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Research Report No. 8-F

Prevention of Moisture Loss in Soil-Cement with Bituminous Materials

1949

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PREVENTION OF MOISTURE LOSS IN SOIL-CEMENT WITH BITUMINOUS MATERIALS

PRESENTED AT THE TWENTY-EIGHTH ANNUAL MEETING

1948

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

WASHINGTON 25, D. C.

SEPTEMBER, 1949

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ABSTRACT

This publication includes the results of four field experiments conducted in Illinois, Kansas, Nebraska and Arkansas to evaluate the efficacy of bituminous cover materials in retaining moisture in soil-cement for seven days following construction. An MC-2, a negative Oliensis spot MC-3, and RC-1 and an asphaltic emulsion were used. These field tests show that these bituminous cover materials, (1) were effective in retaining moisture in the soil-cement, (2) when permitted to penetrate the soil-cement produced inferior surfaces, (3) could be maintained as a surface blanket without penetrating the soil-cement by providing a suitable moisture condition in the surface of the soil-cement at time of bituminous application, and (4) that similar field research data is needed for other grades and types of bituminous material commonly used for prime and tack coat work on bituminous construction and for the various grades of tar products commonly used for prime and tack coat work. The data also shows that failure to prevent moisture evaporation losses in soil-cement, as occurred on the test sections where no cover was used, will produce undesirable inferior soil-cement surfaces.

REPORT OF COMMITTEE ON SOIL-CEMENT ROADS

CARL R. REID, *Chairman*
Pennsylvania Turnpike Commission

The work of the Soil-Cement Committee during the past year consisted of obtaining the cooperation of constructing agencies on field tests of the efficacy of bituminous materials in retaining moisture in soil-cement immediately after construction. Data were obtained and submitted by H. W. Russell, Engineer of Materials, Illinois Division of Highways; R. D. Finney, Engineer of Materials, Kansas State Highway Commission; G. F. Swatek, Materials Engineer, Nebraska Department of Roads, and P. M. Zander, City Engineer, Little Rock, Arkansas. This investigation did not include data to show the relative efficacy of the bituminous materials or other cover materials such as waterproof paper, moist hay, straw or earth. None of the agencies used tar and the committee hopes this gap will be filled in 1949. A summary of these reports follows:

PURPOSE OF INVESTIGATION

Soil-cement like other structural materials using portland cement, needs to be protected against rapid drying immediately after construction and during the early hydration period. A number of materials have been used successfully to provide suitable moisture retaining cover. The materials used have included waterproof paper, moist straw, earth, hay and sawdust and bituminous materials. The use of the latter materials is increasing. This is primarily due to the fact that they are easily and quickly applied and apparently are quite effective moisture retainers. In many instances they serve not only as the moisture retentive cover but as a tack coat for the subsequent bituminous surface course.

Therefore, field test data are essential in determining whether the efficiency of bituminous materials as moisture barriers is sufficient to justify their use. Experience has shown that soil-cement roads require and are built to have a surface that hardens into a durable structural material to which the bituminous surface can be bonded. It is important therefore that field test data include information on the effect of the bituminous cover material on the quality of the soil-cement surface with which it comes into contact.

TEST PROCEDURES

The test projects were divided into three major divisions as follows:

I. To determine efficacy of bituminous material in retaining moisture.

II. To determine most desirable methods of preparing the soil-cement surface for the application of bituminous materials.

III. To determine any influence the bituminous material might have on the soil-cement surface.

Field tests were similar, except in minor detail, for all projects. The primary data consisted of moisture determinations at locations having bituminous cover present and at adjacent locations without cover. The determinations were made daily for seven days in a top layer 3/4-in. thick and in a second 3/4-in. layer immediately below the top layer.

The bituminous material was applied immediately after surface finishing of the soil-cement, special note was made of the texture and moisture condition of the surface of the test areas at time of application of the bituminous material and to the adhesion of the bituminous material to the soil-cement during test and at the end of 7 days when tests were discontinued.

The following test results and conclusions apply only to the specific conditions reported and bituminous materials used.

ILLINOIS DATA

The data from Illinois was obtained on a road project 3.78 miles long, built by R. A. Cullinan and Son, Freeport, Ill., representing 32,517 sq. yd., 6 in. thick, in Mason County, Illinois. It was built during July and August, 1948. An MC-2 was used as a moisture retaining cover and specifications are given in Table 1.

Soil-cement construction was carried out by mixed-in-place methods using heavy duty equipment featuring rotary speed mixers. A cement content of 9 percent by volume or 0.405 bag per sq. yd. was used.

TEST CONDITIONS

The test data for both covered and uncovered conditions were obtained at three separate locations. Tests started the day of construction, July 8, and ended July 15, 1948. Each of the three test locations consisted of a rectangular strip of roadway, parallel with the centerline of the soil-cement and consisted of a covered and uncovered section each about three feet square separated by about two feet of roadway. Two of the test locations were near each other at Station 128. Test Area I, at Station 128, was located adjacent to and on the east side of the centerline of the eleven foot soil-cement widening. Test Area II, at Station 128, was located at the east edge of the 11 foot soil-cement widening and adjacent to the existing concrete paving. The third location, Test Area III, was located at Station 143 at the west quarter point of the 11 foot soil-cement widening approximately two feet from the outer edge of the soil-cement.

Throughout the test period of 7 days the weather was generally clear and warm. There were several light showers. Rainfall was estimated on the job and other weather data were obtained from the Weather Bureau located at Peoria, see Table II.

The soils at the test areas selected were loamy sands containing no material retained on a No. 4 sieve. They were quite similar to two samples lifted and tested in the laboratory to determine the control factors to be used during the construction[1]. The "Summaries of Tests" obtained for these soils are listed in Table III and IV.

At Test Area I and III the moisture content of the soil-cement at time of compaction was at about field optimum, and compaction produced corresponding maximum density. Surface finishing procedures particularly were in conformance with good construction practice--tight, dense surfaces containing the optimum or more moisture were obtained.

Test Area II which was adjacent to the existing concrete pavement was located in a short, narrow strip of soil-cement hav-

[1]"Method of Wetting-and-Drying Test of Compacted Soil-Cement Mixtures", ASTM Designation. D 559-44; AASHO Designation T 135-45. "Method of Freezing-and-Thawing Test of Compacted Soil-Cement Mixtures", ASTM Designation: D 560-44; AASHO Designation: T 136-45. Also see "Soil-Cement Mixtures, Laboratory Handbook" published by the Portland Cement Association.

TABLE 1

SPECIFICATION FOR MC-2 CUTBACK ASPHALT

115.30 ASPHALT· MC-2 This material shall be a medium-curing cutback asphalt consisting of a petroleum residuum fluxed with a suitable distillate. It shall be free from water, show no separation on standing, and shall conform to the following requirements:

(a) Flash point (Cleveland open cup), not less than	150 F.
(b) Viscosity, Saybolt Furol, at 140 F., seconds	100 to 200
(c) Distillation test·	
Distillate, per cent by volume of total distillate to 680 F.:	
Distillate to 437 F., not more than	10
Distillate to 500 F.	15 to 55
Distillate to 600 F.	60 to 87
Residue from distillation to 680 F. per cent volume by difference, not less than	67
(d) Characteristics of residue from distillation test:	
(1) Penetration at 77 F., 100 g., 5 sec. .	150 to 300
(2) Ductility at 77 F., (When the penetration at 77 F., is between 150 and 200), not less than	100 cm.
(3) Ductility in centimeters, at 39.2 F., rate 1/4 cm. per minute, not less than 1/10 of the penetration at 70 F.	
(4) Bitumen soluble in carbon disulphide, not less than	99.5 %
(5) Spot test	Negative

ing a surface moisture content about three percentage points below optimum at the time surfacing finishing was completed. As a result of too little moisture, the surface finishing did not produce as tight and dense a surface as was obtained in Test Areas I and III where the moisture contents were at optimum or above.

Five hours after surface finishing was completed on Test Areas I and II, and two hours in the case of Test Area III, a total of about 0.40 gal. of water was applied per sq. yd. by two trips of a pressure water distributor to the completed soil-cement that included the three Test Areas. These applications of water were made in order to saturate the soil-cement surface with water just prior to the application of the MC-2. The difference in time of water application is also the difference in time of completing final finishing. The surface of Test Areas I and III did become saturated to the degree that free water was present on the surface. Test Area II on the other hand quickly absorbed all the water applied and did not become saturated. Just after this moisture was applied 0.26 gal.

TABLE II

WEATHER DATA

Date	Temperature, Degrees F. Max.	Min.	Relative Humidity at Noon, Per Cent	Total 24 Hour Rainfall, Inches (Estimated)	Wind Velocity at Noon mph.
7/8/48	87	65	56	0.00	7
7/9/48	88	64	43	0.00	7
7/10/48	90	70	63	0.02	4
7/11/48	88	68	65	0.05	10
7/12/48	88	71	61	0.03	7
7/13/48	89	71	60	0.25	6
7/14/48	71	66	86	0.00	9
7/15/48	79	65	94	0.00	8

SUMMARY OF TESTS ON SOIL AND SOIL-CEMENT MIXTURES

PORTLAND CEMENT ASSOCIATION
SOIL-CEMENT BUREAU

Soil-Cement Laboratory, Form Sheet No 13
Date tests completed 7-23-48

State Illinois
County Mason

SOIL NUMBER State or Local	GRADATION - per cent of total: Gravel, Retained on No 4 sieve	Gravel, No 4 to No 10 (2.0 mm)	Sand, 2.0 to 0.25 mm	Sand, 0.25 to 0.05 mm	Silt, 0.05 to 0.005 mm	Clay, 0.005 to 0.000 mm	Colloids,* 0.001 to 0.000 mm	TEXTURAL CLASS	PHYSICAL TEST CONSTANTS L.L.	P.I.	S.L.	ORGANIC CONTENT, p.p.m. (soil mortar)	Sp. gr of soil mortar Assumed	USPRA soil group (soil mortar)
1	0	0	86	9	5			Coarse Sand	16	N.P.			2.65	A-3
Soil mortar only			"	"	"			" "						

*Also included in clay

Plus No 4 material Absorption by dry weight.... ....% Bulk specific gravity ....

TESTS ON MINUS NO 4 MATERIAL

MOISTURE-DENSITY RELATIONS: Opt moisture content, %			Opt density, lb/cu ft			COMPRESSIVE STRENGTHS - lb/sq in**, Age when tested - days: Two		Seven		Twenty-eight	
Cement content by volume - %						Cement content by volume - %					
0	5.6	9.5	0	5.6	9.5	6	10	6	10	6	10
	11.3	10.5		113.6	115.8	87	115	111	228	140	317

Type of moisture-density curve
Regular ~~Irregular~~

**Cylindrical specimens 2" dia and 2" ht. submerged in water 1 hr before testing.

RESULTS OF TESTS

Recommended cement content, Φ	Total	9.0 %
	Minus #4	" %
Laboratory optimum moisture content †	Total	10.6 %
	Minus #4	" %
Laboratory density,† lb/cu ft., dry wt	Total	116
	Minus #4	"

Φ Designate which cement content controls.
† Tests made in field toward end of damp mix govern field control.

DATA FROM SPECIMENS TESTED TWELVE CYCLES IN A S T M WET-DRY AND FREEZE-THAW TESTS

	CEMENT CONTENT % by volume. Theoretical	Obtained, Av	DENSITY, lb./cu ft. oven-dry wt. Theoretical	Obtained, Av	MOISTURE CONTENT, % by oven-dry wt. Theoretical	Obtained Av	SOLIDS % by volume, Av	TOTAL SOIL LOSS, % of original dry weight. WET DRY	FREEZE-THAW	MAXIMUM VOLUME CHANGE, % of molded volume. WET DRY Plus	WET DRY Minus	FREEZE THAW Plus	FREEZE THAW Minus	MOISTURE CONTENT FOR SATURATION, % by oven dry wt. WET-DRY	FREEZE-THAW	MAX. MOISTURE ‡ percentage above or below saturation. WET-DRY	FREEZE-THAW
Total §	6.0	6.0	113.8	114.3	11.2	11.2	68	Not									
Minus #4	"	"	"	"	"	"	"	Molded	38		No. 1	Specimens Not Molded					
Total §	8.0	8.0	115.0	114.6	10.8	10.7	69										
Minus #4	"	"	"	"	"	"	"	8	19								
Total §	10.0	10.1	116.1	117.0	10.4	10.2	70	Not									
Minus #4	"	"	"	"	"	"	"	Molded	7								
Total §																	
Minus #4																	

‡ Maximum moisture is expressed in percentage points above (+) or below (−) moisture content for saturation
§ Note quantity of material "Retained on No 4 sieve" shown under "GRADATION"

Type of soil-cement losses
~~(Increasing)~~ (Decreasing) ~~(Steady)~~

Remarks

U S D A, B of P I, Soil series.
Soil horizon "C"
Color of moist soil brown
Sampling location dune sand taken from roadway cut right at station 109+50 at 3-9'.

PCA Soil No 520A
Specimen No
Field Project No 1576
Project FAS Rt. 461, Forest City

Table III.

SUMMARY OF TESTS ON SOIL AND SOIL-CEMENT MIXTURES

PORTLAND CEMENT ASSOCIATION
SOIL-CEMENT BUREAU

Soil-Cement Laboratory, Form Sheet No 13
Date tests completed 7-23-48

State Illinois
County Mason

SOIL NUMBER State or Local	GRADATION - per cent of total: Gravel, Retained on No 4 sieve	Gravel, No 4 to No 10 (2.0 mm)	Sand, 2.0 to 0.25 mm	Sand, 0.25 to 0.05 mm	Silt, 0.05 to 0.005 mm	Clay, 0.005 to 0.000 mm	Colloids,* 0.001 to 0.000 mm	TEXTURAL CLASS	PHYSICAL TEST CONSTANTS LL	PI	SL	ORGANIC CONTENT, ppm (soil mortar)	Sp gr of soil mortar	USPRA soil group (soil mortar)
2	0	0	55	19	14	12		Coarse Sandy Loam	16	1			Assumed 2.65	A2
Soil mortar only			"	"	"	"			"	"	"			

*Also included in clay

Plus No 4 material Absorption by dry weight ....% Bulk specific gravity ....

