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Val-LIBS: A novel attempt to decipher the transport processes in concrete – A case study

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1. Introduction

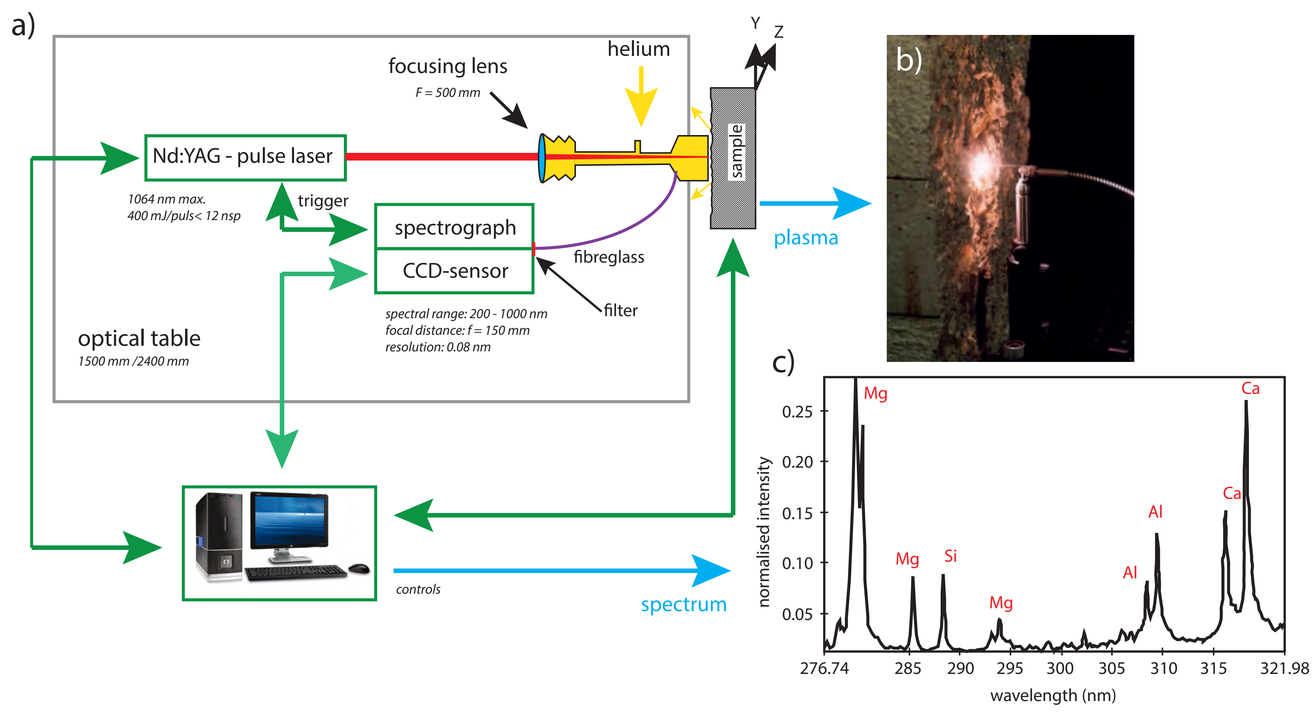
The "laser-induced breakdown spectroscopy" (LIBS) represents a very promising and innovative tool that helps gaining information about the status of buildings during their life cycle. Due to its potential harm for concrete buildings, the detection of chlorine is of great interest (Gottlieb, et al. 2018; Millar, et al. 2018). Especially, in regions where de-icing salt is applied on the streets, the passivity of concrete is destroyed which leads in combination with water and oxygen to chlorine-induced corrosion at the reinforcement.

In contrast to time-consuming wet-chemistry, LIBS is a faster alternative accompanied by a higher resolution (*µm* range). The surface of divided drill cores is spectroscopically analysed and the binding agent can analytically be separated from the aggregates so that solely the cement is measured. Additionally, mm-sized areas can be scanned (2D analysis) allowing closer examination of potential transport processes along cracks. Here, we present LIBS data from a multi-storey car park revealing the transport path of chlorine in cracks.

2. Method

LIBS is based on the bombardment of the sample with a very short (*ns*), focused (~ 100 *µm*) and energy-rich (~ 400 *mJ*) laser pulse. This leads to the ablation of a small amount of the sample material which is converted into a plasma. The chemical bindings are destroyed and the electrons of the atoms excited causing an ionization of the elements. After termination of the energy supply, the plasma cools and breaks down so that the electrons and ions recombine. During this breakdown, element-characteristic light is emitted that can be measured with a spectrometer.

