Subgrade Moisture Conditions Under an Experimental Pavement

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THIS paper deals with one phase of a program to obtain moisture histories of subgrades and specifically covers the first step of this phase which investigates the subgrade condition under an experimental pavement of portland-cement concrete. This step has two purposes: (1) to attempt to evaluate the effects of design variables on subgrade moisture histories and (2) subsequently to aid in the evaluation of the design variations as they affect the pavement performance. This first report encompasses only that part of the complete investigation which deals with the results obtained from the measurement of subgrade moisture content by means of electrical resistance moisture cells.

The experimental pavement includes variables of (1) coarse aggregate (limestone or chert gravel); (2) base treatment (rolled stone, dense design, or sand gravel, open design, or no base); and (3) subgrade treatment (oiled earth treatment or plain earth, no treatment). These variables were combined into 12 comparable sections. These sections vary from 0.2 mile to 0.6 mile in length with the total experimental project approximately 5 miles long.

The moisture cells, installations, instrumentations, and calibration procedures are described. Construction notes and validating field moisture checks are included in the appendixes along with topography notes and the log of the subgrade soil horizons.

Data obtained from 96 moisture cells have been averaged in various combinations to compare the effect of differences in cell location with respect to pavement cover, since the cover changes the degree of exposure to the possible means moisture entrance from above. These data have also been arranged to show differences caused by the variations in construction features and to show the variations in moisture content among the 12 comparable sections. The effects of the oiled-earth subgrade treatment are of especial interest, along with the commentary concerning possible undesirable results of poor construction of the oiled-earth treatment. The influence of drouth on subgrade-moisture conditions is apparent, and possible reasons for the variations in the effects of this influence are discussed. This report is in the nature of a progress report and therefore does not attempt to present final conclusions.

THE purpose of this investigation is to obtain information concerning the subgrade moisture content and its change, or movement, with time under some typical sections of portland-cement-concrete pavement with construction variables of pavement, base, or subgrade.

The information is to be used as a supplement to condition surveys in an attempt to evaluate the performance of the design variables in the experimental sections. It will also be used as pilot information to determine the advisability and practicability of expanded studies to include other types of pavement structures and the variety of soil types normally encountered in Missouri subgrades.

The ultimate need for this information is to aid in the development of rational design methods for: pavement thickness, base, subgrade, and drainage construction.

LOCATION

As shown in Figure 1, the project is located in Warren and St. Charles counties on US 40. It stretches from approximately 1.6 miles west of the county line at Foristell to 3.4 miles east. It ends approximately 44 miles west of St. Louis. This area is in the gently rolling hills north of the Missouri River.

PROJECT DESCRIPTION

This project was so designed as to involve variables of pavement, base, and subgrade. The variable of pavement design was confined to differences in the coarse aggregate, half of the project using a limestone aggregate and the other half using a chert-gravel aggregate. The St. Louis formation limestone came from the St. Charles Quarry located near St. Charles, the chert gravel came from the Meramec River near Pacific, and the sand for both mixes came from the Mississippi River at St. Louis.

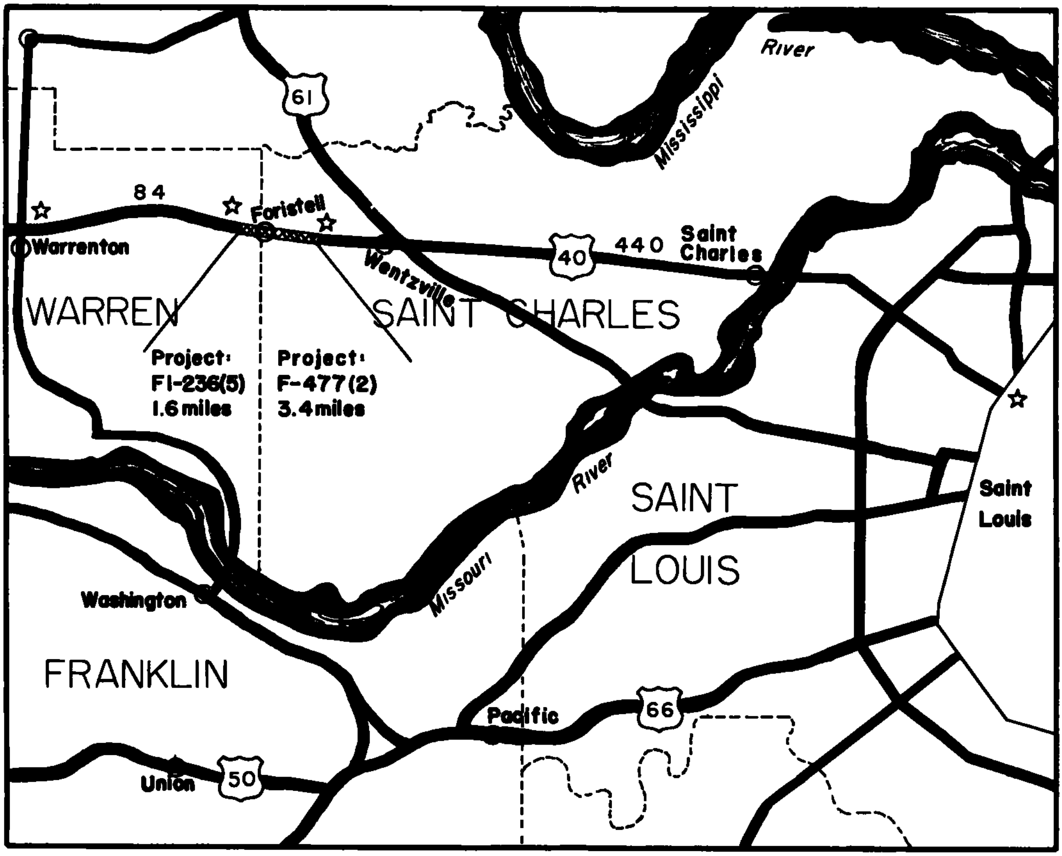


Figure 1. Location of experimental project.

The base variable consists of three types: rolled stone (dense design), sand gravel (permeable design), and no base. The rolled stone base material was from the Burlington formation from a quarry two miles east of Foristell and the sand gravel came from Peruque Creek approximately 1,000 feet upstream from the quarry.

The subgrade variable consists of two types: an oiled-earth treatment and plain earth (no treatment). The oil used was an SC-2 with a positive spot and was to be applied at the rate of 1.0 gal. per sq. yd. in three applications.

The variables of pavement, base, and subgrade were combined so that 12 comparable sections were established which range from 0.23 mile to 0.67 mile in length. Table 1 shows the combination of variables and this combination is also shown schematically in Figure 2.

This experiment is located on the new west-bound lanes of a separated four-lane highway, constructed utilizing parts of the old pavement for two of the lanes. It is 24 feet wide, having a uniform thickness of 8 inches and with a slope to the outside of $\frac{1}{8}$ inch to 1 foot. The expansion joints were $\frac{3}{16}$ inch by 8 inches of premoulded filler with $\frac{7}{8}$-by-16-inch smooth dowels, end capped and placed at 12-inch centers 4 inches deep in the concrete. The expansion joints were placed at 40-foot intervals, and a 49-lb. 6-by-12-inch wire fabric was used 2⅞ inches below the pavement surface.

TABLE 1

COMPARABLE EXPERIMENTAL SECTIONS

SECTION	AGGREGATE	BASE TREATMENT	SUBGRADE TREATMENT
1	Limestone	Rolled Stone Base	Oiled Earth
2	Chert	" " "	" "
3	Limestone	" " "	None
4	Chert	" " "	"
5	"	Sand Gravel Base	"
6	"	" " "	Oiled Earth
7	Limestone	" " "	" "
8	"	" " "	None
9	"	No Base	"
10	"	" "	Oiled Earth
11	Chert	" "	" "
12	"	" "	None

The rough grading on these sections was completed in the fall of 1947. Paving started on June 1, 1948, and was completed by August 7, 1948. Construction progress was delayed due to rain; therefore, some difficulties were encountered in the proper processing of this experiment. Notes concerning some of these difficulties with particular regard to the oiled sections are included in Appendix A.

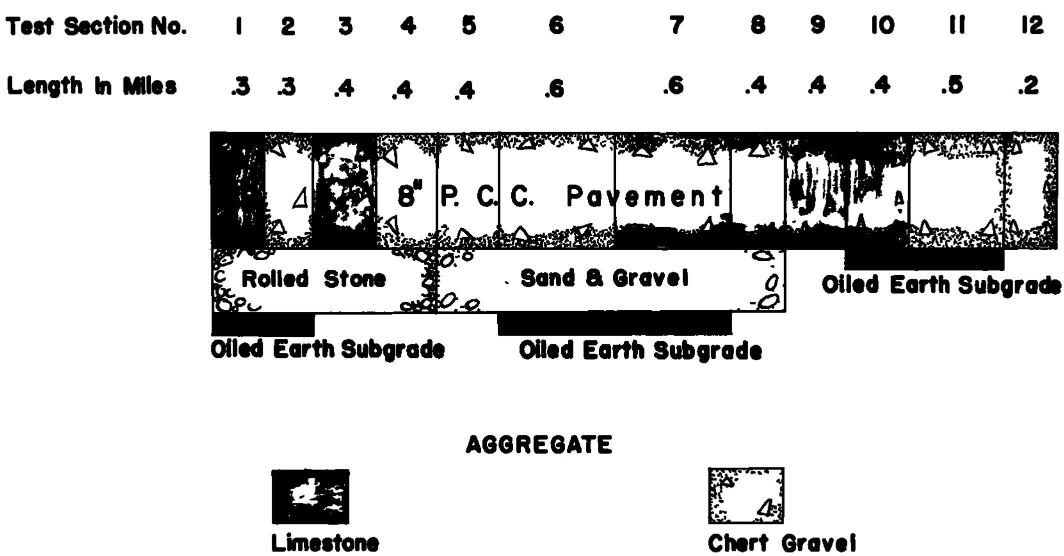


Figure 2. A 5-mile longitudinal section, showing construction variables.

The centerline cuts or fills vary generally up to 8 feet, although a few are up to 15 feet. A more-complete description of the topography of each selected location where this part of the investigation was conducted, is included in Appendix B.

The soil encountered throughout the range of this project is the Putnam Silt Loam.

The results of laboratory tests of typical samples of the various horizons are shown in Table 2.

TABLE 2

PUTNAM SILT LOAM CHARACTERISTICS

Horizon	A 1	A 2	B	C
% Retained No. 40	1.5	9.7	0.8	0.3
% Retained No. 200	3.4	12.2	4.6	1.0
% Sand 2.0 - 0.5 mm	7.5	16.5	6.8	3.2
% Silt	66.1	57.6	44.2	52.9
% Clay	26.4	25.9	49.0	43.9
% Colloids	7.0	7.5	25.0	20.0
Liquid Limit	28.2	26.4	61.2	46.2
Plastic Index	3.7	5.7	27.2	22.8
F. M. E.	26.8	23.3	44.6	29.9
Vol. Change at F.M.E.	7.3	3.5	63.2	28.4
Opt. Moisture	17.2	17.2	29.5	21.0
Max Dry Density	106.7	109.8	87.5	98.9
Classification	A4(8)	A4(8)	A7-5(19)	A7-6(14)

An attempt was made to locate these subgrade-moisture installations within subgrade limits which would be of the C horizon soil. The fill locations were of mixed horizons, due to grading operations; but nevertheless, the locations finally chosen were predominately C horizon soil. Appendix C contains a subgrade log of the entire project distance and a chart showing the results of subgrade moisture and density tests which were taken prior to paving operations.

INSTRUMENTATION

In an attempt to obtain a continuous record of subgrade-moisture conditions, moisture cells were installed at selected locations. These moisture cells are of the two-electrode, plaster-of-paris, electrical-resistance type as designed by Bouyoucos (1). The cells were manufactured according to specifications (1) by a Michigan Company (2).

They are rectangular cells, 2.4 by 1.3 by 0.5 inches with two internal electrodes 0.75 inch apart. The electrodes are the tinned ends of the No. 16 stranded, twin-lead wire. The length of the lead wire varies with the placement of the cell. The cells are illustrated in Diagram C of Figure 3.

The resistance of these cells varies inversely as the free moisture available to the cell. This available moisture maintains a certain relationship to the total moisture present in the soil; therefore, the cell resistance is an inverse measurement of the moisture content of the soil. The relationship between the free moisture and the total moisture content varies with the different soil types; therefore, it is necessary to calibrate the cell resistance against total moisture content for each soil encountered.

One of the bridges used to measure the cell resistance was furnished by the same Michigan Company as above. The bridge is described in great detail by Bouyoucos (3). Briefly, it is a Wheatstone bridge with an oscillator to overcome polarization. It has a series of capacitors with which to balance out the variable capacitance of field lead arrangements and connections. The null or balanced resistance point is determined by the use of earphones and a rheostat (log potentiometric). This bridge is rugged and portable, but difficulty has been experienced in obtaining readings with this earphone type due to extraneous and overshadowing noises occasioned by traffic. On roads of heavy traffic with many trucks this is, indeed, a problem.

The bridge finally selected for use under these conditions is an electric-eye type as manufactured by a New Jersey Company (4). This bridge is a self-contained alternating-current bridge using the cathode-ray eye as the visual indicator of the null point. Otherwise it has essentially the same arrangement as the bridge previously described. Although it does not have quite the capacity as the first bridge, the need for such a range has not become apparent in the field on this project. It was necessary to provide an eye shield for the set to keep the sunlight from interfering with the reading.

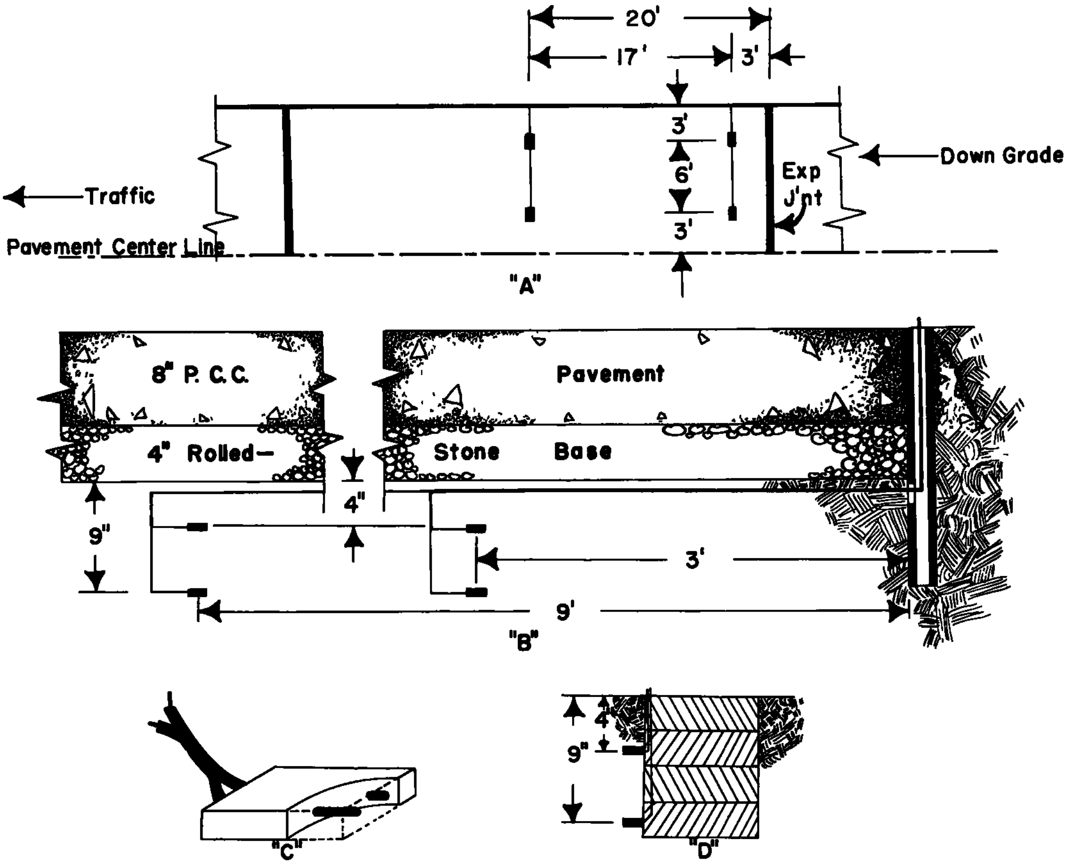


Figure 3. Installation details and cutaway view of a plaster cell.

Soil temperature is determined by a copper thermohm temperature soil, calibrated at 70 F. with a range from 0 to 130 F.

