Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Kentucky
February 29, 1952

S. 1. 3. 4.
D. 1. 7.

TO: D. V. Terrell
Director of Research

Last year, for the first time in several years, the Department had under construction a gravel base containing calcium chloride. Some time after the project was originated, in fact after it had been advertized, the job came to the attention of the Research Division through a request from the Division of Design that detailed observations be made during construction in order that all things affecting performance could be judged for future design considerations.

To accomplish this, W. B. Drake, Research Engineer, spent practically two months either on the job or working in the laboratory with materials pertaining to the job. His effort was centered on the keeping of records which were important to the future evaluation, but also at my suggestion he advised the Resident Engineer on several matters pertaining to materials. For example, he checked proposed sources of gravel and prospective sources of binder soil, calculated the combinations of materials which would meet specification requirements, and made several recommendations regarding the handling of materials. In turn, the Resident Engineer, Jack Crider, and his party gave valuable assistance to Mr. Drake in obtaining data, making density tests, and recording other information which was important. The cooperation was excellent.

Inasmuch as several things recommended by the Research Laboratory became a part of the job, responsibility for their outcome lies with us even though we had no authority in advancing them. For example; there was a binder soil item on the plans and proposal, but the selection of a source and proportioning was based on our recommendation. Also at our suggestion it was decided to attempt raking of oversize, to roll first with pneumatic rollers on the treated courses, and to allow ten days of curing on treated courses before placement of overlying materials. Ultimately, we found that some of these suggestions were not sound, or at least developments made them unsound. On the other hand, some of them were worthwhile and were proved advantageous.

At any rate, in the attached report on this project, Mr. Drake shows that with very limited exceptions the road turned out satisfactorily. Regarding these exceptions, which are the failures near Stations 220 ≁ 00 and 233 ≁ 00 (See Figs. 21 and 23), the treated courses are open for criticism only to the extent that this 4-inch depth failed to accomplish stability over 12 to 16 inches of base which was already extremely unstable. At other points where difficulties developed during construction, the corrective measures have been successful thus far. Of course, it is much too early to make a lasting evaluation of the different parts of the road, but the traffic to and from the Cumberland River Bridge project has been sufficient in numbers and weight to provide some degree of test over this short period.

Quite aside from the main object of the evaluation program, which will be followed up at frequent intervals in the next few years, I would like to make note of the excellent riding qualities of this pavement. Undoubtedly, much of the credit for this lies with the engineering party as a result of its efforts to control the grade and section. However, in my estimation it emphasizes the possibilities inherent in any flexible pavement where the bituminous surface is placed by a mechanical spreader riding on an underlying surface finished with a blade grader.

Respectfully submitted,

L. E. Gregg

L. E. Gregg
Assistant Director of Research

LEG:DDC
cc: Mack Galbreath (4)
Research Committee Members

Commonwealth of Kentucky
Department of Highways

Report No. 1

on

A BANK GRAVEL BASE CONTAINING CALCIUM CHLORIDE

(U.S. 62, Paducah-Eddyville Road)

by

W. B. Drake
Research Engineer

Highway Materials Research Laboratory
Lexington, Kentucky

February, 1952

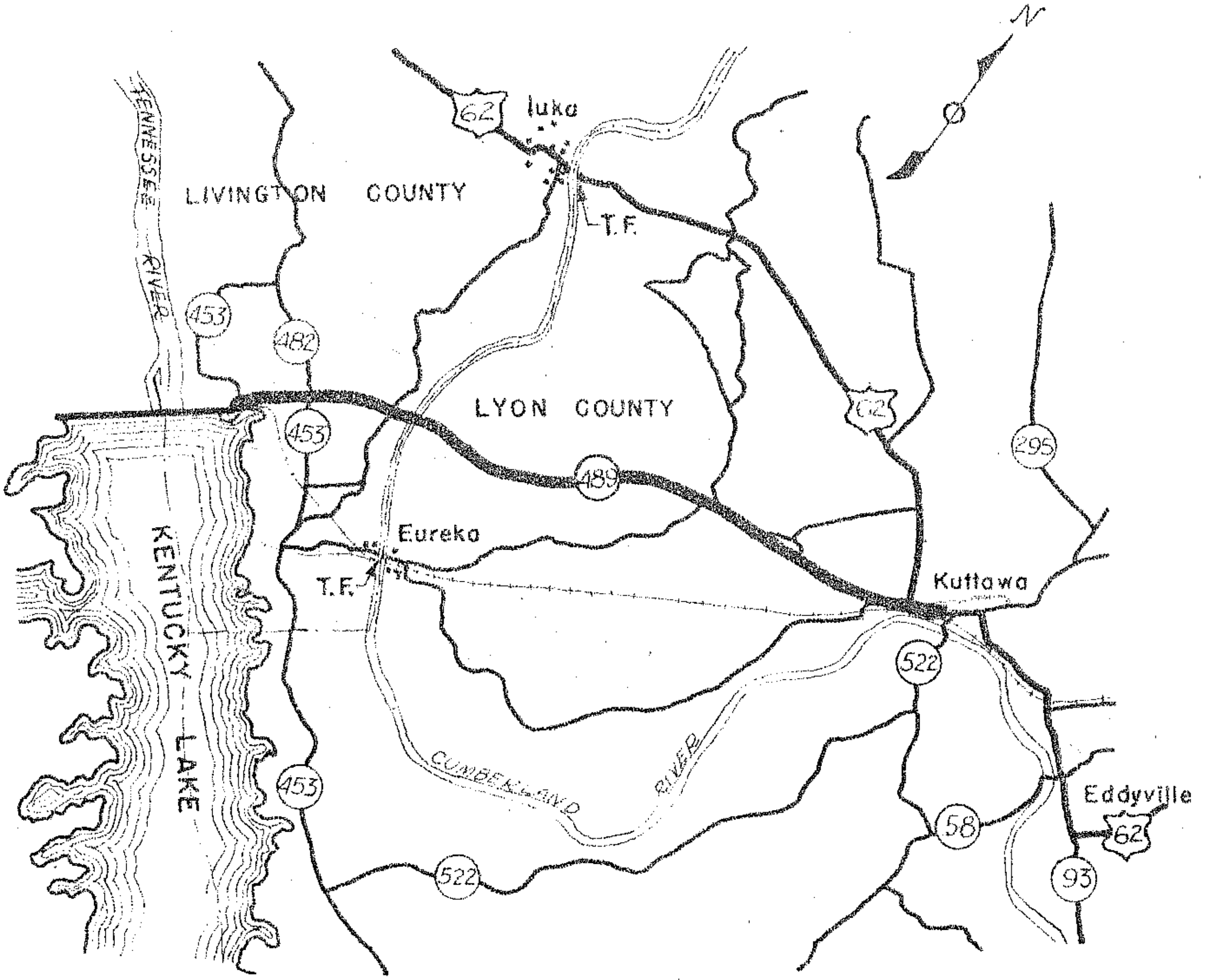
INTRODUCTION

This report is concerned with a bank gravel base construction project, and particularly with that part of the base containing calcium chloride as a stabilizing agent. The project was carried out on a relocation of U.S. 62, between Kuttawa in Lyon County and Kentucky Dam on the Tennessee River. A part of the project, as shown on the general location map in Fig. 1, was in Livingston County between the Cumberland and Tennessee Rivers.

