UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

EVALUATION OF CATIONIC ASPHALT EMULSION AS A WATERBORNE CANAL SEALANT BY HYDRAULIC FLUME TESTING--LOWER COST CANAL LINING PROGRAM

General Report No. 32

DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
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Office of Chief Engineer
Division of Research
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General Report No. 32*
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Subject: Evaluation of cationic asphalt emulsion as a waterborne canal sealant by hydraulic flume testing--Lower Cost Canal Lining Program

SUMMARY AND CONCLUSIONS

Hydraulic flume tests were conducted jointly by the Bituminous Section and the Hydraulics Branch to determine the effectiveness of cationic asphalt emulsion for sealing canals when applied by the ponding method. The tests were made in a 12-inch wide by 20-inch deep by 30-foot long recirculating flume in the Hydraulics Laboratory, Figure 1, using fine sandy soil, Figure 2, and various formulations of cationic asphalt emulsion. Conclusions resulting from the tests are:

1. The flume tests indicate that with an application rate of 1/2 gallon per square yard, cationic asphalt emulsion sealant effects a near watertight seal, Figure 3. However, further tests indicated that most of the sealing developed in the top inch of the sealant treated soil, even though as much as 9 inches of sealant penetration were obtained. Approximately 40 percent of the sealing effected was lost on removing the upper 1/2-inch thickness of treated soil.

2. In the tests where 7 to 9 inches of sealant penetration were obtained, it was determined that the average asphalt content of the treated soil was 5.4 percent for the top 1 inch, 1.4 percent for the next 6 inches, and 0.9 percent for the last 2 inches based upon the dry weight of soil.

3. The cationic asphalt emulsion sealant resulted in a high degree of stabilization of the sandy soil at the surface. No erosion of the treated surface was observed with water velocities of 3.6 feet per second.

*Same as Laboratory Report No. B-32 and Hydraulics Branch Report No. Hyd-512.

4. Tests showed that by use of a small amount of sealant (0.1 gallon per square yard) it was possible to reseal the soil where the original treated sealant surface had been punctured.

On completion of the flume tests the cationic asphalt emulsion treated soil was removed from the flume and analyzed in the Bituminous Laboratory.

INTRODUCTION

Under the Lower Cost Canal Lining Program, a concentrated effort is being made to develop chemicals or other materials to effect sealing in unlined earth canals. This work is being carried on in close coordination with industry. One method of application of sealant materials is by the waterborne treatment where the material is added to the canal either in flowing water or in ponded sections. Thus far, laboratory and field investigations of canal sealants have been chiefly limited to three materials, one being cationic asphalt emulsion.

The cationic asphalt emulsion is a relatively new development of the asphalt industry as an improvement over the old standard asphaltic emulsion having anionic characteristics. Two major advantages have been gained with production of the cationic asphalt emulsion. These are increased bonding capabilities of the asphalt globules and less restrictive conditions for curing or "breaking" of the emulsion.

The use of cationic chemicals for emulsification of asphalt results in positive charged minute globules of asphalt contained in asphalt emulsion. Since most damp surfaces inherently possess a negative charge, the normal attraction of unlike charges will cause a cationically emulsified asphalt to be strongly bonded on most surfaces. The curing out or "breaking" of anionic asphalt emulsion is one primarily of evaporation of the emulsion liquid requiring absorptive surfaces and favorable atmospheric conditions. In contrast, the curing out or "breaking" of cationic asphalt emulsion is largely a chemical action. This makes it possible to use cationic asphalt emulsion under severe wet conditions such as effecting underwater sealing in a canal.

A chemical company that has been active in the development of cationic asphalt emulsions for evaluating as a canal sealant made available several formulations. One phase of a program to evaluate cationic asphalt emulsion as a canal sealant involved testing in a hydraulic laboratory flume. This report describes results of the flume tests and the laboratory analyses made of cationic asphalt emulsion treated soil samples removed from the test flume.

PREPARATION AND OPERATION OF THE TEST FLUME

The study was conducted in a 12-inch wide by 20-inch deep by 30-foot long recirculating flume available in the Hydraulics Laboratory, Figures 1 and 4a. The recessed test section in the flume where the soil was placed is 1 foot wide, 6 feet long, and 1-1/2 feet deep. As shown in Figure 4b, this section of the flume is constructed with a glass wall on one side, making it possible to observe the penetration of the sealant material into the soil and the erosive effects on the treated surface by flowing water.

Before placing the soil, a two-layer reverse filter was installed in the bottom of the test section. The soil was then placed to a depth of about 12 inches bringing the top surface level with the bottom of the flume. The soil used in all tests consisted of a processed fine sand. The gradation is shown in Table 1 and represented graphically in Figure 2. The noncohesive soil was placed in the flume test section dry and without compaction other than that resulting from dropping the material from the shovel and from settlement due to the 1-foot head of water used in the flume.

