UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

EROSION TESTS ON NARROWS DAMSITE FOUNDATION SAMPLE NO. 9B-1040 TAKEN FROM TEST PIT NO. 3 AT AN ELEVATION OF 4373.7 FEET--EMERGENCY SPILLWAY--NARROWS DAM--MISSOURI RIVER BASIN

Hydraulic Laboratory Report No. Hyd.-265

RESEARCH AND GEOLOGY DIVISION

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BRANCH OF DESIGN AND CONSTRUCTION
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Laboratory Report No. HYD-265
Hydraulic Laboratory
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Subject: Erosion tests on Narrows Damsite Foundation Sample No. 9B-1040 taken from Test Pit No. 3 at an elevation of 4373.7 feet--Emergency spillway--Narrows Dam--Missouri River Basin Project.

PURPOSE

To determine the erosion resistance of the clay-like material (weathered shale) located in the proposed unlined emergency spillway channel at Narrows Dam when subjected to water velocities of 2 to 16 feet per second.

Note. Erosion testing of earth samples is a new kind of testing for the Hydraulic Laboratory, and the equipment and procedures used are experimental.

CONCLUSIONS

1. Most of the material that will be removed by a given water velocity is swept away within 4 minutes.

2. The clay is removed in flakes and small pieces which break off along natural seams and fractures, and there is no appreciable tendency for it to wash off in small particles.

3. The clay will withstand velocities up to 8 feet per second without excessive erosion. Velocities of 12 to 16 feet per second will cause excessive erosion.

4. When this clay is weathered by laboratory wetting and drying cycles and then subjected to velocities as low as 1.5 feet per second, the weathered portion of the specimen washes away immediately.

RECOMMENDATIONS

1. If erosion tests are to become a part of the standard laboratory investigation of earth materials, test equipment should be developed that will measure the rate of erosion on a quantitative rather than qualitative basis.

2. Develop a standard test procedure to better compare the erosion resistance of various materials. This will require, in part, erosion tests on several different earth samples.

INTRODUCTION

Narrows Dam is a proposed earth-fill structure to be built across the South Platte River about 10 miles northwest of Fort Morgan, Colorado. To avoid unnecessary expense on the structure, it was suggested that the conventional concrete spillway be designed to accommodate only the normal peak discharges which occur on the river. An emergency spillway, consisting of an unlined channel cut through the clay-like material which exists at the site, would be provided to pass the excess water at the higher flood flows. In order to determine the feasibility of the suggested design and the dimensions required to pass the flood waters, the Dams Division requested information concerning the water velocities which the earth material in the emergency spillway could withstand without eroding excessively. Therefore, an undisturbed earth sample (Earth Materials Laboratory No. 9B-1040) was procured at the site from Test Pit No. 3 at an elevation of 4373.7 feet and shipped to the Earth Materials Laboratory in Denver. Two specimens were cut from the sample and erosion tests were conducted by the Hydraulic Laboratory.

DESCRIPTION OF THE SAMPLE

The sample was a hard, moist, easily fractured, slick, tan-colored clay (weathered shale) containing a few large gypsum crystals. There were many small fractures in the sample and one large fracture zone near a corner.

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 at the different velocities to maintain this depth over the full length of the specimen. The velocity of the water over the test specimen 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 of the test apparatus. 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 made adjustable to permit moving the specimen to keep its top surface level with the chute floor as the specimen was washed away. To avoid surges and excessive velocities over the specimen 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 specimen.

Two test specimens approximately 8 inches thick, 10 inches wide, and 20 inches long were prepared from Sample No. 9B-1040 by the Earth Materials Laboratory for the erosion tests conducted by the Hydraulic Laboratory. One of these specimens was placed in the test box with the side which was uppermost in the field on top in the box and level with the floor of the chute. The space between the sample and the sides of the box were filled with sand to within one-half inch of the chute floor. Modeling clay was then placed in the remaining space to form, as nearly as possible, a smooth continuous transition from the floor to the top surface of the specimen (Figure 2A).

Visual means were used to judge the erosion on the specimens, and photographs are presented in this report showing the conditions as the test progressed. In several instances approximate measurements were made to supplement the photographs. At the time of this writing, a feasible method of determining the quantity of material removed in the erosion process had not been developed. Weight measurements could not be used because a large change in moisture content occurs in the material during the tests. Volume measurements could not be used because some materials (particularly clay) swell when water is absorbed. Material collection methods were restricted because equipment was not available which could filter out the finer material dislodged from the specimen and still pass the large quantities of water used. In addition, the small size of the specimens tested probably prevented a close similarity of the conditions which occur in the field. Therefore, the results presented in this report are qualitative only, and using the laboratory test results to predict field results must be done with care.

