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THE RWS FIELD SETTLING TUBE

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ABSTRACT

A settling tube for field use is described and some results are presented on settling velocities of suspended particles in the Ems estuary. Significant differences were observed between median and mean settling velocities.

Keywords: suspended particles, settling velocity, settling tube

1. INTRODUCTION

The RWS (Rijkswaterstaat) field settling tube was developed in the 1980s by Van Geldermalsen of the National Institute for Coastal and Marine Management (RIKZ) of Rijkswaterstaat in the Netherlands. Therefore it is also called the 'Van Geldermalsen Tube'. The aim was to obtain an *in situ* instrument that combined the advantages of two other settling tubes for field use: the settling-velocity measuring apparatus, used in the siltation study in the Chao Phya Estuary in the 1960s (NEDECO, 1965; Allersma, 1980), and the pipette-withdrawal instrument of Van Rijn & Nienhuis (1985), the so-called FIPIWITU (Field Pipette Withdrawal Tube) (see Cornelisse, 1996).

The advantages were expected to be as follows:

1. Pipette-withdrawal systems do not have the disadvantage of possible incomplete removal of fine sediment particles, accumulated at the bottom of the tube, and leading to erroneous results.
2. Because the settling tube is turned into a vertical position immediately after sampling by closing the end valves, the settling of the suspended sediment particles to one side of the tube is prevented.
3. The exchangeable tubes permit a large number of measurements per unit of time (for example during one tidal period).

2. DESCRIPTION OF THE APPARATUS

The principle of the RWS field settling tube is the pipette-withdrawal system, equipped with exchangeable tubes. A schematic picture of the RWS field settling tube is given in Fig. 1. The tube is lowered in a horizontal position. At the required depth, the frame with the tube is placed in a vertical position. Then the tube is pulled down by an extra weight (*cf.* Fig. 1), and is connected to the bottom of the tube, which is provided with a pipette for taking samples and an O-ring for sealing the connection with the settling tube. This is the starting point of the sedimentation process. On board the tube is carefully hung in a steel frame. This was necessary because of the movements of the research vessel. During these movements of the ship the settling tubes remain in their vertical position.

On board samples are taken of about 200 cm^3, generally at 1, 3, 6, 20, 40, 60 min after the start of the sedimentation process. Due to the limited time the first sample should be taken already before hanging the tube in the frame. The inner diameter of the settling tube is 140 mm, whereas the initial height of the water column is about 210 mm (Fig. 1). This relatively small height results in relatively short measuring times (generally 1 hour, sometimes 3 hours). The tube is double walled and insulated to prevent temperature-induced density flows within the tube.

3. DETERMINATION OF THE SETTLING VELOCITIES

The determination of the settling velocity is based on the principle that at the sampling depth H_i for an elapsed time period t_i all particles possessing a settling velocity larger than H_i/t_i have already passed the sampling point.

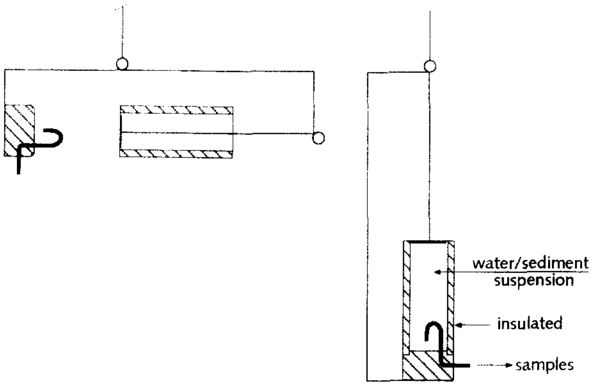


Fig. 1. RWS Field Settling Tube: Schematic diagram of the RWS field settling tube in horizontal (left), and vertical positions (right).

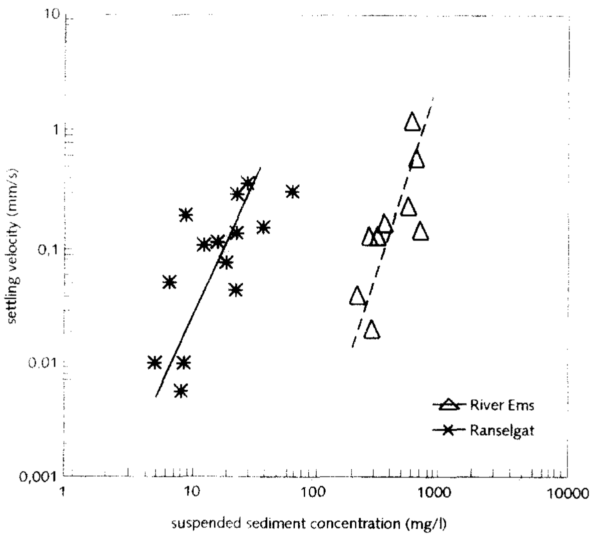


Fig. 2. Median settling velocity, obtained from field settling tube measurements, as a function of the suspended-sediment concentration (Ranselgat and River Ems).

