

Review report

Manuscript title: Mobility of dry granular debris flows over erodible beds: Experimental insights into the influence of flow–bed inertia

Journal: Natural Hazards and Earth System Sciences (NHES)

Recommendation: Revision

Reviewer: Anonym

1. General Evaluation

This study addresses an important and timely question in debris flow research, namely, how the inertial contrast between a flowing mass and an erodible bed influences erosion, entrainment, and runout mobility. The experimental approach is systematic and well-conceived in its basic structure, testing three inertial scenarios alongside a reference case and repeating each experiment three times to assess reproducibility. The finding that solid density contrast alone is insufficient to explain observed mobility patterns, and that particle shape and internal friction play important and previously underappreciated roles, is a scientifically valuable contribution that deserves attention from the debris flow and granular flow communities.

Despite my following comments, the reviewer recognizes the originality and potential value of this experimental contribution. With careful revision addressing the scientific, structural, and linguistic issues outlined in the specific comments below, this manuscript could make a meaningful contribution to the understanding of erosion-driven debris flow mobility.

2. Comments

Language:

The Paper needs revision in writing style genuinely before publication. Reading the paper suffers through e.g.

- Long, heavily subordinated sentences.
- Noun-heavy constructions such “the mechanical complexity of flow–bed interactions”
- Paragraph structure.
The paragraphs tend to be very long and try to cover multiple subtopics It will be very understanding if the writers use more focused paragraphs with a clearer topic sentence.

As an example, the sentence:

“Besides, variations in bed clay content appear to influence the contraction–dilation behavior of the bed, with an optimum clay content at which undrained loading conditions and liquefaction of the upper bed layer produce maximum erosion (Roelofs et al., 2023).”

It tries to deliver four separate subjects and ideas in one sentence:

1. Clay content variations influence bed behavior
2. There is an optimum clay content
3. At that optimum, undrained loading and liquefaction occur together
4. This combination produces maximum erosion

In plain and easily readable text, this would typically be split into at least two sentences, something like (if I understood it correctly!):

"Variations in bed clay content influence the contraction–dilation behavior of the bed. At an optimum clay content, undrained loading conditions trigger liquefaction of the upper bed layer, resulting in maximum erosion (Roelofs et al., 2023)."

The terminology problem.

Takahashi's framework, which is the standard reference in debris flow science, clearly distinguishes between debris flows (which requires a fluid phase, typically water, to mobilize and transport sediment) and dry granular flows, which are essentially a different phenomenon governed by different mechanics. Dry granular flows and debris flows behave fundamentally differently in terms of erosion mechanics, momentum transfer, and mobility. The authors acknowledge it very briefly in introduction, stating that when they use the term "debris flow" it specifically denotes dry granular single-phase flows.

The entire theoretical framework of experiments is based on the work of Pudasaini & Krautblatter (2021), which was developed for landslide mobility broadly, but the applicability to dry granular flows specifically versus water-bearing debris flows needs much more careful justification in the paper.

Comment of Mr. Hervé Vicari

It would be useful to address the points of Mr. Hervé Vicari in his discussion about the validity of Pudasaini & Krautblatter (2021).

However, in geoscience and fluid mechanics, we use many simplified or partially incorrect theoretical frameworks that still provide useful working approximations. The fact that Pudasaini & Krautblatter (2021) has a mathematical flaw does not automatically invalidate your experimental study inspired by it.

Therefore, it is important to discuss the comment of Mr. Hervé Vicari in the paper. Especially in your discussion you mention the point that the observation did not support the hypothesis proposed by Pudasaini and Krautblatter (2021).

Experimental method

In nature the density range is much narrower. Natural bed materials in the mountain torrents, where debris flow occurs, typically range from about 1200-1500 kg/m³ for highly porous or organic-rich soils (if exist), through 1600-1800 kg/m³ for typical alluvial sediments, up to about 2600-2900 kg/m³ for dense crystalline rocks like granite or basalt.

So my question is: If you use such extreme density contrasts, which is understandable from an experimental strategy perspective, what about the relevance and transferability? If the inertial effect is only clearly detectable at such large density contrasts, how does its importance in natural debris flows?

The slope which is selected for experiment is about 75%. It is practically out of range for a torrent with debris flow. We speak in such cases mostly about rock avalanches. Mountain torrents with debris flow have normally a slope range of 25 to 45° (14° - 25°). Lanzoni et al., 2017 used this range of slope, which is reasonable. It needs to justify why this extreme slope is representative for such study.

Rough coated plywood: information about roughness is missing. It is important to have this information.

Measurements

Flow-front velocity was calculated from the ratio of the traveled distance from the reservoir flap to each sensor and the respective time of flow-front arrival. This is not the front velocity (instant front velocity), it is the average velocity of the front from flap to the sensor. The (instant) front velocity can be diverted from the average over the whole distance.

Results:

I would suggest that chapter 3 needs a brief introductory paragraph.

My second suggestion: chapter 3.1.2 consists almost entirely of descriptive reporting of numbers presented sequentially scenario by scenario without any interpretive thread connecting them. The Discussion (chapter 4) does provide physical interpretation of these descriptions. However, the Results and Discussion are so completely separated that the reader has to hold a large amount of raw numbers in their head from Chapter 3 before getting any interpretive context in Chapter 4 or has to jump often between these two chapters. Maybe you can reconstruct the chapter to replace pure numerical reporting with an interpretive approach that guides the reader toward the key findings.

Regarding my last comment related to the front velocity, the increase of your front velocity is interesting. Our observations show that the instant front velocity of debris flows (with water and fine part) does not increase in a channel. This is physically reasonable, because of the equilibrium of forces. Therefore, it is important to emphasize that the velocity measured in your experiment is the average velocity for the distance segment.

The missing introductory text for chapter 3.2 is repeated here again. Section 3.2.1 represents an improvement in terms of scientific explanation of the results, which is worth acknowledging fairly. But again here, as it is discussed above, the reader must jump always between chapter 4 and 3.

Discussion

The Discussion would benefit substantially from the inclusion of comparative diagrams, e.g. using non-dimensional parameters, to place the experimental findings in the context of existing literature. Even a simple statistical summary of key parameters across repetitions would strengthen the quantitative basis of the conclusions.