

Modeling the effect of drying shrinkage-induced damage on coupled moisture and chloride transport in concrete structures

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Abstract

Long-term durability of large scale concrete structures such as bridges, dams, and nuclear power plants is an important issue in civil and structure engineering. The damage of concrete structures induced by drying shrinkage is one of the deterioration factors that could have a significant influence on the durability of the concrete structures. The damage in the concrete induced by the drying shrinkage can be in the form of microcracks and small voids that can provide easy pathways for moisture and aggressive chemicals such as chloride to penetrate into the concrete, which can, in turn, cause more damage. This paper presents a numerical model developed to simulate the effect of damage induced by drying shrinkage on the coupled moisture and chloride transport in the concrete. The simulation model can then be used to predict the long-term performance of the concrete structures.

The simulation model was developed by considering the interactive mechanisms among the shrinkage induced by drying process, the damage induced by the shrinkage strain, and the acceleration of the coupled chloride-moisture transport due to the cumulated damage. The model was formulated based on chemo-hygro-mechanical analysis of fully coupled partial differential equations. The transport parameters of the model takes into account the effect of concrete design and processing parameters such as water-to-cement ratio, curing time, types of cement and the aggregate content on transport properties. The shrinkage strain of concrete is calculated based on a multiphase composite model for concrete. The effect of shrinkage induced damage on mechanical properties of concrete is characterized by damage mechanics. The interaction between the damage and the diffusion coefficients is considered by using the concept of cross property correlation, while the effect of damage on the moisture capacity is evaluated by a composite model for effective moisture capacity of a two-phase composite.

A finite element program was developed to solve the coupled partial differential equations. An numerical example was used to demonstrate the effect of the drying shrinkage induced damage on the coupled moisture and chloride transport process in a concrete structure. The result of the numerical simulations revealed that the drying shrinkage accelerates the transport process in concrete. The results were validated with the available test data in the literature.

Keywords: Drying shrinkage, Damage; Chloride penetration; Moisture diffusion; Modelling.