Efforts were made to obtain accurate seepage rate measurements of the soil prior to treatment with the cationic asphalt emulsion. The soil was first slowly saturated from the bottom to remove the maximum amount of air. After water reached the soil surface, the flume was filled with water to an elevation of 1 foot above the overflow. A 1,000-ml graduate and a stopwatch were used to obtain seepage rates from the overflow, Figures 1 and 5a. When the time to fill the 1,000-ml graduate was relatively short, a number of readings were taken and averaged. Readings were obtained over a period and an average seepage rate computed. The same method of seepage measurement was utilized after treatment with cationic asphalt emulsion to evaluate the sealing effected.

TEST PROCEDURES AND RESULTS

Flume Tests

The hydraulic flume studies included six separate tests utilizing different cationic asphalt emulsion sealants under various operating conditions as described in Table 3. The test section provided 6 square feet or 2/3 square yard of surface area. The amount of sealant added was converted to an application rate of a specified volume per square yard of soil surface.

The predetermined volume of cationic asphalt emulsion sealant was measured and added to the test flume section as shown in Figure 5b.

The sealant was mixed into an approximately 1 foot head of water maintained over the fine sandy soil at the beginning of each test. Seepage measurements were begun as soon as it was observed that the cationic asphalt emulsion was penetrating into the soil. The depth of penetration of the sealant was readily observed through the glass wall of the test flume as indicated in Figure 6a.

The chemical manufacturing company furnishing the cationic asphalt emulsion sealants for the tests described the various samples as experimental formulations. The first four tests were made using early formulations assigned Laboratory Nos. B-3117, B-3137, and B-3138. The remaining two tests were made with cationic asphalt emulsion, Sample No. B-3221, which according to the manufacturer was formulated especially for deep penetration. Basically, the asphalt cement used in the sealant formulations was the same; only the emulsifying chemicals were changed in an endeavor to develop the best penetration-type sealant possible. A laboratory analysis of a typical cationic asphalt emulsion sealant is shown in Table 2.

The results of the hydraulic flume tests are given in Table 3 and represented graphically in Figure 3. It appears that a high degree of sealing can be effected with cationic asphalt emulsion; however, the sealing was largely at the surface of the soil. Even though it was possible to obtain as much as 9 inches of soil penetration with the cationic asphalt emulsion, the asphalt globules were concentrated in the first or top 1/2-inch depth of soil. This was indicated in Test No. 1A (Table 3) where it was determined that about 40 percent of the sealing effected was lost after removing the upper 1/2-inch thickness of treated soil. The surface of the soil was highly stabilized as a result of the asphalt impregnation. The test flume was operated at an average velocity of 3.6 feet per second over the sealant treated surface without any evidence of erosion resulting.

In Test No. 4A, Table 3, the surface of soil treated with sealant, which showed a 93 percent seepage reduction, was punctured by a standard soil penetration resistance tester using a 1-square-inch needle, Figure 6b. In all, 10 holes 2-1/2 inches deep were made to simulate puncturing as a result of animal traffic. It was determined that retreatment with sealant applied at the rate of only 0.1 gallon per square yard resulted in a satisfactory reseal. Figure 7a shows a cross section of the treated soil where a punctured area was resealed by treatment of sealant applied at the rate of 0.1 gallon per square yard.

Laboratory Tests of Sealant Treated Soil

After completion of several of the flume tests, the soil containing cationic asphalt emulsion sealant was removed for laboratory analyses, Figures 7b, 8a, and 8b. The soil removed from the flume was carefully separated at three different depth zones: (1) the top 1/4- to 1/2-inch soil zone, containing a high concentration of asphalt, (2) the zone from 1/2- to 6-inch depth, and (3) the bottom zone at a depth of about 6 to 7 inches. The density and the asphalt content were determined for the different zones of sealant treated soil. The density of the soil was calculated from specific gravity determinations made of wax coated specimens. The asphalt content was determined by the standard reflux extraction test.

The results of the laboratory tests are presented in Table 4. By comparing the asphalt content for the three different zones of sealant penetration, it is apparent that the major portion of the asphalt is at or near the surface, and therefore this is the area where most of the sealing occurs.

Test specimens were molded from the sealant treated soil of high asphalt content for testing in the laboratory wave action machine. The wave action machine is a compact unit consisting of a watertight metal tank about 4 feet square and 3-1/2 feet high, Figure 9a. A horizontal shaft extending through the tank at its midpoint is revolved by an electric motor at 40 revolutions per minute. Three equally spaced stainless steel rods are attached to brackets rigidly welded around the shaft for attaching 3-1/2-inch square test specimens. During testing, the test specimens are revolved within the watertight unit striking normal to the water surface maintained at 20-inch depth, Figure 9b. Thus the specimens strike the water 40 times every minute. A counter attached to the central shaft provides an accurate record of the number of blows received by each specimen. Testing with the wave action machine is a continual process, administering erosion action to 18 specimens through delivery of 57,600 pounding blows each 24-hour period.

