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Estimation of the Efficiency of a Silt Screen using a Vessel-mounted ADCP

Jae Youll Jin[1], Jin Soon Park[1], Won Oh Song[1], Sung Eun Kim[1],
Kwang Soo Lee[1], Ki Dai Yum[1] and Jae Kyung Oh[2]

1. INTRODUCTION

As for quantitative evaluation of the amount of sediments released into the ambient waters by various works for coastal development, the instrument and method of the measurement of suspended sediment concentration (SSC) are critical for estimating the efficiency of a silt screen to reduce the spreading of sediment plumes generated by coastal works.

Traditional seawater sampling and optical instruments for SSC monitoring have limit in understanding the evolution of the shape and SSC of the plumes.

For the last decade, the applicability of acoustic Doppler sensors to profile SSC has been constantly studied (e.g., Kraus and Thevenot, 1992; Tubman, 1995; Land *et al.*, 1997; Land and Bray, 1998; Land and Jones, 2001). Although a rigorous *in-situ* calibration of the acoustic backscatter intensity into the SSC is required, they are recognized as the best way for measuring the sediment flux by virtue of their simultaneous profiling of current speed and SSC. Recently, commercial softwares for the *in-situ* calibration are available (e.g., DRL Software Ltd., 2002).

A silt screen of traditional and simple measure for reducing the detrimental effect of the plumes has only limited efficiency (Ooms, 1997; Shaw et al., 1998; John et al., 2000), but the screens have been still widely used as mitigation measures.

In order to estimate the efficiency of a silt screen of fixed hanging type, a vessel-mounted monitoring using an acoustic Doppler sensor and SSC profiling with optical backscattering sensors (OBSs) at two fixed stations were carried out.

2. FIELD MEASUREMENTS

VM monitoring using an 1.2MHz broadband Acoustic Doppler Current Profiler (ADCP) of RDI was carried out on June 15, 2002 in front of the coal terminal of Incheon Namhang (south port) where capital dredging was conducted for a new container terminal (Fig. 1). The silt

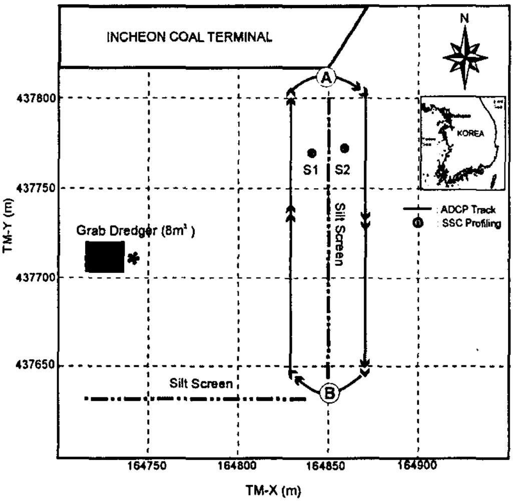

Fig. 1. Location map showing the study area' and the sites of field measurements.

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[1] Corresponding Author : Jae-Youll Jin, Coastal and Harbor Engineering Laboratory, Korea Ocean Research and Development Institute, Ansan, Seoul 425-600, Korea, jyjin@kordi.re.kr

[2] Department of Oceanography, Inha University, Incheon 402-751, Korea

screens installed in the study area were fixed hanging types, 3m of the screen depth. The monitoring track is about 20 m apart from the silt screen of about 100 m eastward from a grab dredger, 8 m^3 of the backet volume. The details of the VM ADCP monitoring system, cell depth, sensing interval, and data processing procedures are described in Jin et al (2003).

In addition to the track monitoring, SSC profiles were simultaneously measured every 10 minutes by the OBSs of the YSI6600 of YSI at sites S1 and S2 on the main route of the sediment plume generated by the dredging.

Durations of the dredging and field measurements on June 15 are presented in Table 1. Low water level of Incheon Tidal Station was 177 cm at 14:16 and high water level was 731 cm at 20:21, which belongs to spring tide.

