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Solid Earth
Discussions

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

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The paper is interesting and follows logically from the previous paper of the same main Author. If I understood correctly, the paper was not accepted for review by 3 potential reviewers and for this reason finally ended up with me (again). I found the idea of lab experiment and pore-scale simulations to be very relevant, we do lack such studies. But while reading this manuscript more deeply i was somewhat taken aback by Kozeny-Carman relationships the Authors use. While I find lab vs. modelling work to be very important and do support this paper to be published with SE (after some rebranding), i regret to say that I have a major point of criticism here as well. It really

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Discussion paper

puzzles me why would modern researchers utilize Kozeny-Carman relationship and why everybody at some point want to establish some kind of K-C relationship? How useful is that? We know very well already that what works for spheres does not work for real porous media samples. Moreover, the concept of hydraulic tortuosity, while still popular, provides very low information bulk measure of flow velocity field (as Authors show depending on the methodology to compute tau, the results are quite different). It may be so that computed tau values are interesting to show that they are different from previously computed, this again provides close to zero scientific value. So, while Authors proposed a "novel" Kozeny-Carman model, my question – how is it even useful, practical or simply scientifically valuable? This puts the conclusion for this work into a state of not really going anywhere. If compared against lab measurements or simulations K-C produces orders of magnitude errors, as is evident from your figures. To relate to previous results for spheres or another K-C relationship you could refer to: Martys, N. S., Torquato, S., & Bentz, D. P. (1994). Universal scaling of fluid permeability for sphere packings. Physical Review E, 50(1), 403. Garcia, X., Akanji, L. T., Blunt, M. J., Matthai, S. K., & Latham, J. P. (2009). Numerical study of the effects of particle shape and polydispersity on permeability. Physical Review E, 80(2), 021304. Now, around lines 270-275 you discuss why the results of permeability for simulations are different from these of lab measured values. While you mention that size and boundary effects could influence your results (for such small volumes i would warily estimate an error due to boundary condition to be up to 20-50%, and in this regard you could refer to Gerke, K. M., Karsanina, M. V., & Katsman, R. (2019). Calculation of tensorial flow properties on pore level: Exploring the influence of boundary conditions on the permeability of three-dimensional stochastic reconstructions. Physical Review E, 100(5), 053312), i think the main reason is different. As you can see from figure 2 you have very high porosity contrast along z-axis. Now, if you have 0.05 porosity down there – this part will dominate the porosity for the whole sample. This makes sense, as you lab values are always lower. What i would do with your (really good!) data? I would leave all this K-C and tortuosity thing, but rewrite it as not useful and your data clearly shows that (which is, again, good). Now, you could assemble all these small pieces of 3D images you modelled with FDM solver into a 3d matrix of permeability values and upscale it (as simply as harmonic means should do the trick i suppose) to compare again the lab. This could lead to something interesting – at least you would be able to show how different model and lab values are. You could use these simple upscaling schemes as inspiration: Jang, J., Narsilio, G. A., & Santamarina, J. C. (2011). Hydraulic conductivity in spatially varying mediaâĂŤa pore-scale investigation. Geophysical journal international, 184(3), 1167-1179. With this little addition you paper could be completely rebranded from meaningless K-C to something really relevant to our field (kind of full core comparison between lab and modelling). Hope this helps and does not introduce too much addition work. Otherwise it is very hard for me to accept the paper as is - i think we have to automatically reject all papers dealing with K-C (just because it is wasting of time, money, pages, you name it).

Below are some additional minor comments: 1) Table 1 – is porosity measured (as computed from mass and volume?) or computed from images? How A is computed? Do all samples have the same trends in porosity as in Fig.2, if so, does porosity represent an average for the whole cylinder? 2) 2.6 – do you state that you use phi_eff for all later computations as porosity? If so, please, make it easier to guess. 3) 2.7 – how do you compute the area? By voxel counting and summarizing the interface as voxel faces? 4) Eq10-11 and Eq.12 utilize different V_b and V_B values but i guess refer to the same volume. 5) Not clear why you report Eq.14-17 if you use Eq.13 (which seems to me to be superior as it calculates hydraulic tortuosity using streamlines instead of lausy porosity-based relationships). 6) 3.2 – your model is basically the same as of Kopponen. The scatter is huge, is there any point in using such relationships? (Later I see you also substitute the points instead of this relationship, but I do not see the difference between them, is there any?) 7) Eq.23 have simply tau, not tau_H (as i guess it should be?). 8) around line 230: sorry, but i could not follow your explanation of critical exponent through, including this paragraph and also appendix D. How did you evaluated phi_c? 9) Could you, please, also describe the sample preparation procedure a bit more, in particular how do you wrap it into resin? I could not get it completely from the current description.

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