TESTS ON MINUS NO 4 MATERIAL

MOISTURE-DENSITY RELATIONS: Opt. moisture content, %			Opt. density, lb/cu ft			COMPRESSIVE STRENGTHS - lb/sq.in ** Age when tested - days: Two		Seven		Twenty-eight	
Cement content by volume - %						Cement content by volume - %					
0	6.1	10.2	0	6.1	10.2	6	10	6	10	6	10
	10.5	10.5		120.5	121.2	87	172	155	309	201	369

Type of moisture-density curve
Regular-~~Irregular~~

**Cylindrical specimens 2" dia and 2" ht. submerged in water 1 hr before testing.

RESULTS OF TESTS

Recommended cement content, Φ	Total 8.0 %	Minus #4 " %
Laboratory optimum moisture content,†	Total 10.5 %	Minus #4 " %
Laboratory density,† lb/cu ft., dry wt.	Total 121	Minus #4 "

Φ Designate which cement content controls.
† Tests made in field toward end of damp mix govern field control.

DATA FROM SPECIMENS TESTED TWELVE CYCLES IN ASTM WET-DRY AND FREEZE-THAW TESTS

	CEMENT CONTENT, % by volume: Theoretical	Obtained, Av	DENSITY lb./cu.ft. oven-dry wt.: Theoretical	Obtained, Av	MOISTURE CONTENT, % by oven-dry wt.: Theoretical	Obtained, Av	SOLIDS % by volume, Av	TOTAL SOIL LOSS % of original dry weight: WET-DRY	FREEZE-THAW	MAXIMUM VOLUME CHANGE % of molded volume: WET-DRY Plus	WET-DRY Minus	FREEZE-THAW Plus	FREEZE-THAW Minus	MOISTURE CONTENT FOR SATURATION % by oven-dry wt.: WET-DRY	FREEZE-THAW	MAX. MOISTURE‡ percentage above or below saturation: WET-DRY	FREEZE-THAW
Total §	6.0	6.0	120.5	120.1	10.5	10.9	72	Not									
Minus #4	"	"	"	"	"	"	"	Molded	31		No. 1 Specimens Not Molded						
Total §	8.0	8.0	120.9	120.4	10.5	10.7	72										
Minus #4	"	"	"	"	"	"	"	3	4								
Total §	10.0	9.9	121.2	119.9	10.5	11.1	72	Not									
Minus #4	"	"	"	"	"	"	"	Molded	4								
Total §																	
Minus #4																	

‡Maximum moisture is expressed in percentage points above (+) or below (−) moisture content for saturation.
§Note quantity of material "Retained on No. 4 sieve" shown under "GRADATION"

Type of soil-cement losses
~~(Increasing) (Decreasing)~~ (Steady)

Remarks

U S D A., B of P I, Soil series
Soil horizon "B"
Color of moist soil brown-black
Sampling location roadway left at Sta. 166+00 at 0-6½"

PCA Soil No. 5205
Specimen No.
Field Project No 1576
Project FAS Rt. 461, Forest City

Table IV.

per sq. yd. of MC-2 cutback asphalt heated to 150 F. was applied. See Figure 1.

Coverage by the MC-2 on the soil-cement was complete with some slight runoff on local high spots. This runoff did not occur on the test areas.

Moisture samples weighing about 150 gms. each were lifted from a 0-3/4-in. depth of the 6-in. base and samples from a 3/4-1½-in. depth were also taken at the same location. They were lifted by using a hammer, chisel, and a spoon and were placed in sample cans having a tight fitting cover. Samples were weighed and dried to constant weight at approximately 110 C. Test holes were subsequently patched with hand mixed soil-cement and covered with moist burlap. From three to four moisture samples were taken each day from both covered and uncovered areas at each of the three locations. The first samples were taken immediately after final finishing and a second set were taken immediately before the application of the MC-2 cover. Every day thereafter for 7

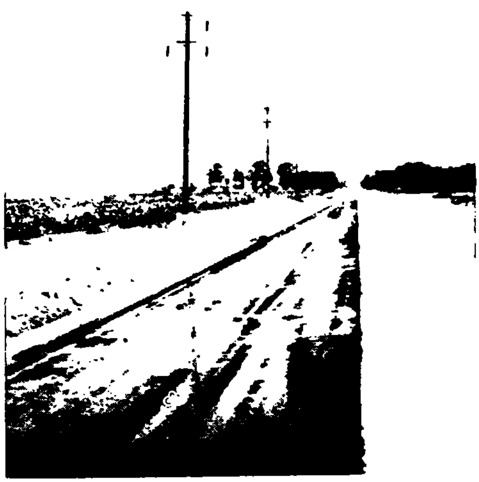

Figure 1. Surface after MC-2 application north of Test Areas I and II.

days, similar moisture samples were lifted.

Additional samples from 0-5 in. were lifted from Test Areas I and III on the first and last day of the hydration period. See Figures 2 and 4. Time did not permit taking a full depth moisture sample representative of Test Area II.

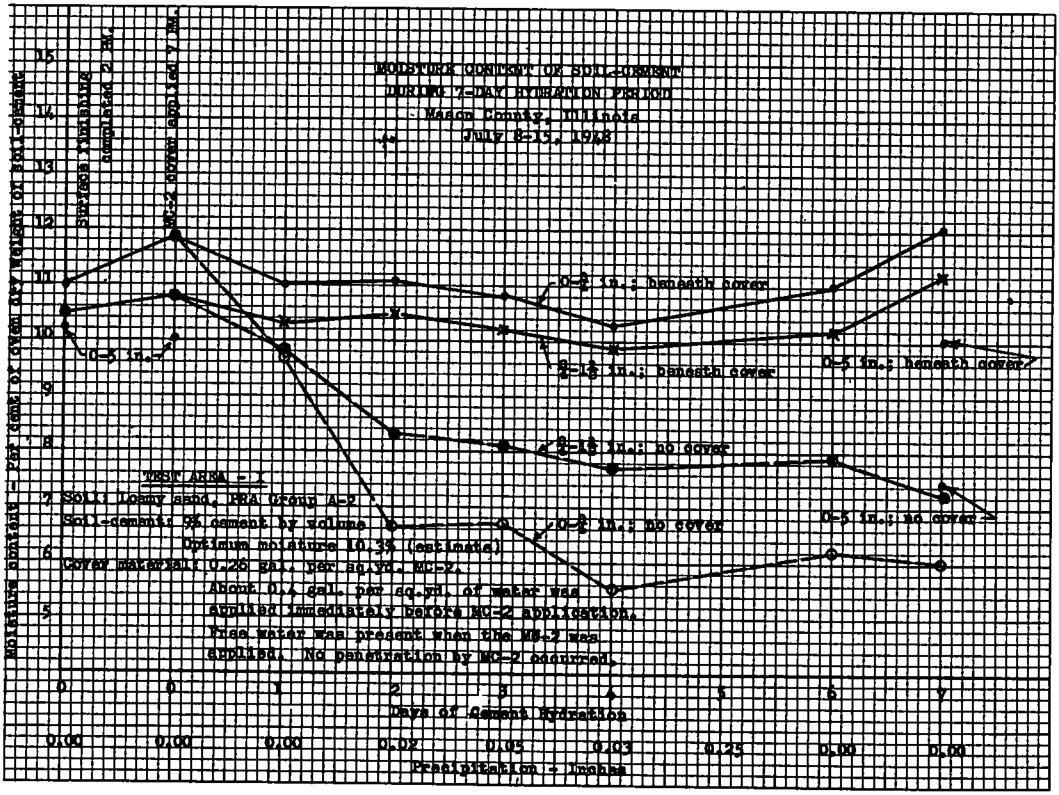

Figure 2.

DISCUSSION OF TEST RESULTS

Moisture Data

The moisture data obtained from the samples at the selected test sites were tabulated in Table V and shown graphically in Figures 2, 3 and 4.

The field optimum moisture content was estimated at 10.3 percent for the soil-cement at all three test areas.

General

The drop in moisture contents of the top 3/4-in. beneath the cover material of 0.9. 0.8 and 1.5 percentage points respectively during the period of test, for Areas I, II, and III indicate that the cover material was quite effective in retaining moisture. This is shown by comparing the moisture content curves of test areas "with" and "without" cover. See Figures 2, 3 and 4. It should be noted that light showers occurred the second, third and fourth days and that a heavy shower fell on the fifth day. This moisture undoubtedly materially decreased moisture losses, particularly from the uncovered areas.

It is indicated that the moisture changes that did occur were probably due to, (1) moisture used for cement hydration and which cannot be driven off with the 110C. temperature used to dry moisture samples (2) moisture migrating from surface portions, where it was concentrated, to material at greater depth, and (3) moisture vaporizing and leaving the soil-cement through the bituminous cover.

For soils of this type, research has

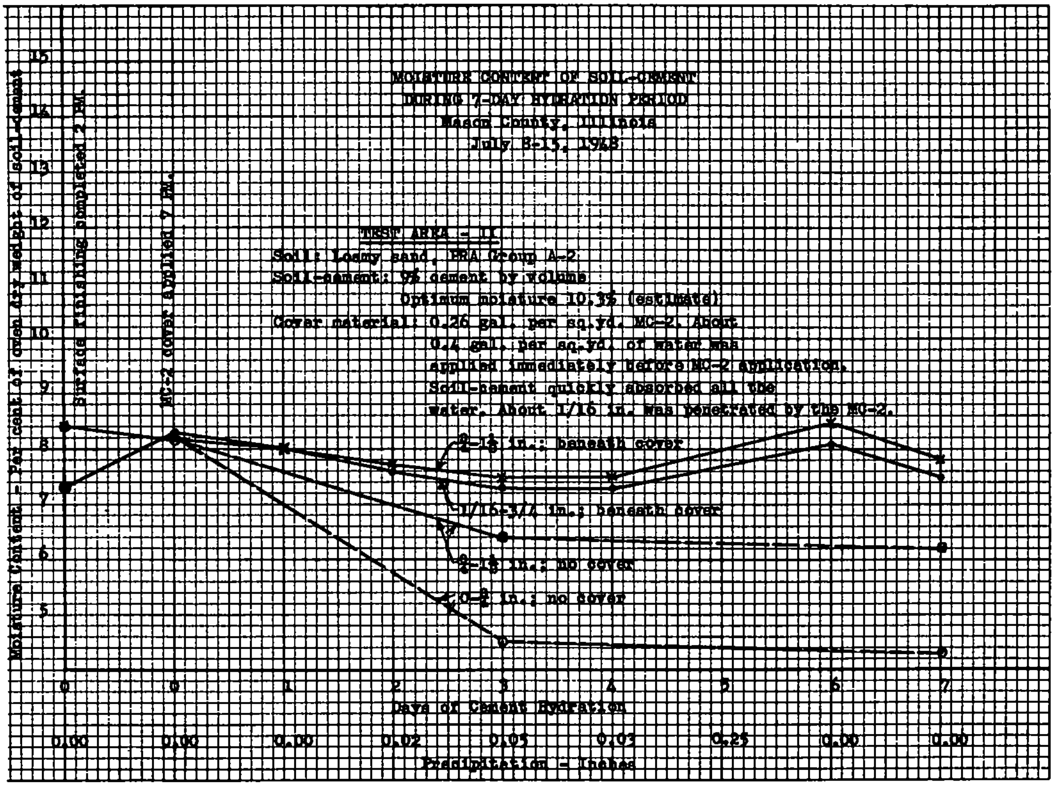

Figure 3.

shown that the ouantity of water taken up by cement hydration during 7 days, and which cannot be driven off by the 110 C. temperature used to dry the moisture samples, is likely to be about ½ of one percentage point. Complete hydration of cement over a long period of time on the other hand would re'uire about ½-gm. of water per gm. of cement.

Sɪnce ½ percentage point of the contained moisture is used for cement hydration during this seven days, the total moisture loss given above for the three respective areas beneath the cover became 0.4, 0.3 and 1.0 percentage points.

Moisture migration is involved in these remaining moisture differences. It should be noted that the moisture content of the surface portion of the soil-cement was built up during final finishing so that it was above the field optimum moisture content and higher than that of the underlying material. In addition, on this particular section sufficient water was added so that saturation was obtained on the surface material on Test Areas I and III and some free water was present, on the surface, when the MC-2 was applied. During the hydration period, particularly the first day or two, there was a tendency for this extra surface moisture to migrate downward and to become distributed for full depth. This is evidenced by the moisture content data beneath the cover at Test Areas I and III which shows a decrease of moisture during the first 24 hours of 0.9 and 1.3 percentage points in the top 3/4-in. material. Test Area II showed a decrease of only 0.3 percentage point of moisture the first 24 hours for the top 3/4-in. beneath the cover, but, as previously noted, the surface portion of this Area had no free or surplus moisture and contained, at time of cover application, about two percentage points less than optimum moisture.

