Erodibility of sand-mud mixtures at the bottom of tidal channels
Critical bed-shear stress of mud-sand sample

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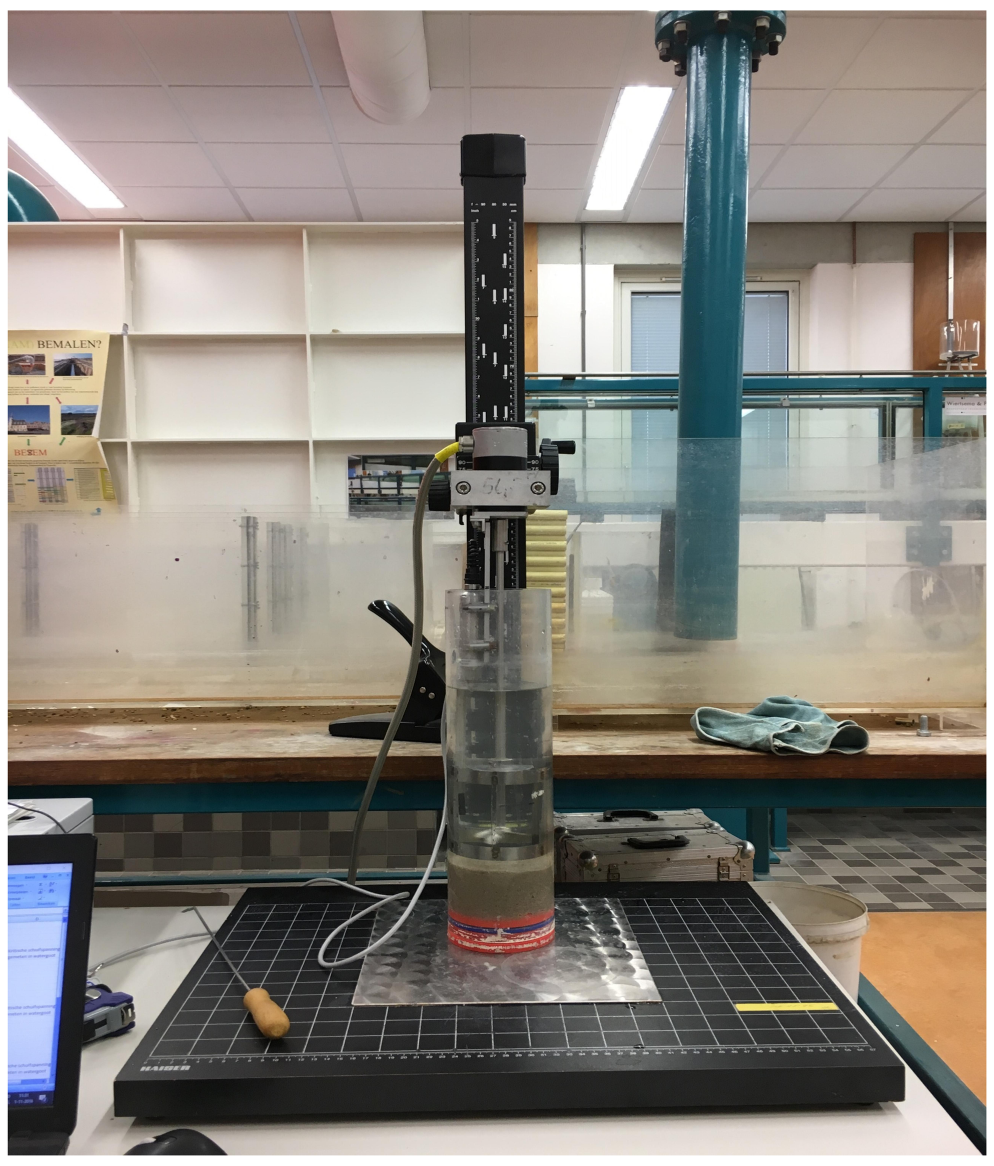
Introduction

