Characterization of capillary pressure–saturation relationships for double-porosity medium using light transmission visualization technique

Motasem Y. D. Alazaiza[1,2], Nadim K. Copty[3], Su Kong Ngien[4,5], Mustafa M. Bob[6], Maher M. Aburas[7]

[1] Department of Civil Engineering, Hasan Kalyoncu Universit, yGaziantep, Turkey
[2] Department of Civil Engineering, College of Engineering (COE), A'Sharqiyah University (ASU), Ibra, Oman
[3] Institute of Environmental Sciences, Bogazici University, Bebek, Istanbul, Turkey
[4] Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Gambang, Malaysia
[5] Earth Resources and Sustainability Centre (ERAS), Universiti Malaysia Pahang, Gambang, Malaysia
[6] Department of Civil Engineering, Taibah University, Madinah City, Kingdom of Saudi Arabia
[7] School of Civil Engineering, Universiti Sains Malaysia, Nibong Tebal, Malaysia

ABSTRACT

Capillary pressure saturation (P_c–S_w) relationship plays a central role in the description of fluid flow in porous media. In this research, the light transmission visualization (LTV) technique was applied to characterize the P_c–S_w relationship in a double-porosity medium. Four experiments were conducted in two-dimensional (2-D) flow chambers packed with a double-porosity medium composed of a mixture of silica sand and sintered kaolin clay spheres. In each experiment, a different volumetric fraction of macropores and micropores was used. The experiment was also repeated by compacting the flow chamber with silica sand only to represent single-porosity medium. Variable saturations of water across the height of the system were applied by controlling the capillary pressure. Images of the 2-D model were collected using a digital camera and analyzed pixel by pixel to determine water saturation in the double-porosity medium. Results from the LTV technique showed that the P_c–S_w relationships for all experiments in double-porosity soil medium were similar in shape but varied depending on the porous media composition. Comparison with the pressure cell test results showed that the P_c–S_w curves for all experiments consistent comparable to those obtained by the LTV technique. The P_c–S_w curves were also fit to van Genuchten model for comparison and validation. For double-porosity media, the best-fit parameters were consistent with published data for sandy clay. Moreover, little variability was observed in the best-fit α and n values for the different double porosity. Overall, this study proves that the LTV technique is a noninvasive laboratory tool that can provide high-resolution spatial data for water saturation distribution in different types of porous media and is capable of producing highly resolved P_c–S_w relationships.

KEYWORDS
Wetting saturation; Light transmission visualization; Porous media; Double porosity; Capillary pressure

REFERENCES

1. Alazaiza, M.Y.D., Ngien, S.K., Bob, M.M., Kamaruddin, S.A., Ishak, W.M.F.: Influence of macro-pores on DNAPL migration in double-porosity soil using light transmission visualization method. Transp. Porous Med. **117**, 103–123 (2017a)

2. Alazaiza, M.Y.D., Ngien, S.K., Bob, M.M., Kamaruddin, S.A., Ishak, W.M.F.: Quantification of dense nonaqueous phase liquid saturation in double-porosity soil media using a light transmission visualization technique. J. Porous Med. **20**, 591–606 (2017b)

3. Alazaiza, M.Y.D., Ngien, S.K., Bob, M.M., Kamaruddin, S.A., Ishak, W.M.F.: Non-aqueous phase liquids distribution in three-fluid phase systems in double-porosity soil media: experimental investigation using image analysis. Groundw. Sustain. Dev. **7**, 133–142 (2018)

4. Alazaiza, M.Y.D., Ngien, S.K., Copty, N., Bob, M.M., Kamaruddin, S.A.: Assessing the influence of infiltration on the migration of light non-aqueous phase liquid in double-porosity soil media using a light transmission visualization method. Hydrogeol. J. **27**, 581–593 (2019)

5. Bauters, T.W.J., Steenhuis, T.S., Parlange, J.Y., DiCarlo, D.A.: Preferential flow in water-repellent sands. Soil Sci. Soc. Am. J. **62**, 1185–1190 (1998)