evidence, however, that when the fine-grained soil mixtures were exposed to 100 percent humidity for lengthy periods, they tended to take up moisture in detrimental quantities.

3. The dynamic test employed in this study, the measurement of pulse velocities through the test specimens, was quite satisfactory. Results were reproducible and there appeared to be little operator error. It is believed that changes in velocity are highly indicative of changes in the quality of the specimens tested and that the method merits further consideration.

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CURING OF SOIL-CEMENT BASES

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SYNOPSIS

THIS PAPER describes field experiments conducted on a secondary road in Appomattox County, Virginia, to study the effect of various methods of curing soil-cement bases. The project extended over two general areas, the soils of which are derived from a granite gneiss (Appling soil) and from Wissahickon schist (Cecil soil). Experimental sections were placed in each of these general soil areas—two groups of six panels in each soil area.

The purpose of the project was to: (1) determine the effect of preparing surfaces for receiving curing materials both with and without a prior application of water; (2) determine the effect of different soils on moisture retention in soil-cement mixes; (3) determine the efficiency of bituminous and other materials for retaining moisture in a soil-cement base during the curing period; and (4) revise the specification to be used for moisture-retention material, if the results of the investigation so indicated.

Types of curing materials studied included moist earth, waterproof paper, calcium chloride, RC-2 asphalt, RTCB-6 tar, and AE-2 asphalt emulsion. One panel, used as a control panel, was left open with no cover. Moisture samples were obtained the day the panels were covered and each day thereafter for seven days. Six samples were taken in each panel, three from 0 to $\frac{3}{4}$ in. and three from $\frac{3}{4}$ to $1\frac{1}{2}$ in. Weather conditions during both construction and subsequent curing were observed and recorded.

Results of the investigation indicated that, if applied and maintained properly, five of the six cover materials used in this experiment are satisfactory curing mediums for soil-cement bases. It was also concluded that the bituminous materials can also serve as a prime coat if the subsequent surface treatment is placed at or near the end of the curing period.

● THE FIRST experimental soil-cement base stabilization, a project 528 ft. in length, was constructed in South Carolina in 1933 (*1*). Since then the number of square yards of soil-cement roads and streets completed equal more than 4,000 miles of 20-ft. roadways (*2*). No attempt was made to cure the initial South Carolina project, and in 1939, in a paper presented before the nineteenth annual meeting of the Highway Research Board, W. H. Mills, Jr., (then testing engineer of the South Carolina Highway Department) stated; "No curing has been specified on any projects constructed to date. So far it has not been demonstrated that this expense is justified. A tar prime is usually applied to the base within 48 hr. after construction and in some cases it has been applied the day of construction as soon as the surface dries"(*3*).

In 1936 and 1937 experimental soil-cement projects were constructed in several states, and among these Iowa, Missouri, and Wisconsin experimented with various methods of curing (*4*). The different projects were cured with tar, straw, Sisalkraft paper, Curcrete, and 1 in. of damp sand. No effort was made to determine the relative merits of the separate methods of curing. As early as 1937, however, the Portland Cement Association recommended that a protective cover of soil or straw be placed on the surface as soon as the section is completed and kept damp for the 7-day curing period.

In 1948 field experiments were conducted in Illinois, Kansas, Nebraska, and Arkansas, under the sponsorship of the Highway Research Board Committee on Soil-Cement Roads, to evaluate the efficiency of bituminous-cover materials in retaining moisture in soil-cement for seven days following construction (*5*). The cover materials used in these tests included RC-1, MC-2, MC-3, and an asphaltic emulsion. It was found that these materials effectively retained moisture in the soil-cement, resulting in satisfactory surfaces when the soil-cement was wetted immediately before the bituminous application and producing inferior surfaces when permitted to penetrate the soil-cement.

Since 1938, when the first experimental soil-cement project was constructed in this state, the Virginia Department of Highways has specified moist soil, hay or straw as the curing medium. More than 120 miles of soil-cement roads have been built and most of the projects were cured with moist earth. The few exceptions made have allowed the contractor to cure by keeping the surface damp with water or, in several cases since 1947, cure with bituminous materials. A suggestion was made by one of the department's engineers that an experimental project be set up to study the effects of various agents on the curing of soil-cement bases. Subsequently, in 1950, a working plan was written and approved and a project selected in Appomattox County. All of this project, except the experiments, was cured with asphalt emulsion (AE-2) (*6*).

Two groups of test panels at each of two locations were planned to: (1) determine the effect of preparing surfaces for receiving curing materials both with and without a prior application of water; (2) determine the effect of different soils on moisture retention in soil-cement mixes; (3) determine the efficiency of bituminous and other materials for retaining moisture in a soil-cement base during the curing period; and (4) revise the specification to be used for moisture-retention material if the results of the investigation so indicated.

FIELD EXPERIMENTS

The experiments were conducted in a project, 3.7 mi. in length, on Route 630 in Appomattox County which was stabilized with cement in late June and early July, 1951. The project extended over two general soil areas, the soils of which are derived from a granite gneiss (Appling soil) and from the Wissahickon schist (Cecil soil). Experimental sections were placed in each of the general soil areas—two groups of six panels in each soil area (Fig. 1). Groups A and B were located in an area of Appling soil about 2 mi. from Groups C and D, which were located in Cecil soil.

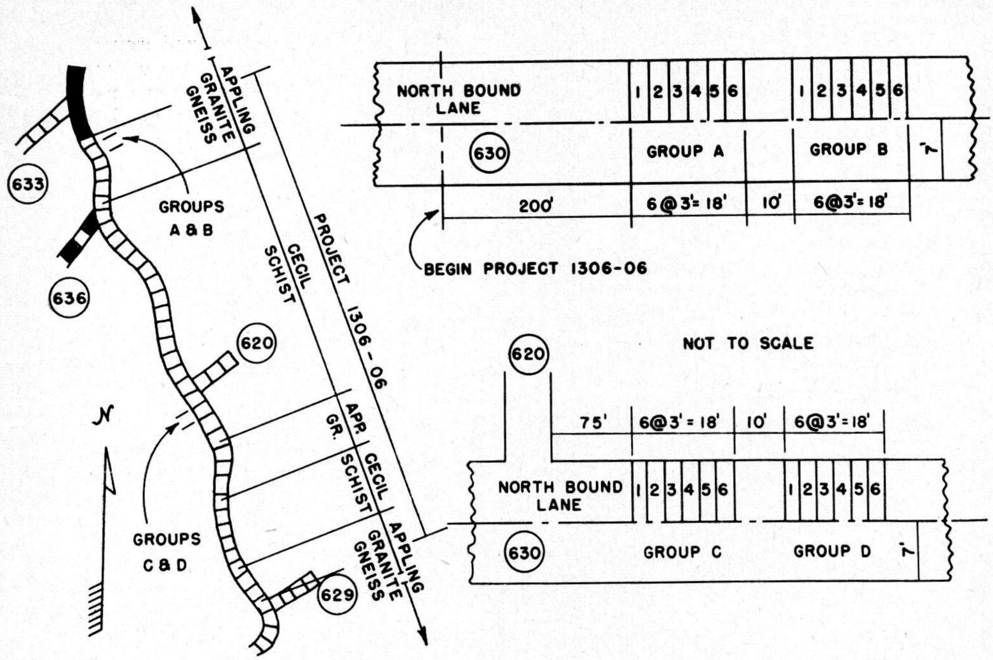


Figure 1. Location of experimental soil-cement curing sections Project 1306–06, Route 630, Appomattox County.

Figure 2. View of soil-cement base after final rolling and clipping and just before application of curing material.

