

Evolution of waterproof performance, mechanical properties, and microstructure in hydrophobically-modified geopolymer concrete during dry-wet cycles

Dong-ming YAN¹, Yi-lu QIU¹, Rong-feng GAO¹, Shi-kun CHEN¹, Yi LIU², Sheng-qian RUAN^{1*}

¹ College of Civil Engineering and Architecture, Zhejiang University, Hangzhou 310058, China

² School of Materials Science and Engineering, Zhejiang University, Hangzhou 310058, China

*E-mail address: shengqian_ruan@zju.edu.cn (S. RUAN)

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1 Introduction

- ◆ The existence of a substantial quantity of uncondensed hydroxyl groups in geopolymer matrix, coupled with the rich capillary pore structure, imparts conventional geopolymers with remarkable hydrophilicity and water absorption.
- ◆ Our previous research found that the incorporation of PDMS and SMS can also reduce the early-stage shrinkage of MK-based geopolymer, and reduce the structural stress generated by unsaturated water inside the material.
- ◆ Nevertheless, research on geopolymers after hydrophobic modification with PDMS or SMS has primarily focused on synthesis methods or performance analysis within laboratory settings. There is a lack of study on modified geopolymers used in real building materials, and their suitability for engineering applications.

2 Materials and experimental methods

- ◆ The materials of ordinary geopolymer concrete (OGC) including metakaolin, alkaline activator (sodium silicate solution and sodium hydroxide solid), water, sand, and CA. The preparation processes of the OGC, PGC, and SGC samples were slightly different.
- ◆ The experimental methods include water absorption, chloride transport depth, dry-wet cycles, water contact angle, compressive strength measurement, fourier transform infrared spectroscopy, scanning electron microscopy and mercury intrusion porosimetry.

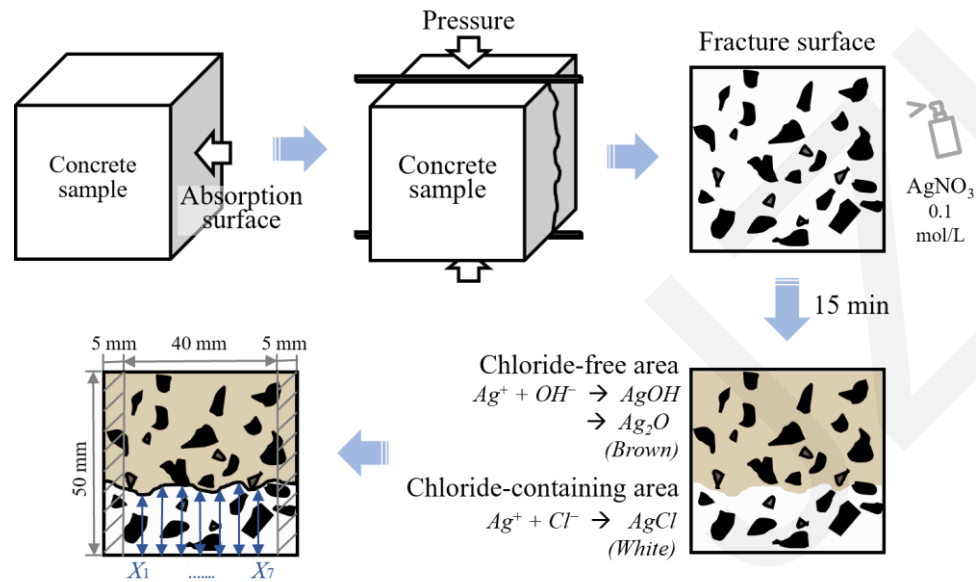


Fig. 2 The measurement procedure for chloride transport depth in geopolymer concrete samples

