IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-75

Soil-Cement Stabilization

PART 1

MATERIALS AND CONSTRUCTION

PREPARED BY
THE RESEARCH DEPARTMENT
OF THE
IOWA STATE HIGHWAY COMMISSION

JUNE 1962

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Iowa Highway Research Board
Project HR-75

SOIL-CEMENT STABILIZATION

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MATERIALS AND CONSTRUCTION

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Of The
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HR-75

EXPERIMENTAL SOIL-CEMENT BASE

Project F-861(6)
Crawford - Harrison - Monona Counties

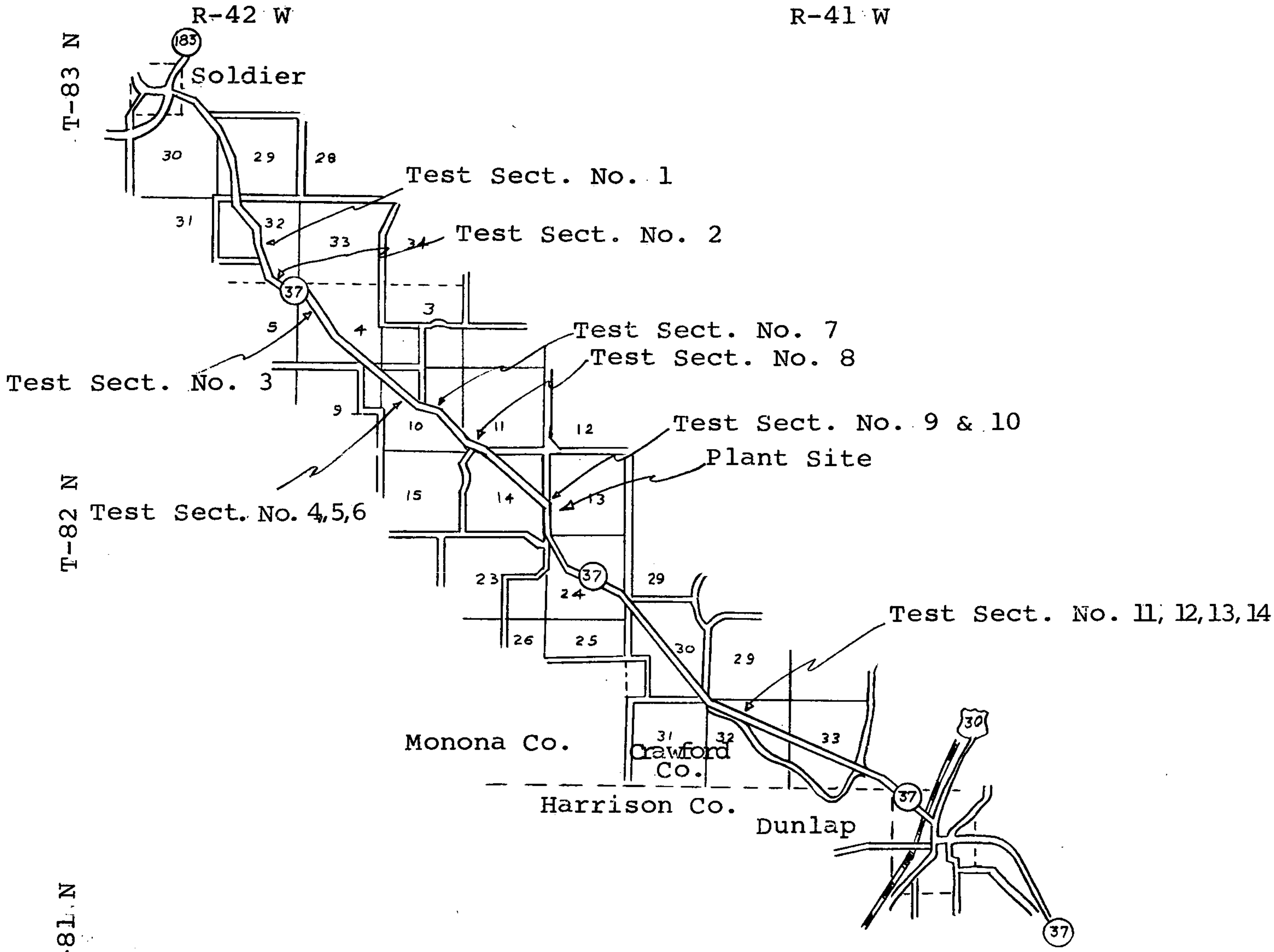

FIG. 1

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INTRODUCTION

This report covers the construction in 1961 of the soil-cement base and related pavement structure on Iowa 37 from Soldier to Dunlap, (F-861(6), Crawford, Harrison, Monona). The report also contains an account of the experimental work performed on the same road under research project HR-75.

Experimental Soil-Cement Construction

The construction project included the placing of 12.83 miles of soil-cement base for which the normal cement content was 11.0 percent of the dry weight of the soil. For research purposes the cement content was varied from 7.0 to 13.0 percent in 14 experimental sections. The construction and performance of these 14 base sections, together with 2 chemically stabilized subbase sections, are part of an extensive research program in soil-cement stabilization.

The principal objective of research project HR-75 is to relate pavement performance to the cement content of the soil-cement base. This performance will be correlated with the results of standard laboratory tests used to establish the recommended cement content for stabilizing fine grained soils.

The performance of the experimental base sections will also be compared with the results of tests made according to laboratory procedures developed at Iowa State University. A complete report on this phase of the research will be prepared at the University.

Details concerning the project location, typical pavement cross sections and estimated material quantities may be obtained from the plan sheets which are contained in Appendix A. Soil-cement base design, materials, construction, and special testing are described in the following sections of this report.

SOIL-CEMENT BASE DESIGN

Soil-Cement bases have been used successfully in Iowa, as well as in other States for many years, and design procedures have been established by the Portland Cement Association and numerous highway agencies. Base design involves two primary considerations. These are as follows:

1. The strength, and consequently the thickness, of the base relative to the expected traffic and to subbase or subgrade support.

2. The ability of the hardened soil-cement mixture to resist the disruptive forces produced by changes in the moisture content and temperature of the base.

These two design factors are interdependent, since the strength of the base at any particular time is dependent upon both its initial strength and its durability. In general, however, laboratory tests used to establish the cement content for a soil-cement base emphasize the durability factor. The normal cement content for this project was selected on the basis of freeze-thaw tests performed in the Materials Department Laboratory.

The freeze-thaw test is conducted on specimens compacted in proctor molds to maximum density at optimum moisture content. After 7 days of moist curing the specimens are subjected to 12 cycles of freezing and thawing. Before each freezing cycle the loose material is removed from the surface of each specimen with a wire brush. The resistance to freezing and thawing is indicated by the weight loss of the specimens during the 12 cycles.

The Portland Cement Association recommends that the freeze-thaw loss should not exceed certain maximum percentages for various types of soil. The borrow soil used in the soil-cement base on this project was classified as A-4-8. The recommended maximum freeze-thaw loss for this soil is 10 percent.

Appendix B shows the laboratory test results for specimens containing various amounts of cement combined with soil obtained from preliminary sampling of the borrow area. On the basis of this laboratory report the desirable cement content was determined to be 11 percent of the dry weight of the soil. Cement contents of 7, 9, 11, and 13 percent were selected for the experimental soil-cement base sections.

Base thickness was not a test variable. Therefore, a uniform base thickness of 7 in. was constructed throughout the project.

MATERIALS

Subgrade Soil

The summary sheet containing the results of the soil survey made on the existing subgrade appears in Appendix C. The grade was constructed in the Monona County portion of this project in 1959-60 and in Harrison and Crawford County in 1954. A gravel surfacing at a rate of 1300 cu. yd. per mile was placed after completion of grading.

Granular Subbase

Material for the granular subbase complied with section 4121.01B of the 1960 Standard Specifications. The material was produced by Mauer Construction Company from a pit located in the SE ¼ Section 27-82-41 Crawford County.

Soil-Cement Aggregate

The loess soil used for the soil-cement mixture was taken from a borrow area near the center of the project. The soil characteristics are shown in Table No. 1 and Table No. 2 in the TESTING section of this report.

Cement

A Type I Portland cement, complying with section 4101 of the 1960 Standard Specifications, was combined with the soil from the borrow area for producing soil-cement. Table No. 3 in the TESTING section is a summary of the laboratory tests on cement.

Bituminous Prime Coat

RC-O was applied to the compacted base within 24 hours after construction to aid curing. The bituminous material complied with section 4138.01 of the 1960 Standard Specifications.

Special Chemicals

Two chemical additives were used for experimental subgrade stabilization One test section contained ET-506, donated by the Dow Chemical Company of Midland, Michigan. This was the first field trial of ET-506 in Iowa. Another test section contained Arquad 2HT, produced by Armour Industrial Chemical Company, Chicago, Illinois. This chemical had a previous field trial in Iowa in 1957.[1]

Seal Coat

MC-4 complying with section 4138 of the 1960 Standard Specifications, was used for the single bituminous seal coat.

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[1] J. M. Hoover, Soil Stabilization Field Trials, Primary Highway 117, Jasper County, Iowa. Department of Civil Engineering, Iowa State University of Science and Technology.

The ½ in. cover aggregate was crushed limestone complying with section 4125 of the 1960 Standard Specifications.

CONSTRUCTION

This project was constructed according to the 1960 Standard Specifications as modified by the special provisions for the project dated October 18, 1960 (See Appendix A).

The planned experimental construction was confined to 14 test sections which had a combined length of approximately 3 miles. Construction of the entire project is discussed in this report with special attention being given to the planned experimental features.

Subgrade

Whenever a subbase was not constructed, standard subgrade correction was made both in grade and cross section to within ± 0.05 ft. of the desired elevation.

Soil-Aggregate Subbase

A 6 in. soil aggregate subbase was constructed in two experimental sections. No granular material was added, but the surfacing material already present on the road was incorporated into the subbase. The subgrade was first scarified, then processed by a P & H Stabilizer, and finally compacted to not less than 95 percent of Proctor density. A different chemical stabilizing agent was incorporated into each of the two sections. These are discussed separately as follows.

Dow Chemical ET-506

The ET-506 was applied at the rate of 0.15 percent of the dry weight of the soil. It was applied through the P & H machine together with a quantity of water sufficient to produce optimum moisture content in the soil (Photos 1 and 2).

The chemical and water were thoroughly mixed by means of a recirculating pumping system on the water truck. The water was not heated, and no difficulty was experienced in obtaining adequate dispersion of the ET-506.

The 500 ft. chemically treated section was processed in four 10 ft. wide strips by the P & H machine. Thus approximately 40 ft. of the total roadway width was treated.

Although the mixing operation with the P & H machine was not completed until late in the day, compaction of the subbase was started immediately. This was accomplished with a sheepsfoot roller followed by a rubber-tired roller.

On the following day a 500 ft. section adjacent to the treated section was scarified, mixed, and compacted in precisely the same manner as the treated section, except that no chemical stabilizer was added.

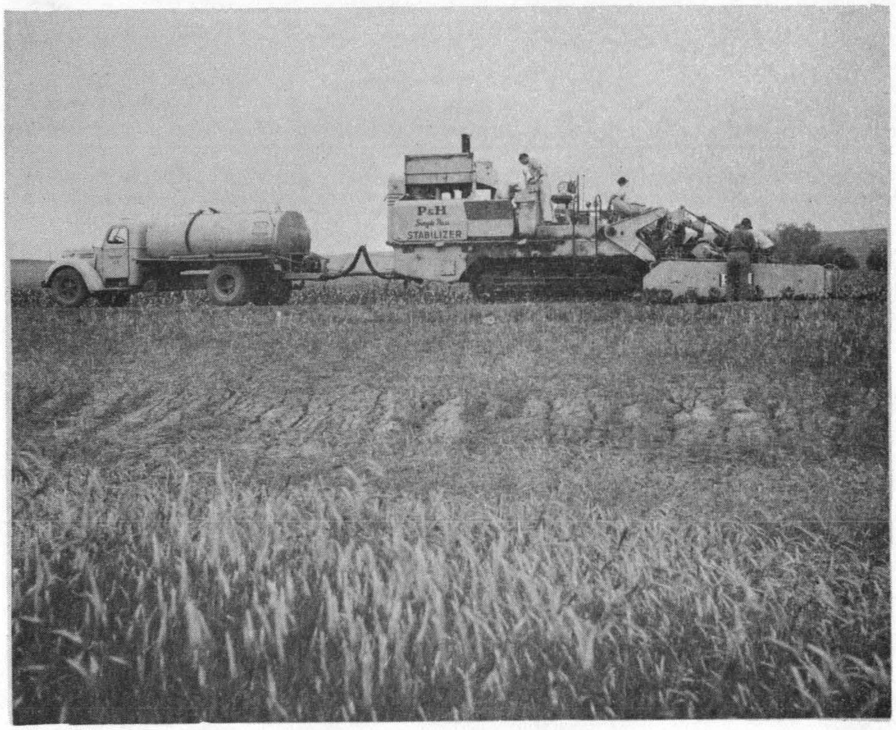

PHOTO 1: The P & H machine and tank truck containing the Dow ET-506 mixture.

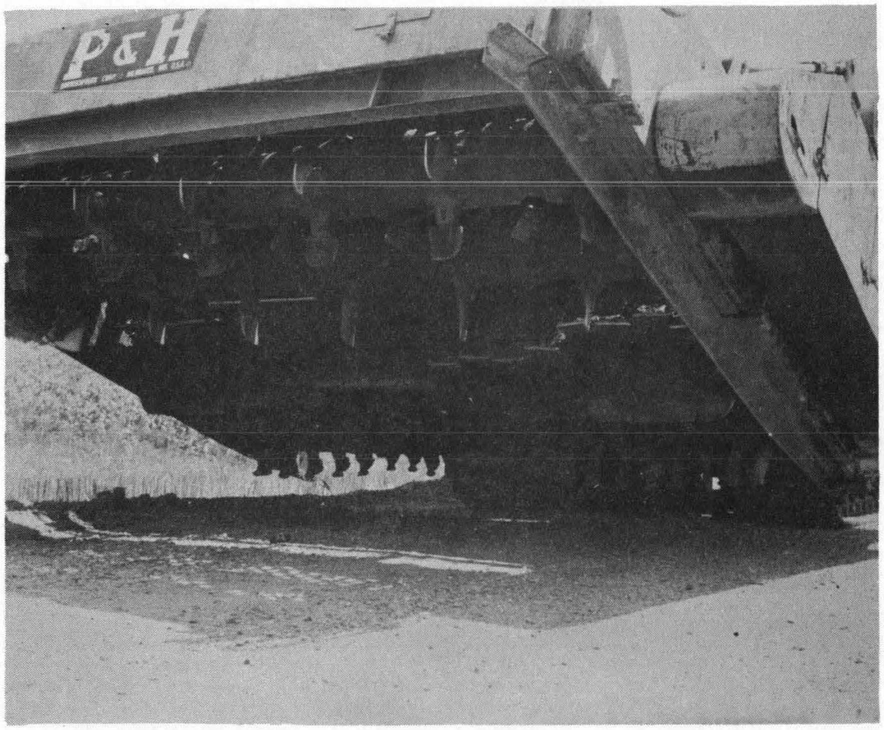

PHOTO 2: Mixing and cutting blades of the P & H machine.

Armour Chemical, Arquad 2HT

The Arquad 2HT was used at the rate of 0.25 percent of the dry weight of the soil. It was applied through the P & H machine together with a minimum amount of water.

Arquad 2HT was delivered to the job in a semisolid form. Dispersion of the chemical in water could be accomplished successfully only if the water were heated to approximately 140F and a recirculating pumping system used to assist in the mixing (Photo 3). The water was heated by placing an open steam line in the truck-mounted water tank. Steam was supplied by a small oil-fired boiler. Even with heated water it was not possible to maintain a concentration of more than 5 percent of the Arquad 2HT. Because of this limitation it was necessary to add an excess of water in the road-mixing operation. This raised the moisture content of the soil considerably above optimum, and aeration of the soil was required before compaction (Photo 4).

Four passes of the P & H machine were required to stabilize approximately 40 ft. of the roadway width. Since the contractor desired to maintain traffic through this section, it was necessary to do one-half of the roadway on each of two different days. The required density was not obtained at this time, however, and several days later the entire width of roadway was again scarified and recompacted, this time to the required density.

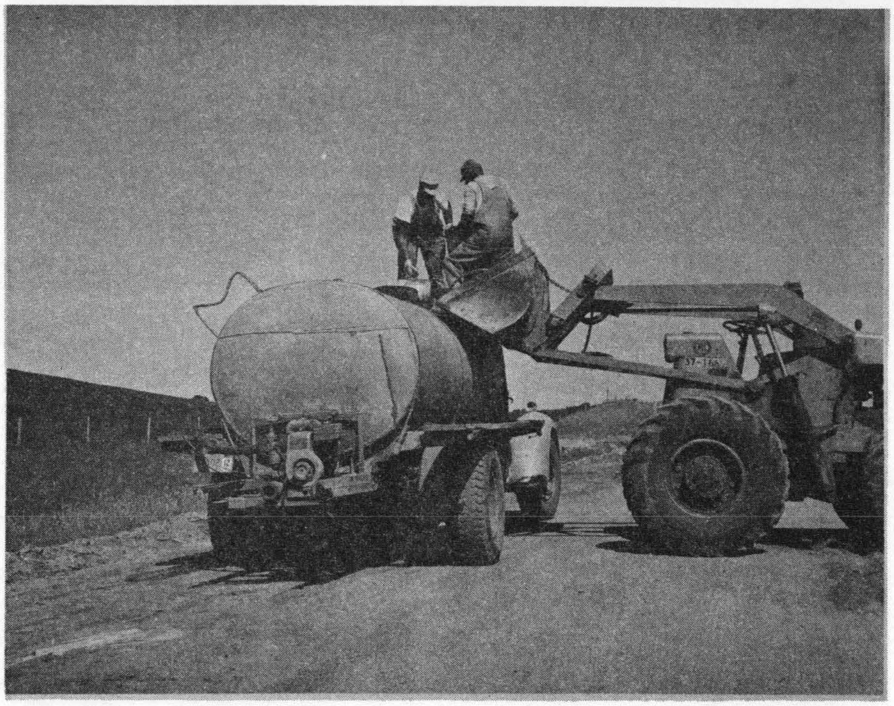

PHOTO 3: Adding Arquad 2HT to heated water. Circulation of the mixture was provided by the pump near the rear of tank.

PHOTO 4: The arquad treated subbase after a single pass with the P & H machine.

A 500 ft. control section was constructed adjacent to the treated section. This section was scarified, mixed, and compacted in the same manner as the treated section, but no chemical stabilizing agent was added.

Granular Subbase

A granular subbase was constructed in specified areas. Material for the subbase was mixed in a pugmill to bring it to optimum moisture content. The material lacked cohesion, and difficulty was experienced in maintaining stability. Limestone screenings were incorporated, improving the mixture to the extent that stability could be maintained. Some granular subbase sections were damaged by traffic, and had to be reworked immediately before the soil-cement base was constructed.

Soil-Cement Base

The soil in the borrow area was farmed with a roam disk to break up the clods and reduce the moisture content (Photo 5). It was then pushed by dozers into a bulkhead feeder from which it was carried on a belt conveyor to a feeder with a grizzly, which screened out the larger clods (Photo 6 & 7). The material was then fed through a calibrated gate and carried on a belt conveyor to the surge bin (Photo 8). It was carried from the surge bin by a metal apron feeder, the cement was added, and the two materials

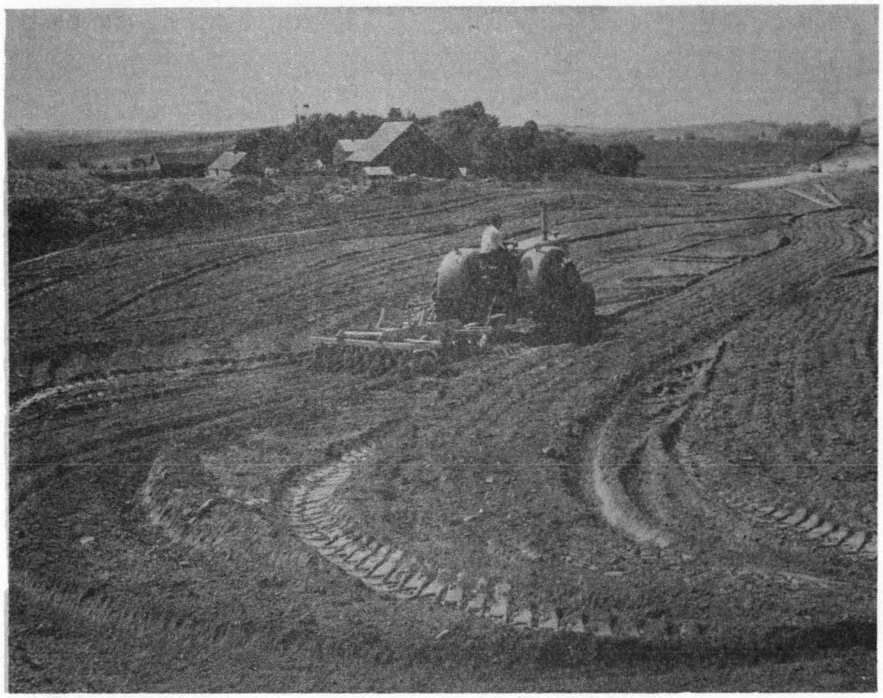

PHOTO 5: Disking the borrow area to reduce the moisture content and break-up the clods.

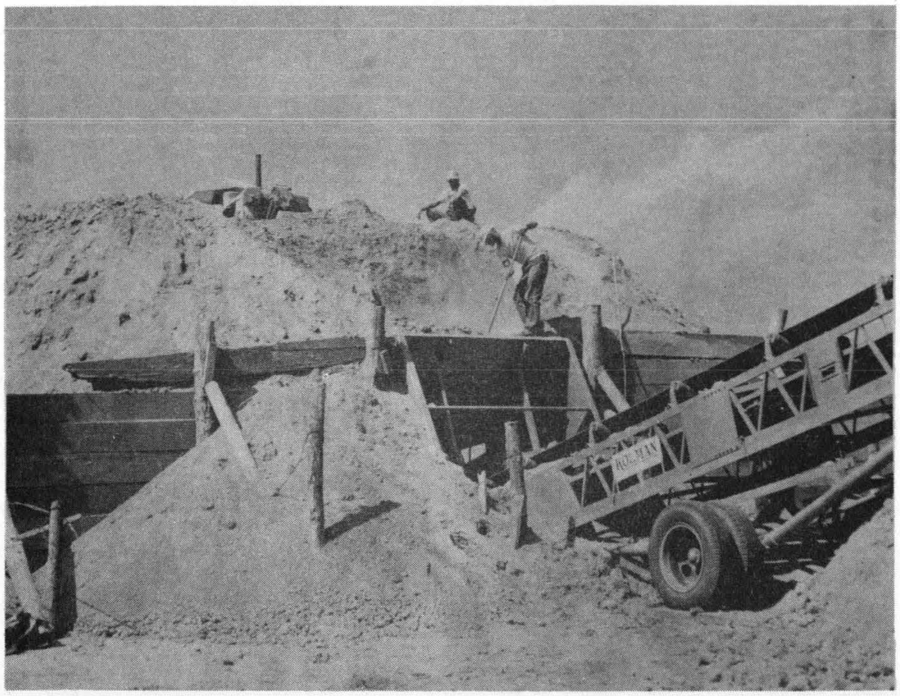

PHOTO 6: A dozer pushing soil into the bulkhead feeder.