Groups C and D

Processing, on that portion of the road in which Groups C and D were located, was not completed until late afternoon of June 26. The next morning, after the surface had been clipped with a motor grader and given an application of water (Fig. 2), building paper was laid over the experimental sections as illustrated in Figure 3. This was done to allow the distributor to apply the AE-2 without covering the test panels. The contractor did not place the asphalt emulsion until about four o'clock in the afternoon. In the meantime a rainstorm had wet the

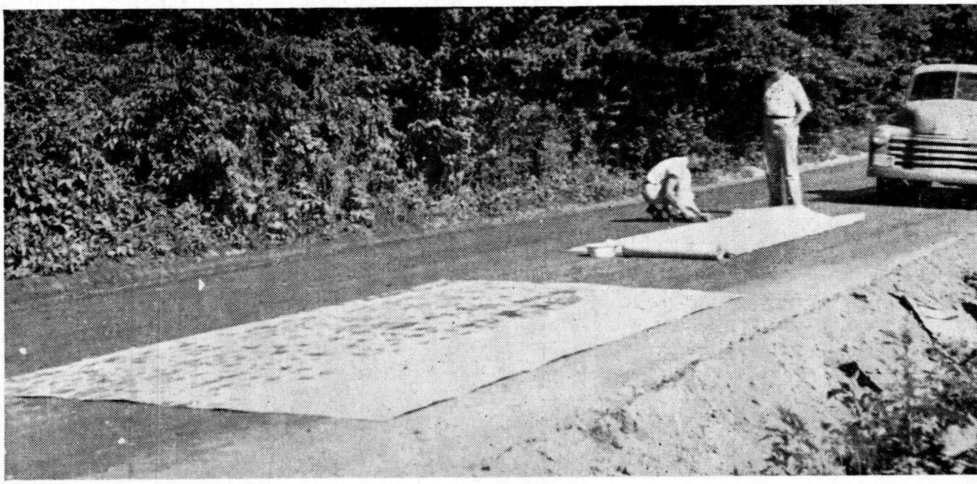


Figure 3. Laying of building paper over experimental sections prevented application of asphalt emulsion over test panels.

Figure 4. One panel in each group was covered with waterproof paper. The paper was fastened to the road with roofing nails.

surface of the road and water had run under the building paper, adding moisture to the already damp surface. After the AE-2 had been placed, the building paper was removed, the surface of Group C watered, and the experimental cover materials applied.

Each group was divided into six panels (3 by 7 ft. each). The first panel (the control section) was left uncovered. The second was covered with 2 in. of loose soil from the shoulder, of the road. Being already damp the loose soil was not given another application of water on the first day. Waterproof paper was placed over the third panel and fastened

to the road with roofing nails (Fig. 4). On the fourth panel was spread flake calcium chloride at the rate of 1½ lb. per sq. yd. An RC-2 asphalt was applied, at the rate of 0.2 gal. per sq. yd., to the fifth panel by pouring it on the surface and spreading it evenly by means of paint brushes. This operation is shown in Figure 5. An RTCB-6 tar was placed on the sixth panel at the same rate and by the same method used on Panel 5.

Figure 5. An RTCB-6 tar was spread evenly over one test panel with paint brushes. Another panel was covered with an RC-2 asphalt.

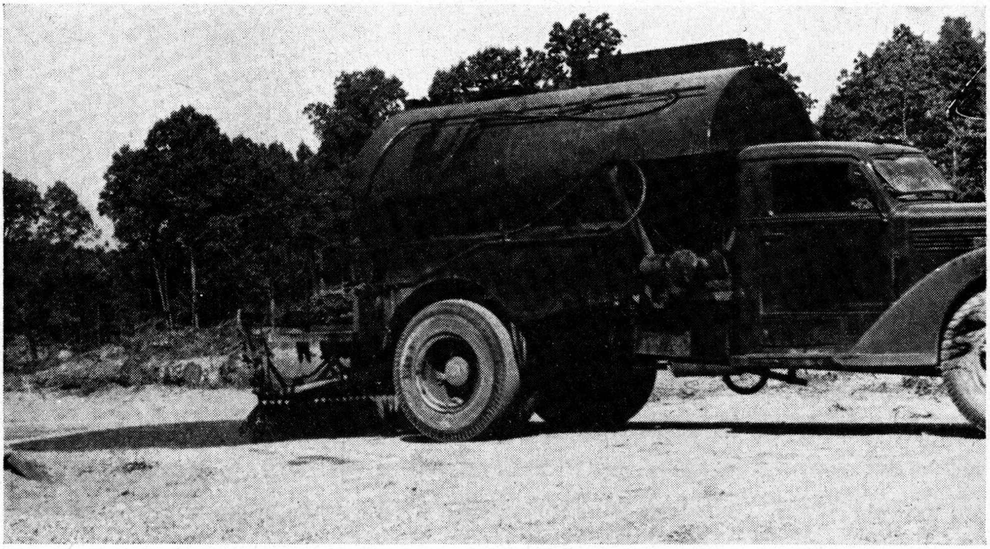


Figure 6. The distributor used to apply the AE-2 asphalt emulsion.

Figure 7. Experimental panels as they appeared after curing materials had been applied.

Figure 8. Three moisture samples, at each of two levels, were removed from each panel every day during the curing period.

The 10-ft. panel between the two groups had been previously covered with AE-2 asphalt emulsion with the distributor at the rate of 0.2 gal. per sq. yd., as is illustrated in Figure 6. A view of Groups C and D after the cover materials had been applied is shown in Figure 7.

As soon as the two groups were covered

six moisture samples (three from 0 to $\frac{3}{4}$ in. and three from $\frac{3}{4}$ to $1\frac{1}{2}$ in.) were taken from each panel (Fig. 8).

After the 78 samples were secured they were taken to the field laboratory, weighed and placed in electric ovens to dry. The samples, left in the ovens overnight, were then removed, weighed and the moisture contents computed.

The above procedure for sampling was repeated every day during the 7-day curing period. On June 28, the second day of curing, a field density test (Fig. 9) was performed in the 10-ft. panel.

Figure 9. A field density test was performed during the 7-day curing period.

Groups A and B

That portion of the road in which Groups A and B were located was processed on July 5. The processing of this section was not completed until about 8 P.M. so moisture samples could not be taken on that day. Building paper was laid over the test sections at 8 A.M. At 3 P.M. when the AE-2 still had not been applied, the paper was removed and the test materials placed.

Good control was obtained in applying the cover materials on Groups A and B since there was no rain that day. The panels in Group A were watered immediately before the application of curing materials. In contrast, those in Group B were allowed to dry somewhat before application. The AE-2 was finally applied to the 10-ft. panel between Groups A and B at 4:30 P.M. As planned, it had not been watered since 8 A.M.

The same sequence of panels, curing materials and application methods were used for Groups A and B as for C and D. Moisture samples were obtained the day that the panels were covered and each day thereafter for seven days. On July 9, four days after construction, a field density test was performed in the 10-ft. panel.

The total contract cost for the 3.7-mi. project was $39,855.65, including $0.14 per gal. (applied) for the AE-2 and $4.00 per ton for the sand (applied). Thus, curing cost was about $0.03 per sq. yd. Since the contract price for both AE-2 and OH-1 (which was used for subsequent surface treatment) was the same, it is reasonable to assume that the cost of the RC-2 and the RTCB-6, which were supplied from highway department stocks, would also be $0.14 per gal. applied on the road. At present prices, waterproof paper costs around $0.15 per sq. yd. and this

price does not include laying the paper. Of course, the paper can be salvaged and reused, thus reducing the cost per job. At an application rate of 1½ lb. per sq. yd., calcium chloride costs $0.02 per sq. yd. Adding to this the cost of application the total cost should be about $0.03 per sq. yd. The average cost for curing with moist soil is $0.02 per sq. yd. which includes placing the soil, keeping it damp, and removing it after the curing period is over.