The sampling depth H_i is:

$$H_i = H_o - \sum_{j=1}^{i-1} h_j - \frac{1}{2} h_j \qquad \text{(eq. 1)}$$

H_i=settling height (mm)
(vertical distance from sampling point to the water level)
H_0=settling height at t=0 (mm)
h_i=vertical distance, over which the water level is lowered as a result of taking sample i.

Introduce the following terms:

$$w_{s,i} = \frac{H_i}{t_i} \qquad \text{(eq. 2)}$$

$w_{s,i}$= settling velocity (mm·s^{-1})

$$P_i = \frac{C_i}{C_o} * 100 \quad (\%) \qquad \text{(eq. 3)}$$

P_i=Weight percentage (%) of particles with a settling velocity smaller than $w_{s,i}$
C_0=Initial suspended sediment concentration (mg·dm^{-3})
C_i=Suspended sediment concentration of sample i (mg·dm^{-3})

Then $w_{s,i}$ and P_i give the settling velocity distribution of the suspended sediment. At P=50 the median settling velocity $w_{s,50}$ will be obtained. From this curve also the mean settling velocity w_s can be obtained, as well as the standard deviation of the settling velocity distribution. More details can be found in Van Leussen (1993).

4. SOME CHARACTERISTIC RESULTS

An extensive series of measurements with the RWS field settling tube were conducted in 1990 in the Ems estuary. The measurements were carried out at five locations over a complete tidal cycle. Each hour samples were taken at 2.80 m below the water surface. Here we will concentrate on the results from the measurements in the Ranselgat (mouth of the estuary) and the River Ems location (freshwater tidal area of the Ems estuary). More details are given in the paper on the underwater video system VIS (Van Leussen & Cornelisse, 1996).

Results of *in situ* measurements with field settling tubes in a number of estuaries showed an exponential relation between the settling velocity and the suspended sediment concentration, obeying the formula:

$$w_s = K \cdot C^m \qquad \text{(eq. 4)}$$

where C is the suspended sediment concentration, K is an empirical constant and m is an empirical exponent. Generally the exponent m varies between 1.0 and 3.0.

Fig. 2 shows the median settling velocity as a function of the suspended sediment concentration, both for the measurements in the Ranselgat and in the River Ems, which are locations of relatively low and high suspended sediment concentration, respectively. In both cases the settling velocity increased exponentially with the suspended sediment concentration. The exponent m was 2.5 and 3.6, respectively.

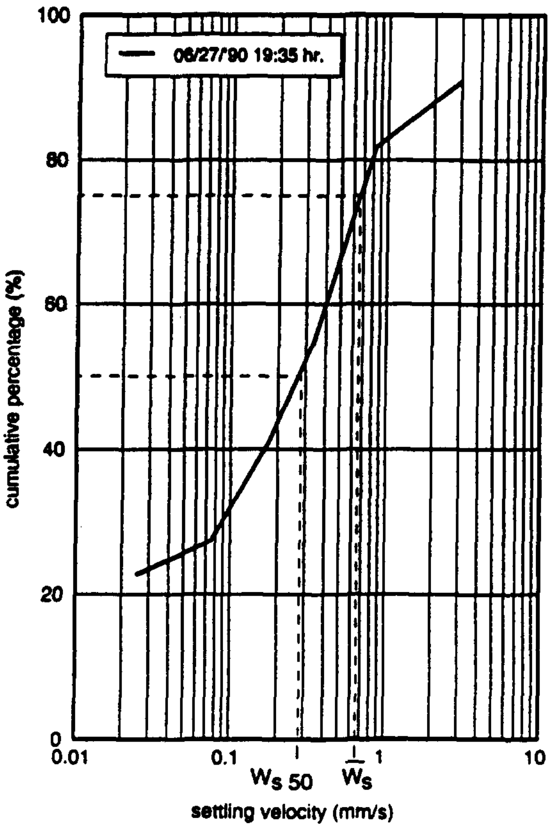
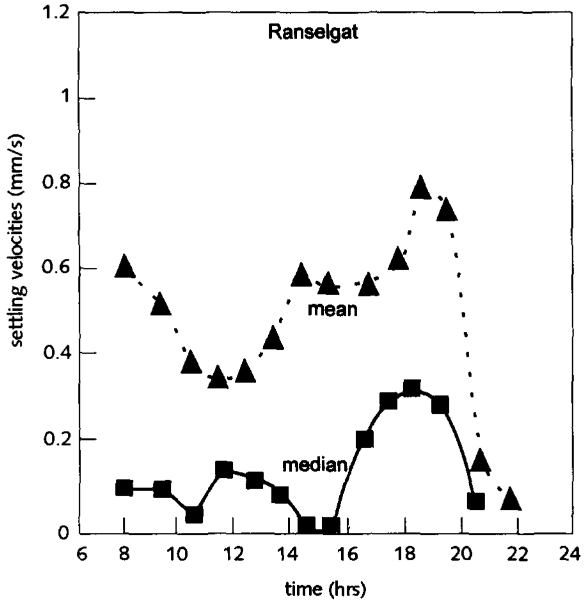


