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The Influence of Sediment Concentration on Settling Velocity

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Abstract: *Aggradation occurred in many rivers in Indonesia, causes flood due to the decreasing capacity of rivers is decreased, especially on the downstream or estuary. Citanduy River is among those rivers and needs special attention. Aggradation occurred because of the continous sedimentation process. As the transport sediment increases, the probability of sedimentation to occur is also increases normally. The sediment that is easily carried to the downstream and subsectionally sedimented in estuary is called cohesive sediment. One of the characteristics of sediment that influenced the sedimentation is settling velocity. The settling velocity of cohesive sediment in Citanduy River was observed with 7 – 8 concentration levels. The research is conducted in laboratory. The obtained result shows that the optimum settling velocity is reached on certain concentration level.*

Keywords: *Settling velocity, Sediment concentration.*

1. INTRODUCTION

Indonesia has many rivers with various geographical and geological conditions affecting the watershed. In average, many rivers in Indonesia are subjected to aggradation. It is due to the upstream watershed of the rivers are not preserved well. The establishment of agricultural or plantation areas is not supported with the planting of trees that could be used to resist erosion. Erosion can also occur when the mountain slope is planted with the wrong plant. In Dieng plateau, Central Java, potatoes are harvested by revoking it from its root. This harvest method will cause erosion on mountain slope when raining and swept by current runoff to the river. Generally, great quantities of cohesive sediments are found in estuary because it is easier to get carried in river flow as the suspended sediment.

Citanduy River, located in West Java, is considered as the river that carried cohesive sediments and experiencing aggradation. This river has Segara Anakan estuary and its estuary mouth is located in Nusa Kambangan island. The estuary is protected from the big wave of Indonesia Ocean. But unfortunately, its flora and fauna is on the verge of extinction due to the aggradation. Most of mangrove forests in that area are lost, the breeding locations of fishes, shrimps, crabs, and scallops are decreasing, and the sailing lane become narrow and shallow.

In order to prevent a severe aggradation in the estuary of Citanduy River, sediment characteristics study is needed. One of the sediment characteristics observed in this research is the settling velcity of cohesive sediment. This study is expected to bring an accurate modeling that matches its actual condition because every sediment, including cohesive sediment in Citanduy River, has different characteristics from other sediments.

1.1 Research Objective

This research is aimed to study the settling velocity of cohesive sediment in Citanduy River which is affected by sediment concentration and salinity.

1.2 Research Methodology and Approach

The research is conducted with experiments in laboratory using samples of sediment and water from Citanduy River. The measurement of settling velocity of cohesive sediment is also done in laboratory. Bottom wirhdrawal tube is used to determine the settling velocity of cohesive sediment (Berlamont et al, 1993). The working principle of bottom withdrawal tube is based on the sedimentation of particles in uniform suspension.

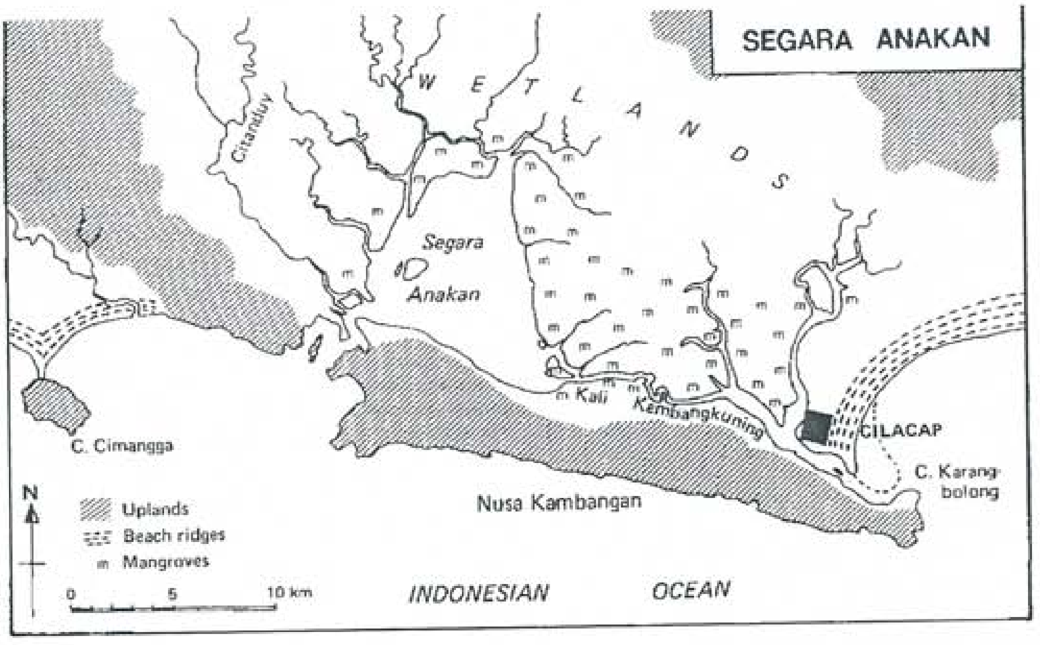

Figure 1 Location of Citanduy River (http://sidhat.blogspot.com/2011/05/budidaya-sidhat-7.html)