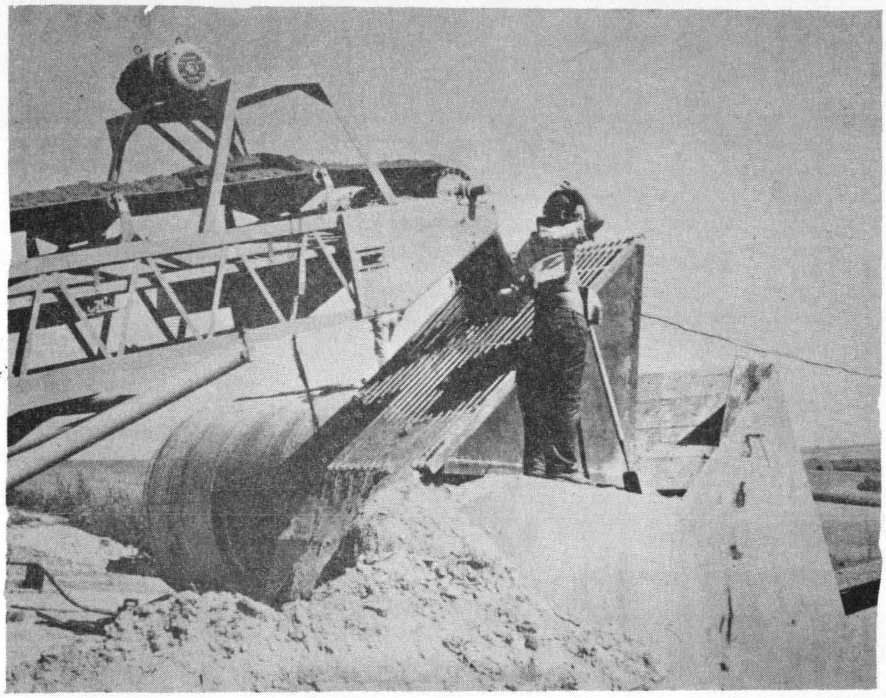

PHOTO 7: Soil being fed through the grizzly.

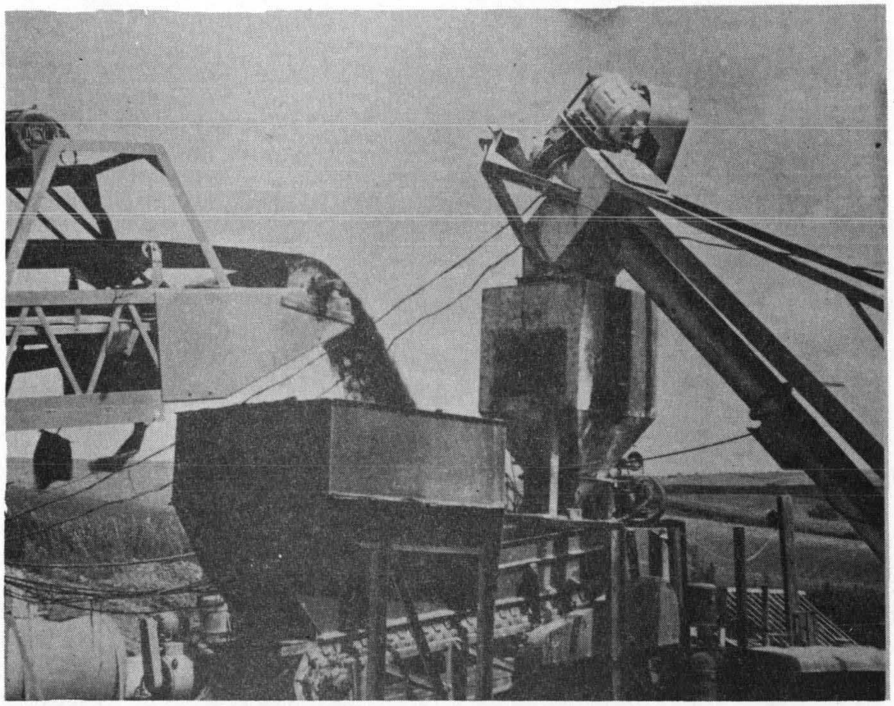

PHOTO 8: Soil being fed into a surge bin. Note cement hopper to the right.

were carried to the pugmill.

The cement was hauled by truck-tankers from the nearest rail siding to the plant. It was carried by an auger type conveyor into a storage tank (Photo 11), and then carried by another auger to a surge bin, from which it was deposited directly on the loess soil by means of a calibrated vane feeder.

The pugmill was 10 ft. long. The soil and cement were dry mixed in the first 4 ft. At this point the water was added. The specified total mixing time was 15 seconds. The soil-cement was discharged from the pugmill into a hopper, from which it was loaded into trucks by means of a belt conveyor (Photo 9 and 10).

On the road the material was spread by two Jersey spreaders mounted on crawler type tractors (Photo 12). A 10 in. loose thickness was necessary to provide a 7 in. compacted base (Photo 13) Scarifying teeth were attached to the tractor to break up track impressions. Directly behind the spreaders was a sheepsfoot roller (Photo 14). Behind the sheepsfoot roller was a spike-tooth drag which broke up the top 1 to $1\frac{1}{2}$ in. to prevent laminations in the upper surface (Photo 15). The loosened material was given a light application of water (Photo 16), and then compacted by a rubber-tired roller. The edge was compacted by a Lima Vibra Road Pack (Photo 17 and 18).

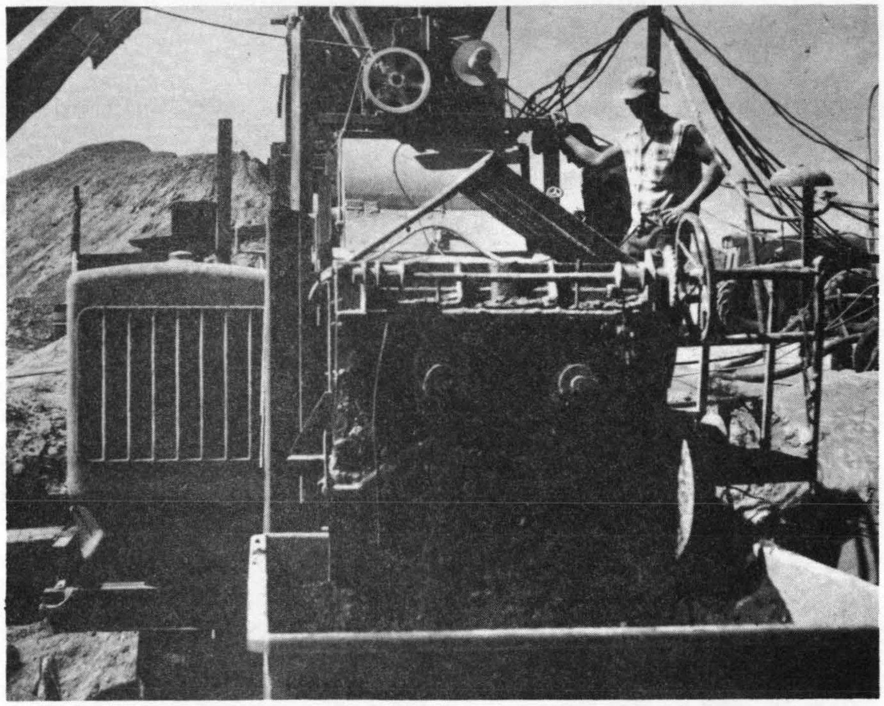

PHOTO 9: Soil-cement mixture leaving the pugmill.

PHOTO 10: Loading soil-cement mixture.

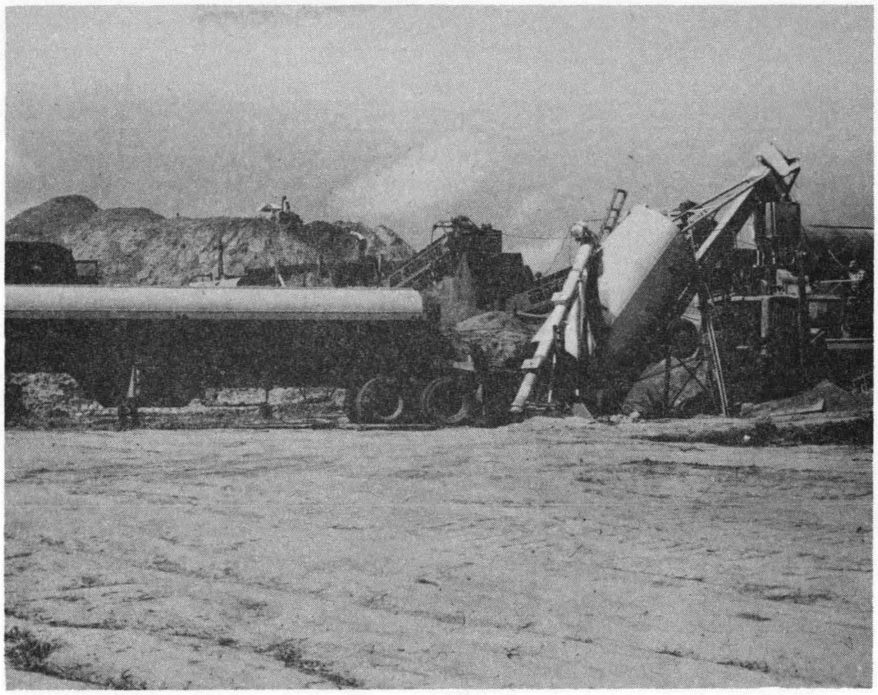

PHOTO 11: Cement transport charging the cement storage bin.

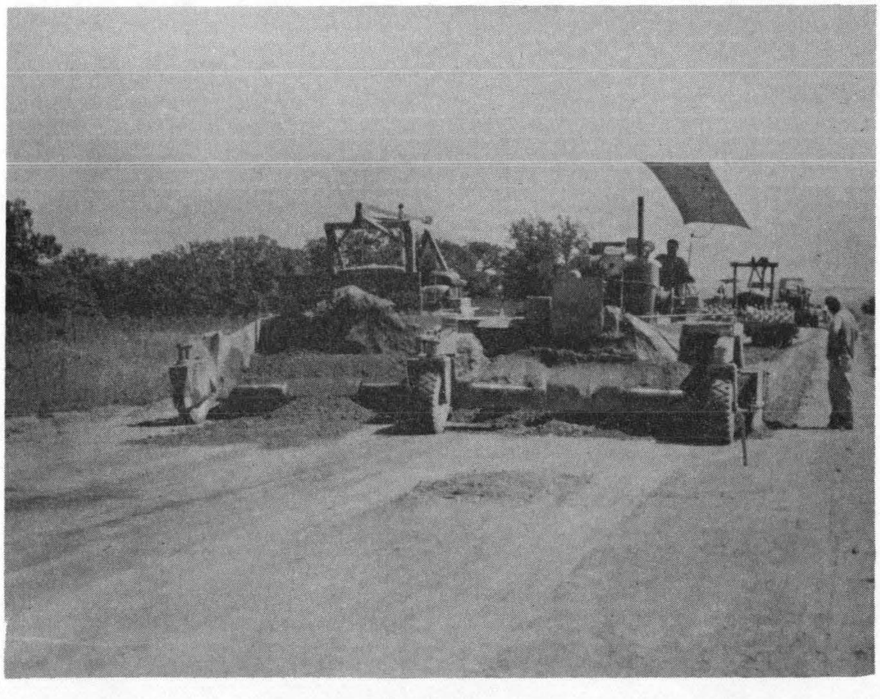

PHOTO 12: Jersey spreaders awaiting arrival of soil-cement.

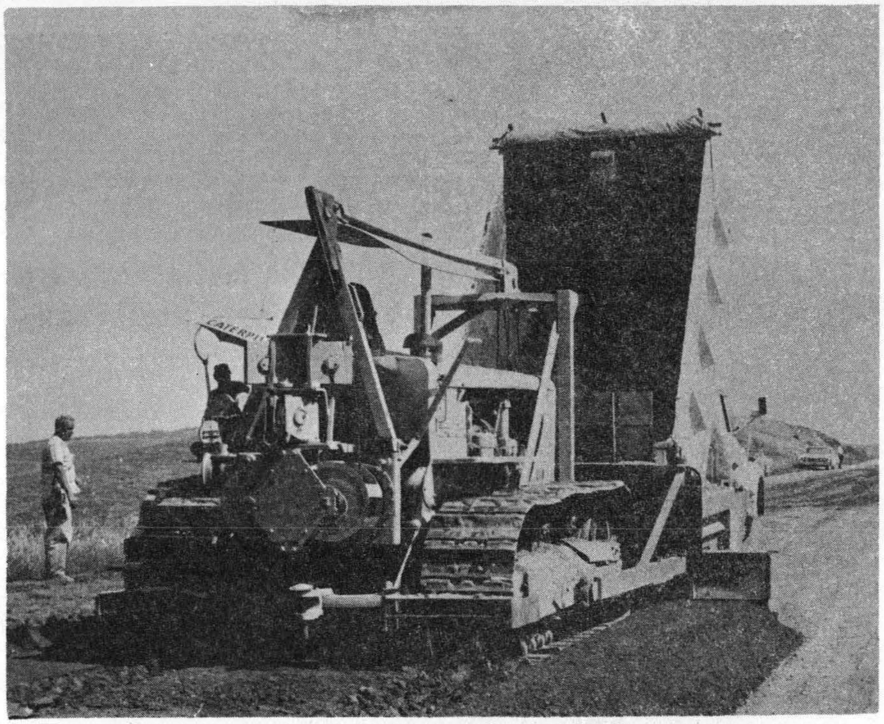

PHOTO 13: Spreading soil-cement on the subgrade.
Note the 10 inch loose thickness.

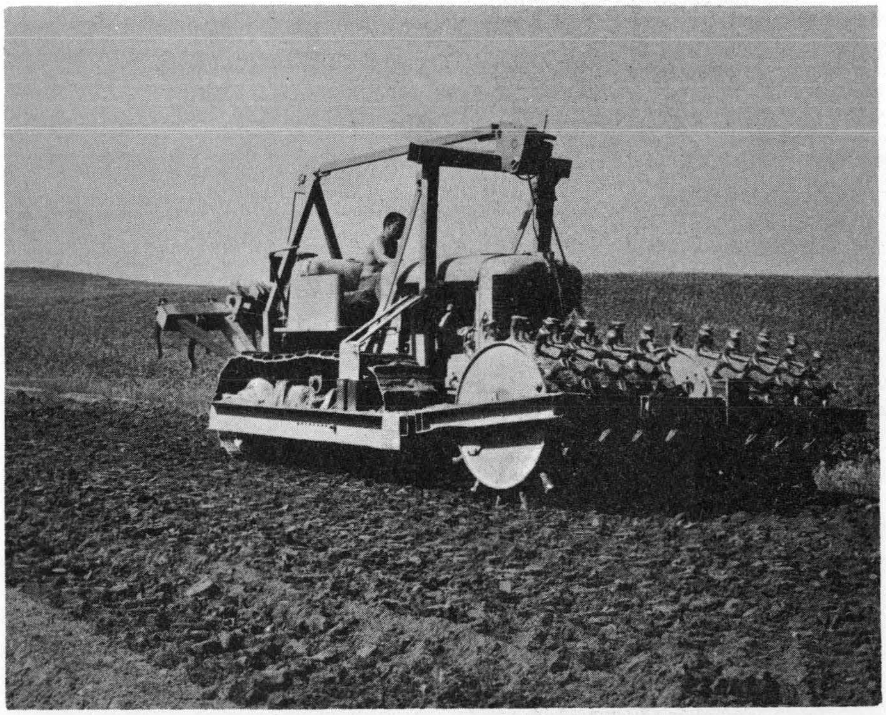

PHOTO 14: Sheepsfoot roller making initial compaction.

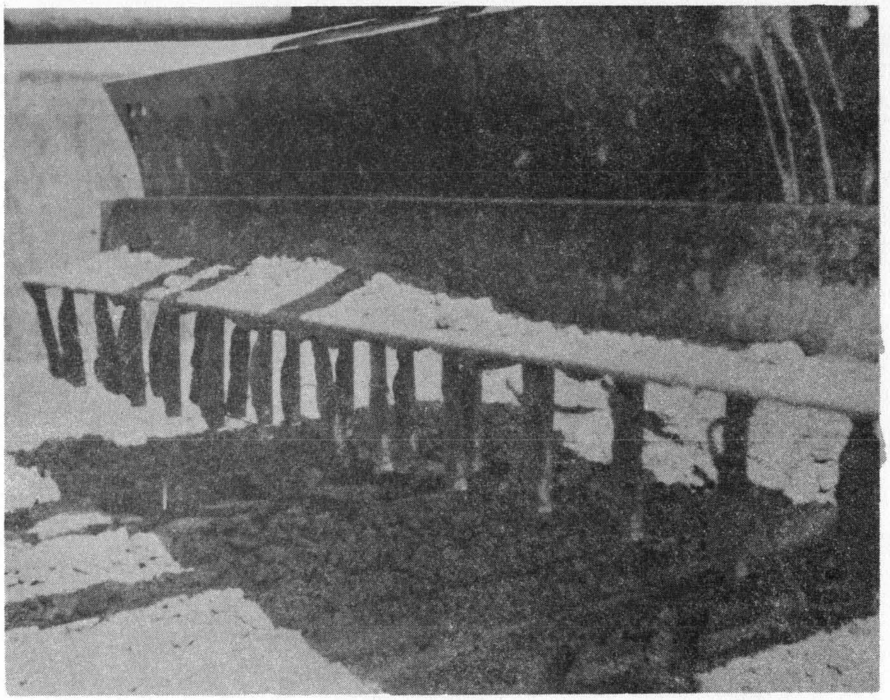

PHOTO 15: Spike-tooth drag.

PHOTO 16: Applying water to the base following first coverage by the spike-drag.

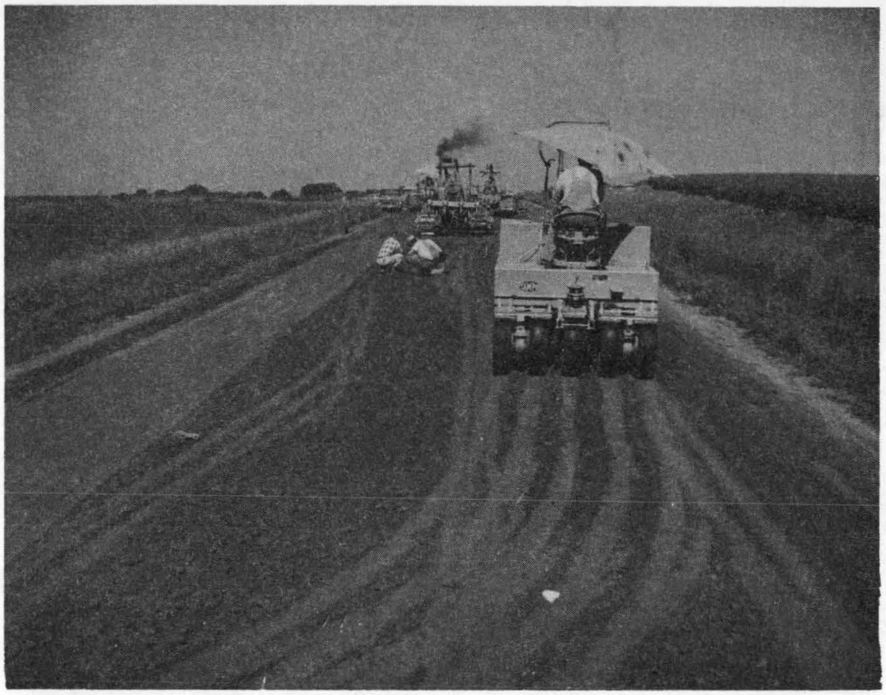

PHOTO 17: First coverage of the base by rubber-tired roller.

PHOTO 18: Lima Compactor compacting the edge.

The surface was again scarified with the spike-tooth drag (Photo 19) and wetted if needed prior to final shaping by the motor grader (Photos 20 and 21). A spring-tooth drag was used to spread any unevenly distributed material and to remove tire impressions. This was followed by a rubber-tired roller for the final compaction. The surface was dressed up with a broom drag and sealed with the rubber-tired roller. The elapsed time to this point was about 3 hours. If the surface of the completed base began drying, it was given a light application of water. The last operation was to shape the edge slopes after the base was completed for the day (Photo 22). A diagram of the equipment alignment for the construction of the base throughout the length of the project is shown in Appendix D. Equipment used on the entire project is also listed in Appendix D.

Within 24 hours after completion of the base it was primed with RC-O at a rate of 0.2 gal. per sq. yd. for the roadway and 0.3 gal. per sq. yd. for the edge (Photo 23). When cracks were observed in the prime from shrinkage cracks in the base, the rate was increased to 0.25 gal. per sq. yd. This increased rate required the application of blotter sand (4 to 5 lbs. per sq. yd.). One section, which was cured with MC-3, did not crack when the base shrinkage occured.