The territory through which this road passes is on the fringe of the natural gravel area, which includes the coastal plain or Jackson Purchase section of Kentucky and extends a few miles eastward. Some of the cuts on this project were made through these granular deposits, and as a consequence at least part of the adjacent fills contained gravel.

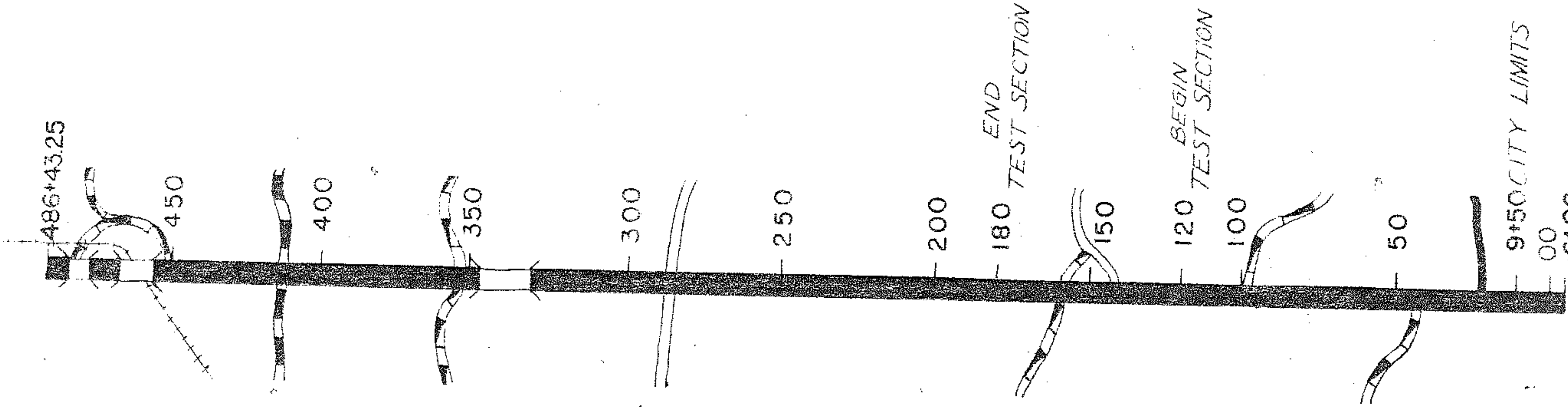
The contracts for grade and drain on this road were let in 1947 and 1948, and completed in 1949. In the interim from 1949 to 1951, the surface was left open with traffic bound stone but received very little traffic because there was no bridge or ferry on this location at the Cumberland River. Erection of the bridge was in progress during the period of construction for this base, and traffic to and from the bridge project had some effect on the base as noted later in this report.

Design thickness for the base varied from 4 to 16 inches (See Fig. 2) depending upon the distribution of subgrade bearing values. The 4-inch thickness, of course, applied to the sections where gravel formed the subgrade. Calcium chloride stabilization, in accordance with Section 3 of the 1945 Standard Specifications, was set up for just the top 4 inches of



PROJECT LOCATION
PADUCAH—EDDYVILLE
NEW U.S. 62

Fig. 1



STA 6+00 to STA 150+00 12" Base
STA 150+00 to STA 195+00 4" Base
STA 195+00 to STA 275+00 16" Base
STA 275+00 to STA 479+83.53 12" Base
STA 227+00 to STA 234+00 Additional 4" Base

PROJECT LAYOUT AND DESIGN THICKNESS

Fig. 2

the base. In fact, deviations from the Standard Specification set forth in the plan notes were minor, and it was even stated specifically in a plan note that "The gradation of the course to be treated with calcium chloride shall conform to the Standard Specifications, Art. 3.3.3, on page 109."

Gravel bases containing calcium chloride had been built on two or three occasions in the vicinity of Kuttawa, but this was the first project in which the gravel was bank-run rather than dredged from the Cumberland River. Similarly, bank gravel had been used extensively for base construction in the western part of the state, but this was the first major project in which calcium chloride was combined with the bank-run material.

Because of these unusual conditions, and an interest in specific information from the work for future reference, the Research Division was asked to make observations and record data during construction, and to follow the performance from time to time over a period of years. This report covers the base construction for the entire project and, also, includes the performance of the finished pavement in Lyon County during the first four months of use. The bituminous pavement in Livingston County will not be completed until some time during the construction season of 1952.

PRELIMINARY SAMPLING AND MIX DESIGN

On the layout map which was Sheet No. 1 of the plans, two prospective gravel pits were located. One was in Lyon County, 4.5 miles from the project, and the other in Livingston County, approximately two miles from the project. Both were shown merely for the convenience of those interested in the work, and not as an indication that materials in these pits would meet the requirements for either the stabilized or non-stabilized base courses.

So far as the non-stabilized portion of the base was concerned, a plan note covered the required gradation. This gradation and, also, the one pertaining to the calcium chloride treated material are outlined by values listed in Table 1, and plotted graphically in Fig. 3. The requirements for the non-treated material were quite general. This is customary for bank gravel base projects in order to qualify all deposits which are considered usable but which are naturally variable.

Table 1. Gradation Requirements for the Two Portions of Bank Gravel Base.

Sieve Size	Percentage Passing For	
	Non-Treated Base	$CaCl_2$ Treated Base
2"	100	--
1"	75-100	100
3/4"	60-70	80-100
3/8"	--	50-90
No. 4	20-60	40-75
No. 10	--	30-55
No. 40	--	20-35
No. 200	--	10-20

