환경영향평가 제18권 제5호(2009) pp.245~256

연구논문

A Study on the Efficiency of the Seawater-Overflow Reduction Device Installed on a Sand Dredging Vessel

Chul-hui Kwoun* · Nam-do Lee* · Kyu-Sang Jang · In-Soo Kim** · Baek-Hoon Jung*** · Hoon Kang* · Min-Sun Kwoun***

Land Ocean Environment Co.,Ltd.*, Korea Rural Community Corporation, Rural Research Institute**
Korea Ocean Research & Development Institute***

(Manuscript received 3 January 2008; accepted 8 September 2009)

해사채취 선박에 설치된 월류수 저감장치의 효율성에 관한 연구

권철휘* · 이남도* · 장규상 · 김인수** · 정백훈*** · 강　훈* · 권민선***

(주)국토해양환경기술단*, 한국농어촌공사 농어촌연구원**, 한국해양연구원***

(2008년 1월 3일 접수, 2009년 9월 8일 승인)

Abstract

해사채취 선박에 설치된 월류수 저감장치의 효율성을 파악하기 위하여 월류수 저감장치가 설치된 선박과 설치되지 않은 선박의 작업시 부유사 농도를 관측 · 비교하였다.

부유사 관측결과 월류수 저감장치가 설치된 선박과 설치되지 않은 선박의 작업시 부유사 농도는 부유사 발생원으로부터 거리가 멀어질수록 감소하는 경향을 보였고, 1km 정점부터 배경농도와 비슷한 농도를 나타내었다.

월류수 저감장치의 사용여부에 따른 부유사 농도를 비교 · 분석한 결과 부유사의 저감효율은 52.9~65.5%(평균 60.8%)로 조사되었다. 또한 월류수 저감장치의 효율은 중층에서 평균 62.6%로 가장 높은 효율을 보였다.

본 연구의 부유사 관측 결과만으로 월류수 저감장치의 부유사 저감효율을 산정하기에는 다소 무리가 있으나, 관측 결과 나타난 월류수 저감장치의 부유사 저감효과는 비교적 양호한 것으로 조사되었다. 또한 월류수 저감장치는 해사채취시 부유사 저감에 효과적인 방법으로 판단되며, 추후 월류수 저감장치 여과망의 여과효율 등 여러 인자들과의 상호 연관성을 종합적으로 고려하여 해사채취 선박에 설치된 월류수 저감장치의 효율을 도출할 예정이며 해사채취 대상해역의 정기적이고 세밀한 연구가 필요하리라 판단된다.

주요어 : 해사채취, 월류수 저감장치, 부유사 관측, 저감효율 산정

Corresponding Author: Chul-Hui Kwoun, Land Ocean Environment Co.,Ltd., MetroPlaza 202, #524-1, Jinan-Dong Hwaseong-si, Gyeonggi-do, Korea Tel: 82-31-221-7812~3 Fax: 82-31-221-7801 E-mail: kwounch@hanmail.net

I. Introduction

Sand is an important aggregate resource whose smooth supply is paramount in various construction industries for houses, roads, harbors and such. Because of its importance as an aggregate resource, and because sand extractions on land have not been able to satisfy the demand for construction aggregates, interest in the sand resources of the ocean has been steadily increasing. And as a way to efficiently satisfy the demand for construction aggregates, sea sand extractions are being carried out. However, although these practices stabilize the supply of and demand for aggregate resources, they cause various problems related to the marine environment. As a response to this many have carried out studies in the past regarding the impacts that sea sand extractions can have on the marine environment and ecosystem, namely "A Study on the Estimation of Natural Abundance of Sea Sand and the Environmental Impact of Sea Sand Extraction in Gyeonggi Bay" (Incheon Branch of Korean Aggregates Association, 2002), "A Study on the Current State and Management of Demand and Supply for Sea Sand" (Korea Maritime Institute, 2003), "A Study on the Economic/Environmental Integrated Assessment Model for Sea Sand Extraction(II)" (Korea Maritime Institute, 2004), and "A Study on an Eco-friendly Management of Sea Sand Extraction(I, II)" (Ministry of Maritime Affairs and Fisheries, 2005-2006), as well as others. However, at the present moment there still doesn't exist a comprehensive and systematic study regarding the impacts of sea sand extraction on the marine environment and ecosystem. The primary impacts of sand extractions at sea on the marine environment and ecosystem include changes in the sedimentary and physical environments at the extraction areas, as well as the destruction of habitats of benthic organisms. Secondary impacts are changes in the water quality and the submarine environment, increase in noise in the extraction areas, and a deterioration of environment caused by the increase in pollutants coming from the extraction vessels, which leads to the deterioration of habitat conditions of organisms living nearby (A Study on the Current State and Management of Demand and Supply for Sea Sand" (Korea Maritime Institute, 2003)). Also, the pumping activity during sea sand extraction causes the transfer of some marine sediments onto the ship, whose pore water releases nutrient matters, heavy metal substances and organic matters; the release of suspended matters that have been transferred together with the marine sediments pose as a problem as well (A Study on the Economic/Environmental Integrated Assessment Model for Sea Sand Extraction(II) (Korea Maritime Institute, 2004)). Therefore there is a need to analyze the degree of suspended sediments generated during sea sand extraction in the ocean, and to come up with a reduction plan based on the analysis.