WEATHER RECORDS

Air temperature and relative humidity readings were taken each day during the

TABLE 1

WEATHER CONDITIONS, ROUTE 630, APPOMATTOX COUNTY

June 27–July 12, 1951

Date	Air Temperature	Relative Humidity	Rainfall (Approx.)	Remarks
	F°	%	in.	
6/27/51	86	66	0.25	Cloudy in P.M.
6/28/51	86	66	0	Clear
6/29/51	85	80	0	Clear
6/30/51	83	76	0.05	Partly cloudy
7/ 1/51	83	76	0.05	Partly cloudy
7/ 2/51	78	81	0	Cloudy
7/ 3/51	80	68	0	Partly cloudy
7/ 4/51	—	--	0	Clear
7/ 5/51	—	--	0	Clear
7/ 6/51	81	72	0	Clear
7/ 7/51	89	51	0	Clear
7/ 8/51	90	52	0	Clear
7/ 9/51	91	62	0	Partly cloudy
7/10/51	96	44	0	Clear
7/11/51	95	52	0	Clear
7/12/51	93	41	0	Clear

Note. Temperature and humidity readings taken near noon each day.

7-day curing period. These readings were made with a sling psychrometer between 10:30 A.M. and noon. In addition, the amount of rainfall was estimated for each day. Table 1 shows these data along with cloud conditions and Figure 10 presents them graphically.

The period from June 27 to July 12 was hot and dry. Two rainstorms on June 27 deposited an estimated 0.25 in. of water and light showers on June 30 and July 1 totaled only an estimated 0.10 in. There was no other precipitation during the work on the experimental sections.

The humidity readings were relative and are reported as such. Humidities were higher during the first week than during the second week.

RESULTS

Since the experimental sections were located in two soil areas, results of tests from each area will be discussed separately.

Appling Soil

The well-drained Appling soil is derived from granite, granite gneiss, and schist and is closely associated with the Cecil soil. It has a deeply weathered profile consisting mainly of a brittle clay B-horizon. Quartz is found on hilly to rolling areas and exposures of granite are noticeable. Figure A-1, in the appendix of this report, gives the location, description and a typical profile of the Appling soil.

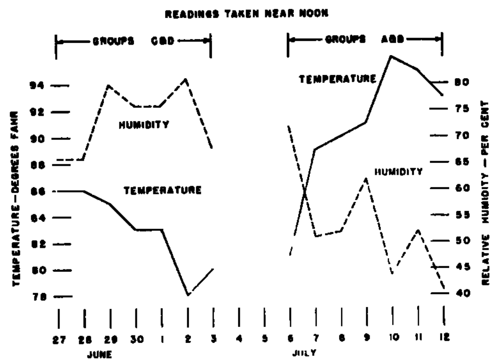


Figure 10. Temperature and relative humidity June 27 to July 12, 1951, Route 630, Appomattox County.

Groups A and B of the experimental sections were located in an area of Appling soil. The surface of Group A was watered just before the cover materials were applied while the surface of Group B was not. Average moisture contents of samples obtained from Groups A and B are tabulated in Table 2 and, for the top ¾ in., are shown graphically in Figures 11 and 12. In addition, Table 3 gives the change in moisture content between the beginning and the end of the curing period.

Group A. All panels in Group A lost moisture in the top ¾ in. during the 7-day period. The control panel (no cover) had the largest drop (10.4 percent) in moisture content with the panel on which calcium chloride was used as the curing medium having the next largest drop (5.4 percent). The waterproof-paper panel actually had more moisture loss than the calcium-chloride panel but this was due

TABLE 2
AVERAGE MOISTURE CONTENT IN GROUP A AND B BY DAYS

	Group A						Group B							
Panel No	1	2	3	4	5	6	10-ft. panel	1	2	3	4	5	6
Cover	None	Moist Soil	Water-proof Paper	Cal-cium Chlo-ride	RC-2 Asphalt	Tar RTCB-6	AE-2	None	Moist Soil	Water-proof Paper	Cal-cium Chlo-ride	RC-2 Asphalt	Tar RTCB-6
	%	%	%	%	%	%	%	%	%	%	%	%	%
						0–¼ in.							
7/ 6/51	15.8	16.2	15.5	12.7	15.2	13.5	10.3	12.1	13.0	13.3	12.1	12.8	12.3
7/ 7/51	12.5	15.7	16.2	12.3	13.7	13.6	10.2	10.1	13.7	14.6	10.9	13.2	13.1
7/ 8/51	8.7	13.4	15.4	9.4	11.7	11.8	9.9	7.1	12.0	12.2	9.0	11.4	11.7
7/ 9/51	7.0	12.7	12.8	8.9	11.2	12.8	8.5	6.2	12.3	13.2	8.7	11.8	11.6
7/10/51	6.3	12.7	12.5	7.1	10.8	11.8	7.9	4.8	11.8	11.4	7.5	10.4	10.5
7/11/51	5.7	13.0	10.7	7.6	11.6	12.1	8.5	4.6	11.7	11.0	7.4	11.5	11.2
7/12/51	5.4	12.8	8.2	7.3	11.3	11.4	8.8	4.7	11.1	10.0	6.9	10.9	10.6
						¼–1½ in.							
7/ 6/51	13.7	13.3	14.0	12.6	13.8	12.7	11.0	12.0	12.7	12.5	12.7	12.4	12.1
7/ 7/51	12.7	15.2	14.8	13.0	13.2	13.5	11.1	11.4	13.3	13.6	12.3	12.8	12.5
7/ 8/51	10.4	12.3	13.4	10.2	12.3	11.8	10.4	9.5	11.7	11.4	9.9	11.3	11.7
7/ 9/51	9.5	12.4	11.5	10.4	12.1	12.8	9.6	8.9	11.9	12.4	10.2	11.4	11.4
7/10/51	8.7	12.1	11.9	8.8	10.8	11.1	9.8	7.5	11.0	11.1	8.6	11.1	10.7
7/11/51	8.2	12.4	11.3	9.1	11.1	11.3	9.6	7.5	11.1	10.5	8.7	11.3	10.1
7/12/51	9.2	12.3	10.0	8.3	11.0	11.7	9.1	7.3	11.2	10.3	8.4	10.3	10.8

