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Analysis and Modeling of Free-Surface Flows in a Prismatic Channel in an Experimental Environment

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ABSTRACT

Algeria is one of the countries with arid and semi-arid climates, characterized by very cold winters and very hot summers. Precipitation in this type of climate generally leads to torrential flows, causing significant sediment transport in the mobile beds of natural watercourses and also very important floods either in natural environments or in cities. This study focuses on natural flows but through laboratory modeling in a prismatic channel with constant dimensions and roughness coefficients to better clarify and approach natural free-surface flows. In this experiment, we calculated the Chézy and Manning coefficients and inferred whether they are influenced by changes in parameters characterizing the channels such as flow slope and flow velocity.

Keywords: watercourse, roughness, free surface, prismatic channel.

1 Introduction

Free-surface flows, whether in natural or urban environments, typically occur under heterogeneous boundary conditions due to the distribution of bottom roughness, whether fixed or mobile, and/or significant deformations of the free surface. Studying channel roughness in free-surface flows helps us properly design watercourses to reduce human and material losses during natural disasters (e.g., floods and inundations). The objective of this work is to determine the roughness coefficient and assess its impact on flow parameters. This study is based on a series of experiments conducted in the laboratory; the following figure illustrates the experimental setup in the laboratory.

2 Experimental

A flow is considered uniform when its characteristics remain constant over time and space. These characteristics include the flow depth (h or y_n), also known as normal depth, the cross-sectional area (A) of the flow, the flow velocity (V), and the discharge (Q). The total energy line is parallel to both the piezometric line and the geometric slope of the channel. Through numerous practical examples concerning uniform flow, it becomes apparent that the formulas known as Chézy's and Manning's (or Manning–Strickler) formulas are the most widely used.

Chézy's formula: : $V = C * \sqrt{(Rh * j)} C * \sqrt{(Rh * j)}$

- C: Chézy coefficient ($m^{1/2}/s$)
- Rh: hydraulic radius (m)
- j: slope (m/m)

Manning-Strickler formula: $V = Ks * Rh^{(2/3)} * j^{(1/2)}$

- Ks: Strickler coefficient ($s/m^{(1/3)}$), where Ks = 1/n
- n: Manning coefficient

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The experimental part of the study was conducted on a test channel 53 mm wide and 2.5 m long, equipped with instruments used for extensive testing aimed at studying free-surface flows and hydraulic phenomena.

3 Results and Discussion

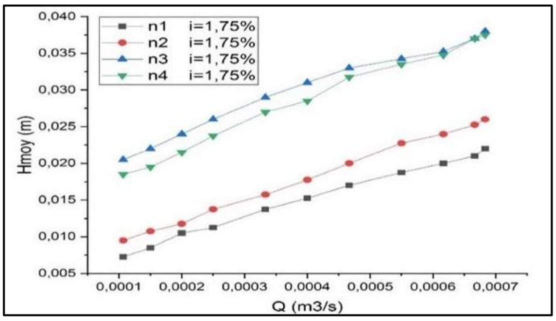

Figure1: The effect of roughness on the Froude number.

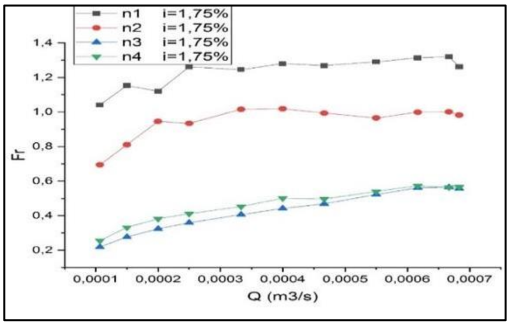

Figure2: The effect of roughness on the water line.

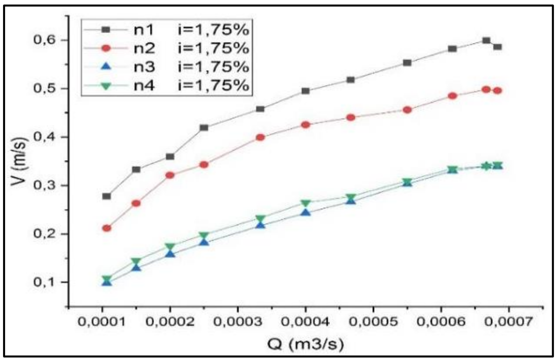

Figure3: The effect of roughness on the average velocity

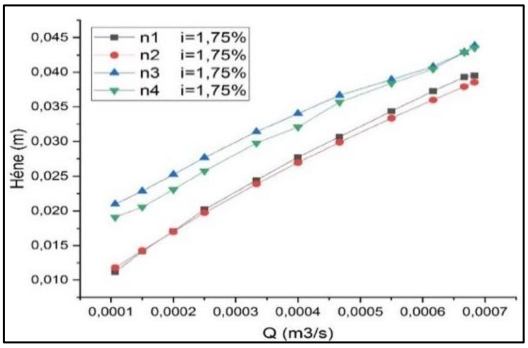

Figure4: The effect of roughness on the energy line

The increase in flow rate "Q" has a positive impact on flow parameters (Fr, Vmoy, H energy, and water level) in the prismatic channel. The increase in roughness leads to a rise in the water level for a given flow rate, due to the greater uniformity of the roughness of the "vegetal carpet" compared to the "gravel plate" bottom. Moreover, the increase in roughness results in a decrease in average velocity and an increase in energy level for a given flow rate. On the other hand, decreasing roughness leads to an increase in the Froude number for a given flow rate.

4 Conclusions

In this work, the points discussed are the experiments conducted in the laboratory regarding the effect of changing the roughness of the canal bed, as well as the various free-surface flow phenomena observed in the experimental channel, along with all the results presented in tables and graphs. The experimental results show that a carpeted bed is rougher compared to sand or gravel beds, which can be explained by uniformity. Flow parameters are influenced by changes in roughness; an increase in roughness (n) raises the water line but decreases the velocity. These findings can influence river management operations in cities and help mitigate damages caused by floods.

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