UNITED STATES
DEPARTMENT OF THE INTERIOR
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DRAWDOWN TESTS ON EARTH COVER MATERIAL PLACED OVER AN ASPHALT MEMBRANE EAST BENCH CANAL--MISSOURI RIVER BASIN PROJECT, MONTANA

General Report No. GEN-29

DIVISION OF ENGINEERING LABORATORIES

OFFICE OF ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

November 1, 1961

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FOREWORD

The study described in this report was conducted in the Division of Engineering Laboratories, Bureau of Reclamation, Denver, Colorado, during the month of April 1961. The asphalt membrane and its soil cover was placed by the Bituminous Laboratory Section of the Chemical Engineering Laboratory Branch. The drawdown tests were conducted by the Sediment Investigations Unit of the Hydraulic Laboratory Branch. Engineers from the Canals Branch of the Division of Design made frequent visits to the laboratory to observe the tests.

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Office of Assistant Commissioner and Chief Engineer
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Denver, Colorado
November 1, 1961

General Report No. 29*
Compiled by: F. H. Geier
R. A. Dodge
Checked by: E. J. Carlson
Reviewed by: L. M. Ellsperman
A. J. Peterka
Submitted by: W. U. Garstka
H. M. Martin

DRAWDOWN TESTS ON EARTH COVER MATERIAL PLACED OVER AN ASPHALT MEMBRANE--EAST BENCH CANAL--MISSOURI RIVER BASIN PROJECT, MONTANA

SUMMARY

Tests to establish the stability of earth cover material placed over an asphalt membrane were conducted jointly by the Hydraulic and Bituminous Laboratories.

The purpose of the study was to investigate the stability of earth material to be placed over an asphalt membrane in a canal 6.63 feet deep and 20 feet in bottom width, having 2:1 sloping banks. However, only one side slope and part of the canal bottom were reproduced in the test box.

The test section of the canal was placed crosswise in a test box 24 feet long, 3 feet wide, and 6 feet deep, equipped with a suitable water supply and drain system for the drawdown tests and a wave generator for the wave tests. The canal test section consisted of a 16-inch layer of specially prepared earth cover material placed over a 1/4-inch thick catalytically blown asphalt membrane, on a plywood base.

For the drawdown tests, the box was slowly filled with water then drawn down at rates from 1 foot per day to 2 feet per hour. For all rates, the earth cover material remained stable but did show surface cracking for the 2 feet per hour rate.

The cover material was found to be more susceptible to wave damage than to drawdown damage. When the earth slope was exposed

*Same as Laboratory Reports No. HYD-484 and B-30.

to waves 0.1 foot high for 5 minutes followed by waves 0.2 foot high for 3 minutes, 0.33 cubic foot of cover material per lineal foot of canal bank was eroded from the initial embankment and redeposited downslope to form a beach.

INTRODUCTION

Sloughing failure of soil cover material on or near asphalt membrane linings in canals has created maintenance problems particularly in the Missouri River Basin and Columbia Basin Projects. An example of a failure, which occurred on West Canal near Station 3606+12, Columbia Basin Project, is shown in Figure 1. In this particular case, the side slopes were 2:1 and freeboard was 1.5 feet.

It has not been clearly established whether sloughing is more frequent on canals with or without membranes. However, it is the consensus of field engineers that when sloughing occurs on or near membranes, the damage is more extensive than when membranes are not present. No clear-cut determination has been made as to the cause of the failure. It has not been established whether the subbase, the protective cover material, the method of hydraulic operation including the drawdown rate, the asphalt membrane, or the combination of two or more of these items are at fault.

PREPARATION OF TEST SECTION

Preparation of Plywood Base

The base to support the canal side slope was constructed of two pieces of 3/4-inch thick by 36-inch wide plywood, having a total length of 161 inches, Figure 2. The horizontal bottom base was one piece of plywood 94 inches long. To provide areas to represent a smooth and a rough subgrade, a strip of plywood 1/4 inch thick and 1 inch wide was nailed lengthwise down the center of the sloping board. This dividing strip was lightly coated with catalytically blown asphalt cement. The area on one side of the dividing strip was covered with metal lath to simulate the rough subgrade. The other half of the sloping board and the entire horizontal bottom board were bare plywood, representing the smooth subgrade.

Preparation and Installation of Asphalt Membrane to Plywood Base

Type 1 catalytically-blown asphalt, having the characteristics shown in Table 1, was used for the membrane in this study. Type 1 asphalt is normally used during warm weather construction. The original decision to spray the asphalt on the plywood base in liquid form was abandoned because the resulting membrane adhered tenaciously to the base, a condition which does not occur in the field. The asphalt, as it is applied in a field installation of a buried asphalt membrane canal lining, upon cooling, is similar to a blanket placed over the subgrade and often can be lifted from the subgrade. A similar condition was desired in the model and was accomplished by using precast asphalt blocks that were made and installed according to the following procedure.