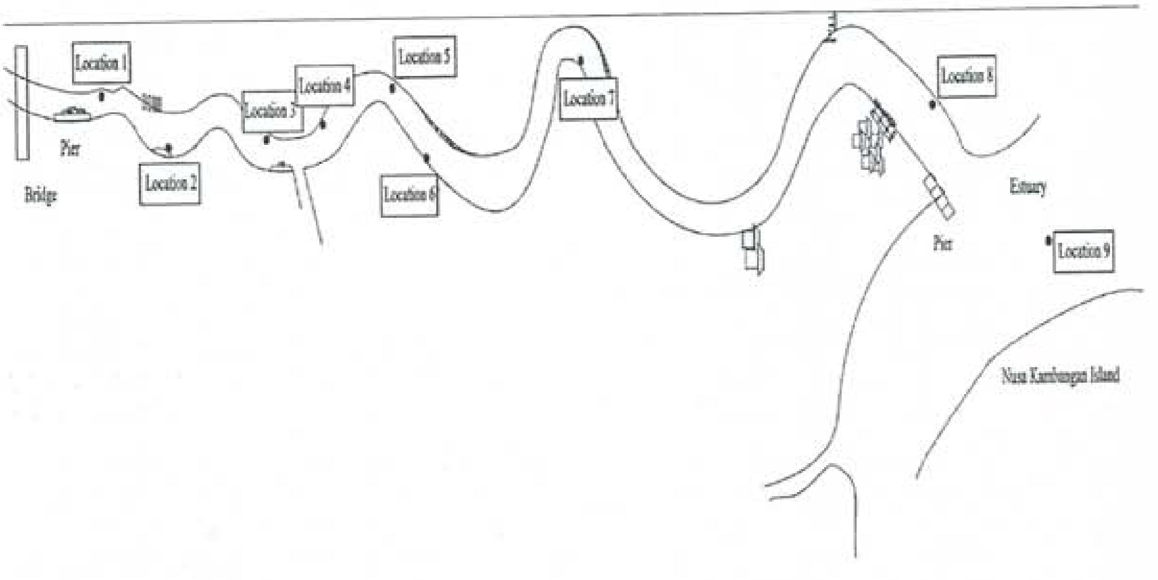

Figure 2 Location of sample extraction

2. SETTLING VELOCITY

Sediments with clay particles (d < 4 μm) more than 10% have cohesive trait due to its electro-statical forces are equal or larger than the gravity force. Therefore, particle sediments do not behave as individual particle, but tend to stick together to form aggregate known as flocs. Flocs have larger size and settling velocity compared to individual particle.

2.1 Deposition Process

Deposition process is the process in which suspended load in water filled the bed channel and becomes cohesive bed sediment. Deposition process of cohesive sediment depends on the combination of various factors, including size of particles, settling velocity, and forces from particle units. These units may consist of single particle, flocculation that might settled together in one unit.

Critical bed-shear stress for deposition is the bed-shear stress that occurs when the bed sediment is deposited (Winterwerp, 1989).

2.1.1 Settling Velocity

Settling velocity is the velocity of particles or flocculation on its way to bed due to mass forces. Flocculation influences the settling velocity of sediment. Flocculation also forms larger particles and will has larger mass to make it easier to settle. Flocculation is influenced by sediment concentration. Larger concentration can forms flocculation with larger particles, which is also enlarging the settling velocity. However, for very large concentrations, particles of settling velocity become slower due to hindered settling effect.

