TRAPPING SAND FROM IRRIGATION AND POWER CHANNELS

by

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The deposition of water-borne gravel, sand and silt has long been recognized as one of the most troublesome problems incident to the operation and maintenance of many of the irrigation and power canals of the West. Inordinate expenditures of time, labor, and money are made annually on this account. The reduction in the carrying capacity of a canal used for the delivery of water for either irrigation or power means direct financial loss. Furthermore, the inert material deposited upon irrigated land decreases in most cases the fertility of the soil, and, when an excessive amount raises the land surface near the margin of the field, this interferes with the spreading of the irrigation head evenly over the field. Periodic cleaning of the channel has in some cases resulted in such an accumulation that the spoil banks are now approaching a limiting condition.

As a means of correcting these conditions, laboratory studies have been made over the past years in the attempt to develop practical means for ridding channels of bed load deposit. The investigation of this problem has been carried on primarily at the hydraulic laboratories at Fort Collins by the Division of Irrigation, Soil Conservation Service of the U. S. Department of Agriculture, in cooperation with the Colorado Agricultural Experiment Station. Various schemes have been investigated and emerging from these investigations have come two practical means of solving the problem of protecting channels from bed load deposits, namely, the vortex tube and the riffle deflector-vortex tube sand trap. These devices will be described later. They are capable of catching the bed load as it is moved along by the flowing water. Extremely fine material carried in suspension can only be recovered by reducing the flow in the channel to a very low velocity thus permitting the fine sand to settle as bed load after which the deposit can be sluiced out by suitable flow regulation.

The Vortex-Tube

The main feature of the vortex-tube sand trap is a tube with an opening along the top side, laid in the bottom of the channel at an angle of about 45 degrees to the axis of flow. The elevation of the top edge or lip is the same as the bottom or grade of the channel. As the water flows over the opening, a pronounced whirling or vortical motion is set up within the tube, and a spiral-flow action extends throughout its length. This whirling cross-stream draws in the bed load as it passes over the lip of the opening and carries it to an outlet at the downstream end of the tube whence it is discharged into a suitable sluiceway for disposal.

Laboratory as well as field tests indicate that the optimum action of the vortex tube occurs when the velocity of the water passing over the lip is at or near the critical, that is, the velocity head is equal to one-half the depth of water at the lip of the tube. In the laboratory various shapes, sizes and length of tubes were studied. For a particular setting with a velocity of about 3 feet per second over the lip, 10 to 15 percent of the total flow wasted through the outlet, it was found that the rate of rotation near the outlet was more than 200 revolutions per minute and for this condition sand and heavy gravel, stones as large hen's eggs, were readily ejected. Further investigations of a 4-inch tube of uniform diameter showed a maximum rotation of the spiraled flow to be 300 revolutions per minute and created sufficient energy to move a cobblestone weighing $7\frac{1}{2}$ pounds at a uniform rate of about $\frac{1}{2}$ foot per second. The distance moved was about 7 feet and the mean velocity of flow over the lip of the trap was 6.6 feet per second. The axis of the tube was at 30 degrees and sloped toward the outlet 2 inches in 4 feet. Discharge of the tube was 3 percent of the total flow. When the 4-inch tube was set at 45 degrees, velocity of flow at 6.9 feet the maximum rate of rotation was 500 revolutions per second and the energy developed was capable of transporting cobblestones having a weight of 3 3/4 to 4 pounds. Laboratory tests on a vortex tube indicate that the efficiency in trapping out the bed load would approximate at least 90 percent.

The vortex-tube sand trap has been tried in the field and in some cases it has been a failure while in other instances it has proved successful. For installations that have been ineffective two things have been wrong. First, the velocity in the canal has been too low, and second, the tube has been set below grade of the channel. In the Jackson Ditch, at the Bellvue laboratory, a vortex tube has been in operation since April 1935 and has proved to be successful. The structure is of concrete 8 feet wide, vertical walls, and the floor rises slightly from the front end to the lip of the tube and slopes downward from the tube to the downstream end of the floor. The tube itself is cast of concrete, the diameter at outlet end being 8 inches and at the back end 6 inches. The tube is laid at an angle of 45 degrees to the axis of the channel. The capacity of the Jackson Ditch is approximately 60 second-feet and during periods of moderate to low river stage, the diversion in the canal is 11 second-feet. It appears that the tube is especially active at this minimum flow. No tests have been made on this particular installation but evidence of the deposit accumulated at the end of the outlet definitely indicates that this sand trap is highly successful.