CALIBRATION

In order that the percent moisture based on the dry weight of the soil might be obtained, it is necessary that a calibration curve be drawn showing the relationship between cell resistance and actual percent moisture. Due to the fact that each soil type has a characteristic water-retention curve and that two soils exerting the same water-holding force will contain different percentages of total moisture, it is necessary to employ a calibration curve for each soil type to show the correct relationship.

The calibration procedure first tried was to place three cells in a gallon bucket filled with soil of a predetermined moisture content. Several buckets for each soil were prepared representing the range of moisture contents from almost complete dryness to complete saturation is a slurry-type mixture. These buckets were stored in a room having constant temperature and constant humidity for several days to insure equilibrium conditions. Resistance readings were also taken on these cells from time to time. When the cell had reached a constant-resistance reading, the readings were recorded and then the soil surrounding each cell was sampled for total moisture percent. From these data a calibration curve, as shown in Figure 4, was drawn with resistance on the log scale vertically and moisture on the normal scale horizontally.

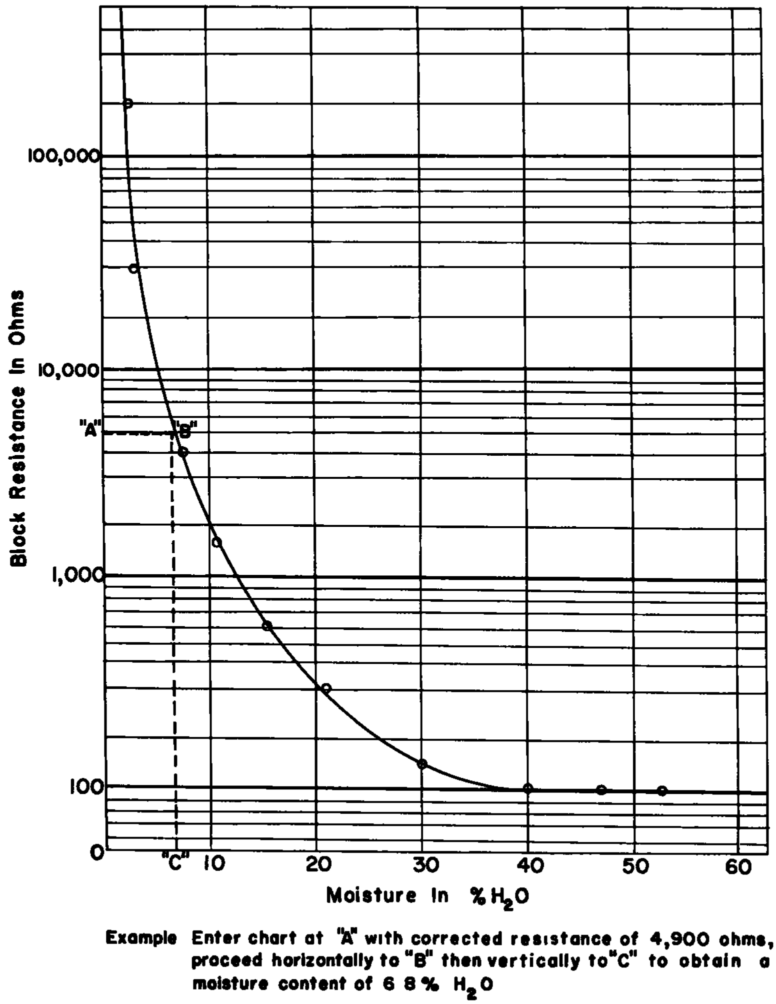


Figure 4. Calibration curve for the plaster cells in Putnam silt loam.

Later, following a more-recent Bouyoucos article (5) on fabric cells, a different procedure was tried: placing a cell in a pan slightly larger than the cell, then adding enough soil to completely surround the cell and saturating it with an excess of water on the surface. These cell-pan setups were then weighed and resistance readings taken as they dried out. Knowing the total tare weight without water, the dry weight of soil used, and then subtracting to find the total weight of water used, the total percent water could be figured to correspond with the resistance reading taken at that time. These later readings were compared with the first and checked fairly well, although it is believed that this method should not be used alone due to lag in the plaster cells.

In the field, the first method was found to give the closest agreement with the actual conditions, so the curve (Figure 4) thus obtained was used. Tables were drawn up from this curve to provide a quick and consistent means of interpretation. The validating test data for the installed cells are presented in Appendix D.

INSTALLATIONS

The cells were installed in specific relation to the transverse and longitudinal joints at the selected locations. Four installation holes were dug, one at each of the following positions; 3 feet from the transverse joint and 3 feet from the edge; 3 feet from the transverse joint and 9 feet from the edge; 20 feet from the transverse joint and 3 feet from the edge; and 20 feet from the transverse joint and 9 feet from the edge. At all locations the cells are located downgrade from the transverse joint. Figure 3 (A) illustrated the installation. The 96 cells were installed eight to a section downgrade from the joint locations as shown in Table 3.

As shown in Figure 3 (B), the cells were placed at 4-inch and 9-inch depths in the subgrade. They were placed in the sides of holes, Figure 3 (D), which had been dug to obtain density tests at the 4-inch and 9-inch depths. A wedge of just slightly larger dimensions than the cell was jacked into the side of the hole at the 9-inch depth. It was then withdrawn and the cell placed in the resulting cavity. The cell was securely wedged in and any excess space was tamped full with the soil that had been removed from that hole. The lead wires were then carefully drawn tight and the hole filled, with the soil which had been removed, to above the cell level.

The same procedure was then used in placing the 4-inch-depth cell and the hole was backfilled with the original soil and tamped to as nearly its original condition as was possible. The leads were placed in a 2-inch trench in the subgrade and led to the edge where they were buried in a 2-inch-diameter pipe 18 inches long just under the form line, if the forms had not yet been set. If the forms were already down, the pipes were buried so that they would extend part way under the slab when it was poured.

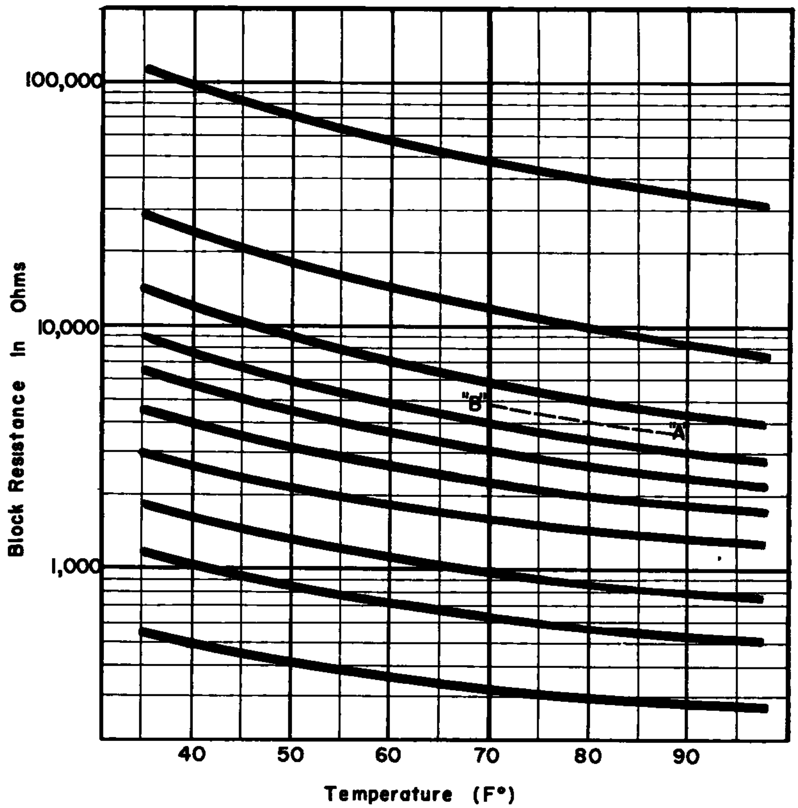
After the slab had been poured, the forms removed and some shoulder soil pulled back against the slab to fill the space left by the forms, the pipes were set upright. The pipes were dug out and the leads cleaned. The pipes were driven into the soil until the top of the pipe was 2 inches below the top of the slab. Concrete was then poured around the pipes sloping off from the top of the pipe and also bonding to and under the slab. A removable plug was screwed into the end of the pipe.

DATA

Soil-temperature data were obtained each time the cell resistances were measured so that corrections could be made. Temperature correction must be made when the soil temperature varies from the 70 F. calibration temperature. Correction curves (Figure 5) taken from Bouyoucos were used. Temperature higher than 70 F. gives a resistance lower than the 70 F. resistance, and temperature lower than the 70 F. gives a resistance higher than the 70 F. resistance. Corrections are slight around 70 F. and increase as the temperature is lowered. The correction for temperatures above 70 F. levels off close to 90 F. and remains almost constant.

The nearest weather station to this project is at Warrenton, Missouri, about 10 miles from the center of the experimental section, which is approximately 5 miles long. The rainfall data used are from this weather station. While perhaps not completely accurate because of possible variations in rainfall over that length of project, these data represent the best available. The Weather Bureau of U.S. Department of Commerce, with W. T. Zimmerman the observer, furnished the data. The rainfall data have been plotted against days of the month and shown in relation to cell moisture variations and data averages.

The cell-resistance readings were taken by one observer in the field at intervals of a week to a month. During the first 2 years of this investigation, the readings were taken at least once a week if at all possible; thereafter the interval was lengthened on occasions, as it was not considered too important to maintain the short interval. At the start of the experiment the field observer merely recorded the resistance and temperature readings and sent them to the main office, where the corrections for temperature and the translation (from calibration curves) to percent moisture were computed. Later



Example Block resistance 3,700 ohms at 87° F Following "A" to "B" parallel to the heavy lines to the corrected resistance at 70° F of 4,900 ohms

Figure 5. Temperature correction chart for plaster cells (After Bouyoucos).

the field observer was supplied with temperature-correction-and-calibration charts, and thereafter he submitted the data in a completed, averaged form.

In order to facilitate these measurements, a small delivery-type panel truck was equipped with the electric-eye bridge and with multiple-lead cables so that the readings could be taken from within the truck away from the strong light. This truck was also equipped for use on another project and had multiple-lead cables and connectors able to establish 80 connections at one time.

ANALYSIS

The data obtained have been averaged in many different ways for study and analysis. Since this phase of the investigation deals with subgrade moisture conditions and since there is a particular interest in the effects of the oiled earth subgrade, the data have not been separated to show the difference, if any, in the effects of the coarse aggregate.

Graphs have been constructed to show, through the use of moisture averages, the effect of construction or location variables. Each graph, in addition to the climatological data, contains four lines, representing the 4-inch and 9-inch depths in a plain earth subgrade and the 4-inch and 9-inch depths in an oiled-earth subgrade.

TABLE 3

CELL LOCATIONS

County	Joint Station	Section
Warren	842 + 00	1
"	857 + 00	2
"	865 + 03	3
"	883 + 03	4
"	911 + 44	5
St. Charles	38 + 05	6
"	70 + 05	7
"	77 + 25	8
"	107 + 25	9
"	124 + 05	10
"	143 + 65	11
"	174 + 85	12

These graphs have been arranged in sets, each set showing the results of averaging all the data from the 96 moisture cells in such a way as to point up the difference in some particular set of variables, i.e., location, base, etc. Set A contains Figures 6 and 7; Set B contains Figures 8 and 9; Set C contains Figures 10, 11, 12, and 13; and Set D contains Figures 14, 15, 16, and 17. It must be remembered that the same data are used in each of the four sets, but they are averaged and compared in a different way.

The data also have been set up to show the difference in moisture variations between all of the 12 sections.

Set A contains those graphs which compare the effects of distance from the edge. Figure 6 shows the comparison between the plain-earth sections and the oiled-earth sections at a distance of 3 feet from the pavement edge, while Figure 7 shows the comparison between the plain-earth subgrade and the oiled-earth at a distance of 9 feet from the pavement edge.

Set B contains those graphs which compare the effects of distance from the transverse joint. Figure 8 shows the comparison between the plain-earth sections and the oiled-earth subgrade at a distance of 3 feet from the transverse joint. Figure 9 shows the comparison between the plain-earth sections and the oiled-earth subgrade at a distance of 20 feet from the transverse joint.

Set C contains those graphs which compare the effects of the base variables. Figure 10 shows the comparison between two sections of rolled stone base on oiled earth. During the construction of the oiled-earth subgrade on experimental Section 1, difficulties (see Appendix A) were encountered which led observers to believe that this section should be regarded with suspicion. Later results tended to bear out this view; so this section has been left out of all averages but is shown here to compare with the rolled-stone base on oiled-earth section, in which it appeared that a fairly good oiled-earth mulch had been obtained.

Figure 11 shows the comparison between the rolled-stone base on plain-earth sections and the rolled-stone base on oiled-earth sections. Figure 12 shows the comparison between the sand-gravel base on plain-earth sections and the sand-gravel base on oiled-earth sections. Figure 13 shows the comparison between the no-base on plain-earth sections and the no-base on oiled-earth sections.

Set D contains those graphs which compare the effects of both the distance from the edge and the distance from the transverse joint. Figure 14 shows the comparison between those cells placed 3 feet from the edge and 3 feet from the transverse joint on the plain-earth and on the oiled-earth subgrades. Figure 15 shows the comparison between those cells placed 9 feet from the edge and 20 feet from the transverse joint. Figure 16 shows the comparison between those cells placed 9 feet from the edge and 3 feet from the transverse joint. Figure 17 shows the comparison between the cells placed 3 feet from the edge and 20 feet from the transverse joint.

The entire state of Missouri experienced a drouth starting in 1952 and extending into 1954. Naturally, the severity varied with the locality. While the area in which this experiment was constructed was not one of the hardest hit, it still was quite apparent, as shown by Table 4.

The effects of the drouth on the subgrade moisture content are shown in each of the Figures 6 to 17 by the decrease in the average moisture content of the wetter locations, generally starting about the middle of 1952. The few exceptions to this general decline are apparent among the graphs which follow. A discussion of these deviations is made later in the text.

TABLE 4
DROUTH DATA

Year	Total Rainfall in Inches	Deviation from Average
1948	41.41	+2.62
1949	44.42	+5.63
1950	33.54	-5.25
1951	42.80	+4.01
1952	29.34	-9.45
1953	23.98	-14.81
1954[1]	11.41[1]	-4.29[1]

[1]Through May 31st.

The comparison of Figure 6 with Figure 7 shows the effect of edge exposure. The distance from the edge evidently has the effect of decreasing variation in moisture content. That is, when the subgrade nearer the center of the pavement becomes wet, it is retarded in its ability to give up that moisture due to the cover above it. While the subgrade close to the edge may get wetter, it also dries more quickly; therefore, the average moisture content remains somewhat even. These tendencies are observed in the case of the plain-earth subgrade, but the oiled-earth sections, which represent an effort to construct moisture barriers, show plainly the effect of the pavement protection and the subsequent reduction of protection at the edge.

In 1952 the oiled sections showed practically the same moisture content as the plain-earth sections. Figure 7 shows that the effect of pavement protection was gradually being overshadowed, perhaps by the interference with the normal evaporative conditions, the accumulation of moisture under the oil barrier, or again by any number of other

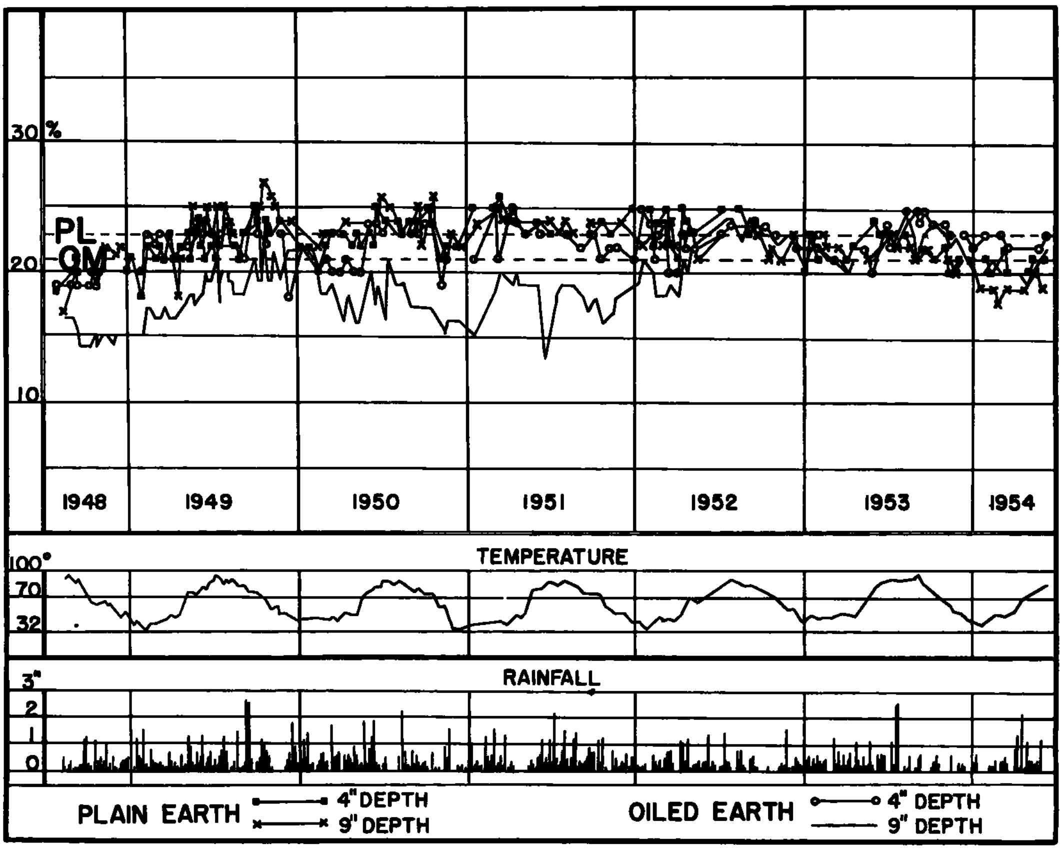


Figure 6. Comparison of the moisture averages of all cells 3 feet from the pavement edge.

contributory conditions. The oiled sections then felt the drouth in 1952 and again showed the effects of edge exposure. An interesting point to note is that the oiled sections did not start their decline until sometime after the plain-earth sections had started decreasing.

