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Stability of Artificial Armouring in Steep Streams

Abstract of the doctoral thesis

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The restoration of steep-slope reaches of water courses is carried out with techniques that present, generally, an environmental impact judged negatively. In addition to the classical restoration techniques of water courses (check dams, weirs,...), morphological restoration techniques have been developed in order to limit or control the sediment transport and to keep or recover the natural appearance of the water course. The utilization of alternative techniques, that, for example, provide for the artificial armouring of bed streams by means of big boulders, is limited by the lacking knowledge of the processes occurring at steep slopes and of bed stability.

The main aim of the study is the systematic definition of design criteria of low environmental-impact restoration techniques of different conception and use. The two restoration techniques under examination consist in the partial or complete covering of the bed surface by means of big boulders.

The first restoration technique treats the longitudinal stabilization of steep reaches of water courses by means of cross-sectional lines of boulders equally spaced along the stream direction. Boulders of a row can be loose, tied, or tied-anchored to the banks. Design criteria were derived from experimental analysis by estimating critical mobility parameter of Shields and its corresponding flow resistance; the flow conditions determining the morphological collapse of the bottom were also defined. Particular attention was devoted to the morphological evolution of the ramp, evaluated by means of a laser-profiling technique.

The second restoration technique consists in complete covering of the bed channel by means of the accurate positioning of boulders. The pavement layer is placed over a loose granular layer usually characterized by a size much smaller than the armouring material. The boulders are so large that they have to be placed one by one, forming a relatively smooth surface. The pavement, reproduced in the experiments, is composed by artificial regular boulders or crushed stones. The effect of reciprocal blockage among the boulders, depending on the shape and arrangement of pavement material, gives an increase of stability with respect to that expected according to the theory available in literature.

The mobilization of pavement elements is due, mainly, to instantaneous pressure gradients along the normal to the bottom direction. So, the pressure field around the pavement elements and within the porous layer plays a crucial role on the stability of the covering material and on

the exchange processes between free surface flow and Darcian flow within the porous medium.

Particular attention was devoted to exchange processes between the surface and subsurface flow. Stemming from experimental observations, the mechanism of pressure propagation within the porous layer has been deeply considered in detail by implementing a 2D numerical model based on the dynamic equation proposed by Biot (1956). The experiments prove that the dynamic component of the pressure has been already damped deeply below the pavement layer.

The mechanism of incipient motion of the material forming the pavement layer can be expressed in terms of the turbulence properties of the flow field. In order to correlate the pressure and the velocity fields on the upper surface of a pavement element, it becomes necessary to characterize the properties of the flow field. In case of large-scale roughness bed the flow field is spatially heterogeneous and, thus, it can be properly described through the double-averaged flow variables, introduced recently by Nikora et al. (2001) for free-surface flow over rough bed. In laboratory experiments PIV technique was used in order to evaluate double-averageed properties of the flow field.