LABORATORY TESTING OF EQUATIONS FOR ASSESSING ROUGHNESS COEFFICIENT DUE TO ARBOREAL VEGETATION

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KEY POINTS

- *Validation of literature models to estimate the roughness coefficient due to arboreal vegetation*
- *The material employed to simulate vegetation is based on a scale model of real vegetation*
- *Vegetation has been characterized based on the young's modulus and inertia moment*
- *Literature models are more reliable for predicting roughness when vegetation is denser*

1 INTRODUCTION

The presence of vegetation on river banks and floodplains is a topic of great interest in river engineering and risk management. The hydraulic resistance offered by the vegetation causes an increase in the water level, a decrease in the velocity and, as a result, an increment of the flood risk.

This study aims to estimate the roughness coefficient due to two typical species of arboreal vegetation present in the floodplains of the Piave River, located in the Veneto region of Italy. For this, literature models were applied to experimental measurements, conducted in a laboratory model.

In case of rigid vegetation, the flow resistance is similar to the one due to immersed bodies, therefore, the roughness coefficient can be expressed as a function of the drag force and other parameters such as the trees density, their spatial distribution and the diameters of the trunk. Furthermore, the total resistance can be determined from the resistance of each plant.

In total, 12 literature models were evaluated from the most classic such as: *Petryk & Bosmajian* (1975), *Kowobari et al.* (1972), *Lindner* (1982), etc., up to the more recent ones such as: *Cheng et al.* (2011), *Luhar & Nepf* (2012), *Li et al.* (2015). From the comparison between roughness coefficients measured in the laboratory and the values estimated from the literature models, it was possible to determine which equations best represent the experimental measurements. These equations were proposed by *Huthoff et al.* (2007), *Baptist et al.* (2007), *Luhar & Nepf* (2012) and *Kowobari et al.* (1972).

2 METHODOLOGY

With the purpose of validating the models present in the literature to determine roughness due to rigid vegetation, 28 laboratory tests were performed on a physical model in which the diameter of dowels, the density and the degree of submergence have been varied. To simulate the vegetation in the laboratory (dowels), an analysis based on the elastic module and the geometry of the tree species present in the Piave River was employed.

2.1 Material to simulate vegetation

To identify the most suitable materials that represent the behaviour of rigid vegetation, rigidity tests were carried out at Laboratory Material Testing (LPM) of the Politecnico di Milano on several samples of Robinia and Sambuco species, typical of the study area.

As a result, the young's module for Robinia was between 2000 - 3000 MPa, while for Sambuco the values vary between 750 - 1000 MPa. Using these values is possible to obtain, for a given material and a fixed geometric scale, the dimensions of the element in which the bending behaviour is equivalent to one of the real trees subject to the passage of flow, through theory of elastic - static models and the equation of deflection in a cantilever beam. Thus, to represent Robinia dowels of Ayous 30cm high and 8mm diameter were chosen, while for Sambuco, the choice was dowels of Balsa 30cm high and with 4mm diameter.

2.2 Experimental Set-up

The experiments were carried out at Laboratory Fantoli of Politecnico di Milano in a horizontal, 30m long, 1m width and 0.60m depth flume. The dowels of 8mm and 4mm were inserted into boards of 1m x 0.5m for a total of 10 boards and 5m length. The tests included staggered and linear configurations and to simulate different degrees of submergence and hydraulic conditions a downstream gate was used as boundary condition. The discharges varied from 40 l/s to 100 l/s and were measured with a typical Thomson weir.

Figure 1 shows the configuration of the experimental model.

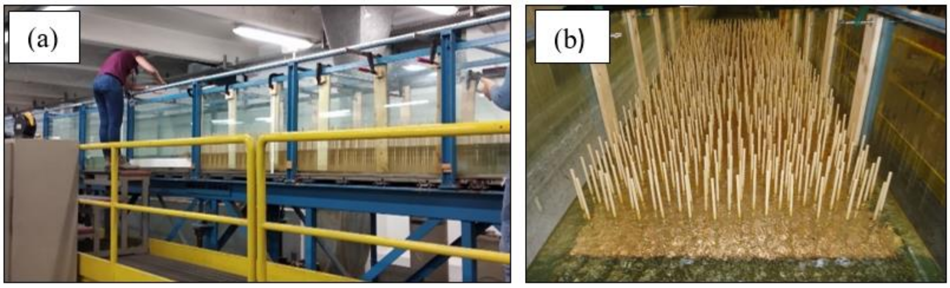

Figure 1. Photographs of the model set-up: (a) Flume with vegetation, (b) Board with dowels inside the flume.

