II - 97 Influence of Suspended Sediment on the Steepness of Sand Waves

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Introduction

One of the major problems in dealing with stage-discharge prediction for alluvial channels is the occurance and break down of bed forms. In the past few decades, despite the success in understanding the initiation and growth process of sand waves is achieved, precise approach to their characteristics and quantitave prediction of their size remains mainly on a rough empirical formulae. Moreover, the reason or the principle which causes the growth process of sand waves to halt at a particular stage is attended by a considerable uncertainty. In this paper, the attention is focused on the geometrical characteristics of sand waves by investigating the steepness of triangular forms simulating dunes and ripples. The theoritical approach to the problem is based to a certain extent on the theory, advanced by Watanabe and Hirano[1]. Steepness of sand waves is derived as a function of the arrangement of parameters characterizing the flow, fluid and sediment properties.The effect of suspended sediments is taken within the scope of the study and a comparison between theoritical results and references data which collected from rivers and experimental flumes is conducted.

Dimensions of Sand Waves

Based on the theory of Watanabe and Hirano[1], and according to the authors's previous study[2], the characteristic wave length was obtained from the dominant wave number equation.The analysis was conducted, based on the concept that the dominant wave number β corresponds to the maximum growth rate of bed disturbance. The value of β is derived analytically from the real part of the complex propagation velocity. The wave number and wave length equations are derived as

$$\beta = K_c \left(\frac{1}{F^2} - 1 \right)^{1/2} , \qquad L = \frac{2\pi h}{\beta} \tag{1}$$

where L is the wave length, h is the water depth in uniform flow and F is the Froude number.The coefficient K_c is equal to 0.63 and 1.4 for both dunes and ripples. On the other hand, according to the study by Watanabe and Hirano[3], the height of fully developed sand waves is obtained though it is shaped as trianguler with gentle upstream slope and steep downstream slope as shown in Fig.1. Hence, by using the developed equations for sand waves length and height, the steepness equation is derived in the form

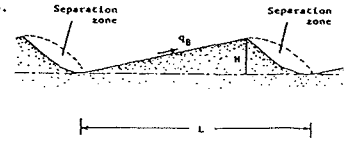

Fig. 1 Schematic sketch of sand waves

$$\frac{H}{L} = 0.16 \, \frac{\beta}{\omega} \cdot \frac{1 - e^{-\alpha_1 (2\pi/\beta) W} + (2\pi/\beta)(1 - \alpha_1) W}{1 - \dfrac{1}{\alpha_1 (2\pi/\beta) W} \left(1 - e^{-\alpha_1 (2\pi/\beta) W}\right)} \tag{2}$$

Where ω is the dimensionless migration velocity of sand waves, W is a function of suspended sediment, H is the wave height and α_1 is a constant equal to 0.67.

To examine the dominant parameters which have influence on the wave steepness, the imaginary part of the complex propagation velocity in Watanabe and Hirano study[1] is used as the dimensionless propagation velocity ω. The solution for the steepness H/L is proposed as follows

$$\frac{H}{L} = f_1 \left(F , \psi , \frac{h}{d} , \frac{w_0}{u_*} \right) \tag{3}$$

Effect of Suspended Sediments on the Steepness

Numerical solution for Eq.2 has been conducted, considering the four previous parameters. Figures 2 and 3 give a family of of curves relate between H/L versus F and ψ, respectively. The parameters used in both graphs are h/d and w_0/u_*. Figure 4 shows the relation between H/L and h/d with the parameter F for different values of w_0/u_*. From Figs.2 and 3, one can notice that H/L increases with the increasing of F, ψ and h/d until it reachs its maximum value then it tends to break down. In Fig.4 the curves increase monotonously with the increase of h/d, then they keep approximately horizontal in the higher value of h/d. In particular, it is noticed that the sand waves steepness is heigher when the intensity of the suspended load is relatively high. This effect disappears for low values of Froude number F during the developing process of the sand waves, or for high intensity of tractive force during the decay of these waves.

