UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

EROSION TESTS ON EARTH SAMPLES NO. 14G-571, 658, AND 661 REPRESENTING VARIOUS STRATA THROUGH WHICH THE PROPOSED UNLINED EMERGENCY SPILLWAY CHANNEL WILL PASS--CANNONBALL DAMSITE--ELGIN AXIS--MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd-266

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Laboratory Report No. Hyd-266
Hydraulic Laboratory
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Subject: Erosion tests on earth samples No. 14G-571, 658, and 661 representing various strata through which the proposed unlined emergency spillway channel will pass--Cannonball Damsite--Elgin Axis--Missouri River Basin Project.

PURPOSE

To determine the erosion resistance of the above clay and uncemented sand materials when subjected to water velocities of 1.5 to 6 feet per second.

Note: The erosion of the above materials under field conditions will probably be greater than the laboratory tests indicated because the material is made up of weakly bonded horizontal layers which will be lifted and broken apart by the water. The laboratory tests were necessarily conducted with the Denison core sample placed horizontal instead of vertical to obtain a test surface of sufficient size. The water, therefore, passed over the bedding planes at right angles instead of flowing parallel to them, and erosion was considerably less than would have otherwise occurred.

CONCLUSIONS

Sample 14G-571

From Hole DM 5 at elevations 2248.1 to 2250.1.

1. This uncemented, compact, layered sand has little resistance to erosion, and about one-tenth of the sample was removed after 10 minutes at a velocity of 1.5 feet per second. Extreme erosion occurs at a velocity of 3.5 feet per second (Figure 2).

2. The sandy material continues to erode as long as water flows over it at a velocity of 1.5 feet per second (minimum possible with test apparatus) or more.

Sample 14G-658

From Hole DM 7 at elevations 2216.0 to 2218.0. This sample was broken when received by the Hydraulic Laboratory, and the additional breakage which occurred while placing it in the test apparatus left the sample too broken for erosion tests.

1. The material in the top foot of this sample is roughly comparable to that in Sample 14G-571, and similar erosion characteristics may be expected.

2. The bottom foot of the sample contains more clay and is less stratified than Sample 14G-571, and probably will withstand velocities of 5 feet per second without excessive erosion.

Sample 14G-661

From Hole DM 7 at elevations 2206.5 to 2208.5.

1. This dense, plastic, somewhat layered and fractured clay has fair resistance to erosion, as shown by the little damage after 30-minute periods at 2- and 4-foot per second water velocities. The sample was slightly eroded after 20 minutes at a velocity of 6 feet per second. The test was then halted because a large broken portion of the sample was lifted out by the water. The sand layers near the top of the sample, comprising about one-sixth of the sample, were eroded severely by the 6-foot per second water velocity.

RECOMMENDATION

To better represent field erosion conditions, obtain larger earth samples (12 inches wide by 21 inches long by 8 inches thick) which may be placed in the test apparatus in the same position relative to the flowing water as occurs in nature.

INTRODUCTION

Cannonball Dam is an earth-fill structure proposed for construction across the Cannonball River on the Elgin Axis 16 miles south of Carson, North Dakota. As part of the usual investigation of a proposed damsite, a number of Denison core samples were obtained at appropriate locations and shipped to the Denver laboratories for test purposes. Included among these samples were No. 14G-571, 658, and 661 which represent various strata through which the proposed unlined emergency spillway channel will pass. Sample 14G-571 was taken at elevations 2248.1 to 2250.1 from Hole DM 5, located on the left abutment of the damsite. Samples 14G-658 and 661 were taken at elevations 2216.0 to 2218.0, and 2206.5 to 2208.5, respectively, from Hole DM 7 located on the right abutment. The three samples were forwarded to the Hydraulic Laboratory for tests to determine their erosion resistance.

DESCRIPTION OF THE SAMPLES

Sample 14G-571

Compact, uncemented, moist, silty, tan-colored layered fine sand.

Sample 14G-658

Compact, uncemented, moist, silty, with some clay, tan- to gray-colored, somewhat layered fine sand.

Sample 14G-661

Dense, plastic, moist, dark gray colored, somewhat layered clay with several compact, uncemented sand layers near the top. The sand layers comprised about one-sixth of the sample.