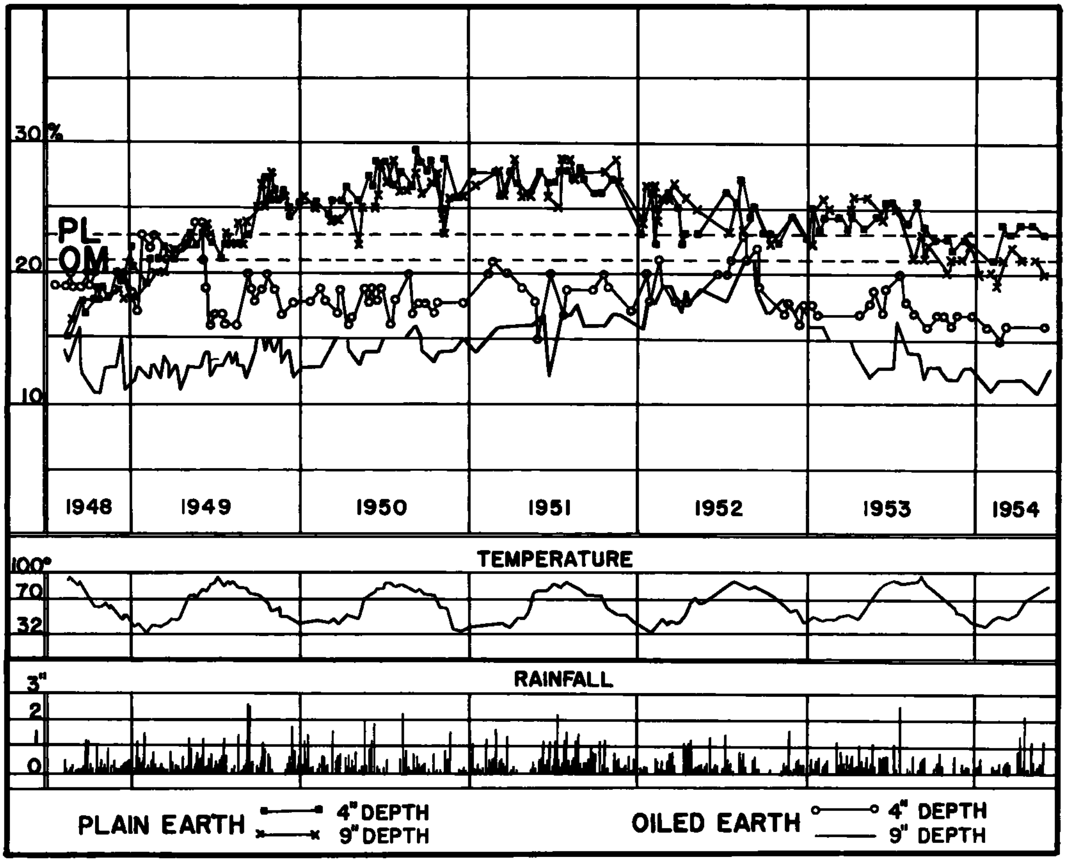


Figure 7. Comparison of the moisture averages of all cells 9 feet from the pavement edge.

The comparison of Figure 8 and Figure 9 were made in an attempt to show the influence of the exposure from the transverse joints. The lack of any significantly great difference between these graphs indicates that the effect of the edge exposure greatly overshadows the effect of the joint exposure. In other words, water can and does enter more easily (and in greater volume) from the edge than from the joint.

The results of all of the cells are used in this averaging so half of the cells 3 feet from the edge are averaged in the group 3 feet from the joint. The reverse was true in Figure 6, where half of the cells 3 feet from the joint are averaged in the group 3 feet from the edge. This fact points up the overshadowing effect of the edge exposure. In all probability the importance of edge-versus-joint exposure is relative to time and maintenance procedure. Efficient and timely crack and joint maintenance will serve to preserve the difference in moisture level with the locations nearer the edge staying the wetter.

Figures 10, 11, 12, and 13 were drawn to show subgrade moisture difference under different types of base treatment. Figure 10 shows the differences in subgrade moisture under two sections of rolled-stone base on oiled-earth subgrade, one of which is considered bad because of a poorly worked subgrade which did not attain the expected results under construction. The oiled subgrade was badly rutted and the seal was broken in such a way that the subgrade had a checkerboard appearance. Since this was purely an experimental project, the best method of subgrade construction was not known ahead of construction. As a result, the desired subgrade treatment was not obtained on this section. Con-

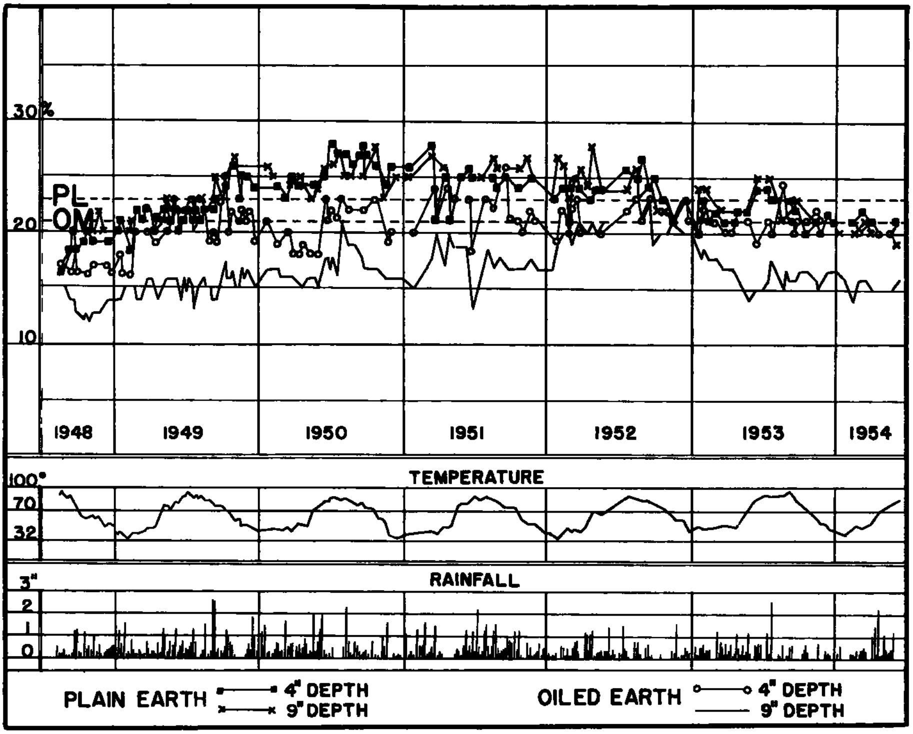


Figure 8. Comparison of the moisture averages of all cells 4 feet from the transverse joint.

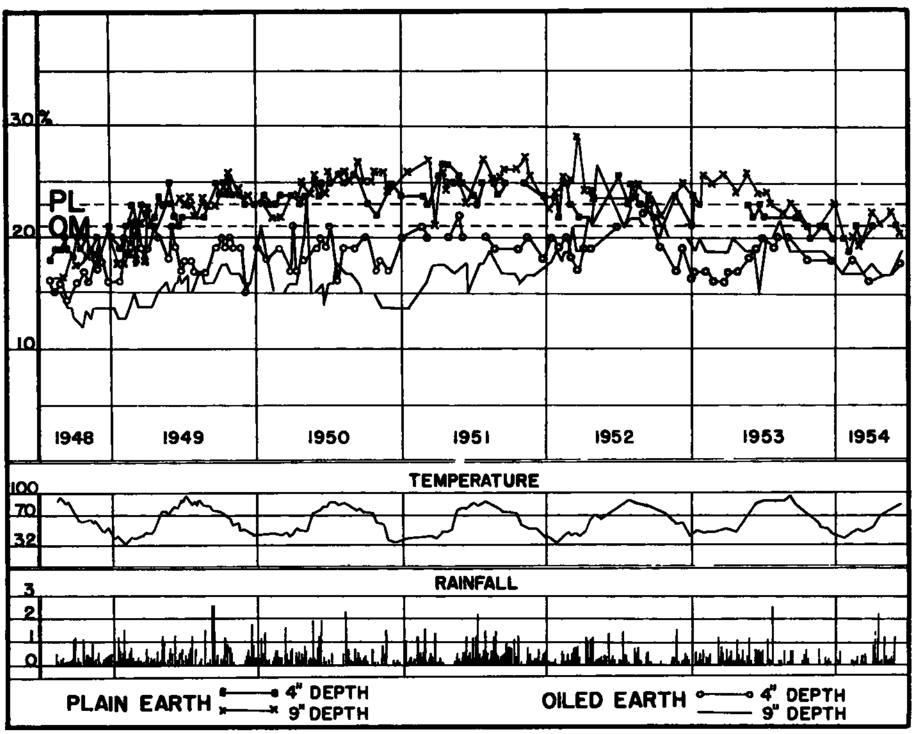


Figure 9. Comparison of the moisture averages of all cells 20 feet from the transverse joint.

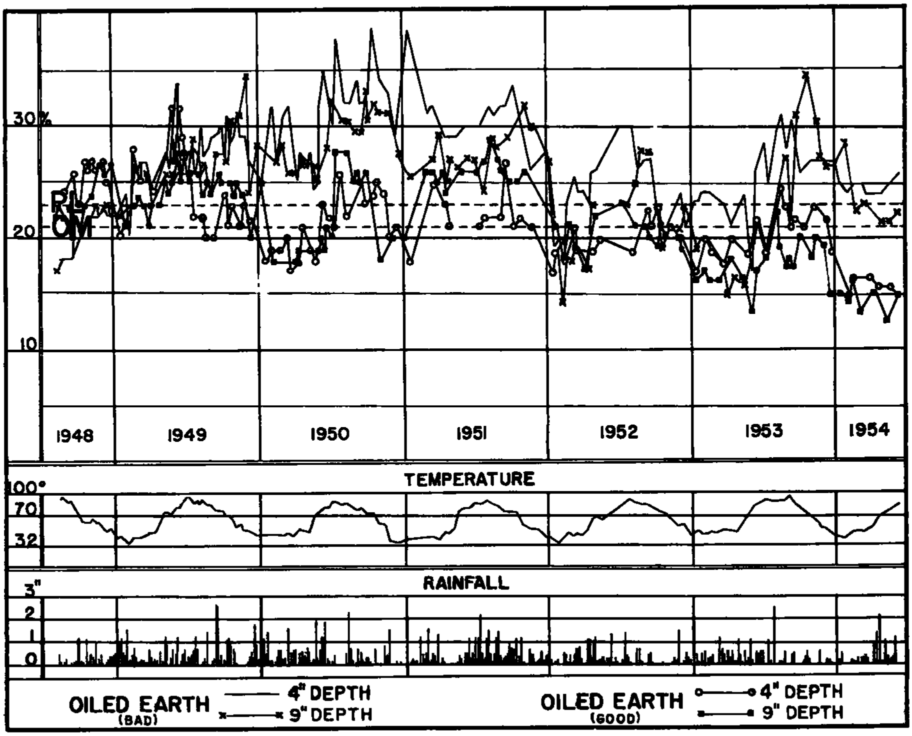


Figure 10. Comparison of the moisture averages of all cells under rolled stone base which had been placed on oiled earth subgrade.

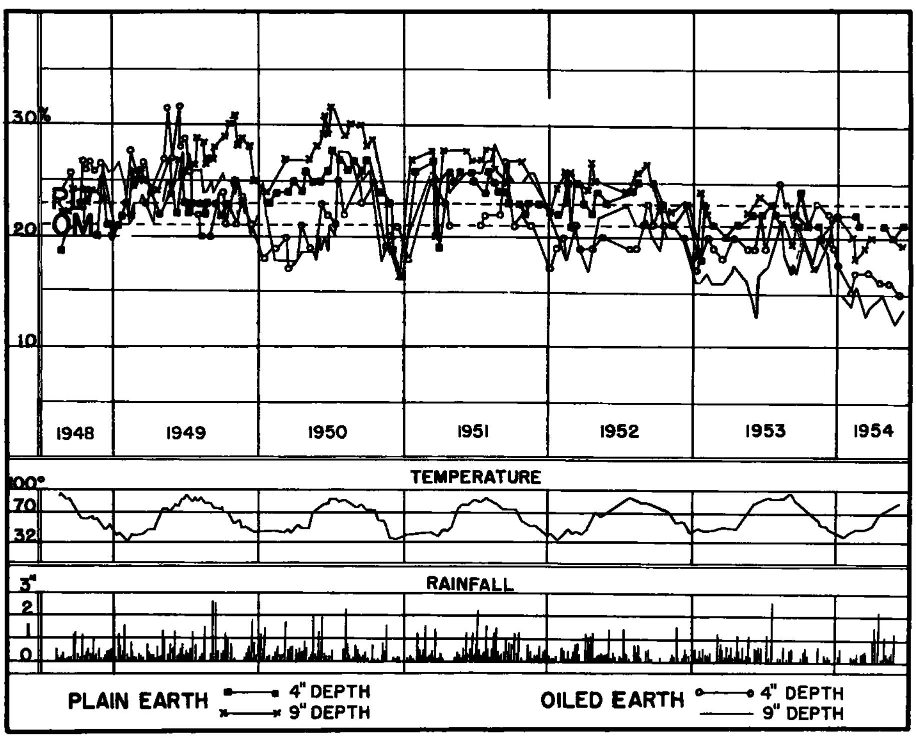


Figure 11. Comparison of the moisture averages of all cells under rolled stone base.

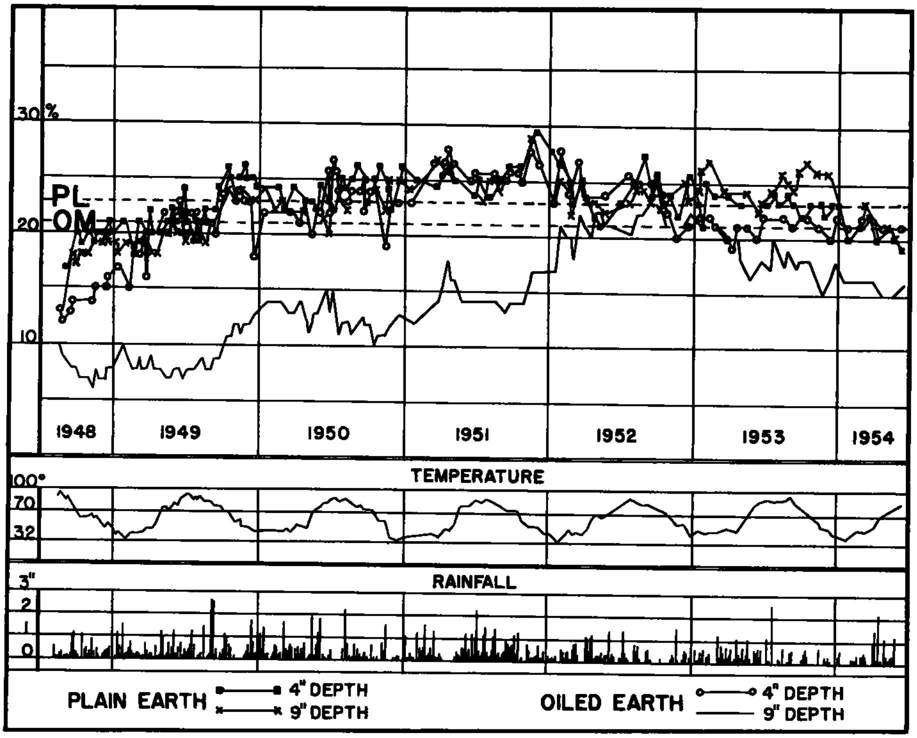


Figure 12. Comparison of the moisture averages of all cells under sand-gravel base.

