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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

EROSION TESTS ON EARTH SAMPLES NO. 13P-95, 96,
AND 97, TAKEN AT ELEVATION 3542.0 FROM TWO
SUGGESTED SITES FOR AN AUXILIARY SPILLWAY--
MOORHEAD DAM--MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd.-269

RESEARCH AND GEOLOGY DIVISION



BRANCH OF DESIGN AND CONSTRUCTION
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Laboratory Report No. 269
Hydraulic Laboratory
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Subject: Erosion tests on earth Samples No. 13P-95, 96, and 97, taken at elevation 3542.0 from two suggested sites for an auxiliary spillway—Moorhead Dam—Missouri River Basin Project.

PURPOSE

To determine the erosion resistance of the above sand and clay materials when subjected to water velocities of 2 to 18 feet per second.

CONCLUSIONS

Sample No. 13P-95

1. This dense, slightly cemented sand withstands water velocities up to 8 feet per second with little erosion (Figure 2B), and velocities up to 14 feet per second with moderate erosion (Figure 3A). A velocity of 18 feet per second causes excessive erosion (Figure 3B).

2. The erosion rate remains practically constant at a given velocity during a test period of 30 minutes.

Sample No. 13P-96

1. Most of the material of the 24-inch deep sample was too broken to be tested. However, the top 12 inches appeared similar to the material tested in Sample No. 13P-95, and similar erosion can be expected.

2. The clay in the lower 7 inches of the sample withstands water velocities up to 18 feet per second without excessive damage (Figure 5B).

3. Most of the clay material that is removed by a given velocity is swept away within 4 minutes.

Sample No. 13P-97

1. The clay and soft sand layers in the top 14 inches of the 24-inch deep sample were too broken to be tested. However a study of the material revealed that excessive erosion should result at velocities of 6 feet per second or greater when the flow occurs along the bedding planes.

2. The well-bonded, thin clay layer immediately above the slightly cemented sand base is partially removed by velocities of 2 to 8 feet per second (Figure 6), and completely removed by a velocity of 14 feet per second (Figure 7).

3. The sand material beneath the clay withstands velocities up to 8 feet per second with moderate erosion (Figure 6), and it erodes severely at a velocity of 14 feet per second (Figure 7).

INTRODUCTION

Moorhead Dam is an earth fill structure proposed for construction across the Powder River 38 miles southwest of Broadus, Montana, and 4 miles north of the Wyoming-Montana border. As part of the detailed investigation of the damsite, a study was made of two gullies or draws which are possible sites for an auxiliary spillway. One phase of this study consisted of procuring three "undisturbed" block samples 12 inches square by 24 inches high from the two draws at elevation 3542.0. These samples were shipped to the Denver office for tests to determine the erosion resistance of the material when subjected to flowing water. Sample No. 13P-95 was taken at Station 1445.00 in Draw No. 2, located to the east of the right abutment of the damsite. Samples No. 13P-96 and 97 were taken at Stations 1441.00 and 12486.00, respectively, in Draw No. 3 located near the left abutment. Upon receipt in the Denver office, the material of the three block samples was inspected and classified by the Earth Materials Laboratory and the samples were then forwarded to the Hydraulic Laboratory for the erosion tests.

DESCRIPTION OF THE SAMPLES

Sample No. 13P-95

Dense, slightly cemented, fine to medium, uniform, clean sand with small (1/8 to 1-1/2-inch) firm sandstone inclusions.

Sample No. 13P-96

Top 12 inches—Dense, slightly cemented, fine to medium, uniform, clean sand with several clay layers (Figure 4).

Bottom 12 inches—Dark, slightly moist, hard, fractured clay.

Sample No. 13P-97

Top 14 inches—Soft, moist, somewhat spongy, uncemented, fine, silty sand and hard clay layers (Figure 6).

Bottom 10 inches—Dense, slightly cemented, fine to medium, uniform, clean sand.

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 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 it was returned to the supply channel by a trough. The floor of the test box was adjustable to permit moving the specimen to keep its top surface level with the chute floor as the material 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.

