P04

Energy loss Mechanism Near an Isolated Strip Roughness

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Introduction

The behavior of flow in open channels over rough beds has always been a major topic of interest for hydraulic engineering researchers. This topic is particularly important because of its role in influencing flow resistance, especially in channels with fixed beds. Therefore, identifying key hydraulic parameters such as energy dissipation, turbulence intensity, and velocity distribution is essential for understanding and predicting interactions between flow and bed roughness, which leads to improved flow management strategies (such as the design of channels, pipelines, and hydraulic structures. Controlling flow resistance in such systems is vital not only for optimizing flow conveyance in channels but also for mitigating erosion and sediment transport issues. Consequently, the study of rough bed flows remains a fundamental area of research in both theoretical and applied hydraulics.

Study Objective

This experimental study investigated the influence of surface roughness by focusing specifically on the effect of a single strip roughness height on flow behavior. This study aims to examine how variations in the height of a single surface strip roughness element can impact key flow characteristics, including velocity distribution, turbulence intensity, and energy dissipation. By analyzing the behavior of flow as it interacts with different roughness heights, valuable insights into the role of surface roughness in hydraulic systems (such as open channel flow) can be obtained.

Methodology

Experimental setup

A rectangular flume (4 m length, 0.6 m width, 0.2 m height) was used for experimental evaluations, following prior studies by Sohrabzadeh Anzani et al. (2024 a, 2024b, 2024c). The system includes a pump, channel, and upstream/downstream tanks (**Fig** 1). The channel slope was 1%, with a pump discharge capacity of up to 8.3 l/s, calibrated using a flowmeter. Forty tests on strip roughness were conducted at five heights (7, 9, 11, 13, 15 cm) with flow discharges ranging from 1.4 to 6.3 l/s in 0.7 l/s steps. The strip roughness thickness was constant (T_s=0.3 cm) for all tests (**Fig** 2).

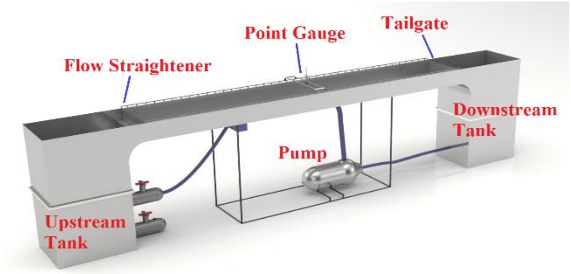

Fig 1. Elements of the laboratory flume.

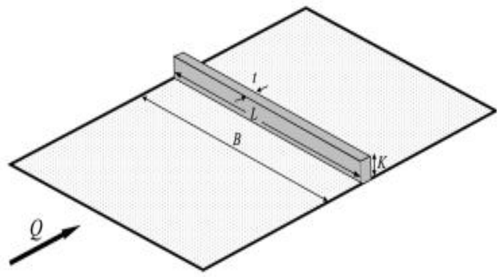

Fig 2. Diagram of the channel with strip roughness

Hydrodynamics of flow over strip roughness

For a strip roughness with a constant height, increased discharge raises upstream water depth, flow depth over the strip, and downstream tailwater depth. As strip roughness height increases, flow over the roughness is further restricted, retaining more water upstream and increasing upstream depth, while tailwater depth downstream decreases. Flow encountering an obstacle causes the surface to rise, creating downstream circulation, as illustrated in **Fig** 3, consistent with.

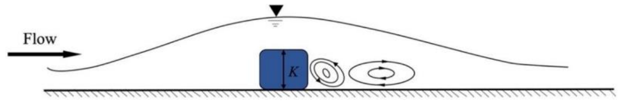

Fig 3. Flow region downstream of a strip roughness

Downstream of the strip roughness, swirling flow forms, characterized by rotational or circular fluid motion around an axis (**Fig** 4). Lower roughness height combined with higher discharge enhances the visibility of this swirling flow.

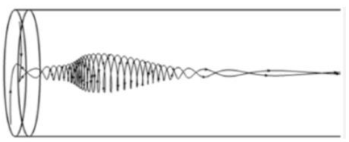

Fig 4. Swirling flow

Results and Discussion

Fig 5 illustrates the relationship between discharge (Q) and velocity (u) for varying strip roughness heights. Velocity increases after the roughness in all cases, showing a consistent upward trend with discharge. This increase is due to the strip roughness acting as an obstacle in the channel. Greater strip roughness heights amplify velocity differences upstream and downstream, demonstrating their significant influence on flow dynamics and velocity profiles. The average increase in the downstream velocity was observed to be significant, reaching 58.28% for the highest roughness height.

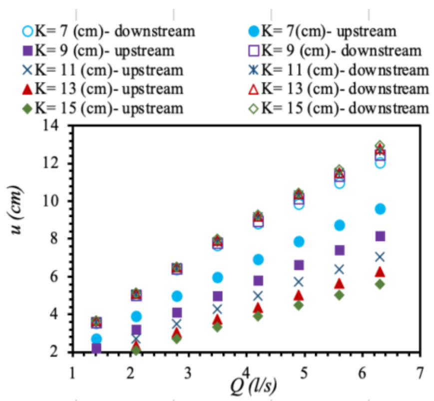

Fig 5. Velocity vs. Discharge for Various Strip Roughness Heights

Fig 6 shows that ΔY ($\Delta Y = Y_{upstream} - Y_{downstream}$, where $Y_{upstream}$ is the water level upstream of the roughness and $Y_{downstream}$ is the water level downstream) decreases slightly as discharge (q) increases, across all roughness heights. Taller roughness heights result in greater ΔY, reflecting higher energy loss. These results indicate that roughness has a more pronounced effect at low discharges but diminishes as discharge increases, especially for shorter roughness heights. Taller elements maintain significant influence even at higher flow rates.

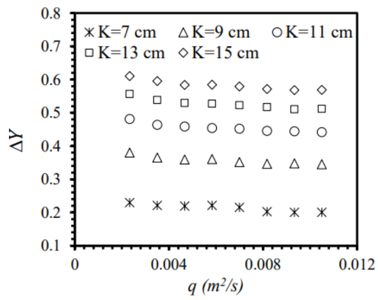

Fig 6. Unit discharge vs. relative water depth difference.

Conclusion and Contribution

The influence of strip roughness on fluid dynamics was systematically evaluated experimentally. The results demonstrate a consistent increase in the flow velocity downstream of the roughness, which is correlated with increased discharge and roughness height. Specifically, the average increase in the downstream velocity was observed to be significant, reaching 58.28% for the highest roughness height. Furthermore, the study revealed that the relationship between the upstream and downstream water depths clearly reflects the impact of roughness on hydraulic resistance, with greater roughness heights exacerbating this effect.

References

1. Sohrabzadeh Anzani H, Kantoush SA, Mahdian Khalili A, Hamidi M. 2024a. *Energy Dissipation Assessment in Flow Downstream of Rectangular Sharp-Crested Weirs.* Water (20734441), 16(23).
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