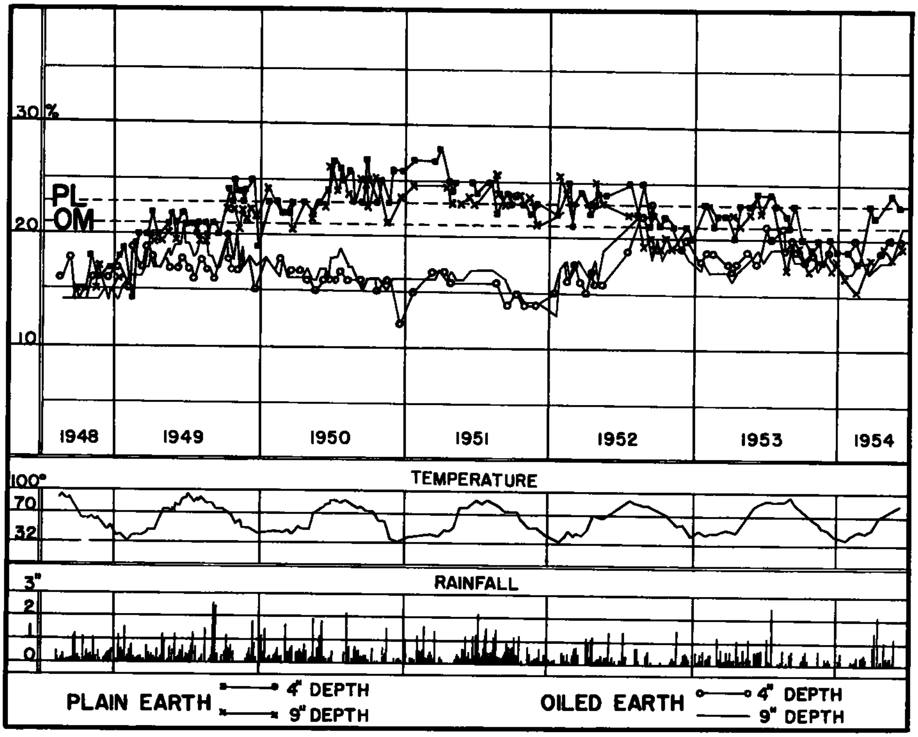


Figure 13. Comparison of the moisture averages of all cells under no base.

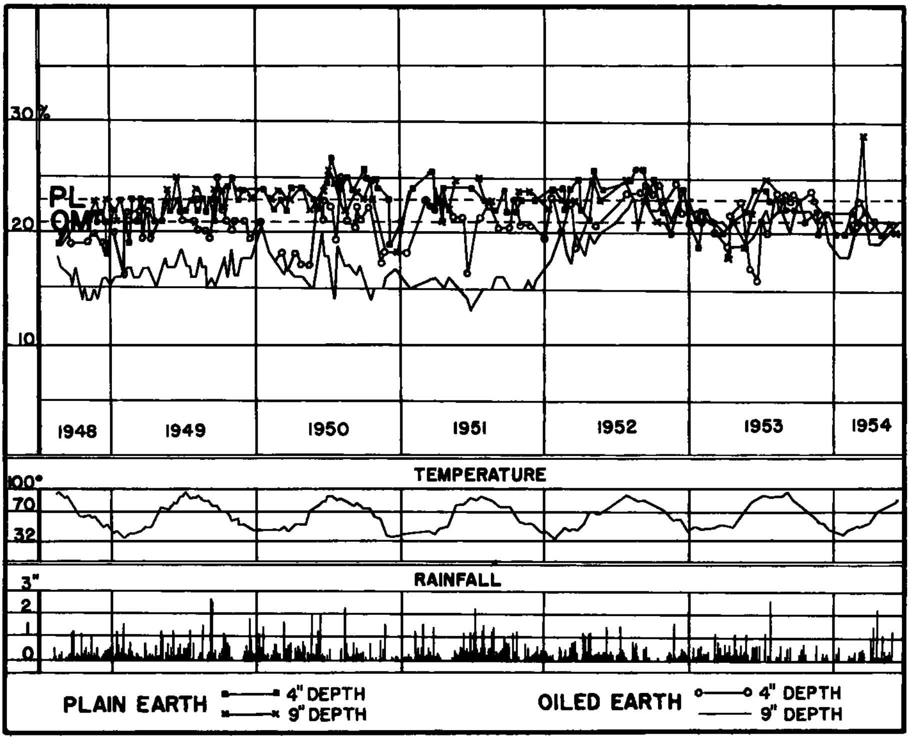


Figure 14. Comparison of the moisture averages of all cells 3 feet from the edge and 3 feet from the joint.

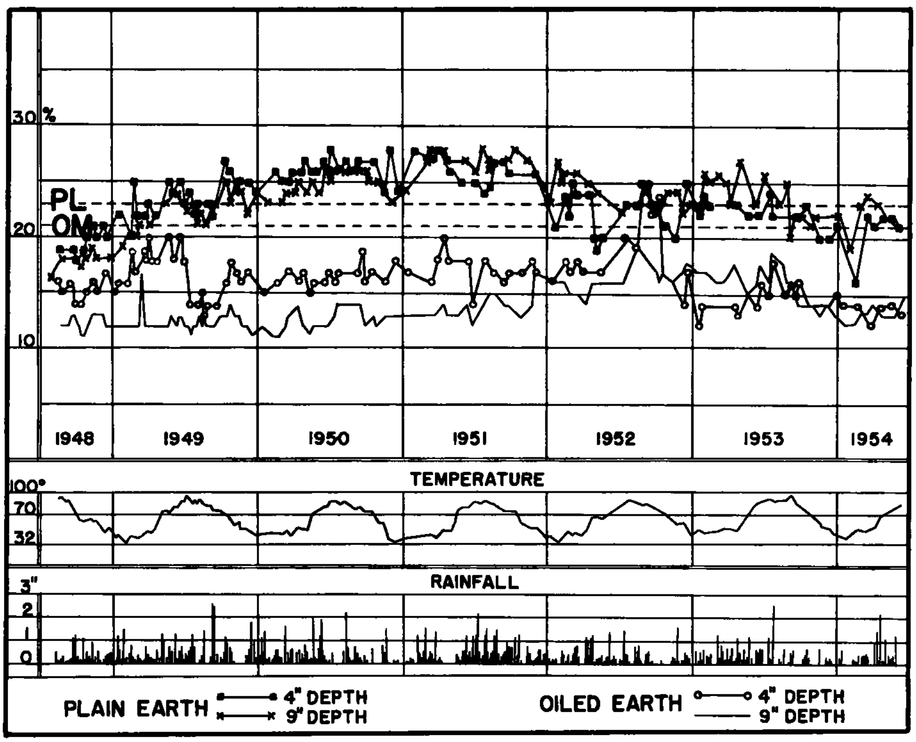


Figure 15. Compariosn of the moisture averages of all cells 9 feet from the edge and 20 feet from the joint.

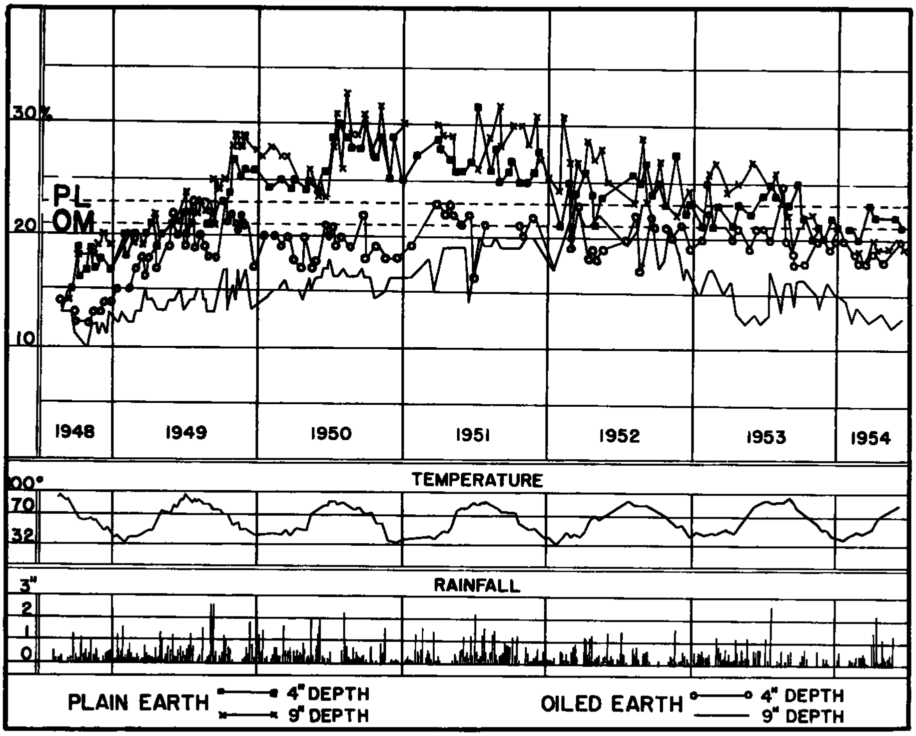


Figure 16. Comparison of the moisture averages of all cells 9 feet from the edge and 3 feet from the joint.

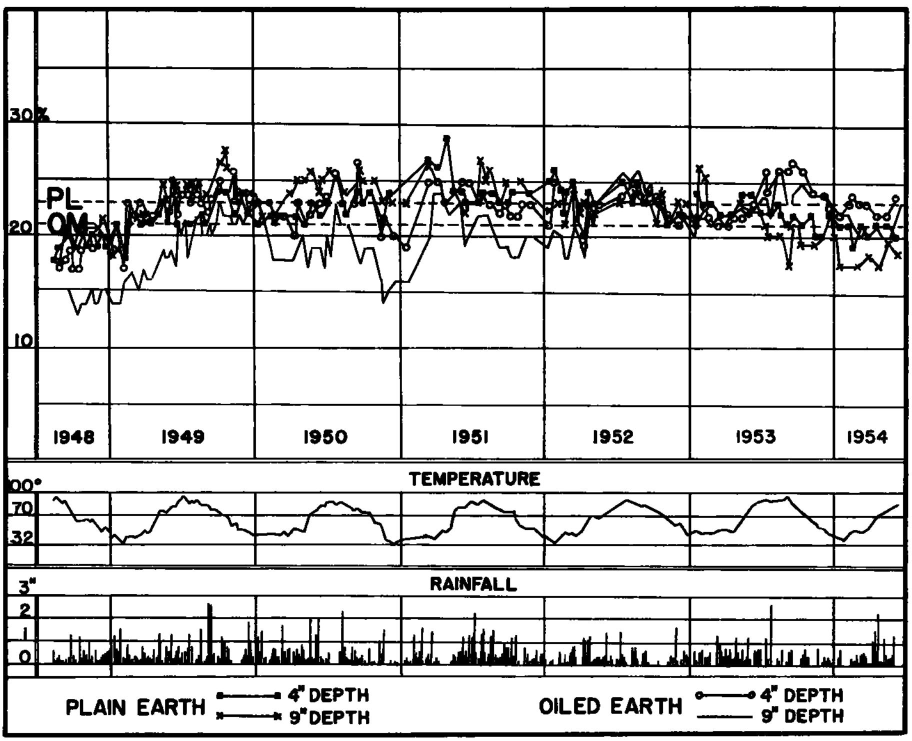
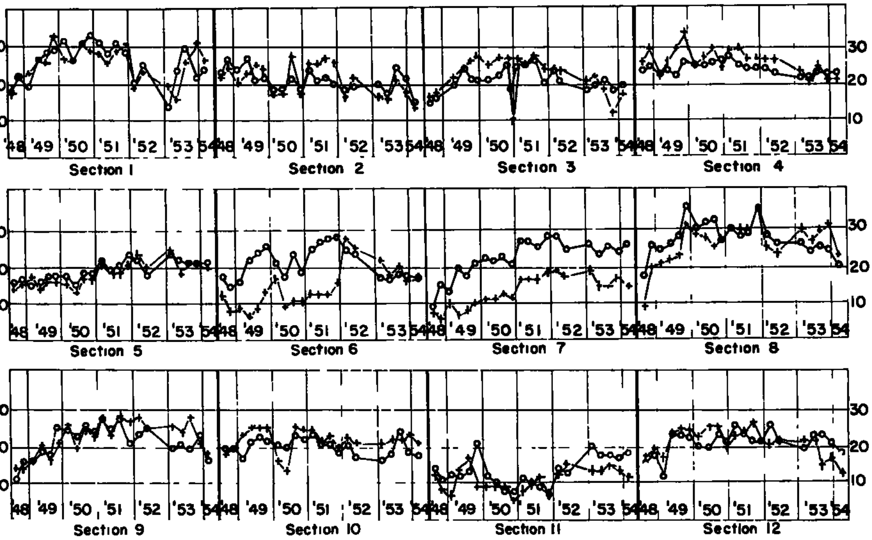


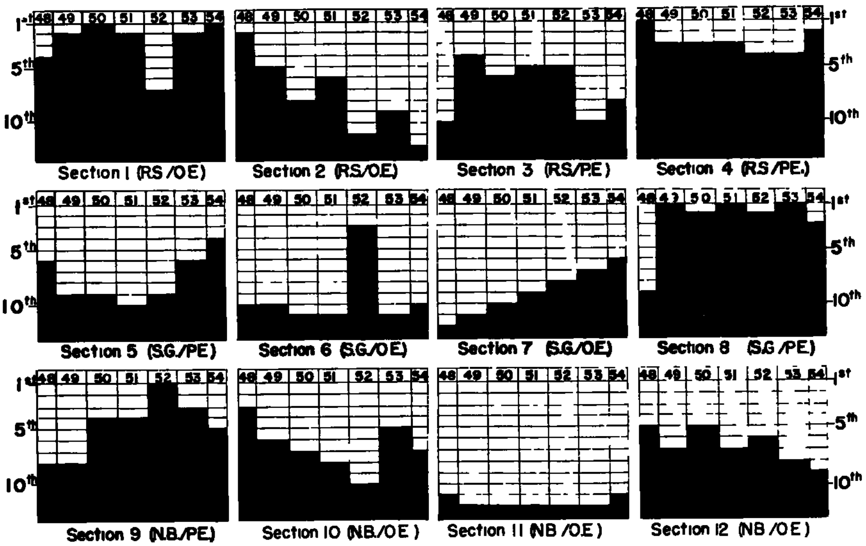
Figure 17. Comparison of the moisture averages of all cells 3 feet from the edge and 20 feet from the joint.



Moisture Averages for Each Section Plotted at Three Month Intervals

o—o—o—o 4" Depth +—+—+—+ 9" Depth

Figure 18. Comparison of the moisture averages of each comparable section.



Yearly Moisture Averages

Example. In 1948 Section No 4 ranked 1st (Wettest)
Section No 2 ranked 2nd (Wet)

Section No 7 ranked 12th (Driest)

Figure 19. Relative wetness of each section.

struction notes covering these difficulties are contained in Appendix A.

In considering Figure 10, it is apparent that a certain type of oiled-earth construction will greatly contribute to the continuing support of a high subgrade-moisture level. The drouth did not have such an appreciable effect upon the subgrade moisture content of this section (No. 1) as it did on other sections.

The comparison of Figures 11, 12, and 13 raises many questions which will only be answerable on this project in years to come, after the performance of the various sections under traffic has been evaluated. The true benefits of this study will be realized as the evaluation is then made. Such data will serve as reference points for these comparisons. Most performance investigations up to this time have not contained sufficient subgrade-moisture history, and this fact has probably been ignored in the evaluations.

As an example, the question is raised as to the benefit (as far as subgrade moisture is concerned) of a base course of either type, for the graphs show the no-base sections to be relatively drier than the base sections, this being especially true for the oiled sections (Nos. 10 and 11). The conjecture is also put forth as to how long this condition might last. This question may be answerable in the future but not at this time.

