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THE UNDERWATER VIDEO SYSTEM VIS

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ABSTRACT

An underwater video system (Video In Situ:VIS) is described that determines sizes and settling velocities of suspended mud flocs *in situ*, without disturbing large fragile aggregates. Some results are presented from the Ems estuary, showing macroflocs of 200 to 700 μm (up to 1 mm) diameter with settling velocities in the range of 0.5 to 8 mm·s^{-1}. They survived high current velocities of >1 m·s^{-1}.

Keywords: suspended material, settling velocity, size distribution, video system

1. INTRODUCTION

VIS (= Video In Situ) is an underwater video system with which the sizes and the settling velocities of suspended mud flocs can be determined *in situ* without disturbing the large fragile aggregates. This system has been developed in the Netherlands by the National Institute for Coastal and Marine Management (RIKZ) of Rijkswaterstaat and Delft Hydraulics. The objective was to obtain more information on the properties of the suspended fragile aggregates, the so-called macroflocs, which were expected to play a significant role in estuarine fine-grained sediment dynamics. Extensive series of measurements with VIS in the Ems estuary are available (Van Leussen, 1994) and are reported below.

2. DESCRIPTION OF THE APPARATUS

The principle of VIS is presented in Fig. 1. The flocs are captured in a capture/stilling chamber, a sort of funnel (vertical pipe Ø100 mm, H=150 mm), from which a vertical settling tube (Ø26 mm) emerges. The settling tube contains two windows. Through one of them a light beam is introduced into the settling tube to illuminate the settling particles. The width of the light sheet is 0.4 mm and its height is 9 mm. Through the other window the video-recordings are made.

An HTH-MX-C CCD video camera with a Frame Transfer CCD NXA1010 has been applied. Its image section has 604x288 pixels with a dimension of 10x15 μm^2 each. Particles with dimensions smaller than the pixel size can still be observed if enough light is reflected. However, because of the resolution of the CCD-camera, these particles will appear to have the size of such a pixel. With a 25 mm lens and a 15 mm extension tube, the total dimension of the video image is about 9 x 6 mm^2. By changing the slits and lenses the light sheet and the camera can easily be adapted to other multiplications.

With the exception of the capture/stilling chamber, the elements of the system (Fig. 1) are placed in a stainless steel underwater housing (Ø600 mm, height 300 mm). The capture/stilling chamber is positioned just above the surface of the housing. The settling tube is going through the bottom of the housing. Around this housing a set of fenders has been placed, to protect the housing with the instruments. A photograph of the system is presented in Fig. 2. To prevent effects of temperature differences the power transfer unit and the halogen bulb are placed in a special compartment, separated by a temperature shield.

Both the capture/stilling chamber and the settling tube are connected to pumps, through which water can be pumped in and out. Thus these elements can be filled with a new water/sediment sample by pumping very cautiously. During the recordings the pumps are standing still. Observations of settling flocs by the video system in areas of high turbidity, for example in the turbidity maximum, are realized by filling the settling tube of VIS with relatively clean water of a salin-

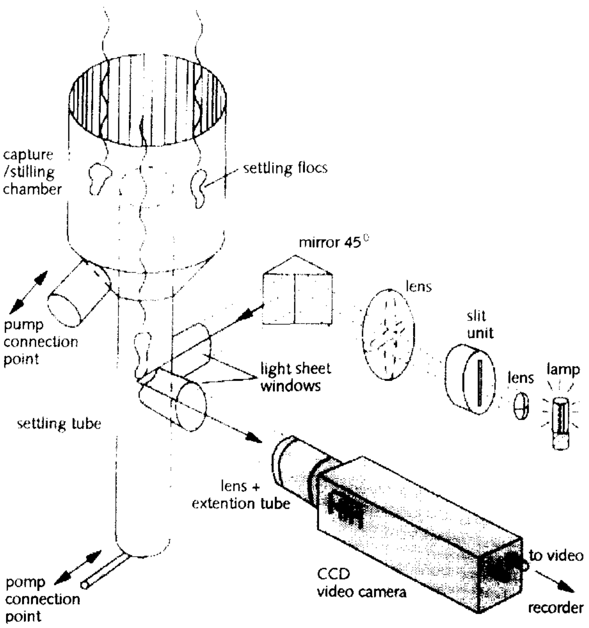

Fig. 1. Schematic diagram of the components of VIS (Video In Situ). This system is placed in a stainless steel underwater housing.

ity slightly higher than that of the surrounding water. In this way a stable situation can be obtained, while the effect on the size and settling velocity of the macroflocs is relatively small.