Table 1. Durations of the dredging and observations on June 15, 2002

Dredging / Observation	Duration
Grab dredging ($8m^3$)	? - 14:00
	15:36 - 16:13
	16:18 - 16:49
VM ADCP monitoring	15:50 - 18:00
Point profiling of SSC	13:40 - 17:30

3. RESULTS

3.1 VM ADCP Monitoring

As mentioned above, a rigorous calibration of the intensity of the acoustic backscatter from each layer should be carried out in order to obtain the SSC profile. The software DRL-SediView® of DRL software Ltd. was used for the calibration, and the result of which is shown in Fig. 2.

Depth-averaged current speed and direction, SSC and water depth along the track of the VM ADCP monitoring is shown in Fig. 3. Measured depth indicates that the monitoring vessel kept the designed route although the time per one cycle shows some variation.

Depth-averaged current speed locally varies from 5 to 30 cm/s, and the observed maximum is 60 cm/s. The main direction of the flooding currents is eastward, but there are local deviations, too.

SSC locally varies from 10 to 60 mg/l. It is noticeable that the range of its local fluctuation became distinctly small after closing of the dredging at 16:50.

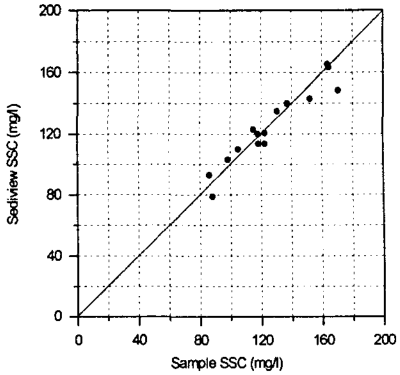

Fig. 2. In-situ calibration of the ADCP signal intensity.

For detail understanding of the results of Fig.3, Fig. 4 shows that current at the northern end of the track referred to site A in Fig. 1 is the weakest, while the strongest at the southern end of site B. Current direction near site A largely deviates from the mainly eastward direction, which is presumably caused by the influence of the silt screen.

During the dredging work, SSC peaks on the upstream

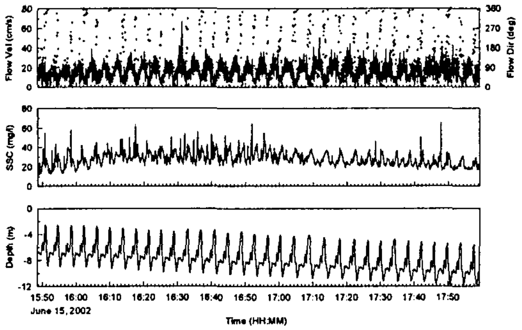

Fig. 3. Depth-averaged results of the VM ADCP monitoring.

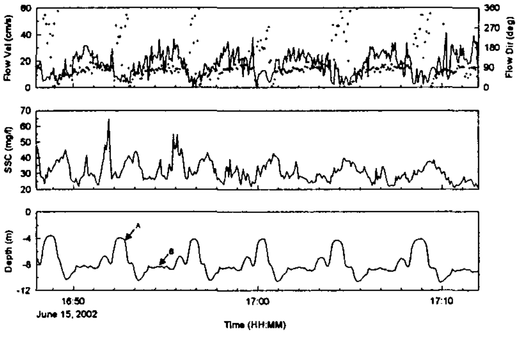

Fig. 4. A magnification of Fig. 3.

section (B→A) are higher than those on downstream section, while the higher peak along the downstream of the screen dies out after closing of the dredging.

Typical results of sectional distributions of SSC and current speed in dredging period and after dredging are shown in Figs. 5 and 6, respectively. The times are those of the vessel's passing the center of the sections. The reference of the horizontal distance is the maximum northern end of the tracks.

These figures show that the background SSC is about 30-40 mg/l. The SSC of the plume increases up to about 80 mg/l in the upstream section, while 60 mg/l in the downstream section.

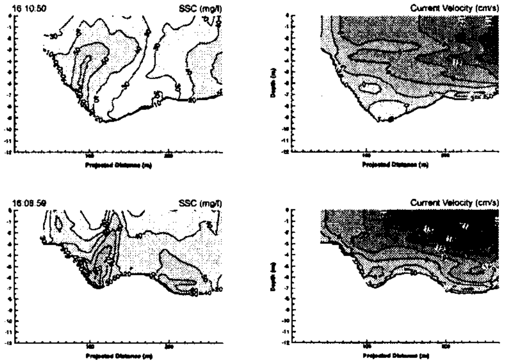

Fig. 5. Typical results of the sectional distributions of SSC and current velocity normal to the screen in dredging period (upper: downstream, lower: upstream of the silt screen, left is north).