If subgrade moisture were the criterion by which the base courses were to be judged, (considering rigid pavement only), the first choice as the best base treatment would have to be no-base on oiled-earth subgrade. Next would be sand-gravel base on oiled earth, then no-base on plain-earth subgrade, and last would be the rolled-stone base on a poorly constructed (bad) oiled-earth subgrade. It is the authors' opinion, however, that the last-mentioned section should be viewed as unsatisfactory and unintentional design, and the data should be used and considered only in this light.

It seems to be indicated that the average moisture contents of all the sections were coming to a common level at the early part of 1952 (at the start of the drouth). Again a question is posed as to what might have happened had not the drouth set in.

One must not jump to the conclusion that all of the sections would have then remained at the same general moisture level and that because of this lack of differentiation that there was no benefit from the base material or construction.

The oiled-earth sections, under each of the base types, average drier than the plain-earth sections for practically the complete period of time under consideration. This is especially true of the no-base sections.

It is interesting to note the spread in moisture contents which was almost constantly maintained between the 4-inch depth and the 9-inch depth in the oiled-earth subgrade under the sand-gravel base. Apparently when the checking action of the oiled earth is present, the greater permeability of the sand-gravel base does not allow the penetration of moisture into the subgrade that the less-permeable rolled-stone base permits. This is probably a question of the available-time element of moisture entrance. It has been observed that rolled-stong bases, constructed of relatively soft stone, have a tendency toward a type of wicking action which might loosely hold and transfer water over a period of time.

Figures 14, 15, 16, and 17 were drawn to show the differences in average moisture contents at the various locations with respect to the edge and joint. As has been expected the cell with the greatest exposure (Figure 14) maintained the wettest average, while the cells with the least exposure (Figure 15) maintained the driest average. The drier average on the part of the least-exposed cells is mainly due to the consistent dryness of the cells in the oiled-earth subgrade. The erratic moisture condition of the cells 9 feet from the edge and 3 feet from the joint and the spread between the plain-earth averages and the oiled-earth averages of these cells is indicative of the exposure from the joint and its relation to the exposure from the edge. Figures 16 and 17 indicate, as noted before, the effect of the construction of a barrier to moisture entrance from above when the barrier has the additional aid of less exposure. These graphs serve to emphasize the greater severity of edge exposure.

Figure 18 was constructed to show the moisture average of each section at 3-month periods. These periods correspond to the subgrade sampling dates of another investigational project. The averages plotted are the averages for particular days at 3-month intervals and not the average over the 3-month periods.

Figure 19 was constructed to show the relative wetness of any section by means of yearly averages. Figures 18 and 19 taken together show the relative wetness and also give the moisture level of the various sections. In evaluating Figure 19, the more massive the black area for a section the higher was the relative wetness of that section. The first-four sections have rolled-stone base, the second-four have sand-gravel base, and the last-four have no base.

As can easily be seen, the first-four are the wettest and the last-four are a little drier than the sand-gravel. With the exception of Section 1 (the poorly constructed, oiled subgrade) the oiled sections are drier than the plain-earth sections under the different base types.

The gathering of soil-moisture data by means of cells is, of necessity, being concluded on this project, because the moisture cells have reached or are about to reach the limit of their expected life due to the deterioration of the leads and the insulation around them. It is not considered feasible to attempt to replace the blocks and leads, so subsequent check on subgrade-moisture conditions on this project will be by manual sampling.

Final conclusions as to which construction variation is the most efficient will only be reached in the future by the evaluation of the respective service records. To date the condition surveys have shown no appreciable differences which can be considered as indicative of pavement performance. This, report, therefore, should be considered as one of progress only. At the present time it should serve as a guide and stepping stone to further experimentation along these lines, especially in terms of studying the effectiveness and efficiency of moisture-barrier design.

The variations of some of the oiled sections in not reflecting the drouth as noticeably as other sections has led to conjectures as to the causes. One reason put forth is that the barrier of oiled earth has a reluctance to permit the release of moisture through surface evaporation, due to its combination with the wicking type base and high humidity. On the other hand, the pavement cover serves to maintain the high humidity level occasioned by even sparse rainfall.

CONCLUSIONS

The following conclusions seem to be justified by the data presented in this report.

1. The edge of the pavement is the main entrance of moisture into the subgrade (not the only).
2. The oiled earth serves to at least slow down the entrance of moisture into the subgrade.
3. Oiled-earth membrane or treated layer, if poorly constructed, can be detrimental as far as subgrade moisture is concerned.
4. There appears to be some benefit from the oiled subgrade in damping the fluctuations of the subgrade moisture content due to the climatic conditions (drouth, extremely wet seasons, etc.).

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable guidance and encouragement which F. V. Reagel, engineer of materials, and W. C. Davis, chief, Geology and Soils Section, gave during the compilation of this report. Thanks also go to M. S. Lattimore, materials engineer, for his considerate efforts in obtaining the field data and to all the laboratory technicians for their tedious work herein involved.

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Appendix A: Notes on Materials & Construction

ROLLED STONE BASE

Material for rolled stone base was produced by the Tobin Quarries Co. from a ledge of Burlington limestone, located two miles southeast of Foristell, in the SE ¼ Sec. 29., T-47-N, R 1-E, St. Charles County.

The stone was produced under the following specification, which was set forth in the Special Provisions.

Passing 1 inch sq. opening sieve	-	100 percent
" No. 4 "	-	40 - 60 percent
" No. 40 "	-	15 - 35 percent

A 5 percent tolerance was allowed between the 1-inch and 1½-inch sq. sieves. The minus No. 40 fraction shall have a liquid limit not greater than 25 and a plastic index no greater than 6.

The results of tests on samples taken during construction shows that the rolled stone base material conformed to the gradation requirements. The average of all tests being as follows; 100 percent passing the 1-inch square opening sieve, 53.1 percent passing th No. 4 sieve and 21.6 percent passing the No. 40 sieve.

The base was constructed in two layers; the bottom layer approximately 3-inches thic followed by a topping layer approximately 1-inch thick.

Compaction was obtained with pneumatic-tired rollers. A flat-wheel roller was used in conjunction with final finishing immediately ahead of pavement construction.

The dry density of the completed base averaged 126.5 lb. per cu. ft. and the moistur content averaged 3.8 percent. Based on a maximum dry weight per cu. ft. of 144.3 lb., which was determined by Lab. Test No. 48-1161, the obtained average weight of 126.5 l per cu. ft. is only 87.6 percent of the standard.

SAND-GRAVEL BASE

The sand-gravel base material was furnished by the Tobin Quarries Co., from a deposit located in Peruque Creek, 2 miles southeast of Foristell and it was produced subject to the following gradation specification.

Passing 1½-inch round screen	------------100 percent
" ½-inch " "	------------50-8- percent
" ⅛-inch sieve	------------30-55 percent
" No. 20 "	------------15-35 percent
" No. 100 "	------------0-10 percent

The fraction passing the No. 40 sieve shall be nonplastic.

According to the test results on samples taken during construction, all of the sand-gravel base material met the specified requirements for gradation. The maximum, minimum and average of all tests being as follows:

	Maximum	Minimum	Average
Passing 1½-inch screen	-	-	100 percent
" ½-inch "	75 %	59 %	68 "
" ⅛-inch sieve	53 %	42 %	47 "
" No. 20 "	35 %	22 %	27 "
" No. 100 "	7 %	4 %	5 "

The base was constructed in a single 4-inch layer and compaction was obtained with pneumatic-tire rollers. A 5-ton flat-wheel roller was used in conjunction with final finishing to produce a compact uniform surface immediately ahead of pavement constructions.

A maximum dry weight of 126.1 lb. per cu. ft. and an optimum moisture content of 8.4 percent was determined for this material by laboratory tests. It was found impracticable to make accurate density determinations of the base during construction, however, the moisture content was maintained slightly above the optimum and rolling was continued until the base was firm and there was no appreciable movement under the pneumatic-tired rollers.

It is the opinion of the observer that the density of 126.1 lb. per cu. ft. was obtained, however, when paving was commenced the batch trucks ravelled and dislodged the base to such an extent that it was necessary to operate the paver on the road shoulder.

OILED SUBGRADE

The experimental variation included several sections of oiled earth subgrade and the special provisions specified that this treatment shall consist of 1-gal. of SC-2 liquid asphaltic material per sq. yd., applied in 3 applications. This type of treatment was used under rolled stone base, sand-gravel base and where no aggregate base was specified.

Between stations 827+69 and 861+20 the subgrade was scarified, using a motor patrol with scarifier attached. The subgrade was quite dry at the time and as a result the loosened material contained many hard soil clods, some of which were 4-inches and even larger in diameter. Efforts were made to pulverize the oversize clods by disking and harrowing, but as this proved unsuccessful the loosened material was recompacted, as much as possible, by pneumatic-tire rolling and SC-2 oil was applied at the rate of 0.92 gal. per sq. yd. It was hoped that the coating of oil would tend to soften the clods and satisfactory compaction could then be obtained by subsequent rolling. However, very little softening of the clods occurred and the results obtained by rolling did not produce the uniform, dense surface desired.

Experience on this section would seem to indicate that scarifying is not a satisfactory method of preparing the subgrade for oil treatment.

Between stations 10+00 and 75+31 a motor patrol grader was used to form a windrow of soil material along the center of the road. This was done by thinly shaving the subgrade until the quantity in windrow was sufficient to produce a loose soil mulch, approximately ¾-inch thick when spread over the full width of subgrade.

Soil clods in the windrowed material were then further reduced by disking and harrowing, following which the material was respread uniformly over the full width of subgrade.

In spite of the care used in these operations the soil mulch after spreading generally contained from 10 to 20 percent of soil clods between 1 and 2-inches in diameter. Some of the difficulty experienced in efforts to obtain a greater degree of pulverization are attributed to the rains which occurred frequently while this work was being done.

On a part of this section, between stations 25+00 and 40+00, a total of 1 gal. of SC-2 oil was applied in 3 applications, at the following rates; first application 0.52 gal., second application 0.26 gal., and third application 0.22 gal. per sq. yd. On the balance of the section SC-2 oil was applied in 2 applications, the first application averaging 0.70 gal. and the second averaging 0.35 gal. per sq. yd., making an average total of 1.05 gal. per sq. yd.

In most instances both applications were made on the same day and each application was followed almost immediately by rolling with both flat-wheel and pneumatic-tired rollers. It might seem noteworthy, in this regard, that "pick-up" by the rollers was practically negligible.

Although the securing of more definite information as to the practicability and efficiency of this method of procedure was clouded by abnormally wet weather conditions, it appears that better results were obtained than on the previously described section on which the initial operation involved subgrade scarifying.

Between stations 120+00 and 164+61 the pavement was constructed directly on the oiled subgrade and a somewhat different procedure was followed in preparing the subgrade for oil treatment.

The subgrade was pulverized to a depth of approximately 1-inch by operating the subgrade machine on the pavement forms, which had been previously set to grade. This produced a well graded soil mulch with all of the material passing a 1-inch screen.

Oiling operations were interrupted several times by heavy rains. An idea of the delays due to intermittent rains can be had when it is stated that the first application was made on June 14 and the final application on July 2. The rains caused the mulched material to flow together and set and as a result it was necessary to re-loosen the subgrade with a spike-tooth harrow, over a considerable portion of the section before oil was applied.

Oil was applied in 3 applications at the following average rates; first application 0.60 gal. per sq. yd., second application 0.25 gal. per sq. yd., and the third application 0.25 gal. per sq. yd.

Rolling with pneumatic-tired and flat-wheeled rollers was done almost immediately following each oil application.

Several measurements which were made after the final rolling showed the oiled mulch thickness to be about ¾-inch.

Appendix B: Topography Maps and Notes

A description of the position of each set of eight blocks in relation to the surrounding topography is as follows:

Station 842+00 and 842+17 Test Section No. 1. Limestone aggregate, rolled stone base on oiled earth.

Centerline cut 4 ft.; 3 ft. special ditches on both sides; blocks placed just west of top of 1200 ft. VC from a +1.38 percent grade; eastbound roadway about 4 ft. higher. Surrounding ground is generally higher and is gently rolling, drainage to east and west.

Station 857+03 and 857+20 Test Section No. 2. Chert gravel aggregate, rolled stone base on oiled earth.

Centerline cut 2 ft.; special V ditch to south and standard roadway ditch to north; blocks placed on -0.25 percent grade; eastbound roadway 1 ft. to 2 ft. higher. Surrounding ground gentle to north and east, but slightly rolling to south and west.

Station 865+06 and 865+23 Test Section No. 3. Limestone aggregate, rolled stone base on plain earth.

Centerline cut 5½ ft.; standard roadway ditch to north and standard parkway ditch to south. Blocks placed on-0.25 percent grade; eastbound roadway 6 ft. higher. Surrounding ground gentle to north and west but slightly rolling to rolling in south and east.

Station 883+06 and 883+23 Test Section No. 4. Chert gravel aggregate, rolled stone base on plain earth.

Centerline cut 3½ ft.; standard roadway ditch to north and standard parkway ditch to south; blocks placed at top of 600 ft. VC going from -0.25 percent to -1.15 percent grade; eastbound roadway 4 ft. higher. Surrounding ground gentle to north and west, slightly rolling to south and east.

Station 911+24.1 and 911+41.1 Test Section No. 5. Chert gravel aggregate, sand-gravel base on plain earth.

Centerline fill 2 ft.; sidehill cut and fill. Special ditch both sides. One inch sand and gravel extended from base sand and gravel through shoulder 11 ft. from pavement edge on a slope of ½ inch per ft. Extends from Station 902+62 to 912+50. Underdrain across road at 911:50. Blocks placed at about original ground level on a +2.282 percent grade. Eastbound roadway 3 ft. lower. Rolling ground to north and west; slightly rolling to south and gentle to east.

Station 37+85 and 38+02 Test Section No. 6. Chert gravel aggregate, sand-gravel base on oiled earth.

Centerline cut 6 ft. standard roadway ditch to north and standard parkway ditch to south

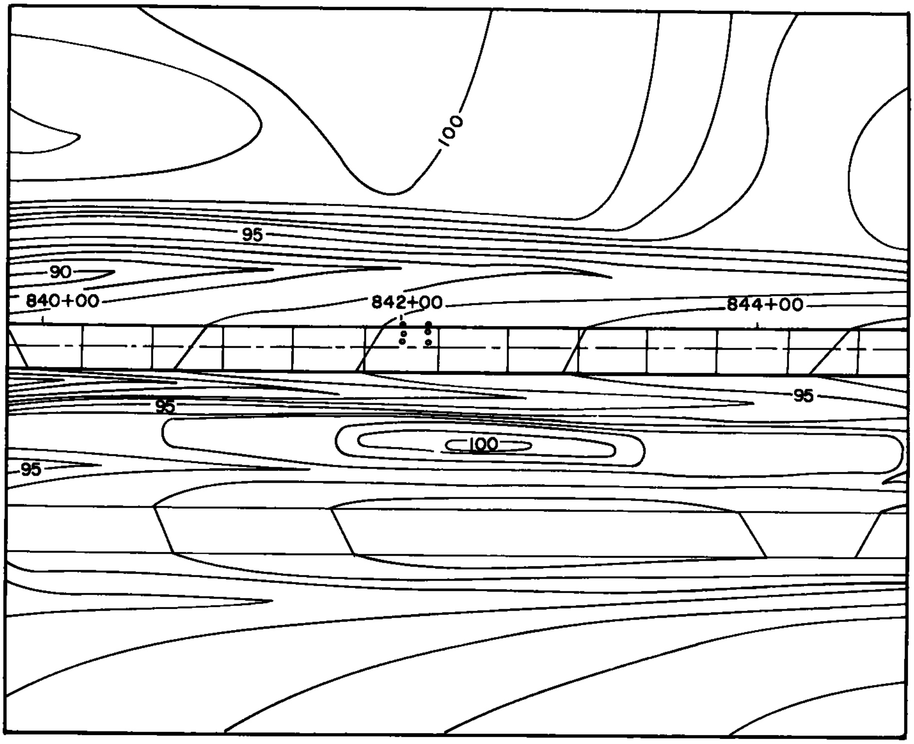

Figure A. A 1-foot-contour map showing relative elevations at cell locations in experimental Section 1.