Standard application rates used by the U. S. Bureau of Reclamation for asphalt membrane canal linings are 1.25 gallons per square yard for smooth subgrades and 1.50 gallons per square yard for rough subgrades. These rates are equivalent to 541.8 and 650.1 grams per square foot, respectively. These weights were used in precasting 1-foot square blocks of asphalt in the laboratory. This was done by carefully melting the desired quantity (weight) of catalytically-blown asphalt at approximately 425° F and pouring into 1-foot square aluminum pans that had been lightly coated with silicone grease to prevent sticking. The metal lath, representing the rough subgrade, was covered with precast asphalt squares that corresponded to the heavier rate of application. The remaining portion of the side slope plus the entire bottom, representing a smooth subgrade, was covered with precast squares that corresponded to the lighter rate of application.

The squares of asphalt were placed side by side, starting at the top of the side slope and working downward, as shown in Figure 3. The joints were sealed by applying heat from a small propane torch so that adjacent edges melted and flowed together to form the continuous membrane shown in Figure 4. The membrane was sealed to the walls of the test box by placing strips of asphalt, 1/4 inch thick by 1 inch wide, along the junction of the membrane and test box wall and applying heat to cause the strips to adhere firmly to both the flume wall and the membrane.

The Preparation and Placement of Cover Material

The gradation of the cover material to be placed over the membrane was based on the criteria that the fraction 25 percent larger than No. 10 sieve would be erosion resistant at the tractive force computed for East Bench Canal and that the fraction 95 percent larger than No. 200 sieve would be free draining during drawdown of the water surface. The components of the cover material were prepared in the laboratory from washed "Clear Creek" aggregate. The material finer than No. 200 mesh was obtained by processing a No. 50-mesh material in a ball mill for approximately 12 minutes. A size analysis of the mixed cover material is presented in Figure 5 and in Table 2.

The required 9,000 pounds of cover material (88.05 cubic feet) was placed in 250-pound batches. Each batch was mixed separately and contained the proper amount of each predetermined size fraction as shown in Table 2. Mixing was done in a wooden chute 30 inches wide, 8 inches deep, and 12 feet long, which was also used to dump the material into the test box. The unmixed 250-pound batches were placed in the chute using a tow-motor loader. After the material was thoroughly mixed, it was dropped on the membrane, Figure 6, simulating the placement of cover material by dragline. Loss of fine material due to dusting was reduced to a minimum by covering the model box with tarpaulins.

Placement and Gradation of Cover Material

Batches of the earth cover material were dropped into place and smoothed to near grade by raking. This was done, starting on the bottom, at the end of the test box and gradually working to the toe of the side slope and up the sloping bank. A final grading was later made to the thickness of 16 inches. A cross section of the test slope is shown in Figure 7. The completed protective cover is shown in Figure 8. The cover material was not compacted by any formal procedure. However, there was some compaction resulting from walking over the material during placement.

After the cover material was placed, a cubic-foot sample was removed from the bottom portion. It was found to weigh 115 pounds. This weight is in close agreement with the theoretical maximum density 115.25 pounds per cubic foot computed by laboratory personnel.

DRAWDOWN TESTS

In preparation for the drawdown tests, the box was slowly filled with water so that all free air in the cover material was displaced. A freeboard of about 6 inches was maintained overnight by the continual addition of water to compensate for box leakage. Prior to the first drawdown test, the entire portion of the cover material above the waterline was moist due to capillary action, as was the case for each succeeding drawdown test. It was noted that the top 2 inches of the submerged sloping bank was mushy. This was due to dilatancy effects and interstitial accumulation of air bubbles.

The first test was for a drawdown rate of 1.0 foot per day or 0.042 foot per hour, a commonly used rate for unwatering earth canals. A valve-controlled city waterline, installed in the end wall of the test section, was used to compensate for leakage from the test box when the leakage was greater than the drawdown rate.

Despite the best efforts, it was found difficult to control and maintain the low rate of drawdown for overnight tests as shown for Test 1 in Figure 9. Figure 9 also shows water depth plotted against time for other rates of drawdown. The solid curves represent the actual occurrence of drawdown and the dashed lines show the desired rates.

The drawdown rates were increased from 0.042 to 2 feet per hour as shown in Figure 9. No major damage to the cover material was found. However, at the rate of 2 feet per hour, the earth cover material on the sloping bank developed surface cracks that were parallel to the falling waterline. Figure 10 shows the cracking just above the water surface. Close inspection revealed that the cracks did not penetrate into the cover material to any great depth and consequently, they could not be considered major damage. Rates of drawdown greater than 2 feet per hour were not tested because greater rates would not normally be encountered in a canal even if a canal break occurred.