APPARATUS AND TEST PROCEDURE

A schematic diagram of the erosion test apparatus is shown in Figure 1. Water was supplied through a 6-inch standard pipe and a transition section to the 16-inch wide by 66-inch long test chute. A valve was provided to regulate the discharge and a flow straightener was placed downstream from the valve to insure smooth, straight flow into the test section. The water entered the chute in a uniform stream 2 inches deep and the slope of the chute was adjusted to maintain this depth over the full length of the sample. The velocity of the water over the test sample was determined by measuring with a Venturi meter the quantity of water flowing, and dividing this quantity by the cross-sectional area of the flowing water in the chute. The water discharged freely from the end of the chute and was returned to the supply channel by a trough. The floor of the test box was adjustable to permit moving the sample to keep its top surface level with the chute floor as the material was washed away. To avoid surges and excessive velocities over the sample when the flow was started, an obstruction was placed across the downstream end of the channel, the chute flooded to a depth of 2 inches, and the control valve slowly opened while the obstruction was removed. A final adjustment of the valve established the desired water velocity over the sample.

Unfortunately, larger surfaces were needed for the erosion tests than were afforded by the cross-section of the 5.5-inch-diameter cores. It was therefore necessary to place the cores horizontal and to cut them along a diameter to form a rectangular test surface 5.5 inches wide by 20 inches long. The metal containers were cut 1/2 inch lower than the surface of the samples and left in place to support the weak, laminated material. Moist sand was packed around the samples to fill the containing box to the level of the chute floor.

Visual means were used to judge the erosion on the samples, and photographs are presented which show the condition of samples at the completion of the tests. At the time of this writing, a feasible method of determining the quantity of material removed in the erosion process has not been developed. Weight, volume, and collection measurements could not be used because of large changes in moisture content during testing, swelling of certain materials (particularly clay) when water is absorbed, and the lack of filtering equipment capable of holding the small particles washed off the sample and still handle the large quantities of water used. Also, the size and shape of the samples tested precludes a close approximation of the field erosion conditions. Therefore, the results presented in this report are qualitative only, and the laboratory test results must be used with care to predict field results.

The test equipment was capable of producing water velocities of 1.5 to 19.5 feet per second, and the selection of the velocities used on a sample depended upon the nature of the material. It was imperative to select an initial velocity low enough to prevent extensive damage to the sample before adequate data could be taken, while on the other hand, time would be wasted by starting with velocities too low. The velocities used on the Cannonball samples ranged from 1.5 to 6 feet per second.

TEST RESULTS

Sample 14G-571

Water was first passed over the sample at a velocity of 1.5 feet per second. Immediately material was removed in sufficient quantities to discolor the water with most of the early action occurring along the sides of the sample where the drill had cut. Three minutes after the flow started, the rate of material removal decreased to a point where the water no longer appeared discolored. Moderate amounts of material continued to be removed, however, during the rest of the 10-minute operating period with occasional pieces breaking away from the laminations. At the completion of the 1.5-foot per second run the velocity was increased to 2.5 feet per second and maintained for an additional 10 minutes. A definite increase in the rate of erosion accompanied the increase in velocity, although the process of the erosion was unchanged. After the 2.5 feet per second run was completed, the velocity was increased to 3.5 feet per second and maintained for an additional 10 minutes. Again the rate of erosion increased while the process was unchanged.