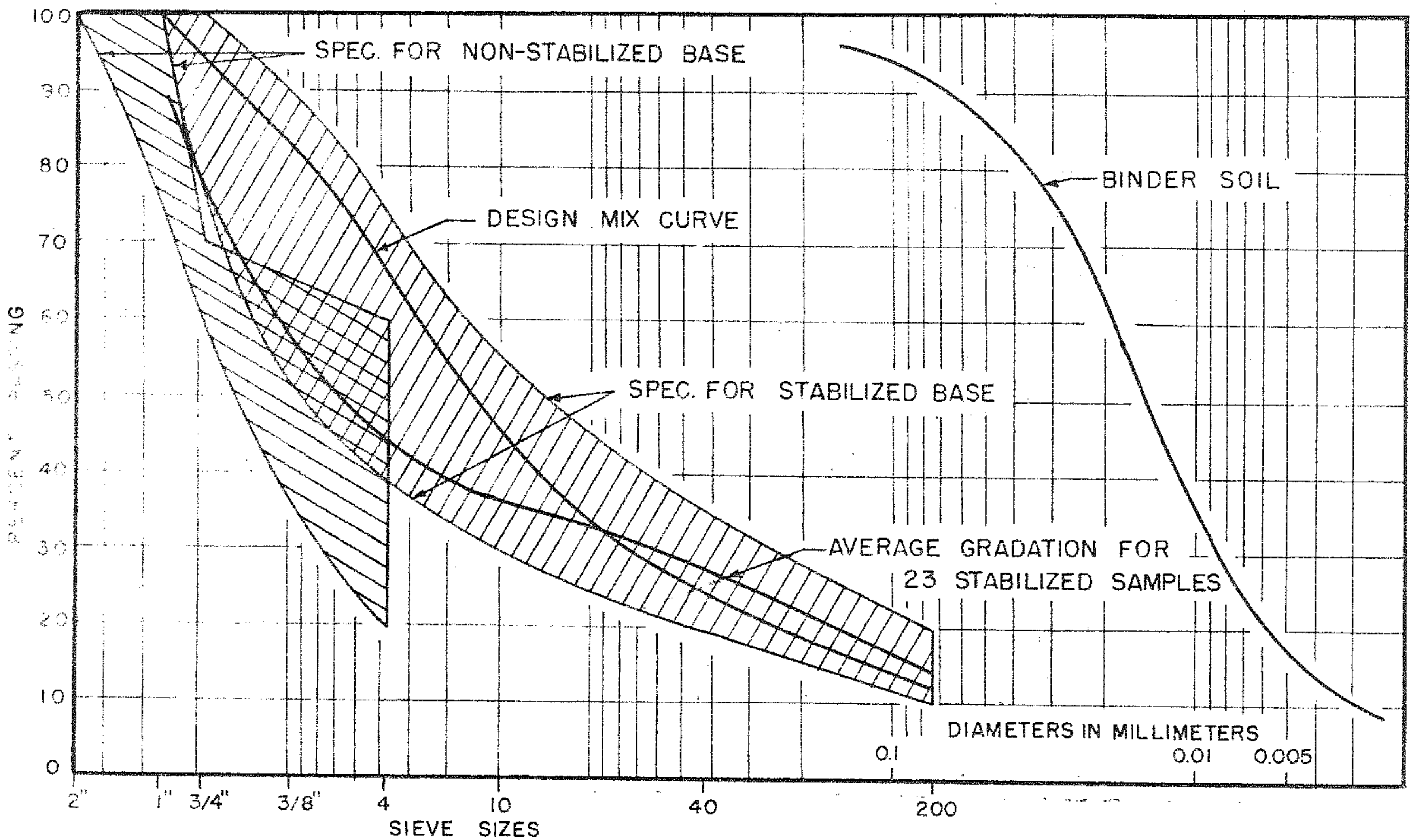


CHART OF GRADATIONS

Fig. 3

The two pits shown on the plans were sampled in May, and tentatively mixes meeting the requirements for calcium chloride treatement were worked out. Neither was particularly suitable, but could be worked into a satisfactory mix with the addition of material from other sources. In the Lyon County pit, for example, three percent of the material consisted of very active clay which produced a high plasticity index in the fraction passing the No. 40 sieve. Addition of non-plastic fines (very fine sand) in this case would reduce the plasticity and also help bring the material to a better gradation.

After the contractor moved onto the job in June, a new pit was opened in Lyon County. This pit, known as the Dycus pit, was located on the Kuttawa-Eureka Road about two miles from the project. Initial Samples taken from the new source and tested on June 29, showed the following properties:

Gradation Pct. Passing	
2"	100
1"	90
3/4"	85
3/8"	74
No. 4	51
No. 10	40
No. 40	15
No. 200	3

Plasticity (Material Passing No. 40 Sieve)	
L.L.	18.6
P.L.	Non-Plastic
P.I.	- - -

While this gravel was well within the gradation range for the non-stabilized portion of the base, it was deficient in fines and had considerable oversize for the calcium chloride treated mix. The most significant point at the time was the complete lack of plasticity in the initial samples.

After 35,000 to 40,000 tons of gravel had been taken from the pit for construction of the non-stabilized courses of the base, the pit was again sampled (on August 6) and tested with the following results:

Gradation Pct. Passing		Plasticity (Material Passing No. 40 Sieve)
2"	100	
1"	85	L. L. - 17%
3/4"	75	
3/8"	55	P. L. - Non-Plastic
No. 4	43	
No. 40	20	P. I. - - -
No. 200	2	

Oversize material was still of concern, and the lack of sufficient fines combined with the non-plastic characteristics of the fines which were present pointed to the possibility for adding binder soil having slight plasticity. Plans and proposals carried a binder soil item estimated at 1605 tons.

A survey of locally available materials to remedy the gradation deficiency and provide binding qualities up to 6 P.I. was made. Several promising deposits, such as a very fine white sand located about six miles from the project, were inspected and some were sampled for test. None had the desirable qualities, until a windblown silt deposit alongside the right-of-way near Sta. 140+00 was tested. This material, which is represented by the gradation curve on the far right in Fig. 3, was quite uniform in composition and contained approximately 70 percent of its grains in the silt size. Tests for P.I. showed 8.7 and 9.9 at the two depths sampled. Only 17 percent of the material was in the clay size, and hence from the standpoint of limited plasticity and uniformity it was well suited for binder soil.

Large samples of gravel from the Dycus pit and windblown silt from the prospective binder-borrow pit were brought to the laboratory for tests on the two in various combinations. The silt was added to the gravel in three different quantities to make mixes with 5, 10, and 15 percent binder soil. Effects of these additions on the P.I. and gradation were as follows:

Percent Binder Soil	P.I.	Percent Passing No. 40	Percent Passing No. 200
0	0	16.5	3.3
5	2.3	20.6	7.8
10	5.9	24.8	12.5
15	7.4	29.0	17.0
100	9.9	100.0	95.0

Obviously, as the percentage of binder soil was increased, the influence of fines in the gravel (approximately 15 percent passing the No. 40) was reduced rapidly. With as little as 15 percent binder soil in the mix, the P.I. of all material passing the No. 40 sieve was very close to the P.I. of the binder soil itself. This was particularly significant in view of the fact that at that percentage binder soil addition, the ratio of materials represented in the fraction passing the No. 40 sieve was about two parts silt to three parts fines from the gravel. Roughly, the relationship between P.I. and the percentage of silt in the fraction of the total mix passing the No. 40 was shown in Fig. 4.