Measurements in the Dutch coastal zone (November 1990) showed that even under windy conditions (up to wind force 6 on the scale of Beaufort) VIS was working well, still giving stable images provided that the system was floating independently of the violently rolling research vessel.

The video system is connected to a monitor, so that the settling of the flocs and aggregates can directly be observed on board the research vessel. Also the light sheet and pumps are controlled from the research vessel. The recordings are automatically marked with date and time (time step 0.01 sec).

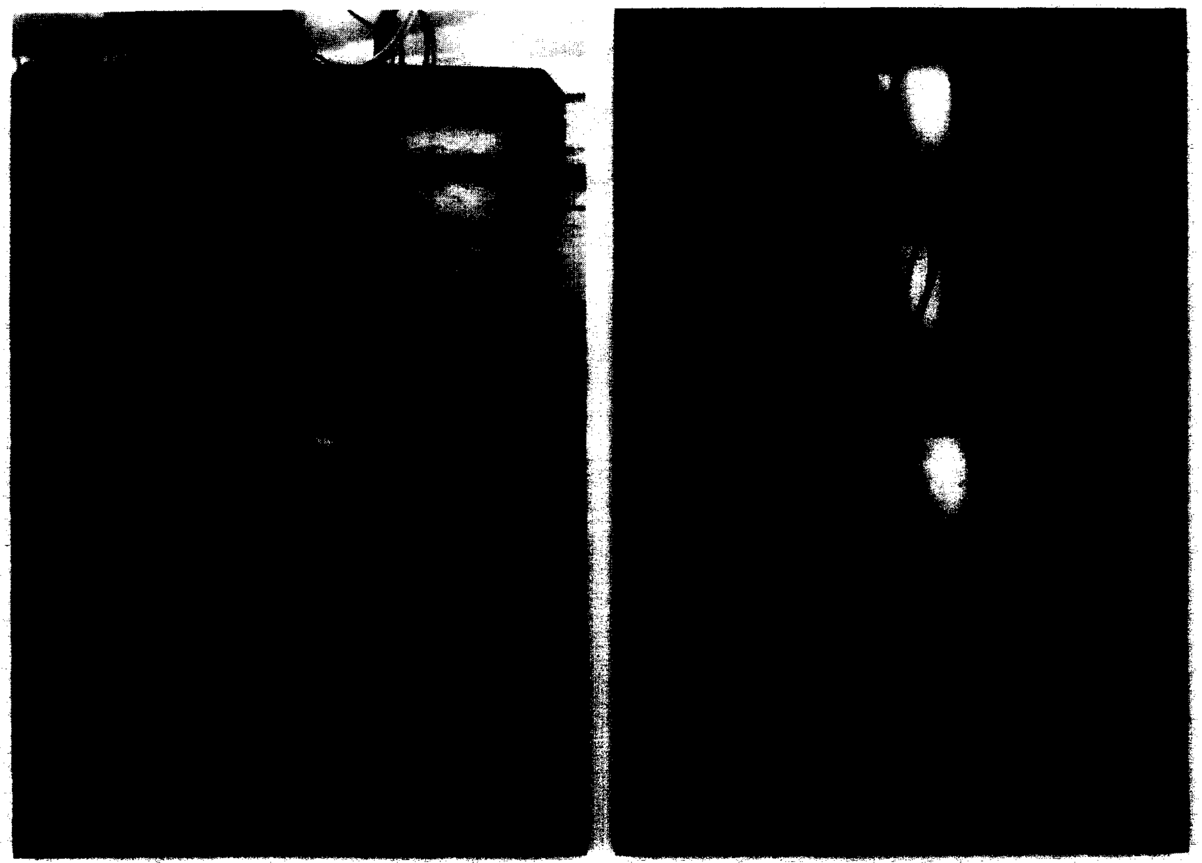

Fig. 2. a) Photograph of VIS. b) The VIS as it is lowered into the water, showing also the floats. During recordings only the highest float is crossing the water surface.

