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Comparative Study of Flow through Vegetation Stems with and without Foliage

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Abstract
The presence of vegetation in rivers, streams and riparian zones affects significantly the flow field and consequently the resistance, pollutant dispersion, sediment transport and ecological habitat. In this paper, a comparative study is undertaken to investigate the effect of an array of simple rigid or compound semi-flexible elements, resembling submerged small plants, on key features of the flow field. Measurements were taken by means of a 3-D ADV instrument at selected locations within the vegetation array and downstream of it. Vertical profiles of the velocities and turbulent shear stresses were obtained and compared.
Keywords: Ecohydraulics, Environmental Hydraulics, Flow through vegetation, Velocity, Shear stresses.

1. Introduction

Growth of vegetation in channels was previously seen as a nuisance, mainly due to the reduction in discharge capacity. Thus design and common practice suggested vegetation removal. Modern approaches, however, recognize the significant environmental benefits of vegetation in aquatic systems, such as increasing the stability of banks, reducing erosion and floods, etc.

Generally, the presence of vegetation strongly influences the flow field, increases flow resistance, changes local conditions, and promotes sedimentation. It is therefore necessary to understand and quantify the natural processes that govern the complex interaction between water flow and vegetation. For this reason, in recent years, much research has been carried out on various aspects of flow through vegetation. A comprehensive overview of the hydrodynamic characteristics of these flows is given by Nepf (2012). Several papers have dealt with the resistance properties and other features of flow through rigid vegetation canopies, simulated as an array of cylindrical elements (e.g. Dunn et al., 1996, Fairbanks, 1998, Stone and Shen, 2002), while others focused on flexible vegetation, including real plants (e.g. Carollo et al, 2002, Velasco et al, 2003). Numerical simulation of flow and turbulence in vegetation channels has also been attempted (López and García, 2001, Souliotis and Prinos, 2008). However, there is no systematic investigation of the effect of the geometry of the vegetation elements in the flow field.

The purpose of this paper is to compare the effect of vegetation stems with and without canopy on basic characteristics of the flow field, namely the velocity profiles and the turbulent shear stresses. It is part of a wider study on the influence of geometry and density of various elements so as to identify and quantify the most important parameters affecting the flow.

2. Experiments

The experiments were conducted in a laboratory flume, 16 m long and 0.50 m wide, with slope 0.001. A perforated bottom was installed, on which the

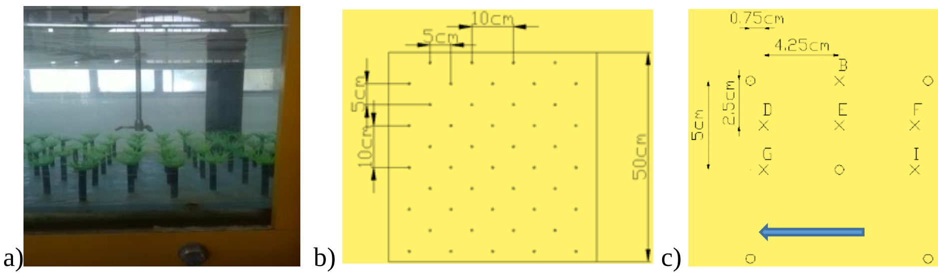

Figure 1. a) Side view of the compound elements, b) Plan view of staggered pattern, c) Measurement positions

vegetation elements were mounted. Two types of elements were used: (a) Thin rods 0.5 cm in diameter, 4 cm high (Exp1); (b) Compound elements consisting of a set of flexible (plastic) 3 cm long needles arranged axi-symmetrically on top of those rods, as in Fig.1a (Exp2). In both cases the elements were placed on a staggered 10x10 cm mesh, yielding a plan density of 200 stems/m^2 (Fig.1b). The flow rate Q= 41 l/s and the flow depth Z= 25 cm were constant throughout the experiments. Measurements were taken by means of a 3-D ADV instrument at selected locations within the vegetation array, as shown in Fig.1c.

3. Results and Discussion

Vertical profiles of the (temporal mean) velocities and turbulent shear stresses are presented below in Figures 2 and 3. All profiles are normalized: the vertical position (z) with element height (h) which is different for each experiment, while velocities and stresses with the respective values at the top of vegetation canopy. It is apparent that in Exp2 the reduction of velocity within the array is more pronounced compared to Exp1. The minimum velocities in Exp2 occur at about half the element height and tend to zero at certain locations. Concerning the turbulent shear stresses, the effect of the vegetation elements is seen to extend well above the top of the canopy; in fact, in Exp2 the stresses are higher above the top of the elements. Moreover, there are no significant differences of velocity profiles and shear stress distributions between the measured locations in each experiment.

4. Conclusions

The presence of foliage causes a more severe reduction of flow velocities within the vegetation array compared to simple stems. In both cases the minimum velocities occur below the top of the elements. Overall, the effect of foliage is significant but there are no appreciable differences between the measured locations in each experiment.

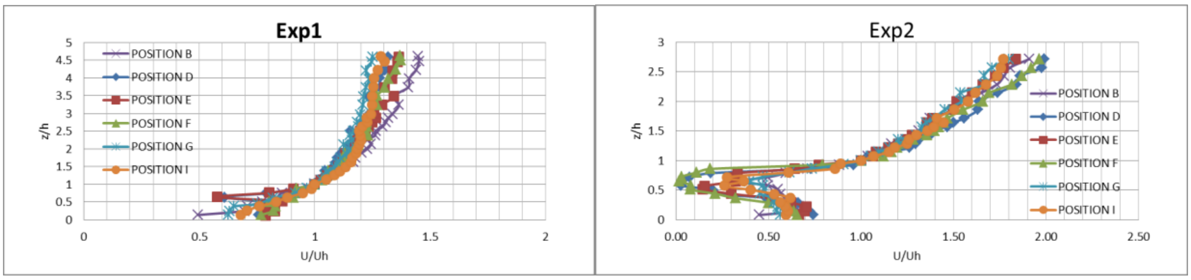

Figure 2. Vertical velocity profiles

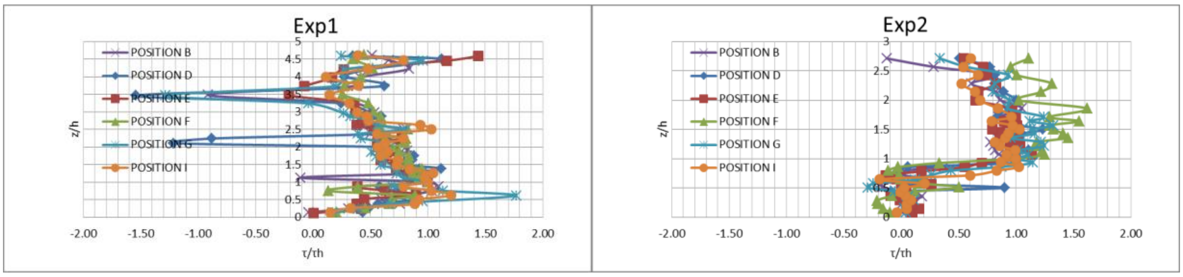

Figure 3. Vertical profiles of turbulent stresses

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