In the case of sea sand extraction vessels used in the past (with overflow elimination systems), the suspended sediments discharged together with the unfiltered seawater that overflows from the barge notably increase the turbidity of the surrounding seawater. And since these suspended solids are directly influenced by the movement of the seawater they are moved about and diffused, which directly and indirectly affects the marine environment and ecosystem of the extraction areas and other areas nearby. Thus one of the reduction measures regarding the impacts on the overall marine environment caused by the suspended solids overflowing unfiltered from a dredging vessel during sea sand extraction is to install a seawater-overflowing reduction device on the extraction vessel.

This study aims to provide the basic data related to minimizing the impacts on the marine environment and ecosystem by installing a seawater-overflowing device on an extraction vessel during sea sand extraction and, through an observation of the suspended solids, figuring out the movement characteristics of the suspended solids and the efficiency of reducing their concentration.

II. Method

1. Seawater-Overflow Reduction Device

One method of preventing the diffusion of suspended solids and the seawater overflow during sea sand extraction is to install a seawater-overflow reduction device on the sea sand extraction vessel. In order to prevent the overflowing, this device, while controlling the pumping speed, sends the water collected in the hold through a filter net, from which the purified water is sent out through a discharge outlet (that functions like a three-layered extendable antenna) installed at the lower part of the hold (Figure 1). This way the water is discharged into the sea approximately 15m below the surface. Because the device sends the water directly into the bottom of sea, it initially reduces the diffusion of turbid water.

Table 1 shows the scale and the extracting volume of two ships that are compared in the study, one of which has the seawater-overflow reduction device while the other does not.

2. On-site observation and the extraction of sample

In order to assess the efficiency of the seawater-overflow reduction device that was installed

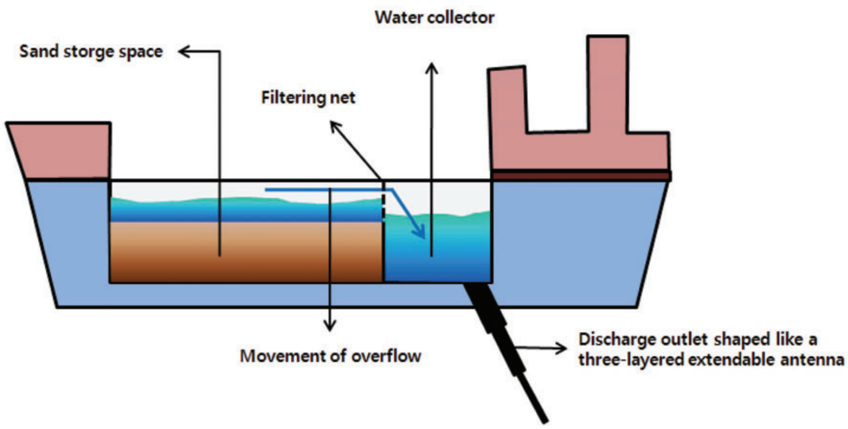


Fig 1. A diagram of the seawater-overflow reduction system

Table 1. Comparison of the vessels with and without the overflow reduction device

	Vessel with the device	Vessel without the device
Method of Extraction	High-pressure compression suction extraction method using a sand pump line	High-pressure compression suction extraction method using a sand pump line
Size of the Vessel	1,138 ton 16m(B)×5.75m(H)×65.6m(L)	781 ton 18m(B)×3.3m(H)×62.4m(L)
Sea Sand Extraction Capacity	1,242m^3	1,472m^3

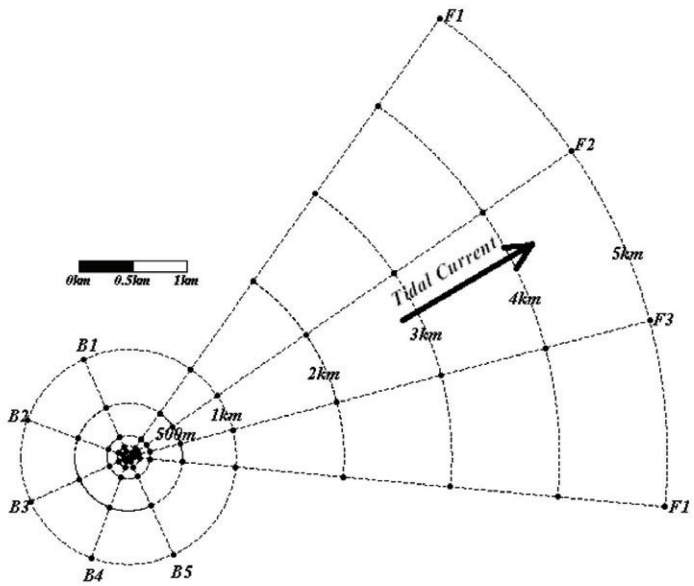


Fig. 2. Suspended solids observation station

on the sea sand extraction vessel, 4 lines in the direction of the tidal current and 5 lines in the opposite direction of the current were designated around the vessel during extraction (Figure 2). The on-site observation was carried out on the ships with and without the seawater-overflow device during a rising tide, and consisted of analyzing the suspended solids found in three different layers within the water (surface, middle layer, bottom layer) and comparing their SS concentrations.

The on-site investigation was carried out from August 27th to 28th, 2007, during a rising tide; it involved extracting the samples from different lines designated around the sea sand extracting vessel (4 lines in the direction of the tide, 5 lines in the opposite direction to the tide to figure out the background concentration). On August 27th, the suspended solids were observed during sea sand extraction carried out by the vessel installed with the overflow reduction device, and on August 28th the same observation was carried out for the vessel without the device. A Niskin Sampler was used to extract the necessary samples, and these samples were transported in an ice box to the laboratory where they were analyzed.

