Gas transport in partially saturated packings of angular and rounded sands: Experiments and theoretical applications

Ghanbarian Behzad[2]、*濱本 昌一郎[1]、川本 健[3]、榊 利博[4]、西村 拓[1]、小松 登志子[3]
Ghanbarian Behzad[2], *Shoichiro Hamamoto[1], Ken Kawamoto[3], Toshihiro Sakaki[4], Taku Nishimura[1], Toshiko Komatsu[3]

1. 東京大学大学院農学生命科学研究科、2. テキサス大学オースティン校、3. 埼玉大学大学院理工学研究科、4. コロラド鉱山大学
1. Department of Biological and Environmental Engineering, The University of Tokyo, 2. Department of Petroleum & Geosystems Eng., University of Texas at Austin, 3. Graduate School of Science and Engineering, Saitama University, 4. Center for Experimental Study of Subsurface Environmental Processes, Colorado School of Mines

Gaseous transport in porous media is mainly controlled by pore space geometrical and morphological characteristics, such as pore throat-size distribution and pore connectivity. In this study, we address predicting gas diffusion and permeability in packings of angular and rounded sand grains. Two average sizes of grain i.e., 0.3 and 0.5 mm were used to pack sands in a column of 6 cm height and 4.9 cm diameter. Angular sand grains were packed loosely, while rounded ones tightly to obtain a total porosity of about 0.4 in all samples. Water contents, gas diffusion, and gas permeability were measured at different suction heads. An X-ray computed tomography method was also applied to scan the pore network under fully dry conditions and to capture pore coordination number distribution. By analyzing the measured water retention curve, we found the pore space fractal dimension D ranged between 0.98 and 1.8, while typically $2 < D < 3$ in natural porous media. This shows that the pore throat-size distribution of these packs is narrower than that in typical natural porous media. Experimental results indicated that both gas diffusion and permeability as a function of air-filled porosity (ε) showed linear behavior at higher suction heads, while deviated substantially from linear scaling at lower suctions. Accordingly, the effective-medium approximation and the universal power law of percolation were invoked at higher and lower air-filled porosity ε values, respectively. The crossover between the two occurs at some intermediate air-filled porosity ε_x. We found that at higher air-filled porosities, the main factor controlling diffusion and permeability is the average pore coordination number (Z), while at lower ε values, near a percolation threshold, effects of both tortuosity and connectivity are nontrivial. Comparing the theory with the diffusion and permeability experiments showed that the determined value of Z ranged between 2.8 and 5.3, not greatly different from X-ray computed tomography results. The obtained results clearly indicate that the effect of the pore throat-size distribution on gas diffuion and permebaility was minimal in these sand packs.

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