Abstract

The thesis deals with suspended sediment transport problems in turbulent flow through an open channel. Several mathematical models have been developed to find the concentration distribution in suspension for uniform and non-uniform grain-sizes considering different turbulent features.

A generalized model for non-equilibrium sediment transport is proposed, which contains many of the existing similar models in literature as special cases. It is a two-dimensional unsteady transport model that contains the effects of hindered settling and a generalized bottom boundary condition with deposition velocity and equilibrium bottom concentration. It is confirmed in this work that hindered settling affects the concentration in the main suspension region only, leaving a small portion near the bottom and top boundaries, which was speculated by previous researchers.

In a flow carrying sediments, the area near the bed has a high sediment concentration, which is known as a heavy-fluid zone, while the remaining area has a relatively low concentration and is called a light-fluid zone. Due to the difference in concentration, the suspension region behaves like a stratified flow region. This slows down the turbulent mixing of fluid momentum and sediment mass in vertical and consequently, the sediment concentration changes. Taking into account this fact, the sediment and turbulent diffusion coefficients are taken in a modified form and models are developed for concentration distribution under non-equilibrium condition. It is found that stratification results in a decrease in the concentration profile and an opposite behaviour is noted for the case of hindered settling at a fixed time and a fixed downstream distance.

In a wide open channel, turbulent-induced secondary flows arise due to longitudinal bedforms with alternate roughness of ridges and troughs in the spanwise direction. Considering this type of secondary flow along vertical and transverse directions, commonly known as cellular secondary current, a suspended sediment transport model is presented where the concentration varies in all three directions along with time. It is seen that concentration shows a periodic variation along the transverse direction and the magnitude of the transverse concentration profile increases when the settling effect of a particle is included.

Naturally occurring flow contains sediment particles of different sizes and characteristics of a particle change in the presence of other-sized particles. So, it is important to explore how different grain sizes are distributed along a vertical and also how the concentration of different particle sizes changes with time. A theoretical model for the grain-size distribution of non-uniform sediments in suspension over erodible sediment beds is proposed based on the advection-diffusion equation. The model accounts for the influence of non-uniform sediment on the settling velocity of a particle through the hiding and hindering effect, which is different from the hindered settling effect considered for uniform sediments. It is observed that the suspension shows a tendency of bimodal distribution with a stronger peak at the coarser side of sediment in the grain-size distribution plot and a weaker peak at the finer side, which becomes nearly opposite as time passes and as the vertical distance from the bed increases.

Keywords : Turbulent flow; Open channel; Advection-diffusion equation; Stratification; Hindered settling; Secondary current; Grain-size distribution; OpenFOAM.