The poster addresses the problem of the erodibility of mud and mixtures of sand and mud at the bottom of tidal channels. Mud is defined as a mixture of clay and silt particles with sizes < 62 µm and fine sand particles. Various laboratory and field studies [1] have been done to determine the critical shear stress for erosion as a function of basic sediment and biological properties (bulk

Study

The present study results are based on flume tests and EROMES tube tests (see fig 1). The EROMES has been calibrated and used in several erosion studies in Germany [2,3]. The original EROMES system was developed by the GKSS Research Centre (Germany) to investigate the erodibility of natural muddy sediments in the laboratory. A portable field-version of the original EROMES has been designed, built, calibrated and tested. The main advantages of the portable EROMES is that it is a simple instrument that it is able to produce data on the erosion thresholds of sand-mud mixtures and that the measurements can be done quite rapidly. The present study is focussed on:

- recalibration of the EROMES-instrument using results of flume tests.



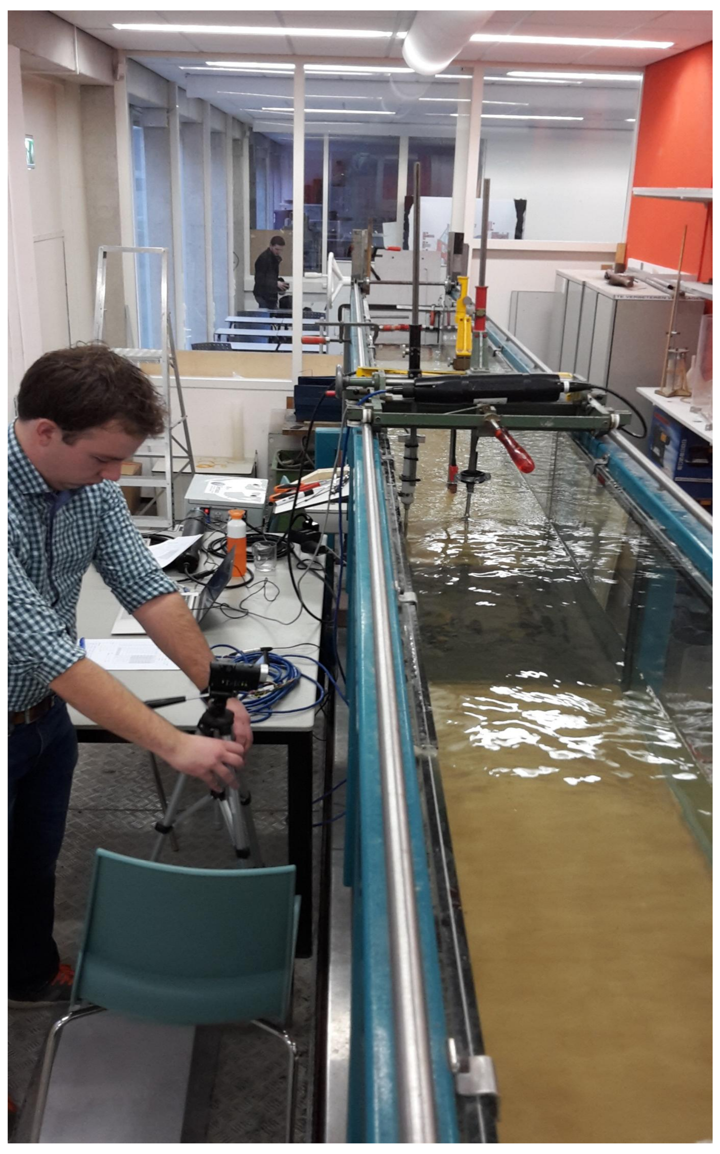


Fig.1 Left: EROMES instrument Right: Flume at the Hanze University

Methods

Several experiments have been carried out in a laboratory flume, fig 1, (length of 10 meter and a width of 0,4 meter) at the Hanze University of Groningen (The Netherlands). The experiments were focussed on the recalibration of the Eromes-instrument and testing of mixtures of sand and mud in the flume and Eromes-instrument. The Eromes-instrument has been calibrated and used in several studies in Germany [2][3] for determination of the in-situ critical bed-shear stress. The flow velocities were measured with a three-dimensional instrument and mud concentration was measured with two different optical sensors. Experiments have been carried out with sands with different gradations and weakly consolidated muds at the bed at increasing flow velocities.

