INFLUENCE ANALYSIS OF PARTICLE SIZE AND DISTRIBUTION ON THE FINAL DEPOSITION OF A DEBRIS FLOW NUMERICAL SIMULATION

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Abstract. *This paper aims to use a three-dimensional model to simulate a debris flow scenario using the Discrete Element Method (DEM) approach, a numerical tool to model the behaviour of granular systems, witch acts by tracking particle trajectories through a dynamic analysis, while considering contacts among them, as well as between particles and obstacles. Debris flow occurs when wet masses of soil rush down mountainsides as result of gravitational forces and water flow and is known to cause severe damage to life and properties due to its destruction force and high speed. Additionally, in Brazil an important part of the oil industries is located in the South and Southeast regions, known to be more prone to landslides that may affect pipeline systems. In this context, a predictive numerical study of debris flows can be fundamental to prevent losses. Experimental results are compared to numerical analysis in order to calibrate the friction parameters, evaluating the surface roughness and the influence of the initial conditions on the final grains deposition.*

Keywords: *Debris flow, Discrete Element Method, granular systems*

1 INTRODUCTION

Debris flows are mass movements that occur in response to a decrease in soil friction under the presence of water, a phenomenon which usually carries a large amount of soil, rocks, trees and mud. The poorly sorted sediment masses, saturated with moisture, rush down mountainsides as a response to gravitational attraction and water flow. Interaction between solid and fluid forces gives to a debris flow a unique power of destruction. Unpredictability, destructiveness, and difficulties on the designing of effective preventive methods are the main reasons to classify debris flows among the most hazardous natural events.

Landslides may occur in a wide variety of environments, damaging properties and lives. In this context, the study of a debris flow behavior becomes important to prevent disasters. In the past two decades, the South and Southeast regions of Brazil have presented the largest number of landslides occurrences in this country (Fig. 1). The Southeast region also concentrates most of the petroleum pipelines, meaning that a landslide phenomenon may cause serious damages to the petroleum industry.

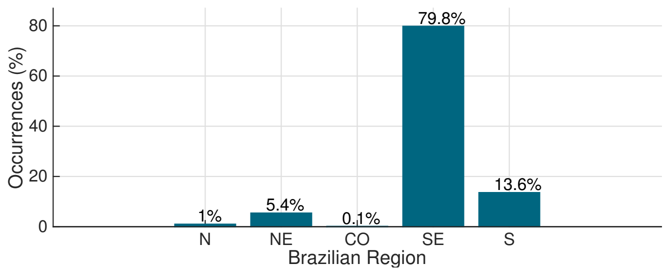


Figure 1: Landslides occurrences in Brazil per region between 1991 and 2012. Source: CEPED (2013)

Martinez (2009) describes a debris flow as a multi-phase flow, which includes not only water, but also a wide range of interacting solid particles. The Discrete Element Method (DEM), introduced by Cundall & Strack (1979) to model granular assemblies, is a numerical tool able to describe discrete systems with a finite number of particles. The procedure considers the solution by incremental time-step and contact detection to update the forces acting on each particle. Using these forces, the Newtonian equations of motion can be solved. In the method, the particles are commonly approximated by objects with regular geometry. Since the transition from a continuum to a discrete approach gives more realistic results, the use of discs (2D) or spheres (3D) can be considered enough approximation for many practical cases. In this paper, the influence of frictional parameters on debris flow events are analysed to perform a numerical calibration.

2 METHODOLOGY

In this work, the debris flow simulation using the DEM approach is carried on the DEMOOP (*Discrete Element Method Object Oriented Programming*) software, (Carvalho Junior et al., 2006). Using the software DEMView, (Amorim et al., 2006), it is possible to convert DEMOOP output files in graphic data and generate a height profile. For each simulated model, the generated height profile is then used to evaluate the effects of the desired parameters. The influence analyses of granulometry and surface roughness are based on a debris flow numerical model with friction parameters calibrated by Braga (2014).

