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Hydraulic Tests of Erosion Control Structures

SLICED-INLET TYPE ENTRANCE

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Report on Department of Agricultural Engineering
Research Project 43, "Soil
and Water Conservation"

Scale model tube structures with a sliced-inlet type of entrance for control of overfall erosion were tested to determine their hydraulic characteristics. Previous tests on tube structures with morning-glory and vertical-riser entrances were reported in Missouri Research Bulletin 544. The hydraulic laboratory in which these tests were conducted is also described in that bulletin.

The sliced inlet is illustrated in Fig. 1 as it might be used on a tube structure for control of overfall erosion. One end of the tube is used as the entrance. This eliminates the need for a separate entrance such as the vertical riser and morning glory. This type of structure is simple in design and is less expensive and more easily installed than vertical-riser or morning-glory structures.

Two tubes were used for the tests. One tube was lucite plastic, with an inside diameter of 2 inches. The other was a scale model of a one-foot diameter corrugated culvert pipe, made of copper. It had a nominal diameter of 1.905 inches. The lengths of these tubes from the bottom of the entrance to the outlet were: plastic, 6.1 feet; copper corrugated, 11.6 feet. The tubes are those used for the tests reported in Bulletin 544 and are further described in that Bulletin.

ENTRANCE DESIGN

Inlet Slope: One series of tests was run on entrances formed by cutting the plastic tube at slopes of 3:1, 2:1, 1½:1, ¾:1, 0, –¾:1, –1½:1 as shown in Fig. 2. In these tests the tube slope was 0.27 foot per foot. The results are shown in Fig. 3.

For the zero and negative inlet slopes, poor entrance characteristics and vortex formation keep the tube from flowing full at entrance heads up to the limits tested. The zero and negative slope entrances cause flow lines of the water entering the structure to be toward the bottom of the tube so that there is little or no tendency for the tube to flow full. The capacity of these

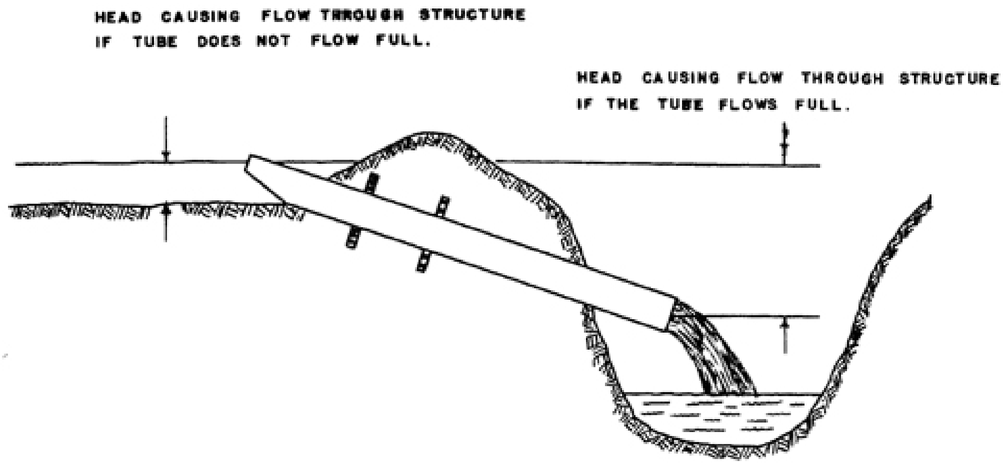

Fig. 1. Use of the sliced inlet type of entrance on an overfall structure for erosion control.

structures is low since the head causing flow through the structure is limited to the depth of water over the bottom of the inlet. In most field installations it would not be practical to impound depths of water comparable to those used in the model tests. Consequently, the capacity of structures with these entrances would be low.