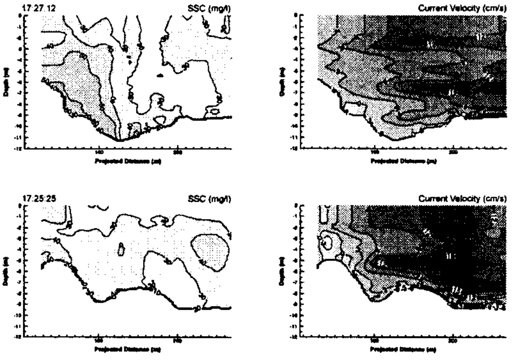

Fig. 6. Typical results of the sectional distributions of SSC and current velocity normal to the screen after dredging (upper: downstream, lower: upstream of the silt screen, left is north).

Current structures believed to be influenced by the silt screen were observed. That is, there are westward currents below the depth of 5m of the downstream in Fig. 5, which can be thought to be the result of vertical eddies. In Fig. 6 of mid-flood, current speeds in the depth of 4-6 m of upstream section is higher than those the upper layers. Additionally, westward currents occur near the northern end of the upstream section.

3.2 SSC Profiles at Fixed Stations

A total of 23 synchronized profiles at site S1 and S2 was made. As shown in Fig. 7, the turbidity in NTU measured by the OBSs of the YSI6600 was calibrated into SSC with the seawater concurrently sampled.

The paired profiles of SSC from sea surface to 0.5 m above the bed are shown in Fig. 8 and it may be proper to analyse their characteristics according to the tidal phase and the state of the dredging.

For dredging period in ebb tides (13:40-14:20)

The sites S1 and S2 are free from the dredging-induced sediment plumes due to the westward ebbing currents, thus the observed SSC can be regarded as the background concentration. The SSC of S1 (40-60 mg/l) is doubly higher than that of S2, which can be interpreted as the results of accumulation of suspended sediments (SS) advected from S2 where is twice deeper than S1.

For suspending of dredging in flood tides (14:30-15:30)

It is noticeable that the surface SSC of S1 markedly increased up to about 120 mg/l even without dredging,

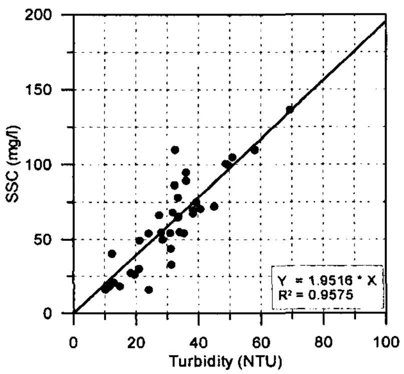

Fig. 7. In-situ calibration result of the OBS of the YSI6600.