It will be noted that the vertical migration losses, plus the hydration

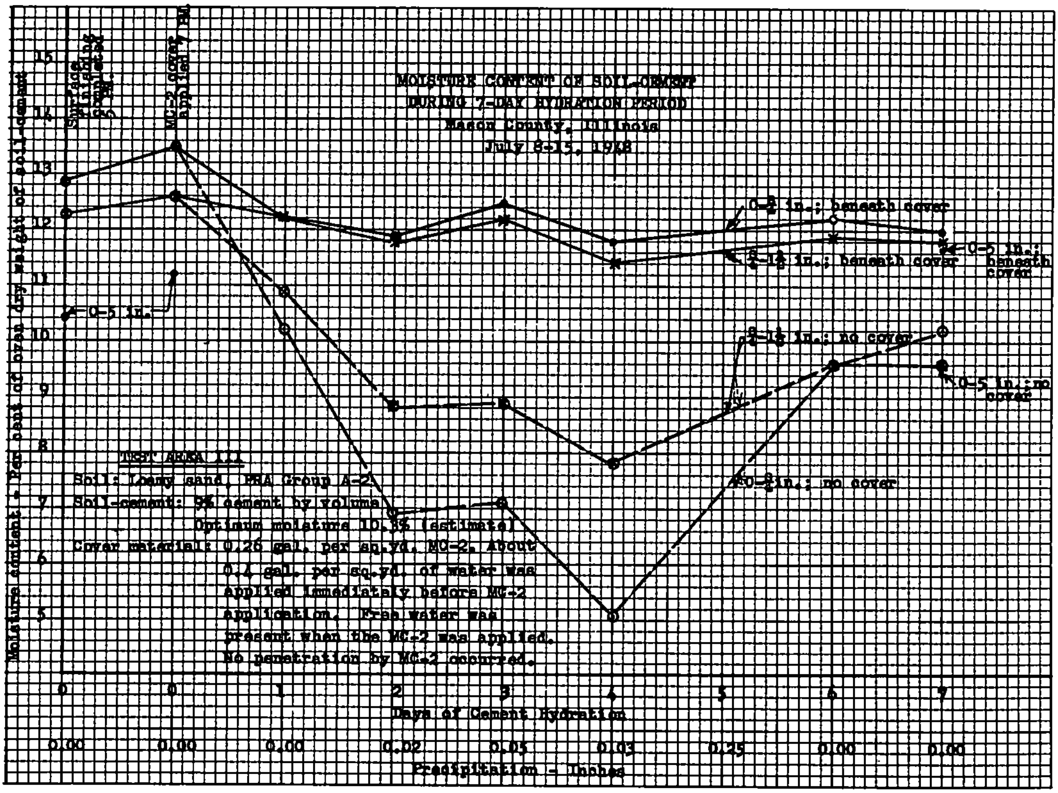

Figure 4.

losses, previously mentioned, on these test areas are greater than the total moisture lost during the 7-day test period.

The moisture losses also include any that may have taken place through the cover. It is evident, since the probable hydration and migration losses are greater than the total losses, that if there were losses through the cover, they were quite small.

The fact that any losses through the cover were quite small is further borne out by the following. At Test Areas I and III where the moisture content beneath the cover was high originally, the moisture contents of the 0-3/4-in. material remained higher throughout the 7-day period, than those of the 3/4-1½ in. material. The opposite is true at Test Area II where there was penetration by the MC-2 into the soil-cement. Apparently there was a small loss of moisture through the cover at this point notwithstanding the fact that the original moisture content was considerably below optimum and that there was no free surface water present. Also of significance in this respect is the gain in moisture at Test Area II beneath the cover, apparently due to the 0.25 in. rain that fell during the night. This indicates transmission of moisture through the MC-2 cover when the residue of asphalt is not a definite film but rather a thin mat consisting of soil-cement and asphalt.

Moisture samples representing a depth of 0-5 in. were taken from Test Areas I and III at the beginning and end of the test period. The moisture contents obtained at these depths beneath the cover showed no loss of moisture during the 7-day period. However, similar moisture samples taken representing a depth of 0-5 in. from uncovered areas showed appreciable loss of moisture during the 7-day period notwithstanding the additional moisture added from several showers during that period. This comparison brings

TABLE V

DAILY MOISTURE CONTENTS*

Date	Test Area I, 0-3/4 in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area I, 0-3/4 in. No Cover	Test Area II, 1/16-3/4 in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area II, 1/16-3/4 in. No Cover	Test Area III, 0-3/4 in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area III, 0-3/4 in. No Cover
	%	%	%	%	%	%
7/8/48[1]	11.0	11.0	7.3	7.3	12.9	12.9
7/8/48[2]	11.9	11.9	8.3	8.3	13.5	13.5
7/9/48	11.0	9.7	8.0	-	12.2	10.2
7/10/48	11.1	6.6	7.6	-	11.9	6.8
7/11/48	10.8	6.7	7.3	4.5	12.5	7.1
7/12/48	10.3	5.5	7.3	-	11.8	5.1
7/13/48	-	-	-	-	-	-
7/14/48	11.0	6.2	8.1	-	12.2	9.6
7/15/48	12.1	6.0	7.5	4.3	12.0	10.2

Date	Test Area I, 3/4-1½ in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area I, 3/4-1½ in. No Cover	Test Area II, 3/4 - 1½ in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area II, 3/4 - 1½ in. No Cover	Test Area III, 3/4-1½ in. Moisture Contents MC-2 Cutback Asphalt Cover	Test Area III, 3/4-1½ in. No Cover
	%	%	%	%	%	%
7/8/48[1]	10.5	10.5	8.4	8.4	12.3	12.3
7/8/48[2]	10.8	10.8	8.2	8.2	12.6	12.6
7/9/48	10.3	9.8	8.0	-	12.2	10.9
7/10/48	10.5	8.3	7.7	-	11.8	8.8
7/11/48	10.2	8.1	7.5	6.4	12.2	8.9
7/12/48	9.9	7.7	7.5	-	11.4	7.8
7/13/48	-	-	-	-	-	-
7/14/48	10.2	7.9	8.5	-	11.9	9.6
7/15/48	11.2	7.2	7.8	6.2	11.8	9.6

*Average of 4 tests.
[1]Samples were taken after final finishing.
[2]Samples were taken after moisture application immediately before application of asphalt emulsion cover.

out further the ability of MC-2 cover to retain moisture.

It is concluded that the MC-2 cutback asphalt cover served adequately as a moisture barrier by retaining practically all of the moisture in the soil-cement during the 7-day hydration period.

Observations on MC-2 Cutback Asphalt

-Daily inspections showed no penetration of the MC-2 into the soil-cement in Areas I and III where free water was present and the moisture content of the soil-cement was at optimum or above. In Area II, built with less moisture content than optimum, there was penetration of MC-2 into the soil-cement to a depth of 1/16-in. However, observations made on areas outside the test sections which were surface dry at time of MC-2 application showed penetrations up to about ½ in.

By the end of the sixth day, on Test Area I and III, the MC-2 had cured out sufficiently so that it could be walked upon without picking up. If it had been necessary to open the section to automobile traffic during the 7-day hydration period, sanding to blot up the MC-2 would have been necessary. On Test Area II, where the MC-2 penetrated into the soil-cement, it could be walked upon with but slight pickup after the first 24 hours.

From the first day of application the MC-2 adhered firmly to the soil-cement on Areas I and III. It became more firmly attached each day and on the last day of test it was removed only after considerable work by scraping with a knife. In Test Area II, the MC-2 and penetrated material formed a 1/16-in. "mat" that could be removed easily from underlying soil-cement.

At Test Areas I and III the soil-cement directly beneath the MC-2 had hardened noticeably the day following construction and the hardness increased daily. It was particularly noted that the soil-cement immediately beneath the cover was as hard as the soil-cement at greater depth. This observation reinforces the conclusion that the MC-2 retained sufficient moisture in Test Areas I and III for adequate cement hydration.

At Test Area II, as mentuoned previously, there was inadequate moisture incorporated during construction, consequently the soil-cement did not harden adequately. The hardness of the material penetrated by the MC-2 was less hard and inferior to the underlying soil-cement which in turn was measurably less hard than the soil-cement in Test Areas I and III. However, the data indicate that the MC-2 cover material did satisfactorily retain the moisture in Test Area II notwithstanding the fact that it penetrated into the soil-cement.

The surface of the soil-cement not covered with the MC-2 did not harden satisfactorily for a depth of about 1 in. at the end of 7 days and could be penetrated with a knife. The soil-cement below the 1 in. depth was considerably harder than the surface material but it did not appear as hard as the soil-cement in any of the areas covered with the MC-2.

CONCLUSION

The data show that the MC-2 cutback asphalt cover as used on the test areas did efficiently retain the moisture in the soil-cement for 7 days. Further, that the MC-2 adhered satisfactorily to the soil-cement and did not penetrate into it when there was free water on the soil-cement surface at time of the bituminous cover application. On the other hand, where the moisture content of the surface of the soil-cement was less than optimum there was penetration by the MC-2 into the soil-cement so that a thin "mat" was formed which could easily be removed from the underlying soil-cement. However, the MC-2 cover retained the moisture in the soil-cement in all the Test Areas whether or not it penetrated into the soil-cement.

The MC-2 did not cure out on Test Areas I and III, until the 6th day so that pickup by automobile traffic would have occurred during this period unless sand was applied to blot the MC-2.

Finally, the use of the MC-2 cutback asphalt had no deleterious effect on the quality of the soil-cement except where it penetrated into the soil-cement. The penetrated soil-cement was definitely not as hard as unpenetrated soil-cement.

The sections without MC-2 cover at all Test Areas lost considerable moisture particularly from the top 3/4-in. and 3/4-1½ in. depths. The hardness of the surface material on these sections was inferior to that beneath the cover. The data clearly show the need of a protective cover for retaining the moisture in the soil-cement during the early hydration period.

These tests were conducted through the cooperation of the Illinois Division of Highways and the Mason County Highway Department. Clarence Melton, Havana, Ill., is County Engineer. E. G. Robbins, Soil-Cement Bureau, Chicago, represented the Portland Cement Association.

KANSAS DATA

The data from Kansas were obtained on a road project 6.05 miles long, built by the Concrete Materials and Construction Co., Cedar Rapids, Iowa, representing 85,128 sq. yds., 6 in. thick in Washington County, Kansas on Route 36. It was built during July and August, 1948. A negative Oliensis spot MC-3 cutback asphalt was used as a moisture retaining cover and specifications are given in Table VI.

Soil-cement construction was carried out by mixed-in-place methods using heavy duty equipment featuring three rotary speed mixers. A cement content of 12 percent by volume, or 0.540 bag per sq. yd. was used.

TEST CONDITIONS

The test data for covered and uncovered conditions were obtained from two areas, located at the north and the south quarter points of the road at Station 360, beginning the day of construction, July 28 and ending August 4. Each test area selected measured about 3 ft. x 3 ft.

The weather was warm, generally clear and sunny the first half of the 7-day test period and cool and cloudy for the remaining portion. There were two showers. Weather data were obtained from the Weather Bureau located at Hanover and are listed in Table VII.

The soils at the test areas selected were sandy loams of PRA Group A-2 containing no material retained on a No. 4 sieve. A representative sample was tested in the laboratory to determine the cement content to be used during construction[2]. The "Summary of Tests" obtained for this soil is listed in Table VIII.

Moisture contents of the soil-cement at time of compaction were near or above optimum; and compaction produced corresponding maximum dansities. Surface finishing procedures particularly were in conformance with good construction practice--a tight, dense surface containing not less than optimum moisture was obtained.

[2] ibid.

Approximately an hour elapsed between final finishing and the application of the MC-3. No additional water was applied after final finishing. The soil-cement surface was quite moist but not wet at the time the negative MC-3 cover was applied. (Subsequent days indicated that by applying 0.3 gal. of water to the surface just prior to applying MC-3 produced a tighter surface. However, these test sections were not included in this technique.)

The MC-3 cutback asphalt was applied at the rate of 0.23 gal. per sq. yd. at 185 F. This application resulted in complete coverage of soil-cement surface.

Moisture samples weighing about 150 gms. each were lifted for a 0-3/4 in. depth from the surface of the 6 in. base and also from a 3/4 in. to 1½ in. depth at the exact location the 0-3/4 in. samples were taken. Three were taken each day from each depth from both covered and uncovered areas at each of the two locations. The first samples were taken after final finishing, just prior to the application of the MC-3 cover. Every day from then on for seven days, moisture samples were lifted at the same locations beneath the cover material and from adjacent areas without bituminous cover.

Moisture samples were also taken from a depth of 0-5 in. at each location, after final finishing and on the seventh day of the hydration period.

DISCUSSION OF TEST RESULTS

Moisture Data

The moisture contents obtained from the samples at the selected test sites are tabulated in Table IX and shown graphically in Figures 5 and 6.

The field optimum moisture content was estimated at 12.5 percent for the soil-cement at both Test Area I and II.

General

The drop in moisture content in the top 3/4 in. under the cover material of 1.9 and 1.2 percentage points respectively

TABLE VI

SPECIFICATION FOR MC-3 CUTBACK ASPHALT

Medium curing cutback asphalt for use in this work shall be homogeneous, free from water, and shall not foam when heated at 250 F. It shall conform to all the requirements of the following specifications.

Specification Designation	MC-3	
	Specifications	Test Results
General Requirements	The material shall be free from water, have good durability, proper curing properties, low temperature susceptibility and good adhesive qualities, shall show no separation on standing and shall meet the following requirements:	
Flash point (COC) F.	150+	165
Viscosity at 140 F secs, by Saybolt Firol	275-475	350
Distillation:		
Distillate (percent by volume of total distillate to 680 F.)		
To: 437 F.	5-	0
500 F.	5-40	23
600 F.	60-85	73
Residue from distillation to 680 F. volume percent by difference	73+	83
Tests on residue from distillation:		
Penetration at 77 F, 100 G., 5 sec.	200-300	221
Ductility at 60 F., 5 cm. per min.	100+	100+
Percent soluble in CCL_4	99.5+	99.81
Reaction to Oliensis Spot Test	Neg.	Neg.
Ductility at 77 F. of residue from distillation reduced to 40-50 penetration by ASTM D243-36 cm.		

during the 7-days for Areas I and II indicate that the cover material was quite effective in retaining moisture. This is shown by comparing the moisture content curves of test areas "with" and "without" cover. See Figures 5 and 6.

It is indicated that the moisture changes that did occur were probably due to (1) moisture used for cement hydration and which cannot be driven off with the 110 C. temperatures used to dry moisture samples, (2) moisture migrating from surface portions, where it was concentrated, to material at greater depth, and (3) moisture vaporizing and leaving the soil-cement through the bituminous cover.

