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Some exact solutions for debris flows on inclines and a new scaling law for settlement of Bagnold's fluids

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Exact analytical solutions to the simplified cases of complicated highly non-linear debris avalanche model equations are very useful for testing and calibrating numerical simulations of flow depth and velocity profiles on inclined surfaces. These problem-specific solutions provide crucial insight into the full system. We present some new analytical solutions, both for steady-state and time-dependent flows. First, we have constructed a simple and very special nonlinear ordinary differential equation to model the debris front profile for Bagnold's fluids. Based on the Lambert-Euler function, the exact solution is constructed in explicit form. Second, for steady-state flows, Chebyshev Radicals are employed and the solution is developed for frictional materials. Third, for time-dependent flows, solutions are constructed in symmetrically stretching and marching form of frictional material. Fourth, emerging from the kinematic wave, we will present also the exact time-dependent solutions for debris flow fronts of Bagnold's fluids. Many interesting and important aspects of these solutions and their applications to real-flow situations will be discussed in detail, including the long-time behavior and the influence of the slope curvature on the flow. Importantly, we establish a new scaling law for Bagnold's fluid to relate the settlement time of debris deposition. Analytically, we find that the micro-viscous fluid settles considerably faster than the grain-inertia fluid, as manifested by dispersive pressure. Our analytical solutions agree very well with data, and results presented in the literature and observed in the field of debris avalanches, and the wave tip of the dam break flow.