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 specimen depended upon the nature of the material. It was imperative to select an initial velocity low enough to prevent extensive damage to the specimen 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 Narrows specimens ranged from 2 to 16 feet per second.

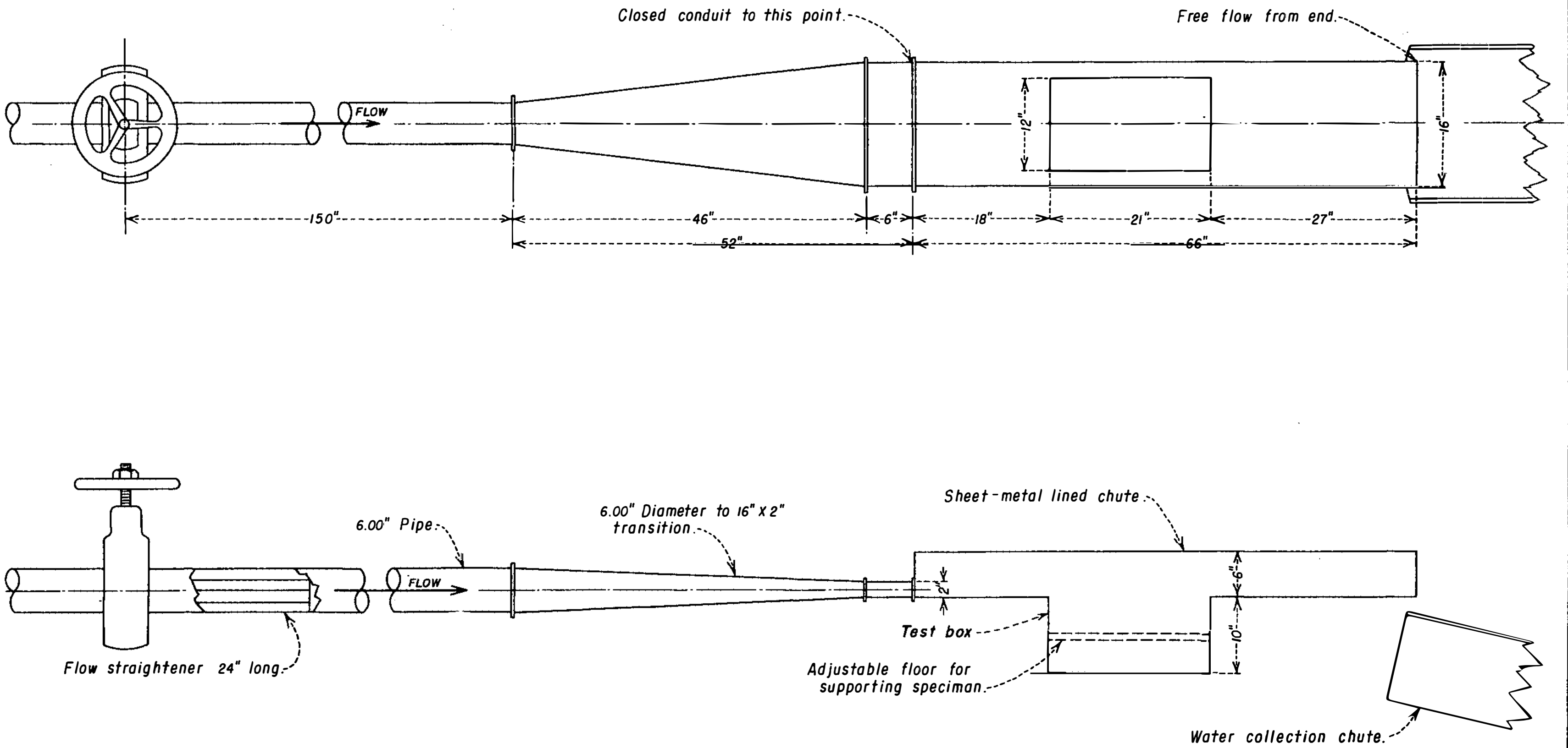
EROSION TESTS

The first erosion test was conducted using a water velocity of 2 feet per second. Considerable clay was immediately dislodged from the specimen in flakes and small pieces which broke away along natural seams and fractures. This action continued at a decreasing rate for about 4 minutes. After this time, only an occasional flake was carried away. There was no noticeable tendency for the clay to dissolve and wash away. After 1 hour and 40 minutes' operation, the flow was stopped and the specimen examined. The regions where the pieces were dislodged were well defined, occurring along seams and fractures, and were eroded a maximum of five-eighths inch below the other portions of the specimen (Figure 2B). A close examination of the "uneroded" material revealed that extremely thin, minute flakes approximately one-thirty-second inch in diameter had been removed from the specimen. However, the clay dislodged by this action was negligible.