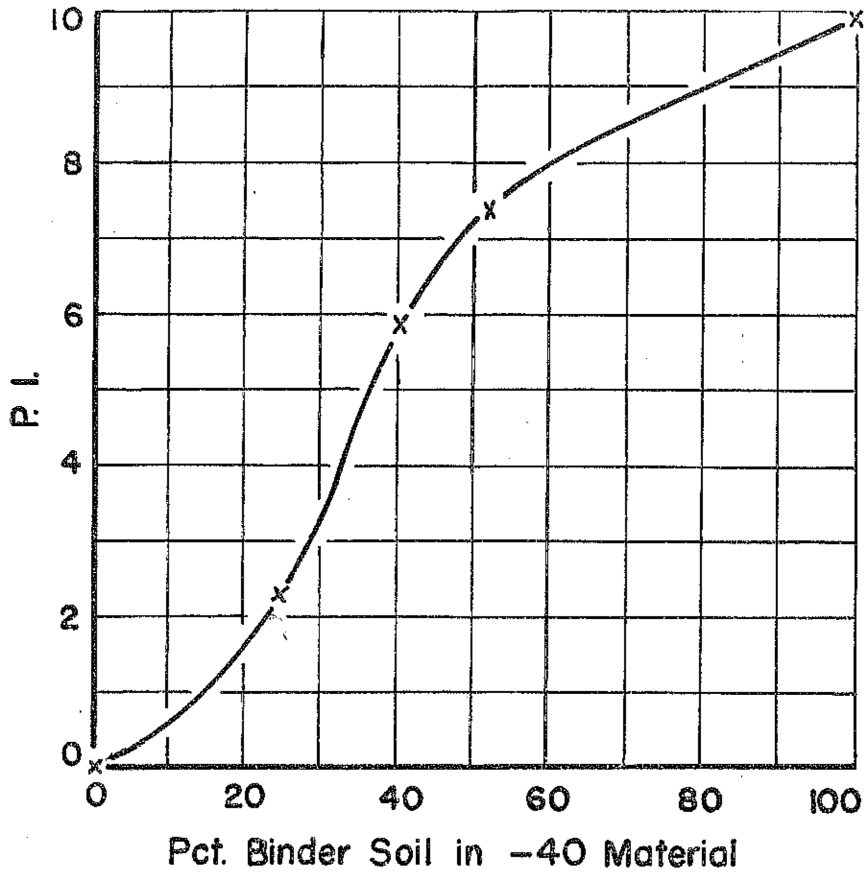


Fig. 4. Relation between P.I. and percentage binder soil in that portion of the combined mixture passing the No. 40 sieve.

Two procedures for elimination of oversize material were considered. First, this material could be removed by shaking or scalping operations at the pit as the trucks were loaded. If this were done, probably it would be necessary to either dry the gravel or reduce the rate of production considerably since the damp gravel would not separate easily. In either case a large part of the fines in the gravel would be lost, and if the method involved drying the natural advantage of moisture in the gravel - a definite aid to compaction on the road - would be lost also. In lieu of scalping at the pit, the contractor proposed removal of oversize material on the road by means of hand rakers. Thus, a deduction of 10 percent from the quantities measured at the weigh house would be made to compensate for the oversize removed later on the road.

After all these factors were considered, the Research Division recommended to the Division of Construction that in the preparation of stabilized courses the following apply:

1. The base course aggregate consist of 90 percent gravel from the Dycus pit and 10 percent binder soil from the deposit of windblown silt at approximately Sta. 140+00 (the Dycus pit being considered acceptable only because it had been previously approved as a source of gravel for the non-stabilized courses.)

2. The contractor be permitted hand raking of oversize in preference to drying and scalping gravel at the pit.

3. A curing period of 10 days be allowed on all courses of stabilized base prior to the placement of a successive course or the placement of overlying bituminous pavement. (This was in accordance with recommendations made by representatives of the Calcium Chloride Inst.)

All three of the recommendations were followed during construction in Lyon County, with the exception of the last 4100 feet of the stabilized course, and also approximately 1000 feet in another section where the base constructed in this manner was removed and replaced with gravel alone after trouble developed in that spot.

There was no particular mix design involved in the base for the Livingston County portion of the project. The gravel for the first 4-inch course and approximately one-half of the second 4-inch course was obtained from the Young pit located between the rivers. This was the site shown on the project layout sheet of the plans. The gravel was highly plastic with a large percentage of oversize material. This pit was thought unsatisfactory for the top course. The remainder of the gravel used in Livingston County came from a new source located in Marshall County on the Max Bohannan property, a distance of approximately eight miles from the job. Gravel from this pit had been used for previous base construction projects, the most recent being the Briensburg Cutoff on U.S. 68. These new sources were selected mainly to avoid the ferry transfer at the Cumberland River which would have been necessary had the Dycus pit in Lyon County been continued as the supply.

As a result of a conference held on October 9, to consider difficulties which developed in Lyon County, it was further decided to eliminate binder soil entirely even though past tests had shown limited fines and no plasticity in the gravel. Properties of the gravel, according to a representative set of tests, were as follows:

Gradation Percent Passing		Plasticity (Material Passing No. 40 Sieve)
2"	- 100	Non-Plastic
1½"	- 99.5	
1"	- 93.2	
3/4"	- 86.2	
3/8"	- 65.4	
No. 4	- 53.5	
No. 10	- 45.0	
No. 40	- 20.0	
No. 100	- 7.0	
No. 200	- 3.0	

In view of these circumstances, the Research Division recommended that calcium chloride be eliminated entirely in the Livingston County base since there was no fine material available with which the calcium chloride could act in bonding the gravel satisfactorily. This suggestion was accepted, and calcium chloride treatment was confined to the Lyon County portion of the job.

CONSTRUCTION PROCEDURES

The non-stabilized courses of the base were laid in three 8-foot lanes, 6-inches loose depth, and were rolled first with a 10-ton three-wheel roller. Only one or two passes with this roller preceded rolling with the pneumatic roller. Final rolling of each 4-inch compacted course was carried out with the three-wheel roller. Water was used as needed. All of the non-stabilized base gravel in Lyon County was placed before any of the treated base work was begun.

The stabilized calcium chloride-treated courses were started on August 22, at the Cumberland River Bridge, and work proceeded toward Kuttawa. Gravel in sufficient quantity to give a 2-inch compacted depth was laid along the south lane of the road (Fig. 7) shortly after the binder soil was spread in the north lane. The rate of placement for the binder soil was 52 pounds per lineal foot. An Apsco Self-propelled Spreader was used in placing the gravel, and an earth-moving pan, as shown in Figs. 5 and 6, shaved the binder soil and placed it on the road. Both operations were carried out very efficiently. The pan was loaded by means of shallow cuts in order to pulverize the silty soil; gravel trucks passing over the soil after it was spread on the road were also effective in pulverizing the soil so long as it remained dry.

