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Effect of crack width on chloride diffusion coefficients of concrete by steady-state migration tests

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ABSTRACT

The purpose of the present study is to explore the diffusion characteristics of cracked concrete according to the width of cracks. Major test variables include crack width, concrete strength, fly ash addition, and maximum aggregate size. The diffusion characteristics have been measured by steady-state migration test. The present study indicates that the diffusion coefficients do not increase with increasing crack widths up to the so-called “threshold crack width.” The threshold crack width for diffusion is found to be around 55–80 μm. Above this threshold value, the diffusion coefficients start to increase with crack width. A composite model with the introduction of “crack geometry factor” was derived to identify the diffusion coefficient in cracked concrete. It was shown that the crack geometry factor ranges from 0.067 to 0.206. Finally, the effects of concrete strength, fly ash addition and maximum aggregate size on diffusion coefficients are also discussed.

1. Introduction

Corrosion of steel reinforcement in concrete due to chloride ions is one of the major causes of deterioration of concrete structures in marine environment or subjected to deicing salts. Thus, the prediction of chloride penetration into concrete has been an important issue in the design of concrete structures for the last several decades, and studied by a number of investigators [1–10]. However, the previous researches have been mostly focused on the chloride transport in sound uncracked concrete. On the other hand, cracks are inevitable in most concrete members due to the weakness of concrete in tension and these cracks may affect greatly the diffusivity of chloride in concrete. Therefore, the effect of cracks on chloride transport must be considered realistically for more reliable design of concrete structures especially under chloride environment. Furthermore, to make more economical and reliable structures, the performance-based design is strongly requested recently. To cope with this request in design, the accurate prediction of the performance of structures is an essential task. If the effect of cracks is not considered realistically in the durability design, the performance and service life of concrete structures may be overestimated which may lead to an unexpected premature failure of structures.

In this paper, therefore, the diffusion coefficients of cracked concrete have been studied to clarify the change of diffusion coefficients according to crack width. The steady-state migration test was employed to measure the diffusion coefficients. Crack width was selected as a main test variable, and a crack of desired width was induced by the controlled split test in the laboratory. Based on the test data, the relationship between crack width and diffusion coefficient is analyzed. The compressive strength of concrete, addition of fly ash and maximum aggregate size were also chosen as test variables in order to explore the effects of these parameters on the diffusion of cracked concrete.

2. Review of previous researches

The effects of crack on transport properties have been studied by several researchers [11–18]. According to Gérard et al. [15], the permeability can be highly increased over 100 times by damage of concrete. The transport properties of cracked concrete may be estimated based on the damage or fracture mechanics, if the quantitative relationship between the transport properties and the cracking of concrete can be established. Some researchers have tried to correlate the transport properties of cracked concrete to the loading level or tensile stress of concrete [19–21], or to the inelastic strain of concrete [15]. However, it is difficult to obtain the quantitative relationship between the loading level, tensile stress or tensile strain and the transport properties because the characteristics of cracking becomes different according to the types of loading such as tension, compression, flexure and combined loadings. Therefore it seems more appropriate to directly correlate the transport properties and the crack width.

Wang et al. [18] and Aldea et al. [11,12] have tried to relate the permeability directly to the crack width measured from the feedback

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