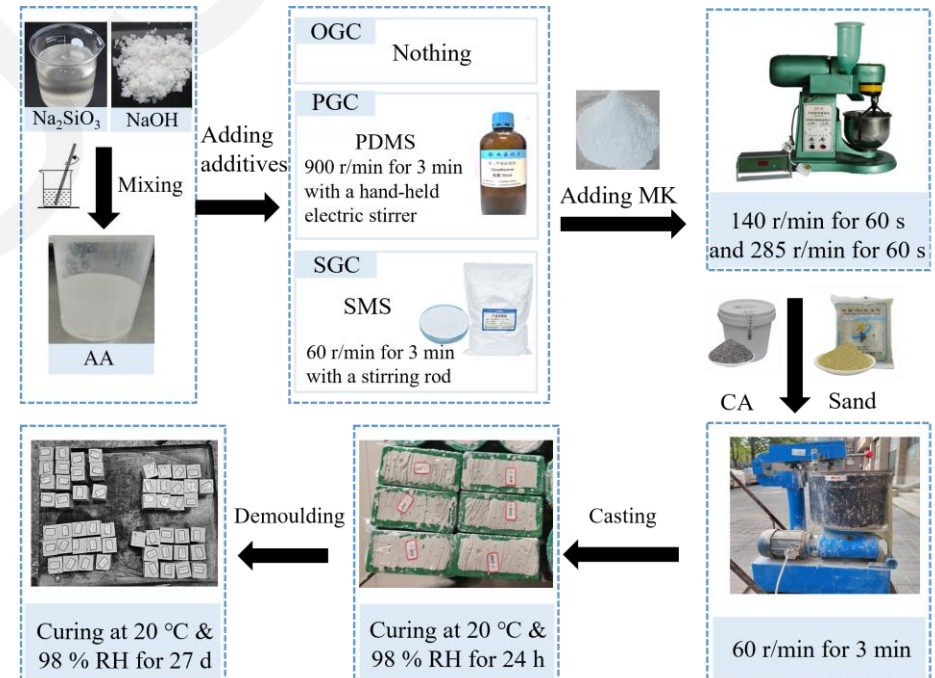


Fig. 1 Preparation processes of OGC, PGC, and SGC samples

3 Results

◆ Water absorption behavior

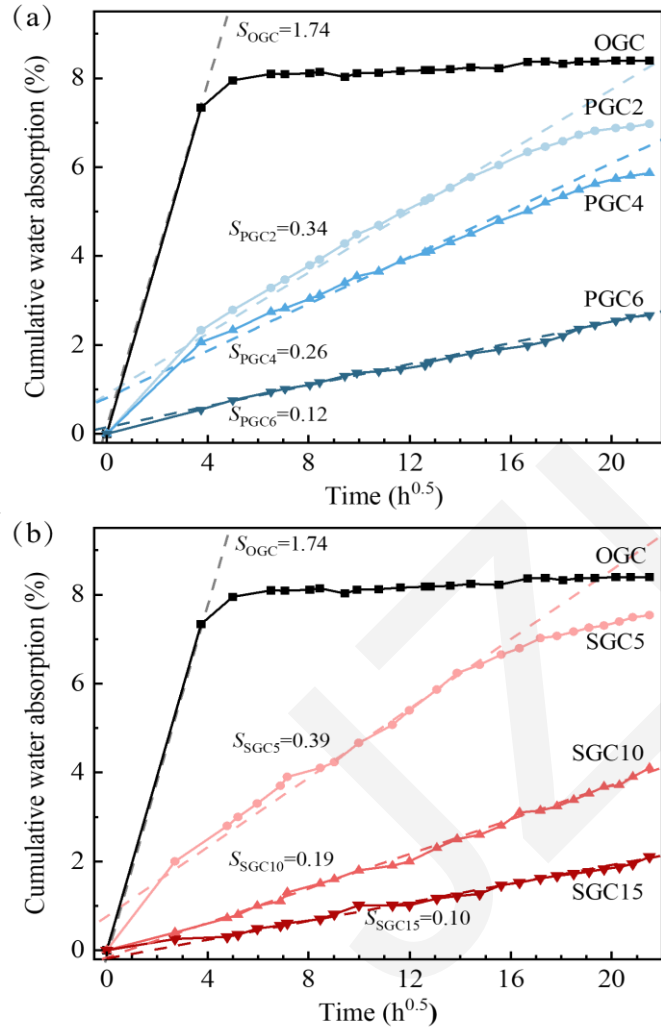


Fig. 3 Time-evolution of the cumulative water absorption of OGC, (a) PGC, and (b) SGC samples

