

Earth Surf. Dynam. Discuss., referee comment RC1
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Comment on esurf-2021-69

Anonymous Referee #1

Referee comment on "Effect of debris-flow sediment grain-size distribution on fan morphology" by Haruka Tsunetaka et al., Earth Surf. Dynam. Discuss.,
<https://doi.org/10.5194/esurf-2021-69-RC1>, 2022

General comments:

The authors investigate how the grain-size distribution of debris flows affects the fan-forming processes. For this, flume tests have been conducted to compare the debris-flow fan morphology under varying sediment source grain-size distributions. The obtained results associated with the debris-flow runout and space-time variations in the fan morphology provide important insights into how the grain-size distribution affects the fan formative processes. The topic is interesting, investigation is novel, and is within the scope of esurf. However, the ms requires a thorough revision in concept, mechanics and dynamics. Detailed suggestions and comments are provided below hoping that they will help to improve the quality, consistency and clarity of the revised ms.

Abstract can be improved. E.g., "Grain-size distribution was closely related to spatial diversity in fan morphology and stratigraphy." Should be other way round, "Spatial diversity in fan morphology and stratigraphy were found to be closely related to grain-size distribution."

Introduction is not that much concerned about the main topic on how the grain-size distribution influences the debris flow fan morphology. So, it needs to be substantially expanded focusing on how the grainsize of the source material affects the deposition and fan formation process including the important and often dominant dynamical processes - the material separation, erosion and run-out dynamics.

Often the writing is not explicit, not smooth and difficult to follow. It seems if the ms was made for very short paper, less for a professional journal, requiring clearer and smoother presentation. Particular attention should be given on these issues.

Specific comments:

L36-37: "Changes in the physical parameters (e.g., flow rate, duration, and sediment concentration)": The writing must be significantly improved, conceptually: flow rate, duration, and sediment concentration are not the physical parameters, rather they are the dynamical quantities. Physical parameters include densities, viscosities, frictions, slope geometry, curvature, etc.

L38-39: "and sediment entrainment rate (Egashira et al., 2001; De Haas and Van Woerkom, 2016)." better change to "and sediment entrainment rate (Egashira et al., 2001; De Haas and Van Woerkom, 2016; Pudasaini and Fischer, 2020: <https://doi.org/10.1016/j.ijmultiphaseflow.2020.103416>) and separation between the particles and fluid in the mixture (<https://doi.org/10.1016/j.ijmultiphaseflow.2020.103292>)."

L39-40: "and depending on the topographic complexity, could produce varying functional changes in subsequent debris flows.": not clear how topography produces functional changes and which?

"functional and structural changes" what are the functional and structural changes?
General readers may not be able to follow the text.

L50: "A straight flume (8 m long and 0.1 m wide, with a uniform 15° bed slope": This is not true, and the text around must be improved appropriately, consistent with the corresponding figure.

L50-67: "erodible bed conditions": Here comes the great thing! I see two major aspects in this ms. First, as the authors say, the effect of particle size in the erodible bed and how it will affect the deposition fan. I understand this differently than the author, it is not the particle size in initial debris mass (initially water is released) that will influence the deposition fan, but it is how the particle size of the erodible bed that affects the deposition fan when that bed substrate is eroded and entrained by the water flood released from upstream, consequently forming a debris mixture that ultimately flows down and deposits in the gentle open flat slope forming debris fan. The text does not mention this. Second, probably even more important, is the fact that the flood erodes and entrains the granular bed converting it in to the debris flow. So, the physical process of erosion, entrainment and the associated mobility must be described. This could however be done with respect to the mechanical erosion rate models and the mechanical model for the mass flow mobility with erosion (Pudasaini and Krautblatter, 2021: <https://www.nature.com/articles/s41467-021-26959-5>). I would focus on these governing aspects of experiments.

Writing style needs to be made more appropriate with better physical understanding. "The supplied water generated a granular flow that imitated a single debris-flow surge and then entrained the erodible bed to the deposition area" This is difficult to follow, probably not

representing reality. Does the water flow first generate the granular front by entraining the granular bed? I guess, as the water front impacts the granular bed it will erode and entrain the grain, mixing will take place resulting in the subsequent debris flow. Not that the way the authors explained. Moreover, you mixed up erosion and entrainment, which are clearly two different mechanical processes as proven by the reference mentioned above. So, the process of erosion and entrainment should be carefully investigated/discussed.

“the fan morphology gradually formed in accordance with the runout and inundation of the released granular flow”: This is rather the fan of the granular-water mixture debris flow. For a granular fan, you must only have the dry material without water, for which the fan will be substantially different than what it is now.

“Two types of granular flow, namely mono-granular and multi-granular, were used to determine the impact of grain-size distribution within a debris flow on the fan-forming processes.”: This is not right. You have two types of granular materials in the erodible bed, resulting in two types of debris flows, one consisting of water and mono-granular material, another composed of water and multi-granular [this term needs to be defined carefully, as mono-granular and multi-granular are not the usual terms, usual terms are the mono-dispersed and poly-dispersed, with respect to grain size, etc.].

Not enough information on the material and channel are provided, e.g., the basal and internal friction angles of the granular material, viscosity of water, their densities, and so on. This information is crucial in understanding erosion-entrainment and mobility, the mixing and separation between particles and fluids, and the transport/deposition of debris mixture.

