1. Introduction

One of the greatest threats to steel reinforcement in concrete is chloride ions. The chloride ions may enter concrete from the external environment via various mass transport processes such as diffusion due to concentration gradient, migration due to electrostatic potential gradient, and convection due to pore pressure gradient. In order to ensure a RC structure works properly in its service life, one has to understand how chloride ions transport in concrete and how to remove them from concrete before they reach to the threshold value able to induce reinforcing steel corrosion. In this study we developed a double-porosity model for describing chloride transport in concrete and a multi-phase transport model for taking account the effect of concrete pore micro-structure on chloride transport, and an electrochemical chloride removal model to demonstrate the effectiveness of electrochemical treatment in removing chlorides from concrete.

2. Double-porosity modelling of chloride penetration in concrete

The double-porosity model was developed based on the concept that the concrete pore system has varying pore sizes, ranging from micro-capillary pores to nano-scale C-S-H gel pores. The pores of different sizes have different transport properties (see Fig.1). Thus the use of two porosities in the transport model can more accurately represent the transport behavior of concrete.

3. Multi-phase modelling of chloride penetration in concrete

Concrete can be treated as a composite with three phases, namely aggregate, ITZ (a thin-layer surrounding the aggregate), and cement paste (see Fig.3). Compared with the cement paste and ITZ, the aggregate is much dense and has much high resistance to the transport of ions and therefore can be assumed to be impermeable. The cement paste- and ITZ-phases can be treated as two individual porous materials with different transport properties.

4. Electrochemical chloride removal

When a direct current is applied between the reinforcing steel acting as a cathode and an external anode mesh attached to concrete surface (see Fig.6), negative charged ions (Cl and OH) will move towards to anode and positive charged ions (Na and K) move towards to cathode due to the action of electrostatic potential. In addition, electrochemical reactions taking place at cathode will produce OH ions and thus the alkalinity of pore solution is also boosted. Fig.7 demonstrates the reduction of Cl ions and the increase of OH ions around the steel bar acting as a cathode with increased treatment time.

5. Conclusion

- The pore size effect on ionic transport in concrete can be modelled by using double porosities, which have different transport properties.
- The aggregate has two opposite effects on chloride transport. One is that it increases the tortuosity which slows the transport of ions in concrete; the other is that it produces ITZs which accelerates the transport of ions in concrete. The near effect of it depends on the volume fractions of aggregates and ITZs.
- Chlorides in concrete can be removed by using the electrochemical method. However, the performance of the process depends on the location of cathode, the position of anode, the magnitude of applied current density, and the time of treatment.