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In situ measurements of surficial mud strength: A new vane tester suitable for soft intertidal muds

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Abstract

A vane fitted to a standard shear vane tester is described, the purpose of which is to obtain better measurements of the rheological properties of soft, surficial, intertidal muds (and consequently, variations in their erodability). Specifications and geometry of this vane are presented. The computation procedure is detailed, so that the methodology can be applied to any vane tester. The main improvement is a greater vertical resolution, typically less than 1 cm. Sets of direct measurements with this equipment and correlation with dry densities for three intertidal mudflats (estuaries and bay) are presented.

Direct easy and quick shear strength measurements with such a vane can constitute basic data to characterise the erodability of a mudflat.

Keywords: Vane tester; Shear strength; Bed erosion; Cohesive sediment; Intertidal environment

1. Introduction

The simulation of cohesive sediment dynamics is dependent mainly upon the knowledge of two factors: the settling rate, which is related to flocculation processes, and the erodability of the surficial sediment. The latter defines the response of the sediment when hydrodynamic forcing induces a shear stress at the interface. The problem is easier to treat in sands and other non-cohesive materials, as the initiation of motion has been described experimentally (Shields, 1936). In particular, the initiation of motion of spherical particles is related simply to particle density and size on the one hand, and to bed shear stress on the other. In contrast, properties of cohesive sediments, e.g. pure mud or sandy mud, are highly variable and dependent upon their stage of consolidation. Furthermore, the composition of sediment, in particular its organic content, is likely to influence cohesion and thus the resistance to erosion. Finally, benthic organisms can change the erodability of the sediment by producing mucus that enhances cohesion (e.g. Montague, 1986). These organisms can be zoobenthos or microphytobenthos, the latter forming a biofilm at the surface of the sediment containing extracellular polymeric substances (EPS) (Black, 1997; Paterson, 1997; Widdows et al., 2000; Friend et al., 2003). A particular characteristic of cohesive sediment erodability is its extreme variability, either in time

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(different time scales of consolidation processes, phases of deposition/erosion, role of temperature, seasonal effects of biota) or in space (benthos is patchy in its distribution). In addition, when heterogeneous sediment is subjected to erosion, patches of different surficial mud do not behave uniformly. This response is site specific, and is difficult to simulate in the laboratory. Therefore, there is a need to explore the variability of natural sediment erodability in the field in order to characterise the latter statistically.

On intertidal mudflats, this can be achieved using a shear vane tester (e.g. Williamson, 1993; Mitchener et al., 1998; Bassoullet et al., 2000), commonly used to measure the undrained shear strength (Cu) of cohesive soils. Even if this kind of measurement does not represent the critical shear stress for erosion (although both quantities are in $N\,m^{-2}$ or Pa, they are often separated by three orders of magnitude), a relationship is often assumed. Erosion tests, which consist generally of long experiments, either in the laboratory or in the field have been undertaken (e.g. Black and Paterson, 1997). Details about the rheological modelling of shear vane tests can be found in Merckelbach (2000).

One drawback of common vane testers is the depth of sediment within which the measurement is made. As they are designed for application to soil mechanics, the range is rather high. However, vertical gradients of natural, consolidating sediment are likely to be strong. Also, we are interested normally in the surficial erodability, which is defined typically within the upper cm. This is why a vane, presented herein, has been designed specifically to overcome this limitation. This vane is suitable for measuring the shear strength of soft mud, in a range representative of intertidal mudflats. A Geonor® H60 classical dynamometric head is used (Geonor®/Oslo, Norway). It consists of a body containing a torsional spring. The rotation of the upper part of the instrument (by hand, typically) tightens the spring between this part and the lower one, which is locked to the vane; the value of the angular displacement is proportional to the applied torque and is read from a graven scale.

The use of a vane tester in the field requires strict control (e.g. maintain a constant vertical load, turn as slowly as possible and at a constant rate). Furthermore, an average of several measurements is needed, for each investigation to be considered robust.

2. Vane tester design

The principle of the new vane is to increase the failure surface whilst confining it within a narrow depth range, in order to control a small vertical resolution (1 cm). For this purpose, the vane is replaced by a ring (Fig. 1) composed of a series of 12

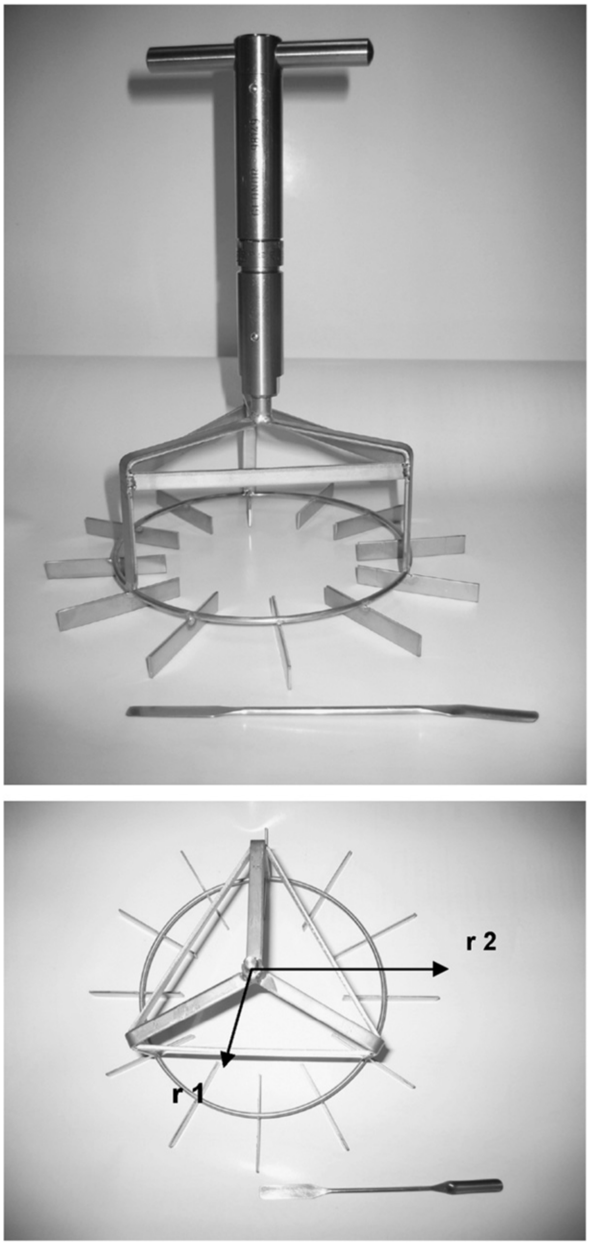

Fig. 1. Vane tester (Geonor® H 60) with the special vane developed for very soft muds (r_1 and r_2: distances from central axis to internal/external blade edge, respectively; spatula scale: 15 cm).