3. METHODS OF APPLICATION OF VIS - DETERMINATION OF THE FLOC SIZES AND SETTLING VELOCITIES

To capture the aggregates in the capture/stilling chamber without disturbing them the difference between the movements of the capture/stilling chamber and the flowing water above should be minimized. Therefore the VIS is generally used as a floating system. Hanging in the winch of the crane of the research vessel, the VIS would be unduly influenced by the movements of the floating ship. Therefore the VIS is mostly applied as a submersible, in which case the float has a small cross-area at the water surface (*cf.* Fig. 2b). In this way successful measurements have been carried out in situations with temperatures between 2° and 20°C, wind speeds up to more than 6 Bft, current velocities up to 2 $m{\cdot}s^{-1}$ and a wave height of 1 m. Such measurements were carried out for example in the Ems estuary, the Zoom Lake, the Dutch coastal zone and the Eastern Scheldt estuary, all located in the Netherlands.

At the beginning of each series of VIS measurements, a calibrated grid is positioned within the settling tube of VIS. This calibrated grid is recorded at the beginning of the video tape.

The size, shape and settling velocity of the flocs can be measured directly from the television screen. To determine the settling velocity the displacements of the floc should be followed over some time and distance. Before applying VIS in the field, the system had been tested in the laboratory by experiments with polystyrene particles, of which the sizes and settling velocities remain constant. The sizes of the particles were determined under a microscope as well as by a marking gauge, and the settling velocities were determined in a 0.90 m settling column. Thanks to the calibration procedure described above, there was a good correspondence between these particle sizes and the sizes determined by VIS. However, there were often significant differences between the settling velocities derived from VIS and those from the settling column experiments. These differences were caused by water circulations within the settling tube of VIS, whose origin is not entirely clear. Possibly temperature differences contribute to these slow fluid motions. This problem has been solved by assuming that the movements of the smallest suspended particlesvisible on the monitor are equal to the water movements. In natural conditions such small particles are always present, and have a much lower settling velocity than the flocs. Following this procedure, a good correspondence was obtained between the settling velocities of the polystyrene particles from VIS and from the settling column experiments. Therefore the settling velocities of the larger flocs are derived by measuring the difference in the vertical movements of the finest particles and the larger flocs.

Because such an analysis by hand is very time consuming, automatic image analysis techniques have been developed. First of all the recordings are digitized, which is relatively simple, because the pictures are already available on tape. Analysis programmes are applied to receive the size distribution with specific parameters such as mean, standard deviation, skewness and kurtosis. Particle track methods were developed to follow the particles over some time and distance and to derive the settling velocity distribution.

4. SOME CHARACTERISTIC RESULTS

In 1990 measurements over a complete tidal cycle were conducted at five locations in the Ems estuary (Van Leussen, 1994). Here, some results are given from two locations: the Ranselgat (mouth of the estuary) and the River Ems location (freshwater tidal area of the Ems estuary). Fig. 3 (a, b, c and d) shows the depth-averaged current velocities and the suspended fine-grained sediment concentrations, averaged over the total depth, over 1.00 m$<z<$H, and over 2.00 m$<z<$H. The Figure illustrates that during periods of decelerating current, significant decreases can occur in the suspended sediment concentration over a relatively short period of time, for example one hour (so-called rapid settling). Results of the settling velocities of the suspended macroflocs, which appeared to be responsible for such phenomena, were determined by VIS and are presented in Fig. 3 (e and f).

In the Ranselgat the water depth was about 14 m. The flow velocity increased during the flood tide to about 1.50 $m{\cdot}s^{-1}$, as it did on the ebb tide. During slack tide the suspended sediment concentration was very low (about 5 $mg{\cdot}dm^{-3}$), increasing to 20-100 $mg{\cdot}dm^{-3}$ during maximum flow velocity, dependent on the distance to the bottom. Fig. 3 shows that during high current velocities the settling velocities increased to about 4 $mm{\cdot}s^{-1}$, both during flood and ebb. The corresponding floc sizes were 400 to 600 µm horizontally and 600 to 750 µm vertically measured (vertically means in the direction of settling). Each point in Fig. 3e and 3f represents the mean value of at least five of such flocs. Exceptionally, flocs with horizontal sizes of somewhat more than 500 µm and vertical sizes in the range of 800 to 1600 µm were measured with settling velocities of about 8 $mm{\cdot}s^{-1}$. Frequently, small water movements were observed in the settling tube. In such cases the settling velocity of the flocs was determined as the difference between the settling of the relatively large flocs and the movements of the smallest particles.