A test specimen 12 inches square by 8 inches thick was obtained from both Samples No. 13P-95 and 97. Sample No. 13P-96 was so severely broken that a specimen only 9 by 11 by 7 inches thick was obtained. One specimen at a time was placed in the test box with the side which was uppermost in the field on top in the box and level with the chute floor. The space between the downstream end of the sample and the end of the test box was filled nearly to the top with sand, and, in all but the first test on Sample No. 13P-95, the remaining space was filled to the floor level with a piece of wood cut for the purpose and wedged in place.

Visual means were used to judge the erosion on the specimens, and photographs are presented which show the condition of specimens 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 found. 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 pieces washed off the specimen and still capable of handling the large quantities of water used. Finally, the size and shape of the specimens tested precludes a close representation of the field erosion conditions. Therefore, the results presented in this report are qualitative only, and the use of the laboratory test results to predict field results must be done with care.

In describing the amount of erosion on the specimen, the following terms are used in this report:

1. Little erosion--Where the quantity of material removed was not sufficient to materially change the appearance of the specimen
2. Moderate erosion--Where sufficient material was removed to noticeably change the appearance of the specimen, but where the average depth of erosion did not exceed one-half inch
3. Excessive erosion--Where sufficient material was removed to materially alter the appearance of the specimen and the average depth of erosion exceeded one-half inch

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 in order that adequate data could be taken, while on the other hand, time would be wasted by starting with velocities too low. Nearly the full range of velocities available was used in the tests on the Moorhead specimens, the values ranging from 2 to 18 feet per second.

TEST RESULTS

Sample No. 13P-95

The loose material on the specimen was immediately swept away by a water velocity of 2 feet per second, and slight erosion was noted at the completion of the 30-minute test (Figure 2A). A small quantity of material was removed from around the harder sandstone inclusions and from soft local areas throughout the specimen, but the erosion did not exceed one-fourth inch in depth at any point. The water velocity was increased to 4, 6, and 8 feet per second, and each velocity was maintained for 30 minutes. At the end of these tests the specimen showed increased erosion, but it maintained the same general appearance it had after the first test (Figure 2B). Additional tests of 30 minutes each at velocities of 10 and 14 feet per second resulted in a noticeable increase in erosion (Figure 3A). However, the specimen was still not severely damaged, and an additional 30-minute test was made at 18-feet-per-second velocity. Excessive erosion occurred during this test, leaving many of the hard inclusions standing high above the new surface (Figure 3B). The average depth of the total erosion was $3/4$ of an inch, and a maximum depth of $1-3/16$ inches was found near the center of the upstream edge of the specimen. One downstream corner and a second area on the opposite side and upstream from the center of the specimen had not been cut down by the water. The test program was then terminated because the slightly greater water velocity (19.5 feet per second) which could be obtained with the apparatus would provide little additional information.