Definition of erosion rates

The water volume (Vw) of the EROMES-tube with internal diameter of 0.1 m consists of clear seawater at the start of the test procedure. Once, sediment is eroded from the bed, the sediment concentration of the water will increase in time. The sediment concentration (c_{mud} in kg/m^3) can be computed as:

$$c_{mud} = e_{mud}\ \Delta t\ A_s/V_w = (\rho_{dry}\ \delta_e/\Delta t)\ (\Delta t\ A_s/V_w) = \rho_{dry}\ \delta_e\ A_s/V_w = \rho_{dry}\ \delta_e\ h_w$$

with: $e_{mud} = \rho_{dry}\ \delta_e/\Delta t = h_w\ \Delta c_{mud}/\Delta t$ = erosion rate (kg/m^2/s), Δt= elapsed time period (s), A_s= surface area of bed (m^2), h_w= A_s/V_w = water depth of EROMES-tube, V_w= water volume (m^3), ρ_{dry} = dry mud density (kg/m^3), δ_e = thickness (m) of eroded bed layer after Δt.

An erosion rate of e_{mud}= 0.1 gram/m^2/s is approximately equivalent with an eroded layer of about 1 mm in 1 hour. This value can be used as the threshold erosion rate to define the critical shear stress for erosion.

The erosion rate depends on the applied bed-shear stress, the dry density of the mud, the sediment composition of the mud (percentage of clay, silt and sand; percentage organic materials).

The dimensionless erosion rate is defined as: $E = e_{mud}/(\rho_{dry}\ w_{mud,max})$

The dimensionless bed-shear stress rate is defined as: $T = (\tau_b - (\tau_{b,cre})/\tau_{b,cre}$

with: emud= erosion rate (kg/m²/s); ρdry = dry bulk density of mud (kg/m3); wmud,max= maximum settling velocity of mud (m/s); τb = bed-shear stress (N/m²), τb,cre= critical bed-shear for erosion (N/m2).

Critical bed-shear stress of mud-sand mixtures

The critical bed-shear stress and basic mud properties of the present tests with relatively soft mud-sand beds are summarized in Table1. Figure 2 shows the critical bed-shear stress of the mud fraction as function of the dry density of the top layer. The critical bed-shear stress of the mud-sand mixture at the moment of bed failure (mass erosion) is also shown.

Data from other Dutch sites [4, 5] with similar properties (percentage of sand < 25%) are also shown. Data from other European and North-American tidal sites are shown [6, 7, 8, 9). The experimental range of GKSS is shown (Tolhurst et al., 2000).

Surface erosion is related to the dry density of the top layer (upper 10 to 20 mm), whereas mass erosion and bed failure is related to the dry density of the total bed layer (about 50 mm in the present tests). The dry density of the top layer is estimated to be about 0.7 to 0.9 times the dry density of the sublayer at 5 cm from the mud surface. The critical bed-shear of mass erosion is much larger (factor

Test	Layer thickness (m)	Dry bulk density of layer (kg/m^3)	Dry bulk density of top layer (kg/m³)	Percentage < 4 µm	Percentage 4-62 µm	Percentage < 62 µm	Percentage > 62 µm	Critical bed-shear stress sand fraction > 63µm (N/m^2)	Critical bed-shear stress mud fraction < 63µm (N/m^2)	Bed-shear stress mud-sand at bed failure (N/m^2)
F685 E685	0.05	≅685	≅ 600	30%	35%	65%	35%	1.3	1.3	2?
F350 E350/E400	0.05	≅350-400	≅ 200-300	30%	35%	65%	35%	0.25	0.25	0.6

