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Settling velocity of sediments at high concentrations

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Abstract

New data on the settling velocity of artificial sediments and natural sands at high concentrations are presented. The data are compared with a widely used semiempirical Richardson and Zaki equation (Trans. Inst. Chem. Eng. 32 (1954) 35), which gives an accurate measure of the reduction in velocity as a function of concentration and an experimentally determined empirical power n. Here, a simple method of determining n is presented using standard equations for the clear water settling velocity and the seepage flow within fixed sediment beds. The resulting values for n are compared against values derived from new and existing laboratory data for beach and filter sands. For sands, the appropriate values of n are found to differ significantly from those suggested by Richardson and Zaki for spheres, and are typically larger, corresponding to a greater reduction in settling velocity at high concentrations. For fine and medium sands at concentrations of order 0.4, the hindered settling velocity reduces to about 70% of that expected using values of n derived for spheres. At concentrations of order 0.15, the hindered settling velocity reduces to less than half of the settling velocity in clear water. These reduced settling velocities have important implications for sediment transport modelling close to, and within, sheet flow layers and in the swash zone.

Keywords: Fall velocity; Hindered settling; Sediment concentration; Suspended sediment transport; Sheet flow; Swash zone sediment transport

1. Introduction

An accurate assessment of the settling velocity of sediment particles is fundamental to the modelling of sediment suspension, mixing processes and sediment transport in the coastal zone. For single particles, or dilute suspensions, the settling velocity can be accurately predicted by equating gravity and drag forces using an appropriate drag coefficient for spheres (e.g. Nielsen, 1992) or sand (e.g. Fredsøe and Deigaard, 1992). Alternatively, a number of empirical expressions for the fall velocity are available (Gibbs et al., 1971; Jiminez and Madsen, 2003). However, in high energy flow conditions and close to the sediment bed, suspended sediment concentrations become significant, approaching the concentration of the immobile bed itself, c_{max}. For example, in sheet flow layers and plug flow, concentrations range from c_{max} to about $0.1c_{max}$ (Zala Flores and Sleath, 1998; O'Donoghue and Wright, 2001, Dohmen-Janssen and Hanes, 2002). At these concentrations, the particle settling velocity may reduce to 10% or less of the clear water settling velocity (hindered settling), leading to reduced (less negative) concentration gradients over

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