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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "The effects of cushion's particle size and thickness on coefficient of restitution under the rockfall impacts" *by* Chun Zhu et al.

Chun Zhu et al.

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Answer to referee 2 comments Reviewer 2 R 1: Primarily, the experimental findings need to be printed alongside with their error bars. Without the given uncertainties, it is not obvious whether the drawn conclusions can be labelled as significant or something be called as leading parameter. It is of key importance for the authors as for the reader likewise to be able to judge the results against their experimental uncertainties. From the description of the experimental work, it seems that the only measure to mitigate statistical outliers is, that each series result is the mean of an experimental triplet. It has to be shown that this procedure is sufficient to generate statistically significant

data. If error bars should even out all recorded differences, the experimental method has to be improved.

AC: Thanks for the reviewer's suggestion. I think the packing structure of the cushion particles don't have the influence on the COR result. Because the proportion of the size of rockfall and the coverage area of cushion is relatively small in the experiment, and the impact range when rockfall collided with the cushion is less than the coverage area of the cushion (See Figure 7 in Supplement). In field engineering, when the rockfall collide with the cushion, the gravel particles cushion of other areas will also generate interlocking effect on the particles in the collision area, which is similar to the packing structure in the tests. The main uncertainties in the test results arise in tests with large cushion particles, where the wider scatter of the values is attributed to the contact conïňĄguration between the large cushion particles and the blocks: large cushion particles have numerous different conïňĄgurations. This also affected the deviation in the trajectory caused by the impact, which had a drastically higher uncertainty than for small cushion particles. In order to counteract the effects of chance, a "three tests for the mean" method was adopted, and the average value was set as the final result for each data point in the figures and tables presented here. For cushion particle sizes of 1.8cm and 2.4cm, each test was repeated five times, and the middle three values were used to obtain the average value, while for cushion particle sizes of less than 1.8 cm, each test was conducted three times. If an obviously outlying result was obtained, the test was repeated to reduce the error, thus this procedure is sufficient to generate statistically significant data. I have mentioned it in 'Experimental procedure' section. The test results including the error bars are shown in Table 1-4 (See Supplement).

R 2: Secondly, the text requires substantial refurbishments with respect to language. The authors should invest in clearer structure when describing the experimental setup as well as the testing procedure. Furthermore, ïňĄgures should be labelled correctly and descriptive in order to facilitate the reading. Additionally, the measurement units should be consistent within the legends and the text (mm and cm, etc.). The use of

prooïňĄng tools and the revision by a native speaker is highly advised to make the text more readable.

AC: Thanks for the reviewer's suggestion. My manuscript has been edited for English by using an English editing service, the embellishment proof is supplied as the supplement. I have added units in Figures 8 and 9. The structure format of this paper and description of Figure have been revised to make readers easier to understand.

R 3: A few technical comments: The Introduction should be shortened, since the paper clearly focuses on open-pit mining questions and an overview and listing of references for general rockfall mitigation measures is not needed. References for the approximate formula for the total energy of rockfall should be backed up with a better accessible source. The experimental setup needs to be clariïňĄed, especially the positioning and use of the cameras (ïňĄeld of view, image processing, etc.). The concept of an orthogonal test theory should be explained and/or backed with a better accessible source. Is it just the altering of the four parameters of interest? The drawn conclusions are not written in a concise manner. Focusing on the main experimental result in a clear way would be favorable.

AC: Thanks for the reviewer's suggestion. I have deleted some outdated references, and introduced some newly important references in the 'Introduction' section to highlight the importance and uniqueness of the current study. The list of references for some general rockfall mitigation measures is to illustrate the current research on protective methods for rockfall is mainly for urban or mountain area, not suitable for open pit mine area. I will shorten some unsuitable references in the 'Introduction' section. I have added some significant references for the approximate formula for the total energy of rockfall, and believe they are credible accessible sources. I have detailed about the experimental procedures. Such as: the calculation of rock velocities, the relative position of the two cameras and preparation process of the cushion platform, the descriptions are as follows: The two cameras, which obtained the motion, velocity, and kinetic energy automatically, were placed symmetrically at a distance of approximately

0.9m from the impact surface (Figure 5). The distance between the two cameras was about 1.2m, making the cameras look down slightly at the targeted platform. The synchronized recordings from the two cameras captured a sequence of image stereopairs at time intervals of 1/200 s. By applying stereo-photogrammetric processing, the position of any point in both images can be computed in 3D space. In general, a digital image is a perspective projection of 3D space to the camera lenses. The image plane has a 2D coordinate system where position measurements can be made using pixel coordinates. The camera has a 3D reference coordinate system that is based on the image plane pointing in the viewing direction of the camera. The speed of the rocks can be obtained by measuring the distance they have moved between adjacent frames. To simulate gravel cushions of different thicknesses, a large number of 40 cm length $\times$ 40 cm width $\times$ 2 cm height hollow gypsum boards were made. A 30cm length $\times$ 30cm width $\times$ 2cm height section was cut out of the center of each board. The hollow gypsum boards were stacked on top of each other to simulate gravel cushions of different thickness, and then the hollow parts of the boards were filled with gypsum particles. The hollow boards were fixed to a massive 40cm length $\times$ 40cm width $\times$ 6cm height gypsum base to ensure the preservation of momentum from the impact. In order to accurately measure the speed of the blocks with the cameras and to avoid interference from the motion of cushion particles affected by the collision, the cushion was blackened (Figure 6). I have introducted the clear principle of 'orthogonal test' in 'Orthogonal test design' section to facilitate readers to understand. The principle of 'orthogonal test' is described as follows: Orthogonal testing is a design method that allows testing of multiple factors and multiple levels. It is based on orthogonality and selects representative points from a comprehensive experiment for testing. The orthogonal test method has the advantages of being uniformly dispersed, neat and comparable, making each test highly representative so that fewer trials can fully reflect the impact of the variation of each factor on the index. The purpose of doing an orthogonal test is to explore the degree of influence of the four different factors on the COR and damage depth, L, and find the best combination to reach the optimal protective effect when a rockfall collides

with a cushion. When these factors cannot be considered in full, the leading factor is considered to achieve the expected effects to a great extent.

The drawn conclusions have been reorganized, focusing on the main experimental result in a clear way.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-16/nhess-2018-16-AC2-supplement.pdf

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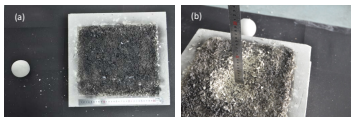

Fig. 7 Photographs of a cushion (a) before and (b) after a rock impact experiment

Fig. 1.