WAVE TESTS

From observations of the condition of the sloping bank upon saturation and from past experience with wave studies in the laboratory, it was decided that the cover material might be susceptible to wave damage. Resistance of the cover material to wave action was, therefore, tested using a hand-operated plunger-type wave generator to produce waves having a period of 1 second. Two waves were generated, 0.1 and 0.2 foot in height, in the pool which was 3.9 feet deep. The 0.1-foot-high waves were allowed to impinge on the saturated sloping bank for 5 minutes followed by the 0.2-foot-high waves for 3 minutes, after which the model was carefully drained. The beach that was formed is shown in the photograph and profile of Figure 11. The cover material became armored with pebbles as shown in the photograph. The wave action caused the cover material to consolidate and lose its mushy characteristics in the wave zone. Measurements of the volume removed by wave action showed that 0.33 cubic foot of cover material per foot of bank was eroded.

CONCLUSIONS

The earth cover material described in this report should withstand drawdown rates up to 2.0 feet per hour without sloughing. When subjected to surface water waves, the cover material eroded rapidly at first, but soon became rather firm and armored with the coarse material. After 8 minutes exposure to waves 0.1 and 0.2 foot high, the erosion of cover material per lineal foot of canal bank was 0.33 cubic foot.

The earth cover material specified for East Bench Canal, in Specifications No. DC-5638, is coarser than the material tested in this study. It should be more resistant to sloughing and beaching than the material tested.

Table 1

CATALYTICALLY-BLOWN ASPHALT SPECIFICATIONS

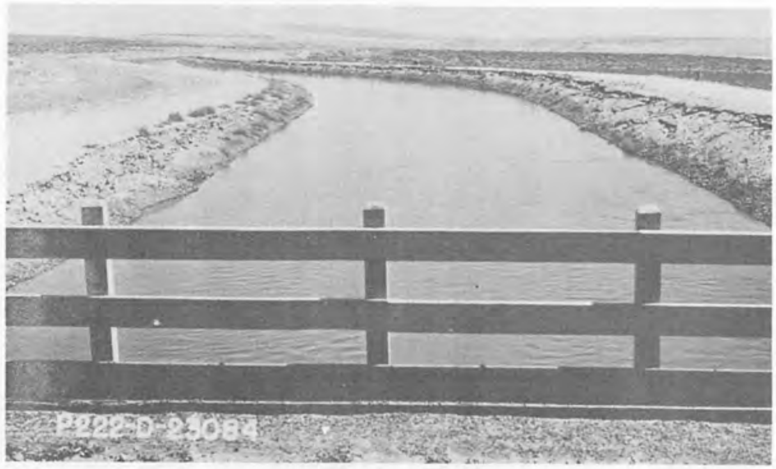
Penetration grade	50-60
Flashpoint (Cleveland Open Cup), not less than	425° F
Softening point (Ring and Ball)	175° F to 200° F
Penetration at 77° F, 100 grams, 5 seconds	50-60
Penetration at 32° F, 200 grams, 60 seconds, not less than	30
Penetration 115° F, 50 grams, 5 seconds, not more than	120
Ductility at 77° F, 5 centimeters per minute, not less than	3.5 cm
Loss at 325° F, 5 hours, not more than	1.0%
Penetration of residue at 77° F, 100 grams, 5 seconds, as compared to penetration before heating, not less than	60.0%
Bitumen (soluble in carbon tetrachloride), not less than	97.0%

Table 2

GRADATION OF COVER MATERIAL FABRICATED IN THE LABORATORY

Sieve size	Percent finer than largest size	Percent in fraction	Pounds in fraction per 250-pound increment	Total cubic feet
1/2 inch to 3/8 inch	100.0	3.5	8.75	3.1
3/8 inch to No. 4	96.5	8.7	21.75	7.65
No. 4 to No. 8	87.8	10.8	27.00	9.5
No. 8 to No. 16	77	11.0	27.50	9.7
No. 16 to No. 30	66	16.0	40.00	14.1
No. 30 to No. 50	50	18.0	45.00	15.8
No. 50 to No. 100	32	15.0	37.50	13.2
No. 100 to No. 200	17	12.0	30.00	10.6
Passing No. 200	5	5.0	12.50	4.4
TOTAL		100.0	250.00	88.05

