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

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ABSTRACT

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 the arboreal vegetation present in the floodplains of the Piave River, located in the Veneto region of Italy. For this, literature methodologies were applied to experimental measurements, conducted in a laboratory model, and field measurements acquired by a monitoring system in the river reach positioned between the municipalities of Ponte di Piave and San Biagio di Callalta.

From the comparison between roughness coefficients measured in the laboratory and the values estimated from the literature methodologies, 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 (1972).

Afterwards, the equations identified were applied in the field for the analysis of the flood event that affected the Piave river in December 2020. Using the water level measurements on the floodplains and the estimated roughness coefficient, it was possible to reconstruct the flow hydrograph of the floodplains.

OBJECTIVES

The objective of this research project is to estimate the roughness coefficient due to floodplain vegetation and to verify its effect on flood propagation.

Specific objectives:

- Estimate the roughness coefficient due to rigid vegetation and validate literature methodologies through an experimental model.
- Explore the suitability of laboratory equations applied to river reach scale using the energy loss measured on field.
- Assess the roughness coefficient in the field and the floodplain discharge for a flood event.

METHODOLOGY

The methodology includes an experimental and field study. To simulate the vegetation in the laboratory, an analysis based on the elastic module and the geometry of the tree species present in the river reach was employed.

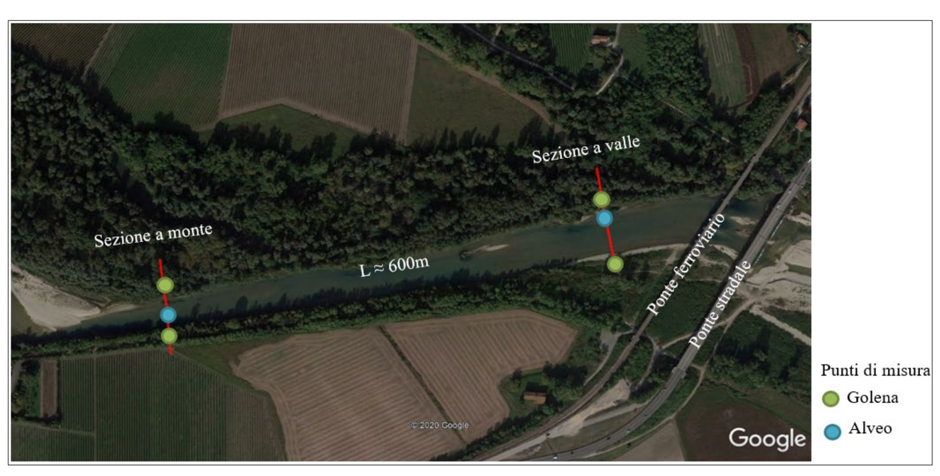
Experimental model set-up:

Lab. Fantoli -Politecnico di Milano
Flume characteristics:
Longitude:30m, width:1m, height:0.60m
Boundary condition: Downstream gate
Discharge measurement: Thomson weir

Vegetation (Dowels):
Diameters: 8mm and 4mm
Height of cylinder: 0.30m
Longitude vegetation: 5.0m,
Material: Balsa and Ayous

Field set-up

Six piezoresistive sensors were installed to measure water levels in the left and right floodplains and in the riverbed. The instruments were arranged in a number of three for each of the two cross-sections that delimit the study reach.

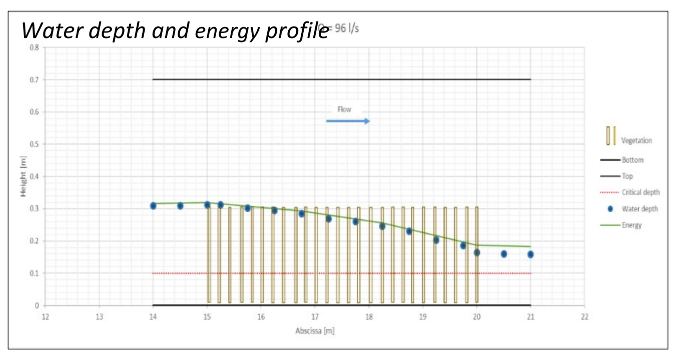


RESULTS

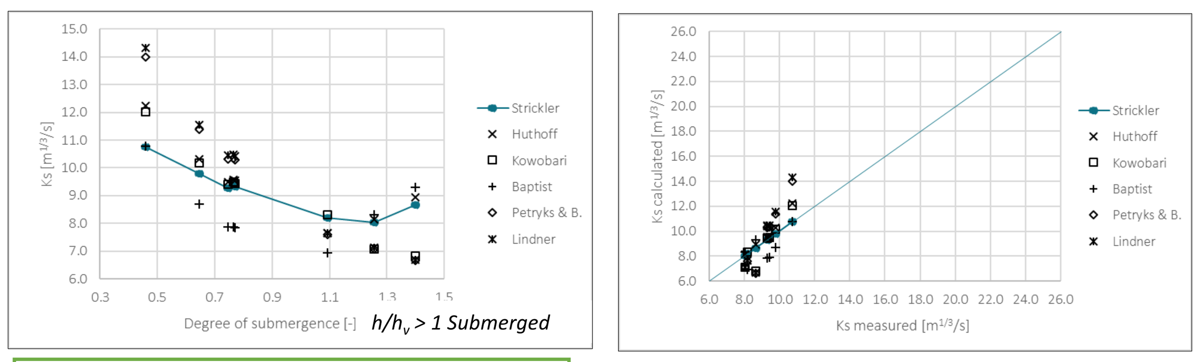
Experimental results

The roughness coefficients were estimated with 12 literature methodologies and compared with the roughness measured in 28 experiments.