For soils of this type, research has shown that the quantity of moisture taken up by cement hydration during 7-days and which cannot be driven off by the 110 C. temperature used to dry the moisture samples is likely to be about 3/4 of one per-

TABLE VII

WEATHER DATA

Date	Temperature, Degrees F. Max.	Temperature, Degrees F. Min.	Total 24 Hour Rainfall, inches
7/28/48	96	74	0.00
7/29/48	90	72	0.70
7/30/48	85	57	0.00
7/31/48	89	60	0.00
8/1/48	86	65	0.00
8/2/48	79	62	1.00
8/3/48	73	62	0.00
8/4/48	-	56	0.00

moisture differences. It should be noted that the moisture content of the surface portion of the soil-cement during final finishing was built up so that it was above the field optimum moisture content and also higher than that of the underlying material. During the 7-day hydration period, particularly the first day or two, there is a tendency for this surplus surface moisture to become distributed full depth. In this instance, during the first 48 hour period the 0-3/4 in. material at the two areas lost about 2½ percentage points of moisture of which an estimated ½ of one percentage point of moisture was due to migration to underlying material, see Figures 5 and 6.

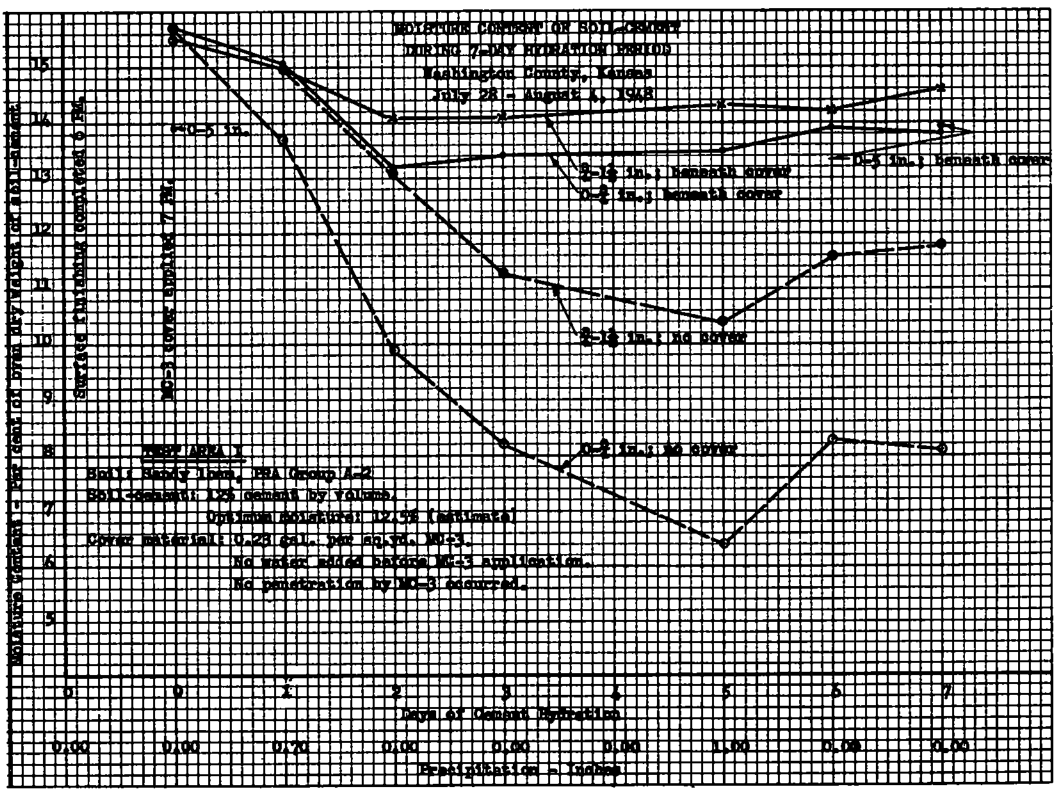

Figure 5.

centage point. Since 3/4 percentage point of moisture is used for cement hydration the total moisture loss given above for the two respective areas beneath the cover become 1.1 and 0.4 percentage points. Both moisture migration and loss through the cover are involved in these remaining

In addition to the loss of moisture due to migration the data show some loss apparently due to moisture vaporizing and moving out of the soil-cement through the cover. This is indicated by the data that show the moisture content of the 0-3/4 in. material at both locations with cover to

TABLE VIII

SUMMARY OF SOIL AND SOIL-CEMENT TESTS

(Characteristics of soil used in preliminary durability tests)

Test No.	Gradation (Percent Retained) 4	20	40	60	100	200	.05	.01	.005	.001	LL	PI
AA 4659 101-16	0	0	2	14	50	64	70	87	90	95	24	5

(Preliminary Durability Test Results)
12 Cycles

Cement Cont. % by Vol.	Density Lbs /Cu.Ft. Oven Dry	Moist. Cont. % by Oven Dry	Total Soil Loss Percent of Original Dry Wt. Wet Dry	Freeze Thaw
6	117	12	16	25.0
8*	117	12	7.5	9.0
10	117	12	2.5	4.5
12	117	12	1.0	1.0

Average characteristics of soils occurring in the top 6 in. of roadway which were stabilized with 12 percent cement.

Gradation (Percent Retained) 4	20	40	60	100	200	Liq. Limit	Plast. Index	Std. Comp.	Opt. Moisture
0	2	3	23	50	58	21	9	118	12

*Although these test results indicate a cement content of approximately 8 percent would be adequate on soils of this type under normal conditions, it was decided to increase the cement content to 12 percent on this project since unusually poor subgrade conditions exist over a considerable percent of the project.

be less after the first 24 hour period by about 3/4 of one percent than the 3/4-1½ in. material. The movement of moisture through the cover is further indicated by the fact that the rain on the fifth day appears to have partially penetrated the cover. The moisture contents after the rain increased at both areas, ½ percent at Area I and 3/4 percent at Area II. It will be noted that the sum of the estimated losses due to cement hydration, migration, and that moisture lost through the cover is greater than the respective loss at each of the Test Areas.

The data for the material 0-5 in. beneath the cover at Test Area I shows no change in moisture content from the first to the seventh day of the hydration period. At Test Area II in the section without cover the 0-5 in. moisture content decreased from 11.5 percent on the first day to 8.7 percent on the seventh day of the hydration period; obviously the decrease would have been much greater had there not been a one-inch rainfall on the fifth day. See figures 5 and 6.

It is concluded that the negative Oliensis spot MC-3 cutback asphalt cover

TABLE IX

DAILY MOISTURE CONTENTS*

Date	Test Area I, 0-3/4 in. Moisture Contents MC-3 Cutback Asphalt Cover	No Cover	Test Area I, 3/4-1½ in. Moisture Contents MC-3 Cutback Asphalt Cover	No Cover
	%	%	%	%
7/28/48[1]	15.7	15.7	15.5	15.5
7/29/48	15.1	13.7	15.0	15.0
7/30/48	13.2	9.9	14.1	13.1
7/31/48	13.4	8.2	14.1	11.3
8/1/48	-	-	-	-
8/2/48	13.5	6.4	14.3	10.4
8/3/48	13.9	8.3	14.2	11/6
8/4/48	13.8	8.1	14.6	11.8

Date	Test Area II, 0-3/4 in. Moisture Contents MC-3 Cutback Asphalt Cover	No Cover	Test Area II, 3/4-1½ in. Moisture Contents MC-3 Cutback Asphalt Cover	No Cover
	%	%	%	%
7/28/48[1]	13.3	13.3	12.6	12.6
7/29/48	12.8	13.4	12.8	14.1
7/30/48	10.7	7.4	11.8	10.8
7/31/48	11.1	6.9	11.5	10.4
8/1/48	-	-	-	-
8/2/48	11.1	4.1	11.6	8.4
8/3/48	11.9	9.8	12.3	11.3
8/4/48	12.1	6.3	12.3	10.3

*Average of 3 tests.
[1]Samples were taken after final finishing just before application of MC-3.

served adequately as a moisture barrier by retaining most of the moisture in the soil-cement during the 7-day hydration period.

Observation on MC-3 Cutback Asphalt Cover

Daily inspections showed no penetration of the negative MC-3 into the soil-cement except in small low areas where the MC-3 was ponded. At these locations a very slight penetration was noted.

By the end of seven days, the MC-3 had cured out sufficiently that it could be walked upon without picking up. If it had been necessary to open the section to automobile traffic during the 7-day hydration period, sanding to blot up the MC-3 would have been necessary.

From the first day of application, the negative MC-3 adhered firmly to the soil-cement. It became more fimrly attached each day and on the last day of test it was removed only after considerable work by scraping with a knife.

The soil-cement directly beneath the MC-3 had hardened noticeably the day fol-

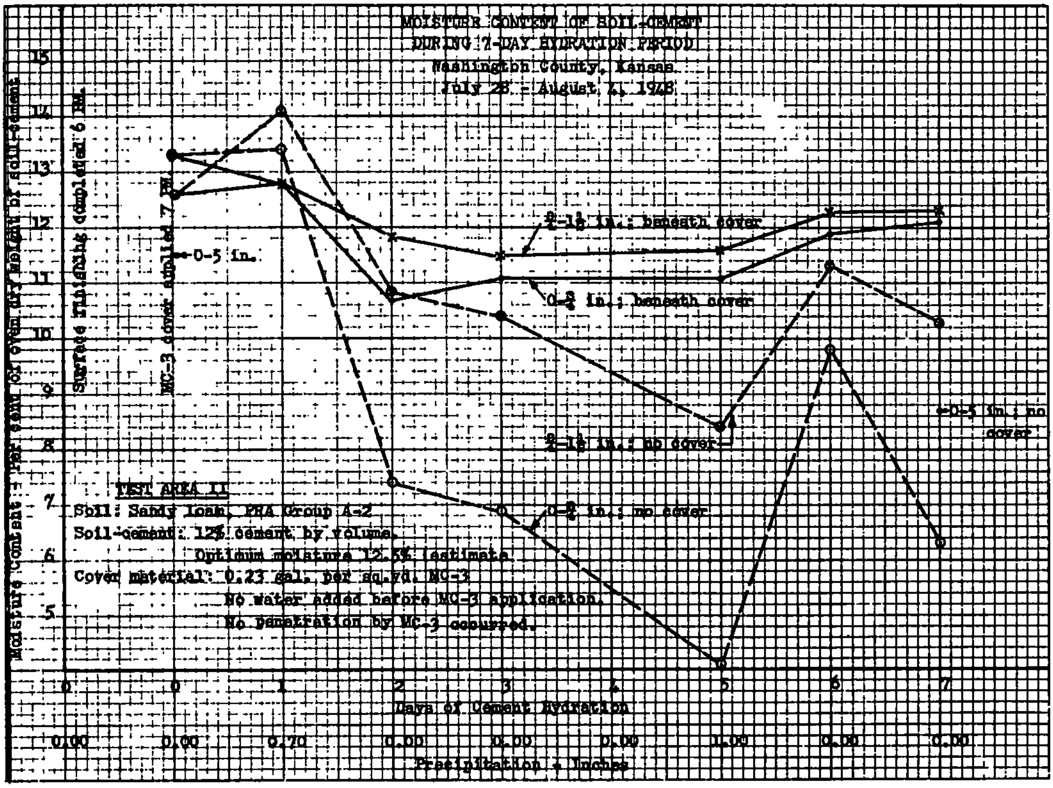

Figure 6.

lowing construction and the hardness increased daily. It was particularly noted that the soil-cement immediately beneath the cover was as hard as the soil-cement at greater depths. This observation reinforces the conclusion that the negative MC-3 retained sufficient moisture for adequate cement hydration.

Where the soil-cement was not covered with the MC-3, the surface for a depth of about 1½ in. did not harden satisfactorily. At the end of 7-days this depth of material could easily be penetrated and removed with a knife. The soil-cement below the 1½ in. depth was considerably harder than the surface material.

CONCLUSIONS

These data show that the negative MC-3 cutback asphalt cover, as used on this project, did efficiently retain the moisture in the soil-cement for seven days. Further, that it adhered satisfactorily to the soil-cement and in general did not penetrate into the soil-cement. The MC-3 did not cure out during the 7-day period so that pickup by automobile traffic would have occurred during this period unless sand was applied to blot up the MC-3. Finally, the use of the negative Oliensis spot MC-3 cutback asphalt had no deleterious effect on the quality of the soil-cement.

The sections without MC-3 cover at all Test Areas lost considerable moisture particularly from the top 3/4 in. and 3/4-1½ in. depths. The hardness of the surface material on these sections was inferior to that beneath the cover. The data clearly show the need of a protective cover for retaining the moisture in the soil-cement during the early hydration period.

Mr. M. C. Burnett was the resident engineer for the State Highway Commission of Kansas and Mr. E. G. Robbins, Soil-Cement Bureau, Chicago, represented the Portland Cement Association in conducting the tests and collecting the data.

NEBRASKA DATA

The data from Nebraska were obtained on a road project 9.2 miles long built by F. B. Orshek Co., Fremont, Nebr., representing 146,240 sq. yds., 6 in. thick in Burt County on Route 73. It was built during September and October, 1948. An RC-1 cutback asphalt was used as a moisture retaining cover and specifications are given in Table X.

TABLE X

REQUIREMENTS FOR CUTBACK ASPHALTS

Cutback asphalts shall be composed of a suitable distillate and asphalt base. They shall be homogeneous, free from water, show no separation on standing and shall meet the following requirements when tested in accordance with the prescribed methods.

	Specification Requirements	Test Data for Material Actually Supplied
Specification Designation	RC-1	
Viscosity, Saybolt-Furol:		
At 122 F., Seconds	75-150	125
At 140 F., Seconds	--	
Distillate, percentage by volume of total distillate to 680 F.		
To 374 F.	10+	20.7
To 437 F.	50+	65.5
To 500 F.	70+	86.2
To 600 F.	88+	96.6
Residue from distillation to 680 F., percentage Volume by difference	60+	71.0
Tests on Residue from Distillation:		
Penetration 77 F., 100 gm., 5 sec.	80-120	86
Ductility at 77 F., cm.	100+	100+
Solubility in carbon tetrachloride, percent	99.5+	99.75
Spot Test:		
Naptha xylene solvent, 10 percent xylene	Neg.	Neg.

Soil-cement construction was carried out by mixed-in-place methods using heavy duty equipment featuring two rotary speed mixers. A cement content of 9 percent by volume, or 0.405 bag per sq. yd., was used.