Earth Shoulders

When the base had attained an age of at least 7 days, the earth shoulders were constructed. The material was obtained

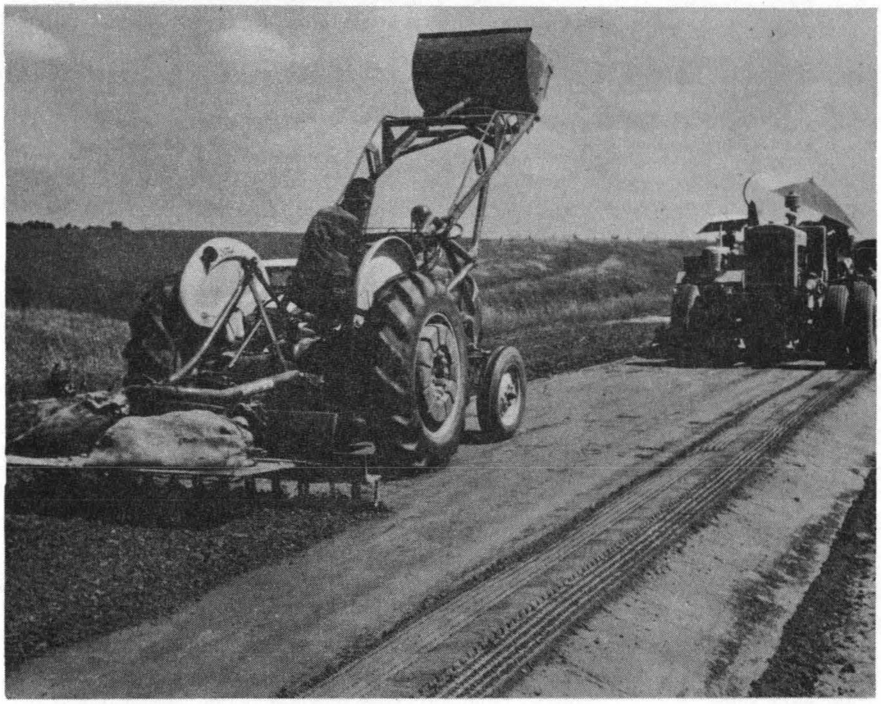

PHOTO 19: Second coverage by the spike-drag.

PHOTO 20: Motor grader shaping base prior to final compaction. Note large quantity of soil-cement carried by the blade. This material, which is approximately 2½ hours old, had a tendency to separate from the rest of the base (See photo 24).

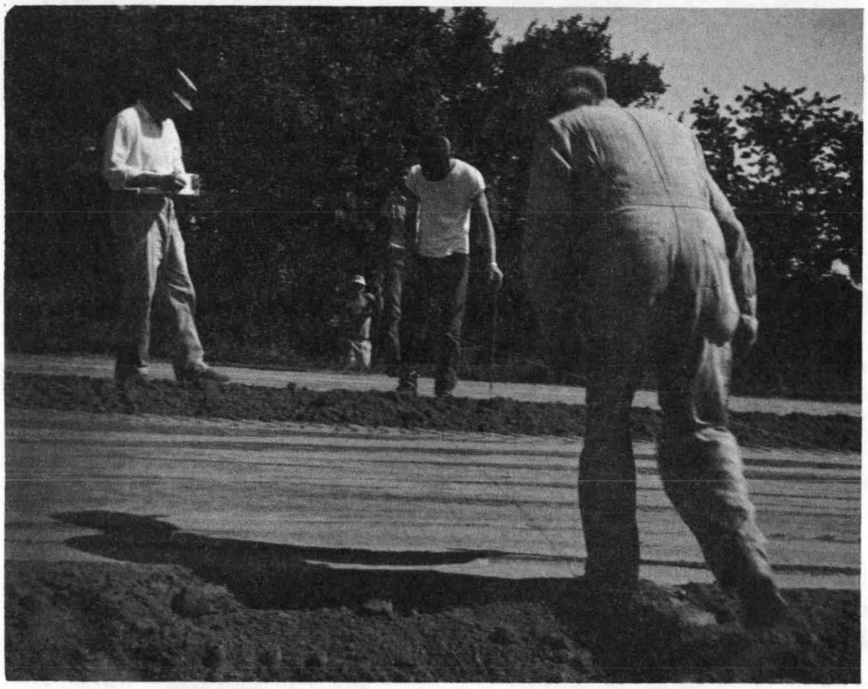

PHOTO 21: Checking crown during final shaping operation.

PHOTO 22: Compacted base.

from borrow areas along the road and hauled by truck to the desired location.

Seal Coat

The final operation was the construction of a single bituminous seal coat using ½ in. cover aggregate. MC-4 was placed at a rate of 0.28 gal. per sq. yd. and the cover aggregate was placed at the rate of 31 lbs. per sq. yd.

Production

The average daily production of soil-cement was about 1,700 tons (dry weight) per day. This rate does not include time lost due to rain and breakdowns. The highest production for a single day was 2,665 tons (dry weight).

Construction problems

One problem connected with construction was the tendency for the mix to form lumps in the pugmill. These balls, up to 2 in. in size, were generally coated with cement on the outside, but were devoid of cement on the inside. This appeared to be caused by clay balls present in the soil (Photo 25). Also the high moisture content, characteristic of loess soils, was a contributing factor. While the disking did reduce the moisture content and break up some of the clods, it was not sufficient to eliminate this condition.

A second problem was the tendency for the upper ½ to 1 in. of the base to become loose after traffic had been on it a short time. With very little effort this upper layer could be separated from the rest of the base (Photo 24). This appeared to be caused partly by the smooth teeth marks left by the spike drag (Photo 26). Also the long period of handling and reworking the surface material during finishing operations was a contributing factor (Photo 20).

TESTING

Various tests were conducted before, during, and after construction of the soil-cement base. Some of these tests are normally associated with this type of construction; others were carried out specifically for the experimental features of this project.

Soil Survey

A soil survey was made of the entire project prior to construction. The results of this survey are summarized in Appendix C.

Soil-Cement Mix Design

The soil-cement mix design has been discussed elsewhere in this report. The laboratory reports are included in Appendix B.

PHOTO 23: Completed base with RC-O cure.

PHOTO 24: Separation of the top 3/4 inch of material from the rest of the base.

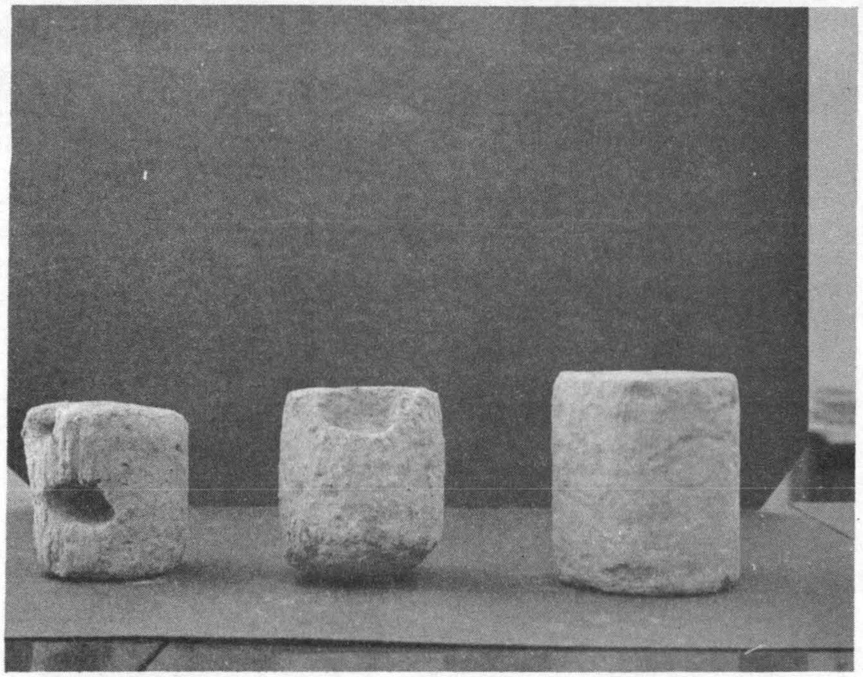

PHOTO 25: Core samples after completion of 12 freeze-thaw cycles. Note the voids in the two cores on the left due to disintegration of clay lumps present in the mix.

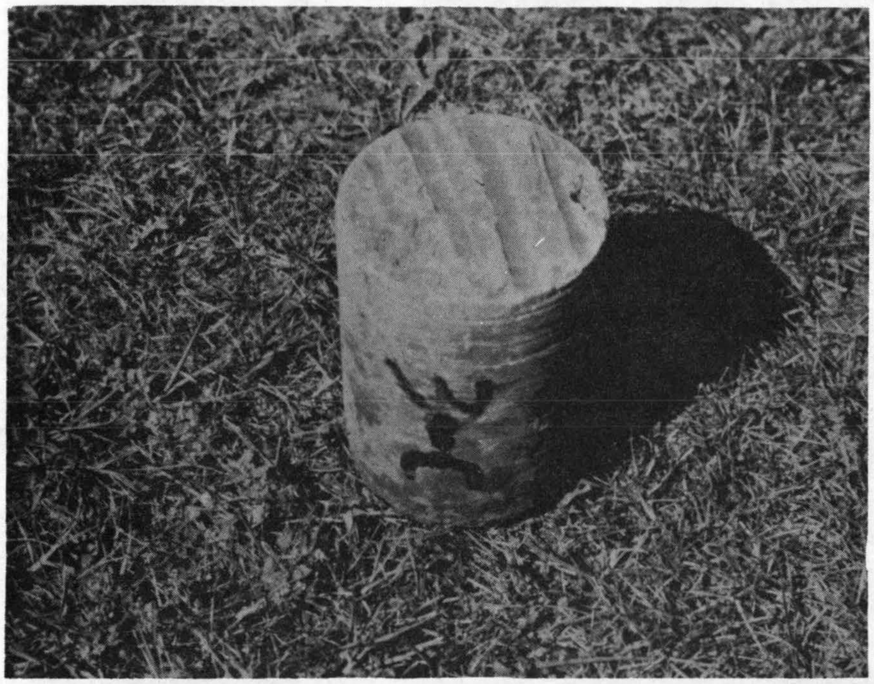

PHOTO 26: Core sample from soil-cement base. Note marks caused by the spike-tooth drag. During coring operations the core broke on this plane (½ to 1" below surface).

Borrow Soil

The soil for the soil-cement base was obtained from a large hill adjacent to the right of way near the center of the project. Before this borrow was selected, samples were obtained at various elevations to a total depth of 25 ft.

Laboratory analysis of these samples showed that the plasticity index of the soil varied from 6 to 12, and that the clay content ranged from 20 to 25 percent. The soil in the top 1 ft. contained 27 percent clay, however, this soil was not used in the soil-cement (See Table No. 1).

It was expected that the physical characteristics of the soil used in the experimental soil-cement sections would not vary appreciably from those observed in the preconstruction samples. Since the soil was not considered as variable, it was important to establish the characteristics of the soil actually used in each soil-cement section and to record any major deviations which might have an effect on the future performance of the soil-cement base. For this purpose composite samples were obtained from the soil entering the pugmill during construction of each experimental section (See Table No. 2).

Cement

In order to determine the uniformity of the cement used in the experimental soil-cement base sections, composite samples were

Table No. 1

SOIL CHARACTERISTICS

Borrow Area for Soil-Cement Base
(Sampled Before Construction)

DEPTH (FT.)	L.P.L.	P.I.	PASSING NO. 200 SIEVE (PERCENT)	CLAY CONTENT (PERCENT)	P.R.A. CLASS.
0 - 1.0	24	12	99	27	A-6(9)
1.0 - 5.0	22	12	99	21	A-6(9)
5.0 - 9.0	22	12	99	23	A-6(9)
9.0 - 13.0	22	12	99	24	A-6(9)
13.0 - 17.0	24	9	99	25	A-4(8)
17.0 - 21.0	25	6	100	20	A-4(8)
21.0 - 25.0	24	9	100	23	A-4(8)
0 - 25.0	23	10	99	22	---

Table No. 2

SOIL CHARACTERISTICS

Experimental Soil-Cement Base Sections
(Sampled During Construction)

TEST SECT.	L.P.L.	P.I.	PASSING NO. 200 SIEVE (PERCENT)	CLAY CONTENT (PERCENT)	P.R.A. CLASS.
1	23	9	99	22	A-4(8)
2	23	12	98	23	A-6(9)
3	22	13	99	24	A-6(9)
4	23	11	99	18	A-6(8)
5	23	10	100	20	A-4(8)
6	23	9	99	20	A-4(8)
7	23	10	100	18	A-4(8)
8	23	12	99	24	A-6(9)
9	21	13	99	24	A-6(9)
10	22	13	100	22	A-6(9)
11	21	12	99	22	A-6(9)
12	21	10	100	22	A-4(8)
13	21	12	100	22	A-6(9)
14	20	15	99	20	A-6(10)

obtained from the cement used during construction of each section (See Table No. 3).

Density of Soil-Cement Base

Soil-cement specimens prepared in the laboratory for the freeze-thaw tests were used to determine the basic cement content (11 percent). These were compacted to maximum laboratory density, which was 101-102 lbs. per cu. ft.

A maximum field density was determined as soon as the plant began operation, and this was checked frequently during construction of the base. The required base density was 90 percent of the maximum field density. During construction of the 14 experimental sections the maximum field density was 98.6 lbs. per cu. ft. The optimum moisture content was 21.8 percent. These figures were obtained by the construction inspectors, who were responsible for the compaction control. Table No. 4 is a summary of the density tests made by the oil method on the compacted base.

A second check on the density of the base was obtained when cores were drilled approximately 5 days after construction. The density of these cores was obtained in the laboratory in preparation for freeze-thaw testing. The average density for each section is shown in Table No. 5.

At intervals during construction of each experimental section, research personnel obtained samples of the soil cement . .

Table No. 3

LABORATORY CEMENT TESTS

Experimental Soil-Cement Base Sections
(Sampled During Construction)

TEST SECT.	BLAINE SPECIFIC SURFACE	AIR CONTENT (PERCENT)	COMPRESSIVE STRENGTH CUBES (PSI)	
			3-DAY	7-DAY
1	3701	9.2	2729	3867
2	--	8.5	2629	3475
3	3715	8.5	2554	3508
4	3805	8.7	2542	3579
5	3701	8.4	2746	3583
6	3615	8.5	2779	3604
7	3562	8.8	2687	3508
8	3940	8.5	--	3313
9	3940	9.0	2575	3687
10	3875	9.3	2604	3708
11	3910	9.0	2483	3454
12	3855	8 6	3154	4517
13	3820	8.7	2442	3321
14	3940	8.6	2458	3458

Table No. 4

DENSITY OF COMPACTED BASE

Experimental Soil-Cement Sections
(Oil Method)

SECT. NO.	DESIGN CEMENT (PERCENT)	MAX. FIELD DENSITY (PCF)	NO. OF TESTS	AVERAGE DENSITY (PCF)	PERCENT OF MAX.	MOIST. CONTENT (PERCENT)
1	7	98.6	3	93.4	95	23.9
2	7	98.6	3	91.5	93	23.3
3	13	98 6	4	91.7	93	22.3
4	7	98.6	3	89.4	91	21 9
5	9	98 6	2	95.8	97	22.8
6	13	98 6	3	92.2	93	22.7
7	11	98.6	3	92.4	94	23.6
8	7	98 6	2	89.3	90	22.1
9	11	98.6	2	92.4	94	23.6
10	9	98.6	3	92.2	93	22.8
11	11	98.6	2	92.1	93	22.7
12	7	98.6	3	86.3	87	19.1
13	9	98.6	1	93.6	95	23.2
14	13	98.6	3	91.9	93	22.9

Table No. 5

DENSITY OF CORES

Experimental Soil-Cement Base Sections
(Drilled At Age 5 Days)

SECT. NO.	DESIGN CEMENT (PERCENT)	NO. OF TESTS	AVERAGE DENSITY (PCF)	AVERAGE MOIST. (PERCENT)	RANGE OF DENSITY	
					HIGH (PCF)	LOW (PCF)
1	7	-	--	---		
2	7	-	--	---		
3	13	6	92.6	23.8	98.4	83.5
4	7	6	91.8	23.0	97.3	84.8
5	7	6	96.7	21.9	100.7	93.9
6	13	6	92.7	20.7	98.5	87.9
7	11	6	94.8	20.0	98.8	91.8
8	7	6	94.5	23.0	99.9	85.6
9	11	5	93.5	21.5	96.8	89.7
10	9	6	94.8	21.2	96.3	92.3
11	11	6	93.2	22.7	94.5	91.6
12	7	6	91.3	21.9	95.6	86.8
13	9	6	91.7	23.2	95.1	89.0
14	13	6	94.4	22.8	98.1	90.9

mixture as it was discharged from the pugmill. One Proctor specimen was prepared from each sample. The delay between sampling and compaction varied from 20 to 30 minutes.

The purpose for preparing these specimens was to obtain a record for experimental sections of the maximum attainable field density. The density of each specimen is shown in Table No. 6.

During construction of the soil-cement base, a special inplace density test was made. A nuclear density probe was used to determine the moisture content and density of the base material immediately after final compaction (Photo 27). While the results obtained by this method have been found to be quite accurate, in this instance there was no way of knowing the depth of influence of the probe. The density indicated may be that for a depth of material either greater than or less than the total depth of the soil-cement base, therefore no results are included in this report.

Moisture in Soil-Cement

In order to compensate for moisture lost during hauling and placing, the mixture was produced at slightly above the optimum moisture content. Weather conditions sometimes affected the moisture content of the borrow soil, and this complicated the control of the moisture during mixing. In general, however, good

Table No. 6

MAXIMUM FIELD DENSITY

Experimental Soil-Cement Base Sections
(Sampled and Compacted by Research Department)

TEST SECT.	SAMPLE NUMBER	DESIGN CEMENT (PERCENT)	MOLDING MOISTURE (PERCENT)	DRY DENSITY (LBS. PER CU. FT.)
1	1	7	23.7	95.9
	2	7	21.9	97.7
	3	7	31.6	90.6
2	1	7	22.7	97.5
	2	7	22.7	99.1
	3	7	24.2	97.8
3	1	13	25.4	96.6
	2	13	25.0	96.8
	3	13	24.2	97.1
4	1	7	22.7	99.7
	2	7	23.5	99.5
	3	7	22.7	99.3
	4	7	23.5	99.0
5	1	9	22.0	100.2
	2	9	23.8	98.8
	3	9	25.0	97.1
	4	9	27.0	93.2
6	1	13	22.7	98.3
	2	13	24.2	97.2
	3	13	23.5	98.2
	4	13	24.6	96.8

Table No. 6 (Contd.)

MAXIMUM FIELD DENSITY

Experimental Soil-Cement Base Sections
(Sampled and Compacted by Research Department)

TEST SECT.	SAMPLE NUMBER	DESIGN CEMENT (PERCENT)	MOLDING MOISTURE (PERCENT)	DRY DENSITY (LBS. PER CU. FT.)
7	1	11	25.0	98.0
	2	11	22.7	99.7
	3	11	22.7	100.0
8	1	7	23.5	97.2
	2	7	25.8	94.7
	3	7	22.0	99.5
9	1	11	22.7	99.9
	2	11	22.7	99.7
	3	11	23.5	97.8
10	1	9	23.5	98.7
	2	9	21.2	100.8
	3	9	22.0	100.8
11	1	11	20.9	100.3
	2	11	22.7	97.7
	3	11	23.1	99.3
12	1	7	21.6	99.2
	2	7	22.0	99.2
	3	7	23.5	99.2
13	1	9	23.1	99.2
	2	9	22.7	99.5
	3	9	22.3	99.4
14	1	13	22.7	99.9
	2	13	23.5	98.4
	3	13	24.6	95.8
	4	13	23.8	98.0

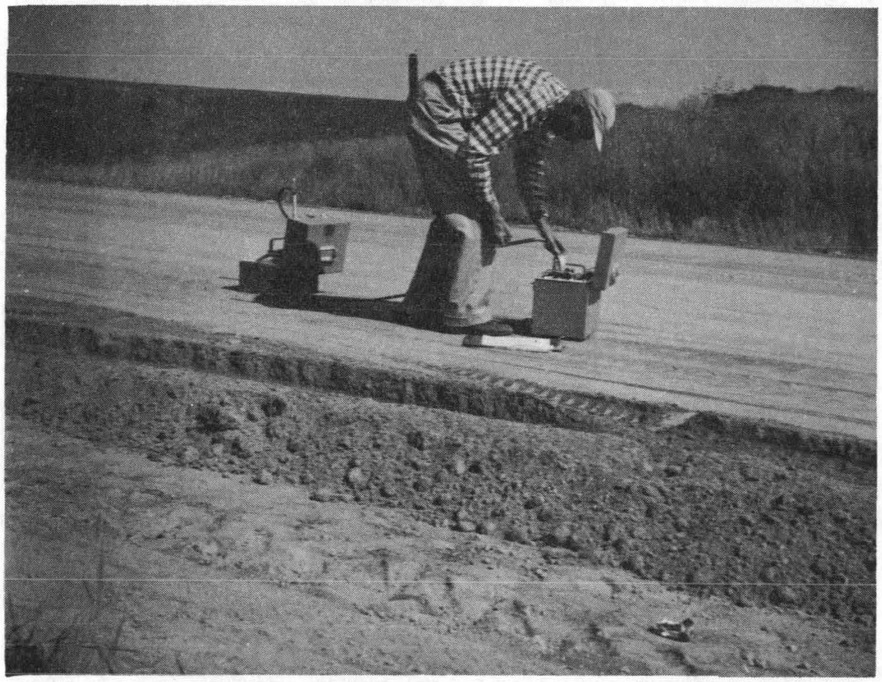

PHOTO 27: Checking base density with nuclear probe.

control was maintained, as is evidenced by the data shown in Table No. 7.

Cement Content

At least once each day the amount of cement actually used was checked against the design quantity. These field checks of cement content for the 14 experimental sections are shown in Table No. 8.

In addition to the field checks, samples of the soil-cement mixture were obtained from the pugmill. These samples were submitted to the Materials Department Laboratory, where the cement content of the mixture was determined by chemical analysis. The results of these determinations are also shown in Table No. 8.

The field checks of cement content do not agree with the laboratory test results. Both methods are, of course, subject to several errors. The laboratory tests are especially affected by two sources of error. One of these is the difficulty of obtaining small representative samples from relatively large amounts of material. No effort was made to measure this error, although it could (and probably should) have been done by taking duplicate samples.

The second source of possible error is the laboratory test procedure. Here the accuracy was established by a series of prepared samples, which were carefully proportioned in the laboratory.

Table No. 7

MOISTURE WHEN MIXED

Experimental Soil-Cement Base Sections
(Sampled at Pugmill)

DATE	NO. OF TESTS	AVERAGE MOISTURE* (PERCENT)	MAXIMUM VARIATION FROM AVERAGE
8- 9	4	22.7	-1.3
8-10	5	24.1	+1.6
8-11	6	25.5	-2.6
8-12	7	24.5	+1.2
8-13	6	23.7	-1.0
8-14	6	23.8	+1.4
8-15	7	24.8	-2.1
8-16	6	23.8	-1.3
8-17	6	23.5	+1.9
8-18	5	22.9	+1.0
8-24	4	23.4	-1.7
8-25	4	23.4	-2.0
8-26	4	22.7	-1.4
8-27	3	23.0	+0.5
8-28	5	23.2	+0.3
8-29	5	23.3	+0.9
8-30	2	22.7	+0.7
8-31	4	23.2	-0.4

*Optimum moisture content was approximately 21.8%.