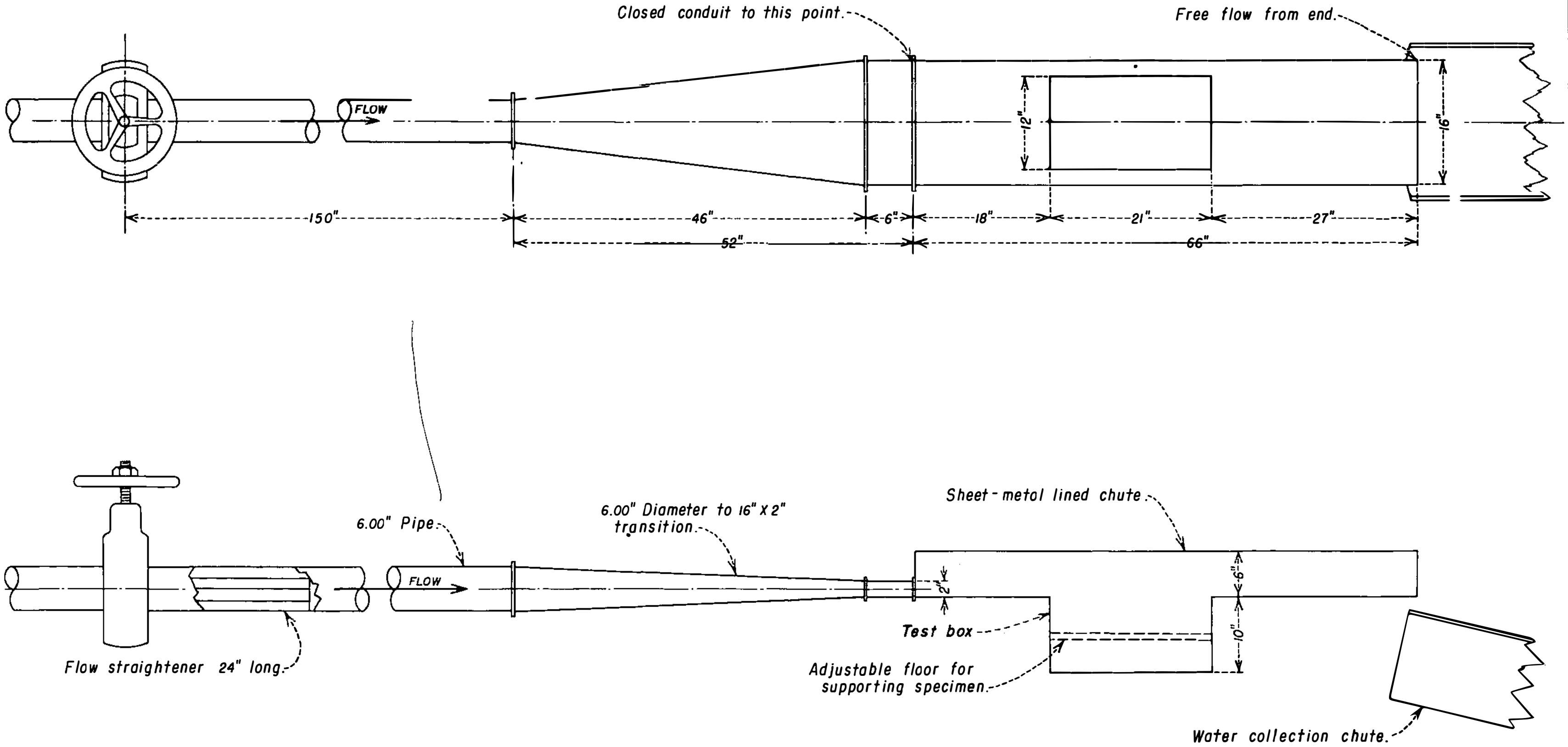
The sample was thoroughly eroded at the completion of the three runs, and further tests were considered useless (Figure 2). Considerable material had been removed from the sides of the sample, particularly toward the downstream end, and much of the material in the seams was washed away. The layers of the material are visible in Figure 2. More extreme erosion would have occurred had the geometry of the sample made it feasible to pass the water parallel to the layers (layers horizontal) instead of at right angles to them.

Sample 14G-658

This sample, when received by the Hydraulic Laboratory, was found to be broken apart in two places. Additional breakage which occurred while placing it in the test apparatus left the material too broken for erosion tests. Examination of the material revealed that the upper 1 foot of the sample was roughly comparable to the compact, uncemented, silty, and layered sand in Sample 14G-571, and that similar erosion can be expected. The lower foot of the sample contained more clay and was less stratified than Sample 14G-571. It is estimated that a water velocity greater than 5 feet per second would be required to produce severe erosion.

Sample 14G-661

The top 14 inches of the sample was found broken when the sample was removed from its container, but the pieces remained in place while the sample was placed in the test box and prepared for the tests. First, water was passed over the material at a velocity of 2 feet per second for 30 minutes, and with the exception of a few loose pieces, little washing away action was noted. The velocity was increased to 4 feet per second, and maintained there for 30 minutes. Several more pieces were carried away, a few of them coming from a broken 2-inch section of the sample, and a small amount of sand was removed from the sand layers. In general, however, little erosion took place. At 6 feet per second most of the broken pieces at the top of the sample were carried away, and considerable sand was removed from the sand layers. No appreciable erosion was noted on the unfractured clay portions. After 20 minutes' operation, the upper half of the sample suddenly failed along a fracture zone, and a large piece was lifted part way out of the test box by the water. The flow was immediately stopped, and the sample returned as nearly as possible to its original position. A photograph was taken of the sample in this condition (Figure 3) and the test program was discontinued because the sample was thoroughly broken.



EROSION TEST APPARATUS

FIGURE 1

Erosion after 10 minute exposures to water velocities of 1.5, 2.5, and 3.5 feet per second.

Flow from left to right.

SAMPLE 14G - 571

EROSION TESTS ON CANNONBALL FOUNDATION MATERIALS

Erosion after 30 minute exposures to water velocities of 2 and 4 feet per second, and 20 minutes exposure to a velocity of 6 feet per second.

Flow from left to right.

SAMPLE 14G - 661

EROSION TESTS ON CANNONBALL FOUNDATION MATERIALS