Figure 1



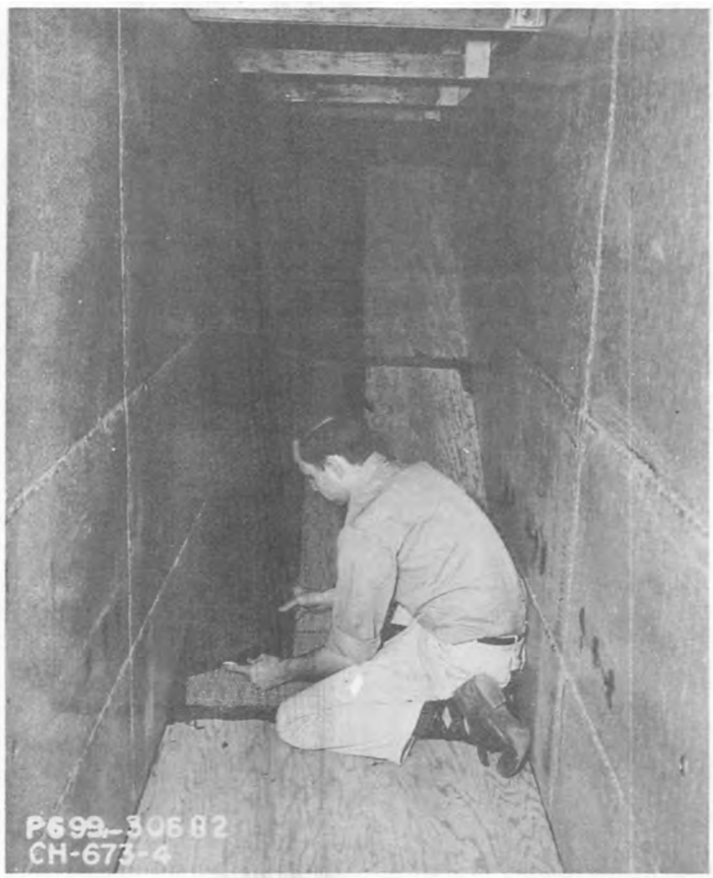
(a) View Showing Extent Of Damage

(b) Closeup Of Bank Failure

Slippage Of Earth Cover Material Over Asphalt Membrane, West Canal Near Station 3606+12, Columbia Basin Project

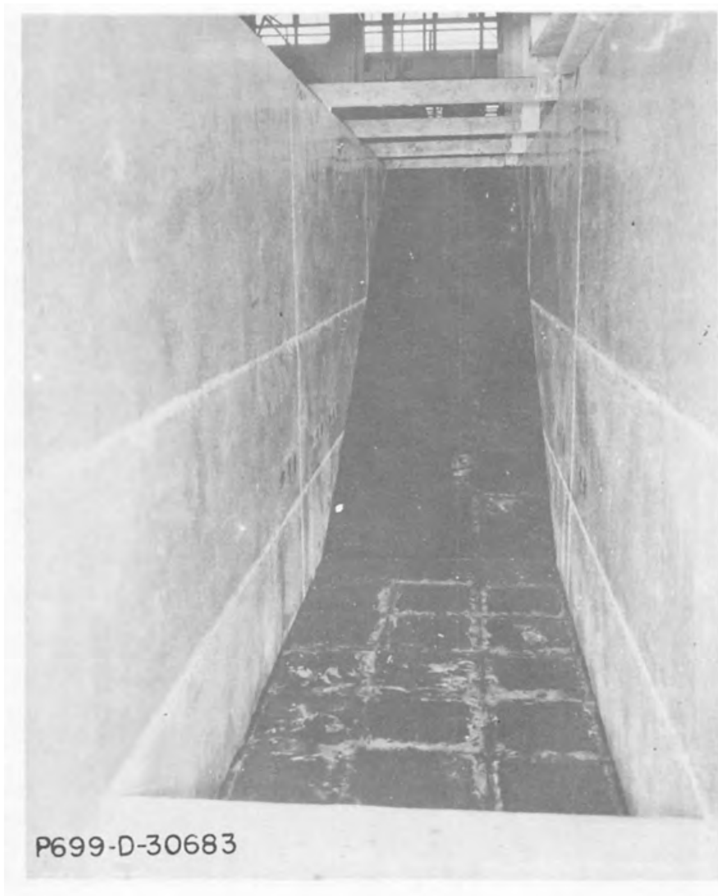
Figure 2

Plywood Support For Simulated Canal Slope And Bottom. Left Half Of Slope Is Covered With Metal Lath Simulating A Rough Subgrade
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model