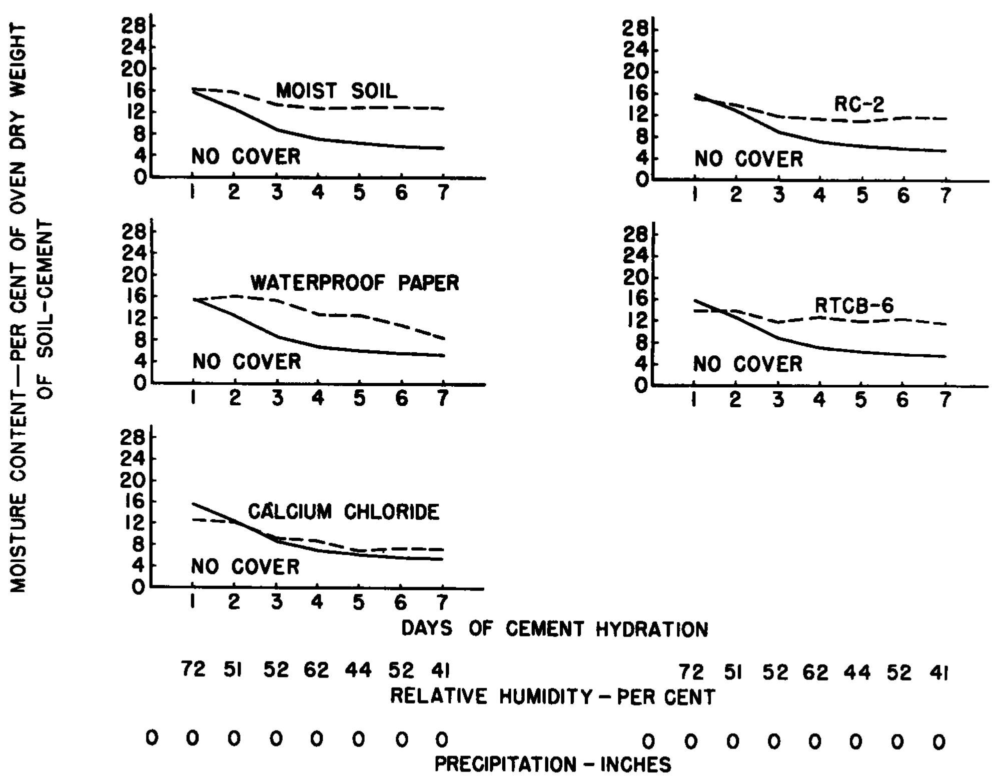


Figure 11. Moisture content of soil-cement during 7-day curing period, Route 630, Appomattox County, Virginia, July 6 to July 12, 1951. Group A, soil-Appling, soil-cement; 10 percent by volume; optimum moisture, 13.3 percent; water applied to surface immediately prior to placement of cover material.

to the paper being destroyed on the fifth day of curing by a power broom. Up to that point the drop in moisture had been 3.0 percentage points where the final loss was 7.3 percentage points. On all the other panels the drop in moisture content ranged between 2.1 and 3.9 percentage points.

In the ¾- to 1½-in. level all panels in Group A also dropped in moisture content. Again, the control panel lost the most moisture that the surface of Group B was not given an application of water immediately prior to placing the cover materials. The control panel dropped 7.4 percentage points in moisture content and the calcium chloride covered panel lost 5.2 percent. The panel covered with waterproof paper had lost 1.9 percent moisture by the fifth day of curing when the paper was partially destroyed by a power broom. The final loss was 3.3

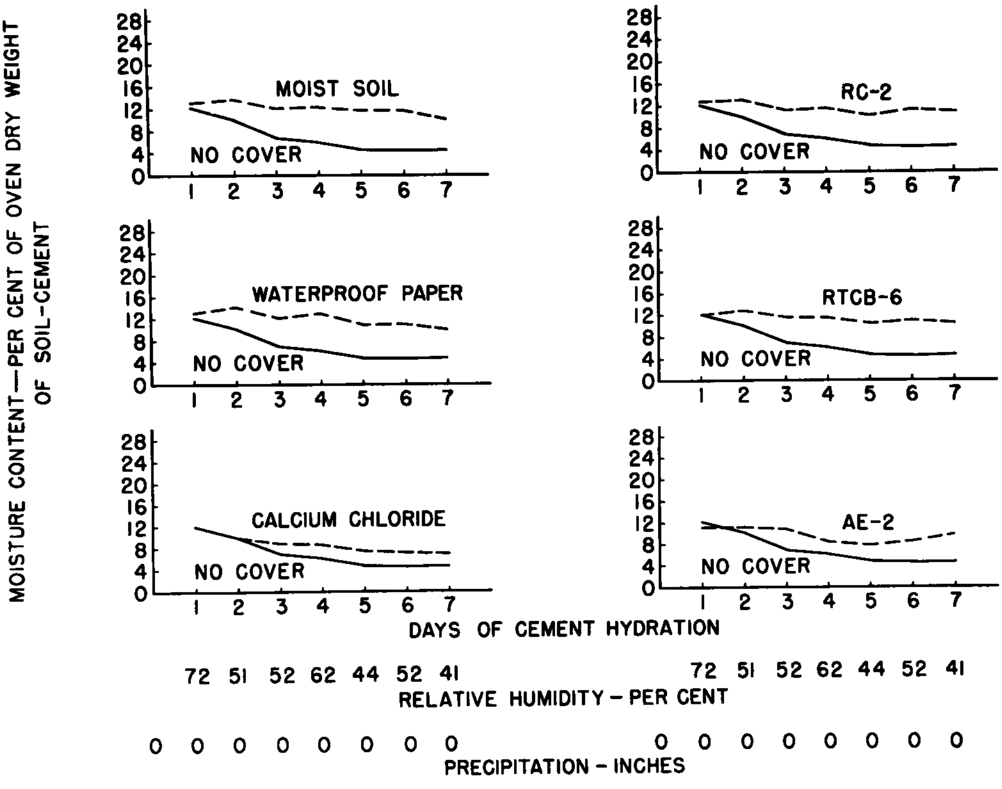


Figure 12. Moisture content of soil-cement during 7-day curing period, Route 630, Appomattox County, Virginia, July 6 to July 12, 1951. Group B, soil-Appling, soil-cement; 10 percent by volume; optimum moisture, 13.3 percent; no water applied to surface immediately prior to placement of cover material.

(4.5 percent) and the calcium chloride panel had the next largest drop (4.3 percent). The panel covered with waterproof paper lost 2.1 percent moisture in the first five days but had dropped 4.0 percent on the seventh day. The earth and tar covered panels dropped 1.0 percentage points in moisture content while the asphalt (RC-2) covered panel lost 2.8 percent.

Group B. Moisture loss in all panels of Group B in the top ¾ in. was less than in Group A. This is probably due to the fact percent. The remaining panels, including the 10-ft. panel covered with AE-2, ranged from 1.5 to 1.9 percentage points in moisture loss.

All panels in the ¾- to 1½-in. level dropped in moisture content. The control panel and the panel covered with calcium chloride lost 4.7 and 4.3 percentage points respectively. Moisture loss in the other panels ranged from 1.3 to 2.2 percentage points.

As can be seen in Figures 11 and 12 the control panels in both Groups A and B lost moisture steadily during the curing period.

The moisture contents in all other panels fluctuated slightly but in all cases, except for calcium-chloride cover, remained near the initial moisture contents.

moisture and suffers a loss of supporting strength. Figure A-2 (see Appendix) gives the location, description and a typical profile of the Cecil soil.

TABLE 3
CHANGE IN MOISTURE CONTENT DURING SEVEN-DAY HYDRATION PERIOD

		Panel No.						10-ft. panel
		1	2	3	4	5	6	
Group A	0-¾	−10.4	−3.4	−7.3[a]	−5.4	−3.9	−2.1	
	¾-1½	−4.5	−1.0	−4.0	−4.3	−2.8	−1.0	
Group B	0-¾	−7.4	−1.9	−3.3[b]	−5.2	−1.9	−1.7	−1.5
	¾-1½	−4.7	−1.5	−2.2	−4.3	−2.1	−1.3	−1.9
Group C	0-¾	−7.5	+3.1	+4.5	−4.2	+1.1	+0.1	+0.1
	¾-1½	−2.5	+0.6	+4.0	−2.0	−0.3	−0.5	−0.3
Group D	0-¾	−8.4	−1.4	−0.8	−3.9	−1.1	−0.1	
	¾-1½	−4.6	+0.8	−0.3	−2.7	−2.5	+0.9	

[a] Waterproof paper was destroyed on fifth day of curing.
[b] Waterproof paper was partially destroyed on fifth day of curing.