Table No. 8

CEMENT CONTENT

Experimental Soil-Cement Base Sections

SECT. NO.	DESIGN CEMENT (PERCENT)	ACTUAL CEMENT CONTENT			
		LAB. TESTS		FIELD CHECKS	
		NO. OF TESTS	AVERAGE PERCENT	NO. OF CHECKS	AVERAGE PERCENT
1	7	3	7.6	1	6.8
2	7	3	8.4	2	6.5
3	13	3	13.8	2	13.0
4	7	4	6.9	2	7.2
5	9	4	9.0	1	10.1
6	13	4	10.3	2	11.9
7	11	3	10.0	2	11.2
8	7	3	7.4	1	8.0
9	11	3	9.2	2	10.4
10	9	3	7.6	2	8.4
11	11	3	11.2	1	11.7
12	7	3	7.2	2	7.1
13	9	3	9.0	2	9.9
14	13	3	13.4	3	13.7

The chemist did not know the cement content of these samples, which were submitted to him in random order. The results of these proof tests are shown in Table No. 9. The details of the laboratory procedure may be found in Appendix E.

The field checks on cement content were made by observing the total tons of soil-cement mixture produced from one or more carloads of cement. It might be suggested that the variation in cement content noted in the experimental sections is due in part to the frequent changes which had to be made in the cement proportioning equipment. Table No. 10 is a summary of cement checks made during periods when soil-cement was being produced for the regular (non-experimental) portions of the road. During these periods the plant operated for several days without change in the design cement content.

From the data shown in Table No. 8 and No. 10 it appears that the accuracy of cement proportioning was about ± 1 percent of the intended amount. These figures also reflect, of course, any inaccuracy contained in the procedure used in making the field checks. A possible source of error was the difficulty sometimes experienced in determining the beginning and end points for any particular carload of cement passing through the plant.

Compressive Strength

The unconfined compressive strength of soil-cement specimens prepared in the laboratory is affected by the cement content. The

Table No. 9

LABORATORY ACCURACY TEST

Cement Content By Chemical Analysis

SAMPLE NO.	ACTUAL CEMENT CONTENT (PERCENT)	CEMENT CONTENT BY TEST (PERCENT)
1	13.0	13.0
2	11.0	11.2
3	9.0	8.9
4	11.0	11.2
5	13.0	12.7
6	7.0	6.8
7	11.0	11.2
8	13.0	12.9
9	9.0	8.8
10	7.0	7.1
11	9.0	9.2
12	7.0	6.9

Table No. 10

FIELD CHECKS OF CEMENT CONTENT

Regular (Non-experimental) Base Sections

DATE	DESIGN CEMENT (PERCENT)	CEMENT CONTENT (PERCENT)
8- 2	11.0	12.5
8- 2	11.0	11.0
8- 3	11.0	11.9
8- 4	11.0	11.8
8- 4	11.0	11.2
8- 4	11.0	11.6
8-24	11.0	11.0
8-25	11.0	11.6
8-25	11.0	11.3
8-26	11.0	10.9
8-27	11.0	10.1
8-27	11.0	12.4
9- 1	11.0	10.9
9- 2	11.0	11.1
9- 2	11.0	11.4
9- 2	11.0	11.3
9- 4	11.0	12.3
9- 4	11.0	12.0
9- 5	11.0	11.8
9- 5	11.0	10.9
9- 6	11.0	11.2
9- 6	11.0	11.1
9- 7	11.0	11.3

upper curve in Figure 2 was obtained from tests made under controlled conditions such that the cement content was the only variable. The specimens were compacted in Proctor molds, moist cured for 7 days, and tested at 8 days following 24 hours immersion in water.

The lower curve in Figure 2 does not show a precise relationship between cement content and compressive strength. This curve was obtained from tests of cores drilled from the experimental soil-cement base sections. They were drilled at an average age of 5 days, and tested on the eighth day, following 24 hours immersion in water. The wide variation in strength may possibly be accounted for by the fact that field control is not equal to laboratory control in the following:

a. Accuracy of proportioning
b. Mixing (Photo 25)
c. Compaction
d. Curing

The data used in preparing Figure 2 is contained in Table No. 11 and Table No. 12. The cement content of the cores is the average for each experimental section as determined by laboratory tests previously described. (The cement content of the actual material in each core was not determined, although this appears to be the preferred procedure for future investigations.)

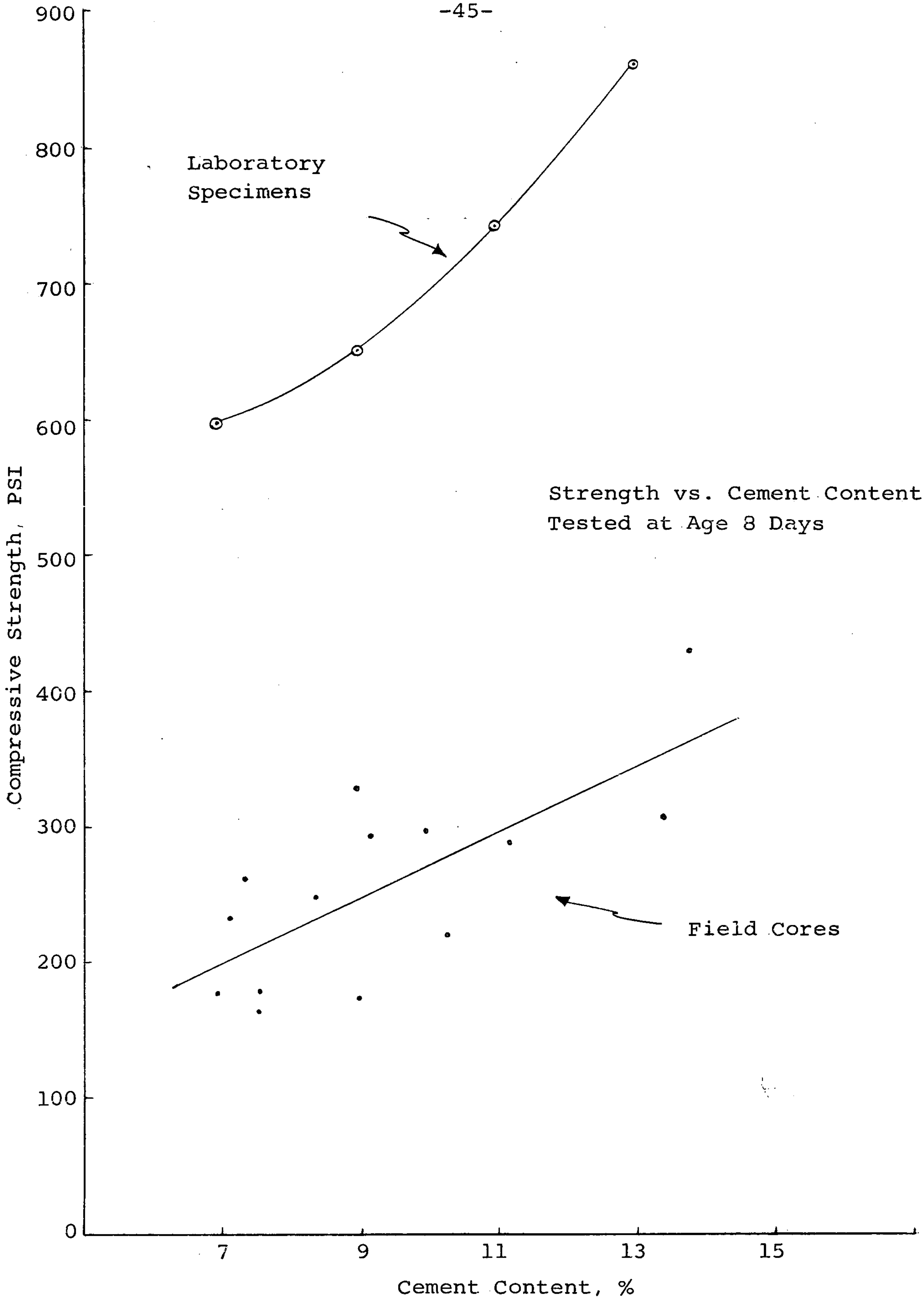
900
800
700
600
500
400
300
200
100
0
Compressive Strength, PSI
Laboratory
Specimens
Strength vs. Cement Content
Tested at Age 8 Days
Field Cores
7
9
11
13
15
Cement Content, %

FIG. 2

Table No. 11

COMPRESSIVE STRENGTH

Laboratory Specimens

CEMENT CONTENT (PERCENT)	SPECIMEN NO.	STRENGTH (PSI)	AVERAGE STRENGTH (PSI)
7	5	540	
	6	569	
	7	628	
	9	627	
	10	624	
			598
9	1	643	
	2	666	
	3	587	
	9	653	
	10	702	
			650
11	1	745	
	2	687	
	6	827	
	9	730	
	10	730	
			744
13	2	784	
	5	880	
	7	887	
	8	875	
	10	876	
			860

Table No. 12

COMPRESSIVE STRENGTH

Experimental Soil-Cement Base Sections
(Cores 4 in. dia. x 4.6 in.)

SECTION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DESIGN CEMENT (PERCENT)	7.0	7.0	13.0	7.0	9.0	13.0	11.0	7.0	11.0	9.0	11.0	7.0	9.0	13.0
CEMENT BY LAB. TEST (PERCENT)	7.6	8.4	13.8	6.9	9.0	10.3	10.0	7.4	9.2	7.6	11.2	7.2	9.0	13.4
AGE WHEN CORED (DAYS)	6	5	5	5	5	5	5	6	6	6	5	5	6	7
AGE WHEN TESTED (DAYS)	11	9	9	8	8	8	8	8	8	8	9	8	8	9
STRENGTH (PSI)	239	225	549	201	382	150	188	342	227	177	304	242	194	356
	231	318	309	183	250	132	383	250	341	186	324	238	135	272
	161	140		172	355	262	259	222	258	184	275	220	203	297
	(83)	282		167	320	338	355	236	348	108	250		166	302
				164										
AVERAGE STRENGTH (PSI)	179	249	429	177	327	221	296	263	294	164	288	233	175	307

Freeze-Thaw Tests

The freeze-thaw test is the principal basis used in Iowa for determining the amount of cement required for a soil-cement base. This is a laboratory test, and the specimens are usually prepared in the laboratory.

In order to compare the results obtained with laboratory and field specimens, cores from the experimental base sections were subjected to the regular 12 cycles of freezing and thawing. The comparison is shown in Figure 3. The average test values for each section are contained in Table No. 13, and the test values for individual cores are in Appendix G.

The large variations in freeze-thaw loss of individual cores appear to be due in part to the presence of clay lumps near the surface of some specimens (Photo 25).

Part of the difference between the laboratory specimens and the field cores can probably be explained by the better mixing, compacting and curing employed in preparing the laboratory specimens. The laboratory specimens had a density of 101 to 102 lbs. per cu. ft., whereas the field cores had a density of 92 to 94 lbs. per cu. ft. (average per section).

CONCLUSIONS AND RECOMMENDATIONS

Observations of the various operations were made during construction of this experimental project. From these observations

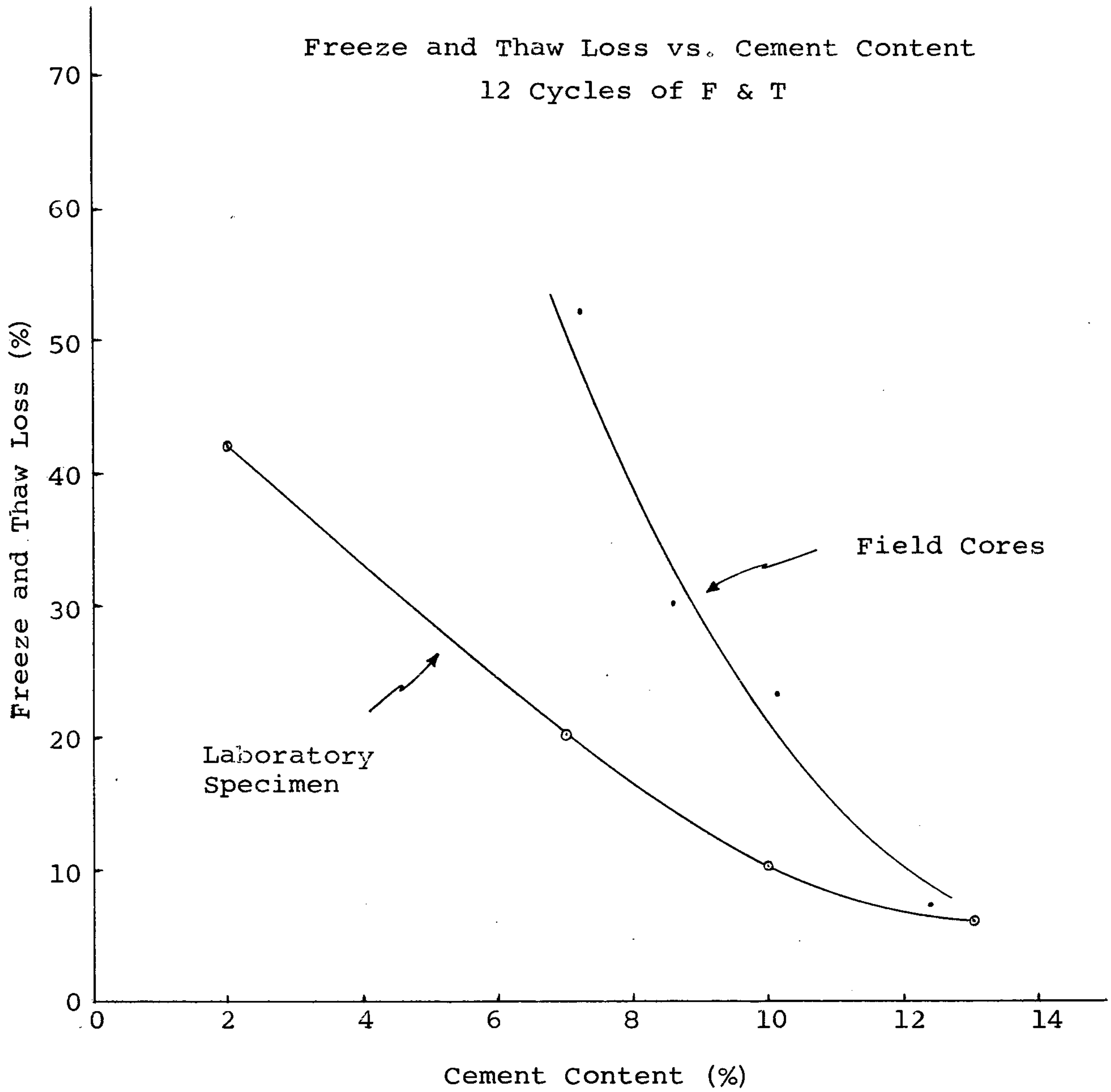
Freeze and Thaw Loss vs. Cement Content
12 Cycles of F & T
Freeze and Thaw Loss (%)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Field Cores
Laboratory Specimen
Cement Content (%)

FIG. 3

Table No. 13

FREEZE-THAW TESTS

Experimental Soil-Cement Base Sections
Cores 4 in. dia. x 4.6 in.

SECT. NO.	DESIGN CEMENT (PERCENT)	AVERAGE CEMENT BY LABORATORY TEST (PERCENT)	AVERAGE DENSITY (PCF)	AVERAGE F - T LOSS (PERCENT)	NO. OF TESTS F - T
4	7	6.9	90.7	58.8	5
8	7	7.4	94.4	29.3	6
12	7	7.2	91.3	58.2	6
AV.		7.2	92.2	51.7	17
5	9	9.0	96.7	17.2	6
10	9	7.6	94.8	36.3	6
13	9	9.0	91.6	35.4	6
AV.		8.6	94.4	29.6	18
7	11	10.0	94.8	9.5	5
9	11	9.2	93.5	31.0	5
11	11	11.2	93.2	28.1	5
AV.		10.1	93.8	22.9	15
3	13	13.8	93.7	7.6	5
6	13	10.3	93.0	8.8	5
14	13	13.4	94.5	5.4	5
AV.		12.4	93.7	7.3	15

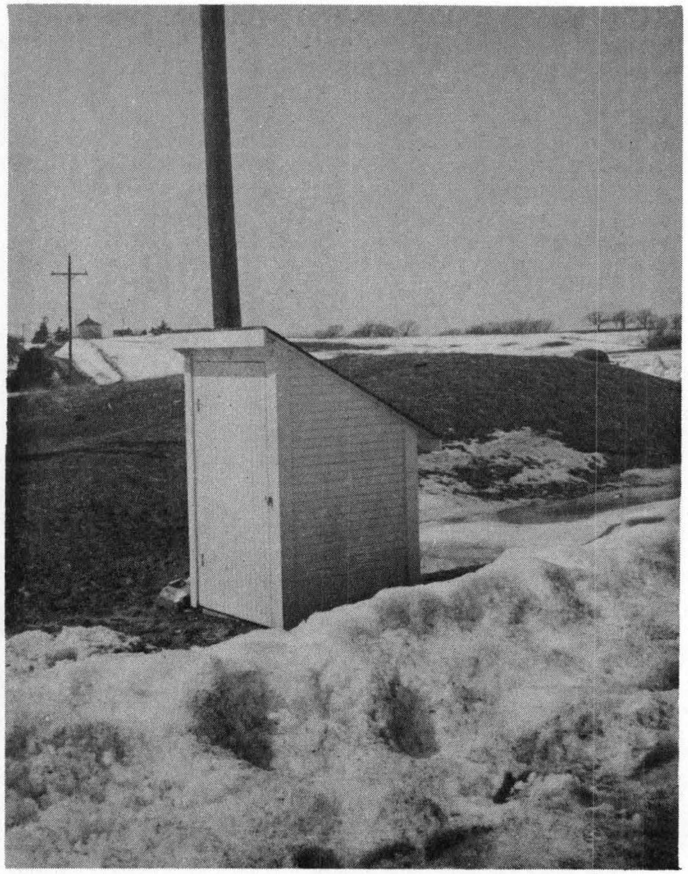

PHOTO 28: Housing for the temperature recording equipment.

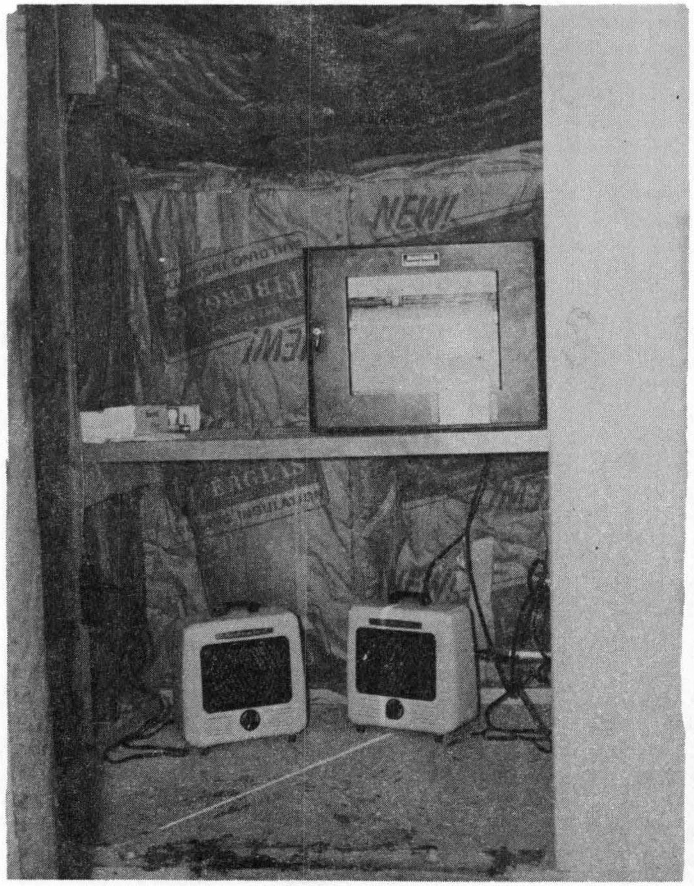

PHOTO 29: Interior of temperature recording installation. Recording potentiometer (upper right), thermostatically controlled space heaters (below).

it is concluded that certain conditions encountered on this project should be corrected in future construction of this type. These conditions, as mentioned elsewhere in this report, are:

1. The high moisture content of the borrow soil caused the soil-cement mixture to form lumps of material which contained very little cement.

2. The spike-tooth drag created slick, dense planes ½ to 1 in. beneath the surface of the compacted base.

3. During final finishing, large amounts of loose material were manipulated and recompacted (2 to 3 hours after initial placement) to form the surface of the base.

To avoid the problems created by the conditions mentioned above, it is recommended that:

1. Fine grained borrow soil of this type (loess) should be maintained at a moisture content of 12 percent or less and pulverization be such that 100 percent of the soil particles will pass a No. 4 sieve (exclusive of rocks). Also, the proportion of the total mixing time devoted to dry and wet mixing might bear further investigation.

2. Teeth of spike drags be kept sharp at all times.

3. Care be taken to minimize the amount of material that has to be worked to shape the finished surface and that loose material be maintained at a moisture content of not less than optimum.

In addition to these recommendations, some consideration should be given to the development of equipment and procedures which would result in the construction of soil-cement bases with a minimum of handling and a reduction in the delay between the placement and final compaction. Also, noting that strength and durability are dependent on the density of the material, it seems desirable to increase the minimum density requirements from 90 to 95 percent of maximum proctor field density.[2]

FUTURE RESEARCH

Observations and testing will be continued as long as additional information can be obtained. Some of these observations and tests have been completed during the writing of this report, some are still in progress, and others will be performed in the near future.

1. Testing already completed (results being analyzed)
    a. Condition surveys
    b. In-place CBR tests
    c. Plate-bearing tests
    d. Benkelman Beam Tests
    e. Core samples for strength determination
    f. Moisture samples

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[2] "Soil Stabilization with Portland Cement", HRB Bulletin 292.

2. Testing in progress

   a. Temperature recording. A recording thermometer was installed at station 1005 + 00 in Monona County. Thermocouples were placed at various depths in the road and a continuous record of the temperatures is being made. See photos 28 and 29 and Appendix F.

   b. Moisture sampling in the immediate area of the temperature recorder and in the sections with chemically treated subbases.

3. Future testing

   a. Condition surveys conducted at regular intervals of time.

   b. Core samples for strength determination when the base is approximately one year old.

ACKNOWLEDGMENTS

We wish to acknowledge the cooperation of all departments of the Iowa State Highway Commission for their part in the preliminary evaluation, design, inspection and testing of this experimental soil-cement base project.