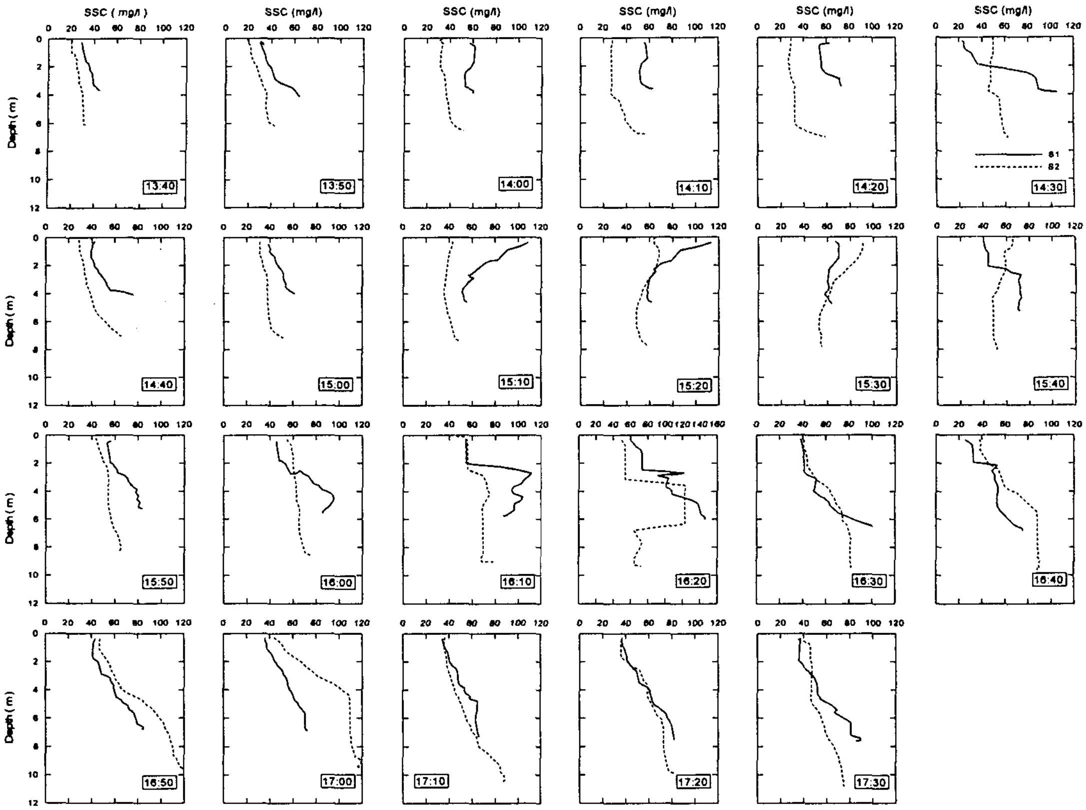

Fig. 8. SSC profiles at sites S1 and S2.

then the SS advected to S2. It means there should be another SS source, and overflowing from a barge might be responsible.

For dredging period in flood tides (15:40-16:40)

The plumes dominate the vertical distributions of SSC. SSC at the depth of about 3 m of S1 abruptly increased from about 50 to 100 mg/l, while the increase at the same depth of deeper S2 does not show such sharp increase with the same frequency due to vertical mixing.

For flood period after dredging (16:50-17:30)

On the contrary to ebbing and suspending periods, the SSC of S2 is rather slightly higher, which may be interpreted as the results of trapping SS resuspended in the upstream.

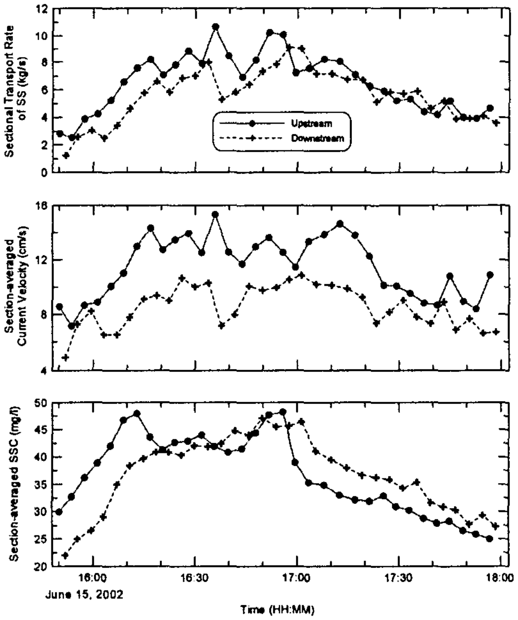

Fig. 9. Temporal variations of sectional transport rate of SS, section-averaged current velocity normal to the section, and section-averaged SSC.

4. ESTIMATION OF THE SCREEN EFFICIENCY

The efficiency of the silt screen based on the amount of SS along the reference up- and downstream sections parallel to the screen is estimated.

Section-averaged SSC, current velocity normal to the silt screen and sectional transport rate of SS during the period of dredging in flood tides are shown in Fig. 9. The patterns of section-averaged SSC and the sectional transport rate can be distinguished by the dredging operation.

