Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-199-RC2, 2020

Solid Earth
Discussions

Interactive comment on "Combined numerical and experimental study of microstructure and permeability in porous granular media" *by* Philipp Eichheimer et al.

Anonymous Referee #2

Received and published: 24 March 2020

This is a neat manuscript that combines experiments and numerical models to investigate permeability in isotropic, low-porosity granular media. The authors measured permeability in sintered glass beads samples using a permeameter, and they evaluate samples' effective porosity and effective specific surface analysing CT-scan images. The results show that the values of permeability computed based on CT-scan images analysis are consistent with measured values. Finally, the authors propose a modified Kozeny-Carman equation that well predicts permeability at low porosities. Reliable predictions of permeability are of primary interest for numerical modelling of large-scale permeability, and this study contributes to its understanding, though limited to isotropic granular medium.

The manuscript is overall well-written. The introduction is focused, the methods are clearly described, and the results are reported in detail. However, a few points of the discussion remain unclear, in my view. Thus, I recommend the manuscript for publication in Solid Earth after the following comments will be suitably considered. These comments will hopefully help to strengthen and clarify certain aspects of the manuscript.

1) In the abstract, the authors stress the importance of characterizing fluid flow at different scales, and they state their study can be used to simulate permeability in large-scale numerical modelling. However, the up-scale of the results and the limitations of the proposed approach are never properly discussed. Therefore, it is difficult to understand how and to what extent the permeability prediction proposed in this paper is applicable to large scale modelling.

2) It is not clear how the porosity of the sintered samples is evaluated. Only through CT-scan analysis? If so, could the authors measure it experimentally (e.g., pycnometer)? This would give a measure of the effective porosity of the samples and could be compared to the computed one.

Moreover, how is the porosity reported in table 1 evaluated, both total and effective? From Figure 2, the porosity in a single sample changes quite a lot from $\sim$5% to $\sim$20% (and the reported value in table 1 is $\sim$13%). During permeability experiments, the low porosity zone at the bottom of the samples controls the overall permeability values resulting in a shift of the points toward higher porosity values in the permeability versus porosity plot (i.e., Figure 5). This could explain the discrepancy between computed permeability using subsamples and measured permeability of the entire sample. Could the authors add in Table 1 the minimum porosities for all the samples (or report in the supplementary material all the curves showing the height of samples versus porosities)? Could the authors plot the measured permeability versus the minimum porosity in Figure 5?

Furthermore, what is the size of subsamples in z direction? Could the author clarify it in the main text?

3) In figure 4b, the relation proposed by Koponen et al. (1996) seems to fit the data similarly to the relations proposed by the authors (Figure 4d). If I understand properly, the authors justify the choice arguing that the fits presented in Figure 4a, b and c have negative or low R2 values. However, they write that also the fit shown in Figure 4d has a low R2. The R2 values for the fits in Figure 4 are not reported in the main text. Thus, it is difficult for the reader to understand why the fit in Figure 4d is better than the fit in Figure 4c. Could the authors add this information in the main text? Could the authors clarify why they do not use Koponen et al. (1996) hydraulic tortuosity-porosity relation?

In the following, I give a few line-by-line comments:

1) line 6: The sentence “We determine flow properties like hydraulic tortuosity and permeability using both experimental measurements and numerical simulations.” could be misleading. Hydraulic tortuosity is not determined by experimental measurement. Could the authors clarify it?

2) line 199: Could the authors define the hydraulic radius?

3) line 200: Is the hydraulic radius constant? Is it not affected by different porosities?

4) line 215 and line 219: Could the authors add R2 values in the text?

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