◆ Chloride transport depth

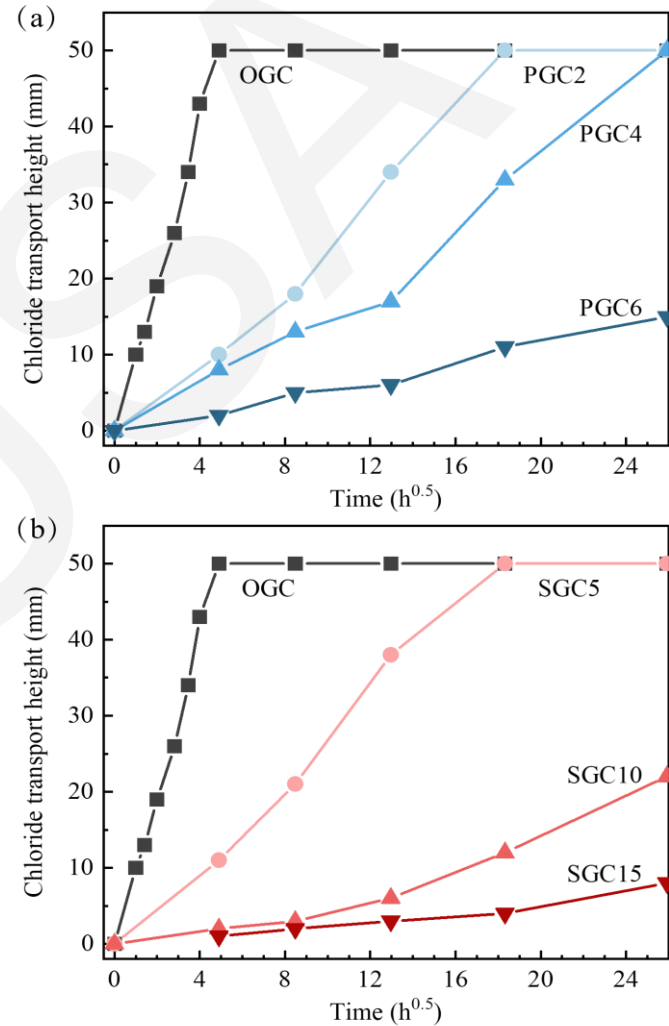


Fig. 4 Time-evolution of the chloride transport depth of OGC, (a) PGC, and (b) SGC samples

3 Results

◆ Dry-wet cycles

◆ Over the course of 32 cycles, the PGC samples maintain efficient water repellence. The average water content gains of OGC, PGC2, PGC4, and PGC6 samples through absorption were 7.1%, 5.6%, 5.0%, and 3.0%, respectively.

◆ Although SGC samples also show effective long-lasting waterproof performance, the single water absorption contents of SGC5 and SGC10 samples exhibit an obvious increasing trend as the dry-wet cycle proceeds.

