Flow Measurement and Instrumentation 61 (2018) 15–25

Contents lists available at ScienceDirect

Flow Measurement and Instrumentation

journal homepage: www.elsevier.com/locate/flowmeasinst

Measurement of dimensionless Chezy coefficient in step-pool reach (Case Study of Dizin River in Iran)

Abbas Torabizadeh[a], Ahmad Tahershamsi[a,*], Mohammad Reza Majdzadeh Tabatabai[b]

[a] Faculty of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
[b] Faculty of Water and Environmental Engineering, Shahid-Beheshti University, Tehran, Iran

ARTICLE INFO

Keywords:
Step-pool
Flow resistance
Mountain streams
Chezy coefficient
Dizin River

ABSTRACT

Step–pool reaches are common bed forms in mountainous streams exceeding 3% gradient and provide an important means of flow resistance in steep rivers. Step-pool channels are characterized by longitudinal steps formed by large boulders which are constituted into discrete channel-spanning accumulations that separate pools comprising finer grain. Flow resistance, reflected by roughness materials, appears to be an important control on bed load transport rates and mean flow velocity. To estimate flow resistance some morphological features and velocity were measured in the step-pool channel of Dizin River, located in Karaj River watershed in Iran. Topographic surveys and bed sediment sampling were made in low flow condition while three-dimensional velocity measurements were made in low, medium and high flow conditions. As flow resistance is a function of geometric, bed material size, longitudinal slope and hydraulic radius, dimensional analysis was conducted to derive a non-dimensional relationship for Chezy coefficient in step-pool reaches. Thereafter, it was calibrated for the measured data set of Dizin, Ammameh and Rio Cordon. Comparable results of calibration with a river located in a different environment may suggest that flow resistance features in semi arid and humid streams may have similar effects on non-dimensional Chezy coefficient.

1. Introduction

Step-pool system is recognized by a regular series of steps, similar to a staircase in the bed of the stream [1]. Step-pool bed forms were identified at low discharges following the morphological classification of Montgomery and Buffington [1].

For large bed element channels, previous researches [2,3] suggested that the flow resistance is mainly due to the pattern and the arrangement of the roughness elements in the channel. In this status, a power flow resistance law is more suitable [4]. Frequently discharge or velocity measurements are not easily performed, and the stage discharge equation for the uniform flow condition is obtained by a flow resistance relationship. The Chezy, the Manning, and the Darcy–Weisbach equations are the most commonly applied empirical flow resistance equations [5].

Hydraulics in step-pool stream differ substantially from low gradient streams as a result of the spill resistance obtained by tumbling flow and hydraulic jumps, which dominates total flow resistance [6–8]. Therefore, existing formulas for calculating flow resistance or sediment transport in low gradient streams, where element roughness is often supposed to be the main factor of flow resistance, have considerable error when used to step-pool and other steep streams [6,7].

Studies of flow resistance dynamics have explored methods for prediction of roughness coefficients as a function of factors such as relative submergence [9], step geometry [10], or unit discharge and hydraulic geometry [11–14]. Based on flume experiments, Wilcox et al. [15] concluded that the combined effects of woody debris and spill resistance dominate total flow resistance in step-pool streams, whereas grain resistance is relatively small. Observations of elevated sediment transport rates following an exceptional flood that destroyed steps in the Erlenbach, Switzerland, illustrate how form resistance can decrease as a result of step destruction [16]. Zimmermann [12], however, suggests that stress partitioning is inappropriate for steep channels where grains actually impart form resistance, as opposed to the skin resistance associated with grains in lower-gradient systems [17].

Giordano and Ferro (1997) illustrated that The differences between the experimental values of the friction factor $C/\sqrt{g}$ and the estimated ones were described by the ratio between the Shields parameter τ^* and its critical value τ^*_{cr}. The critical value τ^*_{cr} was calculated by taking into account that the threshold of grain movement depends on the stability of individual large elements and their concentration. The flow resistance law gives decreasing values of $C/\sqrt{g}$ when $\tau^*/\ \tau^*_{cr}$ increases [18].

* Corresponding author.
E-mail addresses: abbas2929@aut.ac.ir (A. Torabizadeh), tshamsi@aut.ac.ir (A. Tahershamsi), m_majdzadeh@sbu.ac.ir (M.R.M. Tabatabai).

https://doi.org/10.1016/j.flowmeasinst.2018.03.012
Received 13 April 2017; Received in revised form 13 February 2018; Accepted 18 March 2018
Available online 20 March 2018
0955-5986/

