STABILITY OF COMPLETELY ARMOURED BED STREAMS

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The results of an experimental analysis on the stability of an artificially armoured bed stream have been presented. In mountain stream restoration the stream is often artificially formed by boulders accurately disposed on the bed, especially when the torrents cross the villages on alluvial fans. In this case a layer of relatively big natural blocks is placed over a loose material layer, usually characterized by a size much smaller than the surface material. The blocks are so large (0.5÷1.5m) that they have to be placed one by one, forming a relatively smooth surface. The boulders are embedded in order to reduce block spacing and maximize the reciprocal blockage. The building technique often provides for the filling of the voids among the boulders with concrete; however pavements formed by loose boulders are realized. In general the section of artificially armoured channels is compact and its shape is parabolic or trapezoidal. Goal is to study the effect of reciprocal blockage among the boulders, forming an arranged bed, on the stability and the drag coefficient for densely packed bed elements. In the experiments a paved plane bed, formed either by loose crushed stones or regular boulders, is considered. The effect of reciprocal blockage among the boulders gives to the bed a higher stability with respect to the one expected according to the theory present in the literature. This effect is usually neglected in the incipient motion analysis of bed particles, which goes back to the theory of Shields (1936). Shields analyzed the equilibrium condition of a particle laying on a river bed, formed by cohesionless uniform material, at gentle slopes in downward direction. Afterwards other authors investigated the effects of bank slope, of low relative submergence, and of bed slope. Many researchers have focused on the interaction between an armor layer and the sediment bed (Raudkivi et al., 1982; Sumer et al., 2001). Ulrich (1987) evaluated the stability of rock protection, introducing the bearing angle as representative of the limit equilibrium of the particle without flow, instead of the repose angle. The experimental analysis shows that a pavement layer formed by accurately arranged material leads to a significant increase of bed stability with respect to the typical values of critical Shields parameter: 20%÷50% for regular boulders and 80%÷100% for crushed stones. The experimental data are compared with the results of theoretical analysis based on Shields theory, in which the reference velocity is defined by means of double-averaged flow variables (Nikora et al, 2004). The stability of arranged bed depends on the effect of bed slope angle and on the imbrication effect, relative to the bed arrangement and the shape of bed elements. In the theoretical model the imbrication factor represents the stability increase of an arranged bed as opposed to a randomly arranged bed formed by the same material. Unfortunately the field and laboratory measurements of drag and lift coefficients allow to estimate the imbrication factor with a low degree of accuracy, whereas the imbrication angle, and so the bed slope effect, can be accurately calculated.

The direct measures of the hydrodynamic forces acting on a bed element confirm that the interactions among roughness elements reduce the value of the drag coefficient as observed by Bathurst (1996) and by Lawrence (2000).

Keywords: Incipient motion; Artificial armouring; Steep bed streams; Drag coefficient.

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