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New method for in situ characterization of loose material for landslide mapping purpose

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Abstract

The assessment of grain size distribution and plasticity of loose geological material, during in situ geological investigations, is not obvious. Visual appreciation allows an approximative quantification of the coarse granulometric fractions, but not of the fine ones. Field soils determination methods suggested until now, are visual and tactile tests leading to a very rough estimate, which is only qualitative and not very reproducible. The new proposed field test (GEOLEP method) allows a quick quantification of the fine fraction of loose material. It allows the determination of the sand fraction (fine and medium grained sands) as well as the methylene blue value of the samples. The necessary equipment to perform this test is light and compact and the time needed to analyze one sample is approximately 15 min. Thus it is also possible to carry out numerous measurements in one day. The calibrations were carried out on a selection of 13 natural samples, chosen for their representativeness of the typical alpine quaternary deposits. The results obtained with GEOLEP method are relevant compared with standardized laboratory tests; the obtained correlation indexes are of 73% for the comparison with laboratory stain test results and of 89% with a laboratory method using a similar procedure than the field test. The correlation we performed with Atterberg's limits tests shows that a rough approximation of plasticity index can also be obtained ($R^2 = 75\%$). This method thus brings a new tool which should allow taking into account the lithological factor (by some quantitative and representative variables) in a reliable way for the evaluation of landslide hazards.

Keywords: Landslides; Natural hazards; In situ test; Plasticity; Grain size distribution; Methylene blue; Clays

1. Introduction

1.1. Objectives

In the actual economical context, laboratory tests are expensive, hence the tendency to save on the number of tests, to the detriment of information on the variability of the material. Nevertheless, as a geologist, one often prefers to be able to analyze a large number of samples, although it may mean a little less precision on the results. These considerations are particularly relevant in the natural hazard context.

The objective of this research is to develop a new test for fine fraction quantification of loose geological material (e.g. quaternary deposits), to be completed in the field during the geological mapping process. The aim is to obtain more accurate and reliable information on studied material than with a visual or tactile estimate (ASTM D 2488-06; SN 670 005a), without aiming at laboratory precision. The

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use of this test is not proposed as an alternative to laboratory tests, but can be used for applications for which the latter tests are either too expensive (according to the necessity of a large number of samples), or because results have to be obtained directly in the field.

Such a test should be easily and quickly executed. The device used should be compact and light enough, not to disturb the follow-up of the geological mapping. It is also important that the test realization do not need electricity, or large quantities of water.

1.2. Context and motivation

The description of grain size distribution and plasticity of loose geological material is crucial for characterizing their susceptibility toward natural hazards, especially toward landslides or earth and debris slides and flows (Hungr et al., 2001). Taking these parameters into account is particularly important, when deciding about potential evolution of existing slides or mapping the susceptibility towards new slides. To improve hazard maps realization, it would be a great progress being able to describe these parameters in a quantitative, fast and reliable way, directly in the field while one performing geomorphological observations for existing phenomena's map elaboration.

2. Analytical methods

A visual estimation allows a satisfactory description of the coarse fraction of the material, whereas the quantification of the finer fraction is more difficult (Wamytan, unpublished data). The field determinations currently described in international Standards (ASTM D 2488-06; SN 670 005a) are visual and tactile tests, only allowing a subjective estimate, whereas miniature field devices, designed for testing mechanical parameters, such as miniature Vane Test (Torvane) or miniature penetrometer (Zimbone et al, 1996; Moore, 1997; Titi et al., 2000), are not directly focused on fine granulometry description and water–clay interactions as wished for the developed test.

2.1. Sedimentometry

For the characterization of the sandy fraction, the sedimentometric methods are well adapted, because they seem to be most suitable for the field realization. The GEOLEP method is inspired from Andreasen's pipette test, an experienced and standard laboratory test (ASTM D 422-63; SN 670 818). It is based on Stokes' Law (Eq. (1)), which expresses decantation speed v of a spherical particle, with a specific weight γ_p, under the attraction of gravity in a liquid of specific weight γ_w and a dynamic viscosity η, according to is radius r.

$$v = 2/9*[r^2*(\gamma_p - \gamma_w)*g]/\eta. \quad (1)$$

But, for the in situ characterization of the finest fraction, and in particular of the clay fraction, sedimentometry is not relevant any more, because of the very long time necessary for these particles to deposit.

2.2. Methylene blue adsorption

Instead of looking for an alternative to sedimentometry to describe the clay fraction's granulometry, we considered it would be rather interesting to describe plasticity and water sensitivity of the studied material.

Usually, plasticity determination of loose geological material is done in the laboratory with Atterberg's limits (Atterberg, 1911). Since the procedure of this test is not adaptable to field conditions (systematic work with a drying oven), our focus turned to indirect plasticity characterization by methylene blue methods. This strong organic dye [$C_{16}H_{18}ClN_3S \cdot xH_2O$] has surface properties which allow it to fix itself by polar bonds on clay minerals, in a similar way to water molecule. Methylene blue has been used for a long time to measure clay surface areas (Johnson, 1957; Pham Thi Hang and Brindley, 1970), but its use for soil classification has been proposed at the end of the Seventies only (Tran, 1977; Magnan and Youssefian, 1989; Tourenq and Tran, 1989; Benaben et al., 1989). The stain test was then adopted as a standard in several countries (ASTM, 1984; AFNOR, 1993). Methylene blue value, denoted as v_B, represent the ratio between the mass m_{Ba} of methylene blue [10 g/l] solution used to cover all external and internal clay surface areas and the dry mass m_{ds} of this sample (Eq. (2)).

$$v_B = m_{Ba}/m_{ds}. \quad (2)$$

3. New field method

During the recent years, several studies carried out in the Laboratory of Engineering and Environment Geology of EPFL (GEOLEP) tackled the subject (Wamytan, unpublished data; Pouyt, unpublished data; Pantet, unpublished data), aiming at gradually adapting laboratory methods to the realization in the field.

3.1. Sampling

Samples are directly taken from recent outcrops using a quaternarist hammer; a small quantity of material (100–200 g) can be taken after removing altered surface layers.