MEASUREMENTS OF SEDIMENT TRANSPORT ALONG THE BELGIAN COAST

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1. ABSTRACT

Within the frame of some specific research programs along the eastern part of the Belgian Coast, last year some measuring campaigns were organised [5].

To get a proper idea about the sediment transport these in-situ measurements form a very handsome and adequate tool to collect interesting data about these quite complex phenomena. Several practical measuring devices are developped in order to make the experiments more accurate.

This document will give an overview of these recent realisations in practical sediment transport measurements.

2. INTRODUCTION

The Belgian North Sea Coast is protected by a natural defence system consisting of the under water beach, the effective beach and the dune formation. Under influence of waves, wind and tidal flows, the sand and the mud of these bottoms are transported permanently [6].

Coastal morphology continuously changes by the displacement of sediments. Systematic erosion in some regions along the coast can make these defensive formations to disappear. To guaranty the stability of the natural sea defense a systematic control on the evolution of the situation and the governing forces is necessary. The most appropriate way to verify these characteristics consists of in situ measurements during a complete tidal cycle.

3. MEASUREMENTS IN COASTAL REGIONS

In general, in situ measurements of sediment transport demand special focussing on the preparation and operation methodology to get proper results. The aggressive and rough conditions at sea add an extra dimension to practical arrangements for a measuring campaign along the coast. Special attention should be given to the measuring devices and methods used under these special measuring circumstances.

To compose a clear and complete view on the variation of the flow velocity U and sediment concentration C the measurements should be performed during at least one tidal cycle. Since along the Belgian Coast one tidal cycle lasts about 12 hours and 30 minutes, a measuring campaign of 13 hours is needed. As strong current is one of the main determining factors in the sediment transport, a period around spring tide is chosen.

During this period of minimum 13 hours, the flow velocity U and the sediment concentration C are measured simultaneously in some discrete locations at discrete moments.

Beside this general concept, three specific measuring methods can be distinguished :

a. From a gauging vessel.
b. With a measuring palisade.
c. With a sampler bottle for bed load transport.

a. Measurements from a gauging vessel

At locations where the local water depth is more than 3 m, this measuring method is used. By means of a winch an hydrometric current meter of the propellor type and a suction mouth, both mounted on a streamlined ballast, are lowered from the hydrographic launch. A depth indicator on the winch shows the position of the measuring point.

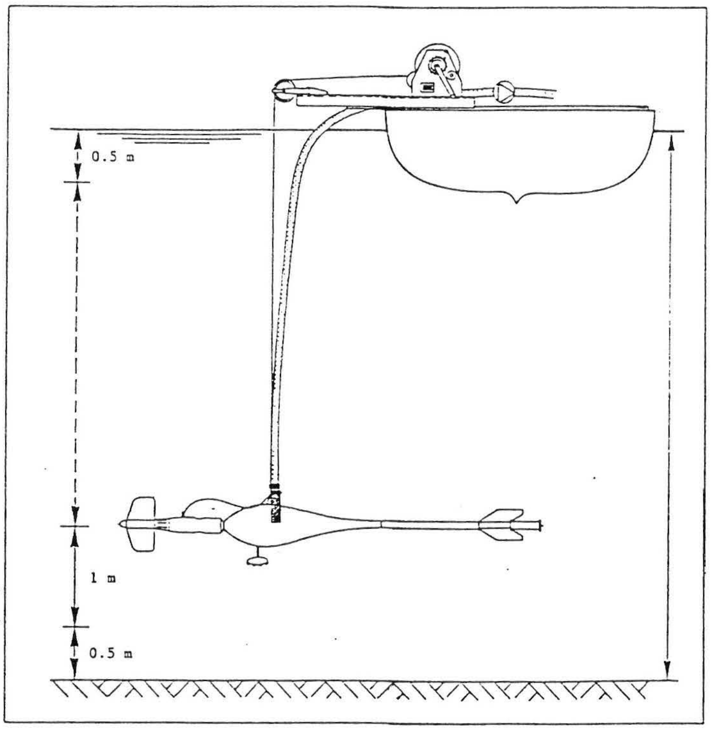

Figure 1 : Measurement from a vessel

To regard the instant sediment concentration, water samples are sucked up by a pump installed on deck of the vessel. The dimensions of the suction mouth, the transport conduits and the pump are chosen in such a way as to get a representative sediment sample. The suction velocity at the entrance is about 0.5 m/s; this value is in good accordance with the mean local water velocity. But, the transportation velocity in the flexible conduits is arranged to be about 1.6 m/s to avoid sedimentation during suction. Given the total suction length of the conduits and the mean velocity, a waiting period of about 30 s is needed to get a representative water sample.