The Riffle-Vane Deflector

This type of sand trap consists of a series of curved sheet metal vanes, each approximately in the shape of a quadrant of a circle with top edge rolled. The sheet metal vanes are attached in a vertical position to the smooth floor of the structure, which has a lateral slope. Experiments were made with deflectors of various sizes and spacing and in some cases the action in moving the bed load was surprisingly good. When the riffles were set in line normal to the axis of the canal the bed load was moved laterally at 90 degrees to the line of flow toward the outlet immediately downstream from the line of riffles. The curvature of the riffle produced the effect which moved the load laterally and the flow of water over the riffles resulted in a condition which maintained the bed load in a ridge downstream from the riffles. The action of the riffles was apparently independent of the depth of flow. Under maximum conditions of channel velocity it was surprising to find that the energy developed was sufficient to move large cobblestones, in fact, sizes which would not pass through a 4-inch square opening. Observations were made where the line of riffles pointed upstream at an angle of 45 degrees and with proper setting of the vanes, it was found that the bed load could be carried successfully upstream behind the line of riffles. No particular advantage from a practical standpoint would be gained in setting the riffles at this extreme angle.

Field tests have been made of this type of sand trap but they have not been highly successful, one of the disadvantages being the fact that considerable debris lodges on the riffles and thus destroys the efficiency of the trap. One installation was made in the Wannamaker Ditch, near Golden, Colorado, where a series of 6 sets of riffles was placed in a channel 6 feet wide. The riffles were 6 inches high. Test of this trap indicated that it removed sand from the ditch at the rate of about 15 pounds per second. It is believed that if attention is given to the removal of lodged material on the vanes, such as roots, grass, tree branches and other fibrous material, this type of sand trap should be highly effective. The riffle-vane deflector sand trap is not intended for wide channels, however, is suitable for moderate velocities of 2 to 3 feet per second.

The Riffle Deflector-Vortex Tube

The most promising sand trap device thus far developed is the riffle deflector-vortex tube type. In general, this device consists of a series of curved riffles placed on the bed of the channel, whereby the bed load is moved laterally to the side of the channel where it is taken off through small vortex tubes outletting into a common compartment. This compartment is provided with an outlet which carries the total trap load back to the river downstream from the diversion dam or deposits it in basins as waste material. The riffles in plan are parabolic, have a vertical face of about $1\frac{1}{2}$ feet, the top surface sloping downward to a feather edge in an axial distance of about 5 feet. Since the riffles are identically curved in plan, they are placed one against the other. The number of riffles depends upon the nature of the bed load. For coarse sand and gravel fewer riffles would be required, whereas, for fine sand the number of riffles would be greater, but in no case probably exceeding a set of 10 or 12 riffles.

This type of trap is flexible, in that it can be readly adapted to either narrow or wide channels and for flows ranging from less than 10 to more than 2000 second feet. For channels ranging from 20 to 50 feet in width it is suggested that the two sets of riffles be provided whereby the bed load is crowded to the middle, or axis, of the channel, and the short vortex tubes from the riffles discharge into a narrow compartment built along the center line of the channel. An outlet pipe carries the trapped sand and water back to the river. For channels ranging from 50 to 100 feet, a double installation is recommended. The outlets from the two installations are joined and a suitable outlet pipe is provided which passes below the bed of the canal and under the canal bank. Tests in the laboratory on the riffle deflector-vortex tube type of trap indicate that it is capable of capturing 90 percent or more of a weighed sample introduced upstream from the riffles.

Several field installations have been made of this type of sand trap and in all cases have been successful, not only in catching bed loads of relatively coarse material but also of very fine sand. As an experimental installation of such a trap was built of timber in the Sheep Creek Ditch near Torrington, Wyoming, which was capable of handling very fine sand. The riffles were fashioned out of 1 x 6 boards, the vertical section of the riffle being a 1 x 12 board bent to the desired curve. In this case there were 6 sets of riffles and 3 short 4-inch vortex tubes. One of the objections to this installation was the fact that tumbleweeds persisted in clogging the short tubes. A double sand trap of this type was built at the heading of the Supply Canal to the C. F. & I. Steel Works in Pueblo at the heading near Florence, Colorado, on the Arkansas River. This installation has been successful but some difficulty was experienced at first, in that no provision was made for regulating the discharge of the vortex tubes into the common collection compartment. A slide gate was later provided, which very materially improved the action of the trap. No tests have been made on this particular installation, but after 3 years of continuous use, observations along the canal downstream from the heading indicate that there is very little, if any, river sand found in the channel. It is therefore assumed that the efficiency of this installation is very good.

Because of the nature of this brief discussion no attempt is made to include detailed drawings of these different designs. If, in the event that any organization is interested in this problem, plans of these various structures can be obtained at the office of the Division of Irrigation and Water Conservation, Soil Conservation Service, Colorado Agricultural Experiment Station, Colorado A & M College, Fort Collins.

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