Evaluation of permeability of concrete specimens affected by chloride attack using reconstruction and probabilistic description methods

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Summary
The spatial distribution of constituents in concrete affects the material performance, and voids present in cast concrete significantly affect permeability and durability because most of the air and water are passed through voids inside the material. Therefore, a proper investigation of the void distribution inside concrete is important to evaluate and understand material characteristics. To visualize and investigate the spatial distribution of voids in a concrete specimen, X-ray CT images and probabilistic description methods including reconstruction were used in this study. Additionally, a virtual concrete specimen was reconstructed using the probabilistic information of real specimens, and the permeability of each specimen was evaluated using finite element simulation, and compared with experimental data. From the results, we confirm that the proposed reconstruction method can effectively generate a virtual cement paste specimen with a specific void distribution.
Keywords: concrete; permeability; void distribution, probability functions, reconstruction

1. Introduction
Concrete is a multi-phase material, and its material properties are significantly affected by spatial distributions of phases. Especially, the void distribution in concrete strongly affects its physical properties, such as permeability and thermal conductivity; therefore, an appropriate method is essential to identify the spatial distribution of voids. In this study, to investigate and quantify the spatial distribution of voids inside the concrete specimen, a computed tomography (CT) image and low-order probability functions are employed. To obtain a series of concrete specimens with statistically identical characteristics with different void clusters, reconstruction is performed using an optimization process. The similarity between material responses, such as the permeability of the original and reconstructed samples, is verified using finite element simulation.

2. CT imaging and the void distribution analysis
In this study, cement paste specimens with two kinds of water/cement ratios (W/C) were used to evaluate the void distribution inside the material. The specimens are prepared using ordinary Portland cement (OPC) with 65% and 40% W/C ratios. To describe the void distribution inside the specimens, the CT imaging procedure illustrated in Figure 1 was utilized.

Low-order probability functions, such as two-point correlation, lineal-path, and two-point cluster functions, were adopted to examine the characteristics of the void distribution in the cement paste specimens with different void ratios. For further understanding of the void distribution in the material, tortuosity of the specimens was also evaluated in this study.

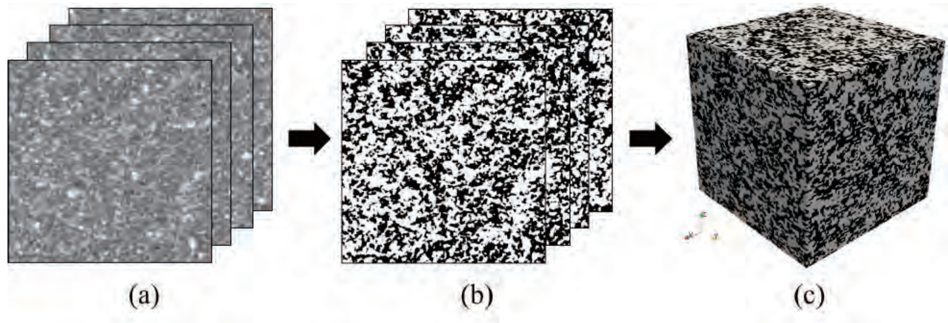

Figure 1. CT imaging process of a cement paste specimen: (a) 16-bit CT image, (b) Binarized image, (c) 3D binary specimen

3. Reconstruction and permeability of the cement paste specimens

Here, the reconstruction method with low-order probability functions was introduced to generate a virtual cement paste specimen. In this study, the reconstruction method used by Chung and Han [1] was implemented to reconstruct the virtual cement specimen. The objective of the reconstruction in this study was to generate the virtual cement specimen with a void distribution gradient for a specific direction. Air permeability of the real and reconstructed specimens was also evaluated using finite element analysis to investigate the material responses of the specimens with different void distribution. In this study, the finite element simulation was conducted using ABAQUS software. A numerical simulation was conducted to estimate the permeability of OPC40, OPC65, and the reconstructed specimens.

4. Conclusions

In this study, the characteristics of the void distribution inside cement paste specimens were described using CT imaging, and probability functions, namely, two-point correlation, lineal-path, and two-point cluster functions. In addition, tortuosity was used to characterize the permeability of the specimens with different void ratios. In addition, the permeability of the specimens with different void ratios was evaluated using finite element analysis to investigate the effect of the void distribution on the material response. It was confirmed that the reconstructed specimen with a gradient void distribution that exhibit reasonable material responses could be effectively generated using probabilistic information of the specimens with different void ratios.

Acknowledgements

This research was supported by a Korea Research Foundation Grant funded by the Korean Government (KRF-2011-0029212 and KRF-2012R1A1A2006629). This work was also supported by the Industrial Strategic Technology Development Program (10041589) funded by the Ministry of Knowledge Economy (MKE, Korea).

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