2.1 Height Profile Parameters

The height profile is a geometrical information that summarizes the obtained deposition of the set of particles used in the simulation. From this profile, two parameters are obtained, as shown in Fig. 2. The coordinate (Xmax, Ymax) is defined as being the maximum profile height point, from which the 'a' and 'b' parameters are defined as the horizontal distances between this point and the points of given height (h) on the profile. In the analyses caried, h is choosen based on the particle diameter. To garantee the particle stacking h must be at least two particle diameters big.

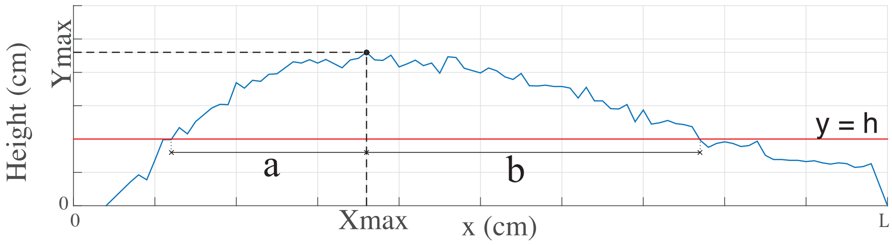
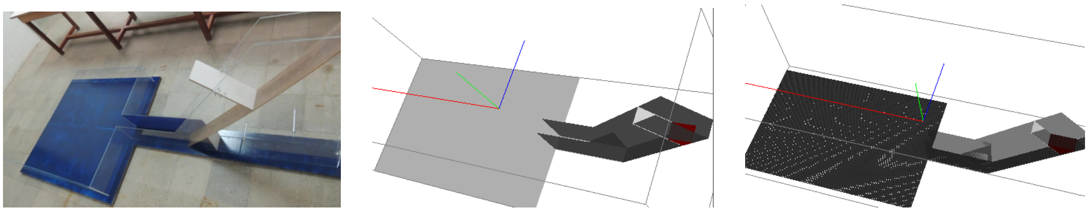


Figure 2: Parameters of a height profile. Source: Braga (2014)

2.2 Numeric and Experimental Models

Experimental analyses are carried on the Laboratory of Geotechnics (LabGeo/UFAL) and the numerical simulations use the computational infrastructure of the Laboratory of Scientific Computing and Visualization (LCCV/UFAL). Figure 3 shows the physical and computational models developed for the calibration of parameters in this work.



(a) Experimental (b) Numerical - smooth surface (c) Numerical - rough surface

Figure 3: Models for debris flow study.

The surface roughness was analysed by switching the obstacles from polygons to particles and changing the friction parameter in a range of analysis. Three different granulometries were modelled to evaluate their influences on the final deposition of the grains.

3 RESULTS

Figure 4 shows the results for the surface roughness analyses ranging the friction parameters (μ) between particles and surfaces. When friction increases, profiles start to accumulate, while lower friction values generate more spread profiles. The numeric calibration curve on Fig. 4 represents the results obtained by Braga (2014) using the numerical model with surfaces composed by geometric obstacle (Figure 3.b). Using the rough surface (Figure 3.c) the friction matching with the experimental data is lower than before. Once the rough surface has the presence of a natural friction between the particles of the flow and the surface particles, the friction parameter to be calibrated during the simulation is supposed to be lower.

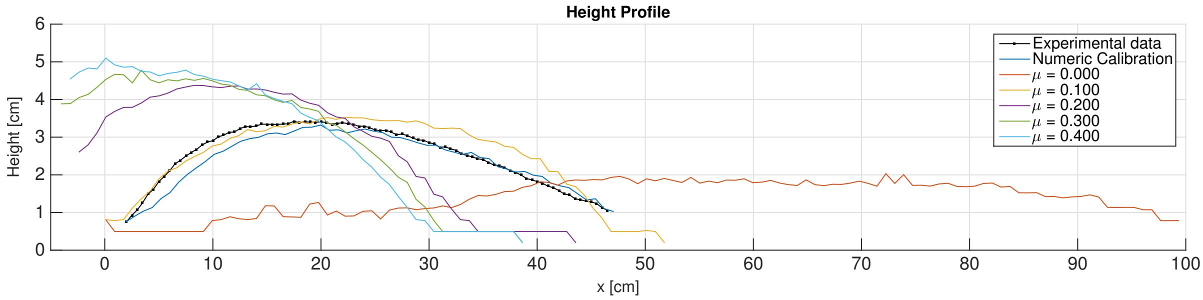


Figure 4: Surface roughness analyses.

