Laser decontamination of high-strength concrete using a high-power fiber laser

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1. Introduction

Laser scabbling technologies coupled with a high-power fiber laser can be a convenient decontamination tool at nuclear decommissioning site due to high remote controllability [1]. It contribute to avoiding radiation exposure to human workers. This technology use the fact that the concrete intrinsically has a large number of pores and water. It is based on the concept that a high-powered laser beam as a heating source is irradiated onto concrete surface. Water particles in local heated area were quickly converted into vapor. In turn, it lead to rapid increase of vapor pressure at pores, resulting in explosive spalling on concrete surface.

In particular, high-strength concrete has a greater tendency to spall than normal-strength concrete when exposed to a high-powered laser beam. It is because high-strength concrete have a less porosity than normal-strength concrete [2]. The less porosity limits the movement of laser-induced vapors inside the heated concrete. It contribute to the rapid increase of pore pressure enough to trigger explosive spalling on concrete surface. In this study, we performed fiber laser scabbling experiment on high-strength concrete.

2. Experiment and Results

2.1 Laser scabbling system

A 10-kW fiber laser (IPG YLS-10000, λ=1070 nm) was incorporated into the laser scabbling system. A high-powered laser beam was fed via process fiber (core dia.: 150 µm, length: 20 m) into the optical scabbling head. The optical head contained a collimator (f = 160 mm), an aspherical lens (f = 300 mm), and a protection window. Its beam parameter product (spot size) was measured to be 7.05 mm·mrad (278 µm). The focused beam passed through the nozzle tip, whose diameters were 3.0 mm. The compressible air was simultaneously discharged from the nozzle while the diverged beam was irradiated on the concrete block. The stand-off distance was set to 950 mm for all trials. The stand-off distance was defined as the distance between the nozzle tip and the front surface of the concrete block. The concrete blocks with 300 mm × 300 mm × 80 mm were manufactured by mixing the ordinary Portland cement, water, sand, the crushed coarse aggregates. The water/binder of the concrete was 0.35. The compressive strength after curing was measured to be 60 MPa.

2.2 Results

A scabbling experiments on concrete block were performed under the condition of stationary 4.8 kW laser beam. Figure 1 shows the concrete block after laser interaction. The divergent laser beam of 76 mm diameter with 105 W/cm^2 was incident on concrete surface. The exposure time varied from 15 s to 25 s. Fig 1(d) shows the captured image in laser scabbling process under the condition of the 15 s exposure time of laser beam, as indicated by the red arrow. The pink light shown in Fig. 1(d) indicates the scattered laser light on concrete surface. The partial vitrification was observed on coarse aggregates under the stationary condition of laser beam at the exposure time of 25 s [3].

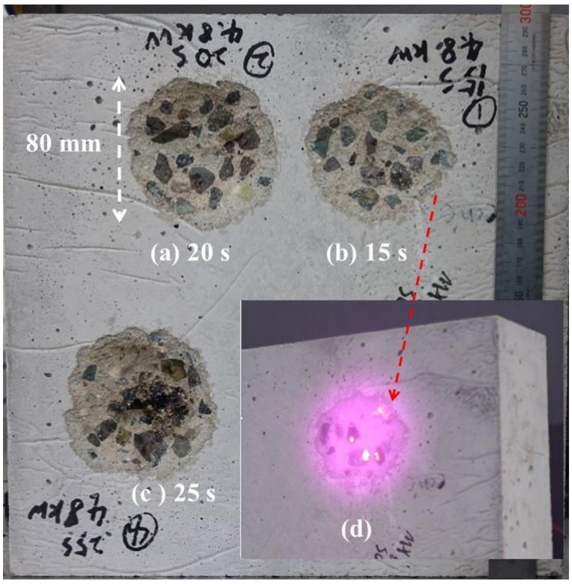

Fig. 1. (a)-(c) A concrete block after laser scabbling. Exposure time of laser beam was 15 s, 20 s, and 25, respectively. (d) Captured image in laser scabbling process under the condition of the 15 s exposure time of 4.8 kW laser beam.

The optical head was moved to peel off a large area of the concrete. The 4.8 kW laser beam with the speed of 300 mm/min was moved from left to right of the specimen for 200 mm length, after which, the beam was moved downward for 40 mm length. The laser beam was horizontally moved back from right to left for 200 mm length, as indicated by red arrows in Fig. 2(b). This process continues along the set route. Fig. 2(a) shows the concrete block after laser scabbling. With the knowledge of scan speed and the density of the concrete block, the spalling rate and depth were calculated using the difference in weight of concrete block before and after scabbling. The spall rates and depth were 62.5 cm^3/min and 4.3 mm.

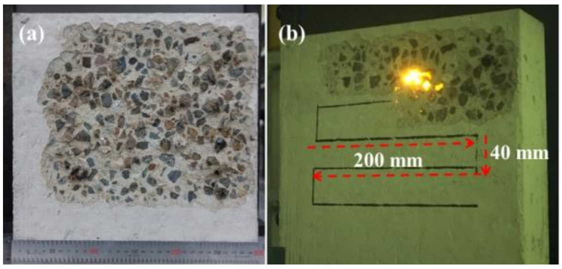

Fig. 2. (a) A concrete block after laser scabbling. (b) Captured image in laser scabbling process.

3. Conclusions

Laser scabbling experiment was conducted on the high strength concrete. We observed the frequent ejection of smaller fragments when irradiating high-powered laser beam onto the concrete surface. It is due to the fact that high-strength concrete have a less porosity and smaller pore size. It leads to a reduction in permeability that restricts the movement of laser-induced vapor, resulting in the rapid increase of pore pressures to trigger explosive spalling on concrete surface.

REFERENCES

[1] P. Hilton, The potential of high power lasers for concrete scabbling and pipe cutting in nuclear decommissioning, Technical report 19124/1/10 (2010), TWI Ltd, Granta Park,F.
[2] K. Metha and Monteiro P., Concrete, third ed. McGraw-Hill, 1993, chap. 2. p. 35–41.
[3] B. Peach, M. Petkovski, J. Blackburn, D.L. Engelberg, An experimental investigation of laser scabbling of concrete, Constr. Build. Mater. 89 (2015) 76–89.