Also in the River Ems location the suspended sediment concentration was much higher, but direct recordings were still possible with VIS. While the current velocity was increasing up to more than 1 $m{\cdot}s^{-1}$ during flood and about 0.80 $m{\cdot}s^{-1}$ during ebb, the sus-

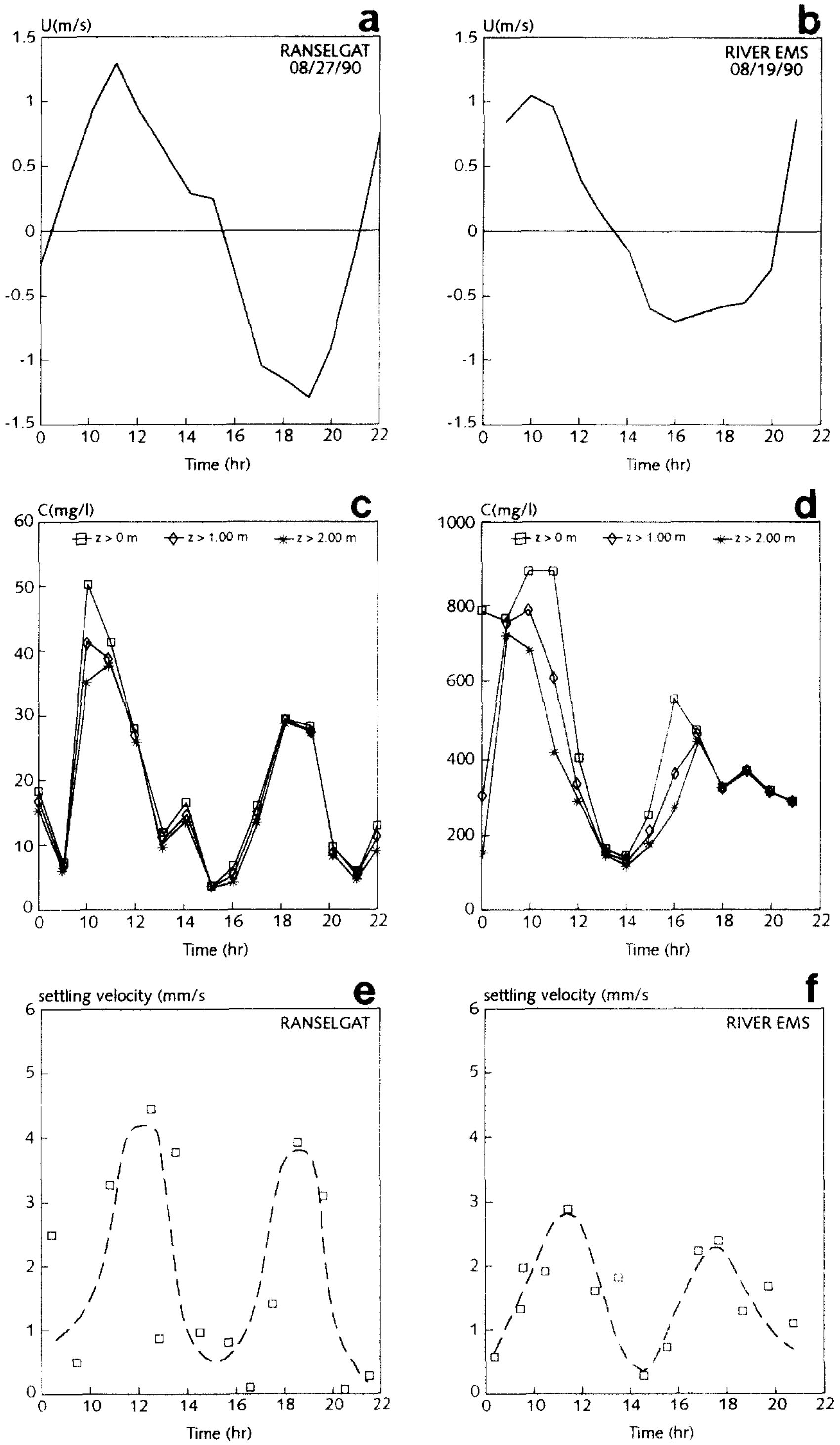

Fig. 3. Results of floating field measurements at two the locations in the Ems estuary: 'Ranselgat' and 'River Ems'.(a and b) Depth-averaged current velocities.(c and d) Suspended fine-grained sediment concentrations, averaged over the total depth H, over 1.00 m<z<H, and over 2.00 m<z<H. (e and f) Settling velocities of macroflocs determined by VIS. Such flocs were abundant during periods of high current velocities, but scarcely observed at slack tide.

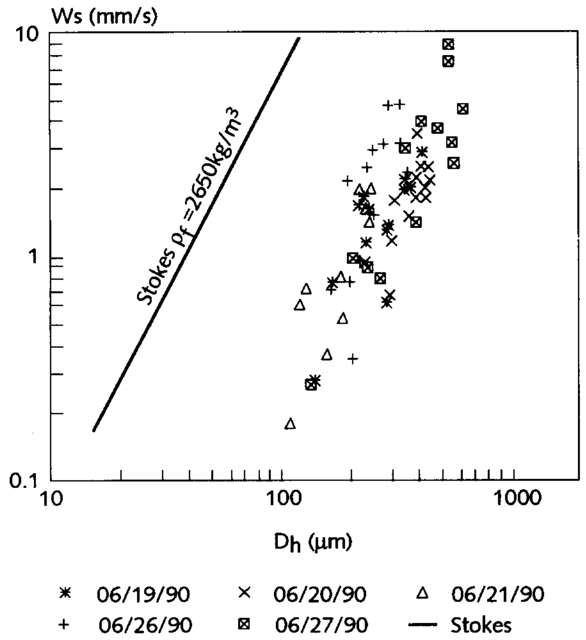

Fig. 4. Settling velocities, obtained from VIS-measurements, as a function of the horizontal diameter of the floc. (Ranselgat, Oost Friesche Gaatje, Emder Vaarwater, Turbidity maximum, River Ems).

pended sediment concentration increased to several grammes per dm^3 in the first metre above the bottom. In the upper layers, down to about 3 m below the water surface, the fine sediment concentration was some hundreds of mg·dm^{-3}. At this depth the floating VIS-measurements were conducted.

The results are quite similar to those obtained at other locations: an increase of the settling velocity of up to several mm·s^{-1} shortly after maximum flow velocity. However, during ebb tide the results are less reliable because the video recordings were difficult to analyse owing to the high turbidity.

