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BEHAVIOR OF LONGITUDINAL AND TRANSVERSE DISPERSION COEFFICIENT IN THREE-DIMENSIONAL OPEN CHANNELS

Il Won Seo[1] and Youngjai Jung[2]

To analyze the two-dimensional pollutant mixing process in open channels, many researchers have developed the numerical model in which the depth-averaged two-dimensional advection-dispersion equation was employed as a governing equation. Since the advection of water contaminants was described by the depth-averaged velocity field, the existing 2-D numerical models could not properly reflect the vertical variation of flow velocity observed in secondary currents in meandering rivers.

In this study, we developed a new model in which visible process of conservative contaminants injected in open-channel was represented arithmetically following Taylor (1954)'s shear dispersion theory. We named this arithmetical model as the Time-split Mixing Model (TMM) in which the three-dimensional velocity profiles were precisely incorporated into the advection process. TMM adopted the concept of operator split method. It first divided the spreading phenomenon of pollutant into longitudinal direction mixing and transverse direction mixing, and each mixing processes were separated into the shear advection and the turbulence diffusion. The longitudinal and transverse shear advection terms were represented by the separation of mass pollutant due to the vertical deviation of velocity. The diffusion term then was represented with full mixing across the vertical direction by turbulence mixing. In three-dimensional grid open channel, as shown in Fig. 1, the log distribution was employed as the vertical profile of longitudinal velocity, and linear distribution as that of transverse velocity.

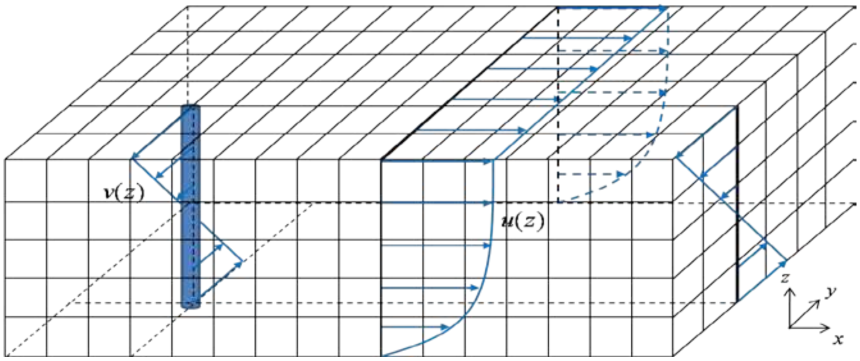

Figure 1 Longitudinal and transverse velocity profile on 3-D grid open channel

In this research, the validation of the suggested model was performed by comparing with the existing model in straight open channel. The simulation results of TMM were in good agreement

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with the numerical solutions of the conventional 2-D numerical model, RAM4 (Lee and Seo, 2011). In addition, the new model successfully reflects the reflection effects of pollutant concentration by channel bank and mass conservation in different flow conditions. In this study, the longitudinal and transverse dispersion coefficients were calculated by applying 2D routing procedure (Baek and Seo, 2010) to the concentration data by TMM. The proposed model gave the dimensionless longitudinal dispersion coefficient as 4.05 ~ 4.18 which were lower than the value 5.9 suggested by Elder (1959). The dimensionless transverse dispersion coefficient was ranging from 0.10 to 0.13 which were similar with evaluation by Okoye (1970). The simulation results shows that the degree of dispersion by TMM was sensitive to hydraulic parameters such as mixing time, intensity of velocity deviation, depth to width ratio. Moreover, as shown in Fig. 2, both longitudinal and transverse dispersion coefficients by TMM tend to decrease with increasing roughness coefficient. This is considered that the change of roughness affects the flow characteristics near the channel bed.

TMM developed in this study can successfully explain the 2-D physical mixing process through an arithmetic procedure without solving the partial differential equation. The new numerical model can incorporate the three-dimensional velocity profile onto 2-D mixing process, and calculate the shear spreading by simple repetition of advection of mass and subsequent depth-average of concentration profile. This model provides the insights into influence of hydraulic and physical factors on the dispersion behavior of mass pollutant in open channel.

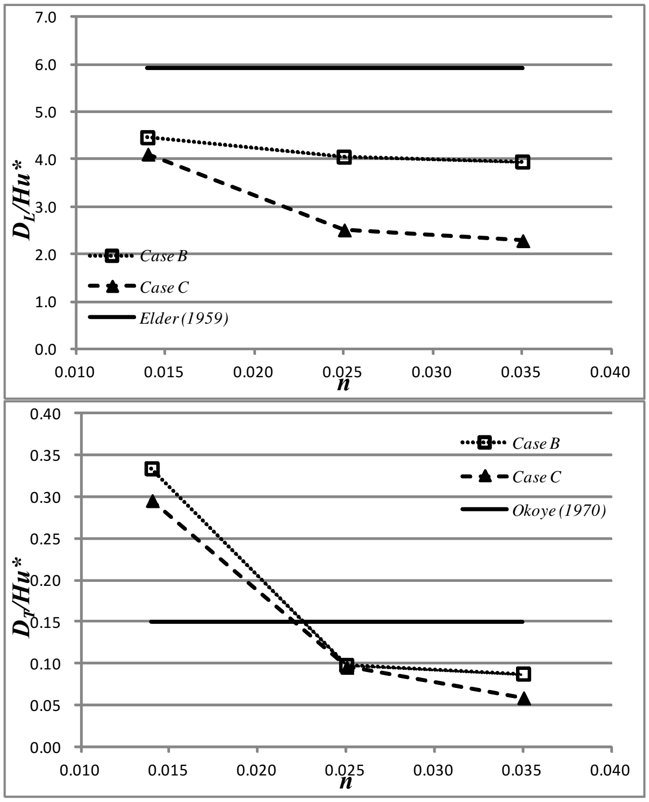

Figure 2 Variation of longitudinal and transverse dispersion coefficients according to roughness

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