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Measurements of strain and humidity within massive concrete cylinders related to the formation of ASR surface cracks

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ABSTRACT

This study aims at proving the validity of a notion that the formation of non-expansive near-surface layer is responsible for surface cracking in ASR-affected concretes by a laboratory experiment. Relationship between the progress rate of the front of non-expansive layer toward inner portions and the formation of the first surface cracks was scrutinized by measuring relative humidity (R.H.) values and strains within a massive concrete cylinder (ϕ450 mm × 900 mm) with reactive aggregates under a dry environment. It was presumed from the measurements that a non-expansive layer of about 40 mm had been formed at the first cracking. Thereafter, the environmental humidity was raised to >95% R.H. Pursuit of the growth of surface cracks and subsequent measurements of strains and R.H. values within the concrete cylinder under the moist environment suggested that the re-saturation continuously gave rise to the generation of tensile stresses in near-surface regions leading to active extension of surface cracks.

1. Introduction

Stark [1] revealed that ASR expansion did not occur below the 80% R.H. He also investigated moisture conditions within ASR-affected field concrete structures. On the basis of these results, Stark [1] insisted that stresses induced by differential volume changes confined to near-surface regions were responsible for surface cracking in ASR-affected concrete structures.

Idorn et al. [2] proposed a similar concept for ASR surface cracking on a concrete member exposed to natural environments. Recently, Hagelia [3] suggested that surface stresses caused by differences in expansion between internal and near-surface regions lead to surface cracking. However, detailed processes from the initiation of ASR expansion to the first surface cracking and subsequent extension of the cracks in ASR-affected concretes subjected to wetting–drying repetitions in natural environments are not clear. Thus, the validity of a notion that the formation of non-expansive layer is responsible for surface cracking in ASR-affected concretes has not been proven by laboratory experiments.

The main objective of this study is to prove the validity of the notion by an experiment. Relationship between the progress rate of the front of non-expansive layer toward inner portions and the formation of the first surface cracks was scrutinized by measuring relative humidity (R.H.) values and circumferential strains at various depths from surfaces in a relatively massive concrete cylinder made with reactive aggregate in a dry environment (the drying process). Heavily cracked surfaces found in field ASR-affected concrete structures are supposed to be brought about by wetting–drying repetitions. Then, after a steady state in strain vs. time relation within the cylinder had been attained in the drying process, the environmental humidity was raised to >95% R.H. to simulate wetting–drying repetitions (the re-saturating process). Further extension of surface cracks in the re-saturating process was pursued measuring R.H. values and strains within the concrete cylinder.

Taking into consideration the fact that a strain measured at a given portion within concrete cylinders was not ASR expansion itself, we carefully discussed relations between time-dependent changes in strain and relative humidity value, and surface cracking. A reasonable interpretation for the suppression of ASR deterioration in field concrete structures by drying can be expected from the results obtained.

We also tried to calculate a critical ASR expansion at the first surface cracking using a thickness of non-expansive layer obtained in this experiment by a simple calculation method proposed by the second author [4].

Alkali leaching contributes to reduce expansion in the near-surface regions in concrete submitted to high moisture environment. However, effects of alkali leaching on the formation of non- or less expansive regions in concrete cylinders were not taken into consideration in this study.

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