TABLE 4
AVERAGE MOISTURE CONTENT IN GROUP C AND D BY DAYS

	Group C							Group D					
Panel No.	1	2	3	4	5	6	10-ft. panel	1	2	3	4	5	6
Cover	None	Moist Soil	Water-proof Paper	Cal-cium Chlo-ride	RC-2 Asphalt	Tar RTCB-6	AE-2	None	Moist Soil	Water-proof Paper	Cal-cium Chlo-ride	RC-2 Asphalt	Tar RTCB-6
	%	%	%	%	%	%	%	%	%	%	%	%	%
0-¾ in.													
6/27/51	23.95	22.3	21.7	21.8	23.0	24.6	22.8	24.3	24.0	24.6	22.7	24.4	24.5
6/28/51	23.6	25.5	27.3	22.7	25.3	26.1	23.3	19.6	23.4	23.4	21.4	22.2	22.9
6/29/51	17.9	23.5	22.9	19.5	23.4	23.7	22.5	17.3	22.9	23.9	19.5	23.0	25.0
6/30/51	22.9	24.2	24.1	22.1	23.6	23.3	22.3	21.2	23.4	23.9	20.9	22.7	22.5
7/ 1/51	20.3	24.0	23.3	19.8	21.8	23.0	21.7	17.9	21.2	23.3	17.4	21.7	22.6
7/ 2/51	14.4	23.4	22.9	17.3	21.9	22.0	22.3	13.8	21.8	24.5	17.3	23.5	21.8
7/ 3/51	16.5	25.4	26.2	17.6	24.1	24.7	22.9	15.9	22.6	23.8	18.8	23.3	24.4
¾-1½ in.													
6/27/51	21.3	22.7	19.9	22.1	23.2	23.0	22.4	24.2	22.1	22.6	22.5	24.4	22.2
6/28/51	22.7	22.8	23.4	22.5	23.5	24.0	22.6	20.4	22.6	22.4	21.4	22.0	22.3
6/29/51	19.6	21.7	21.5	20.8	23.3	23.1	21.6	20.0	21.9	21.3	20.0	22.7	24.5
6/30/51	21.7	23.1	23.5	21.1	22.5	22.9	21.6	20.5	22.1	22.5	20.6	21.8	22.2
7/ 1/51	20.9	20.2	21.7	20.3	20.7	22.4	21.3	19.0	19.7	20.7	19.4	22.6	21.0
7/ 2/51	18.8	21.8	21.8	19.2	20.6	21.0	21.9	17.3	20.5	22.1	18.8	21.1	22.1
7/ 3/51	18.8	23.3	23.9	20.1	22.9	22.5	22.1	19.6	22.9	22.3	19.8	21.9	23.1

Cecil Soil

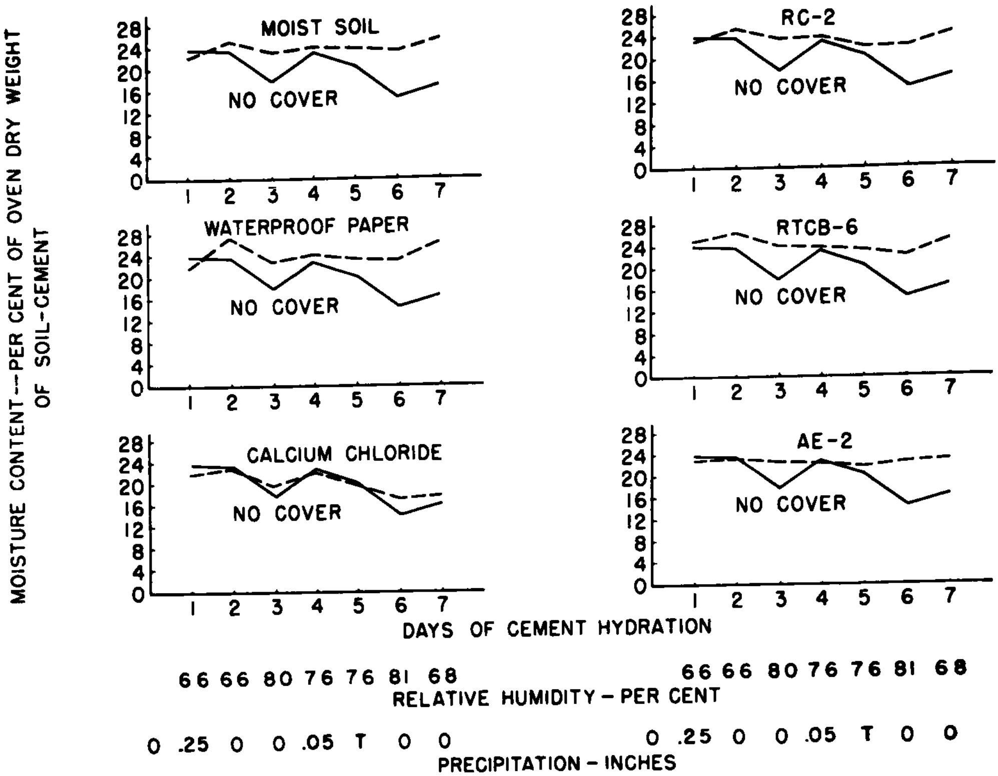
Derived from schist, some granites, syenites, and gneiss, the Cecil is the most common of all soils in the Piedmont. Like the Appling soil, it has a deeply weathered profile and is found in rolling to hilly areas which provide good surface drainage. In a natural state, internal drainage of Cecil soils is excellent (the subsoil has a well developed cubical structure), but once disturbed it retains

Located in an area of Cecil soil were Groups C and D of the experimental sections. The surface of both groups was wetted by rain shortly before the cover materials were placed but Group C and the 10-ft. panel between the groups were given another application of water just before the various curing mediums were laid. Average moisture contents of samples taken from Groups C and D are given in Table 4 and shown

graphically for the top ¾ in. in Figures 13 and 14. The change in moisture content, for each panel, from beginning to end of the hydration period is shown in Table 3.

Group C. In the top ¾ in. of the panels in Group C, the control panel and the one covered with calcium chloride lost moisture during the curing period. All other panels gained in moisture content. The control paper covered panels gained 0.6 and 4.0 percent and the asphalt, tar, and asphalt emulsion covered panels lost 0.3, 0.5 and 0.3 percentage points of moisture.

Group D. The top ¾ in. of all panels in Group D dropped in moisture content during the 7-day curing period. The loss for each panel was as follows: no cover, 8.4 percent earth cover, 1.4 percent; waterproof pape



igure 13. Moisture content of soil-cement during 7-day curing period, Route 630, Appomattox County, Virginia, June 27 to uly 3, 1951. Group C, soil-Cecil, soil-cement; 10 percent volume; optimum moisture, 22.5 percent (estimate); water applied to surface immediately prior to placement of cover material.

panel (no cover) dropped 7.5 percent in moisture content and the calcium chloride covered panel lost 4.2 percent. The earth, waterproof paper, asphalt, tar, and asphalt emulsion covered panels gained 3.1, 4.5, 1.1, 0.1, and 0.1 percentage points respectively.

In the ¾- to 1½-in. level, the control panel and calcium-chloride-covered panel lost 2.5 and 2.0 percent moisture respectively while the other panels dropped less than 1.0 percent or gained up to 4.0 percent. The earth and cover, 0.8 percent; calcium chloride cover, 3.9 percent; RC-2 cover, 1.1 percent; RTCB-6 cover, 0.1 percent. This again shows the calcium-chloride panel to be next to the control panel in amount of moisture loss.

In the ¾- to 1½-in. level the earth and tar covered panels gained 0.8 and 0.9 percent moisture respectively during the hydration period while all other panels dropped in moisture content. The control panel, paper, calcium chloride, and asphalt covered panels

lost 4.6, 0.3, 2.7, and 2.5 percent moisture.

In Figures 13 and 14, the graphs of the control panel test results are quite erratic while those of the other panels, although fluctuating, are relatively level.

Effect of Rainfall

There was no precipitation during the hydration of Groups A and B so this item had no effect on the results from these groups. day did not seem to affect the moisture contents—all panels lost moisture except the tar covered one in Group D which gained 0.1 percent. Thus, all cover materials except calcium chloride were effective in preventing entrance of free water into the soil-cement.

