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Discussions

Interactive comment on "Elasto-plastic-adhesive DEM model for simulating hillslope debris flows: cross comparison with field experiments" *by* Adel Albaba et al.

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This paper addresses an interesting topic, and rather hot topic as studied by different research laboratories worldwide. This contribution is original and of real scientific value as it provides interesting insights into the DEM modeling of debris flow.

The two main interests in this article are, first, the use of a particular DEM contact law accounting for an adhesive force between particles and, second, the use of data from real-scale debris flow experiments for developing the model.

Even though this article is well written, well documented and constitutes an important

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Discussion paper

step forwards different comments rise after reading it. The detailed comments below globally invite the authors revising their article, while some may be considered as food for thought only.

To the referee's knowledge this is the very first publication proposing a DEM model of debris flow accounting for a tensile force between particles. Undeniably this is an interesting point. However, this topic is not really addressed in the article. The motivations for using such a contact law are not detailed nor argued, in particular with respect to other contact laws used for modeling debris flows. It is not explicitly stated what this law is supposed to allow accounting for. Besides, the consequences of using such a model on the granular flow behavior is not addressed in the results presentation neither than in the discussion. For sure, it has an influence on the flowing material velocity and height. It may also have a consequence on the interaction with the sensor (and thus on the impact force). Basically, the adhesive force may favor longer duration contacts between the particles and the wall (considering that contacting particles are pushed downward by other flowing particles). Considering the importance given to the type of contact law in the article title one could have expected more consideration to this crucial and innovative point. Experimental data from Bugnion et al. (2012) are used for developing the proposed model. More precisely, couples of parameters (basal friction angle, restitution coefficient) are calibrated against different flowing materials. In the end, the main conclusions drawn concern the ability of the modeling approach in satisfactorily fitting the experimental data, focusing on 3 measurements (flow height and velocity and pressure on the obstacle). So, contrary to what is suggested in the title, what is cross compared with field experiments is not the model itself, but the modeling approach. This comment is motivated by the fact that the calibration of the model parameters is conducted using these experimental data.

Concerning the area considered for measuring the pressure it seems the simulations do not perfectly meet the experimental conditions. For instance, the dimensions given in Bugnion et al. are the wedged dimensions and not the sensor dimensions. Differences thus seem to exist between the effective experimental measurements conditions and that in the simulations, with possible influence on results validity and discussion. The implication is that, for example, the sensor gives no value for thin flows and that the height of flow concerned by the measurement is not 295 mm, but much less. As dealing with a debris flow, a velocity gradient may be observed from the flow bottom to top, implying a variable impact force on the obstacle. The position and dimensions of the measuring surface should thus be identical between the experiments and the simulations. This point should be clarified.

Table 1 shows a rather large panel of experiments, varying three parameters related to the flowing material (wet density, water mass fraction and fine mass content). Due to these differences, very variable values where measured in relation to the flowing material and impact pressure. But in such a context, it doesn't seem relevant to refer to mean values when comparing the results of all the tests, as done section 3. The initial conditions are extremely variable and consequently the velocities, flow thickness and pressure differ significantly from one test to the other: a comparison based on an average value seems to be of very limited interest and relevance. In addition, and due to these differences in initial material characteristics, tests 9, 14 and 16 seem to pose a problem to the authors, either when comparing the maximum pressure of the different tests or when comparing the experimental data with DEM results. A basic way to compare these results, is to compute the hydrodynamic pressure which is proportional to (unit mass*v^2) and to compare this pressure with that measured (as done by Bugnion et al.). When plotting this term versus Pmax, it appears that most of the test results are aligned, with a ratio of 0.76+/-0.1 between the two parameters. The exceptions are tests 9 (ratio of 0.35) and, to a lesser extent, test 11 (ratio of 0.57). This suggests that the pressure measured for test 14 is in line with other experiments, when considering the unit mass and the velocity, and may not be justified by the presence of large boulders in the flow. The difficulty for the DEM model to well reproduce results of tests 9, 14 and 16 certainly finds an explanation in Figure 16. This figure shows that these tests are far from the domain where the modeling approach gives good results. In other words, Figure 16 reveals the domain where the proposed DEM modeling approach is valid, in terms of restitution coefficient and basal friction angle and after having calibrated the model parameters. Cases 9, 14 and 16 are out of this validity domain.