3. Analysis of the SS concentration

The analysis of the SS concentration was carried out on the samples according to the Marine Environment Process Test Method, using glass fiber filter papers: a certain amount of the sample was filtered through a pre-treated GF/F filter using a vacuum pump, after which it was left to dry for 1 hour at 110°C. The weight of the dried sample was measured and converted into SS concentrations.

4. Method of calculating the SS concentration reduction efficiency of the seawater-overflow reduction device

The reduction efficiency of the seawater-overflow reduction device in decreasing the SS concentration was calculated by observing the suspended solids of the vessels with and without the device.

The effect of sea sand extraction carried out the day before was not taken into account when calculating the SS concentration reduction efficiency of the seawater- overflow reduction device, since the sinking speed of the grains from the extracted sea sand (average diameter: 0.25mm) in the water was 0.03546m/s (according to Van Rijn's formula), which meant that the time it took the grains to sink complete was very short. Also, the current speeds for each water layers in the investigation area during rising tide in summer were 58.5cm/s for the surface, 60.4cm/s for the middle layer, and 67.0cm/s for the bottom layer, displaying similar distribution (Marine Environment Assessment and Post Impact Assessment Regarding Aggregates Extractions in the Sea Area Under the Jurisdiction of Tae-An County, Choongnam Aggregates Association, 2008). Meanwhile, the water temperatures in the investigation area during rising tide in summer were approximately 20.9°C at the surface and 20.4°C at the lower layer (Sea Area Utilization Impact Assessment Regarding Aggregates Extractions in the Sea Area Under the Jurisdiction of Tae-An County, Choongnam Aggregates Association, 2009), and because it was assumed that there was no vertical mixing caused by the water temperature, the vertical mixing of suspended solids and the current speeds for each layer of water were not taken into account in the calculation of the reduction efficiency. The formula for calculating the SS reduction efficiency is as follows:

$$Reduction\ Efficiency\ (\%) = \frac{(A - B)}{A} \times 100$$

A = SS concentration with the use of seawater-overflow reduction device

B = SS concentration without the use of seawater-overflow reduction device

III. Results and Discussion

1. Suspended solids detected during extraction for the vessel with the seawater-overflow reduction device

On August 27th, 2007, during the sea sand extraction carried out by the vessel installed with the seawater-overflow reduction device, the SS concentration was measured for 4 lines in the direction of the tidal current as well as 5 lines in the opposite direction to the current, the latter measurement carried out to check the background concentration.

Table 2. SS concentration measured in the opposite direction to the tide for the vessel installed with seawater-overflow reduction device

Item	B1			B2			B3			B4			B5		
	SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)		
Distance	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
50m	4.7	5.0	5.7	4.0	4.0	4.7	4.7	5.0	5.5	5.3	5.7	7.7	5.7	6.0	6.3
100m	4.0	4.3	5.0	3.3	3.7	4.0	4.3	4.7	5.7	4.3	4.7	5.7	4.7	5.0	5.0
200m	4.3	4.0	4.7	4.3	4.0	4.7	5.0	5.3	5.7	5.0	5.7	5.7	5.0	5.0	5.3
500m	3.0	3.3	3.3	3.7	3.7	5.0	4.0	5.0	5.0	4.7	5.3	5.7	5.7	4.3	4.7
1km	3.0	3.0	3.3	4.0	4.3	5.0	4.7	4.7	5.3	6.3	4.7	5.3	4.3	4.7	4.7
Min	3.0	3.0	3.3	3.3	3.7	4.0	4.0	4.7	5.0	4.3	4.7	5.3	4.3	4.3	4.7
Max	4.7	5.0	5.7	4.3	4.3	5.0	5.0	5.3	5.7	6.3	5.7	7.7	5.7	6.0	6.3
Mean	3.8	3.9	4.4	3.9	3.9	4.7	4.5	4.9	5.4	5.1	5.2	6.0	5.1	5.0	5.2

Table 3. SS concentration measured in the direction of the tide for the vessel installed with seawater-overflow reduction device

Item	F1			F2			F3			F4		
	SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)		
Distance	S	M	B	S	M	B	S	M	B	S	M	B
50m	14.3	13.0	16.1	13.6	13.1	15.3	14.1	14.0	14.8	13.7	13.1	14.3
100m	12.7	12.9	13.1	11.5	10.5	13.1	12.2	12.1	13.3	12.1	11.9	13.3
200m	10.2	10.4	11.5	10.1	9.2	11.2	10.5	9.9	10.3	10.4	10.0	11.5
500m	6.3	6.1	7.9	6.7	6.1	9.0	7.2	6.2	8.3	9.7	7.4	9.1
1km	6.0	4.7	4.9	4.7	5.7	8.2	6.6	4.3	4.9	5.8	4.3	5.3
2km	4.0	8.0	6.3	3.3	6.0	6.0	5.2	3.5	4.8	4.0	4.0	4.0
3km	6.0	3.0	4.3	5.3	6.0	7.3	3.3	3.5	4.2	3.5	6.3	6.0
4km	5.7	3.3	3.0	5.3	3.3	4.0	3.5	3.5	4.5	3.3	4.0	6.0
5km	3.5	3.0	4.7	7.0	5.7	3.9	3.2	4.2	4.0	4.3	4.0	5.7
Min	3.5	3.0	3.0	3.3	3.3	3.9	3.2	3.5	4.0	3.3	4.0	4.0
Max	14.3	13.0	16.1	13.6	13.1	15.3	14.1	14.0	14.8	13.7	13.1	14.3
Mean	7.6	7.2	8.0	7.5	7.3	8.7	7.3	6.8	7.7	7.4	7.2	8.4