By analysing the water sample, the sediment concentrations are retrieved in detail :

- the total concentration of sediment in suspension
- the concentration of the sandy fraction (> 63 μm)
- the concentration of mud (< 63 μm)
- the organic materials

This so-called **pump method** to measure sediment concentrations forms a variation of the traditional pump method. A comparative study with other sediment sampling technics shows the accuracy of this methodology [1]. By taking sediment samples in each measuring location on the verticale simultaneously with the water velocity registration, both the velocity profile and sediment concentration profile can be determined.

b. Measurements from a sampling palisade

In the nearshore zone, close to the coastline, waves are affecting too much the ship movements and thus the measurements. For this, a more efficient measuring technique is worked out. In order to get a clear view on the distribution of the sediment concentrations near the sea bottom, a special measuring device was developped at the Hydraulics Laboratory in cooperation with Eurosense N.V..

The sampling frame, placed on a triangular base, is about 1.60 m high and has five discrete measuring points where a water sample can be sucked up and two locations where the water velocity is measured by a propellor type current meter. Since the mean sediment transport appears near the sea bed, the suction points are situated respectively at 10 cm, 25 cm, 50 cm, 100 cm and 150 cm above the bottom to collect data for an optimum sediment concentration profile calculation; while the velocity registration is done at 37 and 125 cm above the bottom.

