RCEM 2019

THE 11TH SYMPOSIUM ON RIVER, COASTAL AND ESTUARINE MORPHODYNAMICS

BOOK OF ABSTRACTS

AUCKLAND, NEW ZEALAND
16TH–21ST NOVEMBER 2019

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International Association for Hydro-Environment Engineering and Research
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2019

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Dune bed-form contribution to flow resistance in sand river

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1. Introduction

One of the more relevant feature of alluvial sediment-laden channels concerns flow resistance, which depends on many factors, mainly including grain resistance and form drag. A possible approach consists of separate the global flow resistance into two contributions, due to the surface roughness and to the macro roughness. In terms of energy gradient it leads to *S=S'+S'*, where *S'* refers to the dune surface and *S''* to a cumulative losses due to a sudden flow expansion just downstream the dune crest. Based on momentum and energy balance equations, and accounting for hydrostatic pressure distribution, a semi empirical approach is herein proposed to estimate dune bed contribution to flow resistance.

2. Dune bed contribution to flow resistance

Two dimensional steady fully developed turbulent flow in a sediment laden channel is considered (Figure 1). Energy balance equation are applied to the reference control volume of a portion of 2-D dune bed bounded between cross section 1 (i.e., the crest of the dune), and cross section 2 (i.e., the stagnation point on the lee side of the dune) where the streamlines are assumed to be parallel

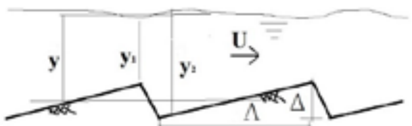

Figure 1: Sketch of 2-D dune bed

Considering a vertical lee side of the dune, and accounting for hydrostatic pressure distribution over the cross section 1 and 2, and after mean water depth *y* has been introduced, we obtain:

$$S'' = \kappa_{\Delta/y}\frac{\Delta H''}{\Lambda} = \kappa_{\Delta/y} F^2 \frac{y}{\Lambda}\Gamma_{\Delta/y} \qquad (1)$$

$$\Gamma_{\Delta/y} = \frac{2\left(\Delta/2y\right)}{\left[1-\left(\Delta/2y\right)^2\right]^2} \qquad (2)$$

where empirical correction coefficient $\kappa_{\Delta/y}$, which is function of the relative dune height Δ/y, is introduced in order to account for energy losses at negative steps are higher for inclined steps than for abrupt vertical steps (Tokyay and Altan-Sakarya, 2011), and for the actual pattern of stream flow and dune bed geometry. Once the measured energy slope *S* and the measured bed dune geometry are known, and after *S'* is calculated assuming logarithmic stream velocity profile and Nikuradse equivalent roughnes $k_s'=2.5d_{50}$ (being d_{50} the mean diameter), it is possible to determine the empirical coefficient $\kappa_{\Delta/y}$. Based on a selection of 122 field data collected on different sand rivers in presence of dune, the best fitting equation results:

$$\kappa = 0.14 \cdot e^{-1.2\Delta/y} \qquad (1)$$

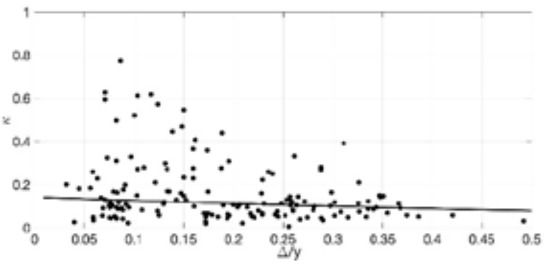

Figure 2: Fitting of empirical coefficient $\kappa_{\Delta/y}$

2. Model validation

The proposed model (Equations 1-3) has been validated, considering 524 field data observed in 15 rivers (Brownlie 1981). To this aim, the relative dune height Δ/y and the relative dune length Λ/y was chosen following Karim (1999) and Yalin (1964) respectively, in order to calculate *S''* (Eqs. 1-3). Hence, the contribution due to skin roughness *S'* and eventually the total energy grade *S=S'+S''* has been estimated. Figure 2 shows the comparison between predicted and measured *S.*

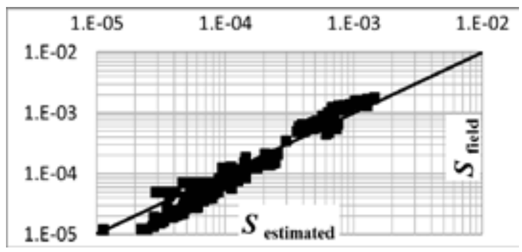

Figure 3: Model validation (303 field collected data)

3. Conclusions

Dune bed contribution to flow resistance is derived accounting for semi-empirical relationship based on momentum and energy balance equations applied to free surface flow over undulated bed, assuming hydrostatic pressure distribution. Comparison with large field dataset of sand rivers shows a satisfactorily agreement.

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