Effect of Humidity

Figures 11 through 14 show the relative humidity as well as moisture contents for

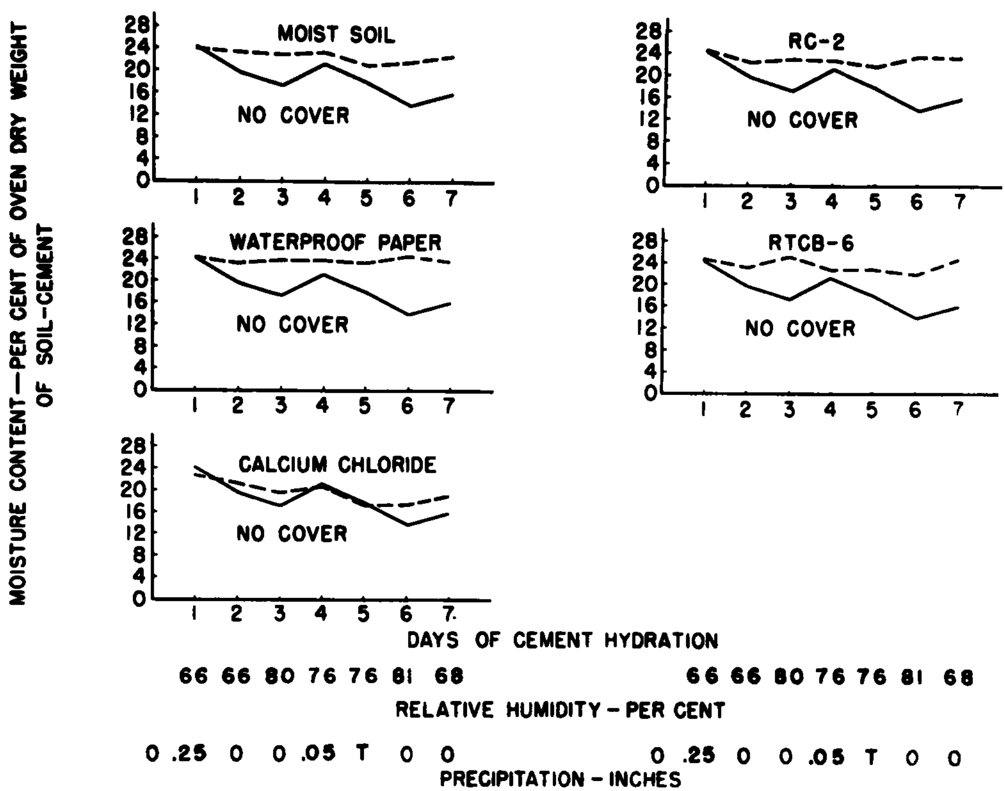


Figure 14. Moisture content of soil-cement during 7-day curing period, Route 630, Appomattox County, Virginia, June 27 to July 3, 1951. Group D, soil-Cecil, soil-cement; 10 percent by volume; optimum moisture, 22.5 percent (estimate); no water applied to surface immediately prior to placement of cover material.

During the curing period of Groups C and D, an estimated 0.25 in. of rain fell on the first day before the materials were applied. Also, an estimated 0.05 in. of rain fell on the fourth day and a trace on the fifth day. The small amount of rain on the fourth day resulted in a sharp increase in moisture in the control panels and in the calcium-chloride-covered panels, but made very little difference in the other panels. The trace of rain on the fifth each day during the curing period. In Groups A and B (Appling soil), humidity seemed to affect the moisture contents of the several panels. It will be noted that when the relative humidity rose sharply on a given day the moisture curve either rose or flattened somewhat in its downward trend. When the humidity dropped, the moisture content also dropped. In Groups C and D the same phenomenon occurred except that there was

generally a time lag of one day before the influence of humidity took effect. In all panels, except the calcium chloride covered panel and the control panel, humidity appeared to have more influence on moisture contents than did rainfall.

Results of moisture content tests from Groups C and D indicate that the reverse was true in these groups. The panels in Group C, wetted before application of cover, gained in moisture content between the first and second curing days. The one exception to this was the control panel which lost moisture slightly. All panels in Group D, without exception, dropped in moisture content between the first and second days of hydration.

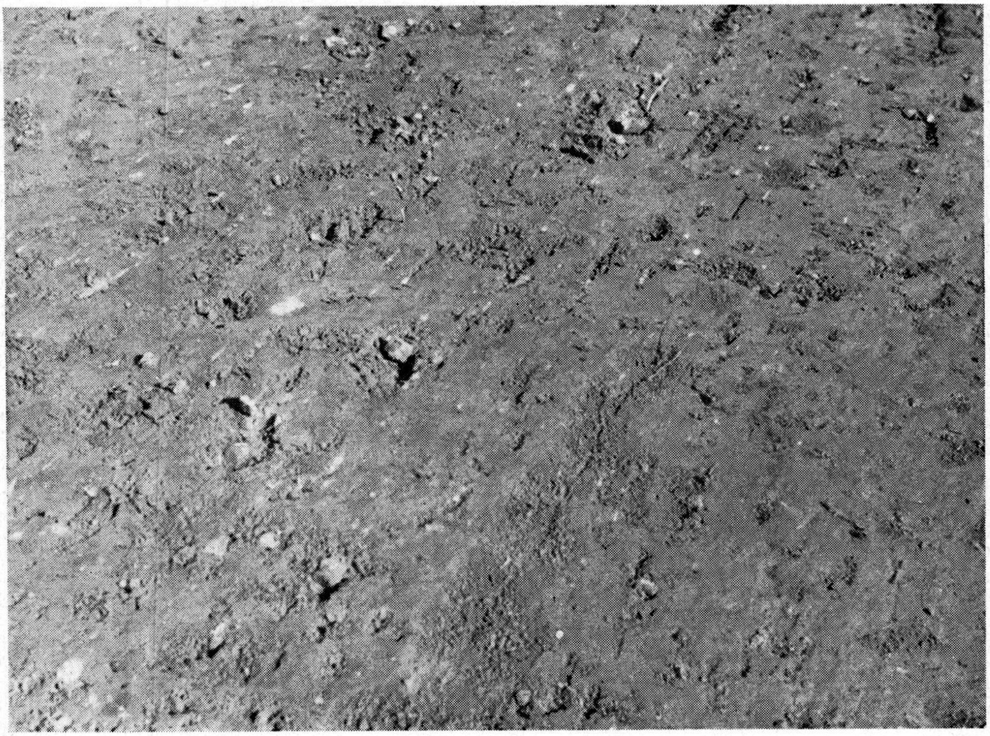


Figure 15. Close-up of surface of soil-cement base (Appling soil) just prior to application of curing materials.

Effect of Wetting Surface Prior to Application of Cover

The Surface of Groups A and B, and the 10-ft. panel between Groups C and D, were given an application of water immediately before the cover materials were placed. By comparing results of moisture tests from Groups A and B, it was noticed that in Group A moisture contents dropped (except for the panels covered with waterproof paper and RTCB-6) between the first and second day of curing. In Group B, which was not wetted just prior to covering, moisture contents rose between the first and second day of curing except for the calcium-chloride-covered panel and the control panel (no cover).

A check was made on the last day of curing on all panels covered with bituminous materials to ascertain if the application of water on the surface, prior to covering, minimized the penetration of the bituminous materials. In Group A the penetration was negligible except around exposed rocks and adjacent soft pockets (See Fig. 15). In Group B, penetration reached a depth of $\frac{1}{4}$ in. In both Groups C and D, penetration of bituminous curing materials was negligible.

Effect of Soil on Retention of Moisture

A greater drop in moisture content was experienced for each panel in the Appling soil than the Cecil soil. The fact that the Appling soil is more granular and has better internal drainage than the more plastic Cecil soil may account for this difference. The test results of samples of Appling and Cecil soils may help to explain the difference in moisture contents. These results are shown in Table A-1 in the appendix.