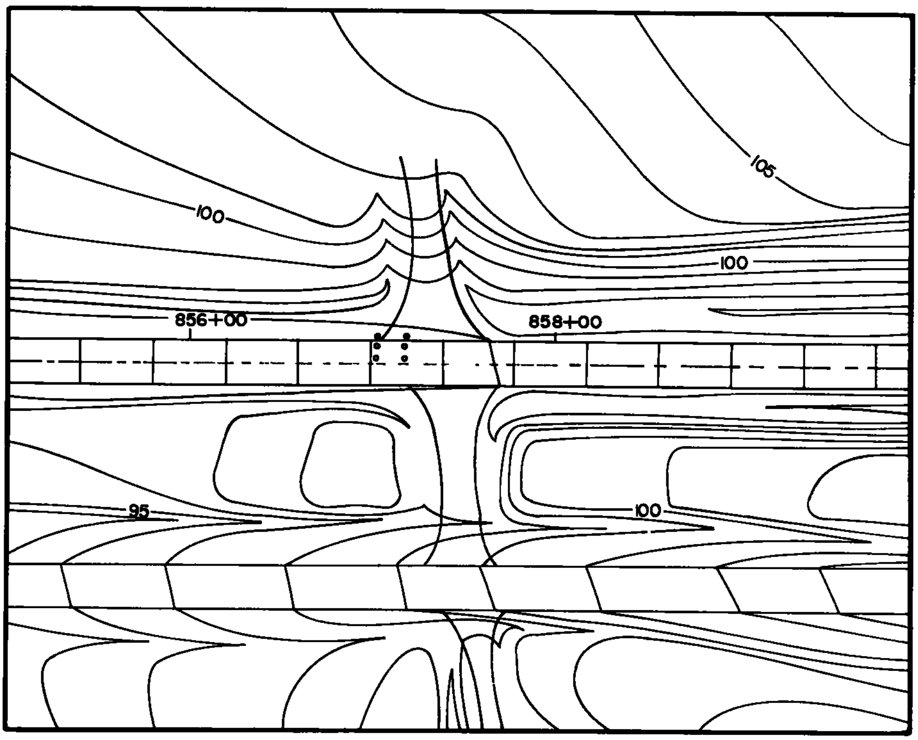

Figure B. Section 2.

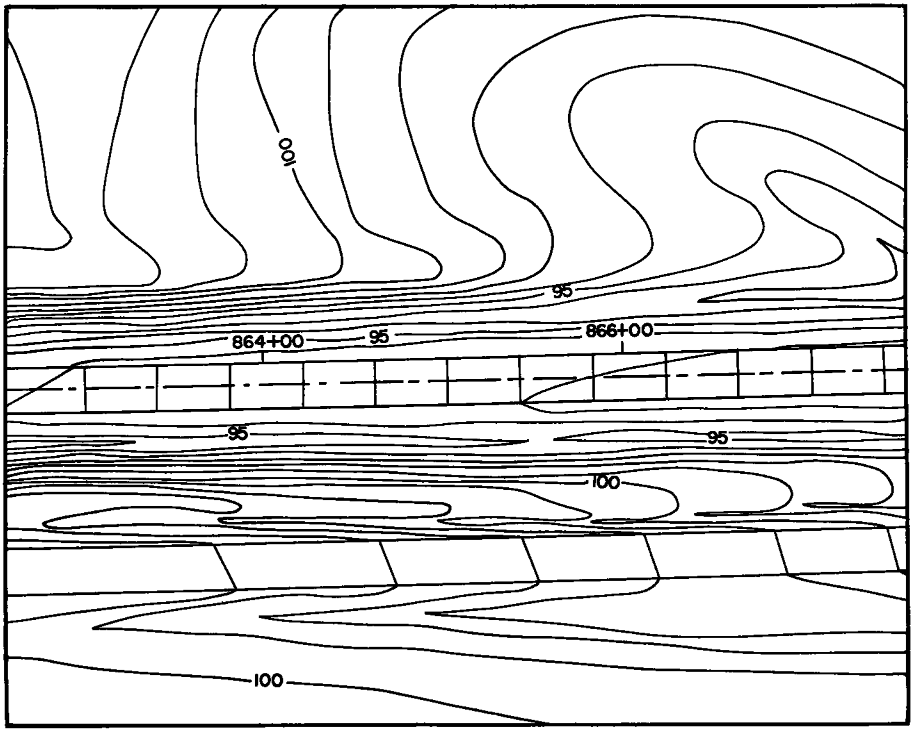

Figure C. Section 3.

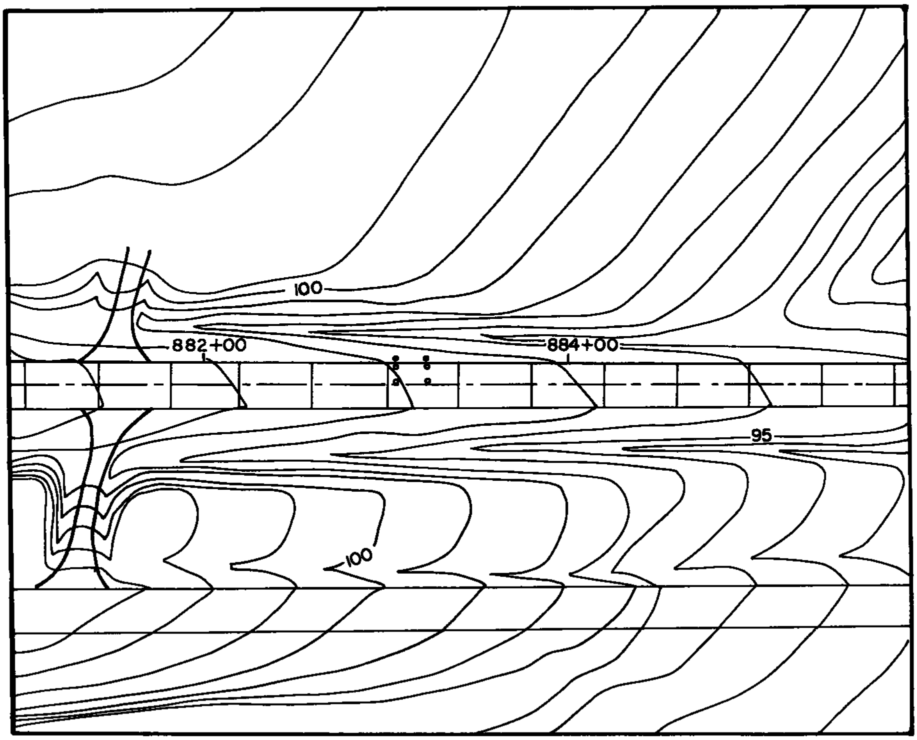

Figure D. Section 4.

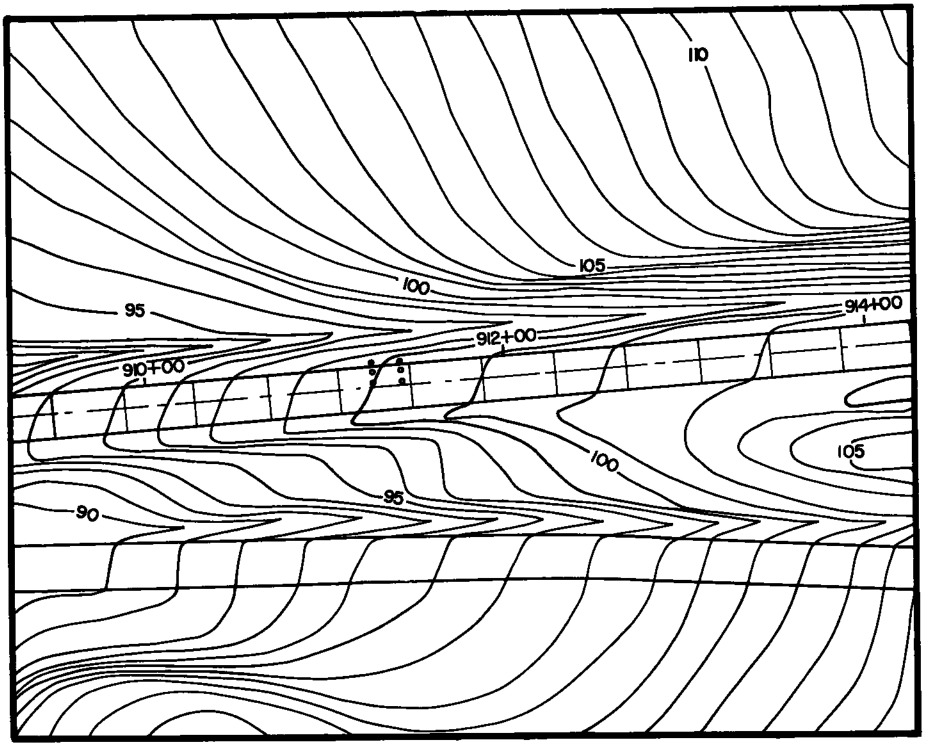

Figure E. Section 5.

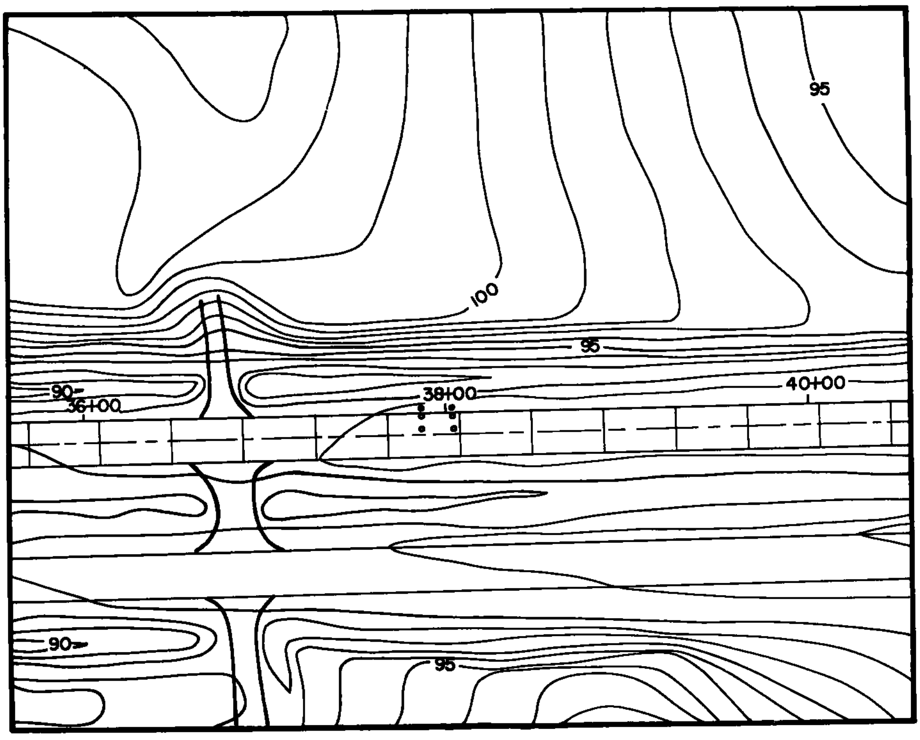

Figure F. Section 6.

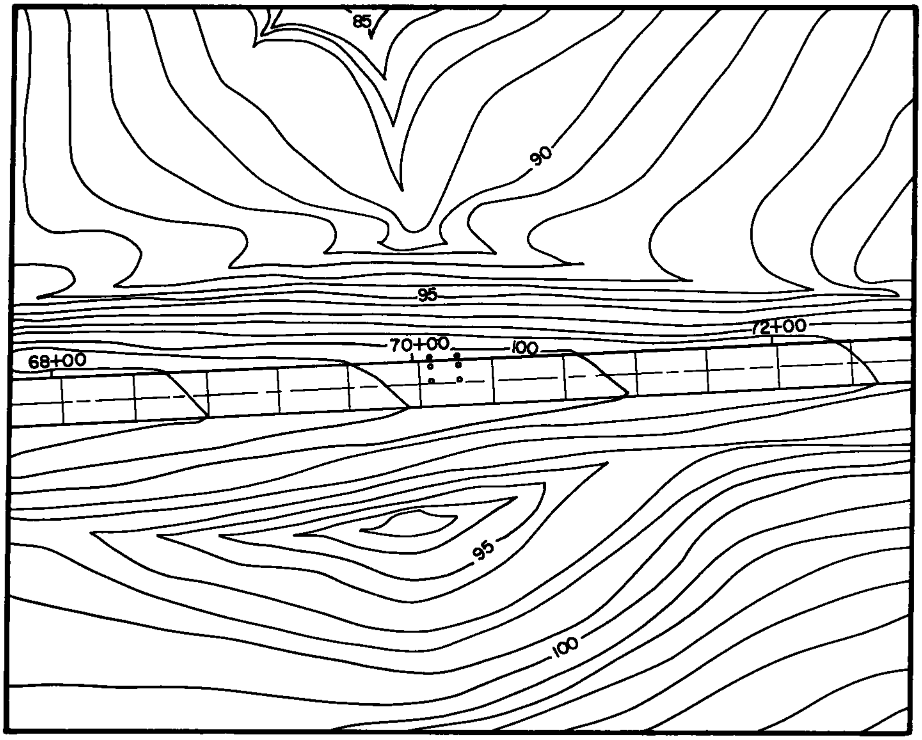

Figure G. Section 7.

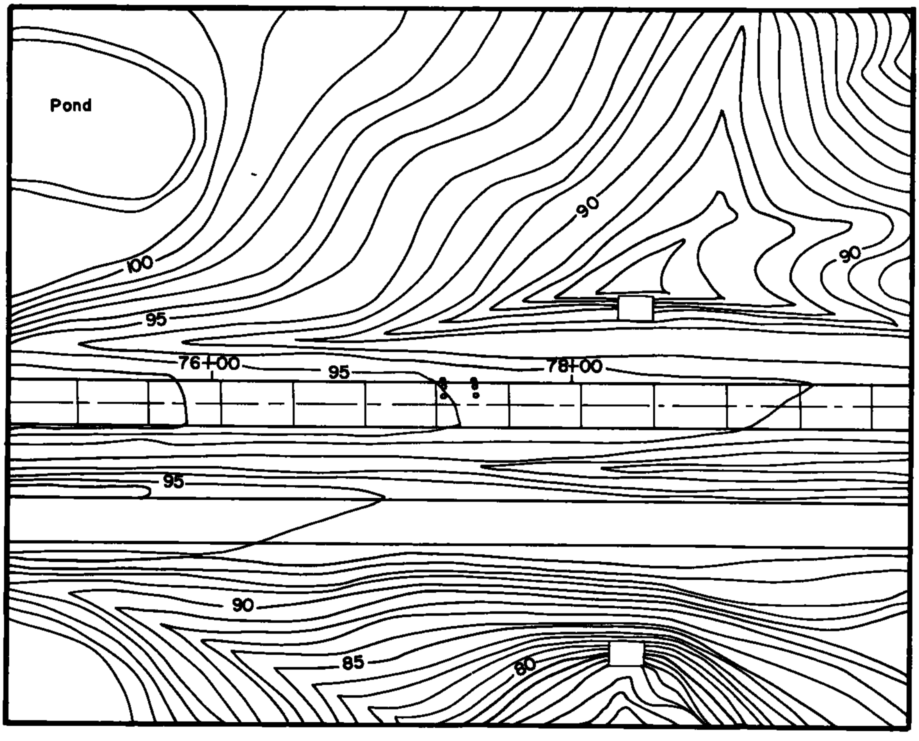

Figure H. Section 8.

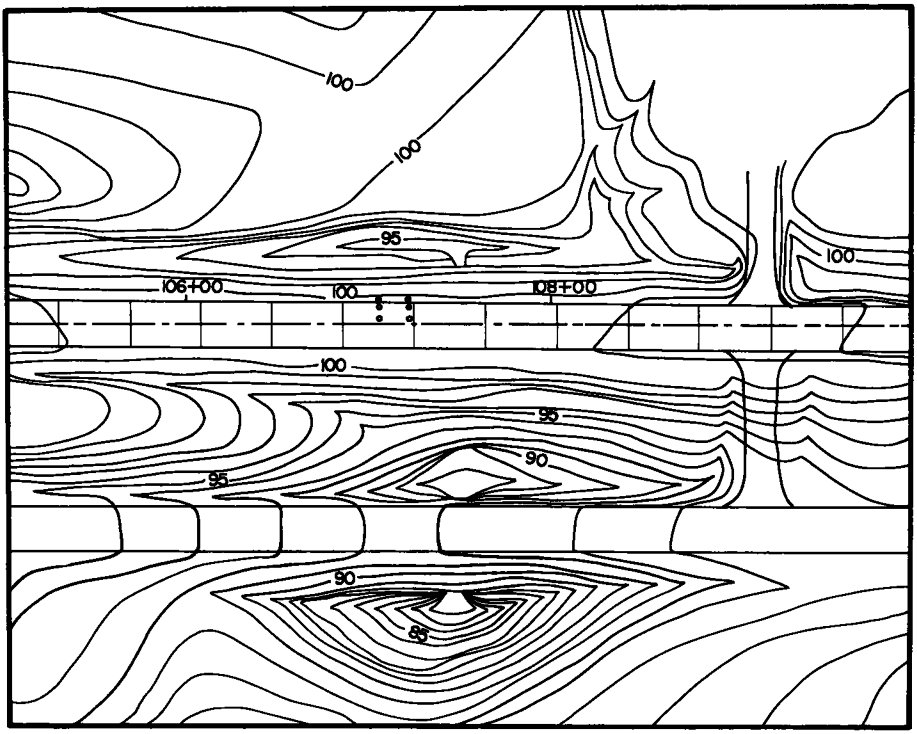

Figure 1. Section 9.

