SUMMARY OF SAND WAVES AND REGIMES OF FLOW
IN ALLUVIAL CHANNELS

by

R. J. Garde

and

M. L. Albertson

Civil Engineering Section
Colorado State University
Fort Collins, Colorado

CER60MLA24

SUMMARY OF SAND WAVES AND REGIMES OF FLOW IN ALLUVIAL CHANNELS

by

R. J. Garde

and

M. L. Albertson

Civil Engineering Section
Colorado State University
Fort Collins, Colorado
(U. S. A.)

CER60MLA24

SUMMARY OF SAND WAVES AND REGIMES OF FLOW IN ALLUVIAL CHANNELS

by

R. J. Garde*
and
M. L. Albertson**

When the characteristics of the flow, the fluid and/or the sediment are changed, the nature of the bed and/or water surface changes and takes different forms. These types of bed and water surfaces are classified according to their characteristics and are called Regimes of Flow. For convenience, these regimes can be divided as follows:

1. Plane-bed (without motion of sediment particles)
2. Ripples and dunes
3. Transition (including bars and flat bed)
4. Standing waves and antidunes

Descriptions of different regimes

In the plane-bed regime (without motion of sediment particles), the average shear stress τ_o on the bed is less than the average critical shear stress for that bed material, and hence the sediment does not move.

With further increase in shear stress, ripples are formed on the bed and they grow into dunes as the shear stress is increased still further. The ripples and dunes have a gentle upstream face and a steep downstream face. Dunes are also characterized by boils rising on the water surface from the separation zone downstream of large dunes.

If the shear stress τ_o is further increased, the flow enters transition regime which may have washed-out dunes, sand-bars, or flat-bed as its bed surface, and the water surface may take the form of boils of plane surface.

* Lecturer, University of Roorkee, Roorkee, India.

** Director of Research Foundation and Professor of Civil Engineering, Colorado State University, Fort Collins, Colorado.

When τ_0 and Froude number values are further increased, the bed forms are standing waves and antidunes. In this regime standing waves are created, which are symmetrical sand and water waves in phase. Finally, still greater shear causes these to move upstream and break intermittently.

Criteria for beginning of motion and beginning of ripple formation

Shields (1936) has suggested a criterion for beginning of motion of sediment particles in which $\frac{\tau_0}{(\gamma_s-\gamma_f)d}$ is related to $\frac{V_* d}{\nu}$. Recently Iwagaki (1956) has given an analytical proof for the criterion for beginning of motion. Based on the instability concept of the interface between flow and the movable bed, Liu (1957) and Plate (1957) have developed a criterion for the beginning of ripple formation. Liu has also shown that in a small range of τ_0 the sediment may move and the bed will be plane -- just as Tison (1949) found for laminar flow.

Characteristics of ripples and dunes

From the point of view of dimensional analysis, it can be shown that

$$\frac{h}{\lambda} = f\left[\frac{\tau_0}{(\gamma_s-\gamma_f)d}, \frac{V}{\sqrt{gD}}, \frac{V_* d}{\nu}, \frac{d}{D}, \sigma\right] \quad (1)$$

The shear term can be arranged in perhaps a more significant form as

$$\frac{\tau_0}{(\gamma_s-\gamma_f)d} = \frac{4}{3}\left(\frac{V_*^2/\omega^2}{C_D}\right)$$

With certain assumptions, Eq 1 can be reduced to

$$\frac{h}{\lambda} = f\left[\frac{\tau_0}{(\gamma_s-\gamma_f)d}, Fr, \frac{V_* d}{\nu}\right] \quad (2)$$

With the help of experimental data it has been found that when the ripples are formed on the bed, the relationship

$$\frac{h}{\lambda} = f\left[\frac{\tau_0}{(\gamma_s-\gamma_f)d}, \frac{V_* d}{\nu}\right] \quad (3)$$

is true, see Fig. 1, while for the case of dune bed, the functional relationship takes the form, see Fig. 2.

$$\frac{h}{\lambda} = f\left[\frac{\tau_0}{(\gamma_s-\gamma_f)d}, Fr\right] \quad (4)$$

Thus it is shown that the transition between ripples and dunes is also the transition from viscosity effects being of major importance and gravitational effects of minor importance to viscous effects being of minor importance and gravitational effects of major importance.