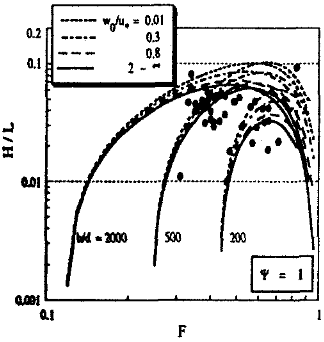

Fig.2 Relation between F and H/L with parameter w_0/u_*.

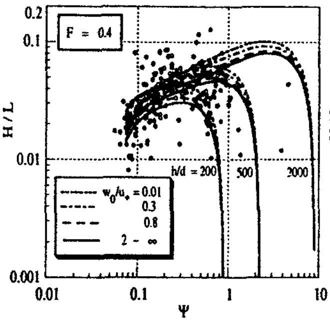

Fig.3 Relation between Ψ and H/L with parameter w_0/u_*.

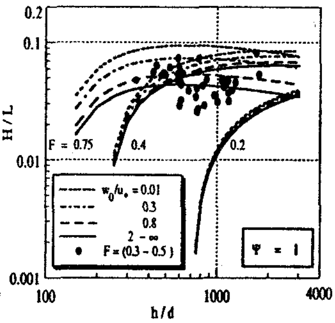

Fig.4 Relation between h/d and H/L with parameter w_0/u_*.

Some Remarks about the Decay of Sand Waves

Figures 2, 3 and 4 furnish a specific opportunity to contribute to reveal the sand waves disappearance. Also, Fig. 5 shows the effect of suspended sediments on the breakdown of sand waves. From the whole presented figures, it is noticed that the gravity force represented by the parameter F and the tractive shear force represented by ψ are apparently play a central role for sand waves growing process till the peak then the decay process takes part after a certain limit.The other pertinent parameters (h/d and w_0/u_*) have indirect effect on the decay process by accelarating or deccelarating the breakdown of the wave.

$$\left(\frac{H}{L}\right)_{max} = f_2 (F , \psi) \quad (4)$$

Comparison with Experimental Results

In Fig.6, H/L from Eq.2 is compared with the measured data of both dunes and ripples, presented by Guy, Simons and Richardson[4] among others. Despite the scattering, the agreement line in both graphs lies in the average of the plotted marks and proves the feasibility of the approach. The range of the data parameters is shown in Table 1.

h/d	100 ~ 3000
F	0.15 ~ 0.85
ψ	0.06 ~ 3
w_0/u_*	0.01 ~ 3

Table 1 Range of data parameters

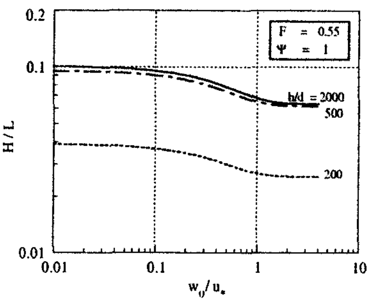

Fig.5 Relation between w_0/u_* and H/L

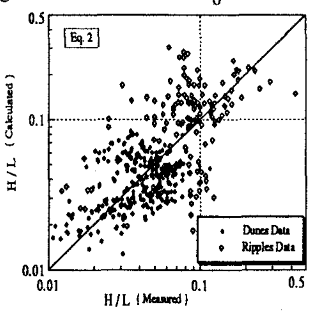

Fig. 6 Comparison of steepness from present equation and measured data

Conclusions

The steepness function is dominated by four distinct parameters representing Froude number, dimensionless tractive force, dimensionless flow depth and suspended sediment · The factor w_0/u_* undoubtly plays a major role in controling wave steepness with the contribute to F and ψ values.The results lead to intriguing possibility of explaining qualitatively the instability of equilibrium sand waves when converted to a flat bed.The results from the proposed equation for steepness yield a good verification with measured data for sand waves collected from several reliable sources.

References

1) Watanabe, K. and Hirano, M.(1988): Effect of Suspended Sediment on Formation of Sand Waves, Journal of Hydroscience and Hydraul. Eng., Vol. 6, No 2, pp. 29-43.
2) Watanabe, K., Hirano, M. and Nagy, H. (1992) : On the Dominant Length of Sand Waves in the Lower Flow Regime, Memoirs of the.Faculty of Eng., Kyushu Univ., Vol. 53, No. 1.
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