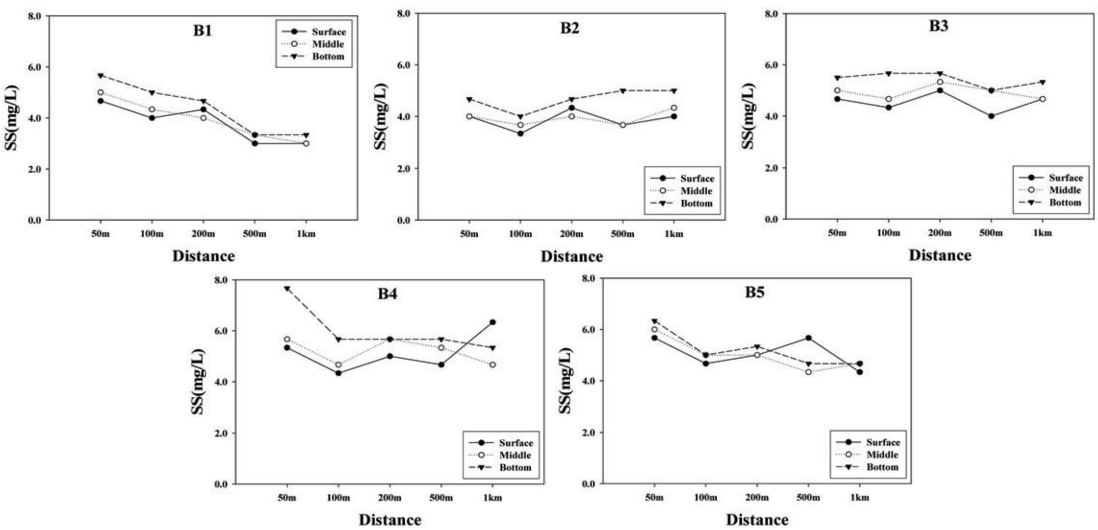


Fig. 3. SS concentration measured in the opposite direction to the tide for the vessel installed with seawater-overflow reduction device

When the SS concentration was measured in the opposite direction to the tide (to measure the background concentration) during the sea sand extraction of the vessel installed with the device, the average was 4.5mg/L for the surface, 4.6mg/L for the middle layer, and 5.1mg/L for the bottom layer. The SS concentration detected in the direction of the tidal current for the vessel installed with the device during the extraction was on average 7.5mg/L for the surface (showing a 3.0mg/L increase), 7.1mg/L for the middle layer (showing a 2.5mg/L increase), and 8.2mg/L for the bottom layer (showing a 3.1mg/L increase). Also, the concentration level decreased as the distance from the SS source increased, and from 1km away the concentrations became similar to the concentration detected in the surrounding area.

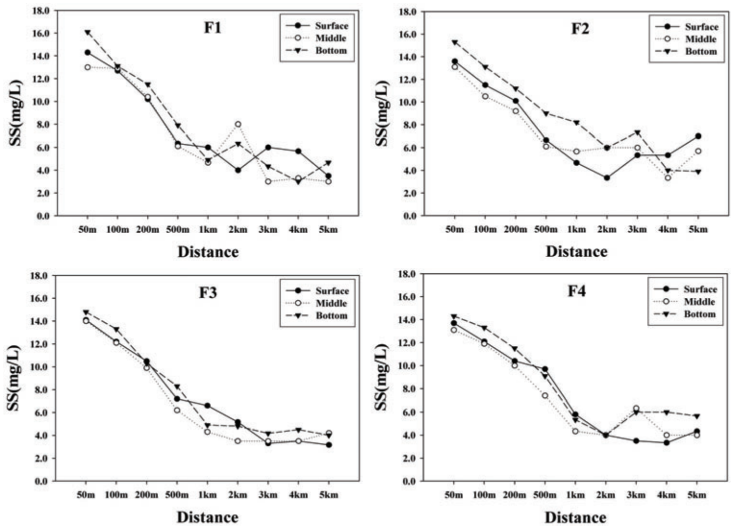


Fig. 4. SS concentration measured in the direction of the tide for the vessel installed with seawater-overflow reduction device

2. Suspended solids detected during extraction for the vessel without the seawater-overflow reduction device

When the SS concentration was measured in the opposite direction to the tide (to measure the background concentration) during the sea sand extraction of the vessel without the seawater-overflow reduction device, the average was 4.7mg/L for the surface, 5.0mg/L for the middle layer, and 5.3mg/L for the bottom layer. The SS concentration detected in the direction of the tidal current for the vessel without the device during the extraction was on average 17.9mg/L for the surface (showing a 13.2mg/L increase), 19.1mg/L for the middle layer (showing a 14.1mg/L increase), and 21.3mg/L for the bottom layer (showing a 16.0mg/L increase). Also, the concentration level decreased as the distance from the SS source increased, and from 1km away the

Table 4. SS concentration measured in the direction of the tide for the vessel without the seawater-overflow reduction device