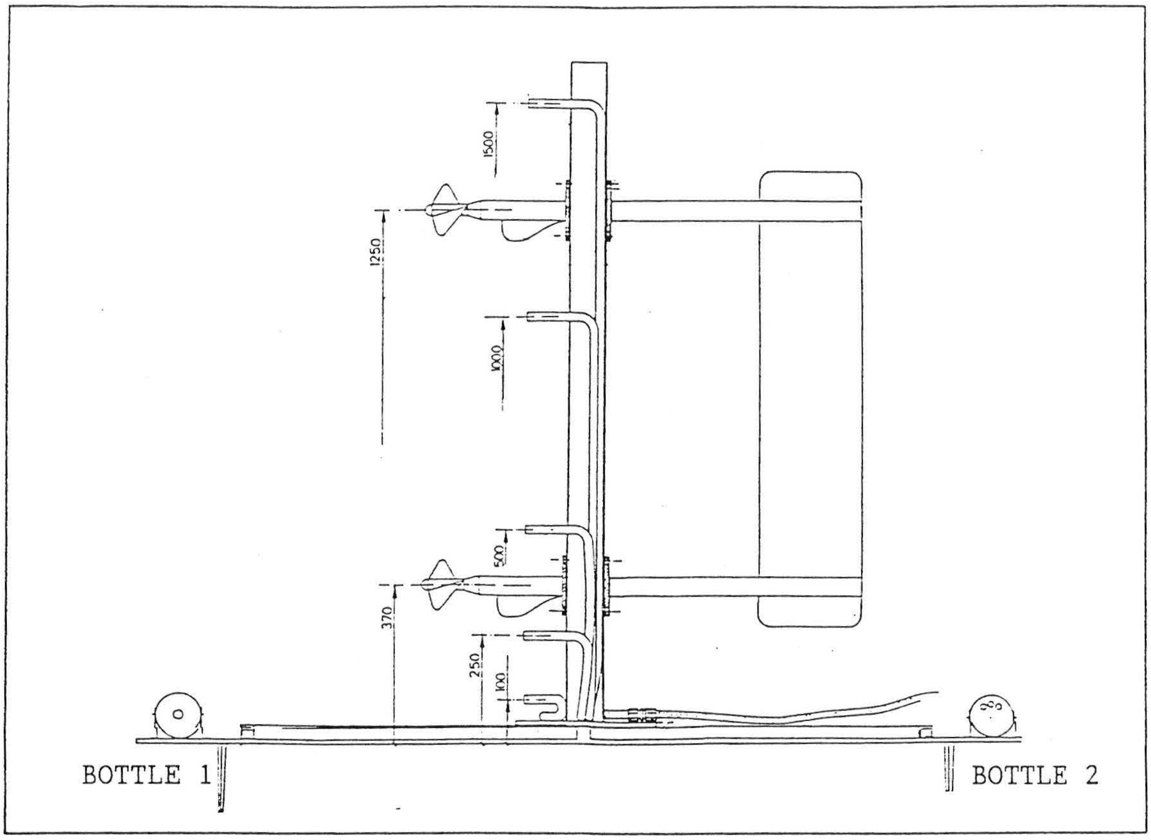

Figure 2 : The Sediment Palisade

The current meters are mounted on a rotating part with a tail piece, so they are always pointed in the flow direction. The opening of the five tap points is oriented perpendicular to the dominating flow direction (in practice parallel with the coastline). In the principal frame these five suction mouths are connected with flexible conduits which are moored on the sea bottom. The electric signal cables for the velocity registrations are fastened to these transportation conduits. For this, a special waterproof connection was designed.

At a certain distance from the free-standing palisade, these suction pipes are suspended on a location buoy from where the measurements can be done. Again, the same operational arrangements for the velocity and water sampling practice must be respected. So a waiting time of at least 40 s before sampling is needed to get a representative sediment concentration. By means of five parallel pumps the samples can be taken simultaneously; so the measurement is an instant record of the distribution of the sediment concentrations and water velocity over that vertical.

On the bottom plates of these palisade, two bed load samplers are mounted. The detailed description of these bottom bottles follows in the next section. This measuring device gives the operator the opportunity to get sediment measurements in shallow water in an easy and accurate way.

c. <u>The Bottle Sampler for Bed Load</u>

As mentioned in the previous paragraph, so-called Bottle Samplers are installed on the bottom plates of the palisade. These bed load transport measuring devices can also be used as an independent disposition, mounted on discrete bottom bases. The bottles are basically designed to measure the time integrated sediment transport near the sea bottom, the so-called bed load zone. The operation of the bottle is based on the **flow principle.** The local water current together with the entrained sediment transport in the bottom region, enters undisturbed the bottle through the intake nozzle. In the geometrical adapted body of the bottle by reducing the flow velocity, the sediment parts settle down, while the water current continues his way out through the back side tubes. At the outflow elbow pieces avoid the reverse flow to enter the bottle.