The results of wave action testing indicated that the high asphalt sealant treated soil had moderate erosion resistance. The appearance of one test specimen before and after 40,800 blows of wave action is shown in Figures 10a and b.

Table 1

GRADATION OF SAND USED IN HYDRAULIC FLUME TESTS

Sieve size	Percent passing by weight	
	Dry Analysis	Wet analysis
1/4 inch	100.0	100.0
No. 4	99.9	99.9
No. 10	99.8	99.8
No. 40	99.0	99.0
No. 100	5.6	5.6
No. 200	0.7	1.0

Table 2

PROPERTIES OF CATIONIC ASPHALT EMULSION USED IN SEALANT TESTS

Laboratory Tests	Test values
TESTS ON EMULSION	
Furol viscosity at 77° F, Sec	130
Furol viscosity at 122° F, Sec	100
Residue from distillation, percent	60
Sieve test (retained on No. 20), percent	5
Oil Distillate (percent of total volume of emulsion)	3
pH	4
Particle charge	Positive
TESTS ON RESIDUE	
Penetration, 77° F, 100 g., 5 sec	150
Solubility in Carbon Techtrachloride, percent	99
Ductility, 77° F, cms	120

Table 3

HYDRAULIC FLUME TESTS
Cationic Asphalt Emulsion Canal Sealant

Test No.	Cationic asphalt emulsion Lab No.	Volume of emulsion added, ml	Application rate gsy	Penetration depth inches	Seepage Cu ft/ sq ft/day Before treatment	After treatment	Percent reduction	Remarks
1	B-3137 B-3138	505 505	0.35	1 to 3	36.5	4.0	89.0	Penetrated an average depth of 2 inches forming a surface crust of about 1/4-inch thick. Results not to reliable as asphalt did not seal completely against sides of flume.
1A	B-3137 B-3138	250 250	0.15	See remarks	36.5	6.5 4.4* 14.8**	98.2 98.8 59.5	Continuation of test No. 1 with additional asphalt emulsion added. Tests made with flowing water resulted in no erosion of the surface with 3.6 foot per second velocity.
2	B-3137	350	0.13	1/2 to 2	36.1	0.8	97.8	Penetrated an average depth of 1 inch with this small amount of asphalt emulsion. About 1/4-inch thick crust was formed which resulted in a good seal.
3	B-3117 B-3137 B-3138	1,140 140 120	0.50	3 to 5	30.2	4.1	84.7	Penetrated an average depth of 4 inches forming a surface crust of 1/4-inch thick.
4	B-3221	1,400	0.50	6 to 8	28.2	2.0	93.2	This asphalt emulsion was formulated for deep penetration. Penetrated an average depth of 7 inches, forming a tough surface crust of 1/2-inch thick.
4A	B-3221	250	0.10	See remarks	23.0	0.5	97.9	The surface seal resulting from No. 4 test was punctured by a standard soil penetration resistance tester using 1 square inch needle. Ten holes of 2-1/2 inches depth were made to simulate puncture by the feet of animals. The small amount of asphalt emulsion was added to determine resealing requirements.

