Doctoral School in Environmental engineering

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Morphodynamics of steep open channels

Abstract

The hydraulic of steep water courses is characterized by a low relative submergence, by a poorly sorted grain size distribution and by an intense solid transport. In this kind of system the uniform flow tends to be unstable under certain boundary conditions and the morphological equilibrium state of the system turns into different configurations. A good knowledge of the behaviour of the steep water courses is very important, also to allow a correct river restoration.

The experimental analysis is performed in the hydraulic laboratory of the University of Trento using a hydraulic flume that allows the recirculation of both the liquid and solid phases. All the phenomena are studied mainly from an experimental point of view, in order to understand the physic behind each aspects, and afterwards the results obtained are compared with some theoretical approaches. In particular a digital image analysis technique was used in order to characterize the shape of the bedforms, the transport layer and to measure the water depth.

Keeping constant the uniform grain size distribution and increasing the water discharge and the solid discharge, the bedforms that can develop are completely different: the equilibrium condition of the system turns from alternated bars to roll waves and to antidunes migrating downstream and upstream (Fig. 1).

Fig. 1: from left to right: alternated bars, roll waves over mobile bed, antidunes moving downstream and antidunes moving upstream in the channel.

The alternated bars have been already studied deeply, therefore the analyses performed deals with the other bedforms: roll waves and antidunes. In particular the roll waves have never been observed and characterized in a mobile bed condition but only in

a fix bed configuration. Concerning antidunes, this bedform is well known but only those migrating upstream in the channel are fully studied. Therefore the present work deals with some new aspects never studied deeply before, that is, the roll waves in mobile bed condition and the antidunes moving downstream in the channel.

The experimental measurements are complicated because of the low water depth and of the presence of a large transport layer. Many different techniques have been tested, in particular the digital images analysis was used to study the movement of the particles transported by the flow and also the acoustic Doppler profiler was adopted for the velocity measurements in some tests.

Other types of bedform can develop using a different grain size distribution. In particular steps and pools and other morphological structures have been observed in laboratory (Fig. 2) using a coarser and not uniform grain size distribution.

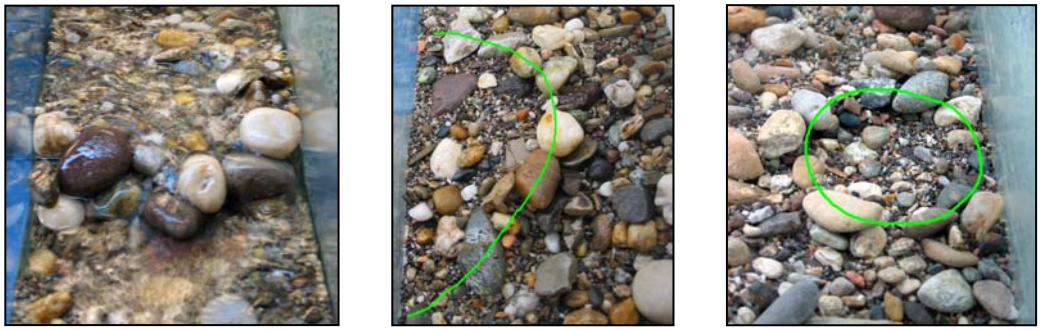

Fig. 2: morphological structures observed with a poorly sorted grain size distribution: step-pool structures (picture on the left), short bars (picture in the centre) and ring structures (picture on the right).

All the bedforms observed are characterized from a morphological point of view and a comparison with the information found in literature, if present, is performed. It appears that, in the tests performed, the roll waves over mobile bed are in agreement with some formation criteria for the fix bed case. Also the antidunes moving upstream in the channel are in good agreement with the Kennedy's (1963) theory, but those migrating downstream are not predicted correctly by this theory. A new mathematical model, based on perturbative methods, is therefore constructed but it is not yet complete now.

Another interesting aspect concerns the mechanisms of propagation for the bedforms observed with an uniform grain size distribution and those proper of a coarser, and not uniform, grain size distribution. It appears that, in the first case, there is a migration process while in the second case a process of construction and reconstruction of the bedforms in the same or in another place. In particular the understanding of the relationship among antidunes and steps and pools is still a point to make clearer. Some

suitable experimental tests are planned, changing the grain size distribution from an uniform one to a wide one.

Finally the experimental tests performed suggest that, changing the boundary conditions, water discharge, solid discharge and grain size distribution, the morphological equilibrium configuration is completely different.