For inlet slopes of 1½:1 through 3:1, the tube flows full with relatively low entrance heads, and greater capacities are obtained because the head causing flow is the difference in elevation between the center of the tube at the outlet and the water level over the entrance (see Fig. 1). For tests reported in this bulletin "entrance head" refers to the depth of water above the bottom of the inlet (see Fig. 2). With an entrance head slightly greater than the diameter of the tube, the flow characteristics are such that the tube fills and its capacity is therefore increased. With an inflow rate less than this

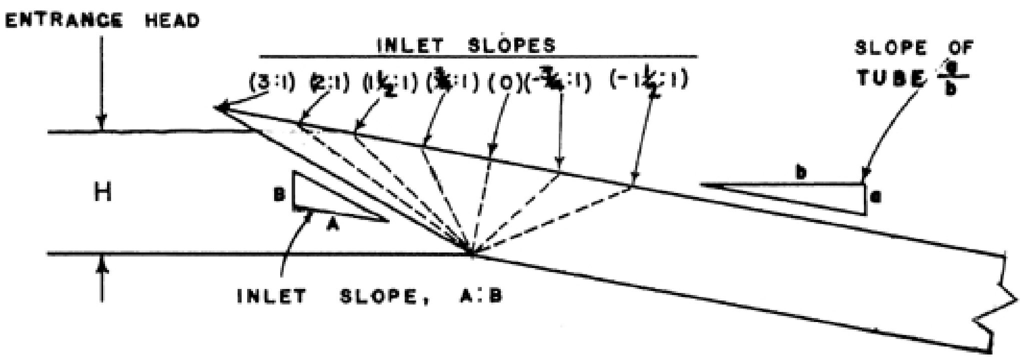

Fig. 2. A series of tests was run on sliced inlets at the inlet slopes shown.

increased capacity, the entrance head is lowered and the tube ceases to flow completely full. When this happens the capacity is reduced and the entrance head increases until the tube again flows full. During this period of unsteady flow the inflow rate is increased appreciably with little increase in the entrance head, as indicated by the nearly horizontal section of the curve in Fig. 3. After the tube begins to flow completely full, greatly increased heads produce only small increases in flow. Thus the design capacity for this type of entrance should be approximately the maximum capacity on the horizontal section of the curve.

The tube with an inlet slope of ¾:1 is in a zone intermediate between the two groups of inlet slopes heretofore discussed. The flow is quite variable due to poor entrance characteristics and a vortex which forms at low heads and disappears when the entrance head rises. This results in considerable fluctuation in both the entrance head and the discharge flow from the tube even though there is a constant inflow to the tank supplying the tube. The upper limits of this entrance head variation were used for plotting the ¾:1 curve in Fig. 3.

Inlet Length: A series of tests was made using the corrugated metal tube with a modification of the sliced inlet. For this design, an inlet slope of 2:1 was used and the length was varied by cutting the tube perpendicular to the longitudinal axis of the tube as shown in Fig. 4. (The advantage of the shorter lengths is that less tube length is required to form the entrance.) Tests were made on inlet lengths of .08D, 1.0D, 1.2D, 1.5D, 1.8D, and 2.0D in which D is the tube diameter, and with tube slopes of 0.08, 0.16, and 0.32 foot per foot. Results of these tests for a tube slope of 0.32 foot per foot are shown in Fig. 5. Similar results were obtained for the 0.08 and 0.16 foot per foot slopes, with the exception that the tubes filled at slightly lower entrance heads.

Results for the 1.8D and 1.5D inlets were the same as obtained with the full length inlet. The performance of the 1.2D inlet was affected slightly by a vortex at the entrance. The 1.0D and 0.8D inlets had even poorer entrance characteristics and larger vortices.

Inlet Plate: A series of tests was run with a third type of sliced inlet. The end of the inlet which was formed by cutting the corrugated metal tube perpendicular to its longitudinal axis was covered with a metal plate. See Fig. 6. This plate was attached so that no leakage of air was possible where it joined the tube. All inlet lengths shown in Fig. 4 were tested with a plate attached. Tube slopes of 0.08, 0.16 and 0.32 foot per foot were tested. Results of these tests for a tube slope of 0.32 foot per foot are shown in Fig. 7. Similar results were obtained for the 0.08 and 0.16 foot per foot slopes with the exception that the tubes filled at slightly lower entrance heads.