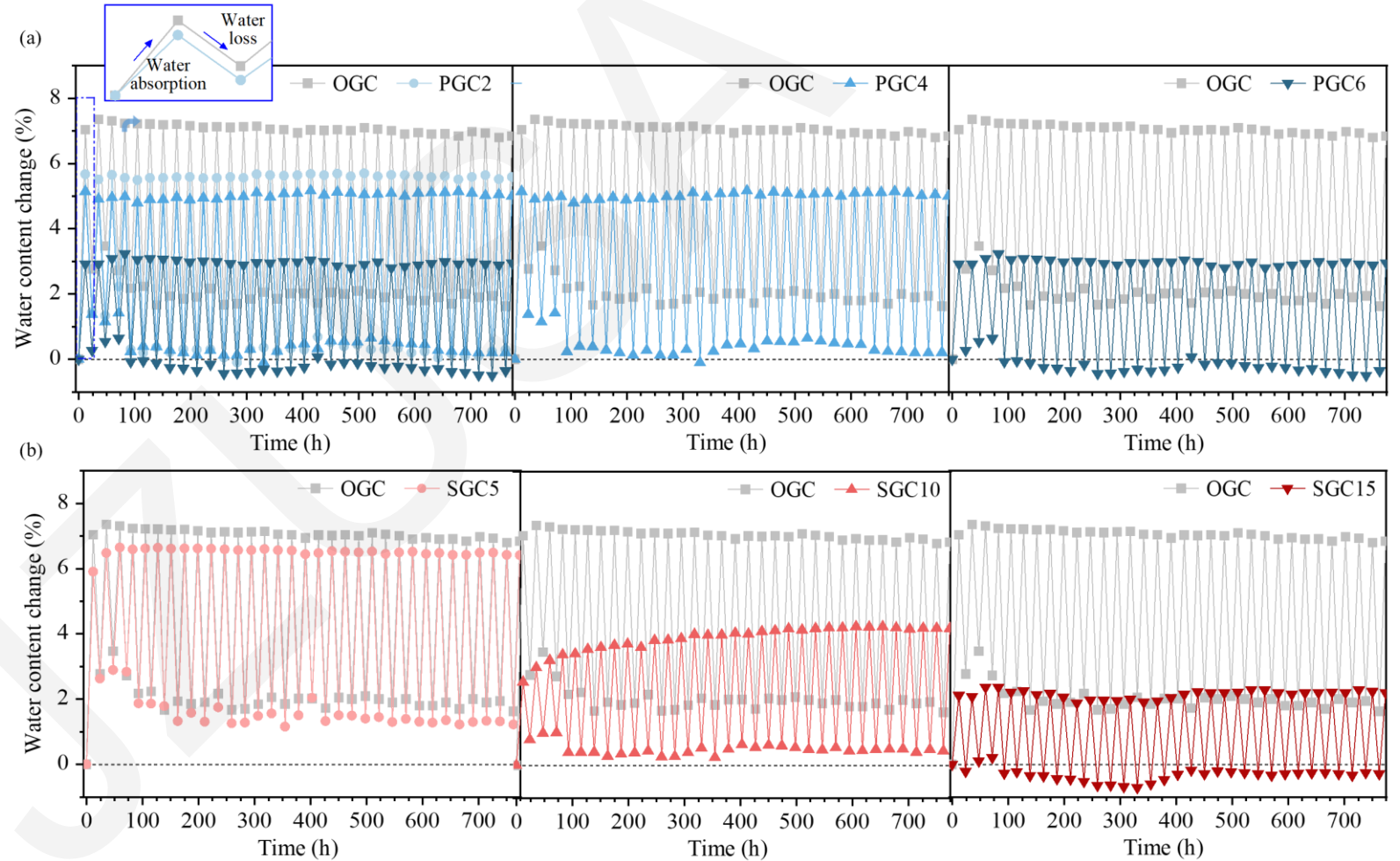


Fig. 5 Water content change of OGC, (a) PGC, and (b) SGC samples during 32 dry-wet cycles

3 Results

◆ Apparent water absorption

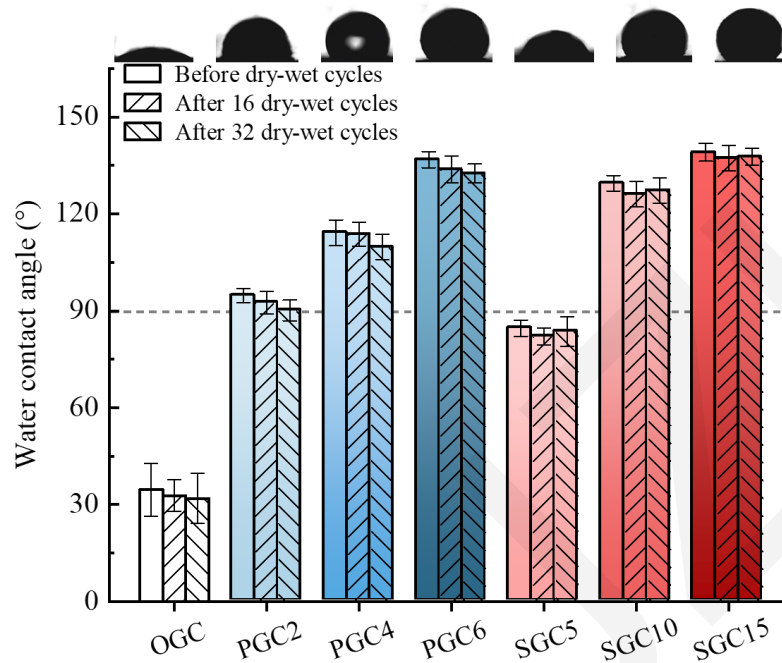


Fig. 8 Water contact angle of the pressed matrix powder from OGC, PGC, and SGC samples before and after dry-wet cycles

