Measurement of Chlorine Concentration in Concrete using Laser

Background

Since the durability of reinforced concrete structures is degraded due to the 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 the concrete structures. We are developing a method to measure chlorine concentration by using laser-induced breakdown spectroscopy (LIBS)*1 which enables on-site measurements with high speed and high spatial resolution*2. The measurement with high spatial resolution enables the prediction of chlorine penetration in the concrete structures with a high accuracy, which is useful for the lifetime estimation of the concrete structures.

Objectives

The purpose of this study is to evaluate the performance of LIBS measurement of chlorine concentration in concrete using concrete core samples.

Principal Results

A core sample with a diameter of 100 mm was picked out from a concrete plate (thickness: 200 mm) in which salt was penetrated from the surface. The chlorine concentration was measured by LIBS on the cross section of the core sample cut along the axial direction, and compared with the result measured by the potentiometric titration method.

1. The sensitivity of chlorine concentration measurement

The emission spectra were measured when the laser pulses were irradiated on the cross section of the core sample moving along the radial direction (Fig. 1). This measurement was repeated at intervals of 1 mm along the axial (sample depth) direction of the core sample, and the variation of the chlorine fluorescence intensity at the wavelength of 837.59 nm (Fig. 2) was measured. The results show that the chlorine fluorescence intensity can be measured with enough signal-to-noise ratio even for the concentration close to the detection limit by the potentiometric titration method (~0.2 kg/m^3).

2. Possibility of the chlorine concentration measurement with a high spatial resolution

The chlorine fluorescence spectra measured by LIBS were accumulated along the axial direction for each thickness of 5 mm in which the chlorine concentration was measured by the potentiometric titration method*3; the chlorine fluorescence intensity showed good linearity versus chlorine concentration (Fig. 3). These results show the possibility of the quantitative measurement of the chlorine concentration with a spatial resolution of less than 1 mm in the depth direction of the concrete structures (Fig. 4).

The above results show that the chlorine penetration profiles in the concrete structures can be quantitatively measured on site with high speed, high sensitivity and high spatial resolution by the LIBS measurements on the cross section of a core sample picked out from the concrete structures.

Future Developments

A method for the remote measurements of the chlorine concentration in concrete with high sensitivity will be developed.

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Reference

T. Fujii, et al., 2008, “Measurement of salt concentration in concrete by laser induced breakdown spectroscopy (II) – Performance evaluation of Cl concentration measurement using concrete core sample –”, CRIEPI Report H08012 (in Japanese)

*1：Laser-induced breakdown spectroscopy: A mehod to identify and quantitatively measure elements contained in a sample by the analysis of the fluorescence from plasma produced by focusing the laser bean on a measurement target.

*2：T. Fujii, et al., 2008, CRIEPI Report H07012 (in Japanese).

*3：A LIBS measurement of chlorine fluorescence was performed in a small region (diameter: ~0.2 mm) on the core sample cross section determined by the laser beam diameter after focusing, while the measurement of chlorine concentration by the potentiometric titration method was performed using a piece of the core sample cut along the axial direction with a thickness of 5 mm.

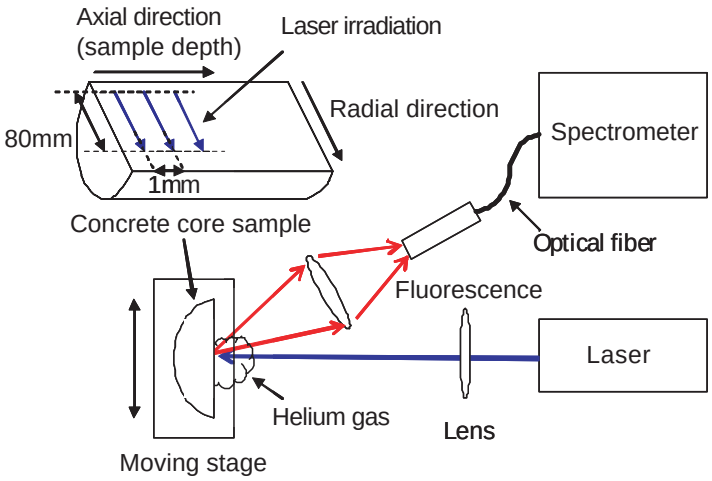

Fig.1 Experimental setup for LIBS measurement

Using helium as a buffer gas, the emission spectra were accumulated when 800 laser pulses were irradiated in the range of 80 mm on the cross section of the core sample moving in the radial direction. This measurement was repeated along the axial direction of the core sample at intervals of 1 mm.

