Measurement of Salt Concentration in Concrete by Laser Induced Breakdown Spectroscopy – Sensitivity Evaluation of Chlorine Concentration Measurement –

Background

Since the durability of reinforced concrete structures is degraded due to corrosion of reinforcing bars by chloride ions penetrated from outside, the quantitative measurement of the chlorine concentration in concrete is important in the evaluation of the durability of concrete structures. So far, measurement of chlorine concentration in concrete has been carried out by a chemical analysis of samples picked out from the structures. However, since the chemical analysis is time-consuming, development of an on-site measurement method for chlorine concentration is required. Laser-induced breakdown spectroscopy (LIBS) can identify and quantitatively measure elements contained in a sample by the analysis of the fluorescence from plasma produced by focusing the laser beam on a measurement target, and can realize the remote and real time measurement on site.

Objectives

This study aims to evaluate the sensitivity of LIBS measurement of chlorine concentration in concrete using grinded and pressed samples of concrete containing salt;

Principal Results

We measured the chlorine fluorescence from the pressed sample by LIBS using single- or double-pulsed lasers *1 and obtained the following results (Fig. 1, 2).

1. Improvement of the sensitivity of chlorine concentration measurement by optimizing the time delay between laser irradiation and fluorescence detection

White light noise occurred after laser irradiation was reduced by optimizing the time delay between laser irradiation and fluorescence detection, and the sensitivity of the measurement of chlorine fluorescence (wavelength: 837.59 nm) was improved. The spectral intensity of the chlorine fluorescence line was successfully measured with signal-to-noise ratio of more than 2 even for the sample with a chlorine concentration of 0.18 kg/m^3. These results show that the chlorine concentration of 0.6 kg/m^3 *2, at which the corrosion of reinforcing bars in concrete structures starts, can be detected by this method (Fig. 3).

2. Possibility of the quantitative measurement of chlorine concentration and enhancement of the fluorescence intensity by double-pulse LIBS

Linearity between the spectral intensity of the chlorine fluorescence line and chlorine concentration was verified. These results show the possibility of the quantitative measurement of the chlorine concentration in concrete. In addition, by optimizing the time delay between the two laser pulses in double-pulse measurement, the spectral intensity of the chlorine fluorescence line was enhanced by a factor of two by using double pulse instead of single pulse (Fig. 4).

Future Developments

The possibility of practical use of LIBS measurement of chlorine concentration in concrete will be verified by using a concrete core sample.

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Reference

T. Fujii, et al., 2008, “Measurement of salt concentration in concrete by laser induced breakdown spectroscopy - Sensitivity evaluation of Cl concentration measurement using pressed sample -”, CRIEPI Report H07012 (in Japanese)

*1：Second-harmonic Nd: YAG lasers (wavelength: 532 nm) were used in this experiments.

*2：It is defined by the Architectural Institute of Japan that the corrosion of reinforcing bars starts when the chloride ion concentration in concrete at the position of reinforcing bars is over 0.6 kg/m^3.

