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Rheological behaviour of lahar flow

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Lahars are mixtures of water and debris flowing down the flanks of volcanoes. These flows generally occur after heavy rainfalls and carry sediments deposited by volcanic eruptions. They are among the most destructive volcanic phenomena, and were responsible, in the 20th century, for 40% of the fatalities associated with volcanic eruptions worldwide. However, the mechanical behaviour and the propagation of these particular debris flows still remain poorly understood. In the frame of the research project Laharisk, Mount Semeru in Java (Indonesia) was chosen as a test site to monitor lahar activity and flows properties owing to the frequent occurrence of lahars on its flanks during the monsoon rainy period.

Two observation stations, situated 510 m apart, were installed in the Curah Lengkong Valley on the southeast flank of Semeru volcano. The relatively straight and box-shaped channel between the two stations represents a natural flume well suited to study the hydraulics of the flows. Both stations are equipped with video cameras, pore-pressure and load sensors, AFM geophones, and one broad-band seismometer to measure the evolution over time of lahar flow height, speed, and discharge. Bucket samples are also directly taken in the flows at regular time-intervals in order to provide sediment concentration and grain-size distribution. The rheological behaviour of the material is studied through laboratory vane tests at constant imposed shear rate conducted on the fine-sized fraction ($< 400\ \mu$m) of the samples.

The flows generally comprise several distinct pulses or ‘packets’ that can be traced between the two instrumented stations. Each pulse lasts between 5 and 30 minutes. Typical flow heights, peak velocities, and maximum discharges range between 0.5–2 m, 3–6 m.s-1, and 25–250 m3.s-1, respectively. The rheometrical tests indicate a mechanical behaviour of the frictional type, the shear stress being almost independent of the shear rate. In addition, the friction coefficient increases with sediment concentration. At the scale of the flow, the rheology of the material can also be investigated through the relationship between flow height and discharge in control sections. The obtained relationship has the form of a power law, and is also indicative of a frictional mechanical behaviour. Here also, the concentration appears as an important parameter controlling the rheological behavior of flow. Hence, both measurement scales consistently show frictional behaviour depending on the concentration of the lahar flow.

The determination of this rheological behaviour constitutes an important step towards the development of efficient numerical simulation tools for lahars.