SELF HEALING OF FROST-DAMAGED CONCRETE INCORPORATING FLY ASH

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ABSTRACT

Cracks may occur at any stage in the life of a concrete structure. In cold regions, freeze and thaw are the most serious factors that can induce cracks. Furthermore, microcracks accelerate the diffusion of chloride ions and carbon dioxide into concrete. Repairing microcracks is an effective method for prolonging the service life of concrete structures.

It is well known that conventional concrete has a self-healing function [1], although the self-healing mechanisms are not fully understood. It is known that high-strength concrete contains unhydrated cement particles, microcracks can also be filled by hydrated products. It is also known that the reaction rate of fly ash is slower than that of cement [2]. After a structure has been built, the pozzolanic reaction of fly ash may continue, resulting in the formation of hydration products, which can then fill the cracks. While self healing of cracks in fly ash concrete is expected to occur, this property has not been fully utilized in optimizing the design of concrete materials.
The aim of this research is to develop a self-healing concrete design that incorporates fly ash for maintaining the durability of concrete structures in cold regions.

Sand was replaced by fly ash in 15% cement by weight. The water–Portland cement ratio was 0.5. Concrete was also prepared without fly ash. The Air entrained concrete and non air entrained concrete were prepared. The concretes were cured in water for 28 days, 91 days and 356 days at 20°C. After curing, the concrete was deteriorated by accelerated freeze-thaw until the relative dynamic modulus of elasticity reduced to 80%. The specimens were then cured in water at 40°C for 28 days.
The relative dynamic modulus of elasticity and the carbonation coefficient (obtained from an accelerated carbonation test result) were adopted by the index for evaluating the healing effect, and a

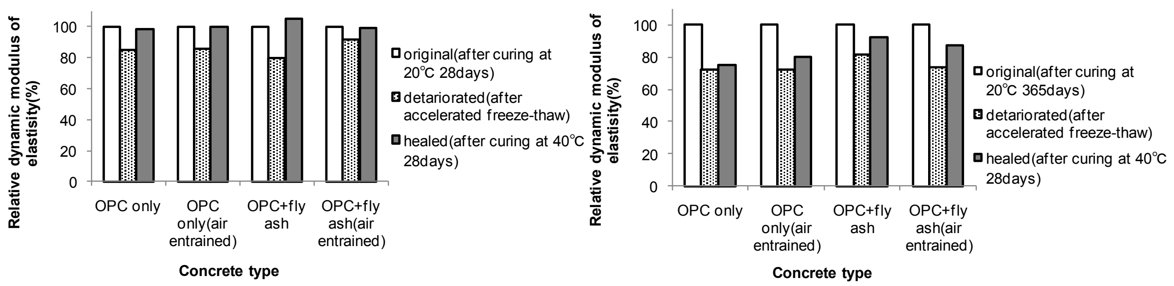


Figure 1: Change of relative dynamic modulus of elasticity by accelerated freeze–thaw and healing

microscope was also used to perform crack observations.

Figure 1 shows the changes in the relative dynamic modulus of elasticity due to the accelerated freeze–thaw process and after healing. Before examination, the specimens were cured for 28 days. For all concrete types, the dynamic modulus of elasticity recovered after curing at 40°C. In the case of the concrete that incorporated fly ash, it was observed that on curing for 365 days at 40°C, the dynamic modulus of elasticity had recovered.

The relationship between age of the concrete (after carbonation has begun) and carbonation depth can be approximated by the follow equation.

$$x = k\sqrt{t} \tag{1}$$

where x is carbonation depth (mm), k is carbonation coefficient and t is time (weeks).

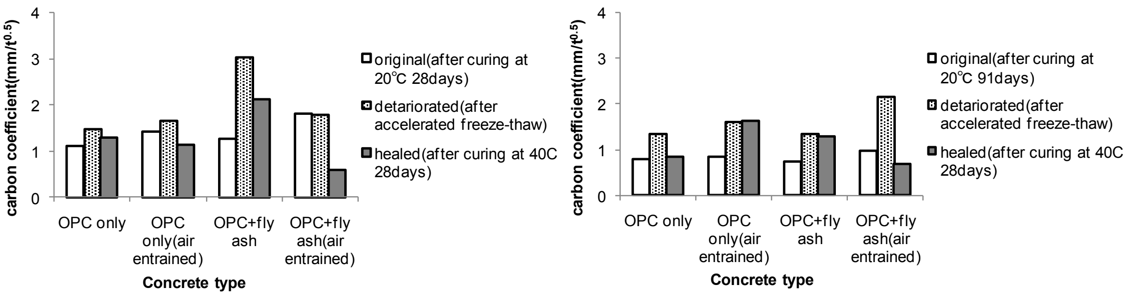
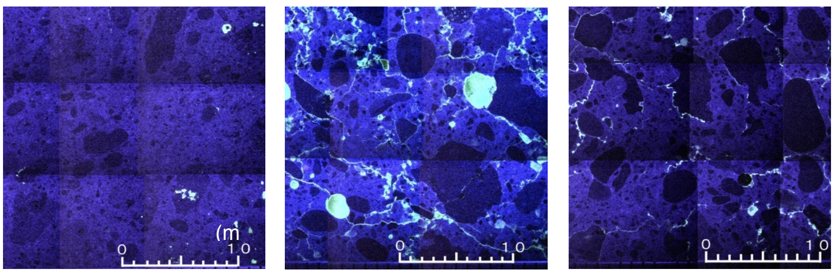


Figure 2: Change of carbon coefficient by accelerated freeze–thaw and healing

Figure 2 shows changes in the carbon coefficient resulting from the accelerated freeze–thaw and healing processes. After being cured for 28 days at 40°C, the carbon coefficient had recovered in all types of concrete. In particular, the carbon coefficient recovery in the concrete that had incorporated the fly ash was significant. When the specimens were first cured for 91days, there was also significant carbon coefficient recovery in the air entrained concrete, which incorporated fly ash.

Figure 3 shows microcracks observations using a microscope. The microcracks were penetrated by fluorescent paint and observed using a microscope and ultraviolet light. In the original concrete, no cracks were observed but in the concrete that had deteriorated and took the shape of a net. In the healed concrete, there were fewer cracks. From these results, we were able to verify the self-healing effect of concrete incorporating fly ash.



original deteriorated healed

Figure 3: Crack observation using a microscope (incorporating fly ash)

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