INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

This study, using an experimental approach, focuses on the effect of downward seepage on a threshold alluvial channel morphology and corresponding turbulent flow characteristics. Experiments have been carried out in a curvilinear cross-sectional shaped channel with two different sediment beds i.e., fine (median diameter = 0.41 mm) and coarse (median diameter = 0.41 mm) sands under no seepage and with seepage conditions. It has been observed that an alluvial channel, which remained at threshold condition of sediment movement during the no seepage experiment, started transporting sediments after the application of seepage in a vertically downward direction. In experimental methodology, Acoustic Doppler Velocimeter developed by Nortek was used to measure instantaneous flow velocities in streamwise, transverse and vertical directions in both the conditions. Bed elevation variations were recorded by using Ultrasonic Ranging System at different time intervals in the presence of seepage.

In case of a fine sand bed channel, results show that Shields stress of the threshold channel is significantly increased from its critical value after the application of downward seepage, leading to the deformation of the cross-sectional shape and subsequent development of bedforms. The role of turbulence in the development of bedforms has also been investigated. Measures of turbulent statistics show that the time-mean velocities and Reynolds stresses are increased significantly with the application of downward seepage. Under the action of seepage conditions, increase in the flux of streamwise turbulent kinetic energy in the streamwise direction is observed in the region close to the channel boundary. Also, quadrant analysis exhibits the increase in the contributions from all the bursting events and the thickness of the sweep-dominated zone in near-bed region after the application of downward seepage. A bedform tracking tool has been used to evaluate the physical characteristics of bedforms. These developing bedforms are classified as current and linguoid ripples according to their evolution with time. It has been further observed that the variations in Shields stress and corresponding bedform geometry reached an equilibrium state in the presence of downward seepage when the experiments were run over a longer period of time (24-31 h).

This work is extended to analyse the flow and statistics of bedform dynamics in terms of multi-scalar bedforms with different percentages of seepage. These multi-scalar ubiquitous bedforms cast a potential impact on flow turbulence as well as stream bed morphology in sand bed channels. Wavelet has been used to analyse temporally lagged spatial bed elevation profiles that were obtained from a set of laboratory experiments and synchronized the wavelet coefficients according to bed elevation fluctuations at different length scales. A spatial cross-correlation analysis based on the wavelet coefficients is performed on these bed elevation datasets to observe the effect of downward seepage on the dynamic behaviour of bedforms at different length scales. Bedform celerity is best approximated by a probability density function such as Rayleigh distribution under varying downward seepage. Statistical analysis of physical parameters of bedforms ascertains that the bedform celerity is reduced as a result of increased bedform size. In addition, wavelet coefficients have been used to perform structure function analysis of bed elevation profiles and to plot exceedence probability. This suggests that bed elevation fluctuations become higher under the influence of increased seepage. Also, the slope of the power spectral density increases significantly with the increment in seepage percentage, which indicates more inhomogeneous and rapid arrangement of bedforms because of increased seepage discharge. In order to get an insight of flow, integral scales of flow are evaluated and it is found that scales of eddy length and eddy turnover time increase significantly with the application of downward seepage, leading to increased sediment transport and initiation of bedforms along the channel length. As the amount of seepage discharge increases, eddy length(s) and turnover time are further increased, causing the development of larger bedforms. It has been established that the geometry of bedforms is linked with the size of eddies.

An experimental investigation of the flow hydrodynamics and temporal changes in the cross-sectional profile with coarse sand bed shows that the stream power and the value of Shields parameter are increased under the action of downward seepage, causing bed particles to move in the form of a sheet layer. Sheet layer development causes reduction in flow depth and rapid channel widening. Cross-sectional parabolic shape of the threshold channel transforms into a trapezoidal shape in the presence of a sheet layer. With the passage of time (11 h), the channel attains a different equilibrium geometrical state with the value of Shields stress around 0.074 (greater than its corresponding value from the no seepage scenario i.e., 0.0399). Measures of turbulent characteristics such as near-bed time-mean velocities and Reynolds stresses have been found increased with the application of downward seepage. Integral scales of flow suggest that the size of eddies increases with the application of downward seepage, which is linked to the evolution of the sheet layer. Also, the hydraulics of sheet flow is defined by formulating an empirical equation for the sheet flow rate with the consideration of downward seepage.