Theoretical Study on Velocity and Suspension Concentration in Turbulent Flow

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Abstract

This thesis focuses on vertical distribution of streamwise mean velocity and mean suspension concentration of sediment particles in turbulent flow through straight rectangular open-channels.

Based on theoretical approach, a fully analytical model, total-dip-modified-log-wake law, for velocity distribution is proposed. The model is tested with a wide range of experimental data including clear water and sediment-water mixture and it predicts velocity well throughout the flow depth of open-channels. From error analysis it is also found that it provides minimum error than previous models. The results of sediment-laden flow shows that the von Karman coefficient decreases with both the Richardson number and average concentration whereas Coles' wake parameter increases with average concentration and decreases with the Richardson number. Besides this, another velocity model, log-parabolic law, which combines log law for inner region and parabolic law for outer region, is suggested and tested in both clear water and sediment-laden flow.

The effect of vertical velocity induced by secondary current on suspension concentration distribution is also investigated in this thesis. A modified form of the Rouse equation for concentration distribution is proposed which includes the effect of secondary current and is verified with experimental data in open-channel flow. From the error analysis it is obtained that the proposed model predicts concentration better than the Rouse equation throughout the flow depth for open-channels. From a theoretical analysis, a new explanation for two different types of suspension concentration distributions namely type I profile and type II profile, is provided which suggests that type II profile always corresponds to upward direction and greater magnitude of secondary current. The modified Rouse equation is further generalized by including the effect of stratification. Besides this, suspension concentration distribution is also studied from observational approach. A fully analytical model for type II profile of suspension concentration distribution is proposed and verified with a wide range of experimental data in dilute and dense flow through pipes and open-channels. From the analysis it is found that type II profile is mostly affected by Stokes' number and fluid uplift force. It is also found that for a fixed Stokes' number, the pattern of suspension concentration distribution changes from type I profile to type II profile if fluid uplift force exceeds a critical value.

Keywords: Turbulent flow, Velocity distribution, Velocity dip-phenomenon, Secondary current, Two-phase flow, Sediment transport, Bed-load and suspended-load transport, Suspension concentration distribution, Stratification, Type I and type II concentration profile, Least square method.