TEST CONDITIONS

Four test areas were located approximately one mile south of the city limits of Decatur. Test Areas I and II were located just west of the centerline about 3 ft. apart. Test Areas III and IV were located at the west quarter point of the road about 3 ft. apart. Test data were obtained beginning the day of construction, September 17 and ending September 24. Each test area measured about 3 ft. x 3 ft.

For the first three days of the test period the weather was hot, generally clear and windy. It rained during the fourth day. The last three days were cloudy, cool and windy. Weather data were obtained from Weather Bureau Stations located at Tekamah and Omaha, and are listed in Table XI.

density was substantially below the theoretical value.

Approximately 15 minutes elapsed between final finishing and the application of the RC-1.

No additional water was applied to Test Areas I or III after final finishing. The soil-cement surface at Test Area I was quite moist (near the optimum) but there was no free water on the surface at the time the RC-1 cover was applied. The soil-cement surface at Test Area III was much dryer than that at Test Area I (appreciably below optimum) at the time the RC-1 cover was applied.

TABLE XI

WEATHER DATA

Date	Temperature Degrees F Max.	Temperature Degrees F Min.	Relative Humidity at Noon, Percent	Total 24-hour Rainfall Inches	Wind Velocity at Noon mph.
9/17/48	90	68	54	0.00	33
9/18/48	92	71	61	0.00	13
9/19/48	96	69	90	0.00	18
9/20/48	79	68	73	0.14	19
9/21/48	80	60	91	0.00	16
9/22/48	76	57	91	0.00	17
9/23/48	72	54	86	0.00	29
9/24/48	71	56	69	0.00	23

The soils at the test areas selected were loamy coarse sands of PRA Group A-2 containing approximately 10 percent material retained on a No. 4 sieve. A representative sample was tested in the laboratory to determine the cement content to be used during construction[3]. The "Summary of Tests" obtained for this soil is listed in Table XII.

Surface finishing procedures at test areas I and II were in conformance with good construction practice -- a tight, dense surface was obtained containing close to optimum or more moisture. The density obtained from the 6-in. base was near the theoretical value.

Test areas III and IV were located on a short and narrow strip of soil-cement containing appreciably less than optimum moisture. As a result of too little moisture the surface finishing did not produce a tight dense surface; and the

[3] ibid.

At Test Area II and IV additional water was applied with a garden type sprinkling can to the soil-cement surface after final finishing immediately before the cover material was applied. The two areas were lightly sprinkled until free water appeared on the soil-cement surface where a very thin film of moisture was visible when the RC-1 cover was applied.

Attention is called to the fact that Test Areas I and II were constructed similarly, containing optimum moisture, and are comparable in every way except that Area II received additional moisture just prior to the cover application. Test Areas III and IV were constructed with appreciably less than optimum moisture and are comparable except that Area IV received additional moisture just prior

TABLE XII

COMBINED AGGREGATE USED IN SOIL-CEMENT BASE COURSE

Laboratory Tests on Individual Materials		Coarse Sand	Fine Sand	Soil	Calculated Gradation	Calculated Gradation Based on Field Test and Field Combination
Percent used in Lab. Mix		74	14	12		
Mechanical Analysis						
Retained on No.	4	9			7	4
Retained on No.	10	26			19	16
Retained on No.	20	50			37	33
Retained on No.	30	62	0		46	--
Retained on No.	40	74	1		55	59
Retained on No.	50	83	5		62	67
Retained on No.	80	92	62		77	--
Retained on No.	100	94	76	0	80	83
Retained on No.	200	96	93	0	84	87
Liquid Limit				34		
Plasticity Index				10	2.5	
Specific Gravity		2.62	2.65	2.69		

OPTIMUM MOISTURE AND MAXIMUM DENSITY DETERMINATIONS

	Optimum Moisture	Maximum Density
Laboratory mixture using 9 percent Cement by volume	7.4	133 lb/cu. ft.
Field mixture using 9 percent Cement by volume (Fresh Mix)	8.7	131 lb/cu. ft.
Field mixture using 9 percent Cement by volume (After 4 hr. Setting Period)	9.0	125 lb/cu. ft.

to cover application.

Between and adjacent to Areas I and II and also between and adjacent to Areas III and IV were areas that received no cover or additional moisture after final finishing.

The RC-1 cutback asphalt was applied at the rate of 0.20 gal. per sq. yd. This application resulted in complete coverage of the soil-cement surface.

Moisture samples weighing about 150 gms. each were lifted for a 0-3/4 in. depth from the surface of the 6 in. base and also from a 3/4 in.-1½ in. depth at the same location. There was penetration by the RC-1 into the surface of the soil-cement at some of the areas and this penetrated material was removed and discarded before the moisture samples were lifted. Three moisture samples were taken each day from each depth from each of the covered and uncovered Test Areas. The first samples were taken after final finishing, just prior to the application of the RC-1 cover. Every day thereafter for seven days, samples were again lifted from beneath the cover material at each Test Area and from adjacent areas without bituminous cover.

Moisture samples were also taken from a depth of 0-5 in. at each Test Area, just before the cover application and on the

TABLE XIII

DAILY MOISTURE CONTENTS*

Date	Test Area I, 0-3/4 in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area I, 0-3/4 in Moisture Contents No Cover[2] %	Test Area II, 0-3/4 in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area II, 0-3/4 in Moisture Contents No Cover[2] %
9/17/48[1]	8 7	8 7	10 4	8 7
9/18/48	8 0	7 0	8 9	7 0
9/19/48	7 9	5 6	8 0	5 6
9/20/48	8 3	8 9	8 2	8 9
9/21/48	8 5	7 5	8 5	7 5
9/22/48	8 3	6 2	8 3	6 2
9/23/48	8 1	5 2	7 9	5 2
9/24/48	8 0	4 8	7 6	4 8

Date	Test Area I, 3/4-1½ in. Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area I, 3/4-1½ in. Moisture Contents No Cover[2] %	Test Area II, 3/4-1½ in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area II, 3/4-1½ in Moisture Contents No Cover[2] %
9/17/48[1]	8 7	8 7	10 2	8 7
9/18/48	8 0	7 7	8 6	7 7
9/19/48	7 8	6 8	8 3	6 8
9/20/48	8 4	9 4	8 3	9 4
9/21/48	8 7	8 2	8 9	8 2
9/22/48	8 4	7 2	8 9	7 2
9/23/48	7 9	7 2	8 6	7 2
9/24/48	8 1	7 1	8 6	7 1

Date	Test Area III, 1/16-3/4 in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area III, 1/16-3/4 in Moisture Contents No Cover[3] %	Test Area IV, 0-3/4 in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area IV, 0-3/4 in Moisture Contents No Cover[3] %
9/17/48[1]	6 7	6 7	13 2	6 7
9/18/48	6 4	6 3	10 2	6 3
9/19/48	6 3	5 8	9 4	5 8
9/20/48	9 7	10 2	9 7	10 2
9/21/48	8 3	8 1	10 2	8 1
9/22/48	7 4	5 9	9 8	5 9
9/23/48	7 0	4 3	9 2	4 3
9/24/48	6 6	5 0	7 8	5 0

Date	Test Area III, 3/4-1½ in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area III, 3/4-1½ in Moisture Contents No Cover[3] %	Test Area IV, 3/4-1½ in Moisture Contents RC-1 Cutback Asphalt Cover %	Test Area IV, 3/4-1½ in Moisture Contents No Cover[3] %
9/17/48[1]	8 0	8 0	12 4	8 0
9/18/48	7 3	7 6	9 7	7 6
9/19/48	7 0	7 3	9 6	7 3
9/20/48	9 9	9 7	9 3	9 7
9/21/48	9/1	9 0	9 7	9 0
9/22/48	8 6	7 6	9 4	7 6
9/23/48	8 0	7 2	8 8	7 2
9/24/48	7 6	7 1	8 5	7 1

*Average of 3 tests

[1] Samples were taken after final finishing immediately before application of asphalt emulsion cover

[2] The area with no cover for Test Areas I and II was located between and adjoining Test Areas I and II No water was added to the surface of this area after final finishing was completed

[3] The area with no cover for Test Areas III and IV was located between and adjoining Test Areas III and IV No water was added to the surface of this area after final finishing was completed

seventh day of the hydration period.

DISCUSSION OF TEST RESULTS

Moisture and Density Data

The moisture contents obtained from the samples at the selected test sites are tabulated in Table XIII and shown graphically in Figures 7, 8, 9 and 10.

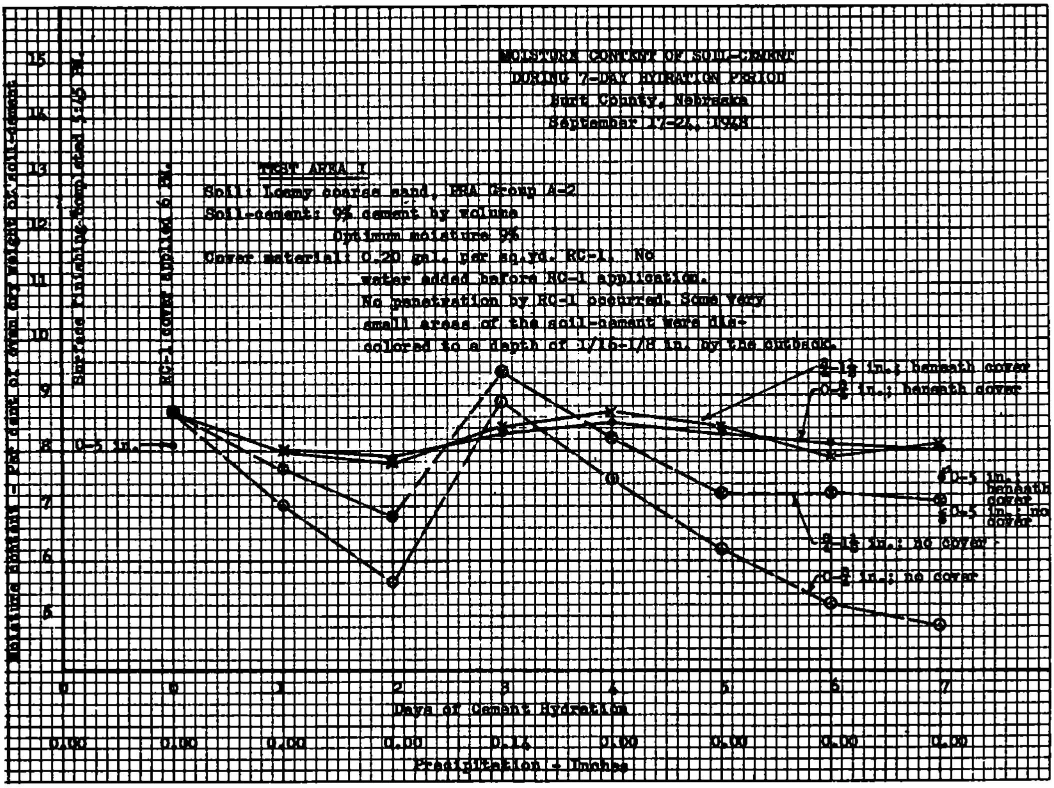

Figure 7.

The field optimum moisture content for the soil-cement was determined as 9.0 percent. The corresponding maximum density was 125.0 lb. per cu. ft.

The density of the completed soil-cement at Test Areas I and II was determined as 122.0 lb. per cu. ft. while at Test Areas III and IV it was 119.0 lb. per cu. ft.

General

The decreases in moisture content from the first to the seventh day in the top 3/4 in. under the RC-1 cover of 0.7 and 2.8 percentage points at Test Areas I and II are small indicating the cover efficiently retained the moisture. The corresponding decrease of 0.1 percentage point at Test Area III while small, in this instance gives an erroneous picture indicating that the moisture retention by the cover was good. The corresponding decrease of 5.4 percentage points for Test Area IV appears large and indicates that the cover at this area was not particularly efficient compared to that at Areas I and II. The discussion below will bring out that it was more efficient than the cover on Test Area III.

By referring to Figures 7, 8, 9 and 10 and comparing the curves "with" cover with those "without" cover it may immediately be seen that the cover was very effective at Test Areas I, II and IV and not so effective at Test Area III. Particular note should be made of the effect of the additional moisture due to rain on the third day. The curves "without" cover at all test areas and the curve "with" cover

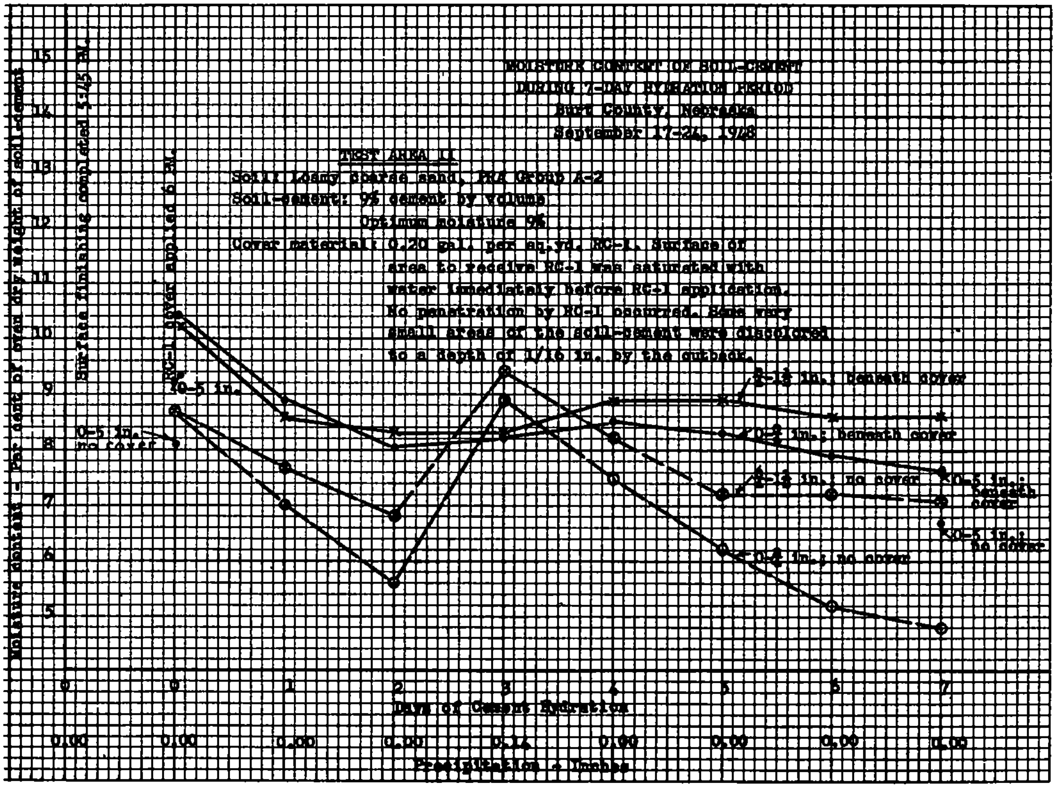

Figure 8.

at Test Area III show the effect of this rain by increases in moisture content. On the other hand, the curves "with" cover at Test Areas I, II, and IV show that the rain was effectively shed by the cover.