Fig. 3. Cumulative distribution of the settling velocities, measured by the field settling tube in the Ranselgat on 27 June 1990 at 19:35 hrs, with resulting median and mean settling velocity: respectively 0.28 and 0.66 mm·s^{-1}).



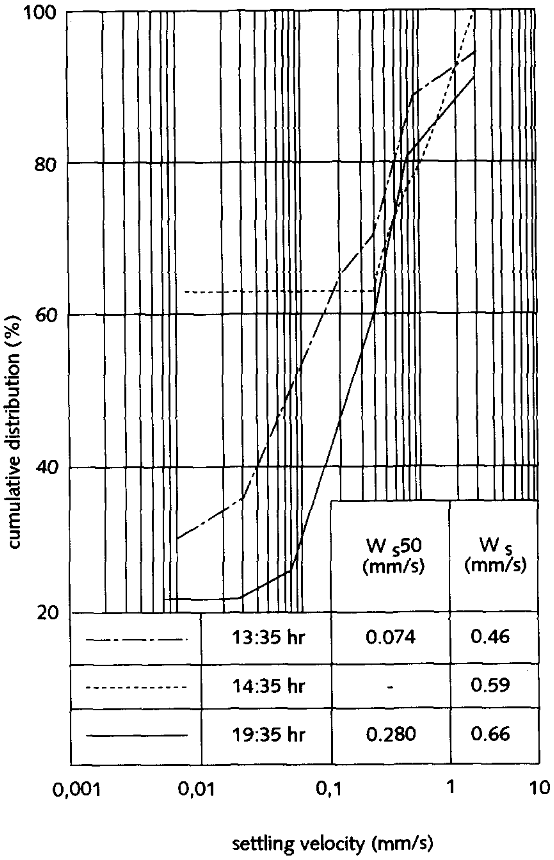


Fig. 5. Cumulative settling-velocity distributions from field settling tube measurements in the Ranselgat: 13:35, 14:35 and 19:35 hrs.

It is well known that a sediment possesses not one settling velocity, but a continuous distribution of settling velocities. An example for the Ems estuary is given in Fig. 3, showing the cumulative distribution at 19:35 hrs from measurements in the Ranselgat. The median value w_{s50} is indicated, as well as the mean settling velocity $\bar{w}_s$, derived from

$$\bar{w}_s = \frac{\sum_i w_{si} C_i}{\sum_i C_i} \qquad \text{(eq. 5)}$$

where i denotes the number of a specific fraction and w_{si} and C_i are the corresponding settling velocity and suspended sediment concentration. In principle the mean settling velocity should be applied in fine-sedi-

Fig. 4. Median and mean settling velocities over a tidal cycle from field settling tube measurements in the Ranselgat.

ment transport calculations (Hunt, 1954; Bagnold, 1966), or a number of fractions should be included in the fine-grained sediment transport model. Fig. 3 illustrates the large difference that can exist between $w_{s\,50}$ and $\overline{w}_s$.

Fig. 4 presents both $w_{s\,50}$ and $\overline{w}_S$ for the Ranselgat measurements. The median settling velocity $w_{S\,50}$ varies between very low values at slack tide up to about 0.3 $mm{\cdot}s^{-1}$ at high flow velocities. The mean values $\overline{w}_S$ were significantly higher.

Three settling-velocity distributions from the Ranselgat measurements are collected in Fig. 5: at 13:35, 14:35 and 19:35 hrs. The measurements at 13:35 hrs belong to slack tide, when the suspended sediment concentration was low and more than 50% of the suspended sediment belonged to a background concentration, remaining continuously in suspension. The table in this figure illustrates the difference between the median and mean settling velocities.

5. CONCLUSIONS

From the field settling tube measurements it can be concluded that the relation between the settling velocity and the suspended sediment concentration is strongly dependent on the location in the Ems estuary. Moreover it was shown that significant differences may occur between the median and mean settling velocities. More details on this subject can be found in Van Leussen (1994).

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