After approximately ½ mile of gravel and soil had been spread, mixing operations were started. Two patrol graders were used for the mixing. The soil was cut into the gravel initially, then the large windrow was moved across the road until the two materials were well mixed.

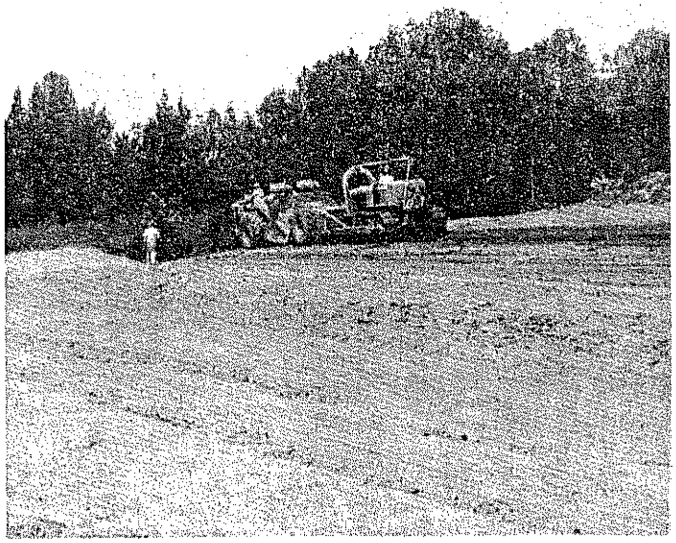


Fig. 5. Cutting binder soil into the pan of the earth moving equipment. This process partially pulverized the silty borrow material. Several passes of the pan over the exposed surface was required to accumulate a load.

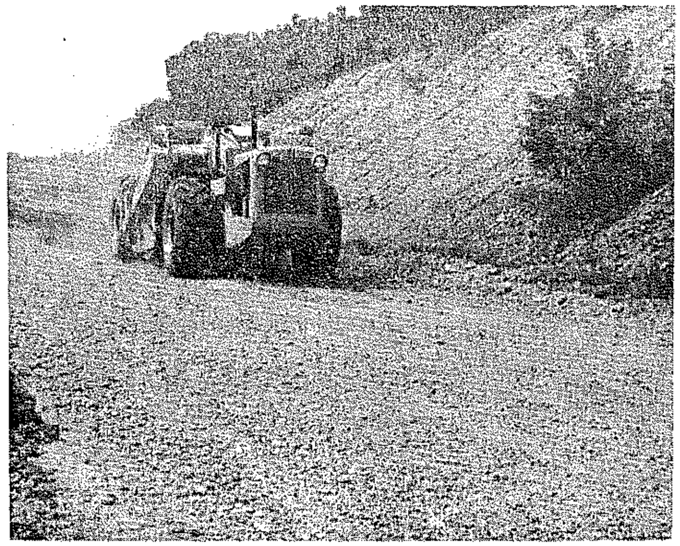


Fig. 6. Spreading binder soil at the rate of 52 pounds per lineal foot.

Fig. 7. Placing selected bank-run gravel uniformly with a mechanical spreader. Binder soil to be mixed with the gravel was spread in the right lane prior to the placing of the gravel.

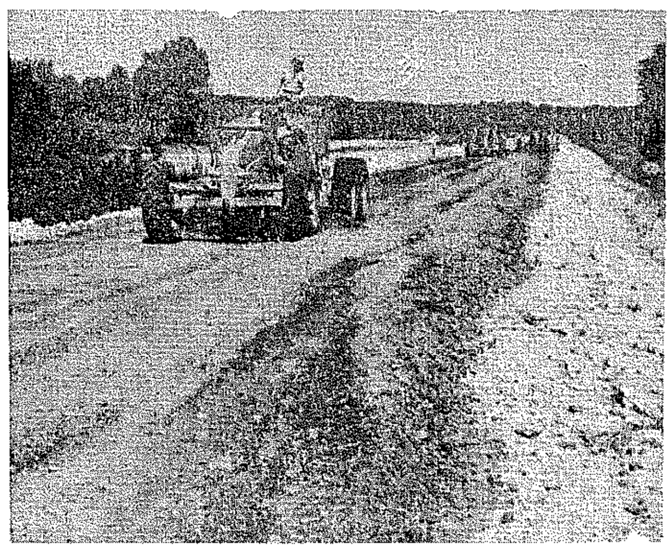


Fig. 8. Mixing binder soil and gravel with a patrol grader. This method was generally successful in producing thorough mixture if the two materials were relatively dry. On a few occasions, rain fell during the period between placement and mixing and as a result the soil was poorly distributed throughout the gravel, sometimes accumulated in pockets. (See Fig. 19)

This mixing was accomplished by rolling the gravel and soil along the grader blade. Eight or ten passes of the graders (four or five passes each) were required to move the large windrow from one side to the other. This procedure is illustrated in Fig. 8.

After the soil and gravel had been thoroughly mixed the windrow was brought to the center of the road and struck off square with the blade. An application of water was given at this time unless the materials were quite damp. Calcium chloride at the rate of one pound per square yard was then spread with a mechanical spreader box. (See Fig.9)

Immediately the calcium chloride was worked into the gravel-soil mixture in the same manner that was used for the binder soil, and water was added in quantities estimated necessary for good mixing and compaction. Once again mixing was carried out with the blade graders, after which the stabilized material was spread to section and compacted almost entirely with the pneumatic roller. A few passes of the three-wheel roller were made to finish off the course.

Throughout the final spreading and rolling, exceptional care was taken to bring the course to proper grade and cross-section. This was done by means of grade stakes set at 50-foot intervals along both edges, and a string line stretched transversely from stake to stake. Measurements downward from the string line to the surface were made frequently and at several points across the road. While this procedure was not a new one, it was carried out so diligently by the Resident Engineer's party that control over the base contour was rigid and constant. Where

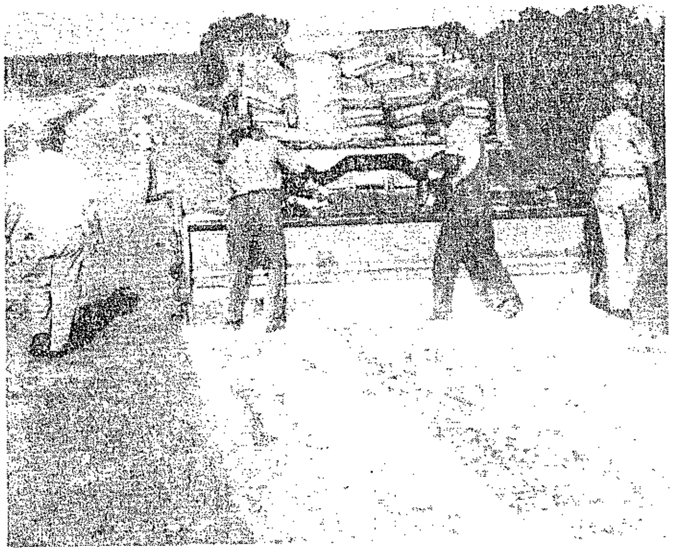


Fig. 9. Application of calcium chloride. A rolling mechanical type spreader box was used to control the rate of application which was one pound per square yard per 2-inch depth, except for two 1000-foot sections where the rate of application was doubled.