Since the weather turned cool and cloudy following the rain on the third day, the rate of evaporation was considerably less the remaining four days than it was the first three days of the test period.

This reduced evaporation rate is evident when the curves for 0-3/4 in. "without" cover are studied: It will be noted that it was not until the fifth day that the moisture contents of this depth material at all Test Areas, had decreased to the amount present the second day. As a result, the net moisture losses at the end of the 7-day period are much less than they would have been had it not rained.

It is indicated that the moisture decreases in the soil-cement directly beneath the RC-1 cover probably occur due to, (1) moisture used for cement hydration and which cannot be driven off with the 110 C. temperatures used to dry moisture samples, (2) moisture migrating from the surface material where it was concentrated, to material at greater depth, and (3) moisture vaporizing and leaving the soil-cement through the bituminous cover. Each of these reasons are discussed below.

(1) The differences between the moisture content determined from moisture samples lifted the first day, and that determined from identical samples lifted the first day but then sealed and stored 7-days, and then dried, is taken as the amount of moisture used for cement hydration. The amount of moisture used for cement hydration during the test period of 7-days was determined as 0.6 of one percentage point.

(2) During final finishing operations the moisture content of the surface soil-cement is normally built up so that it is higher than that of underlying material.

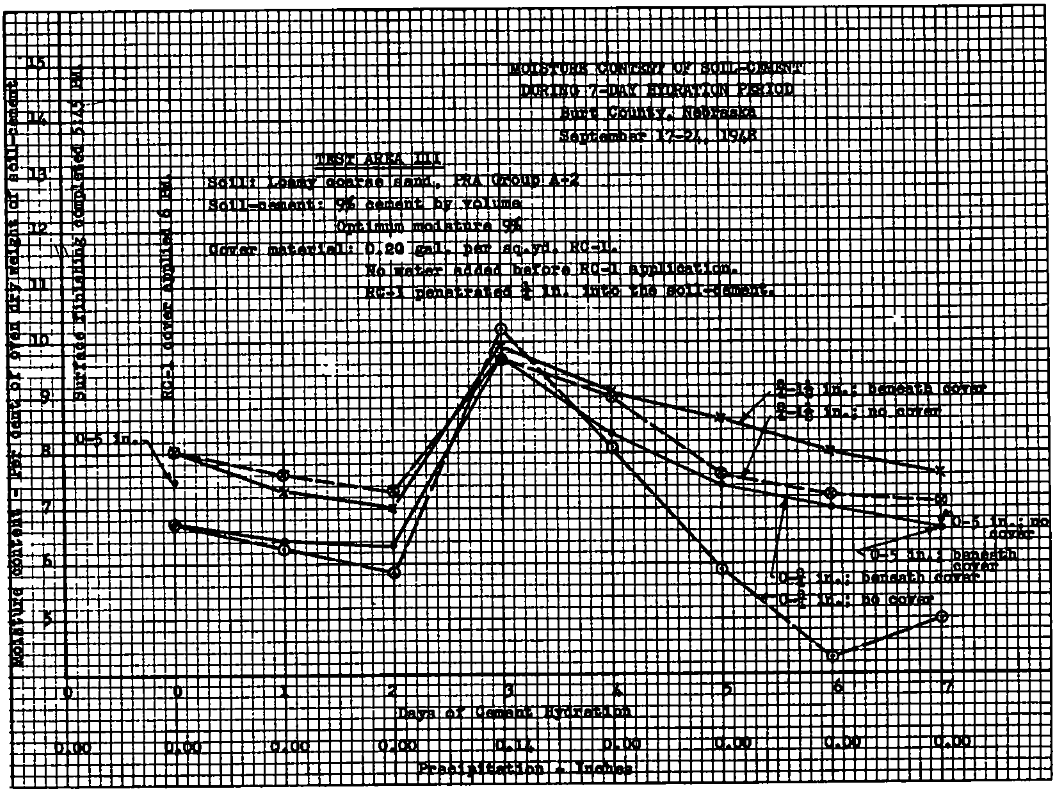

Figure 9.

This excess moisture migrates to the material at greater depth so that there is a tendency towards equalization of moisture throughout the mass. Consequently the moisture content of the surface soil-cement decreases from that at time of construction. This phenomenon at each Test Area is discussed below.

Test Area I was surface finished in a normal manner as described above. The moisture content of the surface soil-cement at time of cover application was 8.7 percent compared to 8.1 percent for the material from 0-5 in. depth. See Figure 7. The moisture content of the surface material beneath the cover changed from 8.7 percent to 8.0 percent during the first 24 hours. It is likely that part if not most of this change was due to moisture migration, some was due to cement hydration, and as will be discussed later, some of this decrease may have been due to loss through the RC-1 cover.

Test Area II was surface finished exactly like Test Area I and the two areas were identical except, as previously noted, additional water was added to the surface of Test Area II just before the cover was applied. See Figure 8. This moisture increased the moisture content of the 0-3/4 in. material to 10.4 percent, compared to 8.7 percent for the 0-3/4 in. material in Test Area I. The moisture content of the 0-5 in. material was 9.3 percent, compared to 8.1 percent in Test Area I. The moisture content of the 0-3/4 in. material of Test Area II was 1.1 percentage points higher than the 0-5 in. material. During the first 24 hours the moisture content of the 0-3/4 in. material changed from 10.4 percent to 8.9 percent, a decrease of 1.5 percentage points. Most of this amount apparently was due mainly to moisture migration, some, possibly a smaller amount, to loss through the cover and the remainder of the decrease was due to cement hydration.

Test Area III was surface finished with

a moisture content 2.3 percentage points below optimum. Consequently there was no extra water to migrate, in fact the moisture content of the 0-3/4 in. material was 1.3 percentage points lower than 3/4-1½ in. material and 0.8 percentage points less than that based on 0-5 in. material. See Figure 9. However, the moisture content of the 0-3/4 in. material decreased 0.3 percentage points the first 24 hours. Apparently this moisture was lost through the RC-1 cover and used for cement hydration.

percent in Test Area III. The difference in moisture content of Test Area IV between 0-3/4 in. and 0-5 in. material was 3.8 percentage points. The moisture content of the 0-3/4 in. material decreased 3 percentage points the first 24 hours; most of the decrease apparently was due to migration and probably some was lost through the cover and the remainder was used for cement hydration.

(3) A part of the change in moisture content of the soil-cement beneath the cover is undoubtedly due to moisture loss

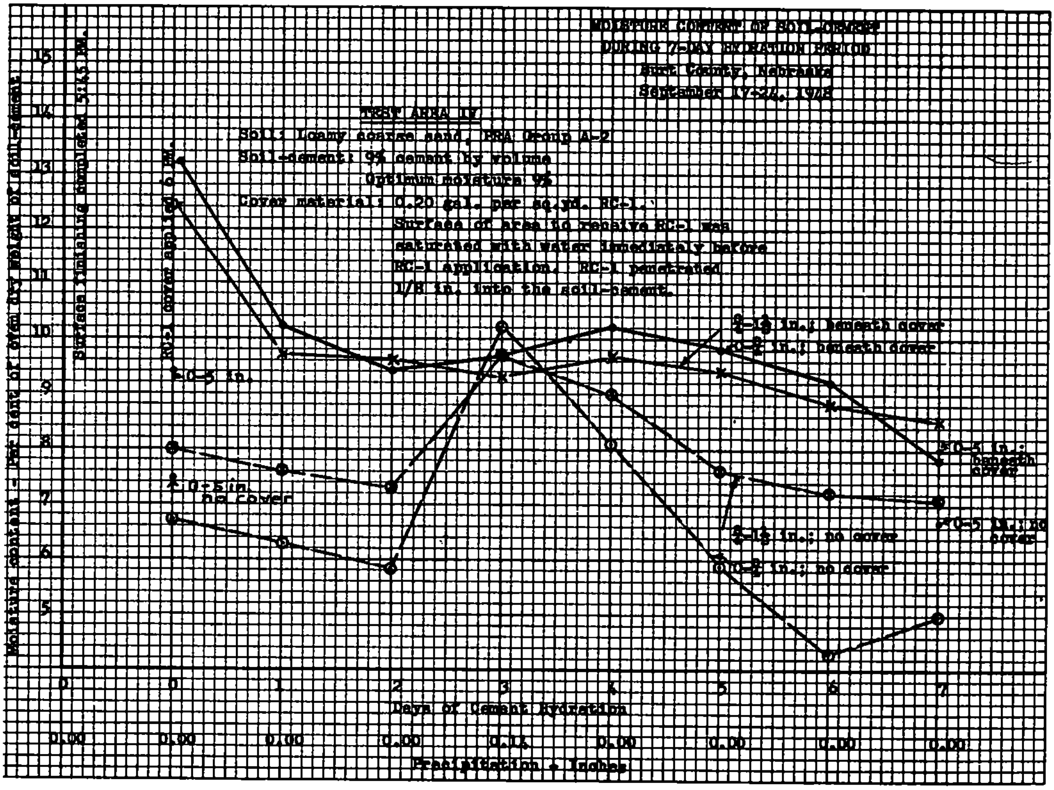

Figure 10.

Test Area IV was surface finished with moisture content below optimum exactly as Test Area III but as was done in the case of Test Area II additional moisture was applied to its surface just before the RC-1 cover was applied. See Figure 10. The moisture content of the 0-3/4 in. material was raised to 13.2 percent, compared to 6.7 percent in Test Area III, and the moisture content of the 0-5 in. material was 9.4 percent, compared to 7.5

through the RC-1 cover. This loss appears to be dependent upon the physical characteristics of the cover itself, and the weather conditions. An estimate of the actual loss of moisture at each of the four Test Areas may be made by (a) noting the trend of the curve plotted from daily moisture contents, that is, whether or not the trend is upward indicating gain in moisture, downward indicating a loss or remains level indicating no change; (b) by comparing the curves at any one test area, to note if the 0-3/4 in. material becomes drier than 3/4-1½ in. material; and (c) by comparing "with" cover curves with "without" cover curves. The estimate of loss of moisture through the cover at each Test Area follows:

At Test Area I, beneath the cover at a depth of 0-3/4 in., a total net decrease in moisture content during the 7-day hydration period of 0.7 percentage point was recorded. As mentioned above, moisture for cement hydration equaled 0.6 percentage points and a similarly small change was likely due to migration. The 0-3/4 in. and 3/4-1½ in. curves practically coincide for the 7-day period indicating almost identical moisture contents. Finally the curves are generally level. It is further noted that the moisture content of the 0-5 in. material beneath the cover decreased 0.5 percentage points during the 7-day period. It is estimated, therefore, on the basis of the influencing factors that the moisture loss through the cover at Test Area I was negligible.

At Test Area II, 0-3/4 in. beneath the cover there was a net decrease in moisture content from the first to the seventh day of 2.8 percentage points. The moisture for cement hydration amounts to 0.6 percentage points and as discussed above under section (2), migration losses would consist of most of the 1½ percentage point change during the first day. After the first day adjustment the curves for moisture content are generally level. However, the curve for the 0-3/4 in. material crosses to below the curve for the 3/4-1½ in. material indicating it dried more rapidly. At the conclusion of the 7-day period the 0-3/4 in. material was 1 percentage point of moisture drier than the 3/4-1½ in. material. Further, it was noted that the moisture content of the 0-5 in. material beneath the cover decreased 1.7 percentage points during the 7-day period which includes 0.6 percent for cement hydration. In view of the above factors it is concluded that the moisture lost through the RC-1 cover at Test Area II is quite small and probably amounts to less than 1 percentage point.

At Test Area III the net moisture loss in the material 0-3/4 in. beneath the cover during the 7 days was 0.1 percentage point. However, by referring to Figure 9, and comparing the curves "with" and "without" cover it is immediately apparent that the cover neither retained moisture effectively nor did it keep out the rain water. The trend of the curve is first steeply upward indicating gain in moisture from the rain, and rather sharply downward after the rain indicating loss of moisture by drying. The curves "with" cover are similar in trend to those "without" cover. The 0-3/4 in. material beneath the cover at 7-days was 1 percentage point drier than the 3/4-1½ in. material although after the rain on the third day they were about identical. It is concluded therefore, that there was substantial moisture losses and also a large gain from rainfall through the RC-1 cover at Test Area III.

At test Area IV the net loss beneath the cover in the 0-3/4 in. material for the 7-day period was 5.4 percentage points. See Figure 10. The total amount of the moisture used for cement hydration and that estimated above as largely due to change by migration total about 3½ percentage points for this Test Area. The trend of the moisture content curves beneath the cover, after the first 24 hours, is level for 5 days and then downward. The rather sharp drop of 1 percentage point in the 0-3/4 in. material from the sixth to the seventh day is unaccountable and perhaps should be disregarded. Except for this last day of the 7-day period the 0-3/4 in. material was more moist than the 3/4-1½ in. material. It is further noted that the moisture content of the 0-5 in. material beneath the cover decreased 1.4 percentage points during the 7-day period. It also was noted that the moisture content of the soil-cement beneath the cover was much higher at 7 days than the material with no cover.

It is concluded that some moisture, perhaps one to two percentage points, was lost through the RC-1 cover.

