Modelling for Frost Damage and Life Cycle Prediction

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Summary

This paper presents modelling of frost-damaged concrete in meso and macro scale. The meso scale modelling can simulate degradation of mechanical and transport property by frost damage which affects various structural performances. Prediction of life cycle of frost-damaged structures is possible by the meso scale modelling which clarifies frost damage mechanism.

Keywords: Concrete, frost damage, degradation, mechanical property, diffusivity, meso scale, RBSM, durability design, life cycle prediction.

1. Introduction

Frost damage induced by freeze thaw cycles (FTC) is a major cause of degradation in concrete structures. This is a physical damage with cracks, scaling and pop-out resulting in degradation of appearance, durability and mechanical property. Durability design which provides prediction method for service life (or chronological change in performance) of structures, for frost damage is far behind those for chloride ion ingress and carbonation. While prediction methods for the period before corrosion initiation due to chloride ion ingress or carbonation are common in many existing durability designs, no rational prediction method of chronological change in structural performance is available for frost damage.

The rational durability design for frost damage is not available due to the fact that there has been no index which directly reflects degradation in structural performance induced by frost damage nor the method to predict chronological change of the index. For carbonation, the index is carbonation depth whose chronological change can be predicted by a formula. For frost damage, however, neither index nor formula for its chronological change is available at present.

In this paper recent studies on mechanical and transport property degradation induced by FTC and its simulation schemes are introduced. Then the expected development for life cycle prediction of concrete structure with frost damage is presented for a more rational durability design.

2. Properties of concrete with frost damage and their simulation

2.1 Experimental results [1][2][3]

In order to obtain experimental evidences on degradation of mechanical properties in frost-damaged concrete, we conducted FTC tests using cylinders and prisms in a climate controlled chamber. The chamber is equipped with not only temperature control and water spray apparatus but also actuator, enabling us to conduct loading and fatigue tests inside. Figures 1 and 2 show the test chamber and specimens. Table 1 shows details of the specimens. The FTC test was conducted under water with the ASTM method (test procedure A) or in open air with spraying water during thawing in the climate chamber (test procedure B). We measured the temperature and the strains at various locations in each specimen (see Figure 2). The measured strain and temperature enabled us to understand frost damage mechanism [1]. The measured strain was also used to verify the reliability of the numerical simulations described in the sections 2.2 and 2.3.

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