to image the transport of harmful ions by cracks (figure 1). In cooperation with system developers and companies a mobile LIBS-system is in development at BAM.

## 2. Mobile LIBS-system

To give the engineer a tool for on-site inspections of concrete buildings, a mobile LIBS-system is in development at BAM. This mobile setup is intended to help engineers making fast statements about the actual condition, the necessity of maintenance arrangements and the durability of structures. The setup of the mobile system is shown in figure 2. The laser is located in the measuring head, which is fixed on a scanner system. The laser head is moved by the scanner to take the heterogeneity into account. The maximum area, which currently can be scanned, is 17,0 cm  $\times$  15,0 cm. With the help of compressed air the scanner can be fixed on vertical surfaces or even overhead. The head is connected with the control unit via a 5,00 m cable. The laser energy is 3 mJ per pulse and can run with a frequency up to 100 Hz. The plasma radiation is delivered to an optical fibre and analysed by the detection unit. To maintain laser safety regulations, a cover in connection with a brush shields the laser beam path.

### 3. On-site measurements on a storm-barrier-bridge

In cooperation with companies and authorities BAM got the opportunity to make first measurements on a bridge with the mobile LIBS-system. The bridge is located at the North Sea and is exposed to a saline environment. The aim was to get an overview of chloride concentration in correlation to the exposure. The results of the investigation give an impression, if areas or parts of the bridge are more exposed than others.



Figure 2. On-site investigation on a bridge; the scanner with the laser-head is fixed with compressed air at the bottom of the bridge to estimate the chlorine concentration.

The investigation includes the bridge structure, including the wall (top and bottom), the cantilever and the floor. Altogether measurements of 23 surfaces, each 140 mm × 140 mm, were done on three days. Figure xx shows the bridge section, where the measurements were made.

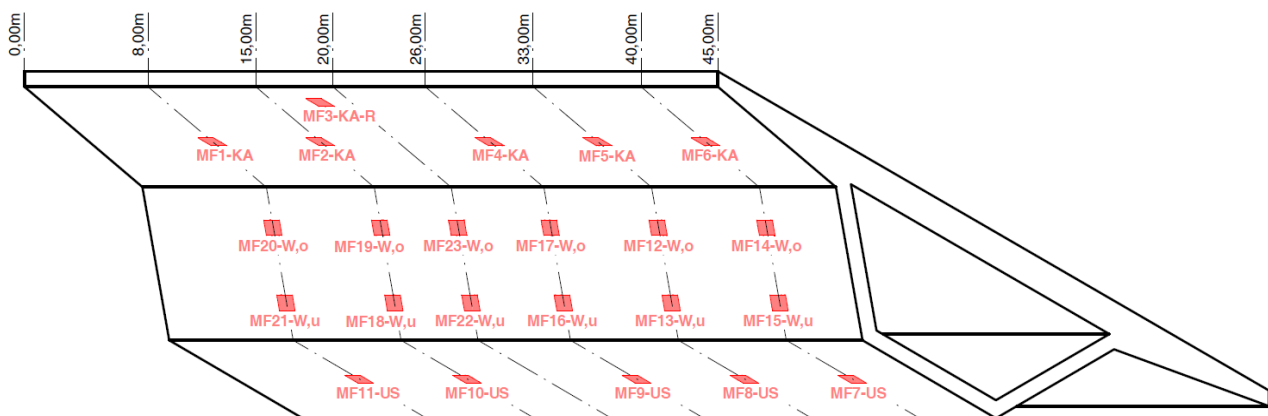


Figure 3. Localisation of the measured surfaces.

The measurements were also made to test the functionality of the mobile system in harsh conditions. First results are shown in figure 4. It displays that the exposure varies between different areas. The top of the wall (figure 10, right) is exposed to a higher chloride attack than the cantilever.

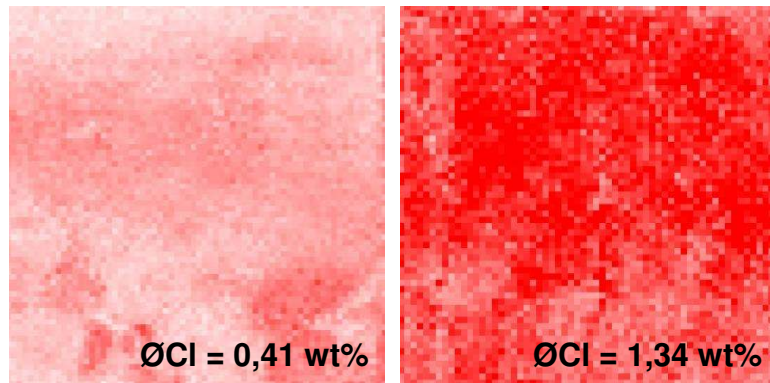


Figure 4. Two surfaces, each 140 mm × 140 mm, measured on a bridge. Resolution = 2,0 mm × 2,0 mm. Surface left was measured on the cantilever and has an average chloride concentration of 0,41 %. The surface right has an average value of 1,34 % and was measured on the wall (top). One measurement took about 15 min. Darker red represents a higher chloride content