The granulometry of the set of particles was generated randomly. However, during flow, a segregation phenomenon was observed: smaller sized particles sinked to the bottom of the profile (see Figure 5).

Figure 6 shows the evolution curves of the two different diameter sized particles mass centers for each time-step. The three curves start near zero (ramdon distribution of the radius) and end showing that the centers are far from each other (segregated). Diameters sizes were based on the D diameter used by Braga (2014) (D = 0.0041 m). The analysis were carried in three granulometric sets of particles (Figure 5.a-c) generated using different proportions of bigger particles (1.25 times of D) and smaller particles (0.75 times of D).

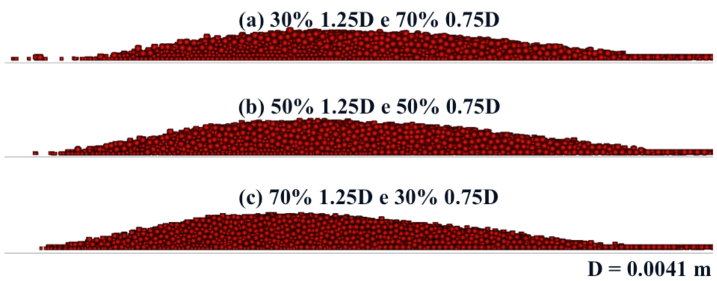


Figure 5: Profile given by different granulometry distributions simulations.

The profiles obtained by the granulometry variations are shown on Figure 7. Granulometries with predominant smaller particles size show a decrease in the x and y values of the profiles top point. The best match to the calibrated data is found in the profile composed mostly of bigger particles.

4 CONCLUSIONS

The addition of a rough surface and granulometry analyses increased the complexity of the study, however, the approach still gives a good compatibility between experimental and numerical results. The next steps consist of an statistical analysis for the repeatability of the experimental model, a physical reproduction of the rough surface, and a comparative analyses of the segregation phenomenon.

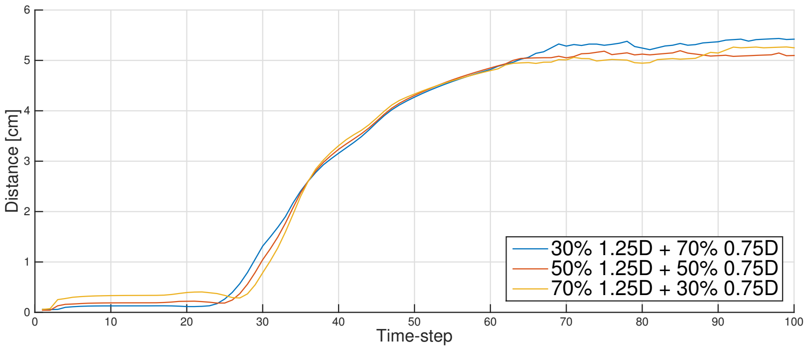


Figure 6: Distance between the center of mass of the two radius.

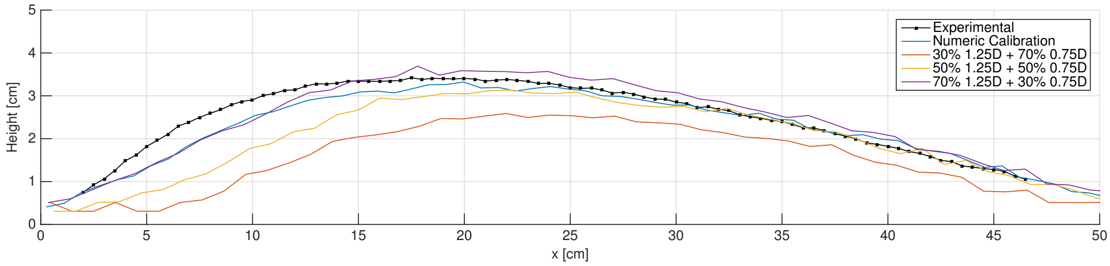


Figure 7: Surface roughness analyses.

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