GRANULAR FLUXES IN LABORATORY AND IN THE FIELD: 3-DIMENSIONAL SURVEY
BY TERRESTRIAL PHOTOGRAMMETRIC TECHNIQUES

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Abstract

Natural hazard phenomena, such as debris flows, rock or snow avalanches, should be surely considered an increasing alarm due to the extremization of the meteorological events related to climate changes. The comprehension of these events, in terms of rheologic and physical behaviour cannot be improved only at a real scale on the field. That’s the reason why an intense photogrammetric laboratory activity was conducted to describe metrically the evolution over time of a granular material flowing down a flume. A number of experimental tests have been performed and elaborated photogrammetrically. A couple of them will be here briefly described. The obtained experimental data, can contribute to the description of the rheology and to the calibration of physical-mathematical-numerical models. A parallel study, regarding a debris flow site, located in the Northern Alps, was performed, thanks to the development of a monitoring system. Data collected by the installed instruments, are intended to enrich the hydrologic and physical knowledge of the phenomena.

Laboratory activity

The calibration of physical-mathematical-numerical models, conceived to simulate the dynamics of wet and dry granular masses, is carried out by physical models based on the similarity theory, together with the direct observation on the field.

Numerical models are widely used in the process of definition of hazard maps of several phenomena: among them dense snow avalanches, rock avalanches and debris flows. In order to provide new experimental data useful for the calibration of numerical models and to test rheological laws, an experimental apparatus has been built at the Geosciences Department. The apparatus has the purpose of reproducing three-dimensionally the outer surface of a moving granular mass from the initiation to the end of its motion. The experimental flume is formed by two tiltable planes. In the presented experiments the upstream plane has an inclination of 27.5°, while the downstream plane of 6.5°. A set of 8 camcorders are fixed to a support system, located above the flume. A dedicated acquisition system controls the camera settings, exposure time and diaphragm shutter aperture. A Labview software ensures perfect synchronization among the frames. Two high frequency illuminators increase the frame quality, allowing to decrease time exposure significantly.

The complete topographic reconstruction determined a complex methodological research aimed to associate high metric quality of the results and high automatization during the processing phase in order to reduce elaboration time drastically.

Laboratory simulations

Two different types of granular materials were used in the experiments in order to analyze the different behavior of the moving mass as a function of some physical parameters.
- well sorted sub-angular material, diameter 0.7 cm and 1.5 cm, density 2600 kg/m³;
- synthetic zeolite material, mean diameter 1.0 mm, density 1080 kg/m³;
The flume configurations used in the experiments are graphically described in Figure 3. 8 tests have been performed using 4 different flume configurations and 2 different materials.

**Figure 3**: The upstream and the downstream planes in the experiments. The granular material has been released on an open and on a channeled slope. On the downstream plane a flow diverter and a mound have been used, to simulate real configurations often used on the field.

In the following is presented an experimental configuration and the associated photogrammetric analysis.

**Channellized coarse material impacting on a flow diverter**

In order to evaluate the metric quality of the photogrammetric study an error analysis has been carried out. This was directly derived from the photogrammetric output, comparing the input Ground Control Points position with the position derived from the photogrammetric analysis. Moreover another indirect approach has been used measuring the flow height of the granular mass directly and comparing that value with the photogrammetric value at the same time in the same position. The obtained accuracy is of about 1 mm - 1.5 mm.
Figure 4: a) The coarse granular mass at eight different instants; b) The evolution over time of the area occupied by the granular material at three different cross-sections; c) The volume evolution over time of the granular material.

An example of the time evolution of a coarse granular mass (9.83 dm$^3$ released at the top of the upstream channelized plane) is presented in Figure 4, where eight different instants are showed. Several metric information can be obtained by the experimental tests, for instance the material volume variations over time (Figure 4c), the variation of the cross-sectional area over time at different positions (Figure 4b) as well as other information about the rheology of the material (dynamic and static friction angles).

Field activity

A lot of work has been performed in order to develop and optimize the monitoring system of Acquabona. Useful field data have been collected over the years at the upstream and downstream stations. An example of acquired data, referred to the debris flow event of May, 21$^{th}$ 2012, is showed in Figure 6. Precipitation and intensity information have been collected by the Vaisala meteorological station at the top of the catchment, while depth debris–flow profile has been created thanks to the ultrasonic sensor and the laser meter located at the downstream station. Video data, gathered at the downstream station, are
important to analyze the rheological behaviour of the debris flows and to characterize the hydrological response of the catchment.

The development of the monitoring system is supported by the (GIS-based integrated platform for Debris Flow Monitoring, Modeling and Hazard Mitigation) Cariparo project GAPDEMM, that will assure the continuity of the field research by the installation of a third station and the ordinary maintenance of the system.

A new low-cost instrument, called Kinect (Figure 5), is being experimented, considering the advantages and the properties of the accessories that can be installed. It is equipped with a RGB camera, an IR projector, and IR camera. The depth image is constructed by triangulation from the IR image and the projector and hence it is carried by the IR image. So we are now evaluating the possibility to exploit it at the station to get a real time evolution of the debris flow surface propagation.

The GAPDEMM project will support the continuity of the field research, and will allow us a future development of the station, besides the ordinary maintenance.

**Concluding remarks**

A new experimental photogrammetric system has been designed and built. An industrial acquisition system was installed, provided with a dedicated software to ensure frames’ synchronization and quality. Three-dimensional dynamic analysis of the surface of a granular mass moving down a slope was undertaken. Experimental data will be very important in the calibration of numerical models.

A debris-flow monitoring system has been designed and built. Data collection at the Acquabona site allows the analysis of the hydrologic factors controlling debris-flow’s initiation, entrainment, and dynamics. The good reliability of the monitoring system allows a future enrichment of the instrumentation, also taking to the field the technics for the 3D reconstruction developed in the laboratory. Expected results at the beginning of the project have been almost thoroughly achieved.
References


SUMMARY OF ACTIVITY IN THIS YEAR

Communications:

DALLAVALLE D., SCOTTON P
Rilievo fotogrammetrico dinamico di ammassi granulari in movimento alla scala di laboratorio.
17a Conferenza Nazionale ASITA, 5 – 7 novembre 2013, Riva del Garda.

Publications:

DALLAVALLE D., SCOTTON P
Rilievo fotogrammetrico dinamico di ammassi granulari in movimento alla scala di laboratorio.
17a Conferenza Nazionale ASITA, 5 – 7 novembre 2013, Riva del Garda.

Teaching activities:

Co-supervisor of MSc Thesis

Workshops and Congresses

International conference, Vajont -1963-2013-, Thought and analyses after 50 years since the catastrophic landslide. Padova (Italy), 08-10 October 2013.

17ª Conferenza Nazionale ASITA, 5 – 7 novembre 2013, Riva del Garda.

Getting data from a debris-flow monitoring system requires a constant and continuous application and money to maintain and improve the whole system.