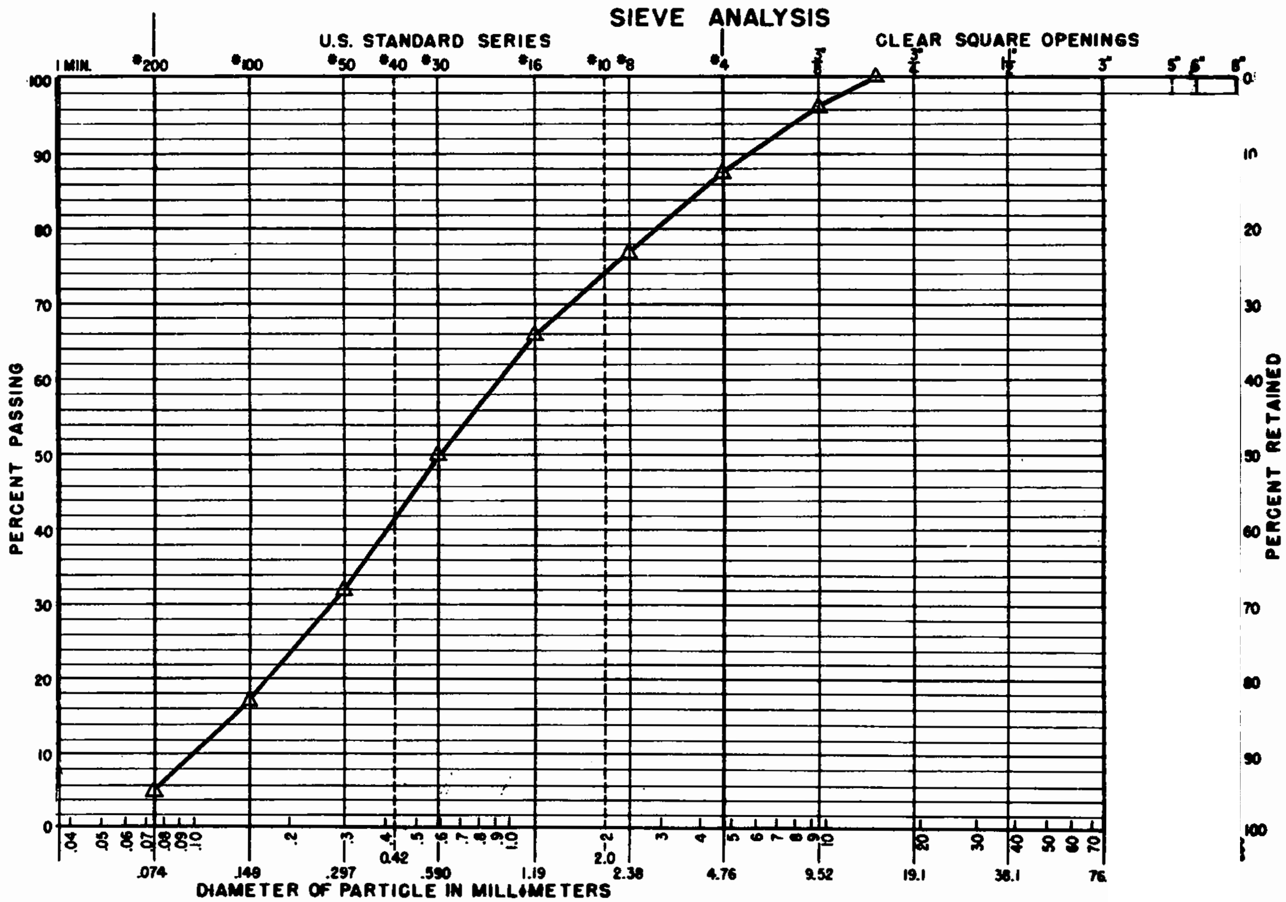


Placing Asphalt Membrane Squares On Plywood Support
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model

Figure 4



Catalytically-blown Asphalt Membrane In Place,
Prior To Placing Earth Cover Material
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model