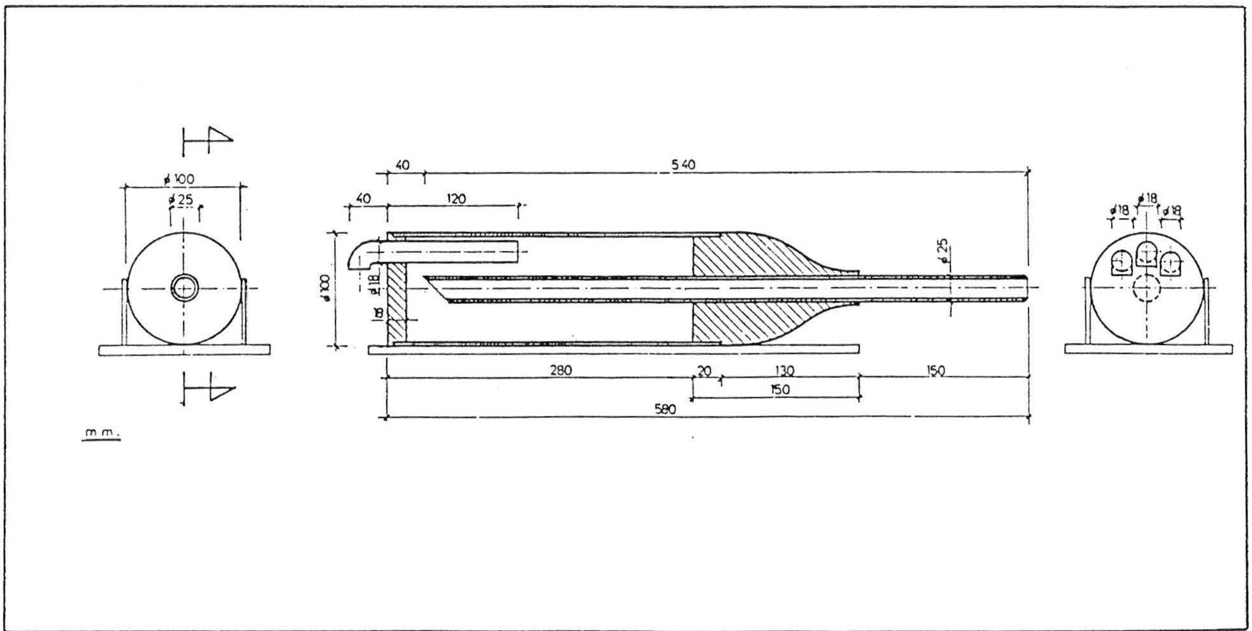

Figure 3 : The Bottle Sampler

By this, one collects a bottom sediment sample during e.g. 12 hours. Special attention should be paid to the start-up and stop operation of the measurement : the installation, the opening and closing with a plug and the recovering of the bottle demand a detailed instruction for the operator-diver.

A clear view on the characteristics of the bed load sediments and a quantitative idea on the amount of the transport near the sea bottom can be obtained from the analyses of the collected samples. By orientating the entrance nozzles of e.g. two bottles in opposite directions one can have a adequate distinction between offshore and onshore transport. At this moment, calibration, verification and comparitive studies are worked out in further research. Anyhow, the main advantages of the instruments are its easy manageability and its low cost price.

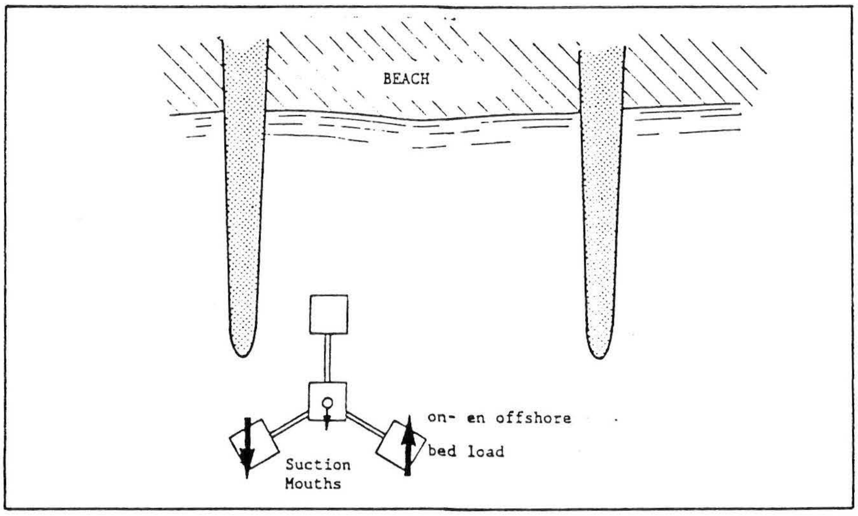

Figure 4 : Positioning of Bottle Sampler and Palisade

4. SOME ANALYTIC CONSIDERATIONS ABOUT THE MEASUREMENTS

First, a general impression of the measured data over a complete tidal cycle is discussed. As shown in figure 5 and 6, the water height h [m], the water velocity U [m/s] and the total sediment concentration C [g/l] as measured from a gauging vessel during two 13-hours measuring campaigns, follow the expected path. To obtain a characteristic parameter for the flow and sediment concentration over the vertical, the mean value over the water depth h is calculated.