T. E. McElherne, Materials Engineer, prepared the specifications contained in the Special Provisions. The Materials Department Laboratory personnel performed the many soil-cement design tests required prior to construction.

Donald A. Anderson, Soils Engineer, provided special soil information related to the project and helped in the selection of the experimental sections.

J. F. Holdefer, District Engineer, arranged preconstruction meetings between the contractor and Commission personnel involved in the project.

Construction of the experimental project was under the supervision of W. A. Pattison, Resident Construction Engineer. Personnel from Mr. Pattison's office gave invaluable assistance to the Research Department in carrying out special testing during and after construction.

D. L. Smith, District Construction Engineer, assisted in the solution of construction problems.

R. F. Mumm, District Materials Engineer, calibrated the central mixing plant equipment.

V. G. Gould and M. J. Stump, Construction Department, gave valuable assistance in determining the correct construction procedure.

M. I. Sheeler, Chief Chemist (IHC) developed a laboratory procedure determining the cement content of soil-cement mixtures by chemical analysis.

Personnel from the Materials Department laboratory took part in the extensive postconstruction sampling and testing.

The Maintenance Department has been helpful in scheduling their maintenance so that it would not interfere with any of the special testing.

J. B. Hemwall, B. Thomas, and W. L. Shearer, all of the Dow Chemical Company furnished technical advice during construction of a section of chemically (Dow ET-506) stabilized soil-aggregate subbase.

J. P Badman, Manager, Highway Construction Chemicals, of Armour Industrial Chemical Company, furnished technical advice during construction of a section of chemically (Arquad 2HT) stabilized soil - aggregate subbase.

Mr. J. M. Gribble, Vice-President of Lee & Johnson Construction Company, cooperated with the Commission in trying suggested changes in procedure during construction.

APPENDIX A

Plan and Estimate of Quantities

Special Provisions; October 18, 1960

Final Estimate

EROSION SEPTEMBER 5, 1961 LETTING

Crawford-Harrison & Monona F-861 (6) Bit. Seal Coat Let Oct-18-1960

FED. ROAD DIST. NO.	STATE	F PROJ. NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
8	IOWA	861 (6)		1	40

CONVENTIONAL SIGNS

- CITY LIMITS
- STATE OR COUNTY LINES
- SECTION LINES
- FENCE LINES
- RIGHT OF WAY LINES
- GUARD RAIL
- TRAVELED WAY
- BASE OR SURVEY LINE
- RAILROADS
- PRESENT TILE DRAINS
- PROPOSED TILE DRAINS
- PIPE LINE
- CULVERTS
- TELEPHONE, TELEGRAPH OR TRANSMISSION LINES
- PRIMARY ROAD NUMBERS (15)
- U.S. ROAD NUMBERS (85)
- INTERSTATE ROAD NUMBERS (80)

STATE OF IOWA

STATE HIGHWAY COMMISSION

PLAN & PROFILE OF PROPOSED IMPROVEMENT ON THE PRIMARY ROAD SYSTEM

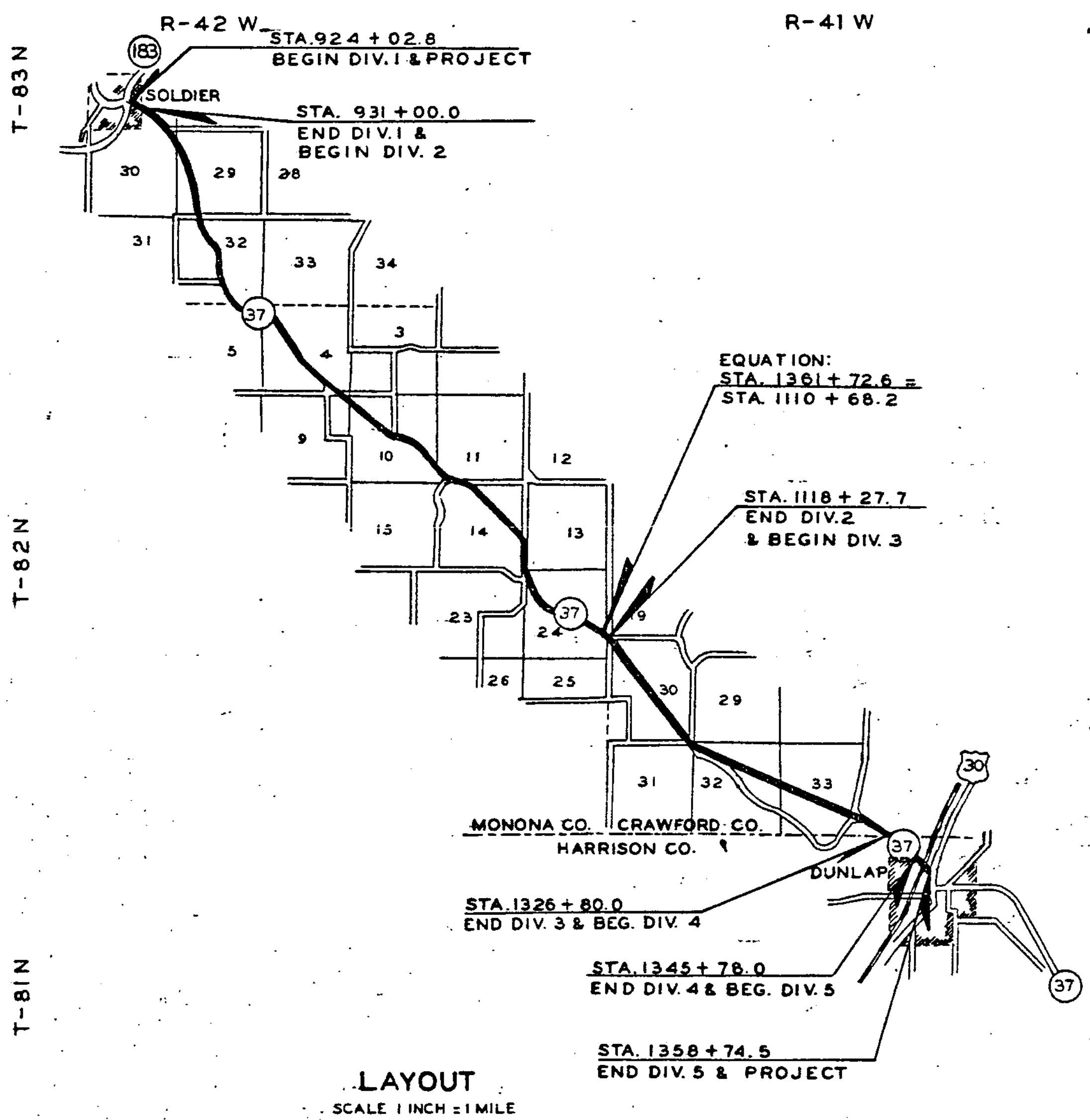
SOIL CEMENT BASE WITH BITUMINOUS SEAL COAT F-PROJ. NO. 861 (6)

ON IOWA NO. 37 FROM SOLDIER TO DUNLAP

CRAWFORD - HARRISON - MONONA CO'S

SCALES { PLAN 1 INCH=100 FT. / PROFILE HOR. 1 INCH=100 FT., VERT. 1 INCH=10 FT.

THE IOWA STATE HIGHWAY COMMISSION STANDARD SPECIFICATIONS FOR CONSTRUCTION WORK, SERIES OF 1960, SHALL APPLY TO WORK ON THIS PROJECT



LAYOUT

SCALE 1 INCH = 1 MILE

MILEAGE SUMMARY

DIV. 1 — URBAN (TOWN OF SOLDIER)		
STA. 924+02.8 TO STA. 931+00.0		697.2 FT.
NET LENGTH OF DIV. 1	=	697.2 FT. = 0.132 MILES
DIV. 2 — RURAL (MONONA COUNTY)		
Sta. 931+00.0 TO STA. 1361+72.6	=	43,072.6 FT.
EQUATION: STA. 991+04.0 = STA. 991+00.0 (LENGTHENS LINE)	=	4.0 FT.
OMIT BRIDGE AT STA. 1057+75.0	=	170.7 FT.
EQUATION: STA. 1120+57.8 = STA. 1117+05.0 (LENGTHENS LINE)	=	352.8 FT.
OMIT BRIDGE AT STA. 1242+45.0	=	183.7 FT.
EQUATION: STA. 1255+67.2 = STA. 1255+73.1 (SHORTENS LINE)	=	5.9 FT.
OMIT BRIDGE AT STA. 1342+46.0	=	215.1 FT.
EQUATION: STA. 1361+72.6 = STA. 1110+68.2		
STA. 1110+68.2 TO STA. 1118+27.7	=	759.5 FT.
NET LENGTH OF DIV. 2	=	43,613.5 FT. = 8.260 MILES
DIV. 3 — RURAL (CRAWFORD COUNTY)		
STA. 1118+27.7 TO STA. 1326+80.0	=	20,852.3 FT.
EQUATION: STA. 1251+14.3 = STA. 1251+43.7 (SHORTENS LINE)	=	29.4 FT.
NET LENGTH OF DIV. 3	=	20,822.9 FT. = 3.944 MILES
DIV. 4 — (HARRISON COUNTY)		
STA. 1326+80.0 TO STA. 1345+78.0	=	1,898.0 FT.
EQUATION: STA. 1344+90.6 = STA. 1344+30.9 (LENGTHENS LINE)	=	59.7 FT.
NET LENGTH OF DIV. 4		1,957.7 FT. = 0.371 MILES
DIV. 5 — URBAN (TOWN OF DUNLAP)		
STA. 1345+78.0 TO STA. 1358+74.5	=	1,296.5 FT.
OMIT BRIDGE AT STA. 1347+20.0	=	284.0 FT.
OMIT RAILROAD AT STA. 1355+23.6	=	18.2 FT.
OMIT RAILROAD AT STA. 1357+06.5	=	27.7 FT.
NET LENGTH OF DIV. 5	=	966.6 FT. = 0.183 MILES
TOTAL NET LENGTH OF PROJECT	=	68,057.9 FT. = 12.890 MILES

INDEX OF SHEETS

A.D.T. 1960	= 220
A.D.T. 1980	= 500
D.H.V.	= 74
D	= 51.0 %
T	= 5.0 %
V.	= 50 M.P.H.
C/A	= PARTIAL

REVISED JULY 17, 1961 SHEETS NO 1, 3, & 33A
REVISED SEPT. 29, 1960 SHEETS NO. 2A, 3, 29A, & 29B
REVISED JULY 24, 1961 SHEET NO 3
REVISED AUG. 3, 1961 SHEET NO. 3 - 37B

APPROVED
R.M. Tutton Sept 8, 1960
Deputy CHIEF ENGINEER IOWA HIGHWAY COMMISSION — DATE

DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
APPROVED
DIVISION ENGINEER — DATE

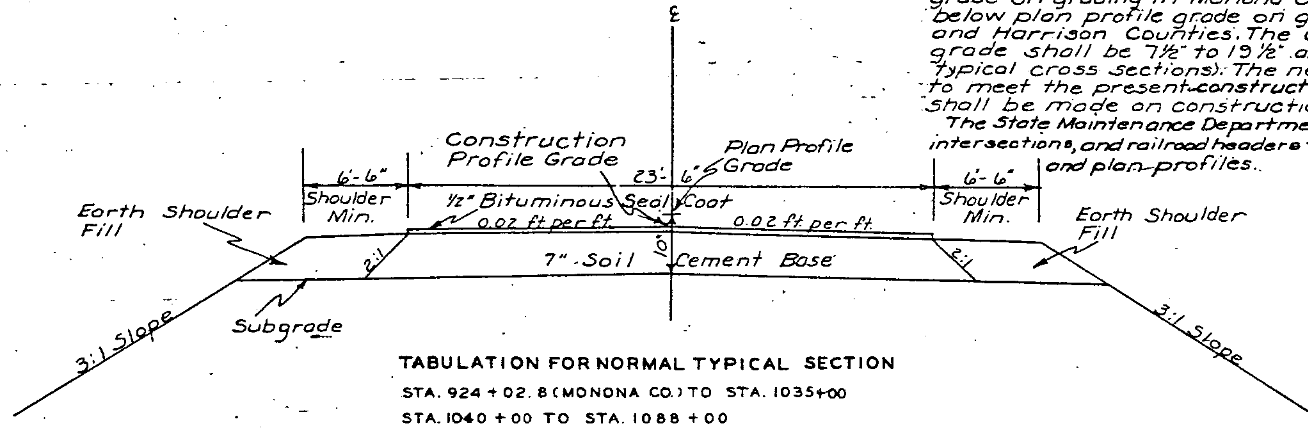
Special 1961

FED. ROAD DIST. NO.	STATE	F PROJ. NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
5	IOWA	861(6)		2A	40

TYPICAL CROSS SECTIONS

Note:
Subgrade was built 10" below plan profile grade on grading in Monona County and 6" below plan profile grade on grading in Crawford and Harrison Counties. The construction profile grade shall be 7½" to 19½" above subgrade (see typical cross sections). The necessary adjustments to meet the present construction grades at bridges and intersections shall be made on construction.
The State Maintenance Department shall place cold mix runouts at bridges, intersections, and railroad headers to allow for 2½" difference between construction and plan profiles.

THIS IMPROVEMENT



TABULATION FOR NORMAL TYPICAL SECTION

STA. 924 + 02.8 (MONONA CO.) TO STA. 1035+00
STA. 1040 + 00 TO STA. 1088 + 00
STA. 1100+00 TO STA. 1206 + 00
STA. 1211 + 00 TO STA. 1245 + 00
STA. 1250 + 00 TO STA. 1303 + 00
STA. 1323 + 00 TO STA. 1353 + 00
STA. 1360 + 00 (MONONA CO.) TO STA. 1316 + 00 (CRAWFORD CO.)

CONSTRUCTION PROCEDURE

1- SOIL-AGGREGATE SUBBASE:

Sta. 1035+00 to Sta. 1040+00
Sta. 1088+00 to Sta. 1100+00
Construct Soil-Aggregate Subbase in accordance with Special Provision No. 452, dated Oct. 18, 1960.

2- GRANULAR SUBBASE:

Sta. 1206+00 to Sta. 1211+00
Sta. 1245+00 to Sta. 1250+00
Sta. 1303+00 to Sta. 1323+00
Sta. 1353+00 to Sta. 1360+00
Sta. 1316+00 to Sta. 1355+12.8
Construct Granular Subbase in accordance with Article 2111.06, 1960 Standard Specifications.

3- SOIL-CEMENT BASE:

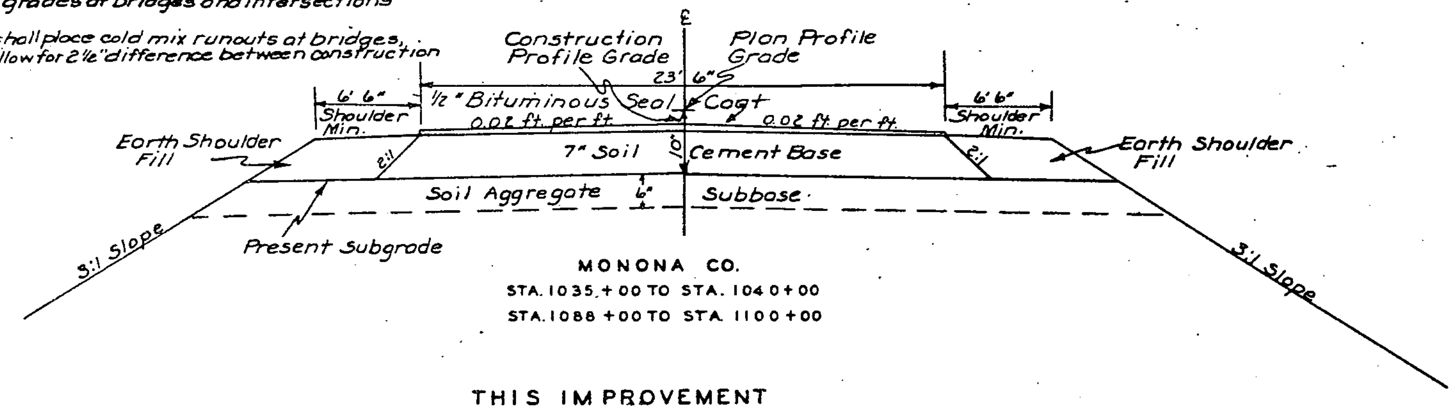
Construct Soil-Cement Base thruout the entire project in accordance with Art. 2207.05 1960 Standard Specifications as modified by Special Provision No. 452 dated Oct. 18, 1960.
Prime soil cement base 26' wide at the rate of 0.2 gal. per sq. yd. within 24 hours after the base has been compacted and finished. When this has set, prime edge slopes of base and adjacent 1 ft. of subgrade 2.25 ft. wide at each edge at the rate of 0.3 gal. per sq. yd.

4- BITUMINOUS SEAL COAT:

Construct ½" Bituminous Seal Coat in accordance with Article No. 2307.04, 1960 Standard Specifications.

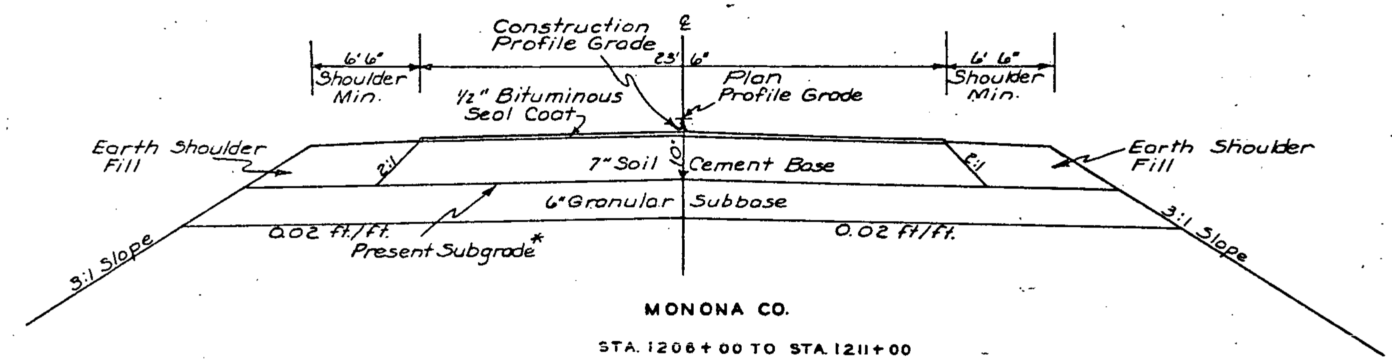
RATES OF APPLICATION:
Binder Bitumen - 0.3 gallons per sq. yd. of bituminous seal coat.
½" Cover Aggregate - 30 pounds per sq. yd. of bituminous seal coat.

THIS IMPROVEMENT



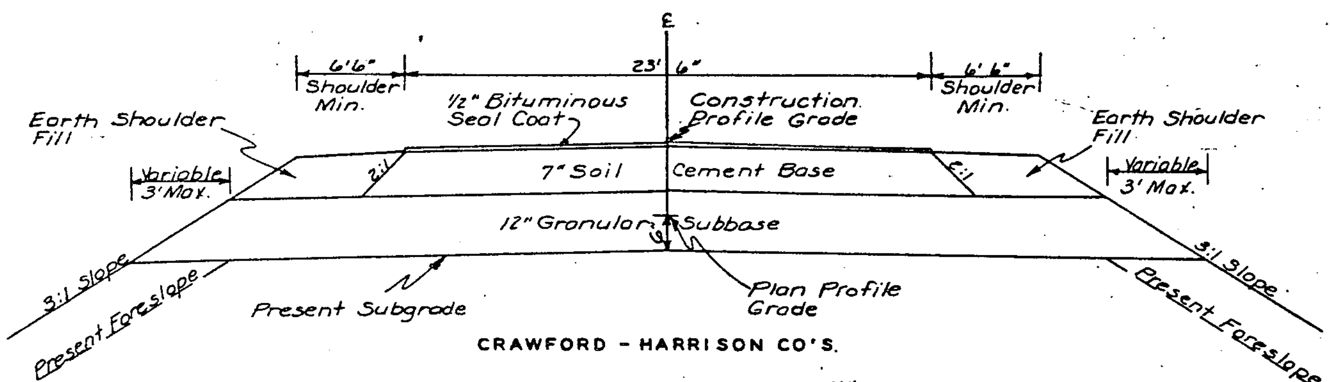
MONONA CO.
STA. 1035 + 00 TO STA. 1040+00
STA. 1088 + 00 TO STA. 1100 + 00

THIS IMPROVEMENT



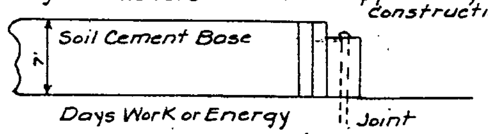
MONONA CO.
STA. 1206 + 00 TO STA. 1211+00
STA. 1245 + 00 TO STA. 1250+00
STA. 1303 + 00 TO STA. 1323+00
STA. 1353 + 00 TO STA. 1360+00

* Material excavated in preparation for placing of granular subbase is included in Class 10 excavation and shall be placed on foreslopes to widen subgrade.



CRAWFORD - HARRISON CO'S.
STA. 1316 + 00 TO STA. 1345 + 78 **
STA. 1348 + 62 TO STA. 1355 + 12.8 **

Note:
Paving contr. shall construct a vertical days work or emergency joint using a removable wooden jig shaped to fit crown. Jig shall be of sufficient strength to hold a hold a straight transverse line and be approved by the engineer in charge of construction.



** Note:
Contractor to familarize himself with this area. The width of subgrade in this area varies from 40' to 45'. Due to the proposed 12" granular subbase, the subgrade will have to be widened to a minimum of 46'. Class 10 excavation is estimated at 3620 cu. yds. Material is available within the right-of-way.

Revised Sept. 29, 1960

FED. ROAD DIST. NO.	STATE	F PROJ. NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
5	IOWA	861(6)		3	40

TABULATION OF SUPERELEVATED CURVES

P.I. Station	Δ	D	e	s
927 + 80.44	33°10'30"	6°	.042	150
950 + 14.4	37°36'	3°	.050	150
1003 + 85.3	21°51'	1°	.018	150
1025 + 67.8	36°27'	3°	.050	150
1047 + 49.5	47°17'	3°30'	.056	150
1113 + 62.5	6°39'	1°	.018	150
1148 + 46.5	26°48'	3°	.050	150
1174 + 85.3	14°15'	2°	.035	150
1192 + 73.3	5°53'	0°30'	* R.C.	150
1247 + 78.12	24°02'	1°30'	.027	150
1276 + 91.0	6°41'	1°	.018	150
1359 + 13.1	4°48'	1°	.018	150
Equation: Sta. 1361 + 72.6 = Sta. 1110 + 68.2				
1188 + 74.6	24°21'30"	2°	.035	150
1272 + 67.2	12°55'30"	2°	.035	150
1302 + 76.5	12°12'	2°	.035	150
1334 + 81.2	16°39'	2°	.035	150

e = Superelevation in feet per foot of width of pavement.

s = Transition in feet from a normal crowned section to a fully superelevated section.

