DISCUSSION OF PAPER TO BE GIVEN BY MR. ERNEST B. LIPSCOMB AT FIFTH HYDRAULICS CONFERENCE OF THE IOWA INSTITUTE OF HYDRAULIC RESEARCH

by
E. J. Carlson, Hydraulic Engineer
Bureau of Reclamation Laboratory

Mr. Lipscomb has given us an excellent discussion and some good examples of the use of hydraulic model studies involving movable beds. I commend the Waterways Experiment Station for utilizing the movable bed model as a tool in assisting the solution of river sedimentation problems.

Too often we see someone tackling a problem involving sediment deposition and movement on the basis of an engineer's or construction man's best guess only to find he has gotten into trouble which could be avoided by use of a model study.

The movable bed model is by no means fool proof for solving hydraulic problems involving sediment transportation and deposition, but when it is used wisely the movable bed model is invaluable in the solution of sedimentation problems.

It has been said very aptly by someone "the construction and use of movable bed models demands considerable care, great skill, and the patience of Job."

The movable bed models Mr. Lipscomb has described are river models in which the length and width of the water section under study is usually great with respect to the depth, and for this reason the model scale is usually distorted in order to cause movement of the bed material and to have the gravity force the controlling force in the model. Where depths are very small, surface tension forces become of comparatively great magnitude and turbulence is not reproduced.

A second kind of movable bed model is that involving a structure such as a diversion dam with a comparatively small headworks and sluiceway compared to the entire structure or river width. In this case it is possible to model the headworks and sluiceway and a portion of the dam in order to study sediment distribution at the headworks and sluiceway. On the streams where sediment load is comparatively heavy, the problem is usually one of trying to keep the sediment intake into the canal as low as possible or low enough to have equilibrium sediment movement in the canal. In which case the same amount of sediment is brought into the canal at any section as is moved out at the same section. In most cases it is difficult to reduce the sediment inflow to this quantity.

For a model of this kind, it is impossible to utilize the verification principle because the answer is needed before the diversion dam is constructed. Where a structure is part of the model, it is best not to use a distorted scale in order to not upset the flow distribution and velocity distribution of the prototype. In a distorted model the lateral velocity distribution, as well as the energy distribution, is changed from what it is in the prototype.

It is impossible to reduce the model sediment on the same scale as the model because sediment which moves as bed load in the prototype would move as suspended load in the model. In other words, the type of movement of sediment would not be the same in the model as it is in the prototype. One method of overcoming this difficulty is to use the scale ratio of the settling velocities between model and prototype sediment as the scale criteria. Within quite wide limits of the scale ratios, sediment chosen on this basis for a model study, will have the same type of movement as the prototype bed sediment. The selection of sediment is usually limited to sand coal, plastics, etc., so it is possible to choose the sediment first and then set the scale ratios to fit the sediment. This relationship of using settling velocities as the scale ratio criteria is usable for both undistorted and distorted models.

An important feature of movable bed models is maintaining a continuous sediment feed with the least amount of man handling. A special device which was developed in the hydraulic laboratory of the Bureau of Reclamation for providing a uniform supply of sediment to a movable bed model consists of a sheet metal hopper mounted so the opening in the bottom is just above a pan on a vibratory-type feeder. The feeder is a trough or pan mounted on flexible leaf springs supported in a frame and vibrated at 60 cycles per second by an electromagnet. The magnet, which is energized by pulsating current, pulls the trough sharply down and back, then when the current is broken with a rectifier, the leaf springs return the pan up and forward to its original position. The return is not as sharp as the downpull and the resulting motion causes material on the pan to move forward even when the pan is sloped upward.

The feeder is equipped with a separate control box which contains the operating switch, a rheostat for controlling speed of flow of material, and an electronic valve or rectifier that converts alternating current into sharp pulsating current. The pulsating current activates the magnet intermittently and thus causes the vibratory motion of the feeder. The hopper and feeder can be arranged so that either dry or damp sand can be fed satisfactorily.

At the present time we are operating a model in which we feed sand with the type of feeder described, and we are able to run it continuous day and night which speeds up the time of reaching equilibrium and hence cuts the time needed for the study considerably.