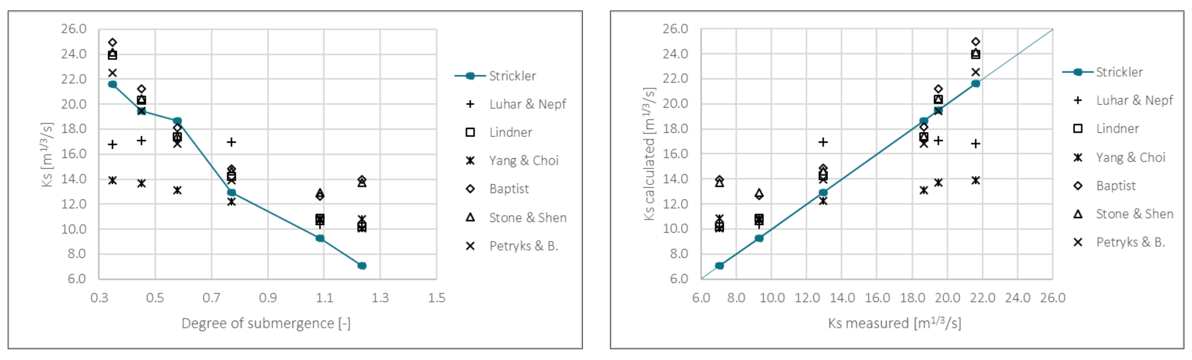
Group	Description	Configuration	Material	No. Test
1	L=5m, ϕ=8 mm	Staggered	Ayous	8
2	L=5m, ϕ=4mm	Staggered	Balsa	6
3	L=5m, ϕ=8mm	Linear	Ayous	8
4	L=5m, ϕ=4mm	Linear	Balsa	6



Results for group 1 – Φ=8mm, Staggered



Results for group 4 – Φ=4mm, Linear

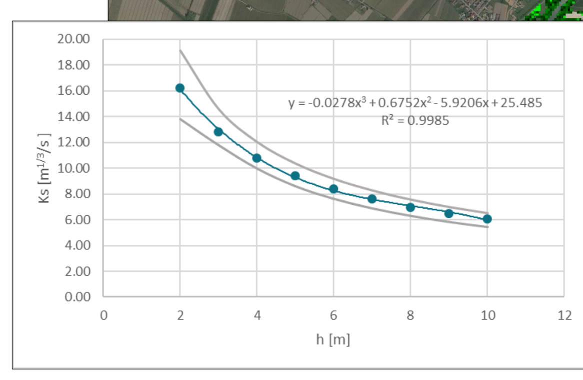


The methods proposed by Huthoff, Kowobari, Luhar & Nepf and Baptist showed the better performance to determine the roughness coefficient.

Field results

The methods were applied in the field to estimate the roughness coefficient of the river floodplains, as a result, an equation calibrated for the reach study was implemented.

Water depth Floodplain [m]	METHODS: Kowobari et al. 1972	METHODS: Baptist et al. 2007	METHODS: Huthoff et al. 2007	Ks average [m$^{1/3}$/s]
2	13.82	19.12	15.82	16.25
3	11.79	14.59	12.07	12.82
4	10.32	12.04	9.97	10.78
5	9.21	10.38	8.59	9.39
6	8.35	9.19	7.61	8.38
7	7.66	8.29	6.86	7.61
8	7.09	7.59	6.28	6.99
9	6.62	7.01	5.80	6.48
10	6.21	6.54	5.41	6.05



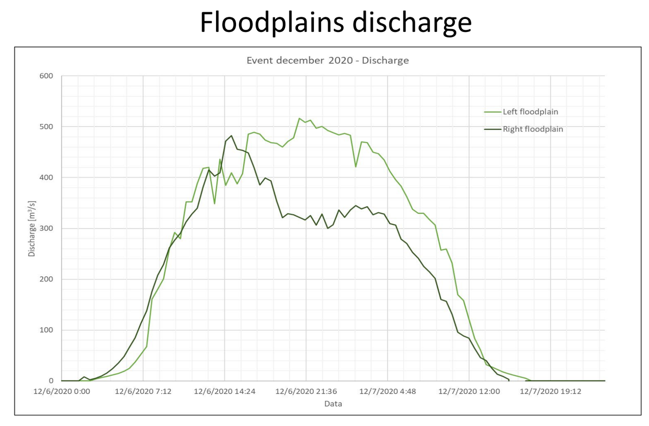
Field application

Flood event: December 5th 2020

Input:
- Raster: diameters & density
- Roughness equation (K_s vs h)
- Water depth (instruments)
- Geometry of the cross sections

Slope - area method

Floodplains discharge



CONCLUSIONS

- The evaluated methodologies demonstrate a greater correlation with the experimental observations for staggered configuration and 8 mm diameter.
- When vegetation density becomes sparser, literature methods are generally less reliable in estimating the flow resistance coefficient due to the vegetation.
- Recent approaches seem to better predict the roughness coefficient in the cases analysed, however, the classical ones are still valid as a good approximation.
- In real scale applications, simplifications are needed, therefore, some equations derived in laboratory become equivalent when applied on field.
- Accurate flow measurements on the floodplain would give a better understanding about the velocity field and the roughness coefficient.

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