GRADATION CURVE OF COVER MATERIAL FABRICATED IN LAE [illegible] RY
FOR EAST BENCH CANAL DRAWDOWN TEST

FIGURE 5
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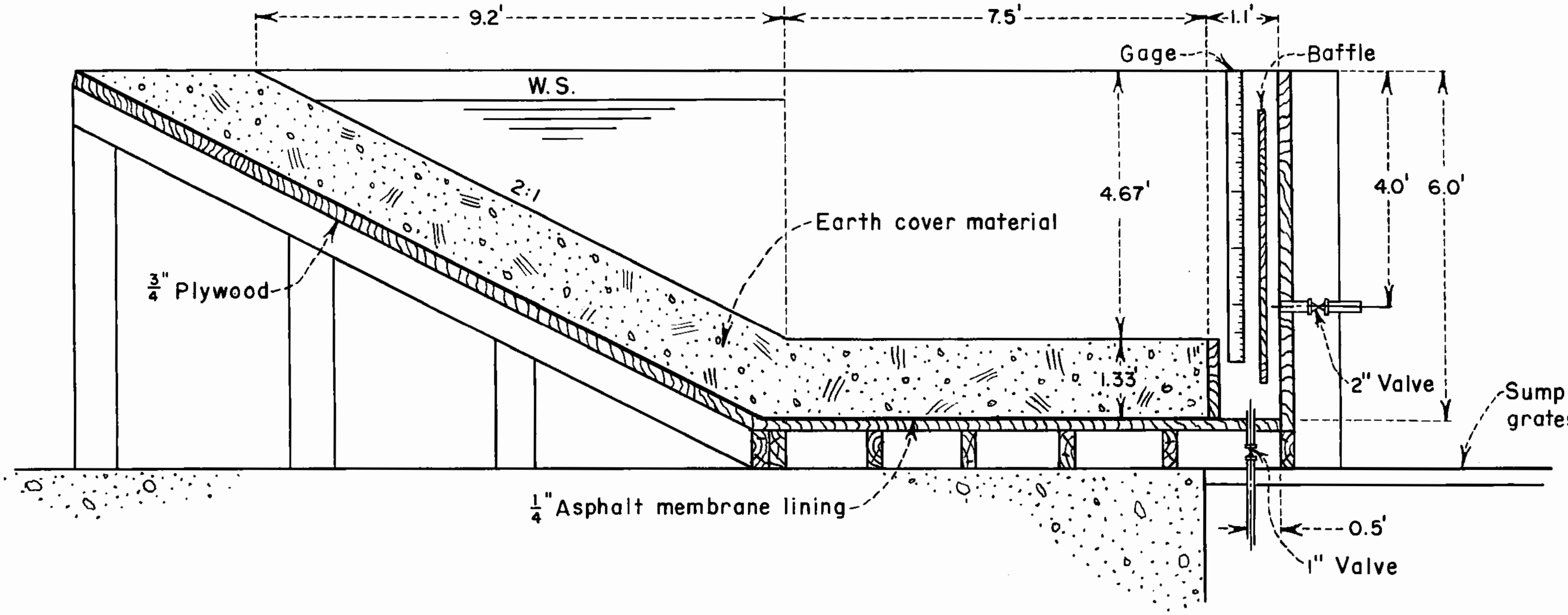
Figure 6

Placing Cover Material Over Asphalt Membrane
Material Is Dropped Simulating Placement By
