Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-199-AC2, 2020

Solid Earth
Discussions
Open Access

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

Philipp Eichheimer et al.

philipp-eichheimer@gmx.de

Received and published: 5 May 2020

Response to comments of an anonymous referee on the manuscript "Combined numerical and experimental study of microstructure and permeability in porous granular media" by Philipp Eichheimer et al., se-2019-199.

We thank the anonymous referee for his review. His constructive comments helped us to improve our manuscript.

Please find below a point by point response to the comments (comments of the reviewer in black and our response in blue).

Sincerely,
Philipp Eichheimer on behalf of the co-authors

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.

   Thank you for this comment. The proposed permeability parameterizations can be used to predict permeability on the large-scale using numerical simulations. For this reason the parameterizations are useful for isotropic low porosity media e.g. sandstones. In nature rocks mostly consists of various grain shapes and sizes, for which the proposed parameterizations are only partially valid. We now discuss this issue in the manuscript (p. 18, line 381 ff.)

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?

Thank you for this comment. The porosity is only measured from the obtained CT-scans. Unfortunately, we do not have access to a pycnometer and therefore it is not possible to provide experimental porosity values.
The effective porosity represents all connected void clusters which contribute to the fluid flow and therefore permeability. The total porosity also takes into account inclusions and clusters which are not connected to the top and bottom of the sample.
We agree that permeability may not necessarily be affected by the total effective porosity, but rather by the minimum effective porosity in a sample (in a slice perpendicular to the flow direction). We therefore also report the minimum effective porosity of each sample and added the values in table 1 and changed figure 5 to plot permeability against the minimum effective porosity.
The height of the sample in z-direction is reported in table 1 and is around

5 mm.

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?

   Thank you for this comment. We added R^2 values to all plots for the hydraulic tortuosity.
   In general, all of the proposed relations for hydraulic tortuosity do not show good agreement, in particular the ones proposing an strong increase in hydraulic tortuosity when the critical porosity is approached. The relation of Koponen et al. (1996) shows that that the value of hydraulic tortuosity does not change significantly with different porosities, thus representing a similar trend to our data. As all fits, represented by a low R^2 value, do not properly fit out data we used the arithemtic mean of all calculated hydraulic tortuosities for the permeability parameterization.

4. 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?

   This is correct, the old formulation was misleading. We modified the corresponding sentences as hydraulic tortuosity and permeability are com-

Printer-friendly version

Discussion paper

puted numerically and the experimental permeability measurements are used to verify the obtained parameterization. (p.1, line 6 ff.)

5. Could the authors define the hydraulic radius?

   We now give a definition for the hydraulic radius. (p.12, line 252)

6. Is the hydraulic radius constant? Is it not affected by different porosities?

   The hydraulic radius only depends on grain size, which controls the effective pore volume between adjacent grains and is thus rather a pore-specific than a volume-specific property. As our samples consist of sintered glass bead packings with a relatively narrow grain size distribution, pore sizes throughout the sample do not vary significantly and thus also not the hydraulic radius. During sintering, some of these pores are closed, but the remaining pores do not significantly change their size. For this reason, the hydraulic radius also remains approximately constant.

7. Could the authors add R2 values in the text?

   We added the corresponding R^2 values to the plots of hydraulic tortuosity.