Item	F1			F2			F3			F4		
	SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)		
Distance	S	M	B	S	M	B	S	M	B	S	M	B
50m	33.0	34.3	34.7	31.1	34.3	33.7	32.3	33.3	34.3	31.3	32.7	34.3
100m	30.3	29.7	32.3	26.3	31.3	34.3	27.7	30.7	31.3	28.0	31.0	33.0
200m	26.1	24.3	31.3	26.3	25.0	29.3	28.3	26.3	29.0	28.7	29.3	33.3
500m	20.7	25.3	26.7	24.3	23.3	27.3	23.0	25.0	27.3	25.7	27.7	29.3
1km	9.7	15.3	19.3	14.3	16.0	20.3	15.3	17.7	21.3	18.7	16.0	22.0
2km	8.3	8.3	9.3	10.7	13.3	10.0	14.0	15.3	16.3	11.3	13.0	15.0
3km	5.7	10.0	9.3	9.7	12.7	14.3	18.0	11.3	12.0	12.3	10.3	13.0
4km	6.7	6.3	8.7	6.3	7.7	11.3	8.0	9.0	11.7	7.0	9.3	15.7
5km	5.3	5.7	6.3	7.0	10.0	8.0	7.3	9.0	10.0	6.7	7.7	11.3
Min	5.3	5.7	6.3	6.3	7.7	8.0	7.3	9.0	10.0	6.7	7.7	11.3
Max	33.0	34.3	34.7	31.1	34.3	34.3	32.3	33.3	34.3	31.3	32.7	34.3
Mean	16.2	17.7	19.8	17.3	19.3	20.9	19.3	19.7	21.5	18.9	19.7	23.0

Table 5. SS concentration measured in the opposite direction to the tide for the vessel without the seawater-overflow reduction device

Item	B1			B2			B3			B4			B5		
	SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)			SS(mg/L)		
Distance	S	M	B	S	M	B	S	M	B	S	M	B	S	M	B
50m	5.0	5.3	5.7	5.0	5.3	5.7	4.3	5.0	6.0	4.0	4.3	5.3	5.7	5.7	6.0
100m	4.3	5.0	5.3	5.3	5.0	5.3	4.7	5.3	5.0	4.3	5.0	5.3	5.3	5.7	6.0
200m	4.3	5.3	4.7	4.0	4.3	5.0	4.7	5.0	5.3	5.0	5.3	6.0	5.3	5.7	4.7
500m	5.3	5.3	4.3	4.0	4.7	5.3	4.3	4.3	5.3	6.3	5.7	5.0	4.7	4.7	5.3
1km	3.0	4.3	4.7	3.7	4.0	4.7	4.7	4.7	5.3	5.0	5.0	5.7	4.3	5.0	5.3
Min	3.0	4.3	4.3	3.7	4.0	4.7	4.3	4.3	5.0	4.0	4.3	5.0	4.3	4.7	4.7
Max	5.3	5.3	5.7	5.3	5.3	5.7	4.7	5.3	6.0	6.3	5.7	6.0	5.7	5.7	6.0
Mean	4.4	5.1	4.9	4.4	4.7	5.2	4.5	4.9	5.4	4.9	5.1	5.5	5.1	5.3	5.5

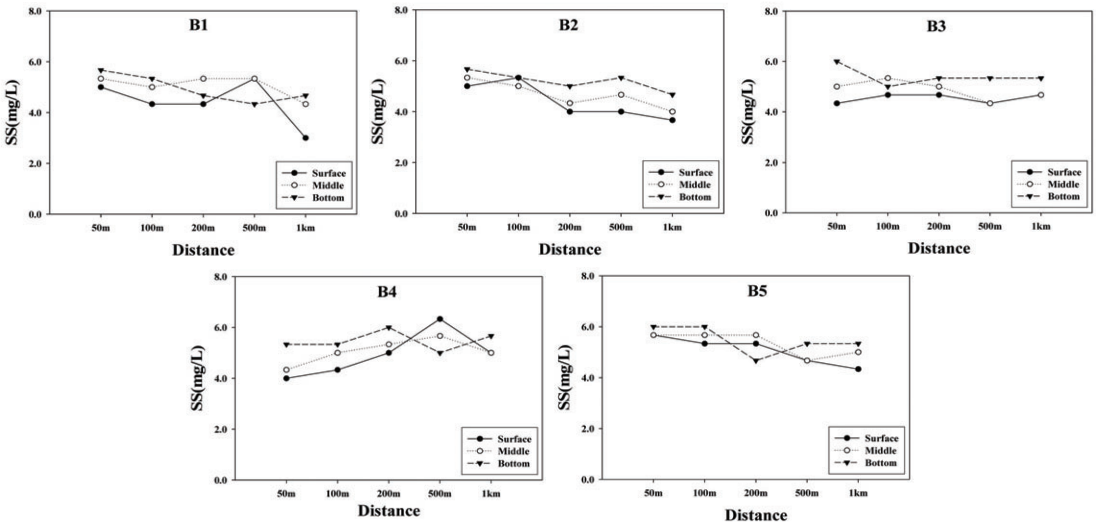


Fig. 5. SS concentration measured in the opposite direction to the tide for the vessel without the seawater-overflow reduction device