*R.C. = Remove adverse crown, superelevate at normal crown slope.

TABULATION OF RESEARCH SECTIONS

County	Station To Station	Length	% Cement	Remarks
Monona	1035+00 To 1040+00	.500	7	* T.B.C. in Subgrade
Monona	1088+00 To 1100+00	1200	7	** Arquad 2H.T. in Subgrade
Monona	1115+00 To 1127+00	1552.8	13	No Additives in Subgrade
Monona	1152+00 To 1164+00	1200	7	No Additives in Subgrade
Monona	1164+00 To 1176+00	1200	9	No Additives in Subgrade
Monona	1176+00 To 1190+00	1400	13	No Additives in Subgrade
Monona	1195+00 To 1206+00	1100	11	No Additives in Subgrade
Monona	1230+00 To 1241+00	1100	7	No Additives in Subgrade
Monona	1275+00 To 1287+00	1200	11	No Additives in Subgrade
Monona	1287+00 To 1300+00	1300	9	No Additives in Subgrade
Equation	Sta. 1361 + 72.6 = Sta. 1110 + 68.2			
Crawford	1208+00 To 1219+00	1100	11	No Additives in Subgrade
Crawford	1219+00 To 1230+00	1100	7	No Additives in Subgrade
Crawford	1230+00 To 1240+00	1000	9	No Additives in Subgrade
Crawford	1250+00 To 1265+00	1470.6	13	No Additives in Subgrade

* The subgrade is to be scorified to a depth of 6 inches and recompacted to at least 95% of maximum standard density with the addition of 0.25 per cent Dow Chemical Co. T.B.C. based on dry weight of the soil.

** The subgrade is to be scorified to a depth of 6 inches and recompacted to at least 95% of maximum standard density with the addition of 0.25 per cent Arquad 2H.T. based on the dry weight of the soil.

TABULATION OF EXPANSION JOINTS

Sta. 1355 + 48
Sta. 1355 + 97
Sta. 1357 + 68
Sta. 1358 + 42

Construction shall be so arranged to maintain traffic on Iowa Primary No. 183 and on U.S. No. 30. Blading and shaping or any other incidental work in preparation for and maintenance of temporary crossings or detours shall be considered incidental to other work on the project and shall be at no extra expense to the State.
Traffic shall be detoured off of Iowa No. 37 during construction.

General Note:
Contractor to notify all Utility Companies whose facilities are within construction limits of construction starting date.

ESTIMATE OF QUANTITIES

Div.	Class 10 Excavation Roadway & Borrow (Cu. Yds.)	Correction of Subgrade (Miles)	Granular Subbase (Tons)	Soil Stabilizer: Dow Chemical Company TBC (ET 506) (Pounds)	Soil Stabilizer: Arquad 2HT (Pounds)	Soil Cement Base (4): Construction of Soil-Cement Base (Miles)	Soil Cement Base: Aggregate (Tons)	Soil Cement Base: Cement (Barrels)	Soil Cement Base: Primer Bitumen (Gallons)	Bituminous Seal Coat: Cover Aggregate (Tons)	Bituminous Seal Coat: Bituminous Binder (Gallons)
1	1643	0.132	—	—	—	0.132	817	369	507	33	666
2	5311	7.938	5499	2991	7182	8.260	38,183	17,193	31,707	1708	34,658
3	1,656 (9)	3.944	3132	—	—	3.944	18,120	8,231	15,138	815	16,449
4	3620	0.371	5041	—	—	0.371	1774	802	1,423	77	1,539
5	50	0.123	1888	—	—	0.123	665	721	703	25	592
Total	12,280 (8)(1)(2)	12.508	15,560 (3)	2991 (12)(3)(4)	7182 (4)(5)	12.830	59,539 (13)(14)	26,018 (14)	49,478	2658	53,898

Div.	Removal of Existing Conc. Pavement (Sq. Yds.)	Construction of Soil Aggregate Subbase (Mile)	Portland Cement Concrete Pavement 10" Standard (Sq. Yds.)	Shoulder Construction (Sta.)	Corrugated Metal Rdwy. Pipe Culv.: Corr. Metal Rdwy. Pipe Culv. 24"φ (Lin. Ft.)	Metal Aprons 24"φ (No.)	Corrugated Metal Elbows 24"φ No. 12½°	15°	25°	Conc. Rdwy. Pipe Culv.: Conc. Rdwy. Pipe Culv. Lin. Ft. 30"φ	Aprons No. 30"φ	Type "A" Diaphragm 24"φ (No.)	Bridge Sign Assembly (No.)	Project Signs (No.)
1	—	—	—	16.717	—	—	—	—	—	—	—	—	—	1
2	—	0.322	—	872.270	128	—	—	—	—	—	—	3	3	—
3	—	—	—	416.458	620	17	1	16	6	50	1	17	—	—
4	—	—	—	39.154	—	—	—	—	—	—	—	—	—	—
5	805	—	860	19.624	—	—	—	—	—	—	—	—	1	1
Total	805 (5)	0.322 (4)	860	1,364.223 (6)	748	17	1	16	6	50	1	20	4 (11)	2

(1) Includes 1643 cu. yds. for regrading intersection at Sta. 924 + 02.8, 3,186 cu. yds. for excavation for 6" granular subbase, 2,125 cu. yds. for dike fills and 50 cu. yds. for regrading intersection at Sta. 1358 + 74.5.

(2) There will be no overhaul allowed for class 10 excavation. Excess material will be spread along the foreslopes and used for shoulder material. Borrow for dike fills is available with in right-of-way.

(3) Includes 15% of additional material in Div. 2 for irregularities in width of subgrade.

(4) To be constructed according to Special Provision No. 452, dated Oct. 18, 1960.

(5) Broken concrete to be disposed of as directed by the Engineer in charge of construction. Maximum haul one mile. No payment for overhaul will be allowed.

(6) Estimate 28,585 cu. yds. which includes 60% shrinkage. Payment made on stations of shoulder measurement. No payment for overhaul will be allowed.

(7) To be furnished and placed by the State Maintenance Department in accordance with Safety & Traffic, Instruction No. 11 dated March 1, 1956.

(8) Includes 3,620 cu. yds for widening subgrade from Sta. 1316+00 to Sta. 1355+12.8 (Div. 4) and 1656 cu. yds. for excavation for flume at Sta. 1250+00. (Div. 3)

(9) For 3'x2' flume at Sta. 1250+00 see sheet No. 37B

(10) For junction box see sheet No. 37A.

(11) Material shall be taken from Borrow "J" Lt. Sta. 1297+00 to Sta. 1308+50

(12) To be furnished free at Midland Michigan.

(13) Aggr. estimated at 120# per cu. ft. wet weight.

(14) Cement estimated in percentage at 102# per cu. ft. dry weight of aggregate.

SEPTEMBER 5, 1961 LETTING

ESTIMATE OF EROSION CONTROL QUANTITIES

DIV	Special Ditch Control Alternates: Jute Mesh (Squares)	Special Ditch Control Alternates: Sodding (Squares)	Seeding (Acres)	Mulching (Acres)	Fertilizing (Acres)
1	—	—	0.6	—	0.6
2	1579.5	1579.5	186.7	87.9	186.7
3	134.5	134.5	29.4	14.0	29.4
4	—	—	1.7	0.7	1.7
5	—	—	1.0	0.2	1.0
[illegible]	1714.0	1714.0	219.4	102.8	219.4

Div.	Reinforcing Steel (Pounds)	Concrete (Cu. Yds.)	Vitrified Clay Pipe 30"φ (Lin. Ft.)	Conc. Rdwy. Pipe Culv. 24"φ (Lin Ft.)	Concrete Apron 24"φ (No.)	Class 20 Excavation (Cu. Yds.)
1	—	—	—	—	—	—
2	—	—	—	—	—	—
3	1673 (9)	[illegible] (9)	—	—	—	147 (9)
4	—	—	—	—	—	—
5	204 (10)	2.8 (10)	10 (10)	14 (10)	1 (10)	20 (10)
Total	1877	[illegible]	10	14	1	167

Revised 8-3-61 Concrete Estimate in Div. 3 corrected & Total quantities changed accordingly.

Revised Sept. 29, 1960
Revised July 17, 1961
Revised July 24, 1961

Spec. 452

IOWA STATE HIGHWAY COMMISSION
Ames, Iowa

SPECIAL PROVISIONS
for
Project F-861(6), Crawford, Harrison, Monona Counties

October 18, 1960

SUBGRADE

Where no subbase is specified on the plans, the subgrade shall be prepared in accordance with the provisions of Section 2111.04 of the Standard Specifications.

SOIL-AGGREGATE SUBBASE

The soil-aggregate subbase shall be constructed in accordance with Section 2110 of the Standard Specifications. No granular material shall be added. From station 1035 to station 1050 (Monona County) Dow Chemical Company TBC shall be added to the scarified subgrade before compaction in the amount of 0.25 percent of the dry weight of the soil. From station 1088 to station 1100 (Monona County) Arquad 2HT shall be added to the scarified subgrade before compaction in the amount of 0.25 percent of the dry weight of the soil.

SOIL-CEMENT BASE

The soil-cement base shall be constructed in accordance with the Standard Specifications as modified by the following.

2207.02C. In lieu of Section 2207.02C the following shall apply.

Soil. The soil used for the soil-cement base on this project shall be obtained from the borrow area designated on the plans.

2207.04B. In lieu of Section 2207.04B the following shall apply.

Soil for Base Imported. The soil for the soil-cement base on this project is to be 100 percent imported.

2207.05C. In lieu of Section 2207.05C the following shall apply.

Pulverizing. Before the cement is applied, the soil shall be pulverized to such an extent that all of the soil particles will pass a 2-inch sieve and at least 80 percent of the soil particles will pass a No. 4 sieve.

2207.05D. In lieu of Section 2207.05D the following shall apply.

Application of Cement. The cement shall be applied to the unwetted base material by means of regulated feeders or devices which shall insure a uniform cement content in the material being processed.

2207.05E. In lieu of Section 2207.05E the following shall apply.

Mixing. The mixing equipment shall be of the central plant type and shall be so designed that the material can be retained in the mixing chamber under vigorous mixing action for at least 15 seconds. If the mixer is of the continuous-flow type, it shall have twin mixing shafts and shall be equipped with a hopper or bin at the discharge end of the mixer so designed as to minimize the segregation of the mixed materials and of such capacity as to obviate the necessity of stopping the mixer between successive truck loads, under normal operating conditions. Water shall be added to the mixer only during the time that the material is in the middle one-third of the pugmill.

If a batch type mixer is used, the cement and soil shall be mixed for at least ten seconds before the water is introduced into the pugmill. After the water has been added, mixing shall continue until a uniform and intimate mixture of soil, cement, and water is obtained.

2207.05F. In lieu of Section 2207.05F the following shall apply.

Spreading and Compacting. The surface on which the soil-cement is placed shall be moist at the time the mixture is spread. In order to obtain this moist surface, the engineer may require that water be applied to the surface immediately prior to spreading the soil-cement mixture.

The mixture shall be placed on the moistened subgrade in a uniform layer by a spreader or spreaders adapted to this type of work and approved by the engineer. A single spreader may be used provided it is capable of placing a uniform, full-depth layer of material across the full width of the roadbed in one pass. Otherwise, two or more spreaders will be required, and they shall be operated so that the spreading progresses along the full width of the roadbed in a uniform manner. The spreaders shall be operated along the road as close to each other as possible, but at no time more than 100 feet apart. Dumping of the mixture in piles or windrows will not be permitted, unless such action is consistent with the operation of the spreader being used. It may be done only with the approval of the engineer, and under whatever restrictions he deems necessary. Not more than 60 minutes shall elapse between the start of mixing and the start of compacting of the soil-cement.

The initial compaction shall be accomplished with equipment which will insure that compaction will proceed from the bottom of the base upward. The wetted mixture shall be compacted to not less than 90 percent of the maximum density as defined in Section 1101.01, determined on a representative sample of the soil mixed with the designed quantity of cement.

The surface of the base, when the initial compaction has been completed, shall be bladed with a motor grader to secure a uniform cross section. During the blading operation, the surface shall be checked, as necessary, with a template to assure that the desired cross section is secured. The loose mulch produced by the blading operation shall be brought to a moisture content which will insure proper compaction and adhesion. If so directed by the engineer, the surface shall be roughened with a nail drag or similar device. The resulting surface shall then be rolled with a pneumatic-tired roller until all loose material has been thoroughly compacted and the surface brought to a smooth condition. The rolling shall be supplemented with one or more light bladings with a motor grader. The surface blading and rolling shall follow the initial compaction immediately, and shall be completed with minimum delay.

The elevation of the edges of the subgrade or subbase will be indicated by grade stakes. The finished surface of the soil-cement base shall be constructed to within 0.05 feet of the desired elevation of grade and cross section indicated by these stakes. This shall be done as an integral part of the final finishing operation.

2207.05I. In lieu of Section 2207.05I the following shall apply.

Curing. After the soil-cement base has been finished it shall be protected against drying by the application of bituminous material. This curing material shall be applied as soon as possible but not later than 24 hours after the completion of finishing operations. The finished soil-cement shall be kept continually moist until the bituminous material is applied.

At the time the bituminous material is applied, the soil-cement surface shall be dense, shall be free of all loose and extraneous material and shall contain sufficient moisture to prevent penetration of the bituminous material. If so specified by the engineer, the surface of the base shall be lightly wetted immediately prior to application of the bituminous material. Granular material shall be applied to the bituminous surface if necessary to prevent pick-up as directed by the engineer.

2207.06. The following shall be added to Section 2207.06.

This project contains experimental features and the right is reserved to make slight changes in construction procedures.

2207.07. The last sentence of Section 2207.07 shall be changed to read as follows.

If the soil for the base has been imported, the base shall be primed using the method specified in Section 2208.06.

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson Inc.
ADDRESS: Sioux City 1, Iowa

PROJECT: F-861(6)
COUNTY: Monona
ESTIMATE NO.: 6-EE (final)
SHEET NO.: 1 of 3

No.	Class	Items	Unit	Rates	Quantities Contract	Quantities Actual	Quantities Over-run	Quantities Under-run	Amounts Contract	Amounts Actual	Amounts Over-run	Amounts Under-run
1		Division I (urban)										
1	301	Class 10 excav. rdwy and borrow	c.y.	0.30	1,643	2,241	598		492.90	672.30	179.40	
2	303	Correction of subgrade	mi.	2500.00	0.132	0.132			330.00	330.00		
6	303	Constr. of soil-cement base	mi	6500.00	0.132	0.132			858.00	858.00		
7	303	Aggr. for soil-cement base	ton	0.55	749	844.615	95.615		411.95	464.54	52.59	
8	303	Cement	bbls	5.20	398	425.186	27.186		2,069.60	2,210.97	141.37	
9	303	Cover aggregate	ton	6.00	33	43.55	10.55		198.00	261.30	63.30	
10	303	Bituminous binder	gal.	0.19	666	714	48		126.54	135.66	9.12	
14	301	Shoulder constr.	stas	25.00	16.717	16.717			417.93	417.93		
27	303	Primer bitumen	gal.	0.19	507	477		30	96.33	90.63		5.70
		SUB TOTALS							5,001.25	5,441.33	445.78	5.70
		Division II (rural)										
1	101	Class 10 excav. rdwy and borrow	c.y.	0.30	5,311	3,693.0		1,618	1,593.30	1,107.90		485.40
2	103	Correction of subgrade	mi.	2500.00	7.938	7.704		0.234	19,845.00	19.260.00		585.00
3	103	Granular subbase	ton	2.20	5,499	5,733.80	234.80		12,097.80	12,614.36	516.56	
		Totals Carried Forward							33,536.10	32,982.26	516.56	1,070.40

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

ROAD: 09 - Primary

PROJECT: F-861(6)
COUNTY: Monona
ESTIMATE NO: 6-EE (final)

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

PAYABLE TO: Lee & Johnson, Inc.
ADDRESS: Sioux City 1, Iowa

No.	Class	Items	Unit	Rates	Quantities				Amounts			
					Contract	Actual	Over-run	Under-run	Contract	Actual	Over-run	Under-run
		Totals brought Forward							33,536.10	32,982.26	516.56	1,070.40
4	103	Incorporating soil stab. Dow Chem TBC	lbs.	0.30	3,226	1,700		1,526	967.80	510.00		457.80
5	103	Soil Stabilizer Arquad 2HT	lbs.	0.80	7,745	7,020		725	6,196.00	5,616.00		580.00
6	103	Const. of soil-cement base	mi.	6500.00	8.260	8.215		0.045	53,690.00	53 397.50		292.50
7	103	Aggr. for soil-cement base	ton	0.55	35,001	35,777.361	776.361		19,250.55	19,677.55	427.00	
8	103	Cement	bbls	5.20	17,853	16,510.639		1,342.361	92,835.60	85,855.32		6,980.28
9	103	Cover aggregate	ton	6.00	1,708	1,953.05	245.05		10,248.00	11,718.30	1,470.30	
10	103	Bituminous binder	gal.	0.19	34,658	36,250	1,592		6,585.02	6,887.50	302.48	
12	103	Const. soil Aggregate subbase	mi.	5000.00	0.322	0.322			1,610.00	1,610.00		
14	101	Shoulder Construction	stas	25.00	872.270	867.470		4.80	21,806.75	21,686.75		120.00
15	111	24" corr. metal Roadway culvert	l.f.	6.00	128	128			768.00	768.00		
17	111	24" corr. metal elbows	only	42.00	None	6	6		None	252.00	252.00	
20	111	24" Type "A" diaphrams	only	40.00	3	3			120.00	120.00		
27	103	Primer bitumen	gal.	0.19	31,707	35,356	3,649		6,024.33	6,717.64	693.31	
	103	EWO #1 Const. Add. 1000' soil agg. sub.	mi.	5000.00		0.189	0.189			945.00	945.00	
		Totals Carried Forward							253,638.15	248,743.82	4,606.65	9,500.98

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

PROJECT: F-861(6)
COUNTY: Monona
ESTIMATE NO.: 6-EE (final)
SHEET NO.: 3 of 3

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson, Inc.
ADDRESS: Sioux City 1, Iowa

No.	Class	Items	Unit	Rates	Quantities Contract	Quantities Actual	Quantities Over-run	Quantities Under-run	Amounts Contract	Amounts Actual	Amounts Over-run	Amounts Under-run
		Totals Brought Forward							253,638.15	248,743.82	4,606.65	9,500.98
	103	EWO #2 Cost Haul P&H Stab. to & from job	Lump Sum							400.00	400.00	
	111	EWO #3 Extend 18" C.M.P.	l.f.	2.35		10	10			23.50	23.50	
	103	EWO #4 Blot sand	ton	1.80		458	458			824.40	824.40	
	105	EWO #7 - blanket Class "C" Gravel	ton	2.90		253.5	253.5			735.15	735.15	
		Unincorporated Material (Form 616 attached)										
		Material taken over -										
	103	Dow Chemical TBC	lbs.	0.0306		425	425			13.00	13.00	
	103	Armour Chem. Arquad 2HT	lbs.	0.4425		780	780			345.15	345.15	
		SUB TOTALS (RURAL)							253,638.15	251,085.02	6,947.85	9,500.98
		TOTALS							258,639.40	256,526.35	7,393.63	9,506.68
		Pd. previous estimates No. 1-EE to No. 5-EE (sub final) voucher inclusive.								230,873.72		
		Due this No. 6-EE (final) estimate voucher.								25,652.63		

Original Contract Amount $258,639.40 - 100.00%
Net Underrun $ 2,113.05 - 0.82%
Total Amount Paid $256,526.35 - 99.18%

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson Inc.
ADDRESS: Sioux City 1 Iowa

PROJECT: F-861(6)
COUNTY: Crawford
ESTIMATE NO.: 5-E (final)
SHEET NO.: 1 of 2

No.	Class	Items	Unit	Rates	Quantities				Amounts			
					Contract	Actual	Over-run	Under-run	Contract	Actual	Over-run	Under-run
1	101	Class 10 excav. rdwy and borrow	c.y.	0.30	1,656	6,084	4,428		496.80	1,825.20	1328.40	
2	103	Correction of subgrade	mi.	2500.00	3.944	3.944			9,860.00	9,860.00		
3	103	Granular subbase	ton	2.20	3,132	2,900		232	6,890.40	6,380.00		510.40
6	103	Constr. of soil-cement base	mi.	6500.00	3.944	3.944			25,636.00	25,636.00		
7	103	Aggr. for soil-cement base	ton	0.55	16,610	16,895.790	285.79		9,135 50	9,292.68	157.18	
8	103	Cement	bbls	5.20	8,629	8,015.685		613.315	44,870.80	41,681.56		3,189.24
9	103	Cover aggregate	ton	6.00	815	952.70	137.7		4,890.00	5,716.20	826.20	
10	103	Bituminous binder	gal.	0.19	16,449	16,343		106	3,125.31	3,105.17		20.14
14	101	Shoulder Constr.	stas	25.00	416.458	416.458			10,411.45	10,411.45		
15	111	24" corrugated metal rdwy culvert	l.f.	6.00	620	620			3,720.00	3,720.00		
16	111	24" metal aprons	only	60.00	17	17			1,020.00	1,020.00		
17	111	24" corrugated metal elbows	only	42.00	23	17		6	966.00	714.00		252.00
18	111	30" reinforced conc. rdwy culvert	l.f.	15.00	50	50			750.00	750.00		
19	111	30" concrete apron	only	140.00	1	1			140.00	140.00		
20	111	24" Type "A" diaph.	only	40.00	17	17			680.00	680.00		
		Totals Carried forward							122,592.26	120,932.26	2,311.78	3,971.78

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson, Inc.
ADDRESS: Sioux City 1, Iowa

PROJECT: 5-861(6)
COUNTY: Crawford
ESTIMATE NO.: 5-E (final)
SHEET NO.: 2 of 2

No.	Class	Items	Unit	Rates	Quantities Contract	Quantities Actual	Quantities Over-run	Quantities Under-run	Amounts Contract	Amounts Actual	Amounts Over-run	Amounts Under-run
		Totals Brought Forward							122,592.26	120,932.26	2,311.78	3,971.78
21	111	Reinforcing Steel	lbs.	0.20	1,673	1,673			334.60	334.60		
22	111	Concrete	c.y.	60.00	23.7	24.2	0.5		1,422.00	1,452.00	30.00	
26	111	Class 20 excav.	c.y.	2.00	147	147			294.00	294.00		
27	103	Primer bitumen	gal.	0.19	15,138	21,587	6,449		2,876.22	4,101.53	1,225.31	
	103	EWO #4 - blanket blotter sand	ton	1.80		85	85			153.00	153.00	
	105	EWO #7 - blanket Class "C" gravel	ton	2.90		90	90			261.00	261.00	
		TOTALS							127,519.08	127,528.39	3,981.09	3,971.78
		Pd. previous estimates #1 to #4-E (sub final) voucher inclusive								114,775.55		
		Due this #5-E (final) estimate voucher								12,752.84		

