Abstract

This thesis mainly focuses on the semi-analytical and numerical modelling of sediment transport in open channel turbulent flow. Theoretical models for suspended sediment concentration, grain-size distribution in suspension and flow velocity have been developed incorporating various important turbulent features.

A theoretical model for steady two-dimensional suspended sediment transport in an open channel turbulent flow mixed with sediments, has been proposed incorporating hindered settling mechanism and taking realistic boundary conditions. An approximate analytical solution (series solution) of the obtained highly nonlinear partial differential equation (PDE) with variable coefficients is proposed using two different approaches, namely, Laplace transform based homotopy analysis method (LHAM) and method of lines based homotopy analysis method (MOL-HAM). Besides this, another model for one-dimensional unsteady suspended sediment transport equation taking arbitrary sediment diffusivity and same boundary conditions as well as settling velocity considered in the previous model, is suggested and a semi-analytical solution is presented using the method of lines based homotopy analysis method. The convergence of this semi-analytical solution is gained through a convergence control parameter. This model is further extended considering the effect of stratification and a numerical solution is proposed. Changes between stratified and non-stratified concentration profiles with respect to time have been investigated. To compute the concentration distribution of various grain-sizes over erodible beds of different configuration in a steady transport problem through an open channel, a mathematical model has been developed based on advection-diffusion equation. Effects of various parameters in the computation of reference level and reference concentration are considered. The concentration distribution of different grain-sizes along a vertical as well as along the main flow direction has been investigated by considering hiding and hindering effect.

For studying mechanism of sediment transport in river flows, open channel flow is a prototype. A model for two-dimensional distribution of streamwise velocity is derived from the RANS equation for an open channel turbulent flow which is steady and uniform along the main flow direction. Secondary flows both along vertically upward direction and along lateral direction are considered. Inclusion of secondary current brings the effect of dip phenomenon in the model. The resulting second order partial differential equation is solved numerically and is compared with the experimental data. To understand the sediment transport process in an open channel turbulent flow completely, simultaneous study of velocity and concentration is important as they are interconnected by particle-turbulence interactions. A coupled model of these two has been developed including stratification and hindered settling effect and the nonlinear system has been solved by homotopy analysis method (HAM).

The knowledge acquired from the overall study may help to address problems in the field of river erosion and sedimentation, coastal sediment transport and two phase flow.

Keywords : Turbulent flow; Advection-diffusion equation; RANS equation; Grain-size distribution; Hindered settling mechanism; Stratification effect; Secondary current; Homotopy analysis method.