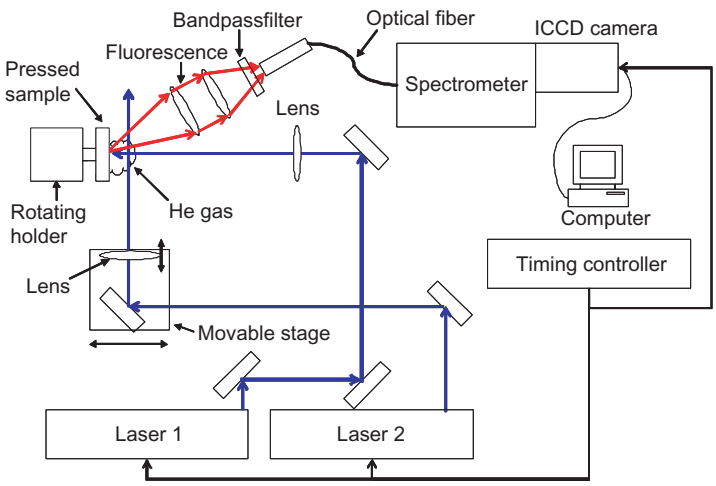

Fig.1 Experimental setup for LIBS measurement

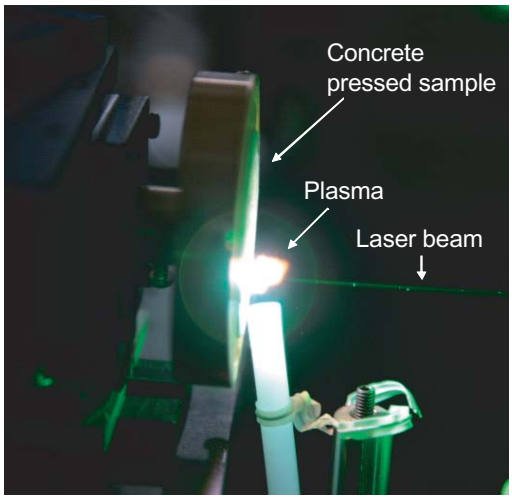

Fig.2 Plasma generation on pressed sample

Chlorine fluorescence in plasma generated by irradiation of the laser beam on the sample is measured. Laser 1 is used for the single-pulse measurement and laser 1 and 2 are used for the double-pulse measurement. Plasma is generated using laser 1, and atoms and ions in plasma are re-excited or re-heated by laser 2.

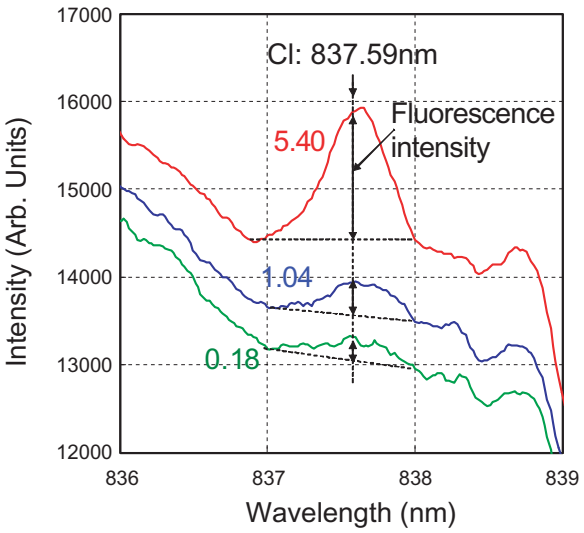

Fig.3 Dependence of chlorine fluorescence spectrum on chlorine concentration

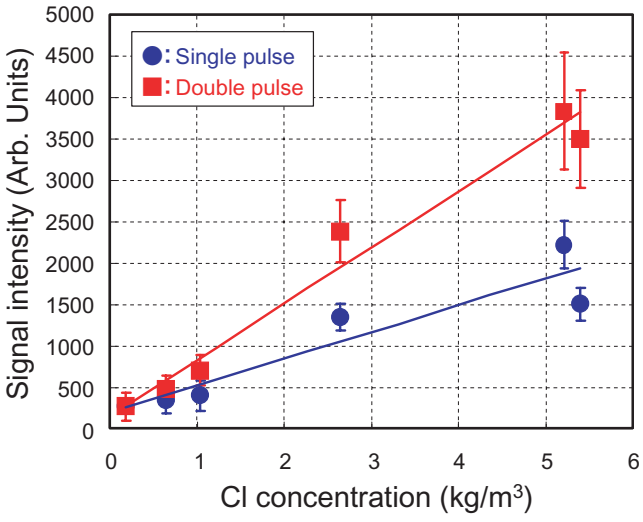

Fig.4 Dependence of chlorine fluorescence intensity on chlorine concentration

Signals from 500 laser pulses are accumulated, and 5 successive data points are accumulated for wavelengths. The numbers in the figure show chlorine concentration (kg/m^3).

Linearity between chlorine fluorescence intensity and chlorine concentration is verified for single- and double-pulse measurements.