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A Probabilistic Model for the Evolution of Porous Structure Caused by Solid-Phase Precipitation/Dissolution within Building Materials

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1 Main Idea

Saline intrusion is a critical issue in building material because of the severe damages caused by the salt precipitation/dissolution process, especially for the porous material, which has good connectivity (Huang *et al.,* 2015). When porous material is exposed to aggressive ambient, the pore structure, not only porosity but also pore size distribution (PSD), will be altered by salt precipitation/dissolution (JR Nimmo, 2013). As one of the most significant characteristics in the porous material, pore size distribution is always paid much attention in many literatures. However, a quantitative and practical determination method is still absent.

This work aims to establish a probabilistic model to investigate the pore size distribution induced by solid-phase precipitation/dissolution. First, a lognormal distribution is proposed for the simulation of initial pore size distribution tested by the mercury intrusion porosimetry (MIP) method. Then we develop a probabilistic-based porous network to represent the evolution of microstructure due to precipitation/dissolution. To this end, two different transformation models are constructed to interpret the relation between initial pore radius and modified pore radius before and after precipitation/dissolution. With the probabilistic methods and transformation models, we could illustrate the precipitated profiles evolves near the capillary interface during the process of salt precipitation/dissolution for a given porosity and water saturation degree. Such a method could be used to interpret the mechanism of the local precipitation/dissolution process in pore scales, which cannot be implemented by experimental measurements.

2 Methodologies

Figure 1 gives us profiles of two different transformation models between initial pore radius and modified pore radius with the influence of salt precipitation/dissolution. Figure 1a presents a monotonic model of pore radius, in which the salt precipitates within all the unsaturated pores. In contrast, for the non-monotonic transformation model shown in Figure 1b, the salt precipitation occurs mainly near the capillary interface.

Moreover, we have the initial probability density function $P_0(r_0)$ that obeys to the lognormal distribution and two transformation models for pore radius, the new PDF P_{n+1} for n+1th transformation could be determined by the following two methods, which are shown in

Table 1. Note that ϕ_n is the global porosity for the nth time of transformation; r_n is the transformation model for the nth time of pore radius.

Table 1. Two probabilistic methods and their properties.

Probability Density Function	Method one	Method two
P_{n+1}	$\left\|\left(\frac{dr_{n+1}(r_n)}{dr_n}\right)^{-1}\right\| P_n(r_n)$	$\frac{\phi_n}{\phi_{n+1}}\frac{r_{n+1}(r_n)}{r_n}P_n(r_n)$

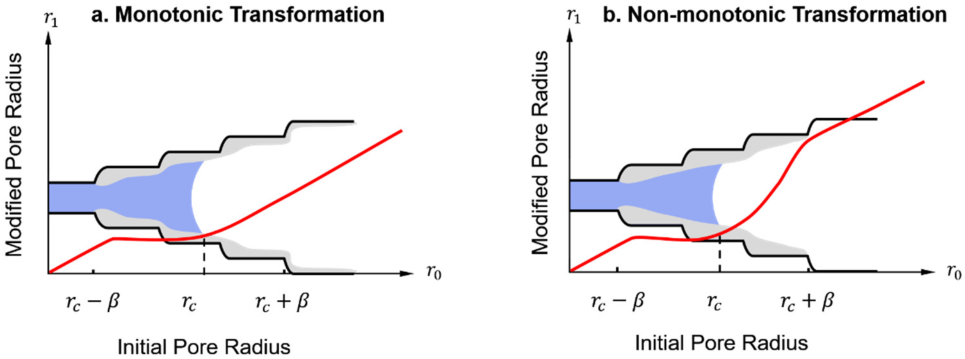

Figure 1. Two transformation models of pore radius due to solid-phase precipitation/dissolution (r_c is the maximum aperture filled with water, the so-called waterfront or capillary interface; β is the opening zone, indicating the extent of solid precipitation/dissolution).

3 Conclusions

In studying the evolution of porous structure ascribed to the precipitation (pore filling) and dissolution (pore emptying) of a solid phase in the porous medium, we applied two different probabilistic methods to realizing the transformation between probability density functions of initial PSD and modified PSD. Accordingly, two kinds of transformation laws were constructed as the bridges connecting the relationships between the initial and modified pore radius. By using the two methods, we could estimate the porous filling rate as well as the water saturation degree induced by salt precipitation/dissolution.

For further investigation, proper consideration for the mobilization of waterfront in a closed system should be taken into account to fully understand the evolution of microstructure in the durability research for a porous material.

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