Original Contract Amount $127,519.08 - 100.00%
Net Overrun $ 9.31 - 0.01%
Total Amount Paid $127,528.39 - 100.01%

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

PROJECT: F-861(6)
TYPE: Soil-Cement Base & Bituminous Surface
ROAD: 09 - Primary
COUNTY: Harrison
PAYABLE TO: Lee & Johnson Inc.
ESTIMATE NO.: 5-H (final)
DATE: November 27, 1961
ADDRESS: Sioux City 1, Iowa
SHEET NO.: 1 of 3

No.	Class	Items	Unit	Rates	Quantities Contract	Quantities Actual	Quantities Over-run	Quantities Under-run	Amounts Contract	Amounts Actual	Amounts Over-run	Amounts Under-run
		Division IV (rural)										
1	101	Class 10 excav. rdwy & borrow	c.y.	0.30	3,620	2,747		873	1,086.00	824.10		261.90
2	103	Correction of subgrade	mi.	2500.00	0.371	0.371			927.50	927.50		
3	103	Granular subbase	ton	2.20	5,041	6,027.75	986.75		11,090.20	13,261.05	2,170.85	
6	103	Constr. of soil-cement base	mi.	6500.00	0.371	0.371			2,411.50	2,411.50		
7	103	Aggr. for soil-cement base	ton	0.55	1,626	1,690.470	64.47		894 30	929 76	35.46	
8	103	Cement	bbls	5.20	865	792.979		72.021	4,498.00	4,123.49		374.51
9	103	Cover aggregate	ton	6.00	77	81	4		462.00	486.00	24.00	
10	103	Bituminous binder	gal.	0.19	1,533	1,396		137	291.27	265.24		26.03
14	101	Shoulder constr.	stas	25.00	39.154	39.154			978.85	978.85		
27	103	Primer bitumen	gal.	0.19	1,423	1,391		32	270.37	264.29		6.08
		SUB TOTALS (RURAL)							22,909.99	24,471.78	2230.31	668.52
		Division V (Urban)										
1	301	Class 10 excav. rdwy and borrow	c.y.	0.30	50	152	102		15.00	45.60	30.60	
2	303	Correction of subgrade	mi.	2500.00	0.123	0.123			307.50	307.50		
		Totals Carried Forward							322.50	353.10	30.60	None

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson, Inc.
ADDRESS: Sioux City 1, Iowa

PROJECT: F-861(6)
COUNTY: Harrison
ESTIMATE NO.: 5-H (final)
SHEET NO.: 2 of 3

No.	Class	Items	Unit	Rates	Quantities				Amounts			
					Contract	Actual	Over-run	Under-run	Contract	Actual	Over-run	Under-run
		Totals Brought Forward							322.50	353.10	30.60	None
3	303	Granular subbase	ton	2.20	1,888	1,967.25	79.25		4,153.60	4,327.95	174.35	
6	303	Const. of soil-cement base	mi.	6500.00	0.123	0.123			799.50	799.50		
7	303	Aggr. for soil-cement base	ton	0.55	591	560.606		30.394	325.05	308.33		16.72
8	303	Cement	bbls	5.20	314	255.553		58.447	1,632.80	1,328.88		303.92
9	303	Cover aggregate	ton	6.00	25	29.5	4.5		150.00	177.00	27.00	
10	303	Bituminous binder	gal.	0.19	592	483		109	112.48	91.77		20.71
11	301	Removal Exist. concrete pavement	s.y.	1.00	805	805			805.00	805.00		
13	302	10" stand. port. cement conc. pave.	s.y.	12.00	860	895.12	35.12		10,320.00	10,741.44	421.44	
14	301	Shoulder constr.	stas	25.00	19.624	19.624			490.60	490.60		
21	311	Reinforcing steel	lbs.	0.20	204	204			40.80	40.80		
22	311	Concrete	c.y.	60.00	2.8	5.08	2.28		168.00	304.80	136.80	
23	311	30" Vitrified Clay pipe	l.f.	15.00	10	None		10	150.00	None		150.00
24	311	24" reinforced conc. rdwy culvert	l.f.	7.00	14	14			98.00	98.00		
25	311	24" concr. apron	only	110.00	1	1			110.00	110.00		
		Totals Carried Forward							19,678.33	19,977.17	790.19	491.35

FINAL ESTIMATE OF ROAD OR BRIDGE WORK

TYPE: Soil-Cement Base & Bituminous Surface
DATE: November 27, 1961

ROAD: 09 - Primary
PAYABLE TO: Lee & Johnson, Inc.
ADDRESS: Sioux City 1, Iowa

PROJECT: F-861(6)
COUNTY: Harrison
ESTIMATE NO.: 5-H(final)
SHEET NO.: 3 of 3

No.	Class	Items	Unit	Rates	Quantities				Amount			
					Contract	Actual	Overrun	Underrun	Contract	Actual	Overrun	Underrun
		Totals Brought Forward							19,678.33	19,977.17	790.19	491.35
26	311	Class 20 excavation	c.y.	2.00	20	20			40.00	40.00		
27	303	Primer bitumen	gal.	0.19	703	460		243	133.57	87.40		46.17
	303	EWO #4 - blanket blotter sand	ton	1.80		14	14			25.20	25.20	
	311	EWO #5 - Delete Item #23 Add Item #18	l.f.	15.00		50	50			750.00	750.00	
	302	EWO #6 incidental concrete	c.y.	60.00		13.17	13.17			790.20	790.20	
	301	EWO #6 Pavement removal (extra)	s.y.	1.00		74.1	74.1			74.10	74.10	
	302	EWO #6 Extra 10" P.C.C. Pavement	s.y.	12.00		74.1	74.1			889.20	889.20	
	305	EWO #7 - blanket Class "C" Gravel	ton	2.90		10	10			29.00	29.00	
		SUB TOTALS (URBAN)							19,851.90	22,662.27	3,347.89	537.52
		TOTALS							42,761.89	47,134.05	5,578.20	1,206.04
		Pd. previous estimates No. 1 to No. 4-H sub final vouchers inclusive.								42,420.64		
		Due this No. 5-H final estimate voucher.								4,713.41		

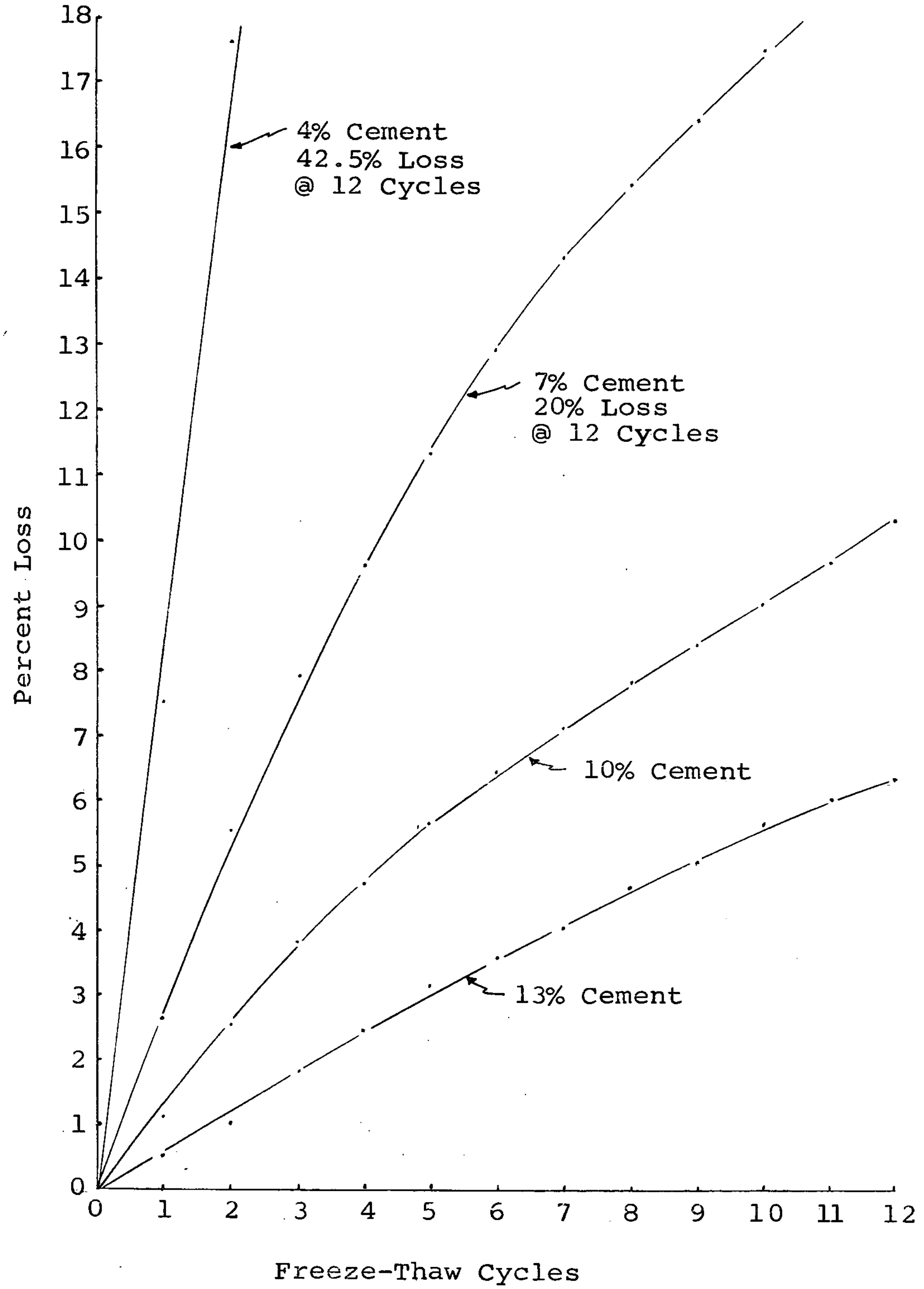
Original Contract Amount $42,761.89 - 100.00%
Net Overrun $ 4,372.16 - 10.22%
Total Amount Paid $47,134.05 - 110.22%

APPENDIX B

Soil-Cement Design Curves

APPENDIX B

Soil-Cement Design



APPENDIX B

SOIL-CEMENT DURABILITY TESTS

County: Monona Project: F-861(6) Date Rep'd.: 12/16/60

1	Laboratory Number	AADO-6825			
2	Gravel, +10	0			
3	Sand	1			
4	Silt	77			
5	Clay	22			
6	Colloids	14			
7	Liquid Limit	33			
8	Plasticity Index	10			
9	Shrinkage Limit	--			
10	Shrinkage Ratio	--			
11	Textural Class	Silty Clay Loam			
12	P.R.A. Class	A-4(8)			
13	Carbon	--			
14	Color, Moisture	Dark Yellow Brown			
15	Cement Content Percent by Weight	4	7	10	13
16	Cement Content Percent by Volume	4.1	7.1	9.8	12.5
17	Proctor Density W.C.F.	--	101#	--	102#
18	Proctor Water %	--	19.4	--	19.3
19	Compressive Strength P.S.I. -- -day	--	--	--	--
20	Percent Solids	--	59.8	60.0	60.2
	Data From Specimens Used For Twelve Cycles of Durability				
21	Soil Loss - W&D %	--	15.5	8.5	5.6
22	Soil Loss - F&T %	42.5	20.0	10.3	6.3
23	Maximum Volume Change - W&D %	--	--	+2.1	+0.4
24	Maximum Volume Change - F&T %	--	--	+1.5	+0.7
25	Maximum Moisture Content - W&D %	--	--	--	--
26	Maximum Moisture Content - F&T %	--	24.9	23.0	22.6
27	Percent Water of Saturation	--	24.9	24.6	24.4
28	Recommended Cement Content - Weight %				
29	Recommended Cement Content - Volume %				

Samples made at 4% and 7% cement content spalled and had a loose skin surface that precluded measurement or weighing of samples.

APPENDIX C

Soil Survey Results

APPENDIX C

SOIL SURVEY

Soil Cement Research   Crawford, Harrison, Monona County   Project F-861(6)

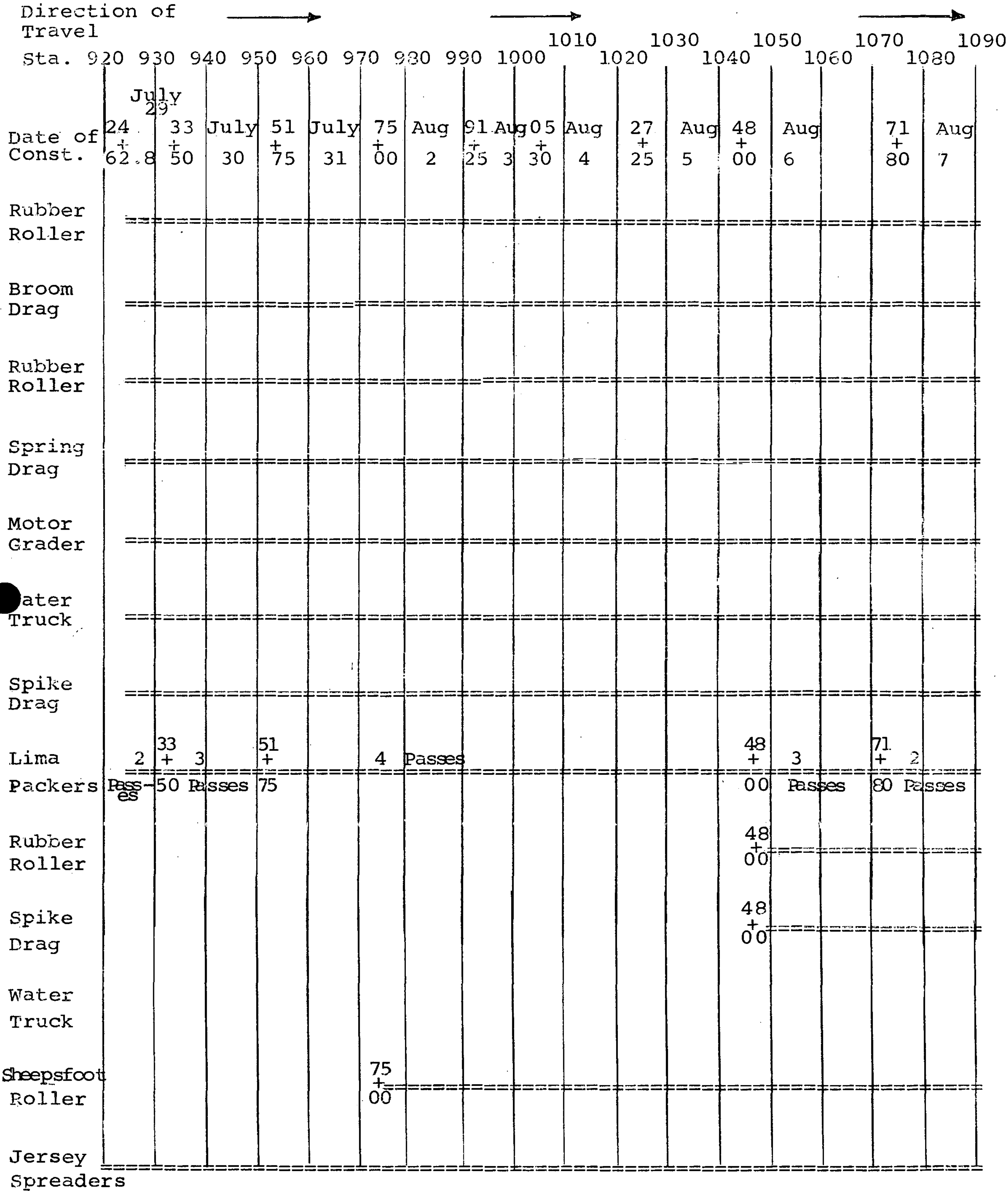
IDENTIFICATION STATION	DEPTH LAYER FROM	TO	Mechanical Analysis Grav over 2.0	Sand 2.0-0.074	Silt 0.074-0.005	Clay 0.005-0.0	Atterberg LPL	P.I.	Density Lbs./Cu.ft. Proctor	Moisture Content Proctor	A.A.S.H.O. Subgrade Group
1036 + 00 ℄	0.0	4.0	0	2	72	26	23	10	106	17	A-4(8)
1044 + 00 ℄	0.0	4.0	0	2	74	24	23	10	107	18	A-4(8)
1049 + 00 ℄	0.0	4.0	0	1	72	27	21	17	107	17	A-6(11)
1091 + 00 ℄	0.0	4.0	2	4	68	26	21	15	108	18	A-6(10)
1099 + 00 ℄	0.0	4.0	0	1	74	25	21	14	109	19	A-6(10)
1116 + 00 ℄	0.0	4.0	1	3	67	29	22	13	107	18	A-6(9)
1117 + 25 ℄	0.0	4.0	1	3	66	30	23	16	109	17	A-6(10)
1125 + 25 ℄	0.2	4.0	0	1	72	27	21	15	108	20	A-6(10)
1154 + 00 ℄	0.3	4.0	0	1	74	25	21	13	106	10	A-6(9)
1151 + 00 ℄	0.2	4.0	1	1	69	29	22	13	109	16	A-6(9)
1169 + 00 ℄	0.2	4.0	0	2	74	24	22	12	109	16	A-6(9)
1177 + 00 ℄	0.2	4.0	0	1	72	27	21	14	108	18	A-6(10)
1186 + 00 ℄	0.2	4.0	1	1	70	28	21	14	107	16	A-6(10)
1190 + 00 ℄	0.2	1.6	20	16	44	20	20	15	117	14	A-6(8)
1195 + 00 ℄	1.0	1.6	10	19	47	24	21	14	116	13	A-6(9)
1197 + 00 ℄	0.3	4.0	1	1	67	31	23	13	107	18	A-6(9)
1204 + 00 ℄	0.3	4.0	1	4	67	28	21	16	107	17	A-6(10)
1232 + 00 ℄	0.2	4.0	0	1	75	24	22	11	106	18	A-6(8)
1238 + 00 ℄	0.2	4.0	1	2	74	23	22	10	107	17	A-4(8)
1278 + 00 ℄	0.0	0.6	2	4	71	23	23	12			A-6(9)
1278 + 00 ℄	1.4	4.0	18	22	40	20	21	17			A-6(8)
1285 + 00 ℄	0.0	4.0	0	2	75	23	21	17	107	18	A-6(9)
1291 + 00 ℄	0.0	4.0	0	1	74	25	21	14	107	18	A-6(10)
1298 + 00 ℄	0.0	4.0	1	2	72	26	23	13	107	17	A-6(9)
1212 + 00 ℄	0.2	4.0	0	1	68	31	20	18	105	18	A-6(11)
1221 + 00 ℄	0.1	4.0	0	1	66	33	21	20	104	19	A-7-6(12)
1230 + 00 ℄	0.1	4.0	0	1	76	23	22	10	107	18	A-4(8)
1236 + 00 ℄	0.1	4.0	0	2	66	32	21	20	102	19	A-7-6(12)
1252 + 00 ℄	0.3	4.0	2	1	67	30	20	18	106	19	A-6(11)
1251 + 00 ℄	0.1	4.0	2	5	59	34	21	19	104	17	A-6(12)
1302 + 00LT300	0.0	1.0	0	1	72	27	24	12			A-6(9)
1302 + 00LT300	1.0	5.0	0	1	78	21	22	12			A-6(9)
1302 + 00LT300	5.0	9.0	0	1	76	23	22	12			A-6(9)
1392 + 00LT300	2.0	13.0	0	1	75	24	22	12			A-6(9)
1302 + 00LT300	13.0	17.0	0	1	74	25	24	9			A-4(8)
1302 + 00LT300	17.0	21.0	0	0	80	20	25	6			A-4(8)
1302 + 00LT300	21.0	25.0	0	0	77	23	24	9			A-4(8)

APPENDIX D

Equipment Alignment Diagram

Equipment

EQUIPMENT ALIGNMENT DIAGRAM



EQUIPMENT ALIGNMENT DIAGRAM

Direction of Travel →

Sta.	1090	1100	1110	1120	1130	1140	1150	1160	1170	1180	1190	1200	1210	1220	1230	1240	1250	1260
Date of Const.	Aug 7 / Aug 8 98+00	02+25	Aug 9 16+70	Aug 10	35+75	Aug 11	59+25	Aug 12		80+90	Aug 13	00+15	Aug 14	24+33	Aug 15	45+00	Aug 16	