Three characteristics of sliced inlets with plates were noted:

1. As the inlet length was decreased a larger plate was used and the

vertical distance from the bottom of the entrance to the bottom of the plate decreased and full flow came at a lower entrance head.

2. As the inlet length was decreased and the plates became larger, the size of the inlet opening was decreased. When the area of opening was reduced to approximately the cross-sectional area of the tube or less, the capacity of the tube was decreased. This condition existed for the 1.0D and 0.8D inlet lengths.
3. There was practically no tendency for vortex formation.

The performance characteristics of inlets with and without plates can be compared by referring to Figs. 5 and 7. It will be noted that:

1. The tubes with plates flow full with considerably lower entrance heads and at these low heads they have much higher carrying capacities.

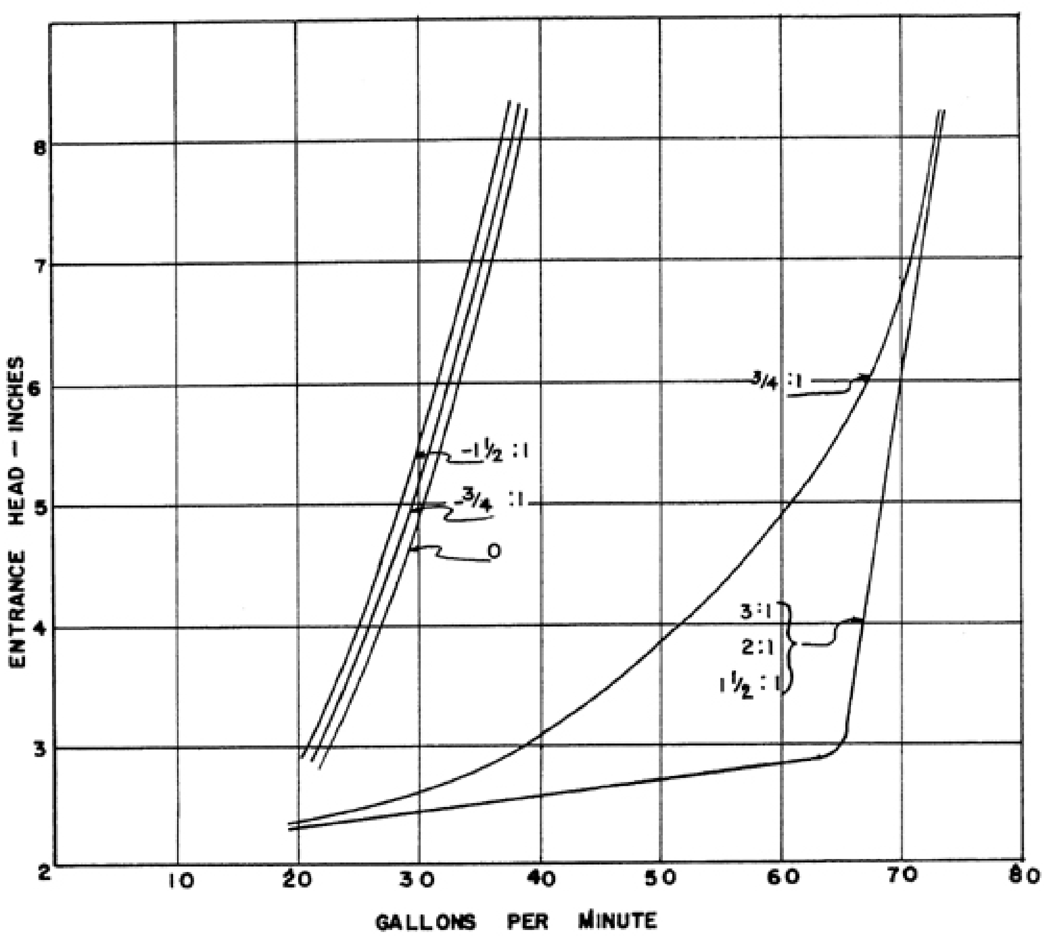

Fig. 3. Capacities of the plastic tube on a slope of 0.27 foot per foot, with inlet slopes of 3:1, 2:1, 1½:1, ¾:1, 0, –¾:1, –1½:1.