Criteria for regimes of flow

Langbein (1942) showed that VD and Fr are significant parameters which govern regimes of flow. Albertson, Simons, and Richardson (1958) plotted $\frac{V_* d}{\nu}$ against $\frac{V_*}{\omega}$ for all experimental data available to them and presented generalized criterion for different regimes of flow. This plot demonstrates significant facts regarding the influence of viscous effects, but it also has limitations in its application to large streams. Based on the studies reported herein, and other studies of the writers, the writers present $\frac{\tau_0}{(\gamma_s - \gamma_f)d}$ vs. Fr criteria, see Fig. 3, for regimes of flow. Flume data as well as natural river data indicate that this relationship has considerable merit.

Notation

τ_0 is the average shear stress on the bed

V_* is the average shear velocity

γ_s and γ_f are the specific weights of sediment and water

D is the depth of flow

d is the size of bed material

V is the mean velocity of flow

ν is the kinematic viscosity of fluid

σ is the standard deviation of bed material

ω is the fall velocity of sediment

h is the average height of ripples or dunes

λ is the average length of ripples or dunes

C_D is the drag coefficient for a single sediment particle

BIBLIOGRAPHY

1. Albertson, Simons, and Richardson. Discussion of "Mechanics of Sediment-ripple Formation" by H. K. Liu. Proceedings of A. S. C. E. Journal of Hydraulics Division. Feb. 1958, Vol. 84, No. HY-1, p. 1558 - 22-31.

2. Barton and Lin. A study of sediment transport in alluvial channels. Colorado A. and M. College, Fort Collins, Colorado. Civil Engineering Department, Report Number 55 JRB 2 March 1955.

3. Garde. Total sediment transport in alluvial channels. Colorado State University, Ph. D. Dissertation. Civil Engineering Department. January 1959.

4. Gilbert. The transport of debris by running water. U. S. Geological Survey, Professional paper, No. 86, 1914.

5. Iwagaki. Fundamental study on the critical tractive force; Part I, Hydrodynamical study on critical tractive force. Japan Society of Civil Engineers, Transactions No. 41, Dec. 1956 (In Japanese)

6. Langbein. Hydraulic criteria for sand waves. A. G. U. Transactions 1942, Vol. 23.

7. Laursen. An investigation of the total sediment load; Iowa University, Iowa Institute of Hydraulic Research. Final Report to the Office of Naval Research. June 1957.

8. Liu. Mechanics of sediment - ripple formation. Proceedings of A. S. C. E. Journal of Hydraulics Division, Apr. 1957. Vol. 83, No. HY-2.

9. Plate. Studies of sediment-ripple formation. Colorado State University, M.S. thesis. 1957.

10. Simons, Richardson, and Albertson. A study of roughness in alluvial channels. Progress report No. 1. U. S. Geological Survey, Colorado State University, Fort Collins, Colorado. 1958.

11. Shields. Anwendung der Ahnlichkeitsmechanik und der turbulenzforschung auf die geschiebebewegung, Mitteilung der praussischen Versuch sanstalt fur wasserbau und Schiffbau, Heft 26, Berlin, 1936.

12. Tsubaki, Kawasumi, and Yasutomi. On the influence of sand ripples upon the sediment transport in open channels. Kyushu University, Research Institute of Applied Mechanics. Report 1953.

13. Tison, L. J. Crigine des Cndes de Sable et des Bancs de Sable sous l'action des Courants. Association International de Recherches pour Travaux Hydrauliques, Third Meeting, September, 1949, Grenoble, France.

