New Look on Hydrodynamics of Sediment Motion and Fluvial Instabilities

by

Sk Zeeshan Ali (14CE90J01)

Abstract of the Thesis:

In this study, new look on the hydrodynamics of sediment motion and fluvial instabilities is provided highlighting the delicate role of the turbulent flow that drives several fluvial processes. First, a mathematical model for the threshold of sediment particle motion is presented, considering the deterministic approach of force balance. The role of flow regimes on sediment threshold are investigated, incorporating the effects of velocity fluctuations.

Then, the stochastic mechanics of entrainment of loose bed particles is studied. The particle entrainment in rolling and lifting modes is analysed. The mean entrainment probabilities in rolling and lifting modes are derived, applying a suitable probability density function of the near-bed instantaneous streamwise velocity.

The governing equations driving the mechanics and the turbulence characteristics of two-phase flow system are derived, applying the dynamic equilibrium linked with suspended particle concentration, fluid flow and energy of the system.

For flow over bedforms, a theoretical framework is developed to obtain the flow profile, bed shear stress and the Reynolds shear stress distributions. A power law of velocity in conjunction with the effects of curvilinear streamlines are included in the analysis. The mobile bed flow is derived by means of the sediment continuity equation to obtain the phase lag distance between the locations of the maximum bed shear stress and the maximum sediment flux.

To study the hydrodynamic instability of meandering channels, a regular expansion technique is applied to linearize the governing equations by introducing the perturbations on the undisturbed flow. The channel exhibits a resonance phenomenon depending on flow regimes, meander wavenumber, Shields number, channel aspect ratio and relative roughness number. The evolutions of the characteristic parameters of the channel flow are examined.

Finally, the origin of some of the scaling laws of key fluvial processes is explored from the standpoint of the phenomenological theory of turbulence. The scaling laws of threshold of sediment particle motion, bedload flux, suspended load flux, scour in a contracted stream and the onset of meandering of a straight river are derived. These scaling laws offer an insight into the flow physics, providing a new way of exploring the fluvial processes.

Keywords: Fluvial hydrodynamics, sediment transport, turbulent flow, open-channel flow, bedforms, river meandering