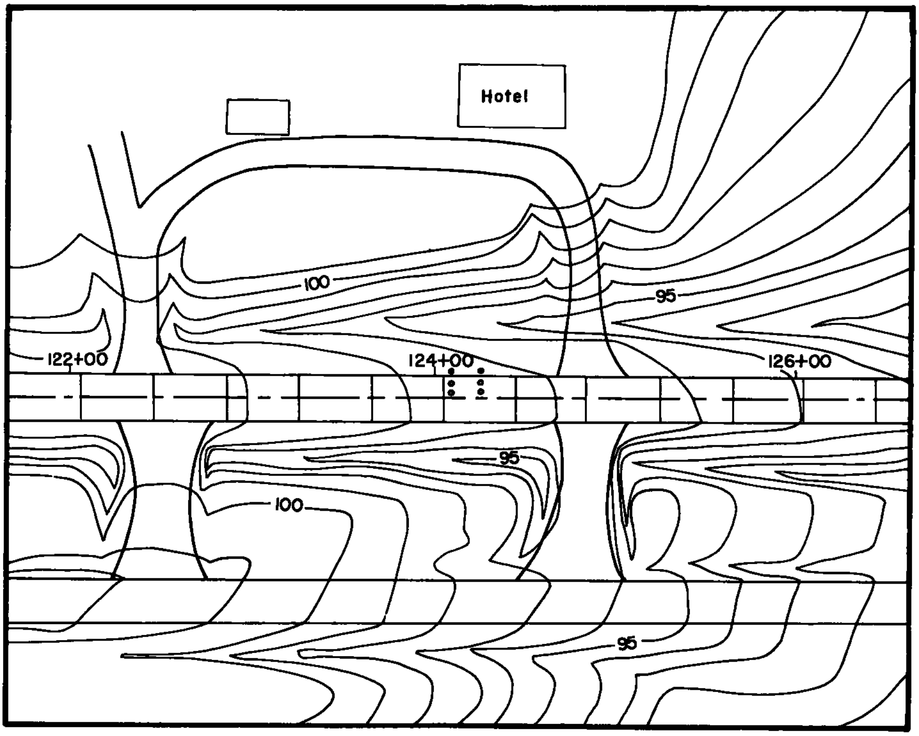

Figure J. Section 10.

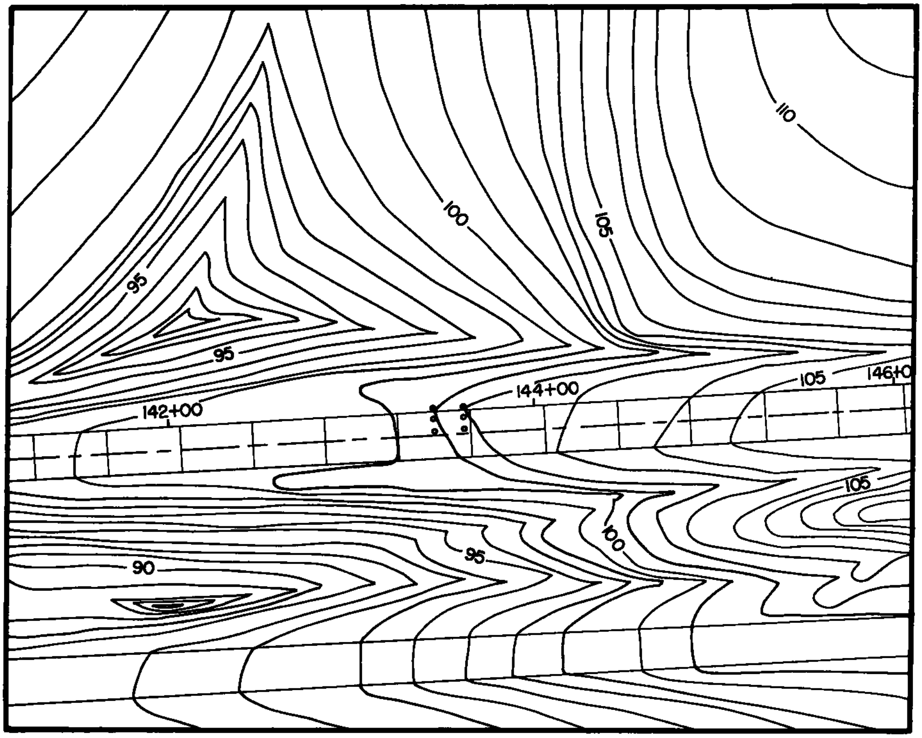

Figure K. Section 11.

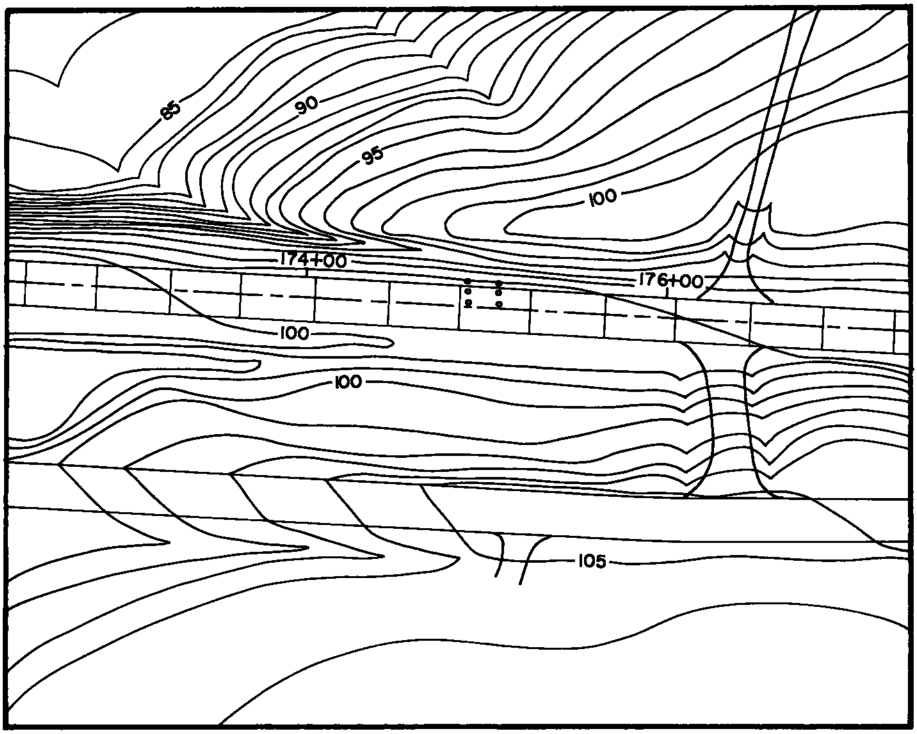

Figure L. Section 12.

Blocks placed on +0.314 percent grade; eastbound roadway even; topography rather level to the north, south, and east and rolling off to the west.

Station 70+08 and 70+25 Test Section No. 7. Limestone aggregate, sand-gravel base on oiled earth.

Centerline fill 7 ft.; special 3 ft. ditch to south and culvert drain to north. Culvert crosses roadway at 70+00. Blocks placed on -0.26 percent grade; eastbound roadway 4 ft. higher; general drain of all surrounding ground is gently to the north directly north of the blocks.

Station 77+28 and 77+45 Test Section No. 8. Limestone aggregate, sand-gravel base on plain earth.

Centerline fill 9 ft.; special 3 ft. ditch to north and standard parkway ditch to south. Blocks placed on -0.26 percent grade; eastbound roadway even on high fill; hill to northwest slopes sharply to south and east. Cattle pass under roadway at 78 ÷ 50.

Station 107+05 and 107+22 Test Section No. 9. Limestone aggregate on plain earth.

Centerline fill 8 ft.; special 3 ft. ditch to north and standard parkway ditch to south. Blocks placed on a +0.39 percent grade; eastbound roadway about 8 ft. lower. Ground slopes gently to south and to culvert on north side at 107+38.9.

Station 124+08 and 124+25 Test Section No. 10. Limestone aggregate on oiled earth.

Centerline cut 2½ ft.; standard roadway ditch to north and standard parkway ditch to south. Blocks on 1100 ft. VC going into a -2.00 percent grade; eastbound roadway about 3 ft. higher; ground gentle to north, west and south, rolling to east.

Station 143+45 and 143+62 Test Section No. 11. Chert gravel aggregate on oiled earth.

Centerline fill 6 ft.; special 3 ft. ditch on both sides. Blocks placed on +1.62 percent grade; eastbound roadway about 6 ft. lower. Ground slightly rolling to north and east, drainage to west and south.

Station 174+88 and 175+05 Test Section No. 12. Chert gravel aggregate on plain earth.

Centerline cut 5 ft.; standard roadway ditch to north and standard parkway ditch to south. Blocks placed on -0.26 percent grade; eastbound roadway about 3 ft. higher; ground slightly rolling in all directions, general drainage to northeast and northwest.

Appendix C: Subgrade Log of Experimental Section and Chart of Subgrade Moisture and Density Tests

Begin Cut Sta. 827+50
Begin Exp. Section 827+69

827+69 - 828+75 Horizon B
828+75 - 831+00 Horizon C
End Cut 831+00

831+00 - 831+50 No. side cut-So. side fill
831+00 - 831+50 Horizon B (At ℄)

Begin Fill 831+50
831+50 - 832+50 Mainly Horizon B
832+50 - 835+00 Mainly Horizon C
835+00 - 835+50 Mainly Horizon B

Begin Cut 835+50
835+50 - 836+00 Undergraded-backfilled with Horizon C
836+00 - 835+50 Horizon B
836+50 - 837+50 Horizon C
837+50 - 841+25 Blue clay layer of Glacial Till
841+25 - 844+75 Horizon C
844+75 - 845+00 Horizon B

Begin Fill
845+00 - 846+00 Mainly Horizon B
846+00 - 854+50 Mainly Horizon C
854+50 - 856+00 Mainly Horizon B

Begin Cut
856+00 - 856+25 Undergraded-backfilled with Horizon B
856+25 - 856+75 Horizon B
856+75 - 858+50 Horizon C
858+50 - 864+25 Blue clay layer of Glacial Till
864+25 - 866+75 Horizon C
866+75 - 867+00 Horizon B

Equation
859+52$\underline{^{68}}$ Bk. = 859+55$\underline{^{40}}$Ah.
-2.72'

Side hill No. side fill-So. side cut
867+00 - 867+50 Undergraded-replaced with Horizon C

Begin Fill
867+50 - 868+50 Mainly Horizon A
868+50 - 879+00 Mainly Horizon C
879+00 - 879+50 Mainly Horizon B

Side hill No. side cut-So. side fill
879+50 - 880+00 Undergraded-replaced with Horizon C

Begin Cut
880+00 - 880+25 Horizon B
880+25 - 881+75 Horizon C
881+75 - 882+30 Blue clay layer of Glacial Till
882+30 - 884+21 Horizon C
884+21 - 884+50 Horizon B

Begin Fill
884+50 - 885+50 Mainly Horizon B
885+50 - 889+75 Mainly Horizon C
889+75 - 890+50 Mainly Horizon B

Side hill So. side cut-No. side fill
890+50 - 891+00 Undergraded-replaced with Horizon C

Begin Cut
891+00 - 891+60 Horizon B
891+60 - 893+25 Horizon C
893+25 - 893+70 Blue clay layer of Glacial Till
893+70 - 896+88 Glacial Till
896+88 - 897+17 Blue clay layer of Glacial Till
897+17 - 897+25 Horizon C
897+25 - 898+00 Horizon B

Side hill No. side cut-So. side fill
898+00 - 898+65 Undergraded-replaced with mixture

Begin Fill
898+65 - 901+00 Mainly Horizon B

Side hill So. side cut-No. side fill
901+00 - 903+00 Horizon B

Begin Fill
903+00 - 905+50 Mainly Glacial Till
905+50 - 906+50 Mainly Blue clay layer of Glacial Till
906+50 - 909+00 Mainly Horizon B

Side hill No. side cut-So. side fill
909+00 - 910+00 Horizon C (Fill at ℄)
910+00 - 912+66 Horizon B
912+66 - 913+00 Horizon C

Begin Cut
913+00 - 914+50 Horizon C
914+50 - 914+88 Blue clay layer of Glacial Till

Cut
914+50 - 914+88 Blue clay layer of Glacial Till
0+00 - 1+25 Blue clay layer of Glacial Till
1+25 - 3+20 Glacial Till
3+20 - 5+72
5+72 - 7+00 Horizon C

Side hill No. side cut-So. side fill
7+00 - 8+00 Horizon B

Begin Fill
8+00 - 10+50 Mainly Horizon C

Begin Fill
8+00 - 10+50 Mainly Horizon C
10+50 - 13+38 Mainly Mixture of Blue clay & Glacial Till
13+38 - 15+20 Mainly Horizon B
15+20 - 16+00 Mainly Horizon C

Side hill No. side cut-So. side fill
16+00 - 16+20 Horizon B
16+20 - 16+50 Horizon C

Begin Cut
16+50 - 17+50 Horizon C
17+50 - 24+15 Glacial Till
24+15 - 25+10 Horizon C
25+10 - 25+50 Horizon B

Begin Fill
25+50 - 33+50 Mainly Glacial Till

Equation
$22+58^{\underline{8}}$ Bk. = $22+67^{\underline{7}}$ Ah
= -8.9'

Begin Cut
33+50 - 33+90 Horizon B
33+90 - 34+51 Horizon C
34+51 - 35+15 Blue clay layer of Glacial Till
35+15 - 35+85 Glacial Till
36+85 - 38+52 Blue clay layer of Glacial Till
*38+52 - 40+82 Horizon C
*40+82 - 43+00 Horizon B

Begin Fill (slight)
*43+00 - 44+50 Mainly Horizon B

Begin Cut (slight)
*44+50 - 45+40 Horizon B
*45+40 - 46+30 Horizon C
*46+30 - 48+00 Horizon B

Begin Fill
48+00 - 53+50 Mainly Horizon B

Begin Cut
53+50 - 54+15 Horizon B
54+15 - 61+65 Horizon C
61+65 - 62+50 Horizon B

Begin Fill
62+50 - 64+25 Mainly Horizon B
64+25 - 72+50 Mainly Horizon C

Begin Cut
72+50 - 73+40 Horizon B
73+40 - 75+75 Horizon C

Side hill No. side cut-So. side fill
75+75 - 76+24 Horizon C
76+24 - 76+80 Horizon B

Begin Fill
76+80 - 80+00 Mainly Horizon C

Begin Cut
80+00 - 81+35 Horizon C
81+35 - 86+85 Blue clay layer of Glacial Till
86+85 - 99+25 Horizon C

Note: Sec. 8 ends at Sta. 97+21

Cut
86+85 - 99+25 Horizon C
99+25 - 101+50 Blue clay layer of Glacial Till
101+50 - 104+40 Horizon C
104+40 - 105+50 Horizon B

Begin Fill
105+50 - 106+20 Mainly Horizon B
106+20 - 108+40 Mainly Horizon C
108+40 - 109+00 Mainly Horizon B

Side hill No. side cut-So. side fill
109+00 - 110+50 Horizon C (topsoil removed left of ℄ and replaced with Horizon C)

Begin Cut (slight)
110+50 - 113+00 Horizon B

Begin Fill (slight)
113+00 - 120+00 Mainly Horizon B (6 in. of topsoil removed from 113+00-120+00 and replaced)

*4 inches removed below base grade and replaced with Horizon C soil from borrow pit from 4 to 12 inches below basegrade is as indicated.