Observation on RC-1 Cutback Asphalt Cover

Daily inspections showed the following

in regard to the RC-1 cover material:

Test Areas I and II - In general there was no penetration into the soil-cement by asphalt but some occasional discoloration by the cutback agent to a depth of 1/8 in. was noted. The film of asphalt on the soil-cement surface was estimated at 1/16 in. in thickness. See Figure 11. The RC-1 adhered firmly to the soil-cement becoming more difficult to remove as time passed. On the seventh day it could be removed only with considerable effort. The RC-1 was quite tacky the first four days and sufficiently tacky thereafter that it picked up on one's shoes.

Test Area III - The RC-1 penetrated 1/16 in. within one hour after application. could be removed intact with difficulty and it stuck rather tenaciously to the soil-cement. The area was quite tacky for three days, less so than Areas I and II, but more so than Area III. Pickup on one's shoes occurred through the 7-day test period.

Daily inspections showed the following with regard to the quality of the soil-cement:

Test Areas I and II - The soil-cement in both Test Areas I and II beneath the cover hardened satisfactorily from directly beneath the cover to full depth. After the second day, the soil-cement could only be removed with much effort using a hammer and chisel. It was particularly noted

Figure 11. The condition of the RC-1 cover at each Test Area is indicated. There was no penetration into the soil-cement at Test Areas I and II. There was 1/4 in and 1/8 in. penetration respectively at Test Areas III and IV.

The next day 1/4 in. penetration had occurred. No film of asphalt was left on the soil-cement but rather the RC-1 and the penetrated soil-cement formed a 1/4 in. "mat". See Figure 11. This mat could readily be separated from underlying soil-cement with a chisel and light hammering. There was no pickup of the cover on one's shoes in this area after the first few hours.

Test Area IV - The RC-1 penetrated the soil-cement only slightly within the first few hours after application. By the end of the second day penetration to a 1/8 in. depth had occurred. A "mat" similar to that at Test Area III but only one-half as thick and consequently more "alive" was formed. See Figure 11. The "mat" that the soil-cement directly beneath the film of asphalt was as hard as underlying material. The surface soil-cement in Test Area I appeared slightly harder than in Test Area II.

The soil-cement in the uncovered area between Test Areas I and II was inferior to that in Test Areas I and II. The top ½ in. particularly hardened slowly and after 7 days could be readily dug into. The quality and hardness increased with depth and below about 2 in. it was practically as good as the material at comparable depth in the covered areas.

Test Areas III and IV - The soil-cement in Test Area III beneath the cover, as discussed previously, was of inferior quality as constructed and was also inferior at the end of the 7-day hydration period. This was due to the low moisture content incorporated during construction and accompanying low densities. The soil-cement in this area after the seventh day of hydration could be dug into by hand chiseling. The material immediately beneath the "mat" appeared of about the same hardness as material from greater depths. The penetrated soil-cement was of very poor quality and did not harden appreciably whatsoever.

At Test Area IV, similar to Test Area III except that additional moisture was added after final finishing, was of better quality. While the soil-cement was much better than at Test Area III and after the third day could only be removed by hammer and chisel, it was inferior to that at Test Areas I and II. The penetrated soil-cement was of very poor quality and did not harden appreciably whatsoever.

The uncovered area between Test Areas III and IV was of very poor quality and the surface 1½ in., even on the seventh day of the period, could be removed by vigorous digging with a spoon. It was harder below the 1½ in. depth but could be easily removed by hand chiseling. Also, it was inferior to the soil-cement in the uncovered area between Test Areas I and II.

CONCLUSIONS

These data show that the RC-1 cutback asphalt cover as used on this project at Test Areas I and II did efficiently retain the moisture in the soil-cement. Further, that in these areas the RC-1 adhered satisfactorily to the soil-cement and did not penetrate into the soil-cement. In these areas, the RC-1 did not cure out during the 7-day period so that pickup by automobile traffic could only be prevented by sanding to blot up the RC-1. Further the use of the RC-1 cutback asphalt had no deleterious effect on the quality of the underlying soil-cement.

The data show that the RC-1 cutback asphalt cover as used on this project at Test Area III did not efficiently protect the soil-cement from moisture changes. Further, that in this Test Area the soil-cement was penetrated and the penetrated material did not harden satisfactorily.

The data also show that the RC-1 cutback asphalt cover as used on this project at Test Area IV protected the soil-cement from evaporation losses better than at Test Area III; and that not as much penetration occurred as in Test Area III. However, the penetrated soil-cement hardened only slightly showing that as used in the Area the RC-1 cover was undesirable.

The sections at all Test Areas without RC-1 cover lost considerable moisture particularly from the top 3/4 in. and 3/4-1½ in. depths. The hardness of the surface material on these sections particularly was inferior to that beneath the cover. The data clearly show the need of a protective cover for retaining the moisture in the soil-cement during the early hydration period.

The data obtained clearly show that in order for the soil-cement to harden into a durable structural material it was essential that the optimum or more moisture be incorporated during construction and retained during the 7-day hydration period. Adequate moisture in the surface of the completed soil-cement at time of application of the RC-1 was definitely helpful in preventing undesirable penetration of the RC-1 into the soil-cement.

Mr. C. J. Schuster was the project engineer for the Nebraska Department of Roads and Mr. J. A. Leadabrand, Soil-Cement Bureau, Chicago, represented the Portland Cement Association in conducting the tests and collecting the data.

ARKANSAS DATA

The data from Little Rock, Arkansas were obtained on a street project in the University Hospital Area representing 22,000 sq. yds., 6 in. thick built by city forces in June, 1948. An asphalt emulsion was used as a moisture retaining cover and specifications are given in Table XIV.

Soil-cement construction was carried out by mixed-in-place methods using heavy duty equipment featuring one rotary speed mixer. A cement content of 10 percent by volume, or 0.450 bag per sq. yd., was used.

TEST CONDITIONS

The test data were obtained from two areas, located at 607 and 615 East 13th Street in Little Rock, beginning the day of construction, June 9, and ending June 16. Each test area selected was located at the North quarter-point of the road and measured about three feet square.

Throughout the test period of 7 days the weather was hot, clear and sunny except for one light shower. Weather data were obtained from the Weather Bureau located at the Little Rock Airport and are listed in Table XV.

Moisture samples weighing about 150 gms. each were lifted from the top 3/4 in. of the 6 in. base. Four were taken each day from covered and uncovered areas at each of two locations. The soil-cement was screened on a No. 4 screen and the material passing was used for the moisture content determination. The first samples were taken immediately after final finishing and a second set were taken just prior to the application of the asphalt emulsion cover. Every day for 7 days, moisture samples were lifted at the same locations beneath the cover material and from adjacent areas without bituminous cover. The average results obtained each day from the above samples are shown graphically in Figures 12 and 13 and are tabulated in Table XVI.

The soils at the test areas selected were clay loams (high in sand) containing approximately 10 percent material retained on a No. 4 sieve. They were quite similar to a sample previously lifted from 13th Street and tested in the laboratory to determine the cement content to be used during the construction[4]. The "Summary of Tests" obtained for this soil is listed in Table XVII.

Surface finishing procedures particularly were in conformance with good construction practice -- a tight, dense surface containing not less than optimum moisture was obtained. Moisture contents at time of compaction were at field optimum or above and compaction produced the corresponding maximum density.

At the conclusion of surface finishing, about 0.15 gal. per sq. yd. of water was applied with a pressure distributor to the completed base. Just after this moisture was applied and the free water had disappeared from the surface, so that only a "sheen" was visible, 0.34 gal. per sq. yd. of diluted asphalt emulsion was applied. (1 part asphalt emulsion and 1 part water.) The emulsion was identified as "Bitumuls HCM". This application resulted in a final film thickness of asphalt cover estimated at 1/32 in. Coverage on the soil-cement was complete with some slight runoff.

DISCUSSION OF TEST RESULTS

Moisture Data

At Test Area I the moisture content in the top 3/4 in. at time of cover application was 19.8 percent and at the end of 7 days it was 16.8 percent, a change of 3.0 percentage points. The optimum moisture content was estimated to be about 18 percent for the fraction passing the No. 4 screen, since the soil at this site is somewhat heavier textured than sample No. 4753 (Table XVII) which was previously

[4] ibid.

TABLE XIV

SPECIFICATION FOR EMULSION COVER "BITUMULS HCM"

The emulsified asphalt shall conform to the following requirements:

Viscosity -- Saybolt-Furol - 60 cc. at 25 C. -- 77 F.	
Modified Miscibility Test	Not more than 4.5%
Cement Mixing Test	Break not more than 2%
Specific Gravity - 25 C./25 C. (77 F./77 F.)	Not less than 1.00
Residue at 163 C. (325 F.) 3 hrs. - 50 gr.	
or	60 - 65%
Residue from Distillation Test (A.S.T.M.)	
Settlement, 10 Days	Not more than 3
Sieve Test	Not more than 0.05%
Demulsibility - 50 ml. 0.10N $CaCl_2$	Not more than 2%
Dehydration 100 F. -- 96 hrs.	Not less than 0.60
Adhesion	Not less than 75% coated

ASPHALT

The asphalt contained in the emulsified asphalt shall have the following characteristics when tested prior to emulsification:

Penetration at 25 C. (77 F.)	150 - 250
Solubility in carbon disulphide	Not less than 99%
Ductility at 25 C. (77 F.)	Not less than 100 cms.
Loss at 163 C. (325 F.) 5 hrs.	Not more than 3.5%

In lieu of the above requirements for asphalt prior to emulsification, at the option of the engineer, tests may be made on the residue from the Distillation Test (A.S.T.M.), in which case the following requirements shall be substituted:

Penetration of residue at 25 C. (77 F.)	100 to 200
Solubility in carbon disulphide	Not less than 97
Ash	Not more than 2
Ductility at 25 C. (77 F.)	Not less than 40

TABLE XV

WEATHER DATA

Date	Temperature Degrees F. Max.	Temperature Degrees F. Min.	Relative Humidity at Noon, Percent	Total 24-Hour Rainfall, Inches	Wind Velocity at Noon, mph
6/9/48	86	68	36	0.00	7
6/10/48	86	64	40	0.00	7
6/11/48	91	64	41	0.00	4
6/12/48	94	65	41	0.00	10
6/13/48	96	74	47	trace	7
6/14/48	95	73	49	trace	6
6/15/48	95	72	55	0.05	9
6/16/48	93	66	56	0.00	8

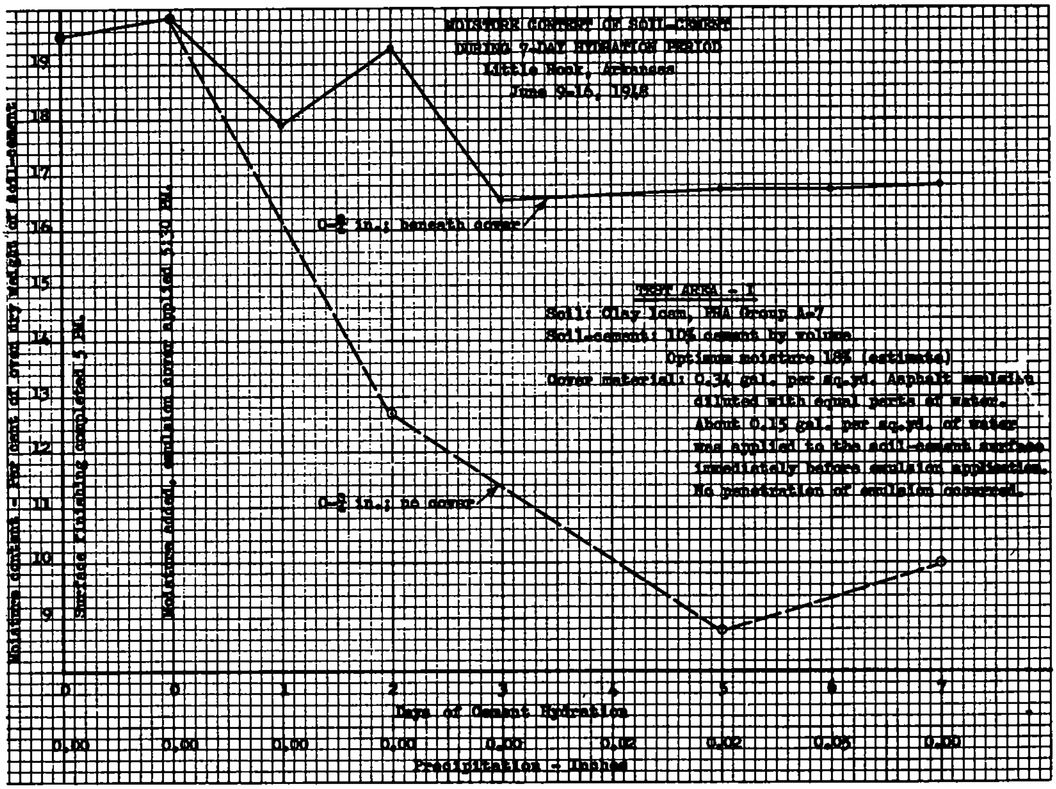

Figure 12.

tested from this street and which had an optimum moisture content of 15.8 percent for the minus No. 4 soil-cement. The 7th day moisture content of an adjacent area with no bituminous cover was 10 percent. Two days earlier it was 8.8 percent. The gain the last day was due to a light rain falling the night of the 6th day. See Table XV.

At Test Area II, the moisture content in the top 3/4 in. at time of cover application was 17.7 percent and at the end of 7 days it was 13.7 percent a change of 4.0 percentage points. The optimum moisture of the soil-cement passing a No. 4 screen was estimated at about 15 percent since the soil at this site is lighter textured than soil No. 4753 (Table XVII) which had a comparable optimum moisture content of 15.8 percent. The corresponding moisture content for the area with no cover was 7.8 percent and two days earlier before the light shower it had been 5.5 percent.

Although the drop in moisture content under the cover material of 3.0 and 4.0 percentage points respectively may at first appear large they are not excessive as will be brought out in the following discussion:

First, a comparison of the curves "with" and "without" cover quickly shows the high moisture retention by the emulsion cover.