Fig. 4 shows the settling velocities w_s as a function of the horizontal diameter D_h of the flocs for all the five locations. It seems that the settling velocity increases almost quadratically with the floc size. This increase is more pronounced than reported in the literature. Mostly the exponent n in w_s::d_f^n is measured in the range of 0.4 to 1.0 for mud flocs (Kajihara, 1971; Hawley, 1982; Gibbs, 1985). Assuming Stokes law to apply, Fig. 4 suggests a differential density of about 35 kg·m^{-3}, which corresponds very well with biological flocs (*cf.* Kajihara, 1971; Tambo & Watenabe, 1979).

Analysis of the video recordings, obtained from the VIS measurements in the Ems estuary (June 1990) and the Dutch coastal zone (November 1990), demonstrated that large fragile aggregates, the so-called macroflocs, govern the vertical fine-grained sediment movements during a tidal cycle (Van Leussen, 1994). VIS measurements in the Ems estuary over a complete tidal cycle showed an abundance of large flocs shortly after maximum flow velocity. Generally these macroflocs had sizes in the range of 200 to 700 μm, and sometimes more than 1 mm, and survived high current velocities. The settling velocities were in the range of 0.5 to 8 mm·s^{-1}. A comparison with measured suspended sediment concentrations over a tidal cycle demonstrated that these large flocs play an important role in the fine-grained sediment dynamics and account for the phenomenon of 'rapid settling'.

5. REFERENCES

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