COMPARISON OF SEVEN PARTICLE SETTLING VELOCITY FORMULAE FOR EROSION MODELLING

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Abstract

Soil erosion and deposition models based on the governing mass balance equation require knowledge of the settling characteristics of sediment. Seven formulae were selected from the literature for comparison in terms of their prediction of settling velocity. Two sets of measured settling velocity data found in the literature were used in the comparison. Results show that some formulae performed better in certain ranges of the grain size distribution. They also show that some formulae resulted in better overall prediction than others.

Additional Keywords: deposition, grain size

Introduction

The settling characteristics of sediment affect whether or not sediments of a particular size class experience erosion or deposition during an erosion event. Soil erosion and deposition models based on mass balance capture this effect by accounting for the "depositability" of sediments defined as the average settling velocity of sediments in suspension. Therefore, it is crucial that a formula that gives reasonable prediction of the settling velocity is used. To select a reliable formula to estimate settling velocity from particle size data, seven settling velocity formulae from the literature are evaluated using two sets of measured data. Relative error and a model efficiency coefficient were used to compare these models.

Materials and Methods

Datasets used

Two measured datasets were used to evaluate the performance of seven formulae used to determine settling velocity of soil particles of various sizes. The sources of these datasets are Raudkivi (1990) and VanRijn (1997).

Models compared and methods of comparison

The seven formulae compared in this study are: (i) Sha (1956), (ii) Concharov (Cheng, 1997), (iii) Dietrich (1982), (iv) Rubey-Watson (Dingman, 1984), (v) VanRijn (1989), (vi) Zhang (1989), and (vii) Cheng (1997). The performances of these models were evaluated by visually inspecting settling velocity versus sediment size graphs from each model with measured values. Moreover, relative errors and a model efficiency measure, denoted E (Nash and Sutcliffe, 1970), were used to rank the performance of these settling velocity formulae.

Results and Discussion

Figure 1 shows both measured and predicted settling velocities (cm/s) as a function of sediment size. It can be seen from Figure 1 that the Rubey-Watson formula produces negative settling velocity values for sediment finer than 0.0228 mm and should not be used for sediments finer than this value. It can also be seen from Figure 1 that the settling velocity of finer sediment is better calculated using either the formula of Dietrich (1982). On the other hand sediments in the medium and coarse size ranges are better calculated using the formula of Zhang (1989). Figure 2 shows measured settling velocity values plotted against those predicted from the seven formulae. Despite some formulae being more suitable for specific range of sediment sizes, both Figure 1 and Figure 2 show that the predictions from all seven formulae are in close agreement with the measured settling velocity values.

The performance of the seven formulae was evaluated by comparing the relative errors and the model efficiency measure, E. Tables 1 and 2 show the average errors and E values using the datasets of (Raudkivi, 1990) and (VanRijn, 1997).