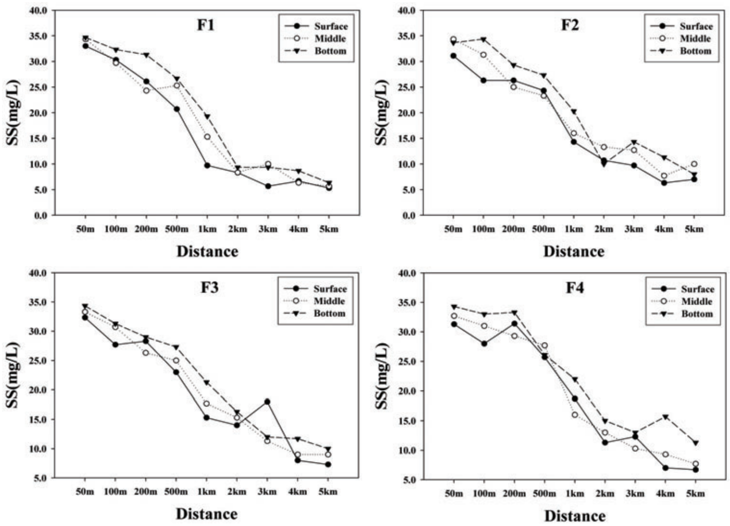
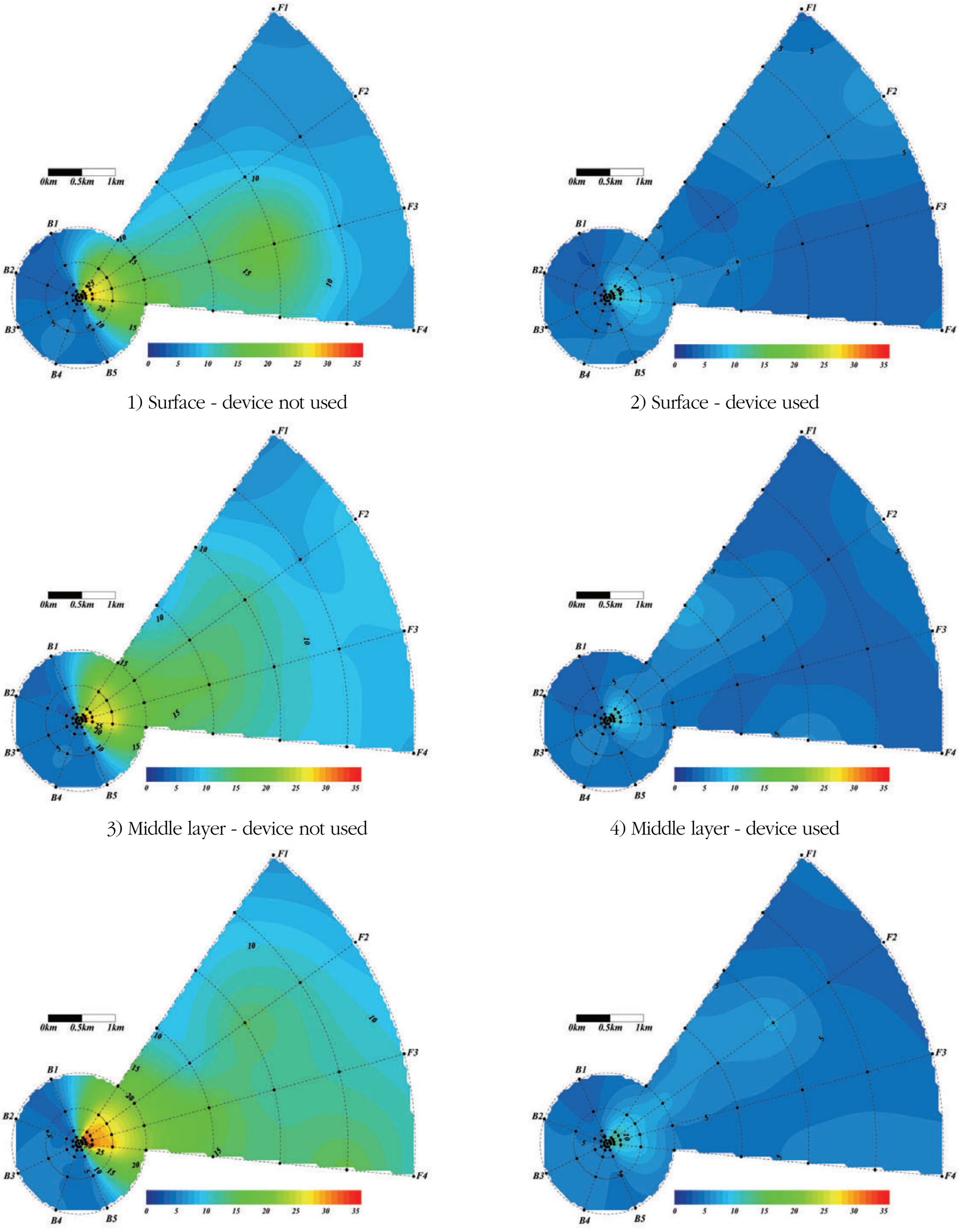


Fig. 6. SS concentration measured in the direction of the tide for the vessel without the seawater-overflow reduction device

concentration became similar to the concentration detected in the surrounding area.