Sample No. 13P-96

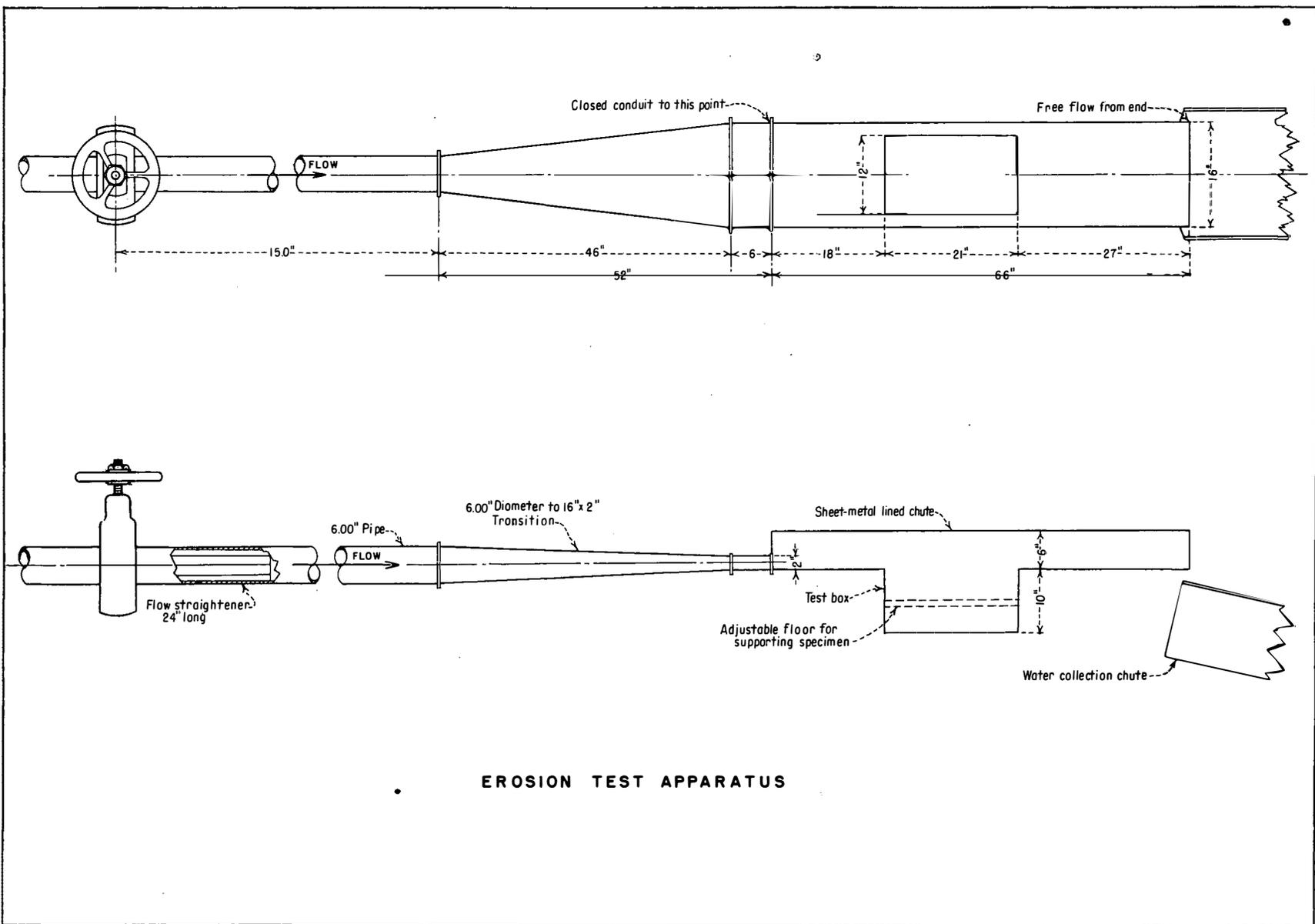
A large crack was found running through the block sample when it was removed from the shipping crate and the protective wrappings surrounding it. Further cracks developed while trimming the sample to fit in the test box, leaving the upper 17 inches so broken that a test specimen of reasonable size could not be obtained (Figure 4A). However, the sandy material which comprised most of the top 12 inches was similar to that tested in Sample No. 13P-95, and similar erosion can be expected.

The only test specimen taken from Sample No. 13P-96 was an irregular 11- by 9- by 7-inch thick piece of clay obtained from the bottom of the sample. This piece was placed in the test box, and water was passed over it at a velocity of 6 feet per second. Several pieces ranging in volume from 1/4 to 3/4 cubic inch were dislodged during the first 4 minutes of operation (Figure 5A). No visible action occurred during the remainder of the 30-minute test. Velocities of 10, 14, and 18 likewise removed material during the early periods of their respective 30-minute tests (Figure 5B). There was no case where erosion was detected during the latter part of each test. No further tests were run on the specimen because the maximum velocity of the test apparatus had nearly been reached.