Another principle concern is the representative grainsize, the two granular materials, mono-dispersed and poly-dispersed are represented by the same average grain size (D_{50}). This does not help to physically clearly study the erosion-entrainment, transport and deposition fans, except that you can say – we observe this and that for the mono-dispersed and poly-dispersed erodible bed. But, we don't know how small and big particles

in the mixture influence the erosion, mixing or separation, dynamics and deposition processes. Moreover, different grains might need to be represented by different rheological equations. These are crucial aspects the authors should discuss. Otherwise the results can not be understood mechanically and dynamically clearly, and these data cannot that easily be used in model validation and parameter calibration.

L69-70: "sediment was released to the deposition area". A bit strange writing. First, it is not sediment, it is the debris material. Second, it is not released to the deposition area, it is the transported material in the deposition area. So, the dynamical perspectives are weak.

L70-73: "The flow depth of a generated granular flow cannot be measured in the flume because the thickness of the erodible bed decreases sequentially in response to the sediment entrainment. Therefore, the displacement of the flow surface at three positions in the flume (upper, middle, and lower, Fig. 1a) was measured to account for this shortcoming, using ultrasonic displacement meters":

I agree with the first sentence, it is a really complex process, however, there are some literature in this direction with some success (Lanzoni et al., 2017: <https://doi.org/10.1002/2016JF004046>). The authors should put some efforts to review relevant literature. The bed erosion process is an under-investigated process, and I respect any attempt in this direction. The second sentence is not the solution to the first, because, the measured flow depth cannot be split into the material from the flow and from the bed. Thus, it cannot be straightforward connected to the erosion depth. Furthermore, the involved energy associated with erosion is the dominant factor to decisively defining the dynamics, runout and the associated impact forces of the erosive mass flows. This needs to be discussed with respect to the references mentioned above.

I stop suggesting and commenting on the mechanical and dynamical aspects of the ms, and hope that the authors will improve the text while revising it.

Fig. 2: Figures are difficult to follow. It should be self-explanatory. For example, Run 1-4, are they repeated exps.?

L98-99: "The thickness of the erodible bed decreased monotonically with time, probably because the entrainment rate was the same in all the test runs, irrespective of the grain-size distribution of the granular flows": This cannot be true, could only be a speculation. Because, as proved in the above-mentioned references, erosion rate is a complex phenomenon, and changes with the dynamic load applied by the flow and resisted by the bed. This needs to be discussed.

L100-102: "Overall, the results from the flume experiment showed that the difference in the grain-size distribution did not lead to substantial changes in the hydrograph and arrival time of the granular flows.": I can't fully agree with this. E.g., if you take the mean of four runs in C and F and plot them in one figure, you will see discernible difference.

L113: Grain size separation is one aspect, but separation between particles and fluid (as seen in the experimental results) is another, even more complex mechanical phenomenon in debris flow. However, the authors did not discuss anything on it.

L123: "avulsed obviously": it is better also to put orthophoto to clearly see avulsion. The quality of Fig. 5-8 should be improved, with filters, or whatever means such that we can clearly see avulsion. The problem I have seen is that avulsion cannot be predicted, or was not possible with the present setup. We should understand why this is happening. This needs to be discussed, because, one of the main aims of experiments should be to generate reproducible results.

L142-144: "Some equations that describe debris flows assume that multi-granular debris flows can be approximated to mono-granular debris flows with the same average grain-size (e.g., Egashira et al., 1997; Takahashi, 2007).": This is not the state-of-the art. The multi-mechanical, multi-phase mass flow model by Pudasaini and Mergili (2019: <https://doi.org/10.1029/2019JF005204>) has proven the necessity of simulating debris flows as mixture of different materials, that has been used in accurately simulating complex multi-phase natural events (Mergili et al., 2020: <https://doi.org/10.5194/nhess-20-505-2020>; Shugar et al., 2021: DOI: 10.1126/science.abh4455). The ms should be up dated with relevant, recent literature.

L144-145: "However, the mono-granular and multi-granular flows with the same average grain-size produced fans with different morphologies": This is probably the most important aspect of this ms, and I like it. However, it has not yet been clearly discussed for why this is so. The authors should put some energy to explore why it is happening, that will lift the importance of this paper to a higher level.

L146-147: "which indicates that existing models that assume a mono-granular approximation may provide ambiguous simulations of the debris-flow deposition and inundation ranges.": This proves the need of multi-phase mass flow models (mentioned above) in properly simulating debris flows. This should be discussed.

Discussion and Conclusion, References:

Needs re-working, including the above suggestions. E.g., multi-phase flow simulations, erosion-entrainment and mobility, separating particles and fluid, and so on. Important point why the flow with the poly-dispersed erodible bed has shorter travel distance and run-out reveals that more energy has been consumed for this than the bed with mono-dispersed particles. This exclusively depends on the erosion velocity controlling the

mobility of the mass flow, this fact has been proven by the mechanical model for the mobility of erosive mass flows by Pudasaini and Krautblatter (2021). The discussion and conclusion should give proper space for these important mechanical and dynamical aspects also observed in this ms.

Technical comments:

L22: "sinks", the meaning was not that clear, better would be "deposits"?

L29: Please check English.

L85: "SfM-MVS": is its meaning clear?

L97-98: "while, apart from run 1, those of the multi-granular flows were around ~ 0.03 m": Not true. Please check all the technical details carefully.