3. Characteristics of the SS movements in the target sea area

The SS concentration measured in the direction



1) Surface - device not used

2) Surface - device used

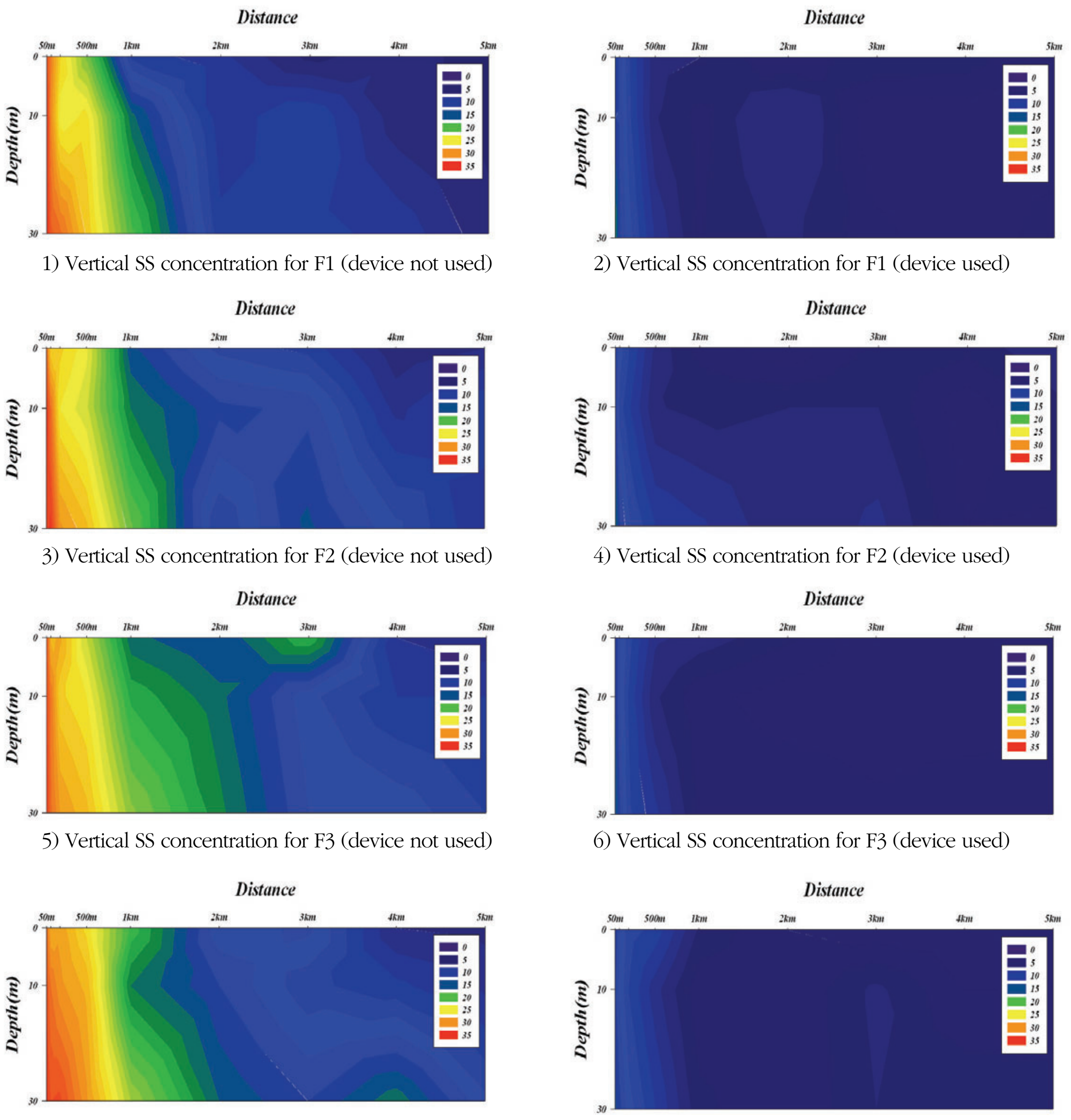
3) Middle layer - device not used

4) Middle layer - device used

5) Bottom layer - device not used

6) Bottom layer - device used

Fig. 7. Horizontal SS concentration during the use/non-use of the seawater-overflow reduction device



1) Vertical SS concentration for F1 (device not used)
2) Vertical SS concentration for F1 (device used)
3) Vertical SS concentration for F2 (device not used)
4) Vertical SS concentration for F2 (device used)
5) Vertical SS concentration for F3 (device not used)
6) Vertical SS concentration for F3 (device used)
7) Vertical SS concentration for F4 (device not used)
8) Vertical SS concentration for F4 (device used)

Fig. 8. Vertical SS concentration during the use/non-use of the seawater-overflow reduction device

of the tide based on the use/non-use of the seawater-overflow reduction device increased on average by 10.5mg/L on the surface, 12.0mg/L in the middle layer, and 13.1mg/L in the bottom layer. The increase was the most noticeable in the bottom layer compared to the surface or the middle layer, and this can be explained by the fact that the bottom layer is influenced more by tide than by wind drift currents.

Regarding the horizontal SS concentration distribution produced during sea sand extraction, the concentration tended to decrease as the distance from the source of suspended solids increased. This can be explained by the fact that the grain-size composition of the target sea area was coarse-grained, which causes the suspended solids to sink rather than to diffuse. Also, for the vertical SS concentration distribution produced during the extraction, the concentration was the highest for the bottom layer, and the diffusion was the greatest at the bottom layer as well. The line F3 showed a relatively high diffusion concentration of suspended solids at the target sea area during sea sand extraction.

