College of Geosciences

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Memorandum
To: Dr. Jorge Isidoro, Editor, Hydrology and Earth System Sciences

Subject: Revision of hess-2021-588

Dear Editor:

We have carefully revised our manuscript following all suggestions and comments of the reviewers. Thanks to the reviewers and editors, the manuscript has been improved substantially by addressing the constructive comments. The followings are responses to all the comments.

Response to Reviewer #2:

In this manuscript the authors perform experimental study of non-Darcian flow in four rock samples with different pore size distribution determined by mercury injection experiment. The authors determine the critical specific discharge and pre-Darcian flow regime using q-K curves for the rock samples. The Forchheimer coefficients are also determined form the experiments. It is an interesting work and, in my view, should be accepted after fixing the following minor issues:

1. The effective diameter (d10) of the pores is usually used to predict the permeability. As stated by Hazen (1892), the influences of the finer grain of the soil is more significant on pore space size and hydraulic conductivity comparing to that of coarser grain. In this work, however, mean grain size is used to draw a relation between hydraulic gradient and specific discharge. The authors should comment on this.

Reply: Implemented! From the point of view of pore composition, the porous medium has been screened for the preparation of permeable stone, which can be regarded as homogeneous. The pore distribution is relatively concentrated over a narrow pore size range, and the proportion of large pores and small pores is very small. The average particle size can reflect the overall permeability of the porous media.

2. Lines210-213: The particle size distribution of each sample should be given.

Reply: Implemented! We have carried out the seepage experiments of permeable stones with four different mesh sizes in this study. The porous media used to prepare the permeable stone are carefully sieved and can be regarded as homogeneous. To facilitate the description, we can convert above four different mesh sizes of permeable stones into corresponding particle sizes. In other words, the four groups of permeable stones in this study are homogeneous porous media. Finally, we obtained the pore distribution of different permeable stones by carrying out mercury injection experiment, as shown in Fig. 8 to Fig. 11.

3. Line 238: Izbash (1931) model is commonly used to simulate the pre-Darcy flow (Dejam et al., 2017). The authors should comment on this.

Reply: Implemented! In fact, Izbash (1931) presented the equation as $q = M\left(\frac{dH}{dx}\right)^m = Mi^m$, where M and m are the coefficients determined by fluid flow and properties of porous media. When m=1, the Izbash equation reduces to Darcy law, when m>1, the Izbash equation corresponds to the pre-Darcy flow and when m<1, the Izbash equation refers to the post-Darcy flow (Dejam et al., 2017; Soni et al., 1978). Besides, Dejam et al. (2017) carried out a more detailed study on the issues related to the pre-Darcy and post-Darcy flows. And the influence of pre-Darcy flow on the pressure diffusion for homogenous porous media is studied in terms of the nonlinear exponent and the threshold pressure gradient. We have added the relevant information, please see lines 264-271.

4. Lines 240-245: As another explanation: The pre-Darcy flow may also be due to an influence of the stream potential which generates the small countercurrent along pore walls in a direction opposite that of the main flow (Bear, 1972; Dejam et al., 2017).

Reply: Implemented! In addition, another justification for the pre-Darcy behavior may be due to an effect of a stream potential which generates small countercurrents along pore walls in a direction opposite that of the main flow (Bear, 1972; Scheidegger, 2020). And Swartzendruber (1962a) stated that the surface forces arose in a solid-fluid interface due to strong negative charges on clay particle surfaces and the dipolar nature of water molecules caused a pressure gradient response to be nonlinear and led to the pre-Darcy flow (Swartzendruber, 1962b). We have supplemented the hypotheses of other scholars, please see lines 274-280.

Reference cited in this reply:

Bear, J.: Dynamics of Fluids in Porous Media, American Elsevier Pub. Co., New York, N.Y., and Amsterdam,1972.

Dejam, M., Hassanzadeh, H., and Chen, Z.: Pre‐Darcy flow in porous media, Water Resources Research, 53, 8187-8210, https://doi.org/10.1002/2017WR021257, 2017.

Izbash, S.: O Filtracii V Kropnozernstom Materiale, Leningrad, USSR, 1931.

Scheidegger, A. E.: The physics of flow through porous media, University of Toronto Press, https://doi.org/10.3138/9781487583750, 2020.

Soni, J., Islam, N., and Basak, P.: An experimental evaluation of non-Darcian flow in porous media, Journal of Hydrology, 38, 231-241, https://doi.org/10.1016/0022-1694(78)90070-7, 1978.

Swartzendruber, D.: Non‐Darcy flow behavior in liquid‐saturated porous media, Journal of Geophysical Research, 67, 5205-5213, https://doi.org/10.1029/JZ067i013p05205, 1962a.

Swartzendruber, D.: Modification of Darcy's law for the flow of water in soils, Soil Science, 93, 22-29, https://doi.org/10.1097/00010694-196201000-00005, 1962b.

Please contact me if you have further questions.

Sincerely Yours,

Hongbin Zhan

Hongbin Zhan, Ph.D., P.G.