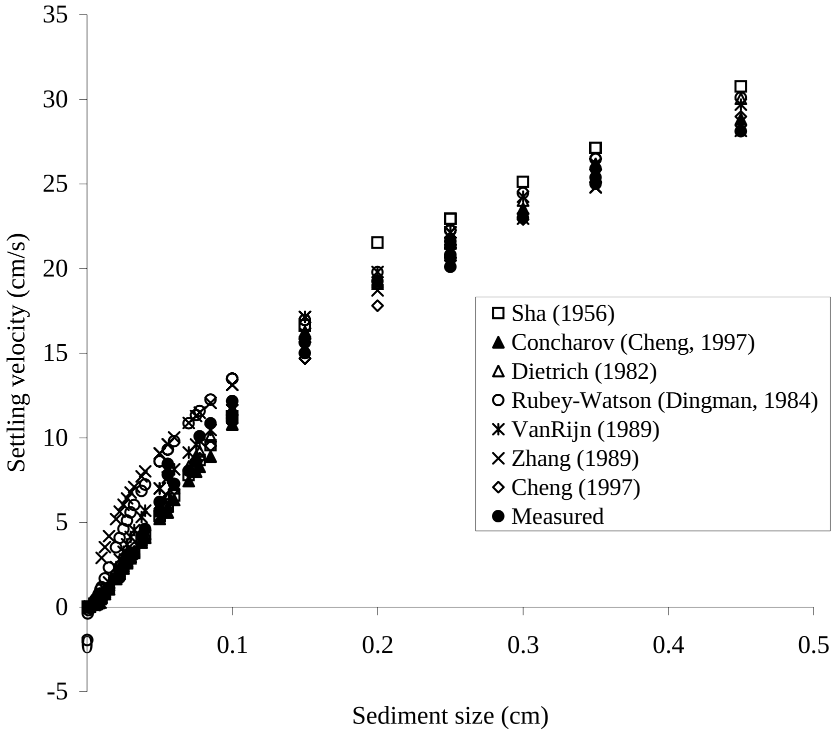

Figure 1. Settling velocity plotted against sediment size

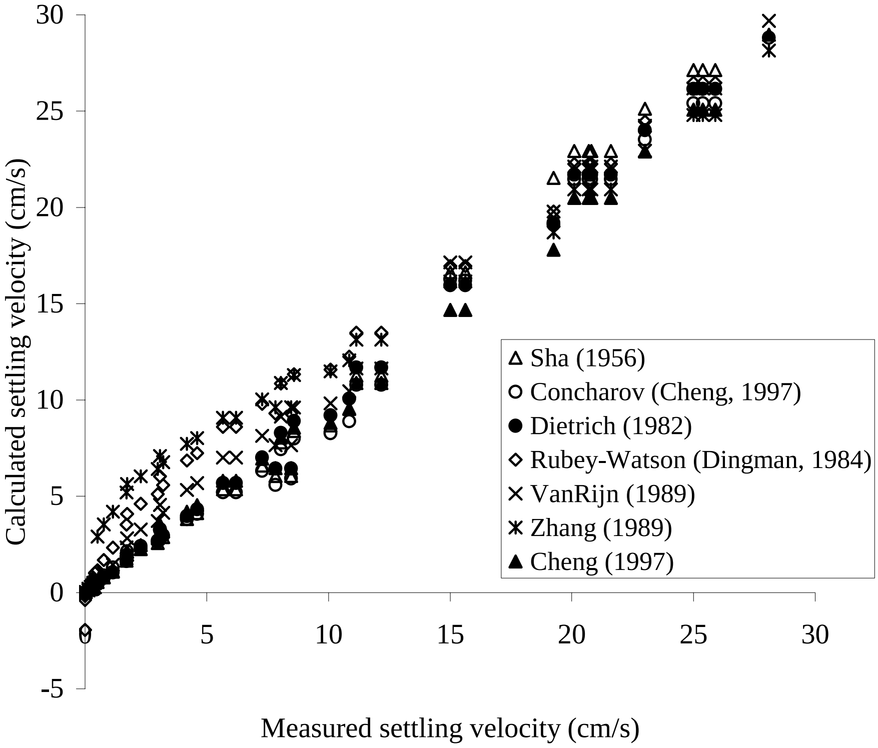

Figure 2. The plot of measured settling velocity against calculated settling velocity

Table 1. Relative error and model performance values for the dataset of Raudkivi (1990)

Formula	**Average error %**	**Model efficiency, E**
Sha (1956)	10.0	0.997
Concharov (Cheng, 1977)	8.6	0.997
Dietrich (1982)	26.3	0.995
Rubey-Watson (Dingman, 1984)	44.0	0.995
VanRijn (1989)	8.7	1.000
Zhang (1989)	49.0	0.986
Cheng (1997)	9.1	0.999

Table 2. Relative error and model performance values for the dataset of VanRijn (1997)

Formula	**Average error %**	**Model efficiency, E**
Sha (1956)	8.9	0.981
Concharov (Cheng, 1977)	9.3	0.991
Dietrich (1982)	28.5	0.971
Rubey-Watson (Dingman, 1984)	58.9	0.962
VanRijn (1989)	21.7	0.989
Zhang (1989)	64.5	0.942
Cheng (1997)	5.9	0.995

For the data set of Raudkivi (1990), the formula of VanRijn (1989) gave the highest E value of 1.0, while the formulae of Dietrich (1982) and Rubey-Watson (Dingman, 1984) gave the lowest E value of 0.995. For the dataset of (VanRijn 1997), the formula of Cheng (1997) gave the highest E value of 0.995, while the formula of Zhang (1989) gave the lowest E value of 0.942). Overall, comparing averages of E values from the two datasets, it appears that the formula of Cheng (1997) is the best settling velocity formula, although the other formulae are not far behind.

Conclusions

Using model efficiency (E) as measures of model performance, and using the average of the two datasets used in this study, the settling velocity of Cheng (1997) has been found to be the best of the seven settling velocity formulae compared. However, the formula of Dietrich performed better in the finer sediment size range while the formula of Zhang performed better in the medium and coarser sediment size ranges. Therefore, the choice of suitable formula depends on the sediment size range under investigation.

Acknowledgements

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