4. SS reduction efficiency according to the use/non-use of the seawater-overflow reduction device

In order to find out the reduction efficiency of the seawater-overflow reduction device regarding SS concentration, the average SS concentrations of each layer were compared for each of the 4 lines in the direction of the current during the extraction of the vessels with and without the device. The reduction efficiency rates for each lines are: for F1, 52.9% for the surface, 59.6% for the middle layer, and 59.6% for the bottom layer; for F2, 56.7% for the surface, 62.2% for the middle layer, and 58.6% for the bottom layer; for F3, 62.2% for the surface, 65.5% for the middle layer, and 64.3% for the bottom layer; for F4, 60.6% for the surface, 63.2% for the middle layer, and 63.7% for

Table 6. SS reduction efficiency for the use/non-use of seawater-overflowing reduction device

Line		Device used	Device not used	Efficiency of the device (%)
F1	S	7.6	16.2	52.9
	M	7.2	17.7	59.6
	B	8.0	19.8	59.6
F2	S	7.5	17.3	56.7
	M	7.3	19.3	62.2
	B	8.7	20.9	58.6
F3	S	7.3	19.3	62.2
	M	6.8	19.7	65.5
	B	7.7	21.5	64.3
F4	S	7.4	18.9	60.6
	M	7.2	19.7	63.2
	B	8.4	23.0	63.7

Table 7. SS reduction efficiency for each water levels

Line	Reduction efficiency for the surface (%)	Reduction efficiency for the middle layer (%)	Reduction efficiency for the bottom layer (%)
F1	52.9	59.6	59.8
F2	56.7	62.2	58.6
F3	62.2	65.5	64.3
F4	60.6	63.2	63.7
Mean	58.1	62.6	61.5

the bottom layer. Overall the reduction efficiency of the device ranged between 52.9~65.5% (average = 60.8%).

When comparing the SS concentration reduction efficiency according to each layers, the greatest reduction efficiency was seen in the middle layer, the efficiency rates being on average 58.1% for the surface, 62.6% for the middle layer and 61.5% for the bottom layer.

IV. Conclusion

The SS concentrations for two vessels (one of which was installed with the seawater-overflow reduction device) were observed and compared to determine the efficiency of the seawater-overflow reduction device installed on vessels that are used to extract sea sand.

The observation of suspended solids revealed that when the two vessels were being used for sea sand extraction, the SS concentrations decreased as the distance from the source of the suspended solids increased, and from 1km away the concentration became similar to that of the surrounding area.

As for the reduction efficiency of the overflow reduction device, the comparison and analysis of the SS concentrations detected during the use and non-use of the device showed a 52.9~65.5% reduction in concentration (60.8% on average). Also, the efficiency of the device was at its highest in the middle layer of the water, showing on average a 62.6% reduction.

Although it would be a rash decision to assess the reduction efficiency of the seawater-overflow reduction device in reducing suspended solids based solely on observing the suspended solids, from the results it can be concluded that the device's reduction efficiency is relatively good. Also, it can be concluded that the seawater-overflow reduction device is an effective method for reducing the suspended solids during sea sand extraction. In the near future the efficiency of the seawater-overflow reduction device installed on sea sand extraction vessels is expected to be drawn by taking into account the overall relationship between various factors such as the filtering efficiency of the overflow reduction device's filtering net. Regular and detailed research should be carried out regarding sea areas designated for sea sand extraction.

Bibliography

Chungnam Aggregates Association, 2008, Marine Environment Assessment and Post Impact Assessment Regarding Aggregates Extractions in the Sea Area Under the Jurisdiction of Tae-An County, 465-471.

Chungnam Aggregates Association, 2009, Sea Area Utilization Assessment Regarding Aggregates Extractions in the Sea Area Under the Jurisdiction of Tae-An County, 79-90.

Incheon Branch of Korean Aggregates Association, 2002, A Study on the Estimation of Natural Abundance of Sea Sand and the Environmental Impact of Sea Sand Extraction in Gyeonggi Bay, 1-585.

Jun Ho Maeng and Byung Jun Kim, 2000, Characteristics of Suspended Solids Movement in the Sand Reclamation of Breakwater, *Environmental Impact Assessment*, 9(2), 127-142.

Korea Maritime Institute, 2003, A Study on the Current State and Management of Demand and Supply for Sea Sand, 1-178.

Korea Maritime Institute, 2004, A Study on the Economic/Environmental Integrated Assessment Model for Sea Sand Extraction(II), 1-144.

Ministry of Maritime Affairs and Fisheries, 2001, A Study Service Regarding the Assessment of the Amount of Suspended Solids Produced and the Efficiency of Filth-Prevention Net (I), 1-193.

Ministry of Maritime Affairs and Fisheries, 2001, A Study Service Regarding the Assessment of the Amount of Suspended Solids Produced and the Efficiency of Filth-Prevention Net (II), 1-261.

Ministry of Maritime Affairs and Fisheries, 2005, A Study on an Eco-friendly Management of Sea Sand Extraction(I), 1-769.

Ministry of Maritime Affairs and Fisheries, 2006, A Study on an Eco-friendly Management of Sea Sand Extraction(II), 1-1042.

Sun-Kwang Co., Ltd, 2007, Post Impact Assessment Regarding Sea Aggregates Extractions at the EEZ in mid-West Sea and the Sea Area Utilization Agreement, 1-488.

최종원고채택 09. 09. 15