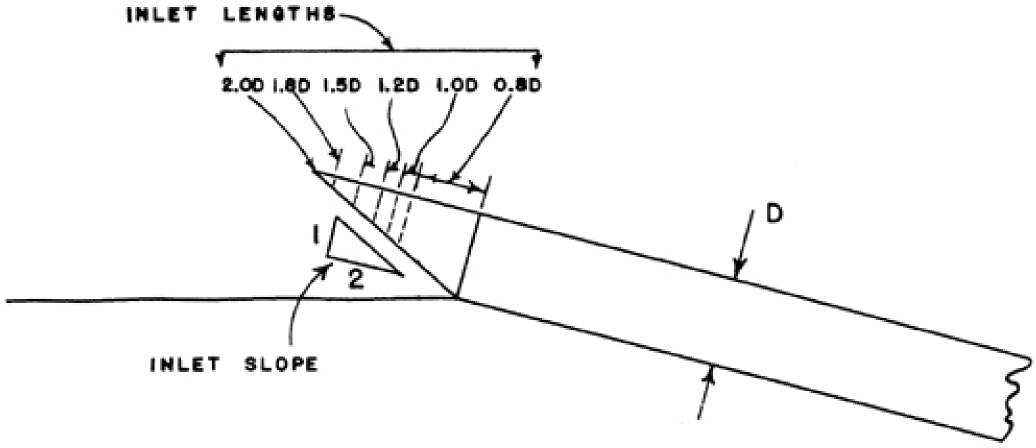

Fig. 4. A series of tests was run on sliced inlets in which the length was varied in relation to the tube diameter as shown.

