June 9, 2023

Dear Editor Prof. Paola Passalacqua,

Thank you for sending me the manuscript "Use of packing models for the prediction of fluvial sediment porosity" by Christoph Rettinger et al. for review. I read the manuscript with great interest. The authors compare three models predicting the packing density of fluvial sediment and evaluate them based on simulated and measured data. The authors find that two of the models, the linear packing model and compressible packing model, work reasonably well, while the nonlinear packing model does not, as it does not consider interaction between multiple size classes.

I think that the overview on the models and information which models work and which do not, and the consideration of cohesion is very useful for anyone interested in predicting sediment porosity. The overall quality of the manuscript is better than that of most manuscripts that I review. In particular the introduction, and the model overview, are well written, though some clarification is needed. The result and discussion sections are less clear. I provide suggestions for textual improvements below.

Overall, the improvements won't require a lot of work, though more than just a minor revision.

Kind regards,

Your reviewer

Clarification needed

Introduction Improve the explanation and illustration of interaction between size classes. The nature nature of the interaction was not clear to me after reading the manuscript, and the recommendation below is based on what I came up with after shortly thinking about the problem:

58 State some of the interaction types.

Figure 1 Reduce the size ratio of sublplot b, where interaction takes place, to about 1:3, currently, the ratios on all subplot is very large (1:20), which does illustrate the filling and occupation well, but not the interaction.

Figure 1 Add a subplot of the porosity of a binary sphere packing vs. size ratio for a couple of volume fractions. The curve has likely a maximum of around 0.36 at $d_1/d_2 = 1$ and a minimum close to $0.36^2 = 0.13$ in the limit $d_1/d_2 \rightarrow 0$ for appropriate volume fractions.

Figure 4 It would be insightful to retransform the functions into a form that their physical meaning can be interpreted (similar to the curve recommended above) and which facilitates a comparison between the models. In the given form, the physical meaning of the interactions is unclear, and the apparent inverse definition of the functions of the CPM and LMPM complicates their comparison.

Introduction It's worth mentioning that the packing of sediment has relevance in the environmental sciences far beyond fluvial sediment, for example, it also determines the pore size distribution and with it the hydraulic conductivity, and because it is linked to the problem of compaction and hence land subsidence.

Introduction Its worth a disclaimer that the study implicitly assumes that the packing density for a given size and shape distribution of the sediment is unique. This is not the case, as sediment can compact.

105 Define d. It is probably the sieve diameter, it is only introduced as "size" which is ambiguous. Also mention how d is determined for virtual grains in the computer simulations, as their size is probably not determined by sieving.

112 "initial porosity" as a parameter is confusing, as the initial porosity should not matter. What the authors probably mean is the porosity for packing sediment of a homogeneous size, i.e. the packing with one size class only. If this is the case, then change "initial porosity" to "homogeneous packing porosity".

226 Discuss why the threshold of 150 um for sediment to become cohesive is considerably larger than the usual threshold at the sand-silt transition at 65 um. Many sand bed rivers have a sizeable portion of bed material in this range without that cohesion is considered relevant.

216 The same shape is assumed for sand and gravel. In my experience, gravel deviates much more from spheres than sand, while sand tends to have sharp edges. Should the interaction function thus not only depend on the ratio, but also on the (geometric) mean of two interacting size fractions? Could this be one reason that the parameters of the interaction functions are site specific?

218 Which resolution had the CT-scans? Did they resolve the fine particles?

220 State the distribution, standard deviation and covariances between the shape parameters, can be done in the appendix or supplement.

381 The packing state (loose vs. dense) of the initial porosity is an input to the "initial porosity". This makes no sense as the sediment is repacked. What is probably meant is the packing state of the final packing. Consequently, I would also refer to it as the "final packing state" and remove the arrow to the "initial porosity". The final packing seems to be related to the compaction and hence non-uniqueness of the porosity, as I mentioned above and therefore worth to be discussed.

401 Why does the simulated packing density of homogeneous sediment differ between the simulation and the lab? Is this due to variation within the size class or does this indicate a systematic error in the models?

Table 2 It's unclear how the model parameters can be derived from the four inputs stated in Figure 11. Some information on the fitting, i.e. what kind of calibration data is required and how it can be best obtained would be helpful for readers who want to apply the models. This could be provided in a supplement. It seems the parameters are fitted to measured porosities, but this makes predicting the porosity a chicken-egg problem. If the porosity has to be extensively measured at each field side, one could directly predict the porosity based on quantiles of the grain size distribution with a non-linear model or neural-network. It would also be interesting to use such a simple fit as a Null-model or benchmark for the packing models.

Textual recommendations

I suggest restructuring the manuscript slightly:

- Move the cohesion model (section 5.1) forward to the end of section 3 (methods section). Currently, it's awkwardly embedded in the result section.
- Give a brief and clear overview of the models in the beginning of section (3), similar to lines 447-450 in the conclusions. Move the first part of the discussion (lines 390-394) including Figure 11 at the start of section 3, as it details the general overview of the model structure and parameters. This will be helpful for readers who are no experts on sediment packing models.
- Use active voice, i.e. "we ..."

- Use present tense where possible to make the results a refreshing read. The persistent use of past tense gives the impression the results were obsolete or outdated.
- For consistency, use "grains" instead of "particles" throughout the entire text. Currently the terms are jumbled without following a conceivable logic.
- Use "evaluate/evaluation" instead of "validate/validation" throughout the text.

Minor textual

Figure 4 A logarithmic scale for ratios is more appropriate.

Figure 6 prediction models → model predictions (lines) ... Rhine sediment (dots)

Figures 6 The figure would be more easy to read when the plots were labelled MPM, CPM, LPM, similar to figure 8.

3,472 "theoretical" → "algebraic". Theoretical implies the models would be derived from first principles, yet they seem to comprise of heuristics and fitting curves. Algebraic makes sense, as they provide a direct prediction without simulations or solving a differential equation.

33 measurements → estimates (because a simulation is not a measurement)

63 between the largest and the smallest grains → between the diameter of the largest and the smallest grains

185 binary packings → for binary packings of spheres

244 for the here considered binary case → for the binary case considered here

284 Additionally, and again as before, → As before, ...

285 anew → new

285 Therefore, no anew adaption of the models to the validation data had been carried out here → Therefore, we did not have to adapt the models for the validation.

299 here considered → considered here

316 remove "as also used ..."

375 The value of the initial porosity → The initial porosity

393 for the size classes → between the size classes

399 The following validation → The validation

399 exactly equal → equal

401 Here, it had to be adapted → Here, we had to adapt

404 these laboratory measurements → the laboratory measurements

404 The porosity prediction that we achieved with this combination → The porosity that we predicted with this combination

405 measurements and simulation → measurements and simulations

406 Such influence factors were fully captured by the applied measurement method in the laboratory but were not accounted for by the packing model, and also excluded in the simulations. → Such factors were fully captured by the laboratory measurement but were neither accounted for in the packing model nor the simulations.

410 available → available.

412 Rhine sediment → Rhine

412 deviation from → difference to

430 here considered grains → grains considered here

444 here considered prediction models → prediction models considered here

446 remove "In this paper,"

446 presented and discussed → compared

446 named → the

457 This applicability was verified by 20 further simulations, → We verified the models further by comparing them to 20 simulations

463 0.02mm → 0.02 mm

467 input variables → input parameters

472 theoretical packing models → why theoretical?

472 Overall, we could showcase → Overall, we show