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Experimental study of ”supercritical-flow plane bed” formed by density currents

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Plane bed is a smooth and flat bedform, which is formed in various environments. Parallel lamination which is a sedimentary structure formed by plane bed is a common feature of sedimentary rocks. It is frequently observed in lower to middle part of turbidites as Bouma’s Tb division. It has been known that plane bed can be formed by subcritical unidirectional flows. However, this study implies that plane bed can also be formed by supercritical conditions. As a result of flume experiments of density flows, plane bed was produced by a supercritical density flow that shows very high Froude number ($>$ 4). This discovery may suggest that previous estimations of paleo-hydraulic conditions of parallel lamination should be reconsidered.

Experimental density flows were produced by mixtures of salt water (1.01-1.04 in density) and plastic particles (1.5 in density, 80 microns in diameter). Salt water and plastic particles are analogue materials of mud water and sand particles respectively. Acrylic flume (4.0 m long, 2.0 cm wide and 0.5 m deep) was submerged in an experimental tank (6.0 long, 1.8 m wide and 1.2 m deep) that was filled by clear water. Inclination of the flume was fixed during experiments. A weir (10 cm long) was set at downstream end of the flume to keep basal sediments. Mixtures of salt water plastic particles were injected from a hose at upstream end of the flume. Ratio of saltwater and plastic particles and flow discharge were maintained constant during each experiment. Features of bedforms were observed when the flume reached equilibrium condition. The experimental conditions range 1.5-4.2 in densimetric Froude number and 0.2-0.8 in Shields dimensionless stress.

As a result of the flume experiments, plane bed was formed under the condition of supercritical flow regime that was not recognized in previous studies. Plane bed was stable against physical disturbances and well reproduced in experiments. Although number of experimental runs is insufficient to examine stability field of this bedform, a typical condition to form the supercritical flow plane bed was 4.2 in densimetric Froude number and 0.8 in Shields stress. This condition is distinctively different from formative conditions of plane bed of the upper flow regime.

The supercritical flow regime plane bed could be a new type of bedforms. Established theories of bedform stability predict that plane bed is unstable in supercritical flow regime, so that another factor that was not incorporated in previous theories should be considered to understand the origin of this supercritical flow plane bed. For example, the supercritical flow plane bed was formed under the condition where sheet flow (traction carpet) is dominant, whereas plane bed of upper flow or lower flow regimes is formed under the condition where bedload and suspended load are dominant process in sediment transport. Also, density currents instead of open channel flows were used in this study. We suggest that these could be factors to be considered in future studies.

Keywords: turbidity current, bedform, flume experiment, plane bed