Field Density Tests

One field density test was performed in each soil area. On the second day of curing, density in the 10-ft. panel between Groups C and D (Cecil soil) was determined as 94.3 lb. per cu. ft. and the moisture content as 23.0 percent. A test on the fourth day after construction, in the 10-ft panel between Groups A and B (Appling soil), revealed the density and moisture to be 114.1 lb. per cu. ft. and 8.5 percent respectively.

SUMMARY OF RESULTS

Results of moisture tests on 1,092 samples of soil-cement, covered with six different materials, are summarized below:

1. All control (uncovered) panels lost moisture during the 7-day curing period. Panels that were wetted just prior to applying materials remained higher in moisture content throughout the 7-day period than the non-wetted panels.
2. Moisture loss and fluctuations in moisture were greater in the top $\frac{3}{4}$ in. than in the $\frac{3}{4}$- to $1\frac{1}{2}$-in. level.
3. The control panels dropped more percentage points in moisture content than did any of the other panels.
4. All earth-covered panels efficiently retained moisture in the soil-cement throughout the curing period. The efficiency of this type of curing is dependent, however, upon constant attention to keeping the earth wet.
5. Waterproof paper efficiently retained moisture in all panels covered with this material. In Groups A and B, the paper was destroyed by the power broom on the fifth day of curing, resulting in a sharp decrease in moisture content.
6. In the amount used, calcium chloride as a cover material was not very effective in retaining moisture in soil-cement during the curing period. Loss in moisture on these sections was exceeded only by the uncovered panels.
7. RC-2 asphalt, RTCB-6 tar, and AE-2 asphalt emulsion were efficient moisture retainers during the 7-day curing period.
8. All cover materials except calcium chloride were effective in preventing the entrance of rain water into the soil-cement base.
9. Humidity affected moisture content in the soil-cement; high humidity resulted in higher moisture contents. Changes in humidity seemed to have greater influence on moisture contents in areas of Cecil than in Appling soils.
10. In practically all cases, panels on which the surface was wetted immediately prior to covering maintained higher moisture contents throughout the curing period than did those panels on which the surface was not wetted.
11. Both in Cecil and Appling soils, penetration of bituminous materials was negligible on those panels with a prior application of water. Where the surface was not wetted, the materials penetrated $\frac{1}{16}$ to $\frac{1}{4}$ in. in Appling soil and was negligible in Cecil soil.
12. Panels located in Appling soil dropped more percentage points in moisture content than did those located in the more impervious Cecil soil.

CONCLUSIONS

The surface of a soil-cement base should be given an application of water before placing the cover material. The experiments showed that moisture content remains higher throughout the curing period if this is done. Also, when bituminous materials are used penetration into the base is minimized.

Although only two different soils were included in the study, tests indicated that greater fluctuations in moisture occur, from day to day, in soil-cement mixes containing the more impervious soils.

Five of the six cover materials used in this experiment are satisfactory moisture retainers for soil-cement mixtures. The five satisfactory materials are: moist earth, waterproof paper, RC-2 asphalt, RTCB-6 tar, and AE-2 asphaltic emulsion.

The three bituminous materials can also be used as a prime coat if the subsequent surface treatment is placed at or near the end of the

curing period. Thus, the additional cost of removing the cover material and adding the bituminous prime can be saved. Cost of cover material plus cost of application is about the same for all five curing methods. If bituminous materials are used for both curing and prime coat the saving should amount to approximately 50 percent for these two items of construction.

As a result of the investigation, a revision in the specifications for protection and cover was written and recommended to the department for adoption. The suggested revision is included in the appendix of this report.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to those who contributed to the successful completion of the project: C. S. Mullen, chief engineer, initiated the investigation following a suggestion by T. F. Loughborough, construction engineer. The work was under the supervision of T. E. Shelburne, director of research. W. C. Poston, resident engineer, furnished space for a field laboratory. R. V. Fielding, Lynchburg District materials engineer, secured the cover materials used for the investigation and spent much time preparing equipment. Robert Canady, Lynchburg District soils engineer, helped in applying the cover materials and performed field density tests. C. H. Pierson, student assistant, helped with all phases of the field work. E. W. Upp, soil-cement engineer, Virginia Department of Highways, and F. W. Vaughan, Portland Cement Association, offered valuable advice and helped with the application of cover materials. J. A. Leadabrand, manager, Soil-Cement Bureau, Portland Cement Association, furnished information concerning soil-cement curing specifications in other states. Student assistants with the Council prepared the graphs and charts. Miss Nora Pollard typed the report.

APPENDIX

SUGGESTED REVISION FOR "PROTECTION AND COVER" SECTION OF SOIL-CEMENT BASE SPECIFICATIONS

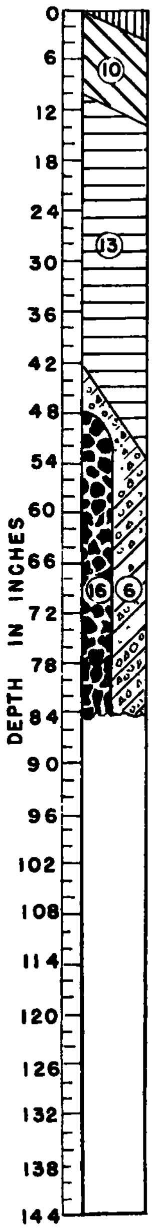
Sec. 306.12. Protection and Cover.—After the soil-cement base has been finished as specified herein, it shall be protected against drying for seven days by applying a 2-in. covering of earth, or not less than 4 lb., dry weight, of straw or hay per sq. yd., which shall be moistened initially and subsequently as may be necessary, by applying bituminous material as described herein, or by applying other cover materials approved by the engineer. The cover material shall be applied as soon as possible after the completion of finishing operations. The finished base shall be kept continuously moist until the cover material is placed.

When a bituminous material is used, approximately 0.20 gal. per sq. yd. shall be applied to the surface of the soil-cement to give complete coverage without excessive runoff. The exact rate of application shall be specified by the engineer. The bituminous materials used may be RC-1, RC-2, MC-2, MC-3, AE-2 or RTCB-6. At the time of bituminous material application the soil-cement surface shall be tightly knit, free of all loose and extraneous material and shall contain sufficient moisture to prevent penetration of the bituminous material. If needed, water shall be applied to fill the surface voids of the soil-cement immediately before the bituminous cover is applied.

TABLE A-1
TEST RESULTS AND CLASSIFICATION OF SOILS FROM ROUTE 630 APPOMATTOX COUNTY

Name	Depth	Horizon	Liquid Limit	Plastic Index	Specific Gravity	Gravel	Sand	Silt	Clay	−200	Classification
	in.					%	%	%	%	%	
Appling	10	A	24.8	4.0	2.67	21.80	36.60	23.00	18.60	44.20	A-4(2)
Appling	30	B	88.5	26.3	2.77	3.01	20.99	15.70	60.30	80.21	A-7-5(19)
Appling	46	C	55.9	14.7	2.84	5.61	28.69	23.90	41.80	73.93	A-7-5(12)
Cecil	6	A	28.0	4.2	2.66	1.88	44.82	30.50	22.80	68.98	A-4(7)
Cecil	24	B	87.8	43.4	2.77	0.0	22.20	20.70	57.10	85.85	A-7-5(20)
Cecil	60	C	56.2	17.9	2.78	0.8	41.70	33.30	24.20	67.33	A-7-5(2)
Appling	3	A	26.1	6.3	2.65	15.34	44.46	20.60	19.60	37.97	A-4(1)
Appling	24	B	62.8	33.2	2.69	9.37	37.83	15.30	38.50	59.67	A-7-6(16)
Appling	40	C	47.6	20.1	2.64	12.43	48.97	16.80	21.80	39.04	A-7-6(4)

FIGURE A-1, APPLING



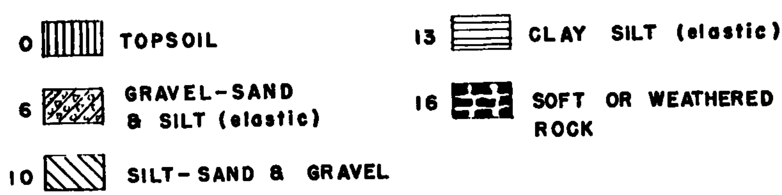
The Appling are light tan to reddish yellow upland soils found on undulating to steep slopes. Intermediate in profile development between Cecil and Durham they are some of the better drained of all Piedmont soils. Sandy silt and sandy silt clay are the prevailing textures. Underlying parent materials include weathered granite and granite-gneiss or schists.