By using chlorine standards, the results are quantitative. The software from SECOPTA analytics GmbH provides the raw data. Additionally, in order to process the data and evaluate the results, the Valtest AG is using a self-developed MATLAB algorithm.

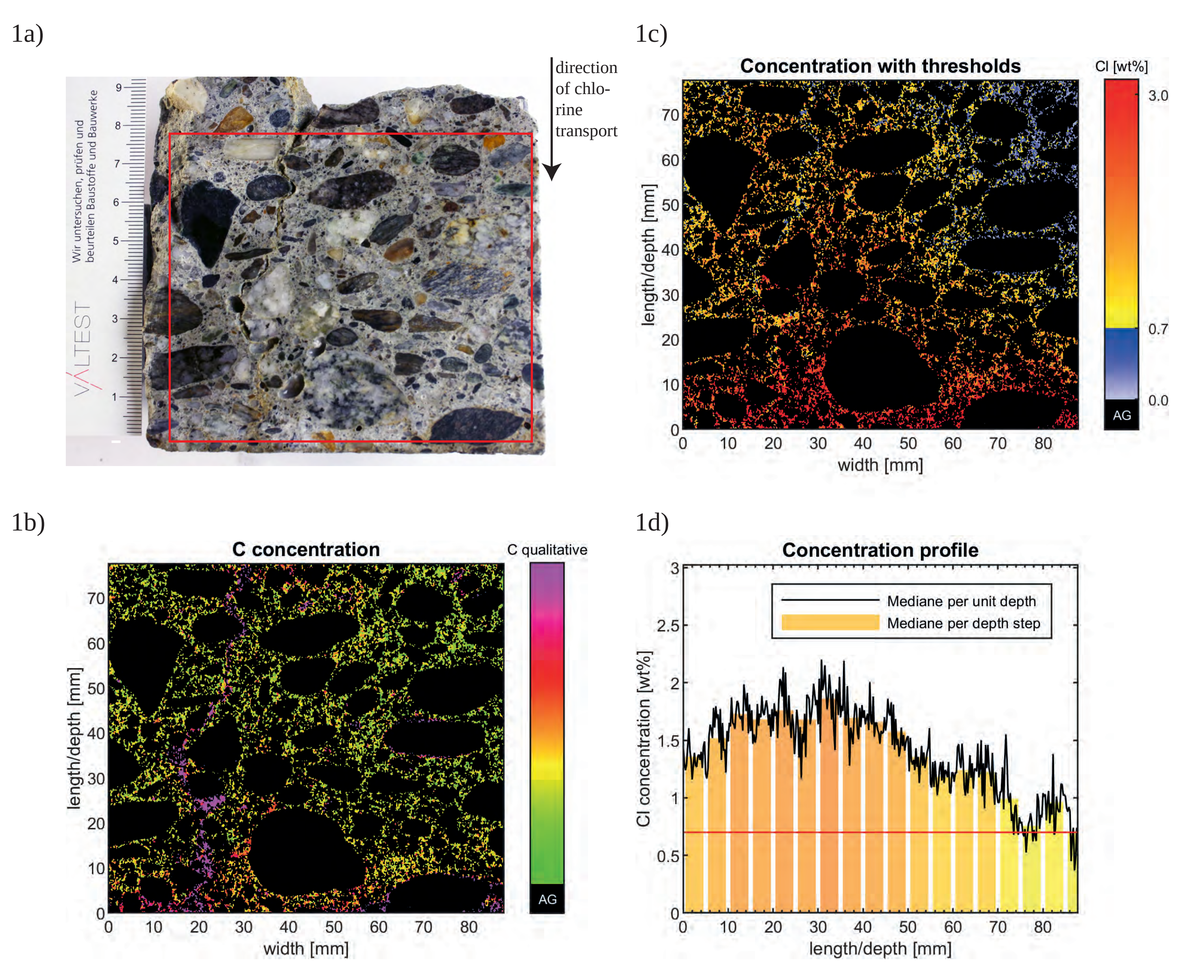


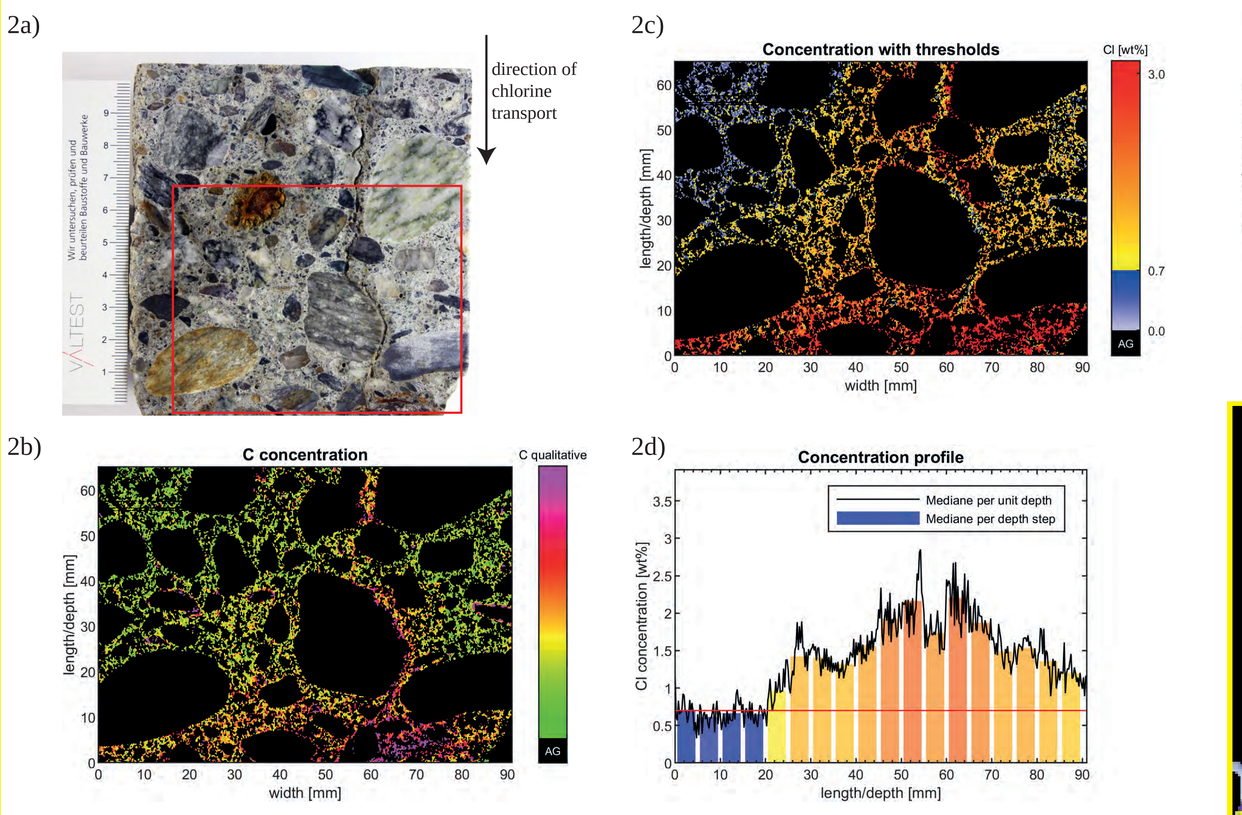
3. Results

The samples were obtained from the ceiling of a multi-storey car park in Switzerland. The most important outcome of this study are the increased chlorine concentrations around cracks and their decay with further distance into the flanks of the crack (chlorine corona around cracks; 1c/d and 2c/d).

The chlorine concentrations reach values of ± 1.5 *wt. %* at depths up to 70 *mm* (1c) indicating that chlorine was transported along the entire crack and leading to relatively high chlorine concentrations (> 3.0 *wt. %*) at the underside of the ceiling.

The carbon data (qualitatively) in the crack are higher in comparison to the concrete mantle data indicating that a possible carbonatation of the cracks occurred into relatively deep levels (1b and 2b).





4. Conclusion & Summary

As the samples were obtained from the ceiling, the chlorine transport occurred downwards along the crack enriching chlorine at the underside of the ceiling. Further transport mechanisms that can be approximated by diffusion were also participating, leading to the appearance of the chlorine corona.

Such cracks represent large threats for concrete structures increasing the probability of local failure. The reinforcement might not only be attacked where the cracks are in direct contact with the reinforcement but also on a wider front caused by diffusion.

According to our knowledge, it is the first time that chlorine transport could efficiently be detected. We would like to emphasize that such close investigations are only possible thanks to the higher spatial resolution and 2D visualisation analysis qualities of LIBS.

References:

Gottlieb C, Günther T, Wilsch G (2018) Impact of grain sizes on the quantitative concrete analysis using laser-induced breakdown spectroscopy. Spectrochimica Acta Part B: Atomic Spectroscopy 142:74-84

Millar S, Gottlieb C, Günther T, Sankat N, Wilsch G, Kruschwitz S (2018) Chlorine determination in cement-bound materials with Laser-induced Breakdown Spectroscopy (LIBS)–A review and validation. Spectrochimica Acta Part B: Atomic Spectroscopy 147:1-8