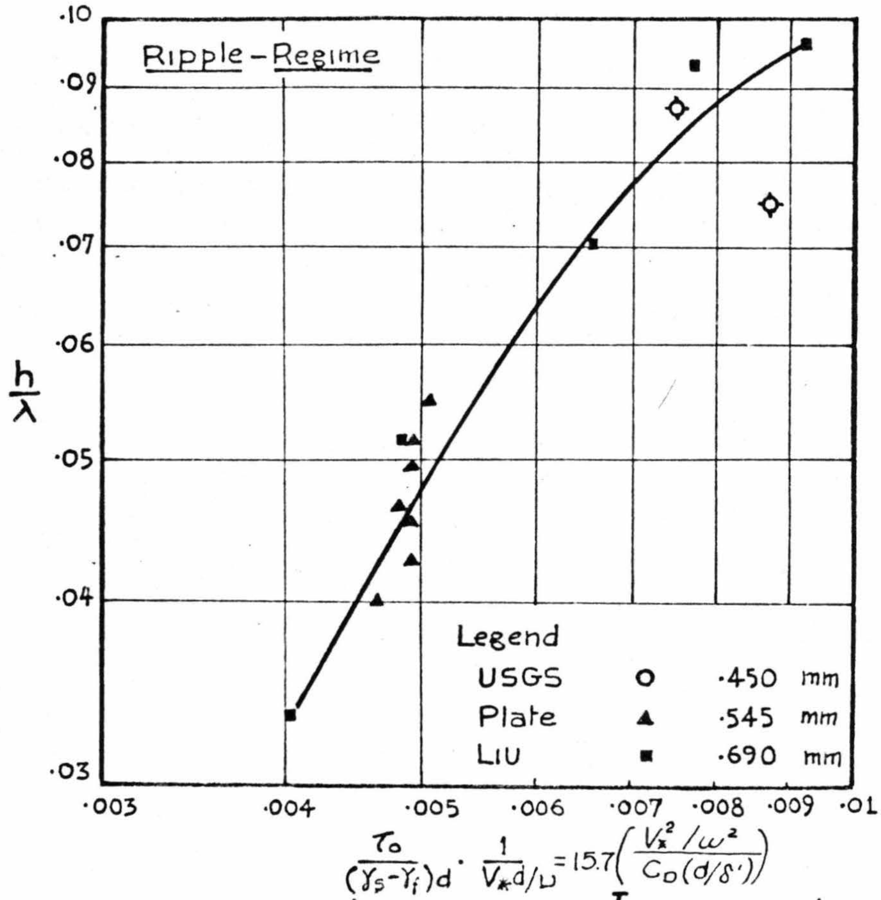

FIG. 1 VARIATION OF $\frac{h}{\lambda}$ WITH $\frac{\tau_o}{(\gamma_s-\gamma_f)d}\cdot\frac{1}{V_* d/\upsilon}$

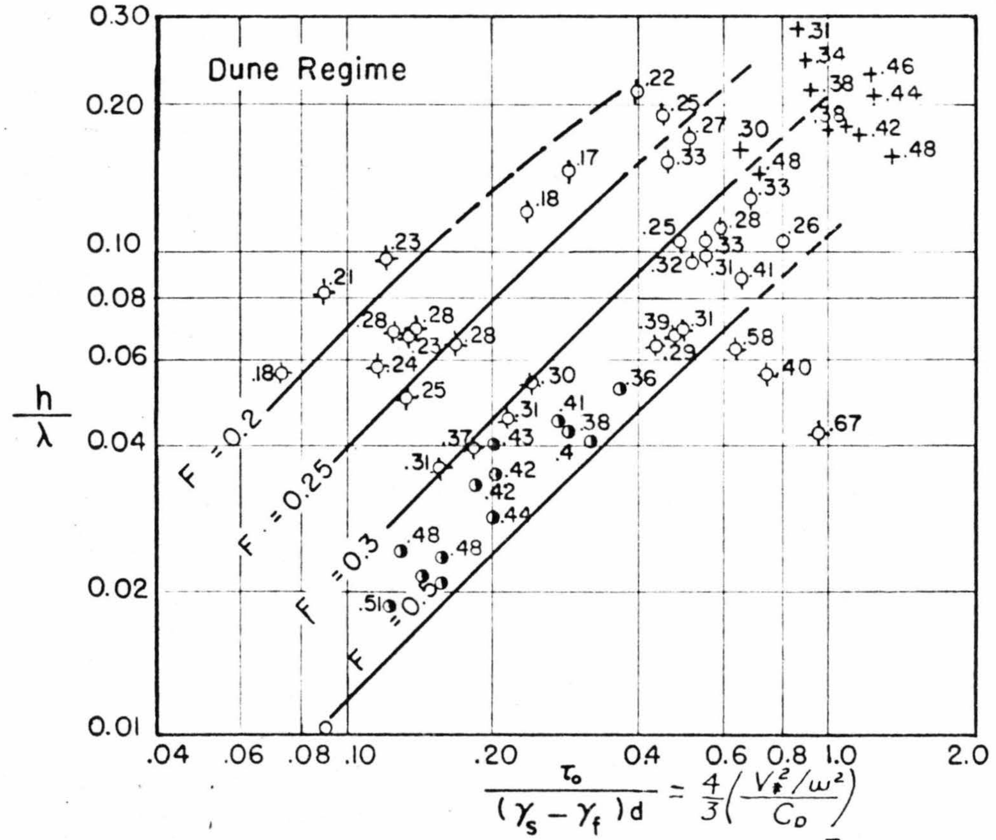

FIG. 2 VARIATION OF $\frac{h}{\lambda}$ WITH $\frac{\tau_o}{(\gamma_s-\gamma_f)d}$ AND F_r