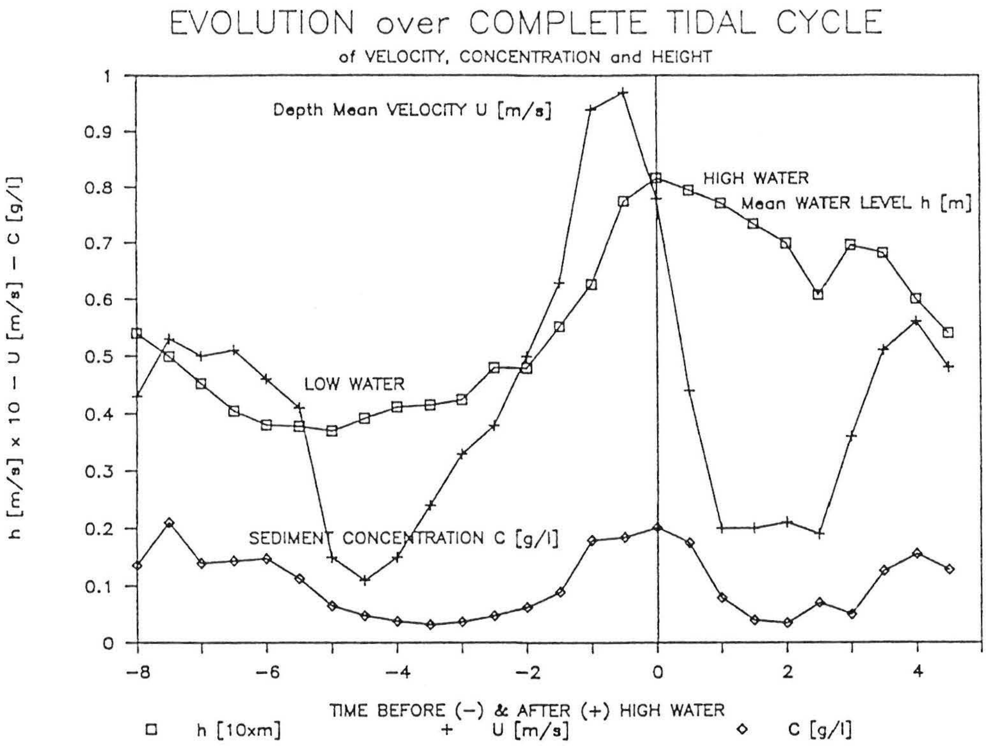

Figure 5 : Evolution over tidal cycle - Location Coast

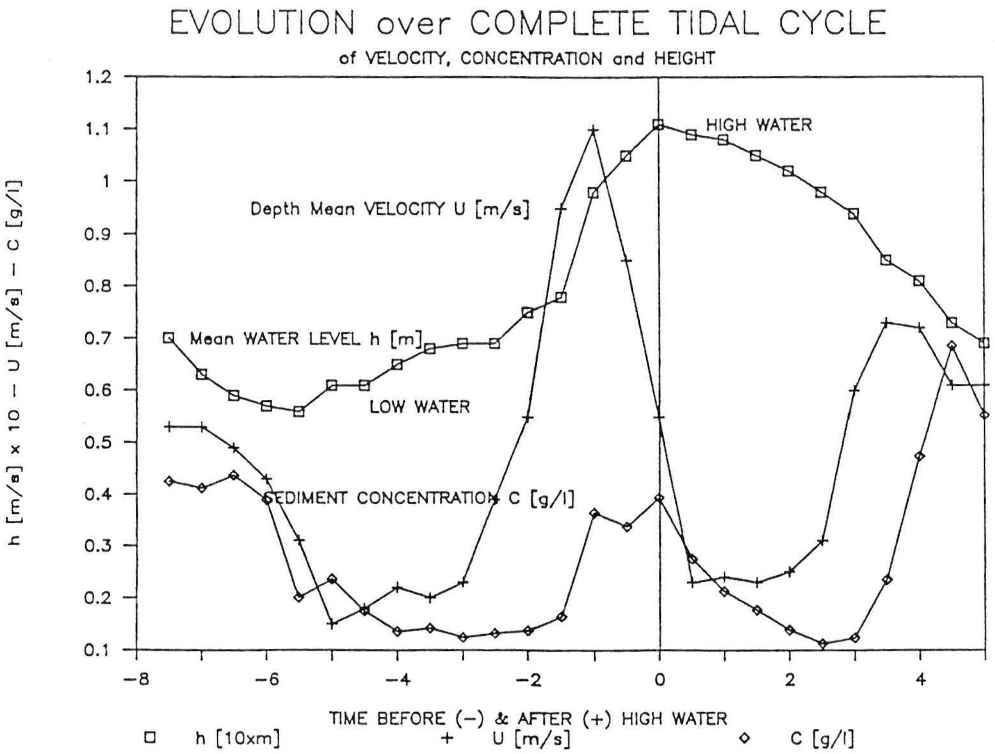

Figure 6 : Evolution over tidal cycle - Location Zwin Entrance

The water velocity U is maximal about 1 hour before high water or low water level. The value of U_{fl} by flood is from 1.5 till 2 times the maximum velocity near low water U_{lw}. The peak to this maximum value U_{fl} is much sharper under flood conditions, while for ebb this maximum velocity U_{lw} is reach after a flatter top. The water velocities reach their minimum values around slack tide, about 1 hour after low water and 2 hours after high water.