To study the scour or deposition of the bed and banks, on a movable bed model similar to those described by Mr. Lipscomb, it requires the measuring and recording of many elevations. The larger the model usually the larger the number of elevations are required. An apparatus developed in the Neyerpic Laboratory at Grenoble, France, utilizes an electronic circuit and a recording stylus to increase the speed of taking these bed and bank elevations. The apparatus is a new development and shows promise of greatly reducing the time for measuring scour and deposition in movable bed models. A description of the apparatus is given in the April 1952 issue of La Houille Blanche, the magazine published by the Neyerpic Laboratory.

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Discussion of
"MECHANICS OF STREAMS WITH MOVABLE BEDS OF FINE SAND"
by Norman H. Brooks
(Proc. Sep. No. 668)

E. J. Carlson[1], M.ASCE and M. Gamal Mostafa[2] A.M.ASCE--Some of the conclusions drawn by the author from his limited experimental data seem to contradict well established theories of sediment hydraulics.

Several of the runs gave higher mean velocities or higher sediment transport for lower boundary shears, and from these runs the author concluded that it is impossible to take the shear or the slope as independent variables. What these runs may actually show is the known fact that when there is sediment in transport, the rate of energy dissipation does not depend only upon rate of flow, water section, and sediment size, but also upon the rate of sediment motion and the mode of bed formation both of which are, in turn, dependent upon the hydraulic conditions and sediment characteristics.

In an attempt to analyze the presented data, two points of interest are raised:

1. The total weight of sand used in the flume was 145 pounds which is extremely small, giving a depth of sediment on the flume bottom of approximately 1/2 inch. The author mentions the possibility of such being the reason that fully developed dunes did not change appreciably in height. This could mean that for some runs, due to shortage of sand, the friction was forced to be less than what would naturally occur if the sand were say 2 or 3 inches deep. Ten runs out of the 22 given in the data are reported to have shown sand dunes. For some, if not all, of these runs, one cannot be certain about the validity of deriving any conclusions as regards the relation of discharge to depth and slope, since the friction was more or less restricted.

1. Hydraulic Engineer, Hydraulic Laboratory, Bureau of Reclamation, Denver Federal Center, Denver, Colorado.
2. Associate Director of Works, Hydraulic Research Station, Barrage, Egypt.

2. The total weight of sand in motion was of the order of 0 to 5 percent of the total weight of sand in the flume. The sand particles in the bed were not of uniform size but had a certain gradation, as shown by the mechanical analysis in the author's Figure 3. The particles which were picked up by the flow and particularly after dunes had formed were certainly the smallest in size and, therefore, should not have been represented by the sedimentation mean of the bed. Determining the characteristics of the sediment in motion in each run by analyzing the dry sand from the samples that were taken for determining concentration would probably show an increase in mean size with increase of sediment load.

In spite of the two above-mentioned objections, the author's data should still show some trend if plotted non-dimensionally, save for the runs where friction may have been restricted through the exposure of a part of the flume bottom, because all the variables of flow, rate of transport of sediment, bed formation, and characteristics of both sediment in motion' and in the bed should all be interdependent.

Plotting $G/60\gamma Q$ against slope, Figure 1, different functions for different sand beds would be expected; however, the data has a wide scatter. Now if in every run, a sample of the sediment in motion was analyzed, each run would have certainly yielded a different mean size always lower than the sedimentation mean since the amount of sediment in motion is relatively very small and would necessarily be finer than the average bed material. Data plotted on Figures 1 and 2 would probably fit a group of lines for different sediment sizes if the actual size of the sediment in motion were known in each case.

In Figure 2, $\frac{r_b S}{D}$ is plotted against $G/60\gamma Q$ both being nondimensional ratios. All runs giving dunes follow a certain function while those giving a smooth bed follow another function with the runs having so-called meanders appearing in both functions. It follows that for the same hydraulic conditions as given by r_b, S and Q, two different ratios of sediment to water discharge might have been produced one with a smooth bed and the other time with a dune formation. Yet it is doubtful that this could have actually resulted if every run was carried to sediment equilibrium condition under a uniform flow of water.