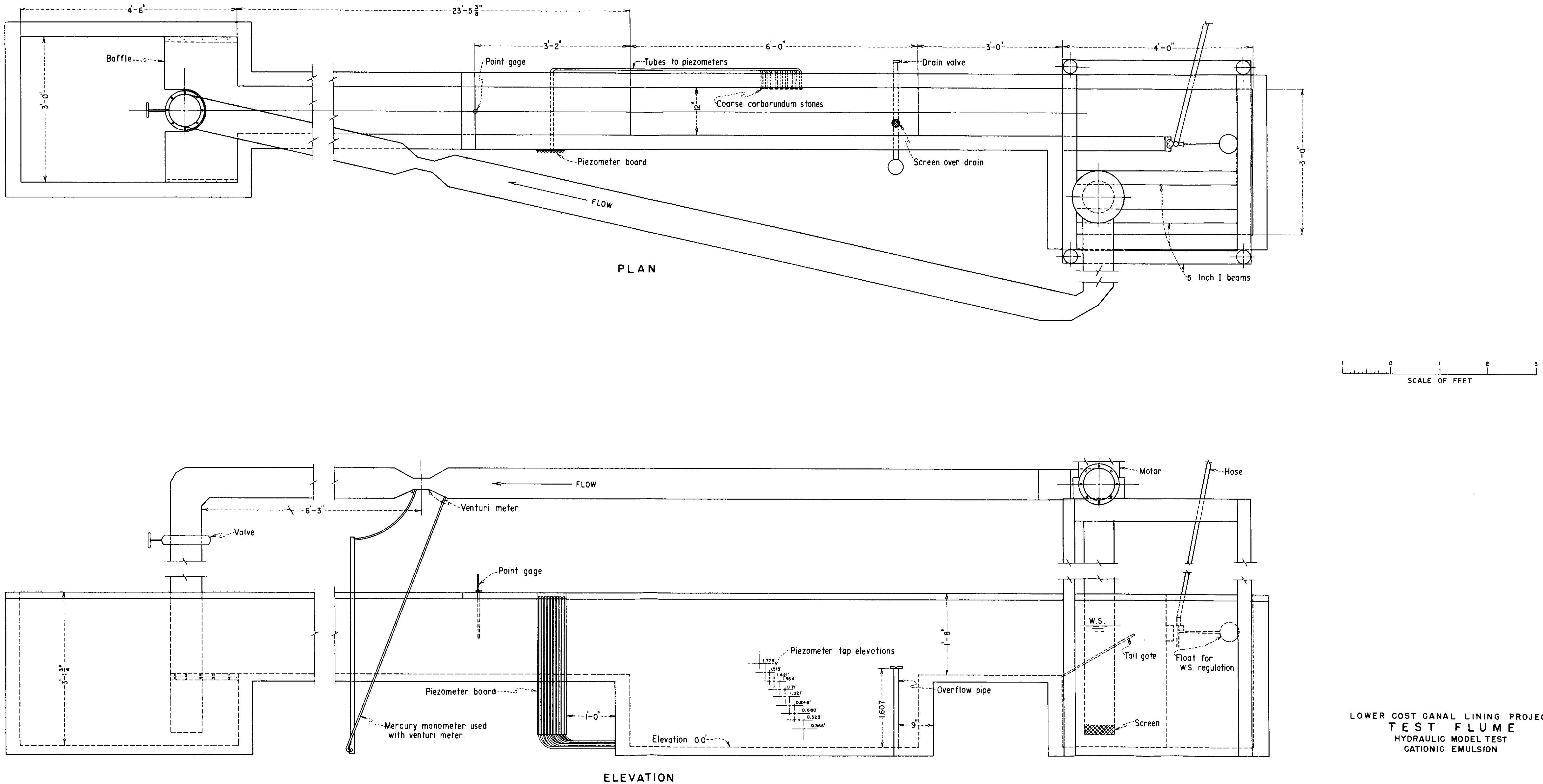
*With water circulating at velocity of 3.6 feet per second.
**After 1/2-inch asphalt crust at surface was removed.

Table 4

LABORATORY TESTS OF ASPHALT EMULSION PENETRATED SAND REMOVED FROM HYDRAULIC TEST FLUME

Asphalt emulsion penetration depth, inches	Color of treated sand	Density of treated sand, lbs/cu ft	Asphalt content* percent
1/4-1/2	Black	90.6	5.42
1/2-6	Dark brown	96.3	1.38
6-9	Light brown	99.6	0.85