Fill (slight)
120+00 - 121+00 Mainly Horizon B

Begin Cut
121+00 - 121+60 Horizon B
121+60 - 125+60 Horizon C
125+60 - 126+00 Horizon B

Begin Fill
126+00 - 126+25 Mainly Horizon B
125+25 - 128+25 Mainly Horizon C
128+25 - 128+50 Mainly Horizon B

Side hill No. side cut-So. side fill
128+50 - 129+65 Horizon B
129+65 - 135+00 Horizon C

Begin Cut
130+00 - 133+15 Horizon C
133+15 - 133+50 Horizon B

Side hill No. side fill-So. side cut
133+50 - 136+00 Horizon B

Begin Fill
136+00 - 141+00 Mainly Horizon C
141+00 - 143+50 Mainly Blue clay layer of Glacial Till
143+50 - 144+50 Mainly Horizon C
144+50 - 145+00 Mainly Horizon B

Begin Cut
145+00 - 145+25 Horizon B
145+25 - 145+75 Horizon C
145+75 - 151+50 Blue clay layer of Glacial Till
151+50 - 152+50 Horizon C

Side hill No. side cut-So. side fill
152+50 - 153+60 Horizon C
153+60 - 157+00 Horizon B

Begin Fill
157+00 - 160+00 Mainly Horizon B
160+00 - 162+50 Mainly Horizon C

Side hill No. side fill-So. side cut
162+50 - 163+25 Horizon C

Begin Cut
163+25 - 165+60 Horizon C
165+60 - 166+25 Horizon B

Begin Fill
166+25 - 168+00 Mainly Horizon B
168+00 - 173+25 Mainly Horizon C
173+25 - 174+00 Mainly Horizon B

Begin Cut
174+00 - 175+50 Horizon C
175+50 - 176+45 Blue clay layer of Glacial Till

End of Experiment

Survey made by M. S. Lattimore

TABLE A

SUBGRADE MOISTURE CONTENT AND DENSITY PRIOR TO BASE CONSTRUCTION

Experimental Section Number	Station	Distance from Joint	3 Ft from Edge Pavement, 4 In Depth, %H₂O	3 Ft from Edge Pavement, 4 In Depth, #/cu ft	3 Ft from Edge Pavement, 9 In Depth, %H₂O	3 Ft from Edge Pavement, 9 In Depth, #/cu ft	9 Ft from Edge Pavement, 4 In. Depth, %H₂O	9 Ft from Edge Pavement, 4 In. Depth, #/cu ft	9 Ft from Edge Pavement, 9 In Depth, %H₂O	9 Ft from Edge Pavement, 9 In Depth, #/cu ft
	832+00	20	21.8	103 6	21 6	102.6	18.1	108.4	28.1	97.6
	832+17	3	21 3	105.5	26.8	98.4	20.9	106.4	22.6	102.7
	833+00	-	16 8	112.7	19.0	103.6	29 3	96 2	16 6	96 2
1	837+00	-	19 1	102.5	23 1	106 0	15.7	114.2	20 5	102.9
	840+00	20	18.3	104.8	26 6	99 6	26 3	95 7	28 0	97 1
	840+17	3	28 8	95 4	27.5	97 0	25.3	99 8	27.3	97 8
	842+00	20	28 6	94.7	23 5	104 2	27 2	100.8	27.7	99.5
	842+17	3	26.4	94.0	24 4	101.7	21.9	102 4	26.3	87.3
	855+20	20	24 3	102.7	14 7	111.2	16.5	113.1	19 0	109 3
	855+37	3	17 6	113 2	13 7	104 3	18.3	111 6	19.9	109.1
2	857+03	3	20.9	107.4	21.3	105.9	21.4	106.6	20.2	106.7
	857+20	20	19 5	110.3	20 4	108.7	19.8	108 8	20 2	110 1
	859+83	3	20.9	107 4	22 1	105.7	21.2	108 4	21.7	106 6
	860+03	20	23 0	99.6	21.1	109.3	22.9	105 5	21.8	104 7
	865+06	3	20 9	104 6	23 8	102 6	19 1	103 7	21 6	105 1
	865+23	20	22 8	101 1	28 3	96.6	22 7	102.6	24.0	101 2
3	875+23	20	18 8	108 3	20 6	102 6	25 2	100 0	24.0	97 7
	875+40	3	16 6	107 1	20.5	107.4	20 3	110 2	21.9	103 4
	881+23	20	22 6	107.8	24.0	103.8	21 4	108.1	22.5	105 9
	881+40	3	24 8	103 0	22.9	104 3	28.8	97 3	27 3	99 8
	883+06	3	18 5	112 2	18.2	107.9	18.8	111.9	23 1	105 7
	883+20	20	19 5	110 2	20 4	106 2	19 2	111 9	20 5	107.8
4	891+06	3	17 8	110 2	21 7	97 0	15 9	104 9	19.6	94 6
	891+23	20	16 6	109.4	23 7	99 4	19 5	108 5	27 9	90 6
	895+06	3	16.6	111 6	18.5	94 3	18 1	104 4	19 7	98 7
	895+23	20	25 5	104 3	15 5	108.4	17 4	106 4	19 9	105 0
	903+07	3	22 2	102 3	20.3	101.1	21 8	98 0	16.2	104 1
	903+24	20	21 8	105.8	18 8	104.0	18.9	107.5	18 9	104 2
5	911+24	20	17.9	97.3	17 5	92.9	15 0	102.3	17 3	94 4
	911+41	3	17.5	87.2	18.6	96.3	17.7	95.1	17 4	93 6
	2+56	20	18.3	110 3	15.6	136 4	20 1	95 8	14.9	119.8
	2+73	3	19.5	109 6	18.3	112 8	19 0	110 5	17 8	114 5
	11+59	3	16.4	99.3	19 2	107 8	27.6	100.6	19.9	108.1
	11+76	20	15 8	91.6	20.0	108 3	21 0	107.9	17 7	93 5
6	28+25	20	18 3	114 1	24 3	98 8	17.9	106.0	18.8	109.3
	28+42	3	19 3	110.9	18 2	96 7	18 4	112 2	18 3	112 5
	37+85	20	23 3	102 7	21 4	107 6	23 8	103 1	19 8	109 0
	38+02	3	21 5	104 8	21 6	102 5	23.9	102 2	20.8	105.5
	45+05	20	21 6	102.5	32 6	89.3	29 8	94 8	30 4	90 3
	45+22	3	25 2	98 5	28 9	94.6	28.6	95.7	31 4	92 2
7	59+68	3	19 7	100 1	21 3	99 3	15 9	102 2	17 4	100 5
	59+85	20	18 9	110 9	19.4	108 9	14 0	113 2	15 1	112.2
	70+08	3	17.2	114 0	16 6	115 4	18.2	105.1	16 3	99 0
	70+25	20	18 9	112.0	16 8	106 5	18.9	112 7	16 2	101.1
	77+28	3	17 9	112 3	22 2	105.1	21 5	105.8	17 8	102.2
	77+45	20	19 3	113.2	22 0	106 6	22 1	107 0	16 7	113.2
8	81+28	3	26 2	100 6	23 9	103 7	26 1	99.3	25 4	99 9
	81+45	20	23 5	103 2	20 0	109 7	23 2	103 1	21 4	107 1
	91+05	20	21.0	107.4	23.0	105.6	18 6	109 6	22 8	104.6
	91+22	3	19 8	110.4	20.6	108 3	18 4	112 4	19 2	110.2
	100+25	20	24 2	102.6	30 9	91 9	26 2	91.8	32.3	91.1
	100+42	3	35 0	89 0	34 9	87 9	36.1	88 2	40 8	82.6
9	107+05	20	24.1	92.4	26 0	100 9	20.3	110.1	21.2	108.0
	107+22	3	22 4	105.6	21 8	108 0	20 5	109.7	18 9	113 8
	111+05	20	27.7	94.9	36.0	87.9	20 0	105 8	35 5	87 4
	111+22	3	21 2	100.1	19 0	100.3	19.7	108.9	32.3	89.8
	124+08	3	19 9	103.8	16 0	108 1	14 8	109.8	14.4	106 5
	124+25	20	16 0	104.6	13.1	108.8	13 4	110.1	13 1	108 5
10	127.28	3	23 8	101.7	23 5	102 0	20 2	98.0	20.2	102 2
	127+45	20	26.4	95.5	23.2	102 3	20 0	94 3	20 0	104.3
	134+48	3	21 7	105 7	14 5	111.9	16.6	114.3	22 4	106 5
	134+65	20	17.3	111.1	12.9	104.4	28 6	97.2	19.2	110 4
	143+45	20	22 1	93 9	15 3	103 0	21 5	106.9	24.7	94.3
	143+62	3	23.2	104.2	23.9	97 4	23.5	102.8	22.6	90 5
11	148+25	20	21 2	100.7	25 0	99 0	29.9	94.6	27.3	98.4
	148+42	3	26 8	95 0	30 7	92 0	21 5	99.0	32 8	88.9
	155+05	20	19.3	102.8	26 6	96 2	21.3	103 7	21 8	104.4
	155+22	3	30.3	92.6	29.7	92.9	17.9	110.6	27.2	96 5
	167+28	3	21.2	101.5	20.9	88 3	21.4	103.2	18.2	92.5
	167+45	20	21.0	103.0	23 4	109.6	20.2	104 3	22 5	98.4
12	171+28	3	16 6	114 9	18.5	105 5	20.3	106.8	20.8	105 8
	171+45	20	18.3	107.6	24 3	107 8	25.6	103 1	16 6	105.5
	174+88	3	16 6	109.8	18.5	106 3	18 4	105 5	17.2	110.6
	175+05	20	20 1	107.3	21.4	105.6	27.7	106.6	20.5	107.1
	Average		21 2	104 1	21.8	103.0	21 3	104 5	21.9	102.0

Appendix D: Validating Tests

The following tables show the results of validating tests which were made adjacent to the installed blocks. These tests were made by drilling the pavement above the blocks and manually sampling the subgrade to determine the moisture content by the dry weight method. The first table shows the comparison of the individual blocks while the second table shows the comparison of the moisture averages.

The moisture averages by the resistance block method vary as much as two percentage points from the manual sampling method. The individual moisture percentage vary from 4.8 percentage points higher to 3.9 percentage points lower with the average deviation as .37 percentage points higher.

TABLE A
VALIDATING TESTS

Block Number	Original Moisture	1954 Validation Resistance Method	1954 Validation Manual Sampling	Block Number	Original Moisture	1954 Validation Resistance Method	1954 Validation Manual Sampling
1	28.5	29.5	31.9	49	17.2	29.0	28.1
2	23.5	25.9	28.0	50	16.6	16.3	18.6
3	29.2	30.7	29.2	51	18.2	24.6	22.7
4	27.7	27.5	29.0	52	16.3	14.9	16.3
5	26.4	28.3	30.0	53	18.9	26.9	24.6
6	24.4	27.0	27.8	54	16.8	21.0	19.6
7	21.9	29.0	27.3	55	18.9	31.0	30.2
8	26.3	35.6	36.7	56	16.2	18.1	19.0
9	20.9	16.5	18.0	57	17.9	21.4	22.3
10	21.3	12.8	16.4	58	22.2	21.4	23.7
11	21.4	26.6	24.2	59	21.5	30.4	29.3
12	20.2	10.9	14.6	60	17.8	31.0	28.3
13	19.5	14.2	18.9	61	19.3	23.7	22.1
14	20.4	21.3	20.6	62	22.0	20.6	23.1
15	19.8	18.6	19.0	63	22.1	28.4	29.5
16	20.2	9.4	13.8	64	16.7	31.8	31.5
17	20.9	9.3	14.1	65	24.1	27.0	27.3
18	23.8	19.0	19.6	66	26.0	27.0	27.5
19	19.1	19.1	18.9	67	20.3	12.6	14.0
20	21.6	8.7	11.6	68	21.2	18.9	20.4
21	22.8	17.8	20.0	69	22.4	26.6	25.6
22	28.3	27.5	25.6	70	21.8	17.9	18.4
23	22.6	16.5	18.4	71	20.5	33.6	32.6
24	24.0	8.8	12.3	72	18.9	21.8	20.8
25	18.5	21.8	20.7	73	19.9	20.5	19.7
26	18.2	17.1	19.0	74	16.0	29.6	29.0
27	18.8	26.2	25.8	75	14.8	25.9	25.1
28	23.1	21.0	19.6	76	14.4	22.2	20.9
29	19.5	17.7	15.3	77	16.0	25.1	27.1
30	20.4	21.4	18.9	78	13.1	20.8	20.3
31	19.2	20.4	20.3	79	13.4	18.3	20.4
32	20.5	18.6	20.0	80	13.1	26.2	25.0
33	17.9	22.1	23.8	81	22.1	26.2	26.6
34	17.5	16.4	18.5	82	15.3	31.8	29.8
35	15.0	22.3	21.7	83	21.5	28.0	29.0
36	17.3	23.4	22.2	84	24.7	24.7	23.9
37	17.5	17.3	18.9	85	23.2	30.4	29.2
38	18.6	17.7	19.2	86	23.9	29.0	27.0
39	17.7	21.0	21.1	87	23.5	18.4	19.6
40	17.4	23.9	24.2	88	22.6	20.0	22.2
41	23.3	31.8	31.8	89	16.6	23.5	21.9
42	21.4	20.4	21.6	90	18.5	10.4	14.6
43	23.8	12.8	14.3	91	18.4	21.5	22.0
44	19.8	9.8	12.6	92	17.2	22.5	21.6
45	21.5	35.6	34.0	93	20.1	21.5	21.0
46	21.6	28.6	29.4	94	21.4	12.6	13.3
47	23.9	29.0	29.9	95	27.7	22.0	20.3
48	20.8	14.9	16.0	96	20.5	24.4	23.2

TABLE B
VALIDATING TESTS: MOISTURE AVERAGES

Figure Number	Position	Original Average	1951 Validating Ave. Resistance Method	1951 Validating Ave. Manual Sampling	1954 Validating Ave. Resistance Method	1954 Validating Ave. Manual Sampling
	O. E. 4" Depth	20.3	23	23	25.6	25.8
	O. E. 9" "	18.6	18	19	23.2	23.2
6	P. E. 4" "	19.8	24	23	20.8	21.1
	P. E. 9" "	21.5	22	23	19.1	19.6
	O. E. 4" "	19.9	20	20	23.3	23.4
	O. E. 9" "	18.8	17	18	17.1	18.5
7	P. E. 4" "	20.2	25	24	22.8	22.8
	P. E. 9" "	19.7	25	25	21.3	21.2
	O. E. 4" "	20.3	22	22	24.2	23.9
	O. E. 9" "	18.6	17	18	19.3	20.4
8	P. E. 4" "	19.1	24	23	21.4	22.2
	P. E. 9" "	19.5	24	25	19.7	20.5
	O. E. 4" "	19.9	20	22	24.8	25.3
	O. E. 9" "	18.9	17	19	20.9	21.3
9	P. E. 4" "	21.0	25	23	22.2	22.1
	P. E. 9" "	20.8	24	23	20.6	20.9
	O. E. 4" "	20.4	21	22	18.9	20.0
	O. E. 9" "	24.0	26	25	29.4	29.7
10	P. E. 4" "	20.5	25	25	13.6	16.3
	P. E. 9" "	25.6	36	34	29.0	30.4
	O. E. 4" "	20.4	21	22	18.9	20.0
	O. E. 9" "	20.5	25	25	13.6	16.3
11	P. E. 4" "	20.2	22	23	18.6	19.2
	P. E. 9" "	22.5	24	24	17.8	18.3
	O. E. 4" "	20.7	28	27	27.6	26.9
	O. E. 9" "	18.7	17	17	18.0	19.1
12	P. E. 4" "	18.6	28	28	23.3	23.6
	P. E. 9" "	18.7	27	27	23.3	23.8
	O. E. 4" "	19.3	14	15	24.1	24.6
	O. E. 9" "	17.9	14	16	25.6	24.8
13	P. E. 4" "	21.3	22	22	23.6	23.1
	P. E. 9" "	20.7	21	20	19.5	20.0
	O. E. 4" "	20.7	22	22	24.8	24.8
	O. E. 9" "	18.1	16	17	22.2	23.1
14	P. E. 4" "	19.3	22	22	20.8	21.6
	P. E. 9" "	21.0	22	23	18.5	20.5
	O. E. 4" "	19.9	18	17	23.1	24.0
	O. E. 9" "	18.6	14	17	17.7	19.2
15	P. E. 4" "	21.6	25	23	23.6	23.7
	P. E. 9" "	19.8	25	25	21.5	22.0
	O. E. 4" "	19.9	22	22	23.6	23.1
	O. E. 9" "	19.1	19	20	16.5	17.6
16	P. E. 4" "	18.9	25	24	22.0	21.9
	P. E. 9" "	20.4	26	26	20.9	20.6
	O. E. 4" "	19.8	23	23	26.4	26.8
	O. E. 9" "	19.2	20	21	24.1	23.4
17	P. E. 4" "	20.3	24	24	20.8	20.5
	P. E. 9" "	22.1	23	23	19.6	19.6