Sample No. 13P-97

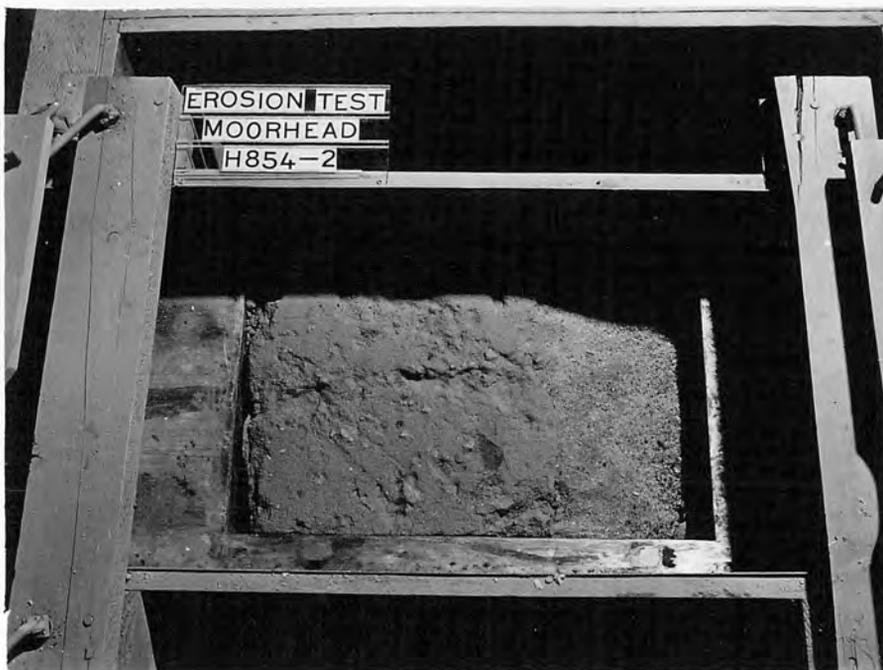
The top 14 inches of the sample (Figure 4B) consisted of thin layers of dense, uncemented sand and moderately hard clay, and was so weak that a test specimen could not be obtained. Examination of the material revealed that the uncemented sand probably would be severely eroded by velocities of 4 feet per second or greater and that the thin clay layers between the sand would be lifted and broken by velocities of 6 feet per second or greater when the flow occurs along the bedding planes.

A test specimen was obtained from the bottom 10 inches of the sample, and it included the thin clay layer visible above the uniform, slightly cemented sand base (Figure 4B). The specimen was placed in the test box, and water passed over it at 2-feet-per-second velocity for 30 minutes. Several thin pieces of clay were dislodged early in the test, but little subsequent action was noted (Figure 6A). Velocities of 4, 6, and 8 feet per second were used in the subsequent 30-minute tests, and more clay was removed early in each test period. At the end of these tests, half of the clay was removed, and the exposed sandy material showed moderate erosion (Figure 6B). A velocity of 14 feet per second removed most of the remaining clay and caused greater erosion on the sand material (Figure 7). A final test was made at 18 feet per second, and during this test, it was evident that the sand was eroding rapidly. After 15 minutes' operation, however, the sample broke in two, and it was lifted out of the test box and destroyed by the water. The tests were, therefore, terminated.



EROSION TEST APPARATUS

FIGURE 1



A. Erosion after 30-minute exposure to 2 feet per second water velocity.



B. Erosion after 30-minute exposures each to water velocities of 2, 4, 6, and 8 feet per second.

Flow from left to right

SAMPLE 13P-95
EROSION TESTS ON MOORHEAD EARTH SAMPLES



A. Erosion after 30-minute exposures each to water velocities of 2, 4, 6, 8, 10, and 14 feet per second.



B. Erosion after 30-minute exposures each to water velocities of 2, 4, 6, 8, 10, 14, and 18 feet per second.

Flow from left to right

SAMPLE 13P-95
EROSION TESTS ON MOORHEAD EARTH SAMPLES



A. Sample 13P-96 after being trimmed to fit in the test box. The top 17 inches was too broken to be tested.



B. Sample 13P-97 after the shipping crate was removed.

Flow from left to right

SAMPLES 13P-96 and 97
EROSION TESTS ON MOORHEAD EARTH SAMPLES



A. Erosion after 30-minute exposure to 6 feet per second water velocity.



B. Erosion after 30-minute exposures each to water velocities of 6, 10, 14, and 18 feet per second.

Flow from left to right

SAMPLE 13P-96

EROSION TESTS ON MOORHEAD EARTH SAMPLES



A. Erosion after 30-minute exposure to 2 feet per second water velocity.



B. Erosion after 30-minute exposures each to water velocities of 2, 4, 6, and 8 feet per second.

Flow from left to right

SAMPLE 13P-97
EROSION TESTS ON MOORHEAD EARTH SAMPLES



- A. Erosion after 30-minute exposures each to velocities of 2, 4, 6, 8, 10, and 14 feet per second.

Flow from left to right

SAMPLE 13P-97
EROSION TESTS ON MOORHEAD EARTH SAMPLES