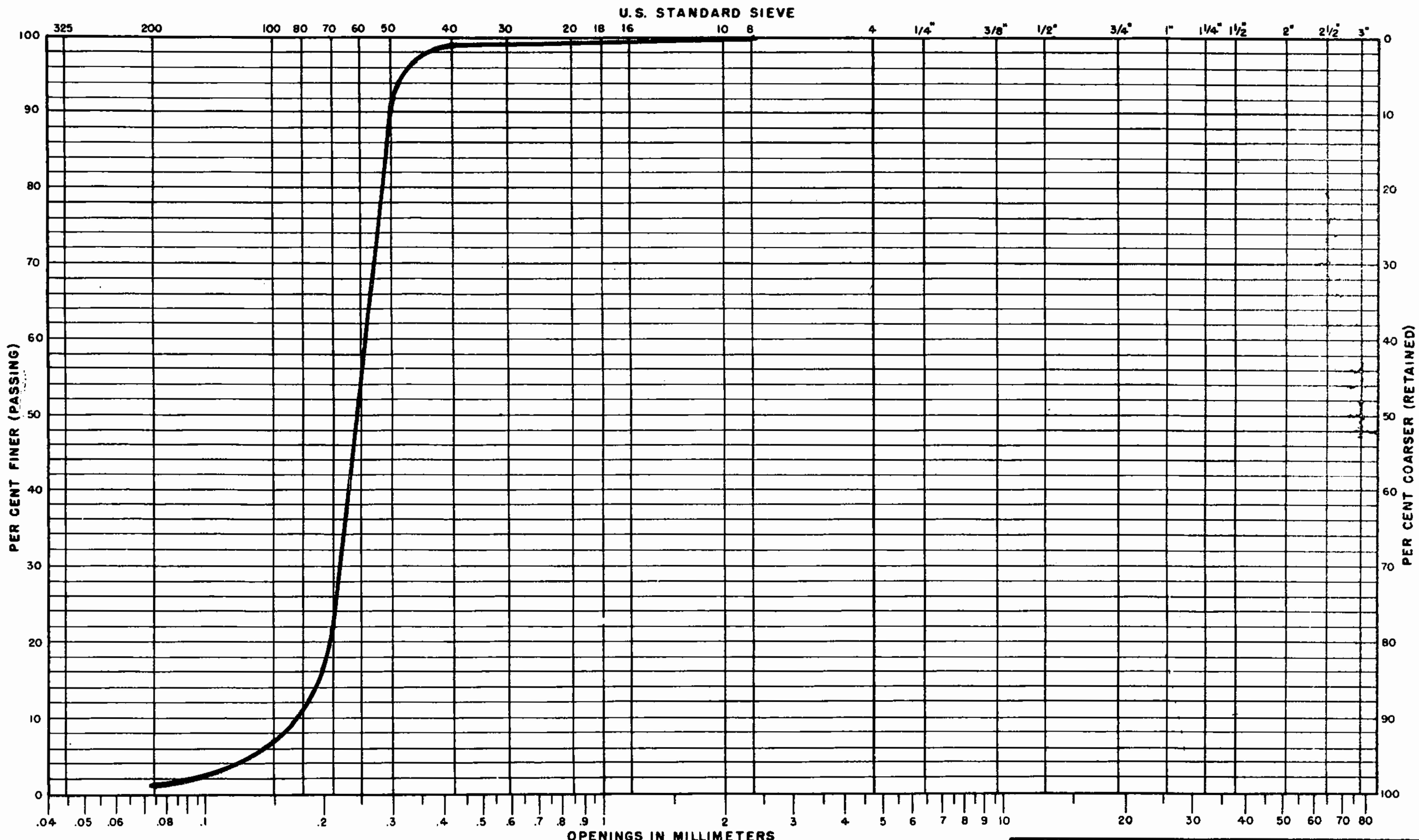
*Based on dry weight of sand.



LOWER COST CANAL LINING PROJECT
TEST FLUME
HYDRAULIC MODEL TEST
CATIONIC EMULSION

622

Form 7-1413
(3-50) Formerly X-D-2977



NOTES:

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WET GRADATION ANAYSIS

HYDRAULIC MODEL TEST

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AGGREGATE GRADATION

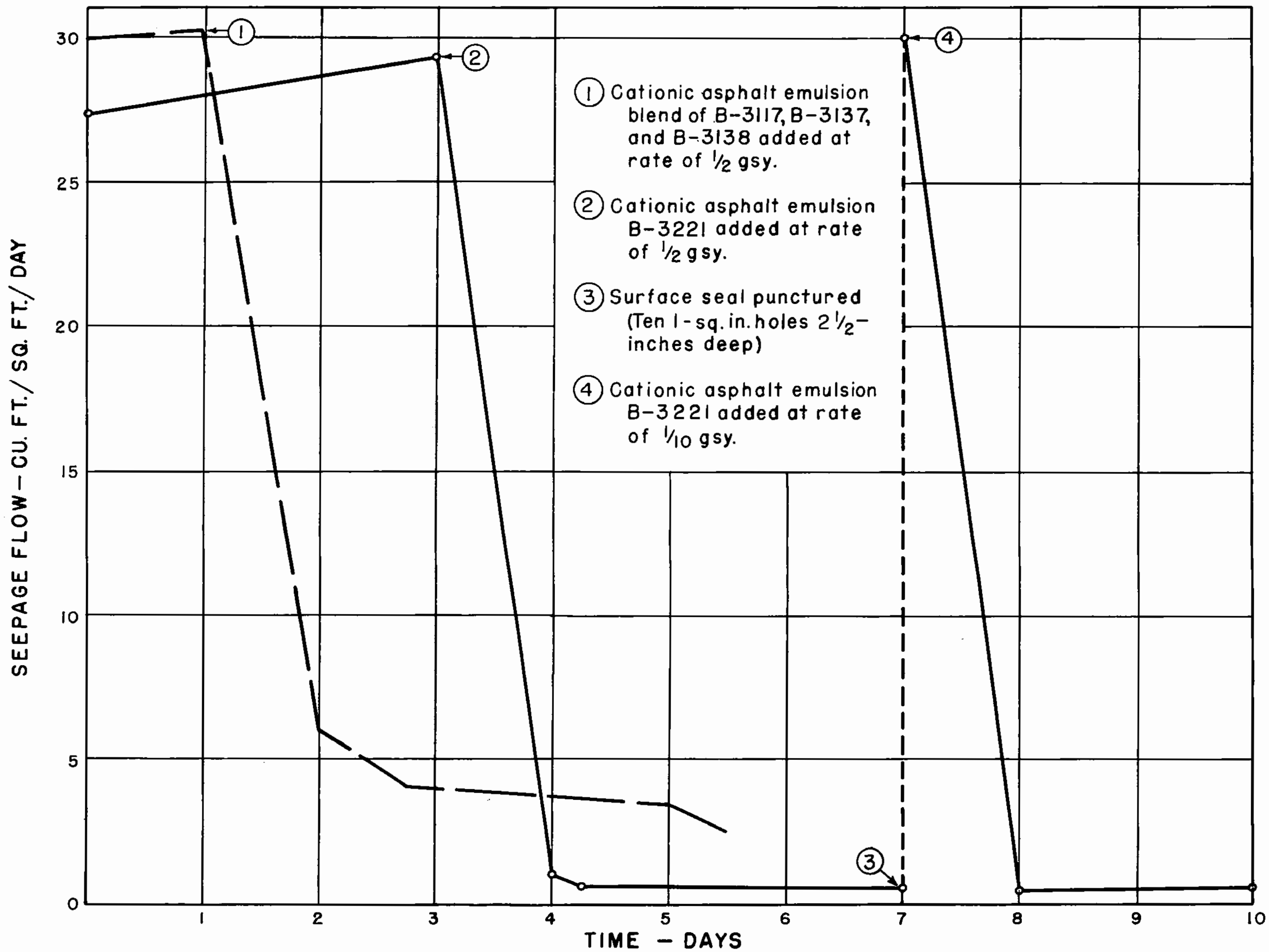
Lab. Sample No. Test Flume Soil

Location

DRAWN CHECKED DATE

FIGURE 2

GPO 838154

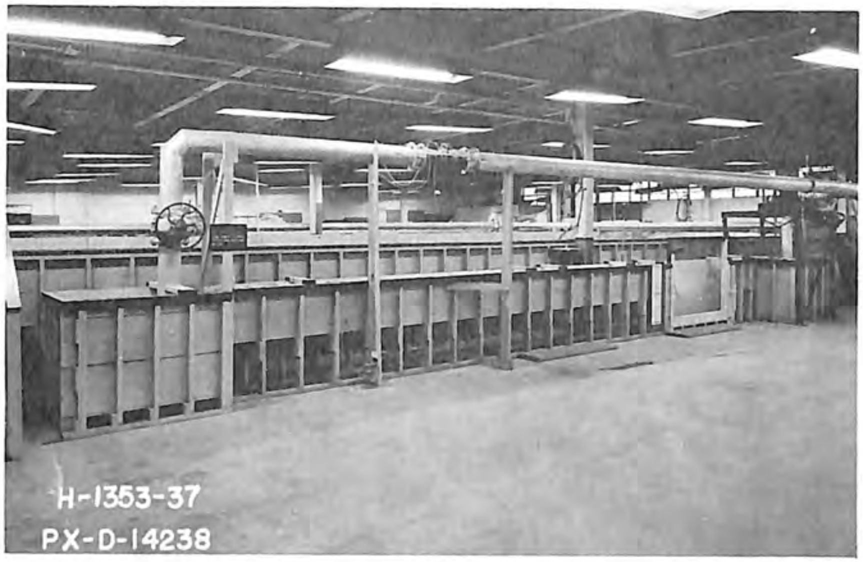


LOWER COST CANAL LINING PROGRAM

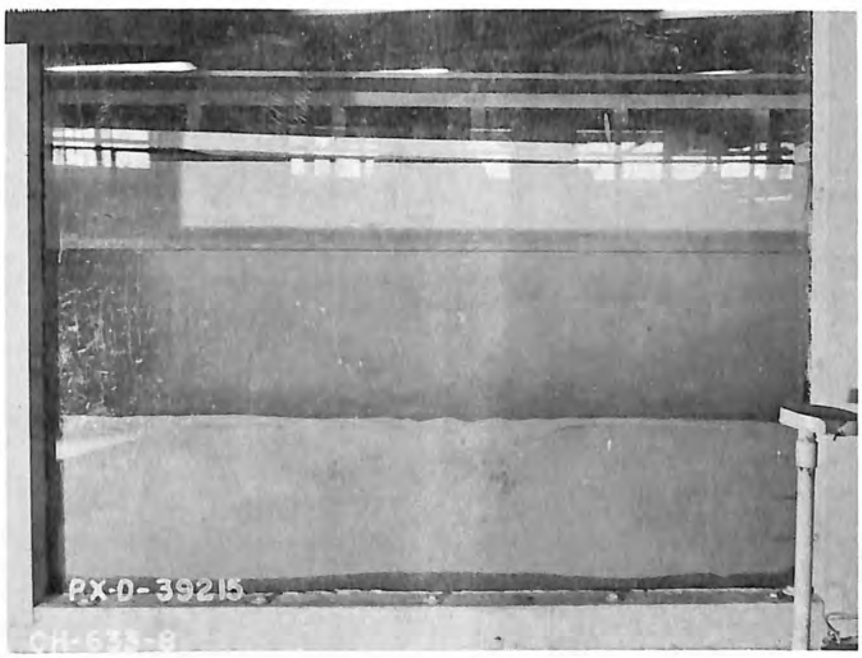
SEALING EFFECTED BY CATIONIC ASPHALT EMULSION SEALANT IN HYDRAULIC FLUME TESTS

HYDRAULIC MODEL TEST

FIGURE 3



(a) General view of 30-foot long by 1-foot wide hydraulic test flume



