XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Compressive Strength Improvement and Water Permeability of Self-Healing Concrete Using *Bacillus Subtilis* Natto

Nguyen Ngoc Tri Huynh[1], Kei-ichi Imamoto[2], and Chizuru Kiyohara[3]

[1] Department of Architecture, Tokyo University of Science (TUS), Japan, nnthuynh@hcmut.edu.vn
Department of Silicate Materials, Viet Nam National University Ho Chi Minh City (VNUHCM), Ho Chi Minh City University of Technology (HCMUT), Vietnam

[2] Department of Architecture, Tokyo University of Science (TUS), Japan, imamoto@rs.kagu.tus.ac.jp

[3] Department of Architecture, Tokyo University of Science (TUS), Japan, ckiyo@rs.tus.ac.jp

Keywords: *Self-Healing Concrete, Calcium Carbonate, Crack, Bacteria, Bacillus Subtilis Natto.*

1 Introduction

Despite advanced properties, concrete still faced many problems caused by cracks. In recent years, bacteria-based self-healing concrete can be a promising solution. In this study, *Bacillus subtilis* natto - Japanese microorganism, will be used to form $CaCO_3$ for the self-healing effect. The concrete structure can be enhanced, associated with the high mechanical resistance and high ability of water permeability. The biomineralization of bacteria immobilized in lightweight aggregate (LWA) was expected to improve the compressive strength of concrete specimens. A continuous water-flow testing system was investigated to access the water permeability of self-healing concrete.

2 Experimental Results

The LWA immobilized bacteria was prepared by immersing in the bacterial urea-$CaCl_2$-based solution. The continuous compressive strength improvement test was investigated for the concrete specimens using LWA immobilized bacteria and the controls (without bacteria). We used the value of 90 % of 7-day compressive strength to create the crack. The self-healing effect was expected to occur over curing time (7, 14, 28, and 60 days). The recovery of the compressive strength of concrete specimens can translate into the self-healing efficiency, and then gives information about the relation between self-healing capacity and curing time. Also, a water-flow testing system to evaluate the self-healing effect on water permeability was investigated for the complex behavior of healing fluid. The measured values of water flow after curing time were compared with the calculated values based on the Hagen-Poiseuille’s law.

Experimental results in this study indicate the following concluding remarks:

- Compressive strength after cracking could be improved (over 40 % higher than the controls just after 7 days of curing) in the case of using LWA immobilized bacteria. The healing capacity increased over curing time with the increase of compressive strength. The massive amount of self-healing products could be observed by using SEM/EDS/optical microscope, played an essential role in healing the cracks and densifying the concrete structure.

- The water permeability of specimens using LWA immobilized bacteria was significantly lower than the controls. Healing capacity increased with the decrease of water flow through cracks over curing time. Under microscopic observation, the surface cracks over 1.5 mm could be healed after 21 days, while the internal cracks were closed little by little over curing time.

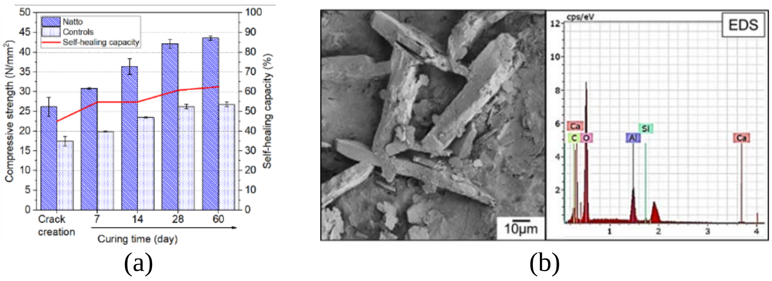

Figure 1. Compressive strength of concrete specimens in the continuous strength recovery test (a), and SEM/EDS result of precipitated $CaCO_3$ inside the crack (b).

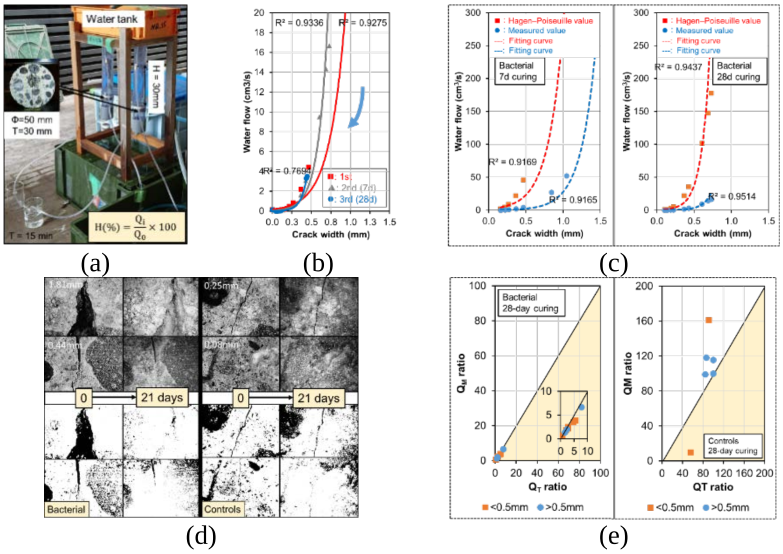

Figure 2. Water flow testing system (a). The change of water flow-crack width in bacterial specimens over time (b, c). Microscopic observation of crack width reduction (d). The relationship between the water flow by Hagen–Poiseuille's law (Q_T) and the measured water flow (Q_M) in the case of bacterial specimens, and the controls (e).

ORCID

Ngoc Tri Huynh Nguyen: https://orcid.org/0000-0003-2085-3564

References

Huynh, N. N. T., Phuong, N. M., Toan, N. P. A. and Son, N. K. (2017). Bacillus subtilis HU58 Immobilized in micropores of diatomite for using in self-healing concrete. Procedia Engineering, 171, 598–605.

Jonkers, H. M. (2007). Self healing concrete: A biological approach. In Self healing materials (pp. 195–204). Springer.

Jonkers, H. M. and Schlangen, E. (2008). Development of a bacteria-based self healing concrete. Proc. Int. FIB Symposium, 1, 425–430.