Successive tests were made using velocities of 4, 6, and 8 feet per second for durations of 1 hour, 1/2 hour, and 1/2 hour, respectively. All tests were made on the same specimen and the cumulative erosion at the completion of each run is shown in Figures 3A, 3B, and 4, respectively. The erosion action at these higher velocities was similar to that for the 2-foot per second velocity whereby nearly all the clay removed was swept away in pieces during the first 4 minutes of operation. The maximum depth of erosion was 1-3/8 inches while the average depth for the specimen was one-half inch.

After completing the 8-foot per second test, the surface of the specimen was raised 2 inches above the chute floor and then cut and trimmed down to the floor level, thereby obtaining a smooth surface (Figure 5A). Water was passed over this new surface at velocities ranging from 12 to 16 feet per second for a total duration of 3 minutes. Considerable clay was dislodged from the specimen, most of it being in irregular pieces 2 to 3 cubic inches in volume. The maximum depth of erosion was 2-3/4 inches while the average depth was 1-1/4 inches. One portion of the specimen, however, remained unaffected by the flow (Figure 5B).

To determine the effect water will have when flowing over weathered areas of this clay, a test was made using the second specimen cut from the original sample. This block was placed in the test box and exposed to alternate 1/2-hour wetting and 3-day drying periods for a total of 4 weeks. At the end of this time, the surface of the specimen was weathered to a depth of about 1 inch and when dry, resembled a dried, cracked mud flat (Figure 6A). Water was passed over this specimen at a velocity of 1.5 feet per second. Immediately the weathered clay began to wash off in quantities great enough to color the water an opaque brown. Only 2 minutes were required to remove the weathered material and at the end of this time the water was shut off. Numerous small loose pieces which would be swept away by higher velocity flows were found scattered over the surface of the specimen. Several mica deposits were found protruding above the specimen surface as they had been unaffected by either the weathering process or the flowing water (Figure 6B). Further erosion on the specimen would have occurred in the same way as in the tests on the first specimen, and therefore the testing was discontinued.



EROSION TEST APPARATUS

FIGURE 1

A. Appearance of Test Specimen No. 1 before start of erosion tests.

B. Erosion after 1 hour and 40 minutes' exposure at 2 fps velocity.

Flow was from left to right.

EROSION ON TEST SPECIMEN NO. 1
EROSION TESTS ON NARROWS DAMSITE SAMPLE NO. 9B-1040

A. Erosion after 1 hour and 40 minutes' exposure at 2 fps, and 1 hour at 4 fps velocity.

B. Erosion after 1 hour and 40 minutes' exposure at 2 fps, 1 hour at 4 fps, and 1/2 hour at 6 fps velocity.

Flow was from left to right.

EROSION ON TEST SPECIMEN NO. 1
EROSION TESTS ON NARROWS DAMSITE SAMPLE NO. 9B-1040

Erosion after 1 hour and 40 minutes' exposure at 2 fps, 1 hour to 4 fps, 1/2 hour to 6 fps, and 1/2 hour to 8 fps velocity.

Flow was from left to right.

EROSION ON TEST SPECIMEN NO. 1
EROSION TESTS ON NARROWS DAMSITE SAMPLE NO. 9B-1040

A. Appearance of Test Specimen No. 1 after being trimmed 2 inches to a new surface for high velocity tests.

B. Erosion after 3 minutes' exposure at velocities ranging from 12 to 16 fps.

Flow was from left to right.

EROSION ON TEST SPECIMEN NO. 1
EROSION TESTS ON NARROWS DAMSITE SAMPLE NO. 9B-1040

A. Appearance of Test Specimen No. 2 after "weathering" period.

B. Erosion after 2 minutes' exposure at 1.5 fps velocity.

Flow was from left to right.

EROSION ON TEST SPECIMEN NO. 2
EROSION TESTS ON NARROWS DAMSITE SAMPLE NO. 9B-1040