(b) Closeup of 6-foot long by 18-inch deep flume test section where soil being tested was placed

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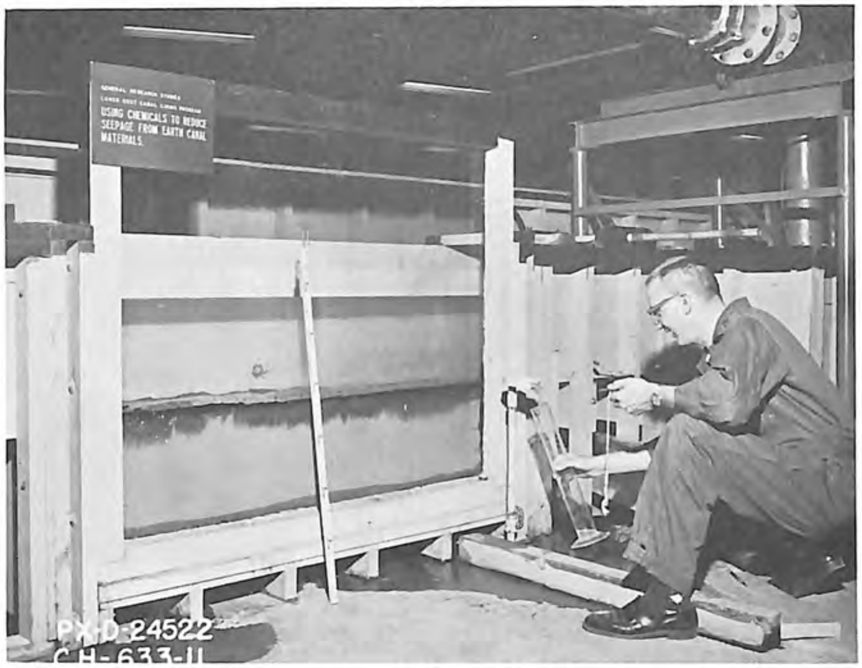
PHOTOGRAPHS OF TEST FLUME

Hydraulic Model Test

Figure 5



(a) Determining seepage rate by measuring the flow in a graduated cylinder during a timed interval

(b) Adding cationic asphalt emulsion sealant to water ponded in flume test section

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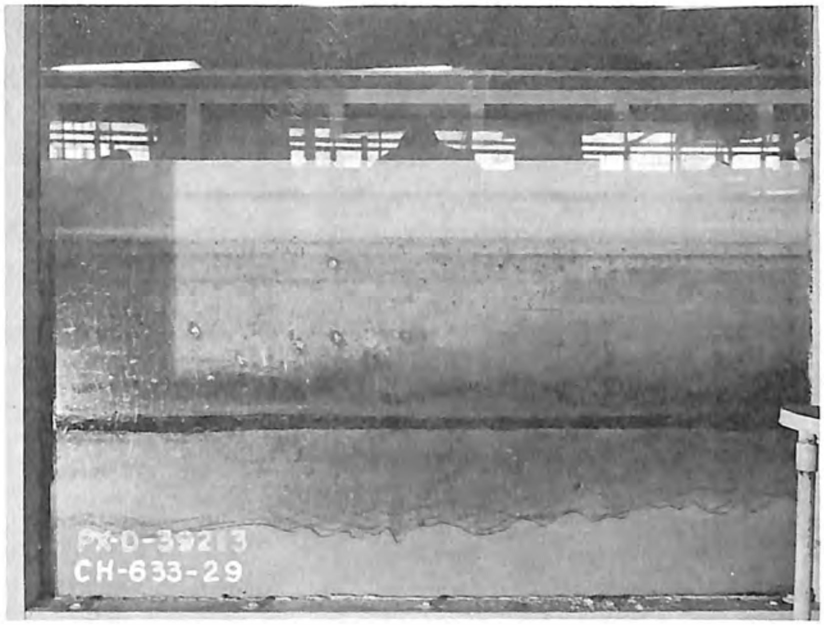
PHOTOGRAPHS OF TEST FLUME