If a run was started with a small depth of flow and then the depth was gradually increased, dunes which form at small depths might not have had enough time to be removed. On the other hand, if a run was started with large depth of water and a smooth bed and then the depth was gradually decreased, dunes might not have had enough time to develop. Nonuniformity of the flow, unstability of flow conditions, or nonequilibrium of sediment discharges, or any of these factors combined would necessarily produce errors that seriously affect the results especially when measurements are in such a narrow flume and within such a small range of slope and depth variation.

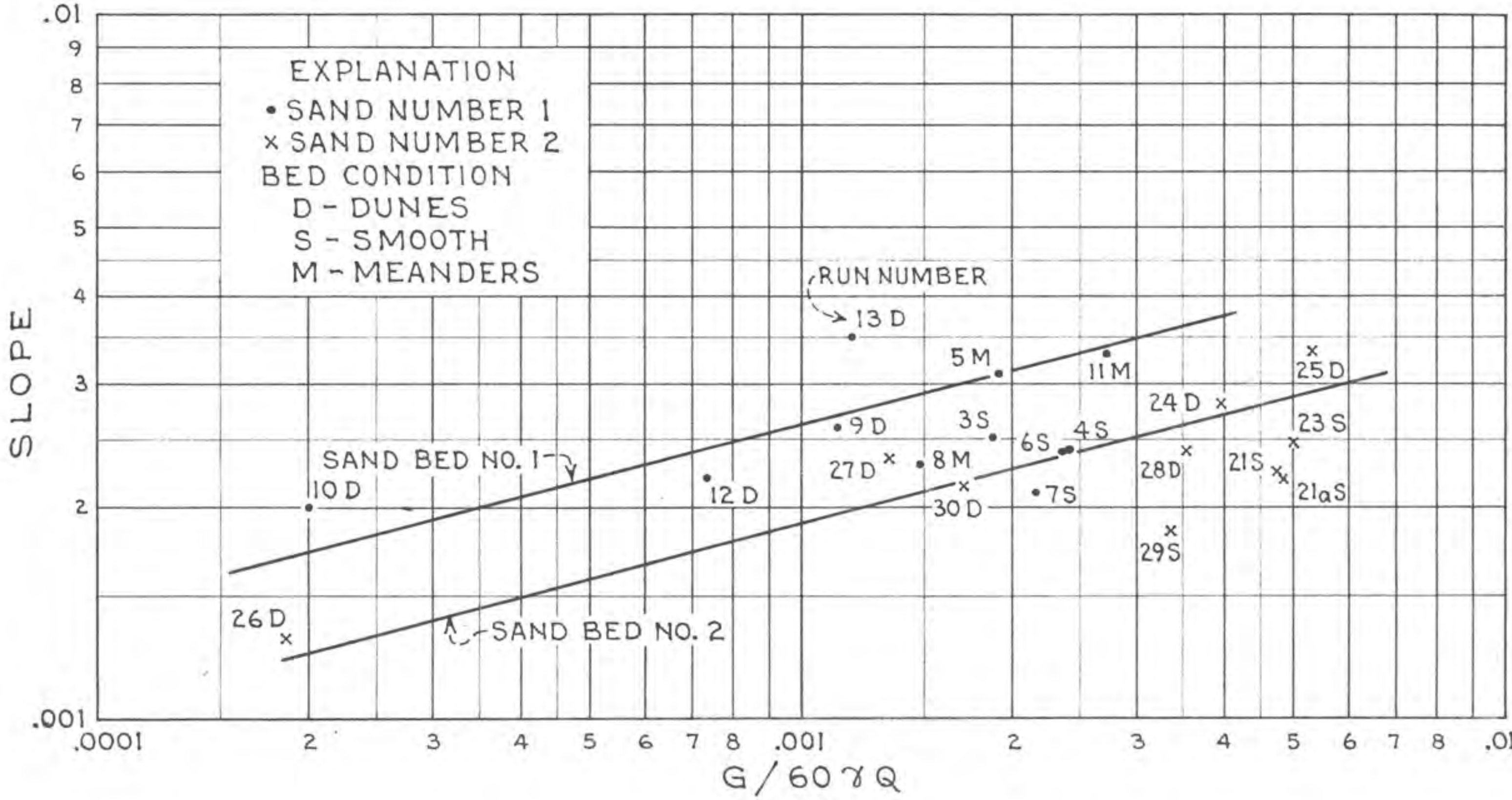

FIG. 1 - EFFECT OF SLOPE UPON RATIO OF SEDIMENT TO FLOW DISCHARGE

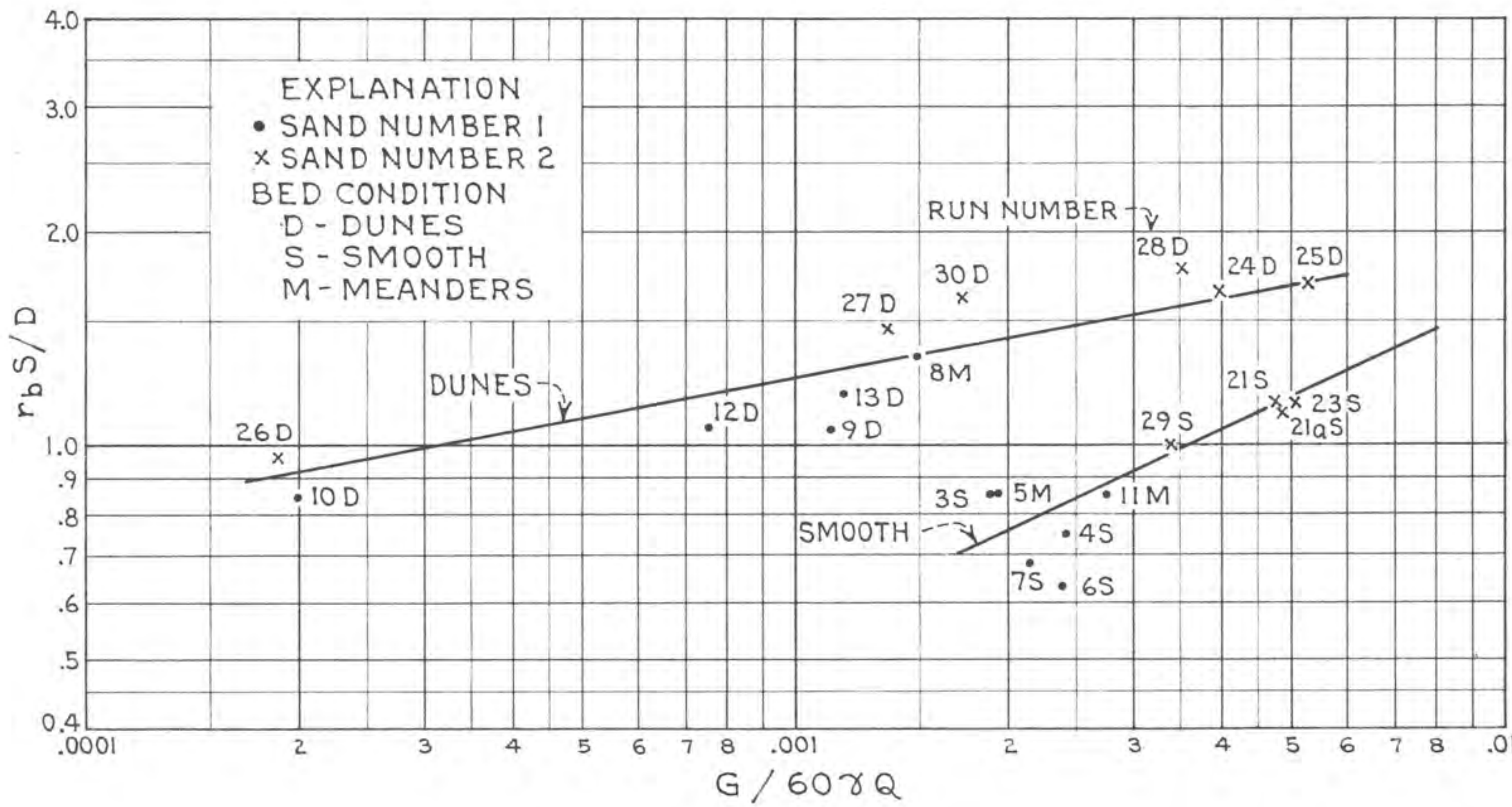

FIG. 2 - NONDIMENSIONAL PLOT SHOWING TREND OF DUNES AND SMOOTH BED