Hindered settling is the effect that the settling velocity of the flocs is reduced due to an upward flow of fluid displaced by the flocs. At very large concentrations, the vertical fluid flow can be so strong that the upward fluid drag forces on the flocs become equal to the downward gravity forces resulting in a temporary state of dynamic equilibrium with no net vertical movement of the flocs. This state, which occurs close to bed, generally is called fluid mud (Van Rijn, 1993). In saline suspensions with sediment concentration up to 1,000 mg/l, an increase of the settling velocity with concentration has been observed as a result of the flocculation effect, both in laboratory and in field conditions. When the sediment concentrations are larger than approximately 10,000 mg/l, the settling velocity decreases with increasing concentrations due to the hindered settling effect. Settling velocity in the two ranges was expressed as follows (Van Rijn, 1993):

$w_{s,m} = k\, c^{m}$ for flocculation suspension (10 – 10000 mg/l) *(1)*

$w_{s,m} = w_s\,(1 - \alpha\, c)^{\beta}$ for suspension with hindered settling (> 10000 mg/l) *(2)*

Where $w_{s,m}$ is the settling velocity of sediment particles (mm/s), k is the coefficient, c is the volume concentration (mg/l), m is the coefficient (1 – 2), w_s is the settling velocity of individual particle (mm/s), α is the coefficient, and β is the coefficient (3 – 5).

Settling velocity is also influenced by salinity and temperature. The effect of salinity is clearly seen towards the settling for salinities up to 10‰ when the sediment concentration is smaller than 1,000 mg/l (Krone, 1962). If the sediment concentration is larger than 1,000 mg/l, settling velocity increases with almost linear pattern towards the observed salinity (Owen, 1970; Allersma, 1967).

2.2. Laboratory Research Methodology

Laboratory research was conducted in Fluid Mechanic and Hydrodynamic Laboratory, the inter-university research center located in Bandung Institute of Technology. The experiment was done by using bottom withdrawal tube to examine the settling velocity of cohesive sediment, including the measurement of time, salinities, and settled sediment concentrated.

3. ANALYSIS

Laboratory experiment for settling velocity used three salinities and 7-8 concentrations for each salinity. Research results can be seen on the tables and figures below. Table 1 shows the research result of settling velocity through calculations.

3.1. Sediment Settling Velocity on 10‰ Salinity

Figure 1 shows the data of sediment settling velocity and concentrations on 10‰ salinity. Settling velocity rises sharply from the concentration of 468.5 mg/l to 4,962 mg/l with its maximum velocity on 1.05 mm/s, then its velocity decreases constantly until it reaches the settling velocity of 0.45 mm/s on 16,704 mg/l concentration.

Table 1 Sediment settling velocity on 10‰ salinity

Concentration	Sediment Settling Velocity
262.65 mg/l	0.045 mm/s
468.50 mg/l	0.040 mm/s
861.00 mg/l	0.185 mm/s
3,130.75 mg/l	0.580 mm/s
4,962.00 mg/l	1.050 mm/s
9,380.75 mg/l	0.690 mm/s
14,349.125 mg/l	0.605 mm/s
16,704.00 mg/l	0.450 mm/s

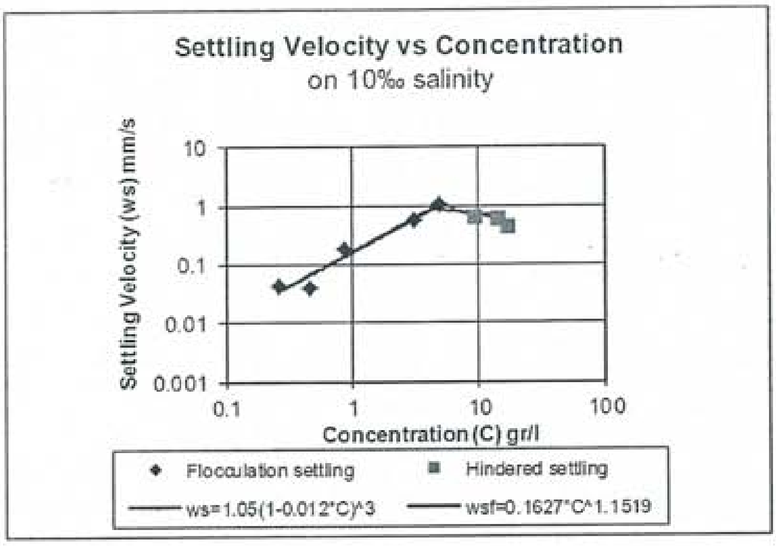

Figure 2 Relation between settling velocity and concentration on 10‰ salinity

3.2. Sediment Settling Velocity on 15‰ Salinity

Experiment result on 15‰ salinity shows the highest maximum settling velocity when compared to other salinities. Settling velocity rises sharply to the maximum settling velocity of 2.1 mm/s at 4,033.88 mg/l concentration. The next increment of concentrations reduced the settling velocity decreases and reaches 0.59 mm/s at 17,943.1 mg/l concentration, as shown in Figure 2.

