Abstract

This dissertation focuses on the mathematical modeling of non-cohesive sediment transport in open channel turbulent flow through new developed models on flow velocity, particles' concentration, grain-size distribution and parameters required to compute those features. To predict the vertical distribution of streamwise fluid velocity and suspended sediment concentration, a theoretical model is proposed based on the Reynolds averaged Navier-Stokes equation and the mass conservation equations of fluid and solid phases. The model includes the effects of secondary current, additional upward vertical velocity of fluid due to suspended particles, mixing length of sediment-laden flow, von Karman constant of sediment-fluid mixture and hindered settling phenomenon.

In general, particles' concentration contains different grain-sizes; as such the concentration equation of Rouse is modified through the ratio of sediment diffusivity to eddy viscosity for predicting the grain-size distribution. Apart from this, theoretical models have also been suggested to compute the suspended grain-size distribution over sand and sand-gravel beds and these models contain the effects of stratification, hindered setting phenomenon, particle-particle interaction and different probabilities of particle's motion near the channel bed.

By including the effects of viscous shear stress and impact shear stress near the channel bed, an analytical expression is developed on bed load layer thickness which is used as reference level in the boundary condition of particles' concentration equation. For expressing hindered settling phenomenon, another analytical model is suggested on the settling velocity of particle in sediment-fluid mixture based on a new concept of apparent particle diameter defined by the diameter of the spherical volume in which the particle whose settling velocity is to be evaluated can move randomly after colliding with other suspended particles.

The derived models explain the real phenomena of their corresponding features through particle-turbulence interaction in the flow region. A wide range of experimental data is used for the verification of each model and good agreement has been observed between computed and observed values. The applicability of these models is proved by their superior determination accuracy through error analysis in comparison to other relevant models in literature.

Keywords: Apparent particle diameter, bed load layer thickness, eddy viscosity, flow velocity, grain-size distribution, hindered settling, mixing length, particle-fluid interaction, particle-particle interaction, Rouse equation, secondary current, sediment diffusivity, stratification, suspended sediment concentration.