◆ Compressive strength

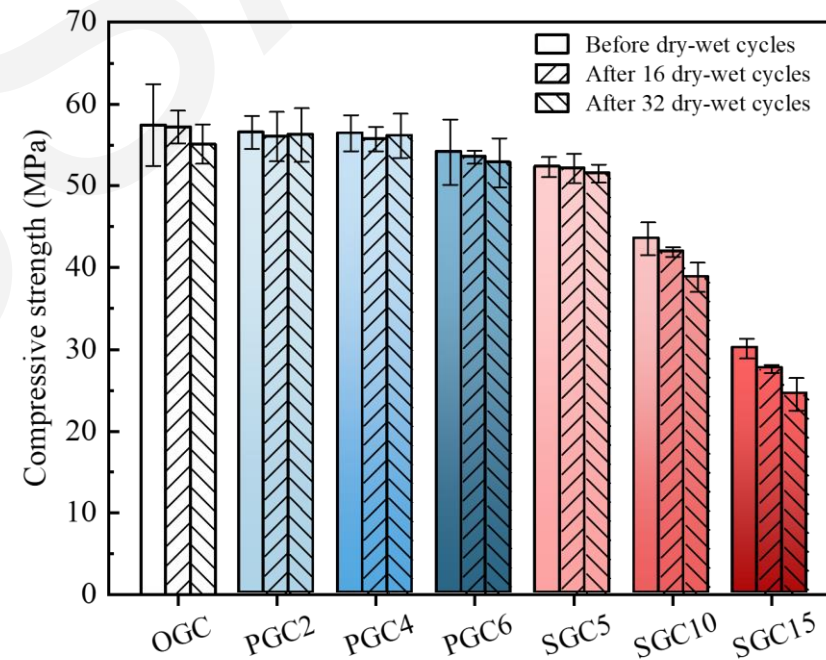


Fig. 9 Compressive strengths of OGC, PGC, and SGC samples before and after dry-wet cycles

3 Results

◆ Porosity characterization

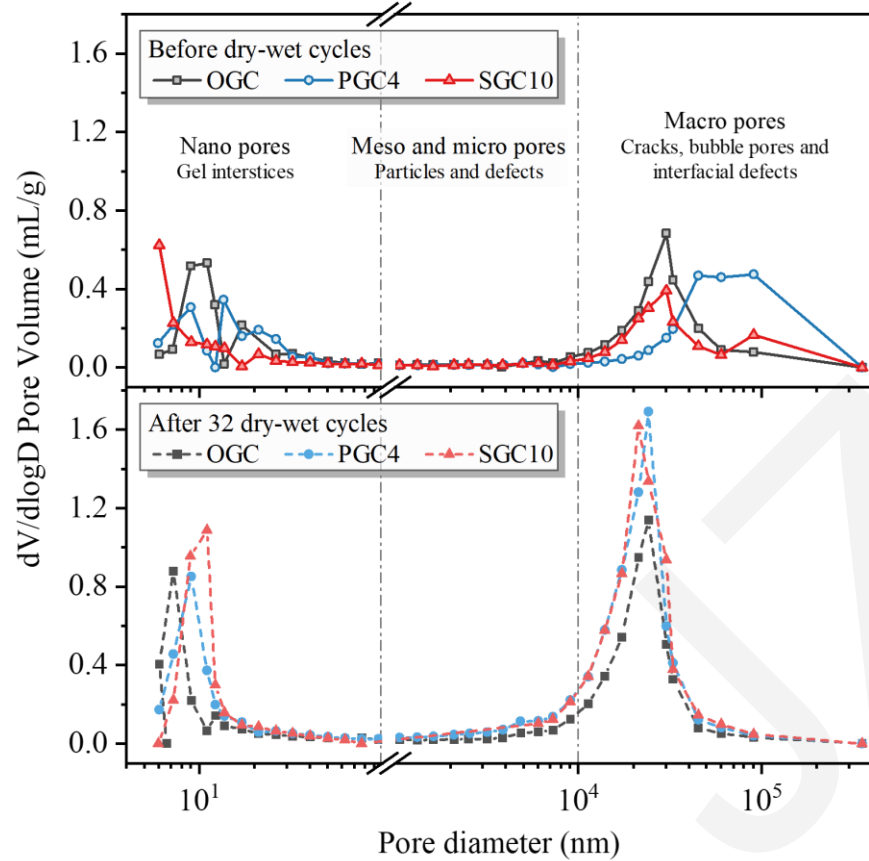


Fig. 12 Pore size distribution of geopolymer matrix from OGC, PGC4, and SGC15 samples before and after 32 dry-wet cycles