Rubber Roller ====================

Broom Drag ====================

Rubber Roller ====================

Spring Drag ====================

Motor Grader ====================

Water Truck ====================

Spike Drag ====================

Lima Packers ========== 2 Passes ==========

Rubber Roller ====================

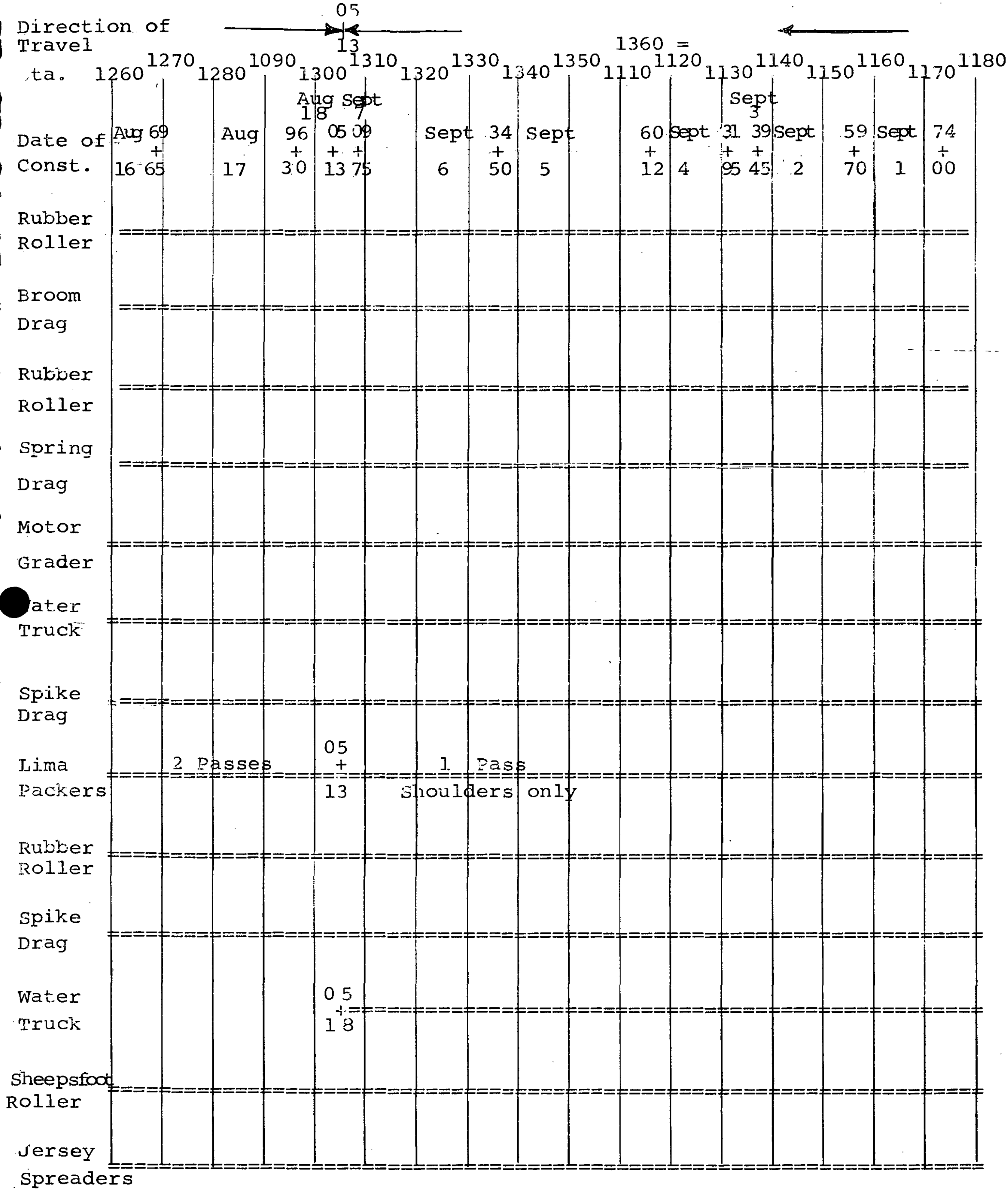
Spike Drag ====================

Water Truck

Sheepsfoot Roller ====================

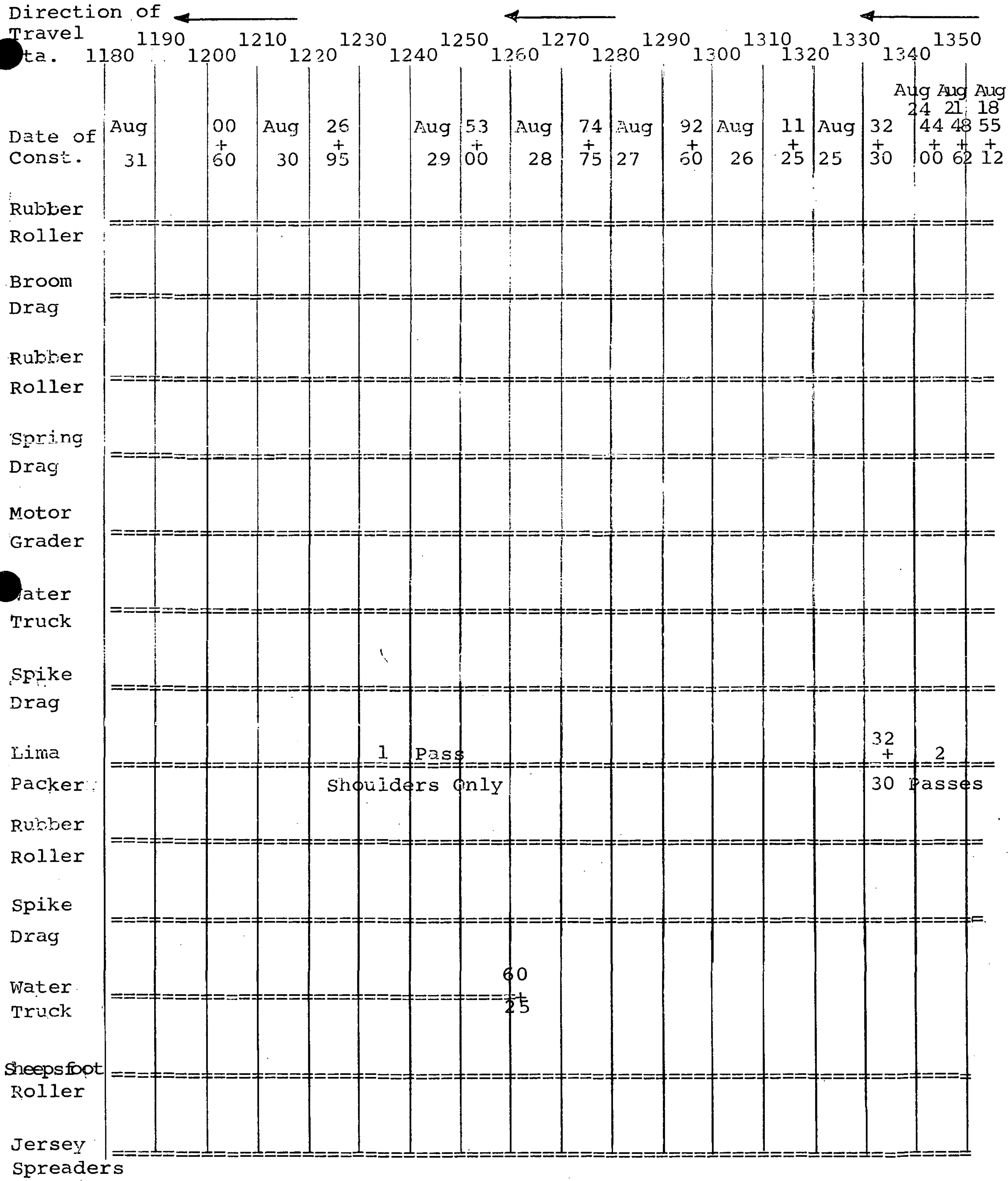
Jersey Spreaders ====================

EQUIPMENT ALIGNMENT DIAGRAM



Appendix D

EQUIPMENT ALIGNMENT DIAGRAM



EQUIPMENT

Central Plant:

1 - Minn.-Moline GVI Tractor with tandem-disk-plow
1 - D-7 Caterpillar bulldozer.
1 - D-8 Caterpillar bulldozer.
2 - End-loaders.
2 - 40 ft. Kolman Conveyors (2 5 ft. wide, electric motor driven).
1 - Barber-Green Mixer with 10 ft. pugmill (200 ton/hr. nominal capacity).
1 - Surge bin.
1 - Con-E-Co cement hopper with auger feed and forced air.
3 - Cement tankers (capacity approximately 100-110 Bbls. each).
1 - Diesel Powered generator.
1 - Water storage tank (capacity = 12,000 gal.).
2 - Water transport trucks (capacity - 1500 gal. each).
1 - Water transport truck (capacity - 3000 gal.).

Base Construction:

1 - Blaw-Knox Spreader on D-7 caterpillar tractor.
1 - Jersey spreader on D-7 caterpillar tractor.
1 - Dual sheepsfoot on HD-10 Allis-Chalmers tractor.
2 - Lima vibrating compactors (6 vibrators).
2 - Tampo rubber-tired rollers (self-propelled).
2 - Caterpillar (No. 12) motor-graders.
1 - Ford tractor with spring-tooth drag.
1 - Ford tractor with spike-tooth drag
1 - Wire broom-drag.
2 - Water distributor (capacity 1500 gal.).
1 - Asphalt distributor (capacity = 1050 gal.).

Shoulder Construction:

1 - Dragline.
1 - Absco widener (self-propelled).
Private trucks.
1 - Rubber-tired roller.

Seal Coat Construction:

1 - Flaherty self-propelled spreader.
1 - Asphalt distributor.
1 - Steel-wheeled roller.

EQUIPMENT (CONTD.)

1 - Rotary broom.
Private trucks.
1 - Drag broom.
2 - Rubber-tired rollers

Chemically-Treated Subbase Construction:

1 - P & H single pass stabilizer.
2 - Water transport trucks.
1 - End-loader.
1 - Steam-generator (oil-burning).
1 - Sheepsfoot roller.
1 - Rubber-tired roller.

Some pieces of equipment were used for more than one operation and therefore are listed more than once.

APPENDIX E

Procedure for Determining Cement Content of Soil-Cement Mixture

APPENDIX E

PROCEDURE FOR DETERMINING CEMENT CONTENT OF SOIL-CEMENT MIXTURE

Reagents

1. Anhydrous Sodium Carbonate
2. Hydrochloric Acid (1:1)
3. Concentrated Ammonium Hydroxide
4. Ammonium Nitrate, 1% Solution
5. Sodium Cyanide
6. Buffer (pH 10) - Dissolve 53.2 gms. of ammonium chloride in 450 ml. concentrated ammonium hydroxide. Dilute the solution 1:1 with distilled water.
7. Erio Chrome Black T indicator
8. Standard Versenate Solution (0.010M)

Preparation of Sample

1. A sample of soil-cement mixture weighing at least 2 pounds is reduced to a fineness of approximately 150- to 200-mesh in a pulverizer. The sample is then thoroughly mixed, quartered down to approximately 50 gm. and dried at 105C. for at least 2 hours.

Procedure

1. Weigh, accurately, a 1 gm. sample of soil-cement mixture into a platinum crucible, add 5-6 gms. anhydrous sodium carbonate, mix and fuse until the fusion is quiet.
2. After cooling, place the crucible in a 400 ml. beaker and dissolve the melt with 1:1 hydrochloric acid, until the contents are completely removed. The crucible is then rinsed off and removed.
3. Dilute the solution to 200 ml., bring to near boiling and add concentrated ammonium hydroxide until the steam has a very faint odor of ammonia. Digest on a hot plate for several minutes and filter into a 500 ml. volumetric flask.
4. Wash the precipitate several times with hot 1% ammonium nitrate and transfer the filter paper and precipitate to the same beaker in which the first precipitation was affected.
5. Dissolve the precipitate in hot 1:1 HCL, dilute to 100 ml., and reprecipitate the hydroxides as before, filtering into the same 500 ml. volumetric flask.
6. Dilute the combined filtrates to volume and transfer a 50 ml. aliquot to a 300 ml. porcelain casserole.

CONTENT OF SOIL-CEMENT MIXTURE (CONTD.)

7. Add 10 ml. of pH buffer, approximately 0.2 gm. sodium cyanide, 5-6 drops of Erio Chrome Black T indicator, and titrate with standard versene to the blue end point.
8. Run a blank determination on the soil using the same sample preparation and procedure except that a 100 ml. aliquot is titrated.
9. Run a blank determination on the cement using essentially the same procedure except that a 0.5 gm. sample is used, the sample need not be fused and a 25 ml. aliquot is titrated.

Calculations

Let:

A = % Calcium and magnesium, calculated as calcium carbonate in the soil-cement mixture.

B = % Calcium and magnesium, calculated as calcium carbonate in the soil.

D = % Calcium and magnesium, calculated as calcium carbonate in the cement.

Let:

a = ml. of standard versene to titrate the soil-cement mixture.

b = ml. of standard versene to titrate the soil.

d = ml. of standard versene to titrate the cement.

$A = a$
$B = b \times 0.5$
$D = d \times 4$

$$\% \text{ Cement in the soil-cement mixture} = \frac{A - B}{D - B} \times 100$$

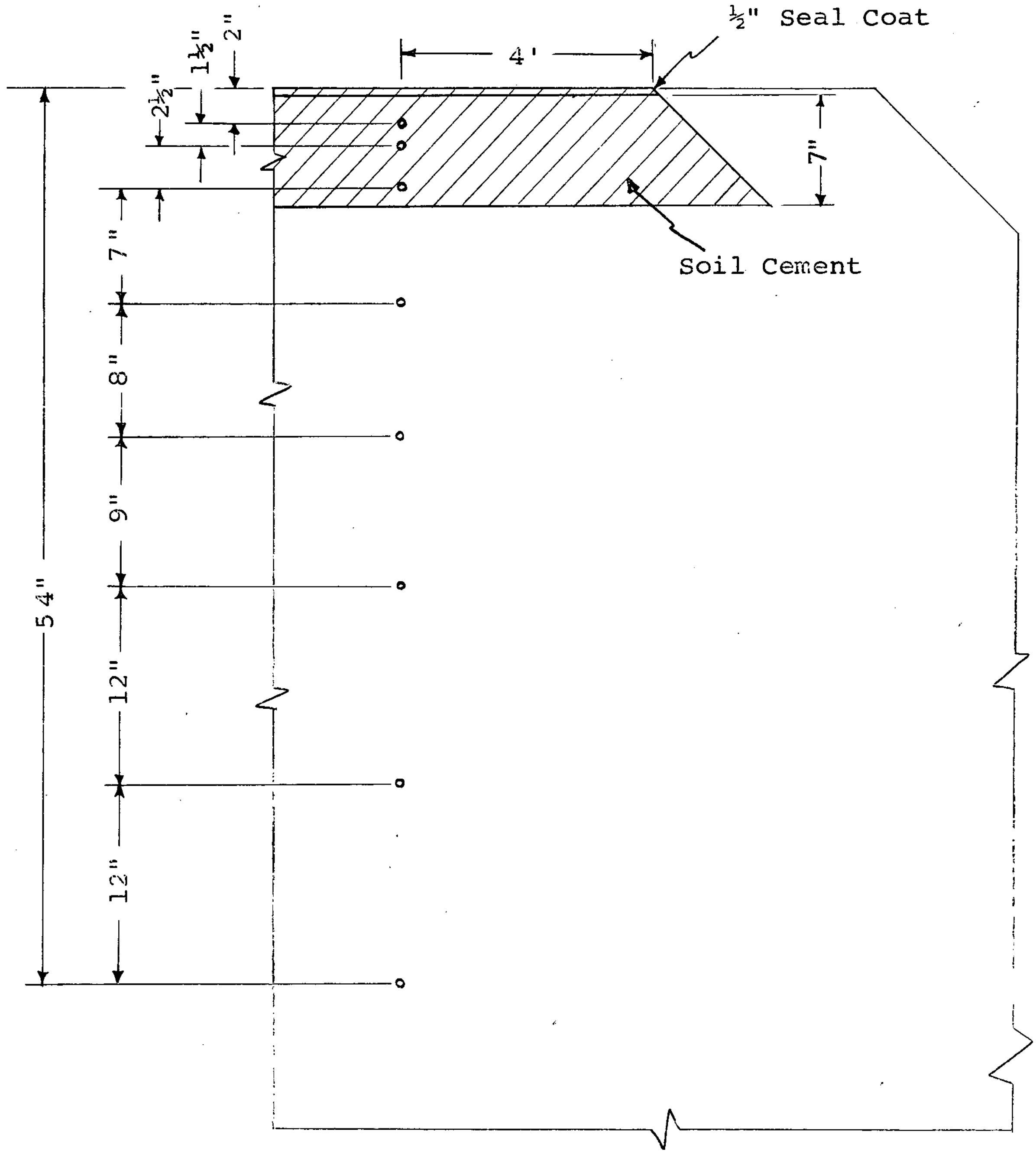
$$\text{Pounds of cement per 100 pounds soil} = \frac{\% \text{ Cement}}{100 - \% \text{ Cement}} \times 100$$

APPENDIX F

Thermocouple Location

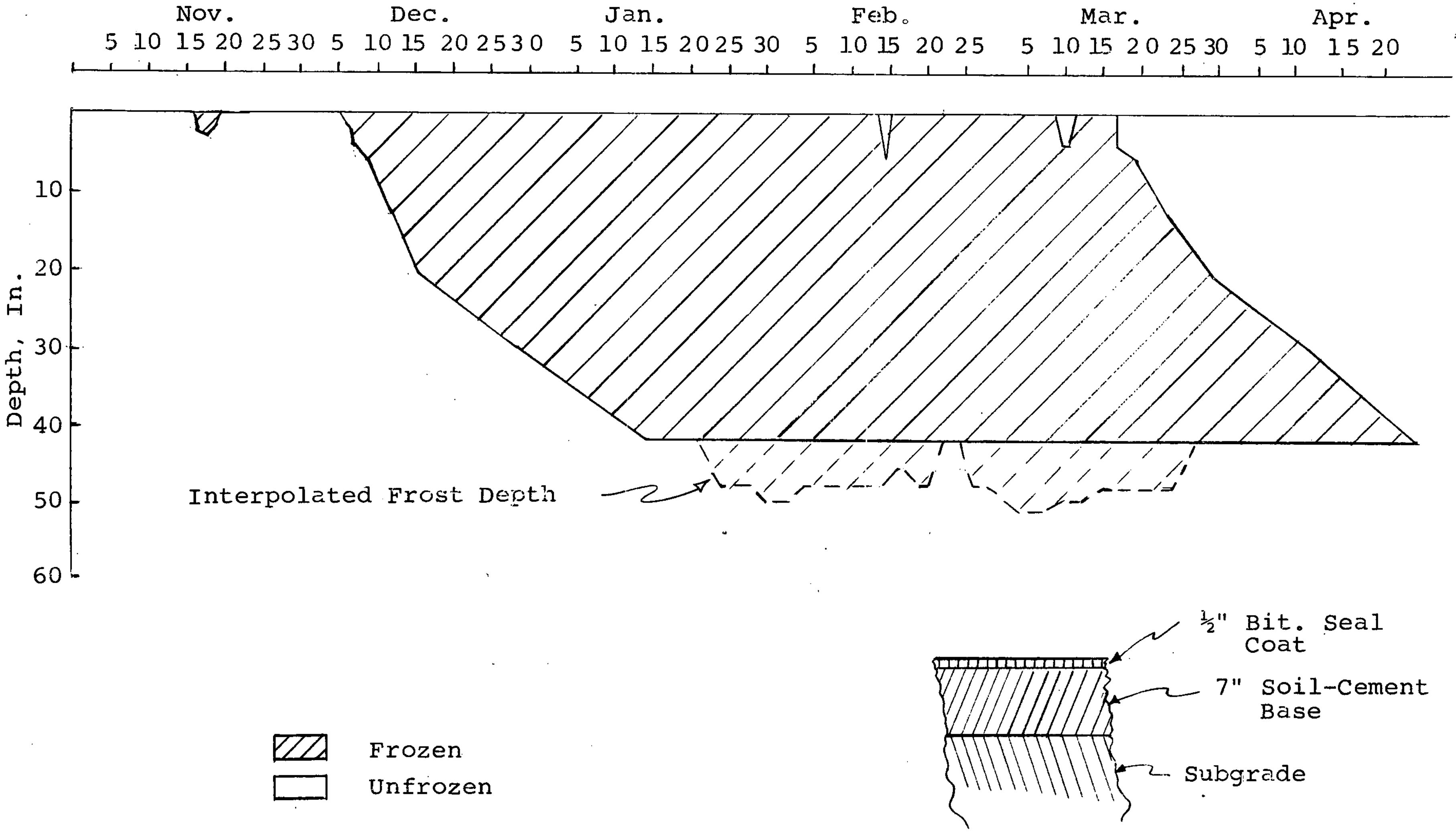
Frost Penetration Chart

Thermocouple Location At
Sta. 1005 + 00



∘ Denotes Thermocouple

Frost Penetration
1961 & 1962



NOTE: This chart indicates the depth to which a temperature of 30°F or less is recorded at station 1005 + 00, Monona County. The estimated freezing temperatures for this soil is 30°F.

APPENDIX G

Freeze-Thaw Tests

APPENDIX G

FREEZE-THAW TESTS

Individual Tests
Cores 4 in. dia. x 4.6 in.

SECT. NO.	DESIGN CEMENT (PERCENT)	CEMENT BY LAB. TEST (PERCENT)	DRY DENSITY (PCF)	F - T LOSS (PERCENT)
3	13.0	13.8	93.5	11.8
			91.5	6.3
			88.3	11.2
			96.9	5.2
			98.4	3.5
AVERAGE			93.7	7.6
4	7.0	6.9	91.2	62.4
			84.8	82.2
			88.9	75.4
			92.2	35.4
			96.6	38.5
AVERAGE			90.7	58.8
5	9.0	9.0	94.8	18.1
			95.4	20.5
			96.9	19.4
			100.7	11.0
			98.6	10.0
			93.9	24.0
AVERAGE			96.7	17.2
6	13.0	10.3	87.9	8.5
			94.7	7.2
			91.4	9.7
			92.6	8.3
			98.5	10.2
AVERAGE			93.0	8.8

APPENDIX G (CONTD.)

FREEZE-THAW TESTS

Individual Tests
Cores 4 in. dia. x 4.6 in.

SECT. NO.	DESIGN CEMENT (PERCENT)	CEMENT BY LAB. TEST (PERCENT)	DRY DENSITY (PCF)	F - T LOSS (PERCENT)
7	11.0	10.0	96.3	6.2
			98.8	5.6
			91.8	12.8
			94.0	13.8
			93.0	9.0
AVERAGE			94.8	9.5
8	7.0	7.4	98.2	25.2
			95.8	19.5
			99.9	23.2
			97.7	16.3
			85.6	46.7
			89.5	44.8
AVERAGE			94.4	29.3
9	11.0	9.2	96.8	24.8
			96.4	13.5
			89.9	29.9
			89.7	59.8
			94.9	27.2
AVERAGE			93.5	31.0
10	9.0	7.6	96.1	32.3
			96.3	44.6
			94.8	30.2
			92.3	41.8
			93.1	40.1
			96.4	28.8
AVERAGE			94.8	36.3

FREEZE-THAW TESTS

Individual Tests
Cores 4 in. dia. x 4.6 in.

SECT. NO.	DESIGN CEMENT (PERCENT)	CEMENT BY LAB. TEST (PERCENT)	DRY DENSITY (PCF)	F - T LOSS (PERCENT)
11	11.0	11.2	94.1	44.0
			91.6	31.9
			94.5	46.7
			92.8	12.8
			92.8	5.3
AVERAGE			93.2	28.1
12	7.0	7.2	95.6	49.3
			90.9	62.8
			91.4	66.6
			86.8	94.1
			92.3	34.5
			90.9	42.0
AVERAGE			91.3	58.2
13	9.0	9.0	89.0	34.6
			89.7	34.9
			90.6	23.3
			92.8	47.5
			92.7	40.9
			95.1	31.3
AVERAGE			91.6	35.4
14	13.0	13.4	95.4	7.7
			98.1	4.2
			93.8	6.0
			90.9	4.9
			94.1	4.3
AVERAGE			94.5	5.4