STEEPNESS OF SAND WAVES

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Introduction

It is well known that investigating on bed forms characteristics requires a full understanding of two fundamental process: one is the bed forms initiation process, the second is there growth process until a certain limit then it stop. In the past few decades, a few number of studies were conducted to relate the dimensions of sand waves, to the flow and the bed material properties. Almost of the proposed relations, either analytically or graphically, simulated the sand waves steepness as a unique function of the tractive shear stress, and the other pertinent factors were ignored.

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]. The steepness of sand waves is derived as a function of the arrangement of parameters characterizing the flow, fluid and sediment properties.The suspended sediments effect is taken within the scope of the study and a comparison between theoritical results and references data collected from rivers and experimental flumes is conducted.

Steepness 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

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

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

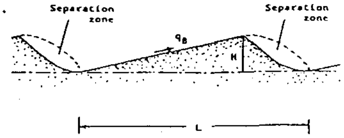

Fig. 1 Schematic sketch of sand waves

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

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 enfluence 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

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

Suspended Sediments and Steepness

Numerical simulation 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_*. Also, Fig.4 shows the relation between H/L and h/d with the parameter F for different values of w_0/u_*. From Figs.2, 3, one can notice that the steepness of sand waves increases with the increase of the parameters F , ψ and h/d until it reachs its maximum value then it tends to break down, while in Fig.4 the curves increase monotonously with the increase of h/d then they keep approximately horizontal in the higher value ofh/d . In particular, the presented graphs devote some sights towards revealing the relationship between the sand waves geometry and the suspended sediments enfluence,and, 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.

The Mode of Maximum Steepness and Decay of Sand Waves

As a result, the presented Eq.2 implies that the dimensions of sand waves is undoutly affected by the whole forementioned contributing factors in Eq.3. Also, Figs.2, 3 and 4 furnish a specific opportunity to contribute to reveal the sand waves disappearance. Also much attention has been devoted to studing the effect of suspended sediments on the breakdown of sand waves, therefore, 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.

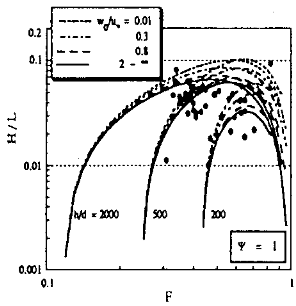

Fig.2 Relation between F and H/L with parameter w_0/u_*.

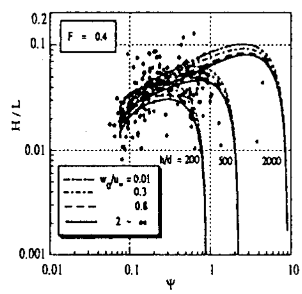

Fig.3 Relation between Ψ and H/L with parameter w_0/u_*.

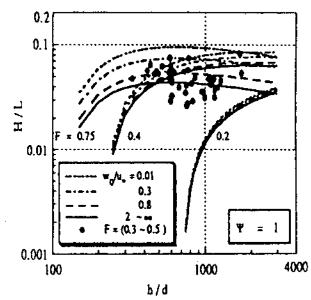

Fig.4 Relation between h/d and H/L with parameter w_0/u_*.

Comparison with Experimental Results

In Fig.5, 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

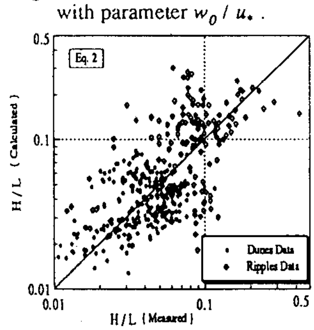

Fig. 5 Comparison of steepness from present equation and measured data

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_* is undoubtly plays a major role in controling wave steepness with the contribute to F and ψ values.The results leads 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 good verification with measured data for sand waves collected from several sources.

References

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