#### 4. Conclusions

To get an overview of critical locations/areas regarding to chloride exposure and to get an impression on the variability of chloride exposure conditions the results of the surface measurements are summarized in the following diagram (figure 5). The highest content of chlorides has been detected on the top respectively in the middle of the wall. Only at the floor at +15,00m a similar content of chlorides has been detected.

The mobile system is able to detect differences of the exposure even in rougher weather conditions. In further investigations the results of the on-site measurements will be verified on drilled cores in the laboratory.

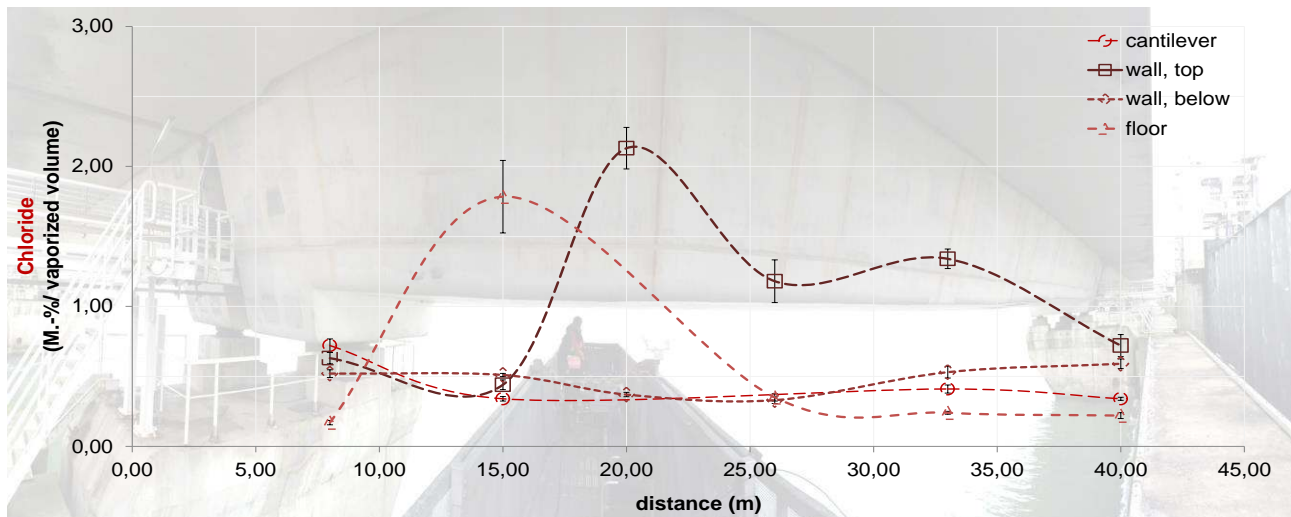


Figure 5. Chloride distribution over the bridge-section

## Acknowledgements

This project is funded by the German Federal Ministry for Economics and Technology (BMWi). We would like to thank our partners SECOPTA GmbH and Specht, Kalleja & Partner GmbH for the great cooperation over the last years.

## References

- [1] Wilsch, G., Schaurich, D., et al. Imaging Laser Analyses of Building Materials – Practical Examples, Review of Progress in Quantitative Non-destructive Evaluation; Vols 30a and 30b 1335: 1315-1322, 2011
- [2] Noll, R.; Laser-induced Breakdown Spectroscopy – Fundamentals and applications; 2012; Springer Verlag; Berlin/ Heidelberg
- [3] Hahn, D. W. & N. Omenetto (2012). "Laser-Induced Break-down Spectroscopy (LIBS), Part II: Review of Instrumental and Methodological Approaches to Material Analysis and Applications to Different Fields." Appl. Spectrosc. 66(4): 347-419.
- [4] Wilsch G., Weritz F., Schaurich D., and Wiggenhauser H. (2005), Determination of chloride content in concrete structures with laser-induced breakdown spectroscopy, Constr Build Mater 19:724-730.
- [5] Weritz F, Schaurich D, Taffe A, and Wilsch G (2006) Effect of heterogeneity on the quantitative determination of trace elements in concrete, Anal Bioanal Chem 385: 248-255.
- [6] Eichler T.; Isecke B., Wilsch G, Goldschmidt S., and Bruns M. (2010) Investigations on the chloride migration in consequence of cathodic polarization, Materials and Corrosion, 61, No.6: 512-517