Before the closing of the dredging at 16:50, the SSC of the upstream section is higher than or comparable to that of the downstream and the transport rate is always higher than that of the downstream. After the closing, however, the SSC and transport rate of the downstream are always higher than and comparable to those of the upstream, respectively. It can be explained by the SS plumes largely influencing the transport rate of SS.

Total amounts of sediments passed through the both sections are presented in Table 2 according to dredging conditions.

Table 2. Mass of sediments passed through the up- and downstream sections of the silt screen

Dredging work	Duration (hr)	Passed mass (kg)		M_d/M_u
		M_u^*	M_d^*	
Dredging	1.10	27,315	20,973	0.77
No work	1.02	22,716	22,122	0.97

* M_u, M_d : mass passed through up- and downstream sections

Consequently, if it is appropriate that the efficiency of a silt screen can be assessed with the total mass passed through the up- and downstream sections of some reference distance apart from the screen, the efficiency of the screen of fixed hanging type installed in the study area is only about 23%.

However, the above concept about the efficiency may be not enough and proper especially for numerical modeling of the SS plumes generated by coastal works. More proper definition is discussed in the next section.

5. DISCUSSION AND CONCLUSION

When a silt screen is considered as a mitigation measure of spreading of SS caused by coastal works, its efficiency should be properly defined and rigorously estimated because its economic charge requires the mitigation effect of a certain degree.

The efficiency may be able to be quantified in terms of the change in SSC, SS flux or the mass of SS passed through a interested region for some period. However, estimated efficiency may yield critical errors unless care is taken to the evaluation method.

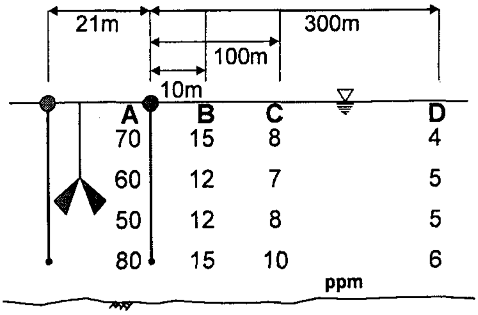

Fig. 10. SSC distribution in/out of a silt screen area (Taiyo Kogyo Co., http://www. taiyokogyo.co.jp).

For example, the efficiency of the silt screen at the first layer of B in Fig. 10 may be provided as 78.6% by taking the SSC (70mg/l) of the inner first layer as the reference SSC. It is, however, not proper approach in that a silt screen is installed to make the SSC of a downstream region lower than that of the same region without the screen but under the influence of coastal works.

Thus SSC measurements prior to the installation of a silt screen are required especially when numerical modeling on the evolution of SS plumes in an area with any silt screen is planned. Numerical modeling generally takes the generation rate of SS obtained by field measurements near the dredging points without any effect of a silt screen as the input data. Hence, taking the efficiency calculated by the fluxes measured at the up- and downstream of the screen as the screen efficiency may be not proper if the upstream flux is largely different from the generating rate of SS at the source point.

Of course, the prerequisite for the estimation of the efficiency with the fluxes before and after the installation is that the hydrodynamic, sedimentary and dredging conditions of the both observation periods should be comparable each other.

In this context, the efficiency estimated with the mass of SS passed through the up- and downstream sections of the screen, as this study, may be not proper.

However, if two conditions are satisfied without a lot errors, the estimation may be regarded as a useful datum for establishing a guidance of the optimal installation of a silt screen. The first assumption is that the flux of plume SS along a upstream section can be regarded as the generation rate of SS if the distance between the monitoring section and dredging point is relatively short. The other is that the influence of the silt screen on the flux can be neglected if the fluxes along a shortly separated up- and downstream sections of the screen are comparable in the period of no dredging.

Considering the distance between dredging points and the sections of monitoring the generation rates of SS generally ranges 40 to 200 m (Lorenz, 1999; Jin et al., 2003), the distance of about 80 m in this study can be regarded to satisfy the first condition. The second condition is also satisfied because the distance between the up- and downstream is only 40 m and their fluxes after closing of the dredging are closely comparable (Fig. 9). Hence, the screen efficiency of 23% can be reasonably accepted as a useful reference to infer the efficiency of a silt screen of similar situation.

In order to establish a more general guidance, however, further field experiments, especially during pilot dredging, are required.

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