Location: These soils are prevalent in areas of high quartz granite or granite gneiss and schists. They occur on undulating to steep topography where surface drainage is excellent.

Description: The Appling profile usually has from two to four inches of organic silt topsoil underlain by a sandy silt A-horizon to a depth of ten to fourteen inches. This texture grades into a yellow or sand colored silt clay containing varying amounts of quartz sand and a myriad of tiny hair cracks that impart a free draining cubical structure. This zone grades into mottled reddish brown and yellow sandy decomposed parent material containing much quartz and small amounts of mica.

Problems: As a whole, Appling soils are well drained and stable—some of the best engineering soils in the Piedmont. When properly compacted, high uniform subgrade support is provided. The granular nature of these soils, which sometimes is deficient in binder, is conducive to surface erosion in the form of small gullies that may incise themselves in a normal highway ditch. By and large, engineering problems associated with these soils are minor.

Corrections: Control of moisture content during construction will pay off in dividends of highly compacted densities conducive to stability and to excellent road performance. Occasionally, small pockets of mica materials should be wasted in favor of the usually better materials. Where grades intersect the contact of B- and C-horizons, excavating and replacing of the silty clay soils will contribute to a more uniform subgrade support. Erosion control should be provided for freshly exposed back slopes, embankments, and ditches.



The bituminous material shall be applied uniformly with a pressure distributor meeting the requirements of Sec. 319.03(b), at the rate and temperature specified by the engineer.

Should it be necssaery for construction equipment or other traffic to use the bituminous-covered surface before the bituminous material has cured, sufficient sand cover shall be applied to prevent pick-up before such use.

The cover shall be maintained by the contractor during the seven-day protection period so that all of the soil-cement base will be effectively covered at all times.

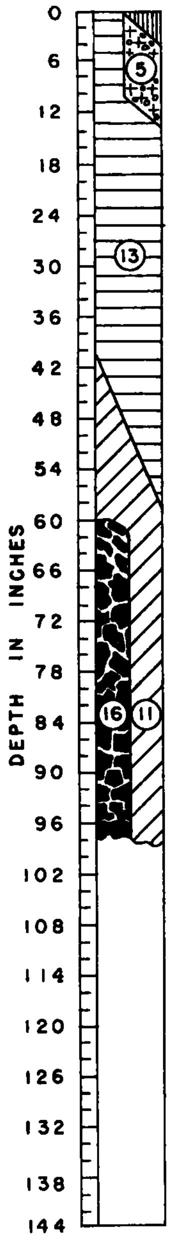


FIGURE A-2, CECIL

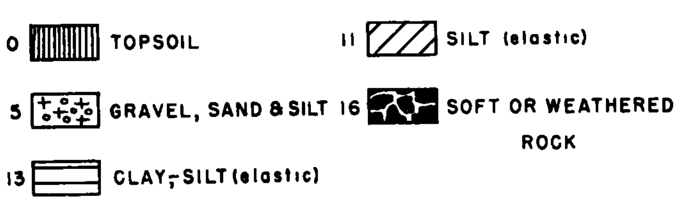
Most common of all soils in the Piedmont are the Cecil series. Developed from schist, some granites and syenites and gneiss, they are found in close association with Madison and Appling soils. They do not have engineering properties as desirable as the Appling group, but are superior to some other soils.

Location: The Cecil occurs on flat to undulating slopes in the smoothly rolling Piedmont upland. Their major occurrence is associated with Wissahickon schist formation.

Description: The Cecil includes from two to four inches of organic matter underlain by gray brown or buff colored sandy silt extending to a depth of about twelve inches which grades into a bright red or brownish red stiff brittle silty clay that crumbles readily into irregular cubical shaped lumps. At a depth of about sixty inches, this gives way to micaceous mottled light red, yellow, brown and gray disintegrated schist.

Problems: Location and earth work are moderate problems since the topography is dissected by broad shallow gullies. Changing subgrade support at the contact of B- and C-horizons can be accentuated if drainage in cut sections is not adequate for removal of surface water. These silt clays are slightly expansive and may be susceptible to swelling with changes in moisture content. Erosion of the friable parent material is extensive.

Corrections: Changing subgrade support at profile contacts can be avoided by minor undercutting and back filling. Close moisture control during compaction can bring about good results with the C-horizon parent material although it does have a moderate amount of mica. The soils appear to be resistive to certain types of stabilization; however, this field must be explored. In some locations the parent material may be suitable for select borrow if precautions are taken during construction.



Any finished portion of the base adjacent to construction which is used as a turnaround area by equipment in constructing an adjoining section shall be continuously covered with at least 6 in. of earth to prevent equipment from marring the surface of the completed work.

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CLAY FRACTION IN ENGINEERING SOILS: III. INFLUENCE OF AMOUNT ON PROPERTIES

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SYNOPSIS

PART III of the series describes the results of a study of one of the important variables affecting engineering properties of soil: the amount of clay present in the soil. Test data for the deep Wisconsin (Peorian) loess of southwestern Iowa affords a rare opportunity for such a study with natural soil. Graphs show that the liquid limit, plastic limit, plasticity index, shrinkage limit, centrifuge moisture equivalent, hygroscopic moisture, field (in-place) density, and field moisture content have an apparent linear relationship with 0.002-mm.-clay content. No simple relationship was found between the field-moisture equivalent and clay content.

● PARTS I AND II of this series (*1, 2*), reporting on investigations of the clay fraction in engineering soils, describe tools and methods suitable for engineering-laboratory use by which certain properties of the clay fraction may be analysed. One of the objectives of the investigations, as stated in Part I, is to study the role of the clay fracton in soils to determine the variables involved and their influence on engineering properties, which are those physical properties of soils used in the design and construction of engineering works. This paper reports the results of a study of one of the important variables: the amount of clay present in the soil.

Test data for the deep Wisconsin (Peorian) loess in southwestern Iowa afforded a rare opportunity for such a study with natural soils. The data were obtained as part of the research being done under Project 283-S of the Iowa Engineering Experiment Station. This project, "An Investigation of the Loess and Glacial Till Materials of Iowa," is being carried on under contract with the Iowa State Highway Commission and under the sponsorship of the Iowa Highway Research Board and is supported by funds supplied by the commission and by the U. S. Bureau of Public Roads.

WISCONSIN LOESS OF SOUTHWESTERN IOWA

Four glacial drifts of the Wisconsin stage, Iowan, Tazewell, Cary, and Mankato, have recently been mapped in Northwestern Iowa by R. V. Ruhe.[1] Each of these four glaciations is believed to have contributed to the formation of the composite Wisconsin loess (also called Peorian loess in the geological literature) which forms a massive surface deposit that mantles older loesses and pre-Wisconsin glacial deposits in southwestern Iowa. The evidence available indicates that the main

[1] Personal communication. Ruhe was formerly an assistant professor of geology, Iowa State College.