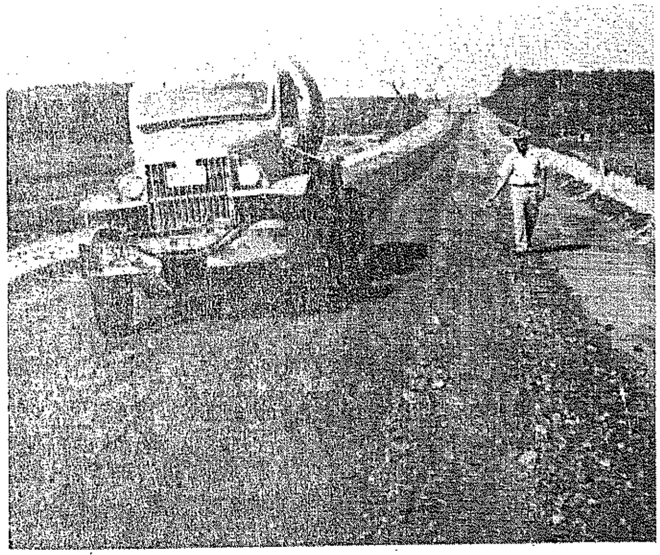


Fig. 10. Applying water to the stabilized mix. Invariably water was applied shortly after the calcium chloride was spread, and when the materials were exceptionally dry water was added in advance of the calcium chloride also.

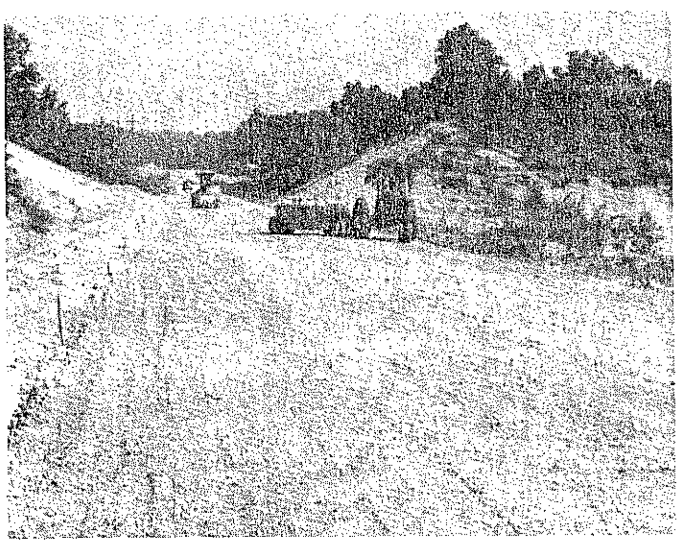


Fig. 11. A pneumatic roller in the foreground and a three-wheel, 10-ton roller in the distance were used throughout the job. On the non-stabilized layers of base three or four passes with the flat-wheel roller were made in advance of the pneumatic roller operation. On the courses containing calcium chloride, all except the final finished rolling was accomplished with the pneumatic roller.

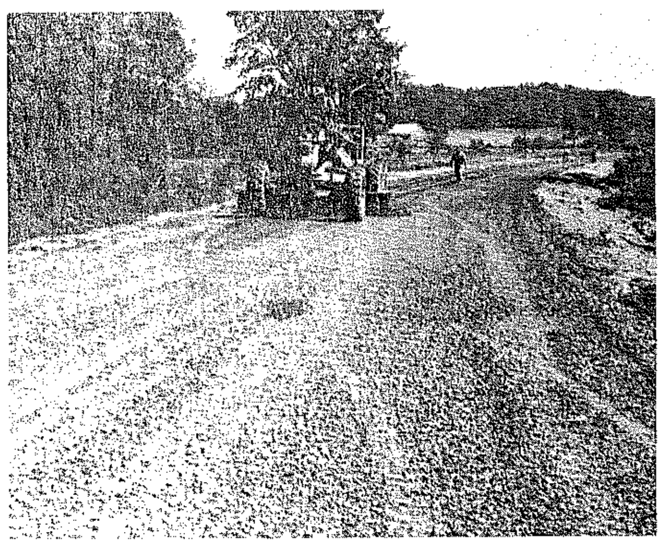


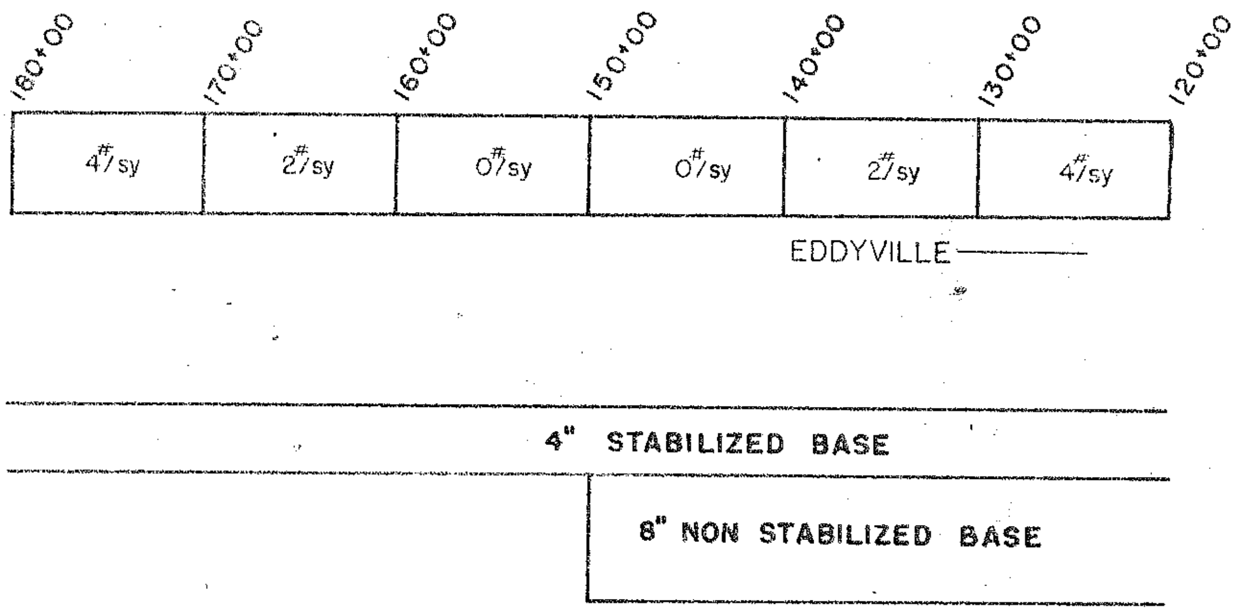
Fig. 12. Finishing to final section with a patrol grader. The cross section in this curve was checked with a string line and it was found that too much super-elevation had been placed in the final course. This condition was remedied easily with the grader followed by the two rollers in the usual order.

measurements showed that the grade or section was in error, as was the case at the location illustrated in Fig. 12, the condition could be rectified quickly and effectively with a few passes of a grader followed by the usual operation for finished rolling.