In total 28 experiments were undertaken, during which water depth measurements were taken every 0.50m, while velocities were measured 1 m upstream, 1 m downstream, and in 3 points within the vegetated reach. In general, 4 groups were defined representing different geometries (diameters and configurations) in which 6 to 8 tests with 3 and 4 flow rates and two boundary conditions (opened or closed gates) were performed (Table 1).

Group	Description	Configuration	Discharges [l/s]	No. Test
1	L=5m, ϕ=8mm	Staggered	40, 60, 80, 100	8
2	L=5m, ϕ=4mm	Staggered	40, 60, 80	6
3	L=5m, ϕ=8mm	Linear	40, 60, 80, 100	8
4	L=5m, ϕ=4mm	Linear	40, 60, 80	6

Table 1. Experimental test groups.

3 RESULTS AND DISCUSSION

To estimate the roughness coefficient in the laboratory, 12 literature models, from the classical to the most recent ones, were evaluated and subsequently compared with the Strickler roughness coefficient (K_s) measured in the laboratory. The Strickler coefficient (K_s) was used as the reference result since takes into account the loss of energy generated by an obstacle, and therefore, considers the entire dissipation present in the experiments.

The analysis performed allowed to identify the literature models that better reproduce the laboratory roughness values calculated according to the Gauckler-Strickler equation. The tests showed that some models significantly overestimate or underestimate the laboratory roughness value in all groups, however, the largest discrepancies were observed in groups 3 and 4 that represent lower densities. Therefore, in the following graphs are reported only the results of the best models in comparison with the roughness coefficient K_s for the group 1, larger density, and group 4, smaller density.

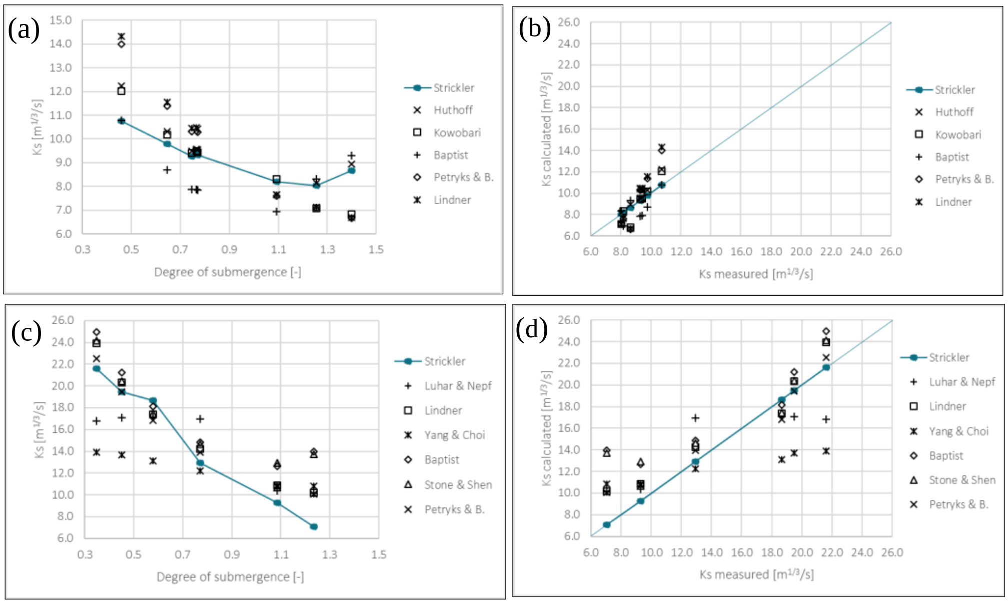

Figure 2. Experimental results for groups 1 and 4: (a) K_s vs degree of submergence for group 1, (b) scatter plot group 1, (c) K_s vs degree of submergence for group 4 and (d) scatter plot group 4.

In general, it can be stated that among the 12 methods examined, the approaches developed by *Huthoff et al.* (2007), *Kowobari et al.* (1972), *Luhar & Nepf* (2012) *and Baptist et al.* (2007) seem to better determine the roughness coefficient in the cases analyzed. Furthermore, the models evaluated show a greater correlation with the experimental tests carried out on group 1 which has the highest density, on the contrary, when the vegetation becomes more scarce the models are generally less reliable.

Regarding the correlation between the roughness coefficient K_s and the degree of submergence, it is clear the decreasing trend as the degree of submergence increases, which indicates how resistance increases as the water level increases.

4 ACKNOWLEDGEMENTS

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