Review of ”Breaking down chipping and fragmentation in sediment transport: the control of material strength”, by Bodek and Jerolmack, submitted to Earth Surface Dynamics (esurf-2021-17).

General comments:

The authors present a well-structured laboratory study on particle attrition do to impact energy during transport (applicable to gravitational and fluvial transport in surface processes). They specifically address the transience between chipping of small parts from and fragmentation of the whole particles for constant impact energies, but varying strength of artificial rock material. For a phase space of weak to hard material (applicable to natural rock), they delineate how hard rocks turn slowly round by chipping, weak rocks fast disintegrate and less round by fracturing, whereas the rocks of intermediate strength show major variability in both process' interactions. These results are well applicable to quantitatively interpret natural transport environments.

This work addresses a fundamental question in studying earth surface processes and well exams it – it is sound and right-suited for ESURF. I was intrigued to thoroughly reading the manuscript and in detail noted where I had problems to follow or where additional work is necessary to clarify issues. Generally, addressing these topics should be manageable by a thorough review of the manuscript by the authors, since no additional data nor major analysis is requested. I thus hope my comments are useful, instructive and are received as constructive criticism for the authors to improve readability.

Best,

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Specific comments:

The term "particle" sounds misleading (to me), it always reminds me on natural grains etc. You could better use the term "sample", or "specimen", since you are dealing with artificial particles.

In Fig.9 you show numbers of particle properties that you mention earlier – better have them in a table earlier or reference them to easier find that.

Part of the introduction is quite long (chapters 1.1 to 1.3); maybe be condensed for a more balanced general picture. The conclusions repeat a certain number of results and discussion thereof; they could more address the topics named in the introduction – e.g., how to determine past transport environments (fluvial, gravitational, planetary).

P1 L21: How does grainsize (specifically in a grainsize distribution) fits into the schematic understanding used here (and sketched in Fig.1)? Maybe it fits for the mean grainsize and specifically large grains are exempt?

Fig.1: What about strong material and high impact energies? Is this for brittle material only?

P2 L10: might also find a reference for fluvial bedrock erosion

P3 L10: Doesn't rock weathering also contribute to rounding particles? Rounded granitic grains might even become angular from transport when fragmenting. Don't know if this is of large contribution or only a specific case, but I would think discussing the influence of weathering in few sentences might round up the general picture.

Eq1: Why do you give this law in volumetric units, when you use it in mass units in fig.6?

P4 L13: In my understanding this is the fracture toughness, right? This, though, all applies to brittle rock – I see you mention this in L17, but

P4 L17: The actual fracture is "plastic" deformation; your sentence sounds confusing.

P5 L18f: These are methods and results and should go their sections; maybe formulate a question on these things here.

P6 L8: You could cite Sklar and Dietrich, 2001 here for creating these samples of different (tensile) strengths.

P6 L15: There was only one particle in the drum each time, right?

P6 L19: How were the particles photographed – always orthogonal to one of their original plane sides for consistency?

P6 L24: Hard to understand, why synthetic CIRCLES should not have been recognized as circles. You mean you created pixeled or distorted ones? What was the resolution of the camera setup (or better the ~pixel resolution on the particles) you used for Fig.4A?

P6 L28: I think you used the SAME 10 mixtures?

P7 L6ff: Mega-Pascal (i.e. N/m2) is a standard unit for rock strength. Can you provide a range of typical rock's values to relate your laboratory material to the field?

P8 L 19: Which "associated material properties"? Name them. You also mean best-fit lines from Figs5b and c?

P8 L24: "Mass fraction" is not really intuitive – do you mean remaining mass fraction or so?

Fig.6: You here set NR (which is not NR, but a normalized version) equal to x in eq.1 and also have a volumetric vs. a mass equation – settle and explain your reasoning and steps. Add R2 to the Sternberg law fits in panels (ace).

P9 L1: In fig.7 are violin plots, not histograms. Though, here you should describe what data you calculated to then show in fig.7.

P9 L6f: Sklar and Dietrich's relation refer to erosion of bedrock due to impacting particles and not to the attrition of particles by mutual collision (or collision on bedrock)! How does a plot of attrition mass vs. energy/strength actually look like (you can plot that)? Would be very interesting to see how this would fit into bedrock erosion theory (specifically, since one may speculate on combined bedrock erosion and particle attrition during a flood or so)! I address this, since you show a largely increased particle attrition for increasing rock strength (Fig.8a), which would mean they decay fast and thence would faster lose their impact erosivity. Would your results (Fig.8a) mean, that with increasing rock strength particles decay fast, so would not contribute much (or better not for long) to bedrock erosion? Also, I don't get your regressions misfit reasoning in Fig.8a – here you refer to k = AbC1, but Ab depends on Y and rho (eq.2) and the Sklar and Dietrich relation only depend on sigma_t. Hence it seems you compare different things – please better explain your steps and reasoning here.

