Study of the siltation process in channel as effects of the submerged structures

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Introduction

A knowledge of the governing and deposition processes of cohesive sediment in navigation channel or anchorage is basic to the countermeasure of the siltation problems. According to previous researches on cohesive sediment transport using numerical modeling, physical modeling, and field study, it is known that installing submerged dike could be one of the effort to handle siltation. Tsuruya *et al. (1990)* reported that in Kumamoto Port submerged dike could reduce siltation around 30% in access channel. Although installing submerged dike might reduce sedimentation, fluid-mud behavior around the submerged dike is still very complex to understand (Irie *et al, 1991)*. For this reason, we assumed one of the important points to understand these problems is the assessment of deposition processes of cohesive sediment in water flow due to the action among current, waves, water density, and sediment concentration.

The aim of this study was to observe the processes of the fluid-mud formation from the each type of cohesive sediment and to observe deposition processes of fluid-mud in channel with and without submerged dike. In this study to investigate settling and consolidation of silt more detail, special flume which is called Slim-tank (see Figure 1) was prepared.

Method of study

Experiment was conducted in two phases. First phase was carried out in mesh cylinder. This test was done to know the basic characteristic of each material test and to consider the submerged dike dimension which will be used in the second phase (flume). This test was conducted in 15 cm diameter by 100 cm height made from acrylic. In one side of this cylinder 15 holes with 6 mm diameter for sampling data was set-up. Into this cylinder water or salt water was poured until 90 cm height, and then followed with the test material and then mixed using pump mixer and waited for a moment until the particle settled, according to a specified time which was desired. Option time was 15,30,45,60,90,120,180 in minute. After that, from the top of hole where cock was installed sample was taken around 100 cc until the lowest one. Concentration then was analyzed using portable density meter. This process was done several times based on specified times determined for each material, i.e. Kaolinite ASP 600 (grain size = 0.64μm) and mud from Kumamoto port to know settling processes of each concentration as shown on Figure 2 for the case of Kaolinite. Second phase was performed in a 0.20 m wide by 3.0 m long and 1.0 m height flume equipped pump to reproduce current and paddle oscillate to reproduce wave oscillation. Both pump and oscillator were driven by a speed variable. Model of channel was designed with a little bit space from the central. Inside the Slim-tank 3 shutters were set up. Material used for experiment was placed between shutter no.1 and shutter no.2. The shutter position was plugged then material was placed and mixed using the mixer which was installed in the Slim-tank. After the needed condition of fluid mud was set, the shutter no. 2 was moved up. Fluid mud would flow into channel direction. This process was then recorded through video record.

As mentioned before, preliminary test was also used to determine submerged dike design, especially the dike height (hs) and concentration of material used in this study. Based on this preliminary test, hs=20 cm, water depth h=40 cm, and Kaolinite concentration 20g/l and 40 g/l for two cases with and without dike, and layer thickness *(hc)* of fluid-mud concentration was 10 cm, 20 cm, and 30 cm, was determined (see Table 1).

Numerical simulation

This numerical model intended to support appreciation about phenomena of deposition processes in slim-tank that was still unclear from the video analysis or from the physical model only. The numerical simulation, based on the Continuity equation (1), Equation of motion (2), and Transport equation (3) was applied. All case in this numerical calculation was based on the experimental situation.

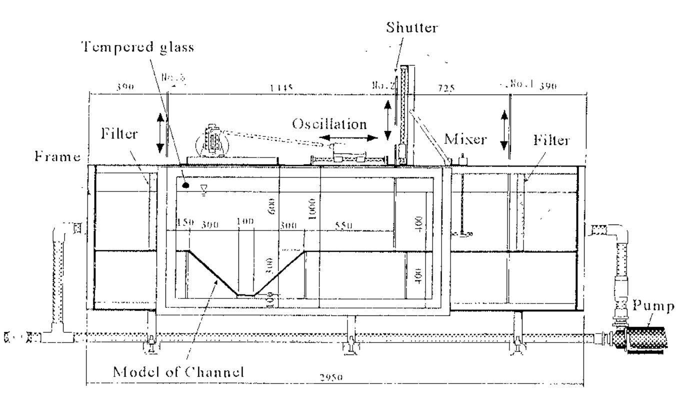

Figure 1　Scheme of Slim-tank

Table 1　The experiment situation

Case	*hc*	*Co(g/l)*	T
Case-1a	10	20	15
Case-1b	20	20	30
Case-1c	30	20	45
Case-2a	10	40	30
Case-2b	20	40	90
Case-2c	30	40	180