As the construction progressed, the Research Laboratory in the interest of comparison between treated and untreated base immediately beneath the bituminous pavement, asked that a small part of the project be set aside as an experimental feature. This was approved, and a set of three variable conditions were worked into the top four inches of base from Sta. 180/00 to Sta. 120/00. Here, as outlined in Fig. 13, the calcium chloride was omitted for a distance of 2000 feet, and by the same token a double application, or two pounds per square yard per 2-inch depth, was placed throughout another 2000-foot distance.

Actually, these were separated into two 1000-foot sections of each type, and between the two types in each instance there was a 1000-foot section containing the normal treatment of one pound per square yard per 2-inch depth. Nothing in the construction procedures was changed other than the elimination of spreading and mixing calcium chloride in the two sections where there was no treatment. The gradation was not changed, and to the extent of added binder soil and reduction in oversize material, the top courses in the untreated test section differed from the underlying untreated courses throughout the project.

Elsewhere in Lyon County County there were different locations where construction was varied, as noted in the discussion of mix designs on page - 11. For the last 4100 feet of the top 4-inches of base approaching



STA 120+00 to STA 130+00	4#/sy/4"	Course
STA 130+00 to STA 140+00	2#/sy/4"	Course
STA 140+00 to STA 160+00	0#	
STA 160+00 to STA 170+00	2#/sy/4"	Course
STA 170+00 to STA 180+00	4#/sy/4"	Course

CALCIUM CHLORIDE TEST SECTION

Fig. 13

Kuttawa, binder soil was omitted but calcium chloride was included. For that distance the operations of the earth-moving pan were eliminated entirely, and the mixing procedure was simplified. At the point where 1000 feet of base was removed and replaced, the replacement consisted of straight bank gravel put down and spread with the blade. Constant compaction with the pneumatic roller was carried out as material was spread, and the three-wheel roller provided the final compaction.

In Livingston County, the construction methods for the first course and half the second course were those used on the underlying untreated courses in Lyon County. However, after the source of gravel was changed to Marshall County, a sheepsfoot roller was passed over the loose material immediately following the initial spreading and shaping of the gravel. This additional operation was considered necessary in view of the lack of binding qualities inherent in the Marshall County gravel. The purpose of the sheepsfoot roller was to "set" the gravel and overcome its tendency to shift under the pneumatic roller.

OBSERVATIONS

The project was subject to many influences during the course of construction, most important of which were unusual and untimely rainfalls. Other obvious influences were the changes in materials from the gravel pits (which went virtually undetected for periods of time that were long enough to cause difficulties), localized subgrade weaknesses, and the inability of the contractor to eliminate oversize material by hand raking on the road.

Records of conditions at various times during construction were kept by means of field notes, gradation- and density-test data representing samples taken from the different base courses, and photographs illustrating things which were considered pertinent to the subsequent performance of the road. The essence of these records is contained in this report, and the records in their entirety are on file for future reference.

Untreated Base - Lyon County.

The untreated courses of base in Lyon County were constructed during July and early August, throughout which time the weather was exceptionally dry. For example, the total rainfall in July, as recorded at the Kentucky Dam Weather Bureau Station, was only 1.94 inches. This was distributed over seven different days, with no more than 0.61 inches rainfall in any single day, as shown by the data listed in Table 2. Although the values for mean monthly rainfall measured at Kentucky Dam Station are not available, it is probable that the total rainfall measured in July, 1951, was

Table 2 - Daily Rainfall at Kentucky Dam Station

Day	July	August	September	October
1	---	---	.04	---
2	---	---	---	---
3	.10	.48	---	---
4	---	---	---	---
5	.05	---	.07	---
6	---	---	---	---
7	---	---	---	.23
8	---	1.31	---	T
9	.53	---	---	---
10	.12	---	.90	---
11	---	---	---	---
12	.17	---	.53	---
13	---	---	.97	---
14	---	---	---	---
15	---	---	---	---
16	---	---	---	---
17	---	---	---	---
18	---	---	---	---
19	---	---	---	---
20	---	.03	---	---
21	---	.02	.22	---
22	---	---	.51	---
23	.61	---	---	.43
24	---	---	1.18	.54
25	---	---	---	---
26	---	---	---	---
27	.36	.74	---	T
28	---	3.81	---	.21
29	---	---	---	---
30	---	---	---	.10
31	---	---	---	---
Total	1.94	6.39	4.42	1.51
Average Kentucky Monthly Rainfall	4.17	3.71	2.93	2.63

less than half the mean for July measured over the period since the station was established.

Even though water was added in large quantities during construction, and even though the measured densities of the untreated base (See Table 3) indicated adequate compaction, the surface of completed courses dried out rapidly and raveled readily under passing construction traffic. An example of this is shown in Fig. 14. Two undesirable conditions were created by the raveling. First, fine material capable of binding the base was lost; and secondly, the remaining loose floater was quite coarse and difficult to tie down when subsequent courses were placed. Large floater material was particularly objectionable when the overlying first course of treated base was placed, because it increased the difficulty of removing oversize and changed the resulting gradation considerably.

No serious difficulties were encountered in the placement of untreated base. Inasmuch as the compacted depth for each of the courses was four inches, material as large as 1½- to 2-inches in size did not hamper the spreading and rolling.