P9 L11: Your formula assumes (mi-1) ~ m, right? Can you elaborate this?

P9 L14ff: Split and better declare the content of this sentence. What is the reason for C1 to be 3 orders of mag smaller for natural particles (weaknesses)?

P9 L15: The independence might be seen in Fig.7 (and Fig.6), but how in Fig.8?

Fig.7: I think the caption should be delta_m* vs. Ab. The distribution is not an average. What is the y-axis – the same as in Fig.6? You could indicate your explanations from the caption also in the figure: strong vs. weak for the x-axis. A second transition for small Ab is not obvious. Further, how the mass of the removed fragments looks like (can show this as a second panel)? This would also give a quantitative feeling relating to your description of chipping vs. fragmentation.

Fig.8: To which data is the regression for Sklar and Dietrich in (a) fit to – the black data? Is the parameter b in the cyan equation equal to 0.838? Where is the data in (b) from – which material in Miller and Jerolmack, 2020? I don't easily see how you got the value for C1, only that it is three orders of magnitude larger than for this data – you got it from (a) with solving the k-equation for C1? Then you should describe this in the text, not in the figure caption.

P13 L3: Having a low amount of sand in the particles (i.e. high strength) means a very fine texture (mostly Portland cement) here. This is different to a hard rock that though consists of large minerals, like a Granite, i.e. there might be a difference in fracture toughness. Is this issue addressed/settled in the natural particle attrition studies?

P14 L1ff May the weaker particles have had (more) initial cracks from curing?

P14 L22: Maybe at low Ab, there is only chipping on sharp edges and where fracture toughness is more important than strength?

P15 L2: Are >50% VCM at Ab<0.014? You could indicate both regimes (pure chipping vs. pure fragmentation) in Fig.12 (maybe showing a gradient)

P16 L18f: So you could even show a 3D regime with x=material strength, y=impact energy, z=impact number, extending the 2D-version of Fig.1?

P17 L2: That would mean that the attrition regime is predicted by a mass (delta_m; eq.2)? I don't get this.

Technical issues:

P1 L19: ... is "of" lower energy, …

Fig.1: I think bedload (or bed-load for consistency) should be bedload transport

Fig.1 caption: "a" debris flow and "bedload transport"; what transport mechanism images do you refer to?

P2 L8: …, and "with" the related phenomenon …

Eq.2 Why do you use the notation "C1" when there is no C2? Better use a more descriptive variable name.

P5 L20: Dropped from the same height in a drum? Can you elaborate here (only one grain per experiment hitting the steel frame or hitting other grains)?

P5 L11: … "sample" particles … This would be clearer

Fig.5: caption: In (b) and (c) better have the (n = 5) at the end of the sentences, respectively. The equations are missing units.

Fig.6: Panels (ace): Is this "Mass fraction" on the y-axis? As I said above, better use a more intuitive (and consistent) terminology here. Note the VCM-% in the figures; the lines are not visible in the legend. You could show the individual lines in gray (doesn't matter which is which) and so could improve the trend picture and reduce the legend. The x-axes are not NR, but normalized. Remove the "We can see".

Fig.8: caption: Instead of 8.38e-1 write 0.838 – or is it e to the power of -1?

P11 L4: What were about extending drum run time - would this have destroyed the weak particles or could you have reached higher circularity?

Fig.9: You may write/name in the figure that you show the shape evolution with number of rotations (NR=0 is initial shape).

Fig.10: Use a color gradient to highlight increase of particle strength. In the caption, combine the last two sentences. You use "transport" here, but write cumulative mass loss on the x-axis (it actually is relative); before you spoke of rotations. Be consistent and explain, if you move from rotations to something else. In panel (b) you could show the relative change of the aspect ratio relative to the initial conditions (i.e. 1). Combine Figs 10 an 11 into panels to not have a confusion with referencing and figure numbering.

Fig.12: Have the increasing VCM as a gradient in color for a clearer picture.

Fig.13: Since you refer to Fig.1 wit this, you may also have it in the same x-axis orientation as this (chipping regime on the right). You could also add some of its arrows or so. Call this phase space (as in the discussion)?

P15 L16: "… shape evolution of PARTICLES in order …". After that you speak of "transport" – have this defined before and be consistent throughout with this (impact, mass loss, transport).

P16 L6: "… that a TRHESHOLD exists …"