Similarly as for the experiments, a 50ms filtering interval was used to smooth the pressure curves. This temporal window aims at smoothing sensor plate vibrations resulting from the impact of solid grains (Bugnion et al.). It was observed that after an impact by a single solid ball the sensor plates vibrates for up to 30 ms. This period of time is much longer than the impact duration : it takes a few milliseconds for having a momentum transfer from the solid ball to the plate. In the case of debris flows, these peaks come in addition to pressure transmitted by the matrix surrounding large particles (this matrix consists in a mixture of water and fine grains). Bugnion et al. stated that this technique was efficient in smoothing peaks due to solid grains contained in the debris flows, without altering the information. Nevertheless, it doesn't seem really justified to consider the same filtering interval for treating the DEM results because there is no plate vibration but just short duration peaks (2ms) related to the plate-particle contacts. Such peaks do not justify having a 50ms filtering interval. This comment is also motivated by the point addressed below.

The DEM model considers an assembly of large grains, with mean diameters ranging from 75 to 150 mm. For the main case, the diameter ranges from 50 to 100mm, which represent only a fraction of the grain-size distribution of the debris flows considered by Bugnion et al (less than 30% in mass). Considering the size of the sensor it appears that the maximum number of d50-particles in contact with the plate goes from about 12 for d50 = 75 mm down to less than 4 for d50 = 150 mm. Such a small number of contacts has a strong influence on the pressure deduced from the DEM simulations. In the absence of matrix, the force exerted by the flow on the sensor is then the sum of a small number of short duration contacts. As the interaction with the sensor is a key issue in this work, a more in-depth investigation of the particle-plate interaction could have been conducted, for instance addressing items such as pressure representativeness (variability in results repeating the test varying the initial particles packing), peak force amplitude, impact duration, number of contacts, ... This is particularly critical for d50 = 150 mm, and results presented in Fig. 17 may be explained by the fact that the variability in force exerted on the plate and resulting from the small number of contact points has not been accounted for. The influence of the small number of contact points should also be checked for cases down to d50=75mm.

The model is calibrated focusing on 2 parameters: the basal friction angle and the ratio of k1 to k2. This later is referred to as restitution coefficient but this term seems improper. It doesn't correspond to the classical definition of the restitution coefficient (ratio of velocities between after and before contact) and thus may introduce ambiguity. This comment seems to be supported by the results plotted in Fig. 18, revealing the very limited influence of this coefficient on the flow velocity and height. For what concerns the basal friction angle, this parameter seems artificial. Figure 16 shows that for a same slope, the basal friction angle varies from 25 to 40° depending on the flowing material. This range may hardly be justified by changes in the slope characteristics from one test to the other, neither than the 40° value be justified. It seems on the contrary that this parameter is a way to account for the flowing material rheology. The debris flows being modeled as a collection of particles of large diameter with respect to the flow thickness, a good agreement of the DEM model with the experiments in terms of flow height and depth-averaged velocity requires adjusting the basal friction angle. This parameter is thus not intrinsic to the channel characteristics, but also accounts for the rheology of the debris flows. This would deserve specific comments and probably discussion.

On a formal point of view the paper organization is sometimes confusing. The calibrated parameters are presented late, after plotting and discussing the results. Technical details concerning the experiments are presented in the discussion, while these pieces of information were discussed by Bugnion et al. and the figure was directly copied from their article. As such, this should be introduced together with the experiments, in section 2. Last, in section 3.3 dedicated to the parametric study, there is a mix between DEM model parameters and physical parameters describing the flowing material and conditions. Considering the former or the later does not fall within the same scope.

Last, curves plotted Figures 13 to 15 do not correspond to the maximum values plotted in Figure 11.

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