Nomenclature

H_{crest}	total drop (of the bed) between step, (m)
H_{max}	total drop (of the bed) between step and pool, (m)
H_r	residual pool depth, (m)
H_s	step height, (m)
L_s	step length, (m)
L_i	pool length, (m)
C^*	dimensionless Chezy coefficient
n	number data
V	average flow velocity, (m/s)
g	acceleration due to gravity, (m^2/s)
R	hydraulic radius, (m)
S_f	energy slope
f	Darcy-Weisbach roughness coefficient
S	average slope of the river
H	step height, (m)
L	step length, (m)
D_i	diameter of the bed material size, (m)
i	percentage of material finer
q	flow per channel width, ($m^3/s/m$)
ρ	fluid density, (kg/m^3)
y	water depth, (m)

Ferro [19] used the two concepts of complete and incomplete self similarity to theoretically deduce the flow velocity profile which was integrated for obtaining the flow resistance law. The theoretical study is supported by field measurements of flow velocity, water depth, river width, and bed slope carried out by Reid and Hickin [20] in 653 reaches of several Canadian steep mountain streams. This analysis allow an estimate of the Darcy–Weisbach friction factor which is more accurate than that obtainable by the approach of Rickenmann and Recking [21] even when it is recalibrated by the field data used in this research.

Although there are many field and experimental studies, regarding flow resistance of step-pool streams, resulting in various empirical relationships. Here in this paper, attempts are made to have an in-depth understanding of step pool reaches of mountain streams in a semi-arid environment to include both channel geometry and flow

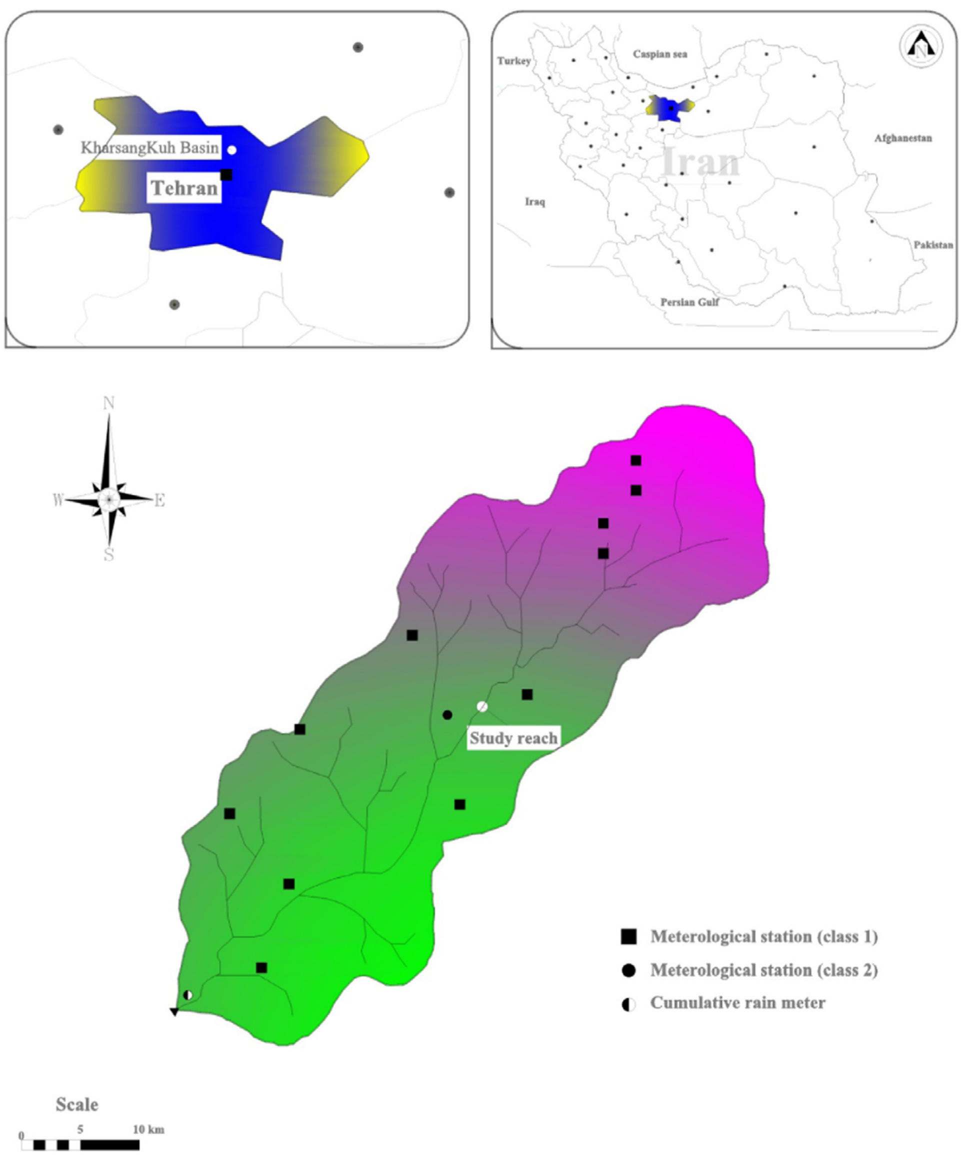

Fig. 1. Study area of Dizin step-pool.