In the evolution of the mean total sediment concentration a general delay of about 1 hour to the velocity evolution can be seen. So the extreme values of the concentration are situated about one hour after the maximum/minimum velocities.

Secondly, a more detailed study on the velocity and sediment concentration profiles in one location is worked out. Some theoretical calculations are compared with the measurements in situ. For the calculation of the velocity profile over a vertical, the theoretical approach from **Prandtl - von Karman** was used. The mathematical formulation gives the variation of the water velocity with the height above the bottom :

$$U = \frac{u_*}{K} \times \ln (z/z_o)$$

with U	:	water velocity on height above sea bottom	[m/s]
K	:	von Karman constant = 0.4	
u_*	:	bottom friction velocity	[m/s]
z_o	:	height above bottom where the velocity becomes zero	[m]

This velocity profile, also called the logarithmic profile, is generally accepted to describe the vertical velocity evolution in coastal waters, where a combination of currents and wave-induced flows occurs [4].

After analysing the water samples, the total concentration of suspended sediments can be calculated in each measuring location. For every vertical position the sediment profile over the water depth can be calculated from the so-called **Rouse**-equation [2] :

$$C = C_a \times \left[\frac{h - z}{z} \times \frac{a}{h - a}\right]^S$$

where : C : total sediment concentration in suspension [g/l]

z : height above the bottom [m]

h : local water depth [m]

C_a : concentration in the reference location at height a above bottom [g/l]

S : suspension number = $\frac{w_s}{\beta \times K \times U_*}$

with w_s = precipitation velocity of suspended sediment [m/s]

$$\beta = 1 + 2 \times \left[\frac{w_s}{U_*}\right]^2 \approx 1$$

K = von Karman constant = 0.4

This equation, verified and used by **Pacheco-Ceballos** for coastal waters [3], assumes a parabolic variation of the fluid mixing coefficient ϵ_ς over the water height, starting from a logarithmic velocity profile and a linear shear stress distribution.

The following figures 7, 8 and 9 show some results of the above described analytical approach to the measurements. These theoretical formulations are shown to be in very good agreement with the corresponding measurements in situ.

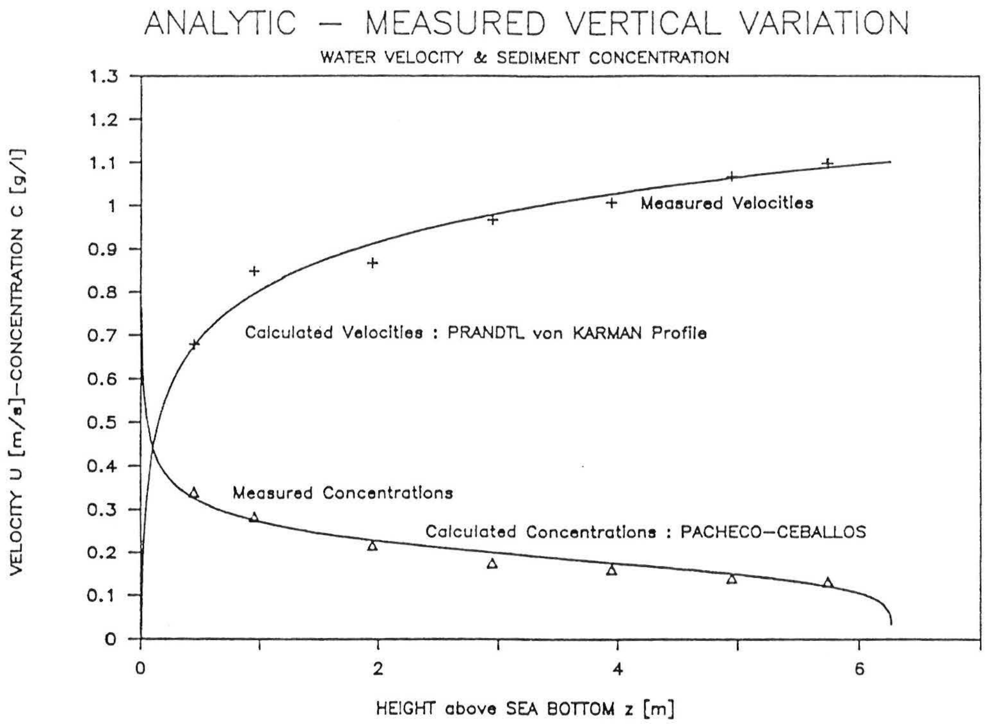

Figure 7 : Analytic - Measured Velocity and Concentration Profiles near High Water in location A