T = time to consolidation counting from mixing until observation starting (minute)

$$\frac{\partial B\eta}{\partial t}+\frac{\partial}{\partial x}\int_{-h}^{l}(uB)dz=0 \qquad (1)$$

$$\frac{\partial uB}{\partial t}+\frac{\partial}{\partial x}(uuB)+\frac{\partial}{\partial z}(uwB)-\frac{\partial}{\partial x}\left(BN_x\frac{\partial u}{\partial x}\right)-\frac{\partial}{\partial z}\left(BN_z\frac{\partial u}{\partial z}\right) \qquad (2)$$
$$+\frac{gn^2}{R^{1/3}}u|u|\frac{\partial l}{\partial z}+Bg\frac{\partial \eta}{\partial x}+\frac{Bg}{\rho}\frac{\partial}{\partial x}\int_{z'}^{\eta}\rho dz'=0$$

$$\frac{\partial cB}{\partial t}+\frac{\partial}{\partial x}(cuB)+\frac{\partial}{\partial z}(cwB)-\frac{\partial}{\partial x}\left(BK_x\frac{\partial c}{\partial x}\right)-\frac{\partial}{\partial z}\left(BK_z\frac{\partial c}{\partial z}\right)=0 \qquad (3)$$

Where, u is horizontal direction of time averaged velocity, w is the vertical direction of time averaged velocity, p is pressure, Nx and Nz are horizontal eddy diffusion coefficient and vertical eddy diffusion coefficient. g,n,R,c are gravity acceleration, Manning's roughness coefficient, radius of hydraulic, and concentration respectively. B is flume width, Kx and Kz were horizontal and vertical diffusion coefficient respectively. l is wetted perimeter and ρ is density.

Result of Research

Physical processes in Slim-tank was recorded by video. Data processing supporting by software Gray-val 32, and one of the results as shown in Figure 3. Fig.3(a) is the condition when shutter no.2 was before moved. Figure 3(b) shown the situation 10 second after. Figure 4 is shown the numerical calculation from Case-1b. It can be seen that installing submerged dike might decrease the mud flowing invasion to the channel. Additionally, installing submerged-dike plays a role in determining deposition processes of fluid-mud with stir-up the mud above dike. However, the studies presented here are an initial investigation with material of Kaolinite only. Moreover, figure or data shown in this study have been being executed. Further investigations with many kind of materials are needed to know these processes more clearly.

Conclusion

The result of study indicated that numerical modeling was closed to physical modeling qualitatively. Both models are needed to explain the settling, consolidation, and deposition processes in channel installed with submerged dike.

References

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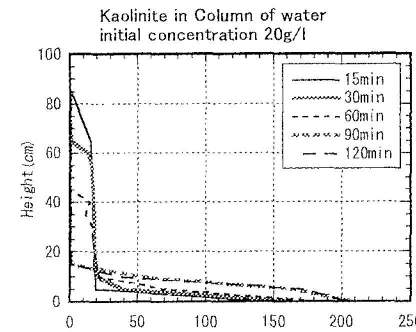

Figure 2 Profile of Kaolinite in mesh Cylinder

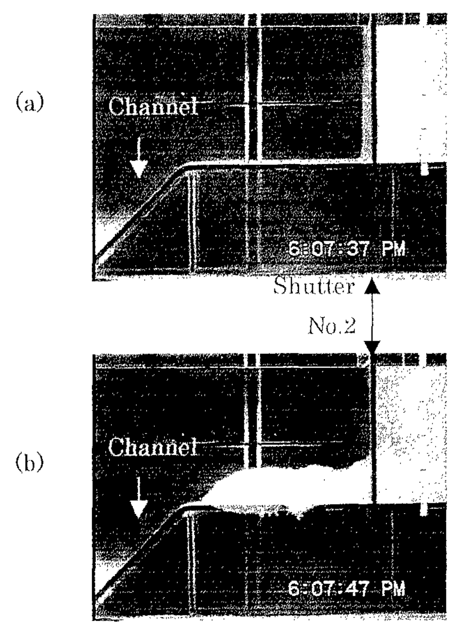

Figure 3 Deposition processes at channel taken from the Slim-tank experiment

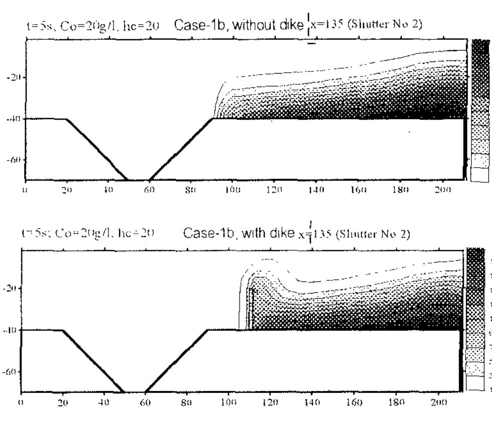

Figure 4 Deposition processes at channel from the Numerical calculation result