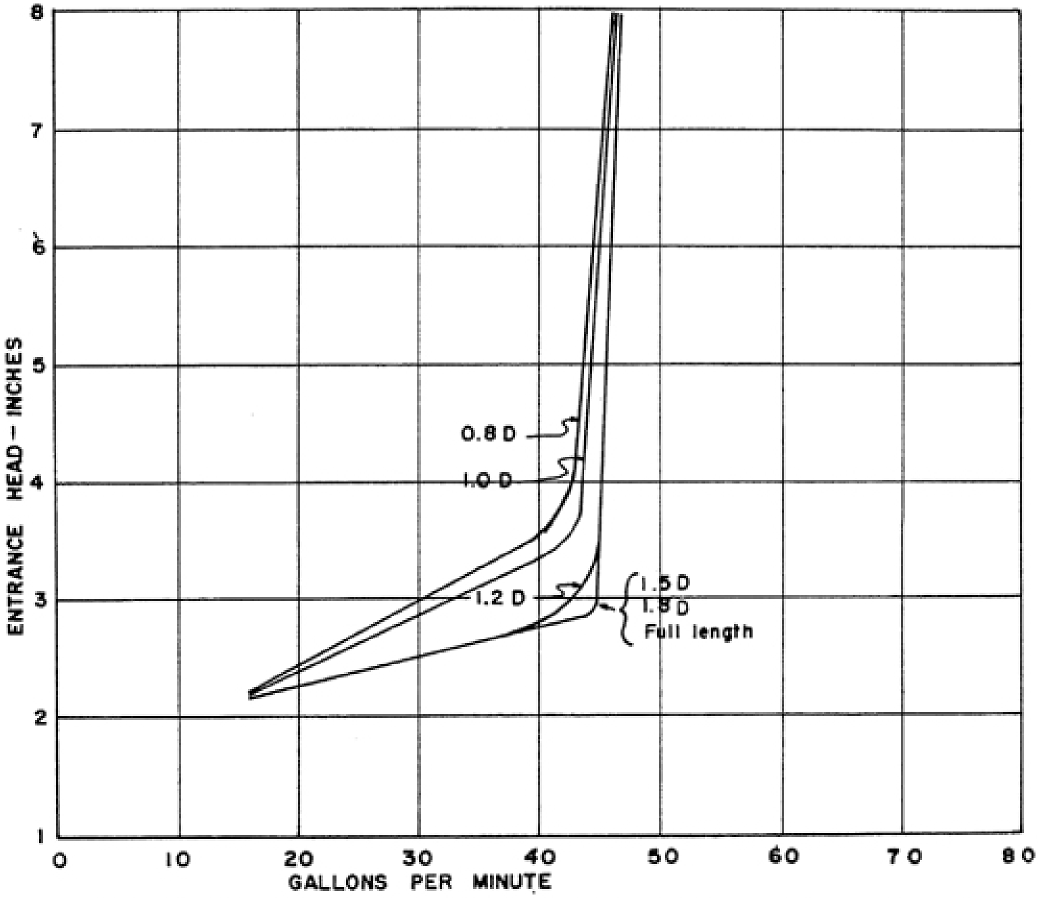

Fig. 5. Capacities of the corrugated copper tube on a slope of 0.32 foot per foot, with inlet lengths of 2.0D, 1.8D, 1.5D, 1.2D, 1.0D, and 0.8D, and with an inlet slope of 2:1.

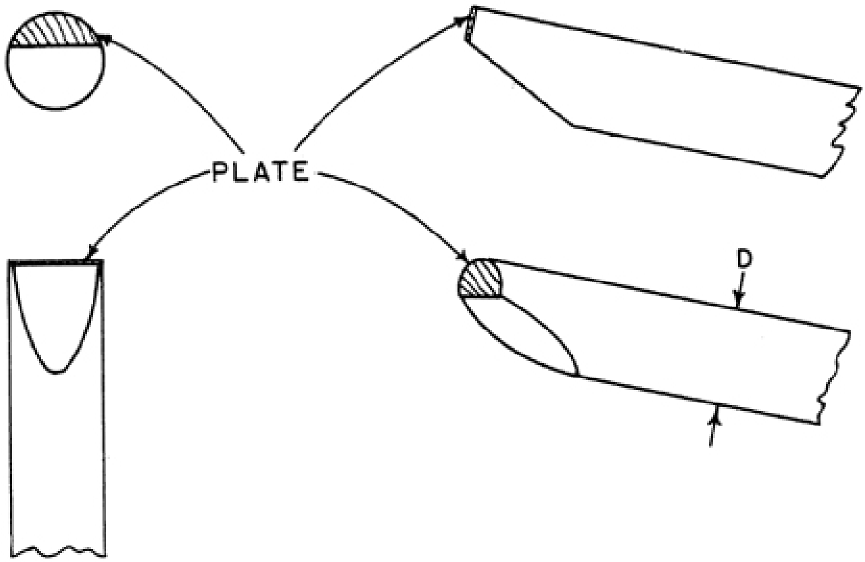

Fig. 6. The sliced inlet with a plate covering the upper section of the inlet.