Hydraulic Model Test

Figure 6



(a) Penetration of cationic asphalt emulsion into sand

(b) Puncturing surface seal by use of a soil penetration resistance tester with a 1 square inch needle

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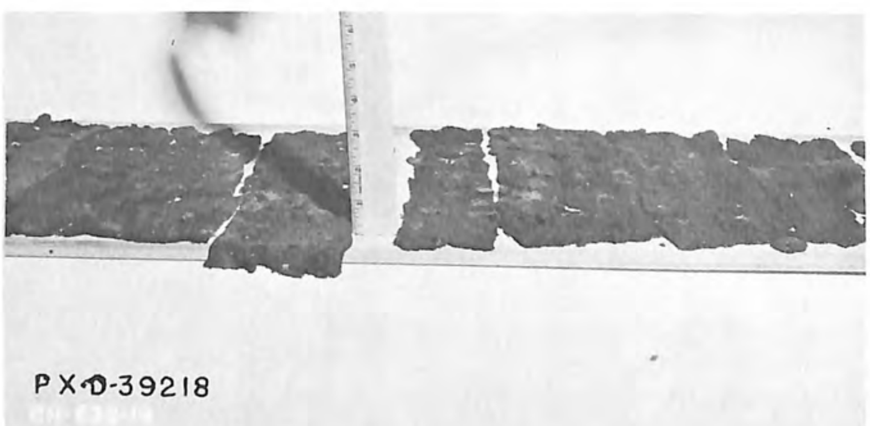
CATIONIC ASPHALT EMULSION IN FLUME

Hydraulic Model Test

Figure 7

(a) Cross section of asphalt emulsion penetrated soil sample removed from flume. Note dark area near center where hole was made and resealed with an additional sealant application of 0.1 gallon per square yard



(b) One-half-inch thick concentrated asphalt impregnated surface soil removed from test section of flume

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SOIL SAMPLES TAKEN FROM FLUME

Hydraulic Model Test

(a) View showing 4-inch depth of soil penetrated by cationic asphalt emulsion sealant

(b) Pans of the mixed sealant-treated soil where small cylindrical specimens were removed for obtaining representative samples for laboratory testing

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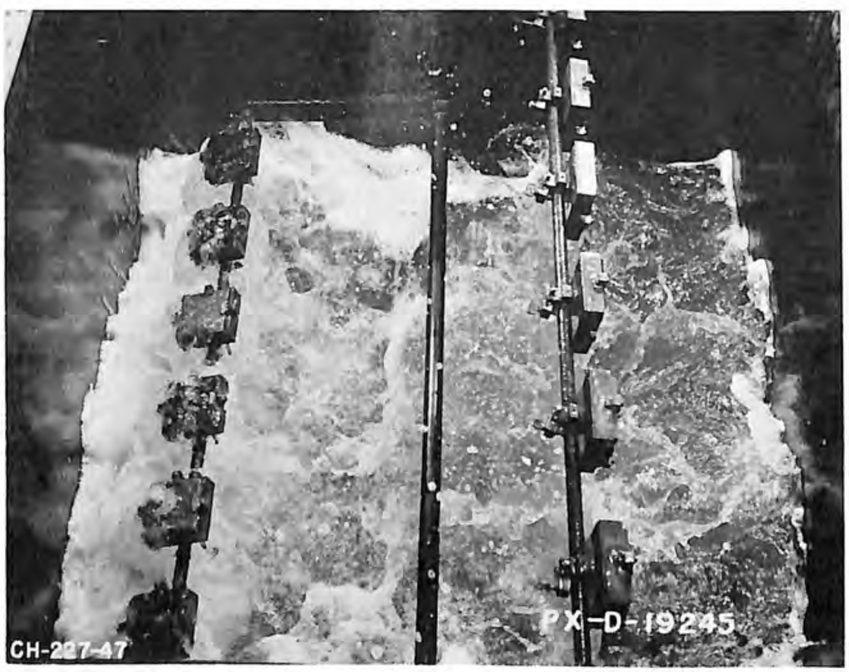
SOIL SURFACE AFTER TREATMENT
WITH EMULSION

Hydraulic Model Test

Figure 9

(a) General view of wave action machine



(b) Interior of wave action machine showing turbulent water action

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WAVE ACTION MACHINE

Hydraulic Model Test

(a) Test specimen molded from asphalt emulsion impregnated sand obtained at surface of test flume

(b) Appearance of test specimen after being subjected to 40,800 blows of wave action

Lower Cost Canal Lining Program

WAVE TEST SPECIMEN

Hydraulic Model Test