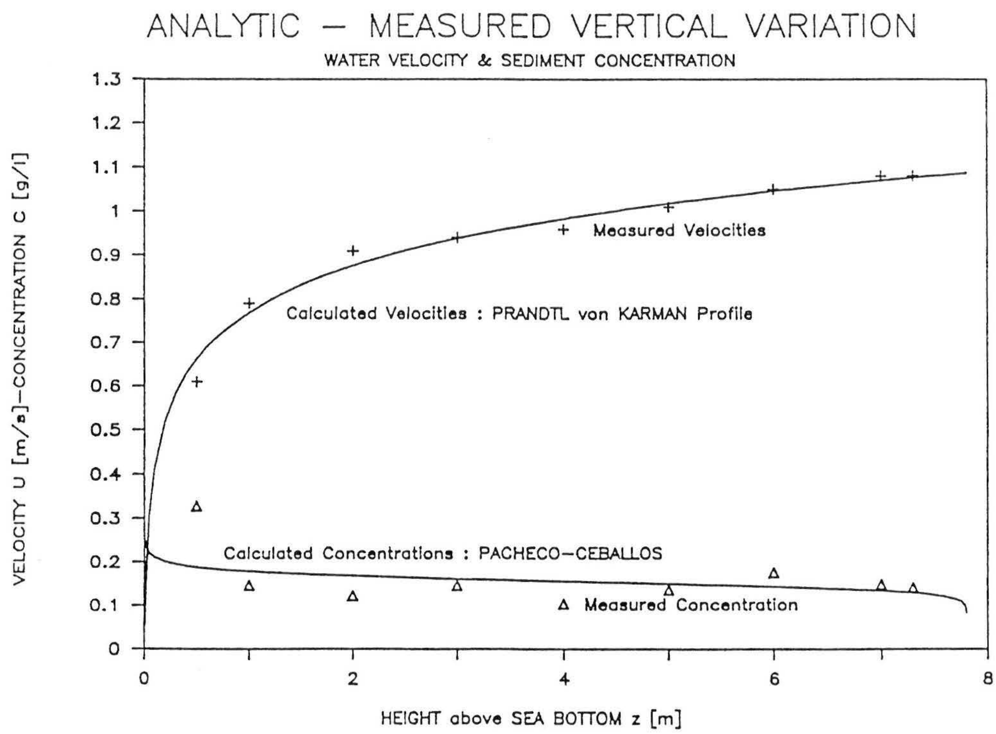

Figure 8 : Analytic - Measured Velocity and Concentration Profiles near High Water in location B