Dragline
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model



HYDRAULIC MODEL FOR EAST BENCH CANAL DRAWDOWN TESTS

SCALE 1:1

FIGURE 7
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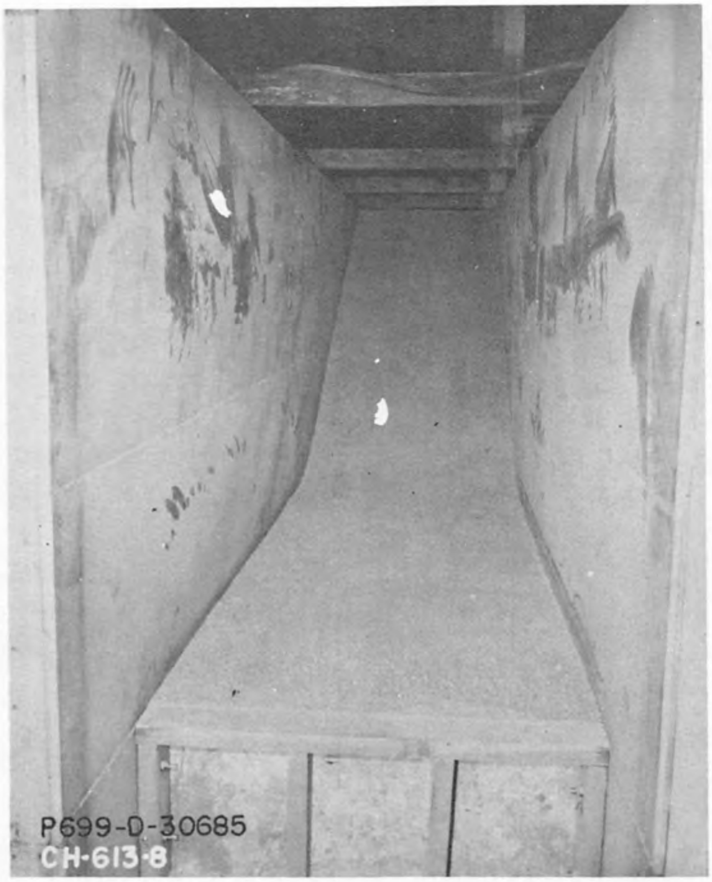
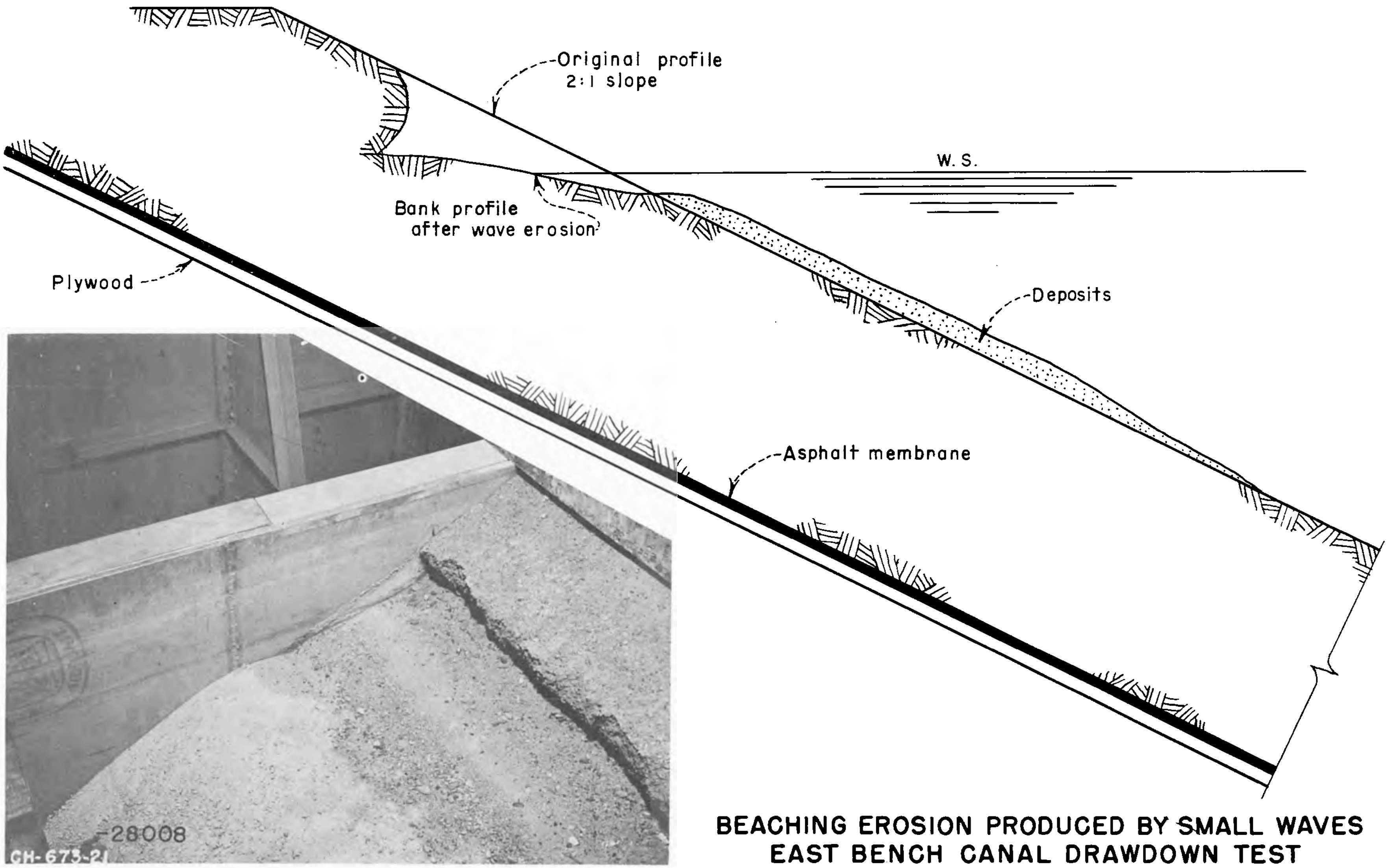
Figure 8