For soils of this type, research has shown that the quantity of moisture taken up by cement hydration during 7-days, and which cannot be driven off by the 110 C. temperature used to dry the moisture samples, is likely to be about 1½ percentage points.

The moisture content of the surface portion of the soil-cement during final finishing was built up so that it was above the field optimum moisture content and also higher than that of the underlying material. During the 7-day hydration period, particularly the first 2 days,

TABLE XVI

DAILY MOISTURE CONTENTS*

Date	Test Area I Moisture Contents: Asphalt Emulsion Cover %	Test Area I Moisture Contents: No Cover %	Test Area II Moisture Contents: Asphalt Emulsion Cover %	Test Area II Moisture Contents: No Cover %
6/9/48[1]	19.5	19.5	17.4	17.4
6/9/48[2]	19.8	19.8	17.7	17.7
6/10/48	17.9	-	16.3	-
6/11/48	19.3	12.7	15.6	10.9
6/12/48	16.5	-	14.3	-
6/13/48	-	-	-	-
6/14/48	16.7	8.8	13.6	5.5
6/15/48	16.7	-	13.8	-
6/16/48	16.8	10.0	13.7	7.8

*Average of 4 tests.

[1]Samples were taken after final finishing.

[2]Samples were taken after moisture application immediately before application of asphalt emulsion cover.

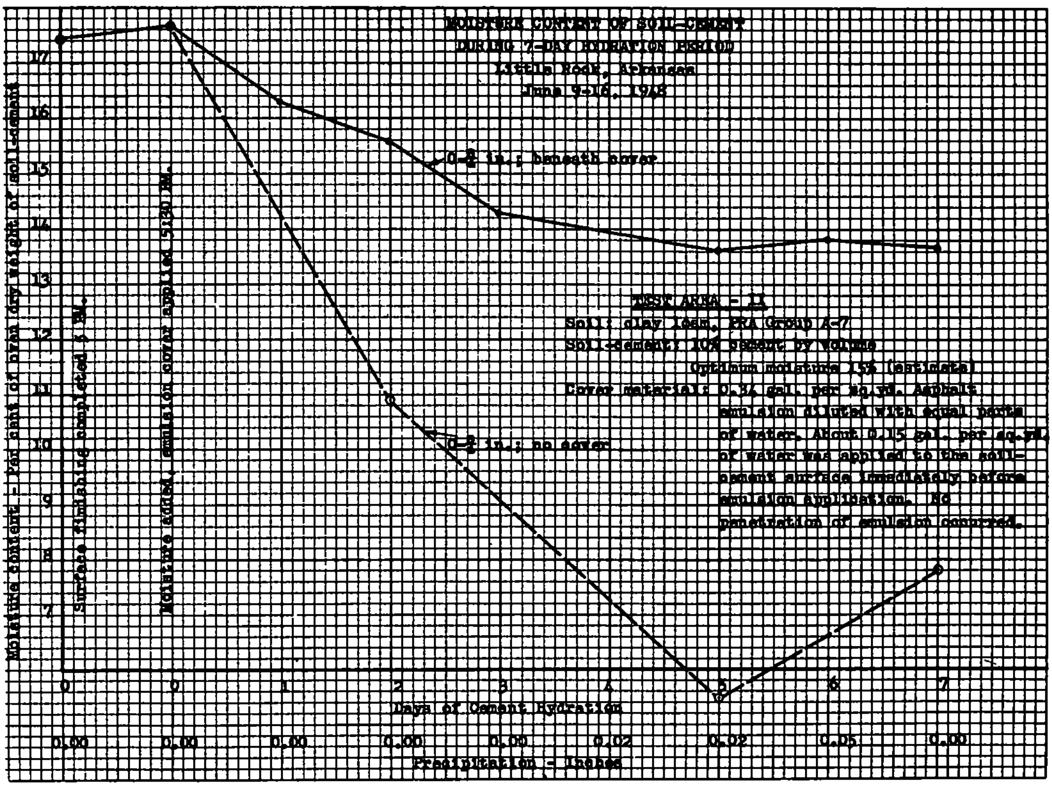

Figure 13.

SUMMARY OF TESTS ON SOIL AND SOIL-CEMENT MIXTURES

PORTLAND CEMENT ASSOCIATION
SOIL-CEMENT BUREAU

Soil-Cement Laboratory, Form Sheet No 13
Date tests completed 5-9-47
State Arkansas
County Pulaski

SOIL NUMBER State or Local	Gravel, Retained on No 4 sieve	Gravel, No 4 to No 10 (2.0 mm)	Sand, 2.0 to 0.25 mm	Sand, 0.25 to 0.05 mm	Silt, 0.05 to 0.005 mm	Clay, 0.005 to 0.000 mm	Colloids,* 0.001 to 0.000 mm	TEXTURAL CLASS	L L	P I	S L	ORGANIC CONTENT, ppm (soil mortar)	Sp gr of soil mortar	USPRA soil group (soil mortar)
	8	0	23	14	26	29	--	Clay Loam	30	11	15		2.66	A-7
Soil mortar only			25	15	28	32		Clay						

GRADATION - per cent of total; PHYSICAL TEST CONSTANTS (L L, P I, S L)

*Also included in clay

Plus No 4 material Absorption by dry weight 8.9 % Bulk specific gravity 2.20

TESTS ON MINUS NO 4 MATERIAL

Opt moisture content, %			Opt density, lb/cu ft			Compressive strengths** Two		Seven		Twenty-eight	
0	8.8	13.2	0	8.8	13.2	6	10	6	10	6	10
	16.0	15.4		109.7	110.3	100	231	157	260	214	381

MOISTURE-DENSITY RELATIONS: Cement content by volume - %. COMPRESSIVE STRENGTHS - lb/sq in**: Age when tested - days; Cement content by volume - %.

Type of moisture-density curve
Regular-[illegible]

**Cylindrical specimens 2" dia. and 2" ht. submerged in water 1 hr before testing.

RESULTS OF TESTS

- Recommended cement content, Φ: Total 10.0 %; Minus #4 10.6 %
- Laboratory optimum moisture content,†: Total 15.3 %; Minus #4 15.8 %
- Laboratory density,† lb/cu ft., dry wt: Total 112; Minus #4 110
- Cement content in total governs.

ΦDesignate which cement content controls.
† Tests made in field toward end of damp mix govern field control.

DATA FROM SPECIMENS TESTED TWELVE CYCLES IN A S T M WET-DRY AND FREEZE-THAW TESTS

	Cement content % by volume, Theoretical	Cement content, Obtained Av	Density lb./cu ft. oven-dry wt., Theoretical	Density, Obtained, Av	Moisture content % by oven-dry wt., Theoretical	Moisture content, Obtained, Av	Solids % by volume, Av	Total soil loss % of original dry weight, Wet Dry	Total soil loss, Freeze-Thaw	Max. volume change % of molded volume, Wet-Dry Plus	Wet-Dry Minus	Freeze-Thaw Plus	Freeze-Thaw Minus	Moisture content for saturation % by oven-dry wt., Wet-Dry	Freeze-Thaw	Max moisture‡ percentage above or below saturation, Wet Dry	Freeze-Thaw
Total §	8.0	8.0	111.4	112.9	15.5	14.8	68	Not									
Minus #4	8.5	8.6	109.7	111.2	16.0	15.3	66	Molded	4	No.	1 Specimens	Not		Molded			
Total §	9.9	9.7	111.6	109.6	15.3	15.3	66										
Minus #4	10.5	10.3	109.9	107.8	15.8	15.8	64	3	3								
Total §	11.8	11.5	111.8	110.3	15.0	14.8	66	Not									
Minus #4	12.5	12.3	110.2	108.4	15.5	15.3	64	Molded	3								
Total §																	
Minus #4																	

‡Maximum moisture is expressed in percentage points above (+) or below (−) moisture content for saturation
§Note quantity of material Retained on No. 4 sieve shown under 'GRADATION

Type of soil-cement losses
[illegible] [illegible] (Steady)

Remarks

U S D A, B of P I, Soil series
Soil horizon "B"
Color of moist soil Light reddish brown
Sampling location roadway cut on north side of 13th street, 600' west of McAlmont at 8-48". Represents the university hospital paving project.

PCA Soil No. 4753
Specimen No
Field Project No 1341
Project Little Rock Streets

Table XVII.

there is a tendency for this surplus surface moisture to become distributed full depth. In this instance, the surface material probably lost 1 or more percentage points of moisture to underlying material, see Figures 12 and 13.

Therefore, the decreases of 3 and 4 percentage points of moisture may be accounted for by allowing 1½ percentage points for cement hydration, 1 percentage point of moisture for migration and the remainder of each decrease, (½ and 1½ percentage points respectively) may be assumed as evaporation loss through the asphalt emulsion.

Similarly, when the optimum moisture contents for these soils are compared with the finally obtained and corrected moisture contents, the differences are quite small.

It is, therefore, concluded that the bituminous emulsion did serve adequately as a moisture barrier by retaining practically all of the moisture in the soil-cement during the 7-day hydration period.

OBSERVATIONS ON ASPHALT EMULSION COVER

Daily inspections showed no penetration of asphalt into the soil-cement. It was particularly noted that although there were occasional small "dry" areas and small "rock-pull" areas in the surface of the base filled with loose uncompacted soil-cement, there was no penetration by the asphalt.

The emulsion began to "break" within 15 minutes of application. At the end of 24 hours it remained tacky, but at the end of 48 hours it could be walked upon with but very little pickup. Although no traffic was permitted on the new work, it is judged there would have been little or no pickup by automobiles or light trucks after 48 hours.

From the first day of application the emulsion adhered firmly to the soil-cement. It became more firmly attached each day and on the last day of test it was removed only after considerable work by scraping with a knife.

The soil-cement directly beneath the asphalt had hardened noticeably the day following construction and the hardness increased daily. It was particularly noted that the soil-cement immediately beneath the bituminous cover was as hard as the soil-cement at greater depths. This observation reinforces the conclusion that the asphalt emulsion cover retained sufficient moisture for cement hydration.

Where the soil-cement was not covered with the asphalt emulsion the surface for a depth of about 1½ in. did not harden satisfactorily. At the end of 7-days this depth of material could easily be penetrated and removed with a knife. The soil-cement below the 1½ in. depth was considerably harder than the surface material but it was not as hard as the soil-cement in the areas covered with the emulsion.

CONCLUSIONS

These data show that the asphalt emulsion cover material "Bitumuls HCM", as used on this project, did efficiently retain the moisture in the soil-cement for 7-days. Further that it adhered satisfactorily to the soil-cement, it cured out and lost its tackiness within a reasonable time and did not penetrate into the soil-cement. Finally the use of the asphalt emulsion had no deleterious effect on the quality of the soil-cement.

These tests were conducted by the City Engineering Department of the City of Little Rock with J. A. Leadabrand, Soil-Cement Bureau, Chicago, representing the Portland Cement Association.

GENERAL CONCLUSIONS

The following general conclusions may be drawn from these four field experiments on the efficacy of bituminous cover material in retaining moisture in soil-cement for the first seven days following construction. They apply *only* to the MC-2, negative Oliensis spot MC-3 and RC-1 cutback asphalts and asphalt emulsion used in the experiments reported unless otherwise noted.

1. The asphaltic cover materials, as used on the experimental test sections, were very efficient in maintaining moisture in the soil-cement for the first seven days following construction.

2. A cover material to prevent moisture evaporation losses from the surface of the soil-cement is essential during the first days following construction. Failure to prevent these surface moisture losses produced an inferior layer of soil-cement in the surface.

3. Penetration of the soil-cement by the bituminous cover material placed immediately after completion of surface finishing resulted in a marked lowering of the hardness and quality of soil-cement so penetrated. See item 6 below.

4. Penetration of the soil-cement by the bituminous cover material materially reduced the efficiency with which the bituminous material adhered to the soil-cement.

5. The asphaltic cover material should be applied the same day as construction and as soon after surface finishing is completed as construction conditions will permit.

6. A tightly knit and even surface shall be produced in final finishing and the surface moisture in the soil-cement shall be such as will prevent penetration of the bituminous material. This surface moisture condition will vary from the field optimum moisture of the completed soil-cement to a water saturated surface condition for the MC-2. This surface saturation is obtained by applying water from a pressure distributor in sufficient quantity to produce a water saturated surface at the time the bituminous material is applied. The surface moisture condition will vary from field optimum moisture for the heavier and faster curing

bituminous types such as RC-3, placed during the hot summer months, to a water saturated surface condition for the lighter and slower curing bituminous types such as SC-1, placed during the cool spring and fall months.

7. The bituminous cover materials used on these experimental test sections adhered firmly to the soil-cement when applied to a soil-cement surface having tightly knit surface and a surface moisture condition which prevented penetration of the bituminous cover materials.

8. It is indicated that for soils generally used on soil-cement construction, that the surface texture will be such, after required and proper knitting and finishing of the surface, that 0.15 to 0.20 gal. per sq. yd. of bituminous cover material will produce a suitable bituminous film. The quantity used should be sufficient to give complete coverage with a trace of run-off in places. Coarse, opened textured soils, such as an A-3, and irregular surfaces containing numerous pockets and equipment tracks will require more bituminous material to compensate for the quantities retained in these pockets and equipment tracks and the quantities required to fill the open, surface voids.

9. When traffic must use the soil-cement before the bituminous material has volatilized to the point where it is no longer sticky and tacky, the bituminous cover material must be covered with a sufficient coating of stone chips or sand to prevent pickup from traffic. (Experiences with various types of bituminous mats and surface treatments indicate that about 10 lb. per sq. yd. of stone chips or sand will give sufficient aggregate cover to prevent pickup.)

10. Properly protected bituminous cover materials, after suitable curing, may also serve as the prime and tack coat material for the final bituminous surface.

11. Data are needed to define desirable surface moisture conditions for the heavier grades of bituminous materials, commonly identified as tack coat materials, of the various curing types. Likewise, other asphaltic emulsions should be defined.

12. Similar field test and research are needed for the various grades of tar products ranging from light prime materials to heavy tack materials.

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