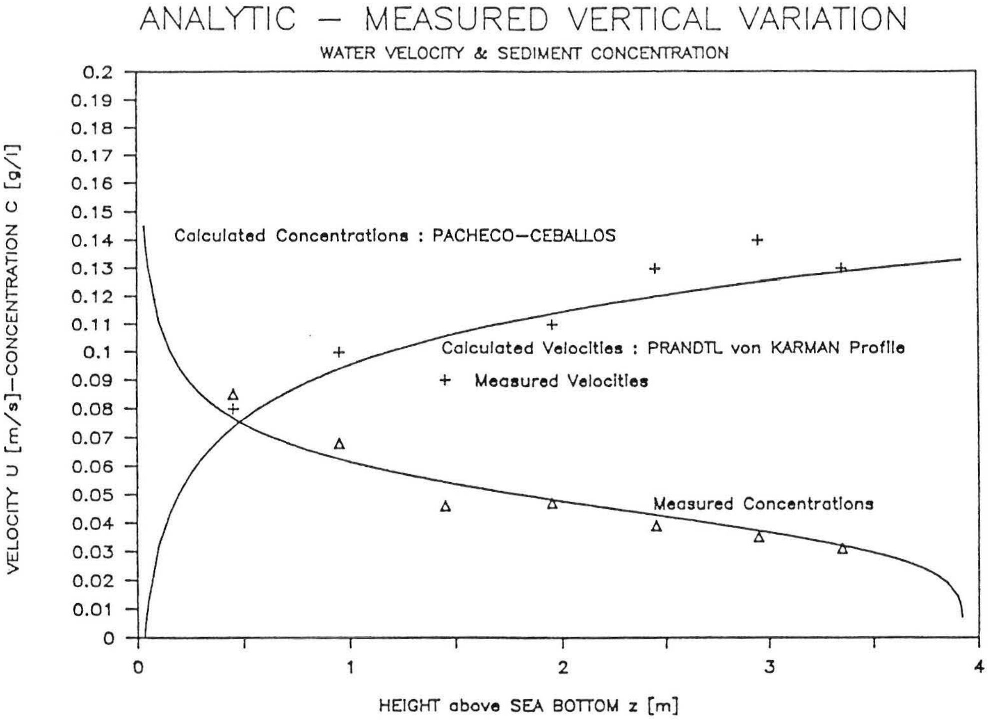

Figure 9 : Analytic - Measured Velocity and Concentration Profiles around Slack Tide

Around slack tide, as shown in figure 9, the sediment concentration profile as well as the velocity distribution, is nearly constant over the water depth; while near high and low water the profiles have a more logarithmic aspect.

At low water, one can assume that the impact of water waves seems to have a greater influence, but this assumption isn't clearly distinguished from the measurements. Theoretically, the wave force can induce a great amount of sediment transport since in the rather small wave boundary layer the turbulence and the shear stress are very great. So, it's assumable that by lower water depths the influence of the water wave force decreases. Further measurements and laboratory experiments must verify these theories [4].

Once the analytic velocity distribution over the vertical is known, together with the sediment concentration profile, the total sediment transport amount can be calculated as the product of both these values. By this, a good idea of the sediment movements and/or properties over some locations can be achieved and verified.

5. CLOSURE

This paper gives a general view on some practical applications and operation modes for in situ measurements of sediment transport along our Belgian Coast. Practical measuring devices as the **bottom sample bottles** or the **sediment sampling palisade** are specially adapted instruments for measuring sediments under sea conditions. The analytical elaborations prove the accuracy of these measurements and suggests new developments for the near future.

6. REFERENCES

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MEASUREMENTS OF SEDIMENT TRANSPORT ALONG THE BELGIAN COAST

SAMENVATTING : SEDIMENTTRANSPORTMETINGEN LANGS DE BELGISCHE KUST

In het kader van een uitgebreide onderzoeksopdracht werden het afgelopen jaar langs de Belgische kust enkele in situ meetkampagnes georganiseerd. In deze bijdrage wordt kort een overzicht gegeven van de praktische verwezenlijkingen betreffende de sedimenttransport meetopstellingen. De introduktie van een specifiek bemonsteringsstaketsel voor metingen in de surfzone en de ontwikkeling van een eenvoudige bemonsteringsfles voor bodemtransport schetsen de operationele mogelijkheden van een adekwate meting op zee.

De theoretisch gefundeerde verwerking van de meetgegevens toont de akkuraatheid van de metingen aan. Zowel het logaritmisch **Prandtl - von Karman** snelheidsprofiel als de sedimentconcentratieverdeling volgens **Rouse (Pacheco-Ceballos)** blijken, binnen de voorziene meetfouten, in goede overeenstemming te zijn met de uitgevoerde metingen.

SYNTHESE : MESURES DU TRANSPORT DES SEDIMENTS LE LONG DE LA COTE BELGIQUE

Dans le cadre d'une mission de recherche extensive le long de la côte Belge, quelques campagnes de mesure ont été organisées l'année passée.

Cet article présente un sommaire des réalisations pratiques lors de ces campagnes, avec l'utilisation de plusieurs montages spécifiques. Par exemple, la fabrication d'un système à prises latérales multiples d'échantillons pour les mesures au voisinage de la plage et le développement d'une bouteille simple pour la mesure du charriage sur le fond de la mer donnent un aperçu sur des possibilités opérationnelles d'une mesure appropriée sur la mer.

Le traitement des données basé sur des lois théoriques confirme la précision des mesures. Aussi bien le profiel logarithmique de la vitesse d'eau selon **Prandtl-von Karman** que la distribution de la concentration des sédiments en suspension selon **Rouse (Pacheco-Ceballos)** concordent, dans la marge de précision attendue, avec les mesures effectuées.