Earth Cover Material In Place Prior To Hydraulic Drawdown Tests
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model



BEACHING EROSION PRODUCED BY SMALL WAVES
EAST BENCH CANAL DRAWDOWN TEST
1:1 SCALE SECTIONAL MODEL

FIGURE 11
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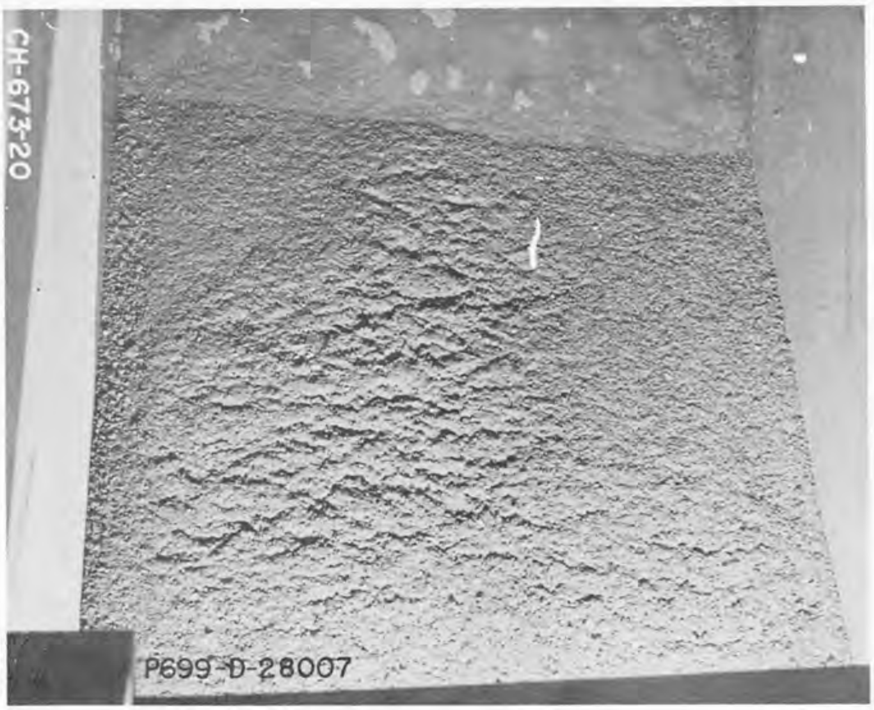
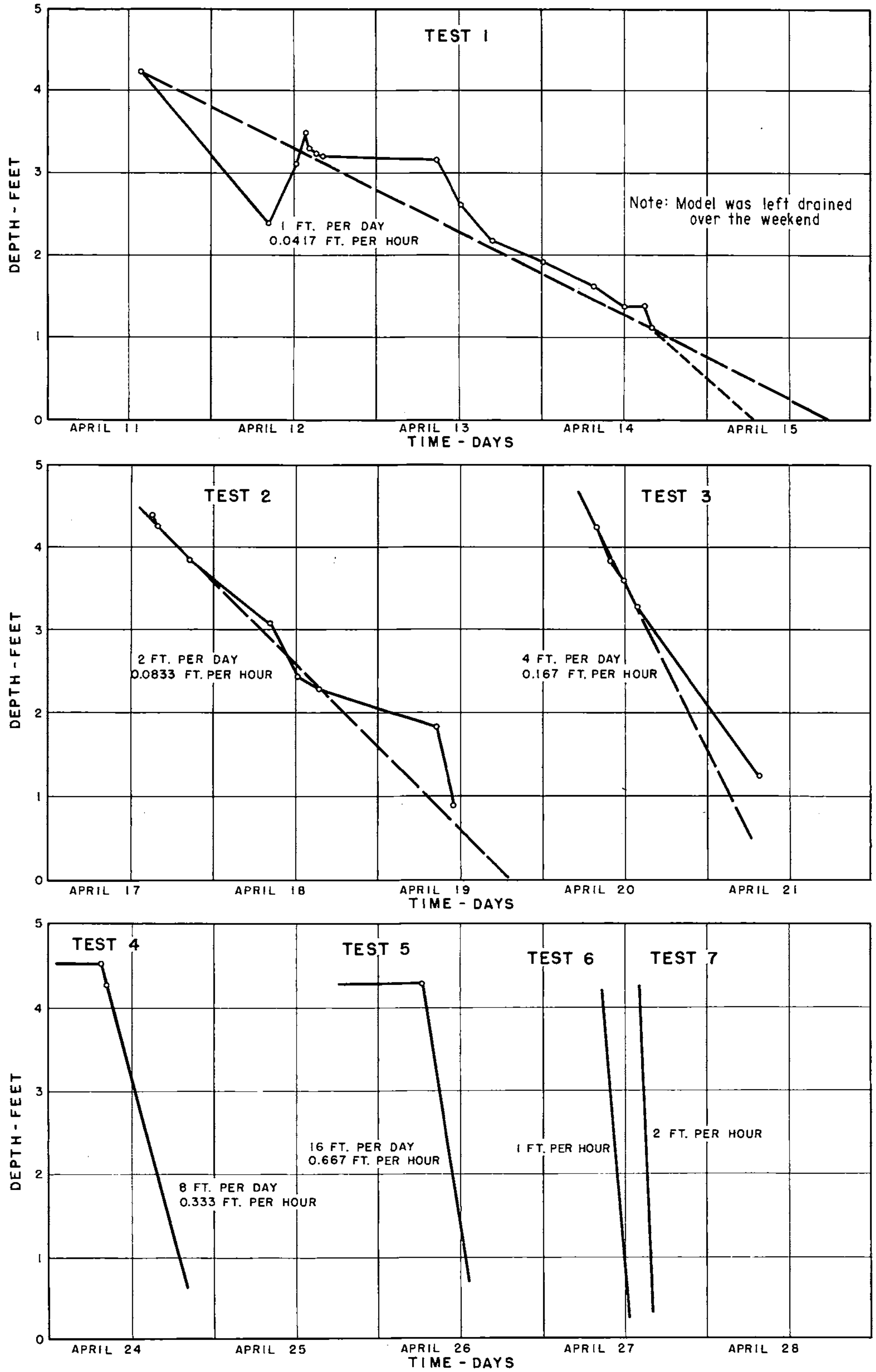
Figure 10



Surface Cracks Forming Just Above Waterline
When Drawdown Rate Was 2 ft/hour. Looking
Down The Slope
East Bench Canal Drawdown Tests
1:1 Scale Sectional Model



GRAPHS SHOWING DRAWDOWN RATES
EAST BENCH CANAL DRAWDOWN TESTS