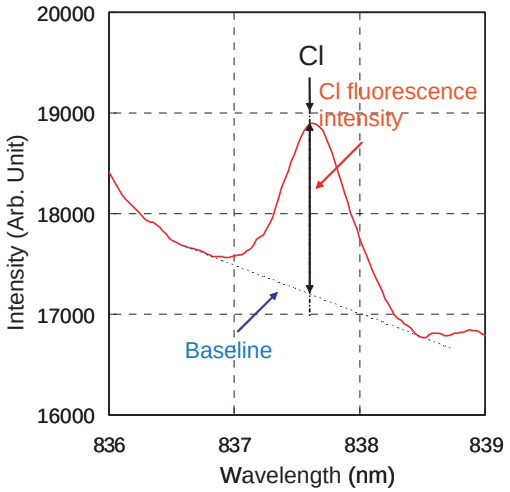

Fig.2 An example of chlorine fluorescence spectrum

A measurement for the chlorine concentration of 9.28 kg/m^3.

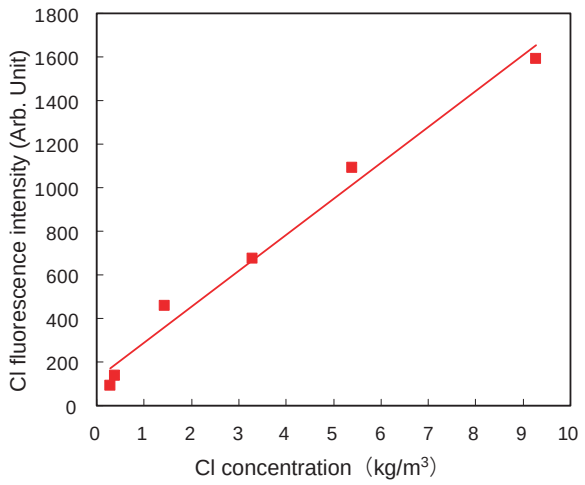

Fig.3 Chlorine fluorescence intensity versus chlorine concentration

Five chlorine fluorescence spectra measured by LIBS were accumulated along the axial direction of the core sample for each thickness in which the chlorine concentration was measured by the potentiometric titration method. The straight line shows the result of least-squares approximation for the measured value (■).

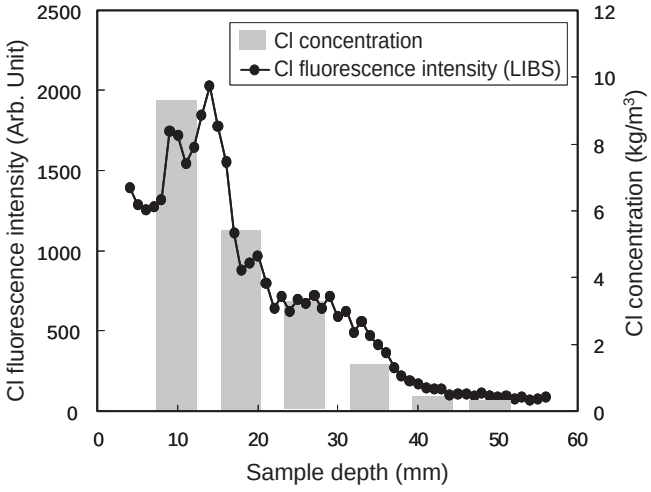

Fig.4 Chlorine concentration and chlorine fluorescence intensity versus sample depth

The chlorine concentration measurements using the potentiometric titration method were performed at intervals of 7~8 mm (averaged for 5 mm) along the axial direction of the sample, while the LIBS measurements were performed at intervals of 1mm.