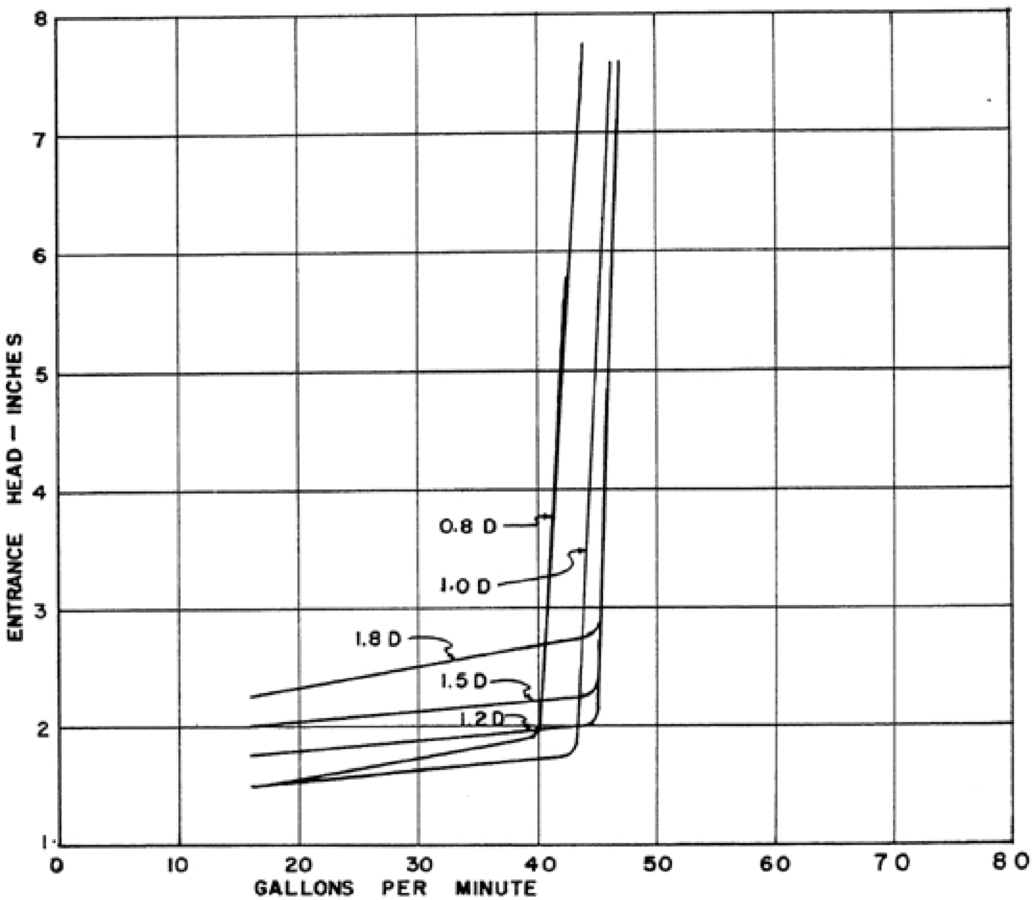

Fig. 7. Capacities of the corrugated copper tube on a slope of 0.32 foot per foot with a plate covering the upper section of the inlet, with inlet lengths of 1.8D, 1.5D, 1.2D, 1.0D and 0.8D, and with an inlet slope of 2:1.

2. The plates do not reduce the maximum capacity of the tubes except in cases of short entrances in which the area of the opening is reduced to approximately the cross-sectional area of the tube or less.

Structures using sliced inlets with plates will have a definite advantage in field application in that they will require lower heights of retaining dam to impound sufficient depth of water to cause the structures to flow full. There is also less tendency for vortex formation with its attendant problems of scouring and decreased capacities.

Capacity of Sliced-Inlet Structures: The capacity to be expected in a full scale structure can be computed from the following formula:

Capacity of full scale structure = Capacity of model X scale ratio raised to the 2.5 power.

The capacity of the scale model sliced-inlet structure with a 1.905-inch diameter tube, 11.6 feet long, on a slope of 0.32 foot per foot, with an entrance head of 3 inches and a total head of 46 inches would be 45 gallons per minute (See Fig. 7).

The full sized structure would have a tube 1 foot in diameter, 73 feet long on a slope of 0.32 foot per foot. The entrance head would be 1.5 feet and the total head 24 feet. The capacity of this structure computed by the above formula is 10.4 cubic feet per second.

Tables in Research Bulletin 544 give the capacity of a vertical-riser or morning-glory structure of similar dimensions as 9.4 cubic feet per second.

ADDITIONAL TESTS TO BE MADE

The tests reported in this bulletin are sufficient to indicate the feasibility of this type of structure entrance. These tests also indicate the approximate entrance dimensions which should be used if the structure is to perform in a satisfactory manner. Additional tests are being conducted, however, to determine the most desirable relationship between the tube slope, the inlet slope, the inlet length and the size of plate.

SUMMARY

Tests were run on scale models of various designs of sliced-inlet tube structures which require no separate entrance such as the vertical-riser or morning-glory type of structure. The design illustrated in Fig. 6 was found to be superior to others tested. It gives full flow with low entrance heads. The tests indicate that capacities of this type of tube structure are slightly greater than capacities of vertical-riser or morning-glory structures when operating under the same total head. Vortex formation is not a problem with this sliced-inlet tube structure. It is also simple in design and is easier and less expensive to install than vertical riser or morning glory structures. It may also have application for use on highway or railroad culverts.