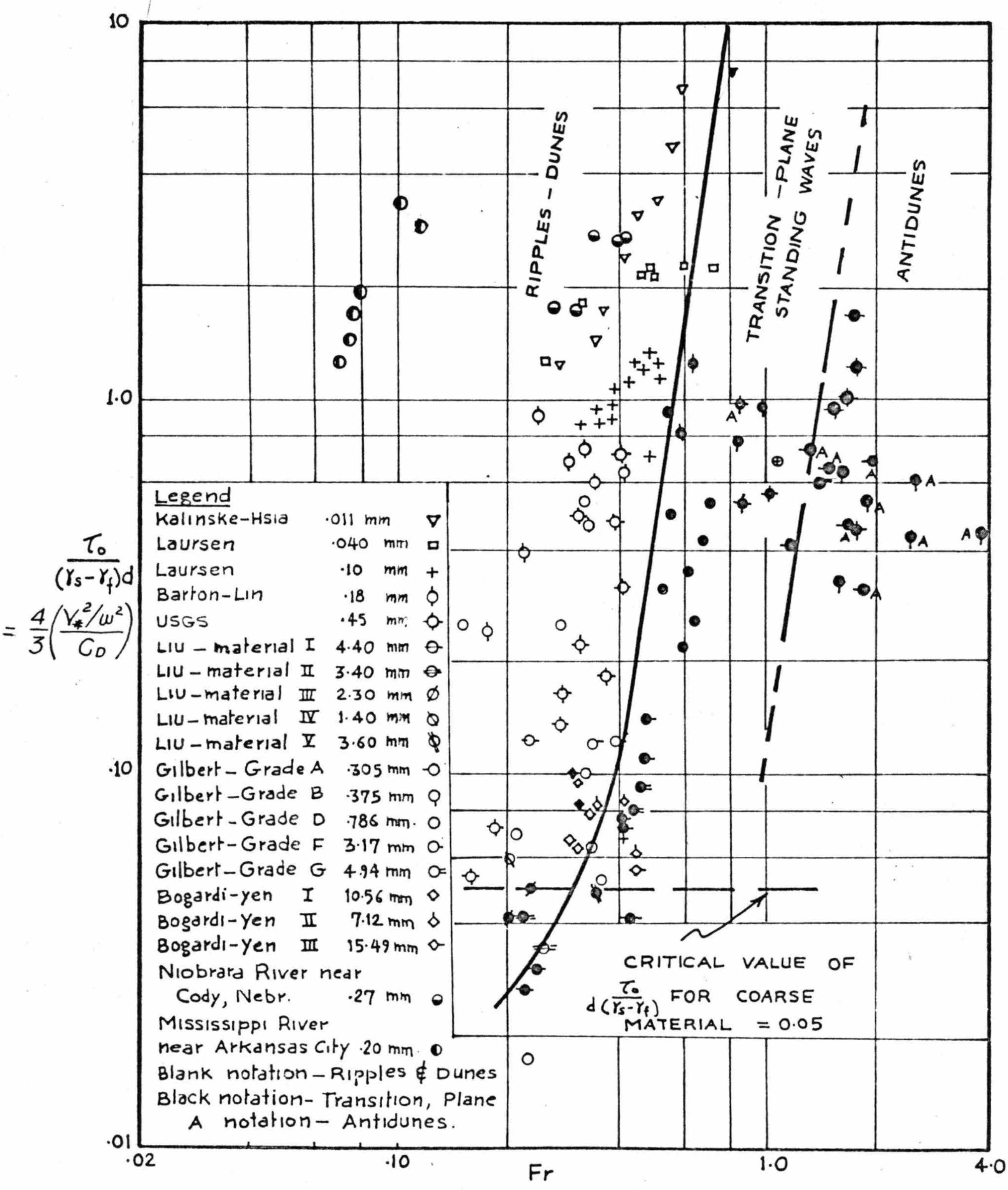

FIG. 3 CRITERIA FOR REGIMES OF FLOW