Exploring Flow Resistance Dynamics in a Physical model

A. Das[a], N. Nandi[b] & B. C. Barman[c]
Indian Institute of Engineering Science and Technology, Howrah, West Bengal, India[a&b]
River Research Institute, Nadia, West Bengal, India[c]
Email-2020amp002.amit@students.iiests.ac.in

1. ABSTRACT

Flow resistance determines the average velocity, flow depth and channel width associated with a specific discharge in an alluvial stream. The present study in a physical model explores the relationship between key hydraulic parameters and mean flow velocity. Data was collected on different flow rates and Ordinary Least Squares (OLS) regression method was employed to find the relationship between the dependent variable i.e. velocity and the independent variables i.e. flow depth, aspect ratio (Width to depth ratio) and hydraulic radius. The regression analysis demonstrated that the selected independent variables effectively explain the variability in flow velocity, with a strong conformity between the observed and predicted velocity values. The plot of observed versus predicted velocities exhibited a high level of agreement, verifying the model's resilience.

2. INTRODUCTION

The difficulty of accurately predicting flow resistance in alluvial channels is highly relevant because it determines the discharge capacity and sediment transport capacity of a channel. The difficulty comes from the fact that the flow boundary in an alluvial channel is dynamic, continuously changing its characteristic i.e., slope, size and shape of bed-form over time. The shape of a channel also affects the flow resistance: channels having sand bars, braided or meandering in nature characterized by variable flow width may exhibit high flow resistance. The sediment particles on an alluvial stream bed cause surface friction or grain friction are also an important component. Considering all these components to develop a resistance equation is quite challenging. The present study conducted in a scaled physical model of Kangsabati river bifurcation explored to build a relationship between average flow velocity and hydraulic parameters. The model investigation was carried out by adding sediment with the flow for various slope. The hydraulic parameters: flow depth, velocity and width were recorded at three different locations within the model section for a range of flow. Ordinary Least Squares (OLS) regression method employed utilizing model data (60 flows) with satisfactory agreement.

3. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The experiment explores the flow resistance (and therefore velocity) in sub-critical flow conditions for a given range of discharges. The flow depth, velocity and width were recorded utilizing sediment ranges from 0.190mm to 0.285 mm and slope of 0.00143, 0.000875 and 0.0015 for a range of flow rate at three different cross-sections. The Ordinary Least Squares (OLS) regression method was employed to model the relationship between the dependent variable (velocity-V) and the independent variables (flow depth-d, aspect ratio- β, and hydraulic radius-D) as presented in the Eq.-1. The relationship expressed in below:

$$V=1.928*d^{0.025}*\beta^{0.124}*D^{0.66} \quad \text{Eq. (1)}$$

The regression analysis yielded an R^2 value of 0.891, indicating that the model explains a significant portion of the variability in flow velocity. The plot of observed versus predicted velocities exhibited a high level of agreement, verifying the model's resilience. The observation made during the experiment suggests that the ripple size grows with larger particle size affecting the flow resistance.

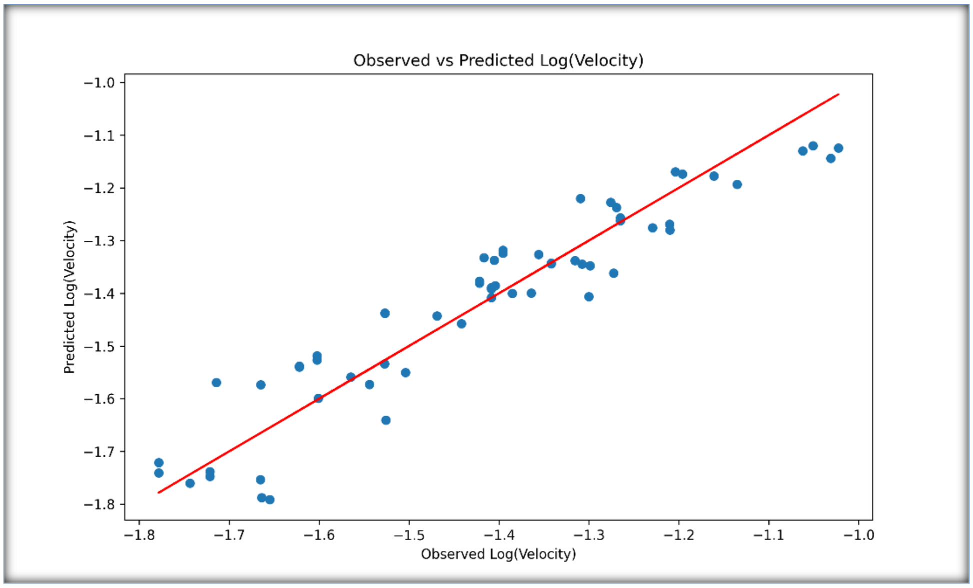

Fig-1: Observed Vs Predicted velocity in Log scale

4. CONCLUTION

Flow resistance processes are at the core of research on fluvial sediment transport, flow dynamics and channel morphology.

- The observed vs. predicted graph generated using Ordinary Least Squares (OLS) regression, demonstrates a strong linear relationship between the observed and predicted log-transformed velocity values.
- The coefficient of determination (R^2) is 0.891 shows a good fit, indicating its suitability for predicting log-transformed velocity under the conditions tested.

However, there are a few points where the predicted values deviate slightly from the observed values, indicating potential areas for further model refinement.

5. REFERENCES

1. Garde, R. J., and KG Ranga Raju. "Resistance relationships for alluvial channel flow." *Journal of the Hydraulics Division* 92.4 (1966): 77-100.
2. Karim, Fazle. "Bed configuration and hydraulic resistance in alluvial-channel flows." *Journal of Hydraulic Engineering* 121.1 (1995): 15-25.
3. Maddock Jr, Thomas. "Equations for resistance to flow and sediment transport in alluvial channels." *Water Resources Research* 12.1 (1976): 11-21.
4. Robert, Andre. "Flow resistance in alluvial channels." *Progress in physical Geography* 35.6 (2011): 765-781.
5. Das, Amit, Bibhas Chandra Barman, and Nityananda Nandi. "On some aspects of flow characteristics of the bifurcated channel–An experimental approach." *ISH Journal of Hydraulic Engineering* 29.2 (2023): 147-153.