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# A laboratory experiment on the incipient motion of boulders by tsunami flows

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Coastal boulders transported inland by tsunamis or storms have been found in many coastal areas worldwide. The study of these deposits is important because of their implications on coastal hazard assessment, since they contribute to the identification of past events and to the study of their magnitude and characteristics. However, pinpointing the event responsible of the boulder transport (be it a tsunami or a storm) is a difficult task, that involves a lot of uncertainties: in fact, the hints provided by the deposited boulders on the transporting water flow, and the link between this flow and its ultimate origin are often ambiguous since multiple factors intervene in the process such as the complex interaction of waves and currents with coastal environment, the initial boulder conditions, etc.

A frequently used method to estimate the minimum flow velocity and height needed to move a boulder is to use simple hydrodynamic formulae, derived by breaking the balance of forces and torques acting on the boulder. In this work, the problem is dealt with by means of an experimental approach devised to study the effect of a tsunami-like current on a boulder. A laboratory experiment was carried out at the Hydraulic Engineering Laboratory (LIDR) of the University of Bologna, Italy, in an 11 m long and 0.5 m wide flume, to study the minimum flow conditions for the transport of boulders. The main objective of this experiment was to provide experimental data for the conditions of the incipient motion, i.e. to relate the threshold values of flow velocity and depth needed for transport to the characteristics of the boulders, i.e. weight and geometry.

A series of laboratory tests was performed with four boulders of different weight and shape (two approximately cubic and two rectangular blocks) by varying the flow conditions. Each test consisted of generating a bore at one end of the flume by opening a gate of a water tank. The bore travelled through the central flat sector of the flume and then climbed up a slope where it hit the boulder. The impact of the flow on the boulder was recorded by a high-frequency camera checking the instant when the boulder started to move from its initial position. The flow velocity was measured by means of two Doppler ultrasound velocity profilers (DVP) allowing to compute the flow velocity component parallel to the slope. By this experiment it was possible to determine the flow velocity and height at the first instant of the boulder motion.

The main result is that boulders are found to move when only partially submerged by the flow. The comparison of observations with the theoretical conditions derived from the breaking-balance laws shows that the theoretical approach overestimates strongly the empirical minimum conditions. This poses the need of a better theoretical description of the interaction between the flow and the boulder and of a better tuning of the main parameters of the theoretical laws, namely the drag and lift coefficients.