II-153 TWO-LAYERED FLOW MODEL FOR KAOLINITE

Nobuyuki Tamai Prof. Takashi Asaeda Assoc.Prof.
Yusuke Hirosawa Res.Assis. Chaisak Sripadungtham Grad.Student
Department of Civil Engineering, University of Tokyo

1 Introduction

The purpose of this two-layered mathematical model is to simulate mud transporting process. The model was set up by modifying the dispersion model for non-cohesive soil in stratified layer. The effect of flocculation was interpreted as a sink term in the model and it was evident that this term could be considered as the product of a small parameter and the first order of concentration. A series of experiment was conducted in a two-layer open channel flow to investigate the applicability of the expression of these sink terms in the model.

2 Experimental work

The experiment was carried out by using a two-layer open channel. Fresh water was supplied in the upper layer at steady rate. The lower layer which was filled up with salt water initially was also supplied by salt water from a pump during the experiment in order to compensate the entrainment into the upper layer flow. Velocity was measured by an X-probe hot film anemometer and salinity was measured by conductivity meter. Kaolinite released from upstream part of the channel was sampled at each section and level at various time and analysed by the same process as in (5).

3 Dispersion model for kaolinite

The governing equation for depth-averaged conditon is

$$\frac{\partial C_1}{\partial t} + U_1 \frac{\partial C_1}{\partial x} = Dx_1 \frac{\partial^2 C_1}{\partial x^2} + \psi_1 (C_2 - C_1) - \varepsilon_1 C_1 \tag{1}$$

$$\frac{\partial C_2}{\partial t} + U_2 \frac{\partial C_2}{\partial x} = Dx_2 \frac{\partial^2 C_2}{\partial x^2} + \psi_2 (C_1 - C_2) - \varepsilon_2 C_2 \tag{2}$$

where $\psi_n = [(w_s - w_e) - 2Dz/(h_1+h_2)] / h_n$; n = 1 and 2. (3)

subscript 1 and 2 refer to upper and lower layer, respectively, C = concentration, x = longitudinal coordinate, U = velocity, Dx = longitudinal dispersion, ε = flocculation parameter, W_s = falling velocity, W_e = entrainment velocity, Dz = vertical dispersion coefficient and h = depth.

The initial condition is the instantaneous emission of substance at x = 0, upper layer concentration = C_{01} and lower layer concentration = C_{02}.

A simple solution, using Fourier's transform, asymptotic expansion and neglecting higher order terms with small values of ψ and ε (5), for each layer is shown below, where n = 1 and 2.

$$C_n = \frac{C_{0n}}{\sqrt{4\pi Dx_n t}} \exp\left[\frac{(x-U_n t)^2}{4Dx_n t} - (\psi_n + \varepsilon_n)t\right] \tag{4}$$

4 Experimental result and comparison

The functional form of the relationship between overall Richardson number (R_i) and entrainment coefficient (E_i) has been suggested by many authors((1), (2) & (3)). However, the formulae used are so much different probably due to the different source of turbulence. From the velocity measurement, R_i was calculated by using the same concept as in

(3) owing to the similarity in the scale of the experiment and parameters. Although this concept bases on the Monin-Obukhov similarity theory for atmospheric turbulence that momentum flux is constant in the layer of consideration, it is widely used and permitted for the case of a thin layer.

The range of the parameters used in the model are shown below:

Run	U_l (cm/s)	$\overline{u'_l}$ (cm/s)	U_* (cm/s)	R_l	E_l	ψ (1/s)	ε (1/s)
1	4.2	0.5	0.41	37	0.00097	0.0015	0.0078
2	5.5	0.69	0.44	20	0.00098	0.0018	0.0099
3	6.3	0.58	0.5	15	0.00124	0.0022	0.0096

The range of E_l is large compare to the field observed value for natural rivers (4). The deviation is attributed to the effect of small vertical velocity generated by the salt supply pipes.

The relationship between ε and turbulent intensity ($\overline{u'_l}$) obtained from the experiment in an oscillating grid tank (5) is shown in Fig.1. Concentration profile from the observation is lower than the predicted one as in Fig.2. This may be because the value of parameters used were taken from (5) in which the condition was slightly different from the flume. And the initial concentration of kaolinite was also set to be high to avoid the inaccuracy of sampling method. This may cause the existence of hindered settling, as could be observed that there was some amount of primary particles in the samples taken from kaolinite deposited on the bottom.

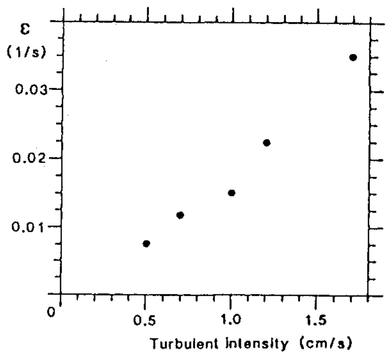

Fig.1 Relationship between flocculation parameter and turbulent intensity.

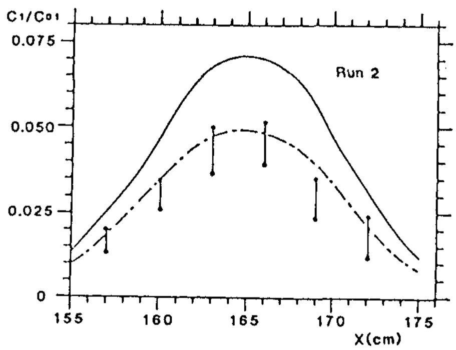

Fig.2 Concentration profile measured from the line of emission. —— $\psi, \varepsilon = 0$. ---- $\psi, \varepsilon = 0$. ⫯ the range of expt.data.

5 Conclusion

The expression for sink terms in the transport model, that was considered to vary with the first order of concentration, seems to be applicable. The depth averaged longitudinal concentration profile predicted in the present model with these sink terms is flatter than the profile without these sink terms. Mathematical expressions established in the present study are found to show good agreement with measured results in the experiment.

6 References

1). Arita, M. & Jirka, G. H. (1987), J. Hydraulic Eng., ASCE, 113, HY.10, 1229. 2). Hino, M. & Hung, N. S. (1983), J. Hydroscience & Hydraulic Eng., 1, 1, 9. 3). Kit, E., Berent, E. & Vajda, M. (1980), J. Hydraulic Res., 18, 1, 35. 4). Suga, K. & Takahashi, A. (1976), Proc. 31st Annual Meeting, JSCE, 383. 5). Tamai, N., Asaeda, T., Hirosawa, Y. & Sripadungtham, C. (1988) Proc. APD Conf., Kyoto.(submitted)