Table 2 Sediment settling velocity on 15‰ salinity

Concentration	Sediment Settling Velocity
644.50 mg/l	0.180 mm/s
118.00 mg/l	1.700 mm/s
4,033.88 mg/l	2.100 mm/s
6,105.38 mg/l	1.600 mm/s
8,524.13 mg/l	1.330 mm/s
10,509.30 mg/l	1.060 mm/s
14,814.50 mg/l	0.610 mm/s
17,943.10 mg/l	0.590 mm/s

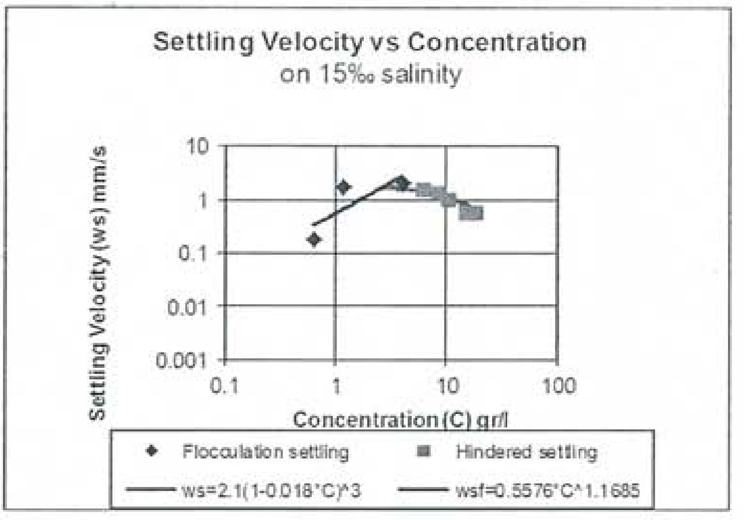

Figure 3 Relation between settling velocity and concentration on 15‰ salinity

3.3. Sediment Settling Velocity on 20‰ Salinity

On 20‰ salinity (Figure 3), settling velocity rises quickly from the starting point in 359 mg/l concentration to 4,211.38 mg/l concentration where the maximum settling velocity of 0.61 mm/s is obtained. Afterward, the settling velocity decreases to 0.39 mm/s in 17,364.5 mg/l concentration. The maximum settling velocity in this salinity is lesser than the maximum settling velocity on 15‰ salinity.

Table 3 Sediment settling velocity on 20‰ salinity

Concentration	Sediment Settling Velocity
359.00 mg/l	0.022 mm/s
541.88 mg/l	0.290 mm/s
1,192.88 mg/l	0.425 mm/s
4,211.38 mg/l	0.610 mm/s
9,789.44 mg/l	0.580 mm/s
13,455.80 mg/l	0.450 mm/s
17,364.50 mg/l	0.390 mm/s

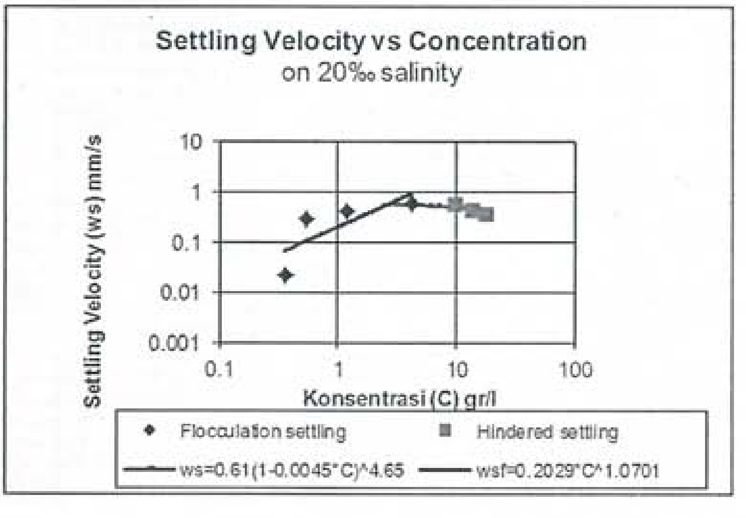

Figure 4 Relation between settling velocity with concentration on 20‰ salinity

4. CONCLUSIONS

From this research, some conclusions can be drawn as follow:

1. Increasing sediment concentrations of certain amount may increase the settling velocity of cohesive sediment. The optimum settling velocity obtained in this research is achieved in 2.1 mm/s on 4,033.88 mg/l concentration.
2. Based on the three salinities observed, optimum settling velocity is obtained at concentrations ranged from 4,000 to 5,000 mg/l.
3. The increase in salinity at certain level can also increase the settling velocity of cohesive sediment. The optimum settling velocity is reached on 15‰ salinity.

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