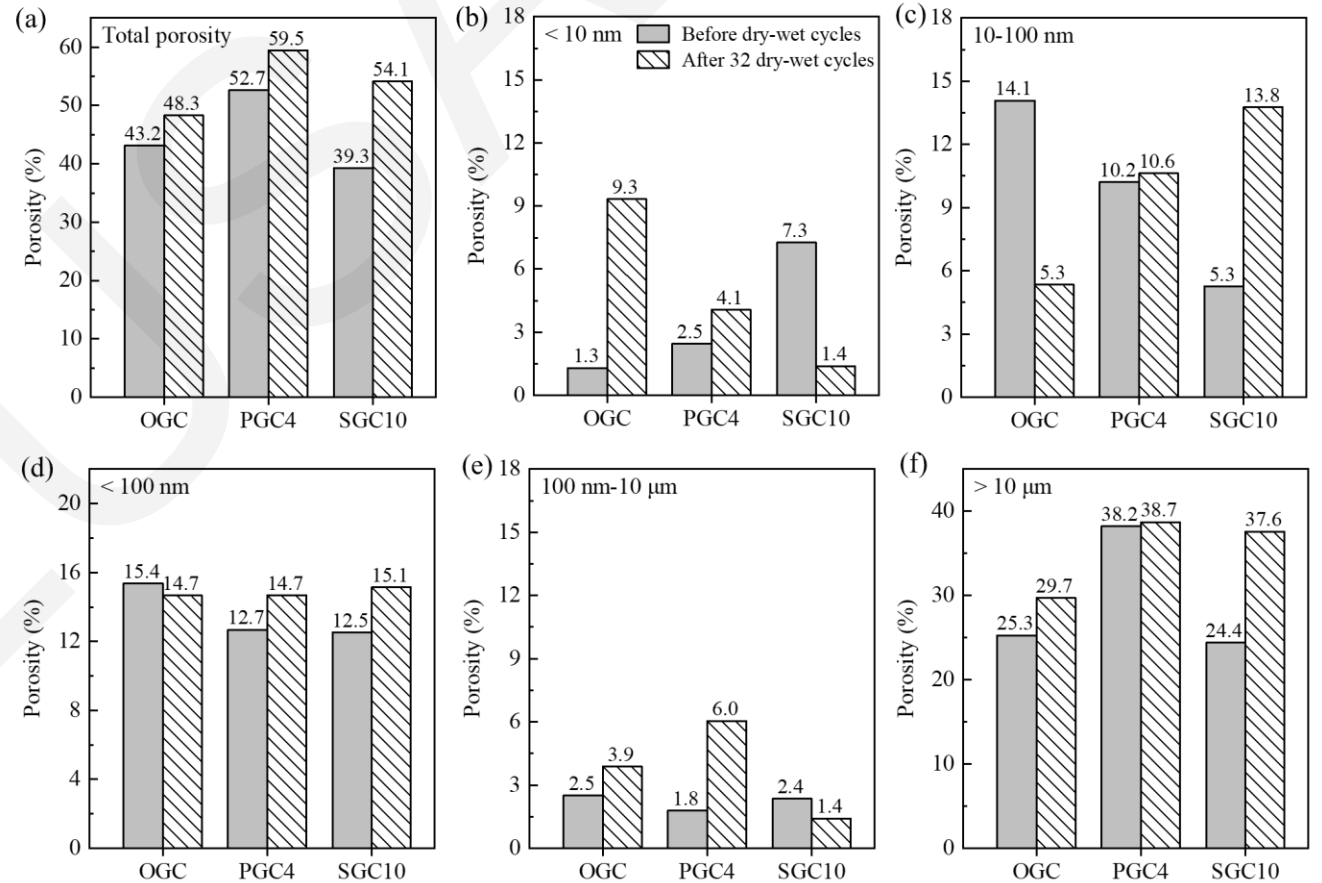


Fig. 13 Porosity of pores of different sizes in geopolymer matrix from OGC, PGC4, and SGC15 samples before and after 32 dry-wet cycles

5 Conclusions

- ◆ The experimental results show that the addition of 2%–6% PDMS or the replacement of 5%–15% SMS can modify metakaolin-based geopolymer concrete to become hydrophobic, having resultant water contact angles ranging from 84.7° – 139.0° . The water absorption and chloride transport rates of modified concrete also significantly decrease by up to 94.3% compared to unmodified concrete.
- ◆ The dry-wet cycle can hardly weaken the hydrophobicity, water resistance and compressive strength of two types of concrete because the hydrophobic groups can be tightly bonded in the geopolymer matrix, although their microstructure slightly degrades.
- ◆ This study lays the foundation for the engineering application of hydrophobic geopolymer concrete in splash and tidal zones in marine environments, where such concrete can significantly reduce the corrosion rate of steel reinforcement.