Table.1 Critical bed-shear stresses

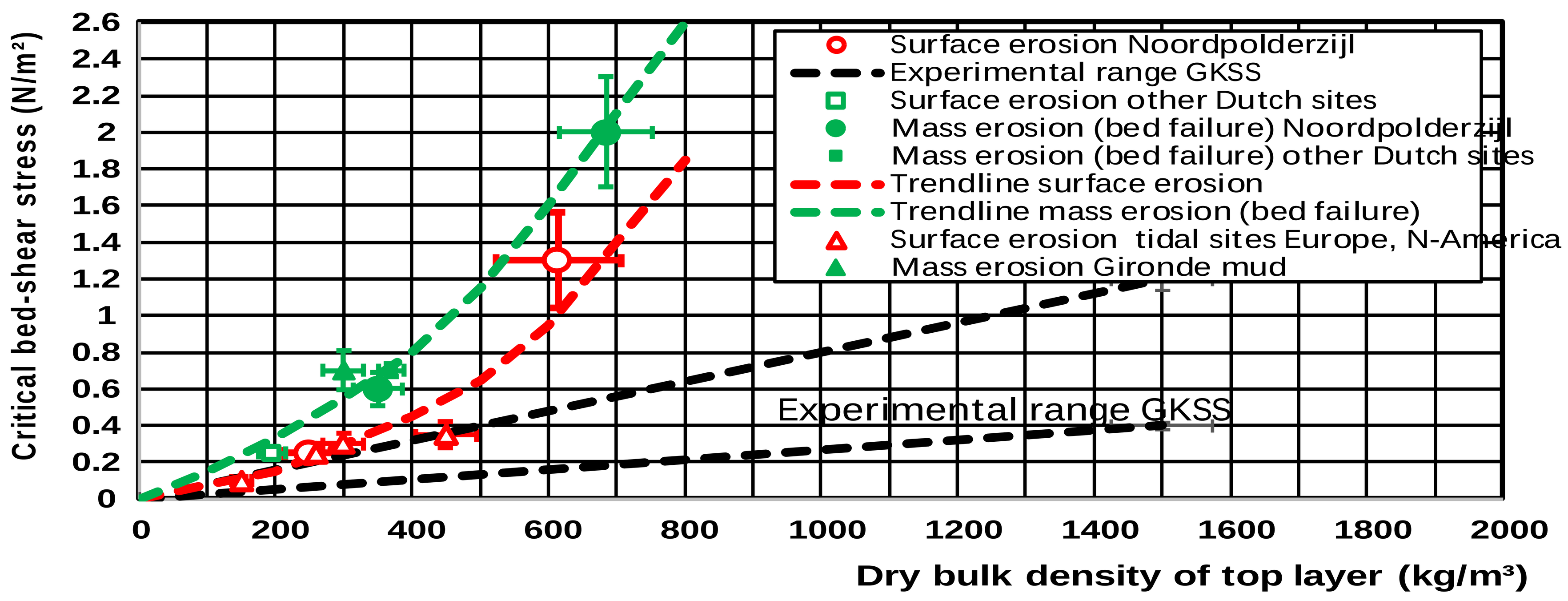


Fig.2 Critical bed-shear stress of mud fraction as function of dry density

Results:

Experiments were carried out in the fall of 2016 at the Hanze University. Preliminary results of the different sand beds show good comparison, for the courser sand beds, between the flume tests, Eromes-instrument and Shields Curve. Results show that measured bed-shear stresses for the fine bed are smaller than Shields bed-shear stress, indicating that Shield curve is not really valid for fine sediments. The test results have been used to estimate the critical bed-shear stress and erosion rates of the mud at two different wet bulk densities.

Discussion:

Based on the preliminary results additional tests will be performed in the spring and summer of 2017 with mud form the small tidal port of Noordpolderzijl (Netherlands). These tests will be done with mud with different predetermined densities and different predetermined percentages of sand.

References:

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