A soft subgrade was encountered between Sta. 227+00 and 234+00 when the section was trenched for shoulder material. This location remained soft after three 4-inch courses of base had been placed. As a result of the soft spots an additional 4-inch course of gravel was applied between Sta. 227+00 and 234+00. Just after completion of the 16 inches of untreated base, a surface application of one pound per square yard of calcium chloride was made. This precaution was taken to prevent raveling and shoving of

Table 3. Densities of Untreated Bank Gravel Base, Lyon County F 530 (6)

First 4" Course

Station	Sample No.	Dry Density lb/cu.ft.
31+50	35	134.2
96+00	13	135.8
124+00	11	133.9
129+00	10	134.4
134+00	9	139.9
139+00	8	141.0
144+00	7	125.4
149+00	6	131.0
212+00	5	137.5
239+00	4	134.8
265+50	3	140.3
292+00	2	141.2
317+25	1	131.6
Average		135.5

Second 4" Course

Station	Sample No.	Dry Density lb/cu.ft.
6+75	33	121.0
13+00	34	121.2
22+50	36	132.3
33+00	37	133.5
123+00	18	130.0
128+00	17	128.5
133+00	16	135.5
138+00	15	138.1
143+00	14	124.9
148+00	12	125.9
Average		129.1

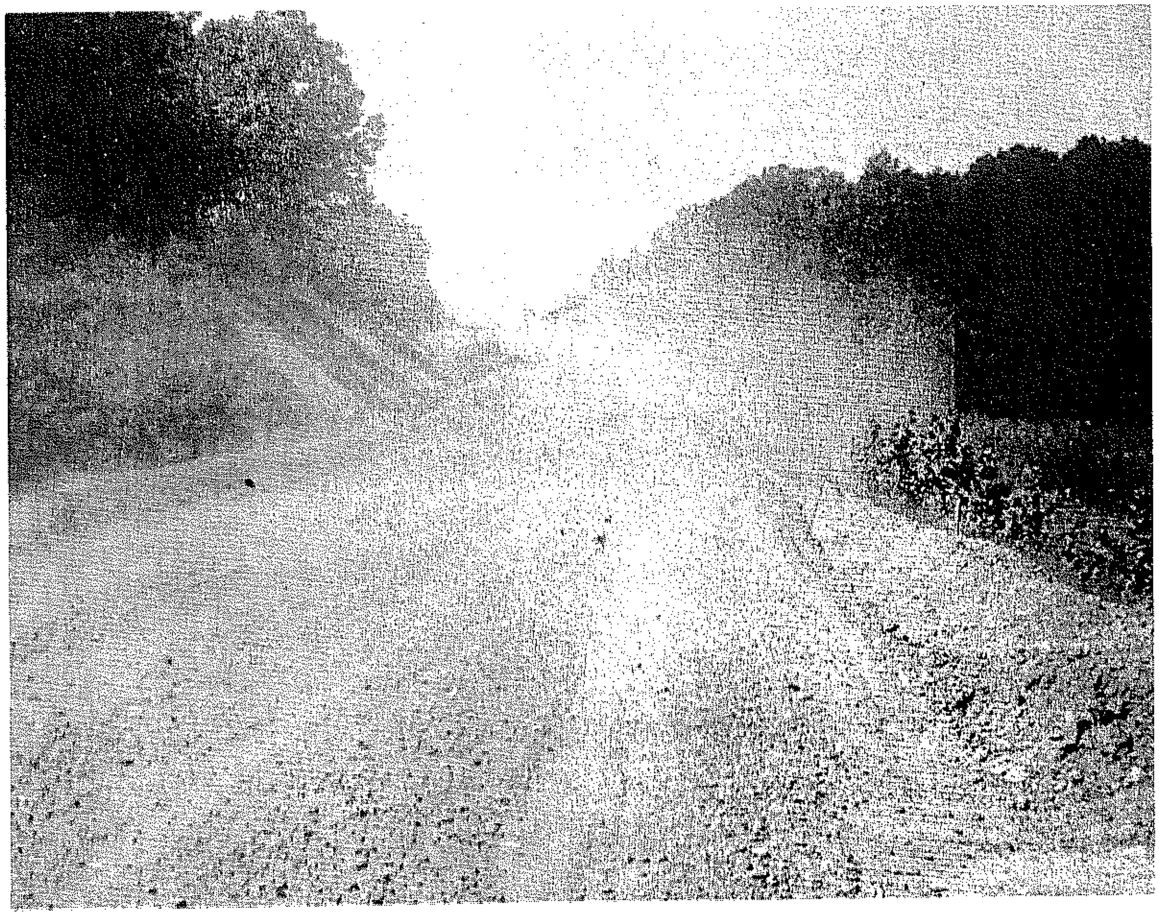


Fig. 14. Section of untreated base with binder soil showing the loss of fines through dust created by construction traffic. Note the loose gravel in the foreground that has raveled from the compacted base. A loaded gravel truck has just passed and the top of the cab can be seen dimly in the distance.

the base through the soft section before the stabilized course could be placed.

According to the results of density tests tabulated in Table 3, the first 4-inch course of untreated base was apparently placed under conditions more favorable to compaction than the second 4-inch course. Density tests were made using the rubber-balloon method which is commonly employed on projects in this state and they were generally made before the course being tested was covered with a succeeding course. The spread of results was rather wide for both courses, which indicates that either the base varied considerably or the limits of accuracy on the test are rather broad when the material is as course and poorly graded as this bank gravel. It is significant that fewer than one-half the determined densities on the second 4-inch course were as high as the second lowest determined density on the first 4-inch course, and that the average for the latter was almost 6.5 pounds per cubic foot higher than the average for the former.

Treated Base - Lyon County.

Calcium Chloride is a hygroscopic material and consequently it absorbs moisture from the air readily. It is also deliquescent so that it dissolves in the moisture absorbed from the air. Under most conditions, the solution itself will continue to absorb moisture until an equalibrium is reached. As a result of these properties, it is postulated that calcium chloride treatment eliminates raveling and controls loss of material, reduces the quantity of water needed for adequate compaction, reduces the compactive effort required to reach a desirable density, increases the density, and improves bonding qualities. It is known too that with fine materials having certain mineralogical identies, calcium chloride can bring about changes in physical properties probably through cation exchange.

Presumably observations on this project were desired partly as a means for determining whether these objectives were accomplished with calcium chloride in the bank gravel, even though the primary objective was to record conditions that may influence performance of the road and to keep account of that performance in the future. Climatic conditions were so variable during the construction of the treated courses that it was hardly possible to estimate the effect of calcium chloride on water requirements. For example, the dry season which previaled during the construction of the untreated courses was reversed very soon after the treated courses were started.

Work on the treated courses began on August 22, and during the last week of August, 4.55 inches of rain fell. Most of the rain, as noted in Table 2 (Page 22), occurred on August 28. In the interval between August 22 and 28, there were two full days of work during which the weather remained dry. Considering the gradation of the treated material with its increased percentage of fines in comparison with the untreated base material, the calcium chloride did permit a reduction in requirements for additional water. From August 28, to the completion of the treated base, rains were more frequent than before and the atmosphere - which became extremely humid with the heavy rainfall of late August - remained such that no attempt was made to obtain any correlation on water requirements.

From the standpoint of compactive effort, observations were also discontinued when the base became severely rutted in several places after the heavy rains. This necessitated reshaping and recompaction of a great deal of the top course, so there was no valid basis upon which comparison could be made. Insofar as raveling and bonding properties were concerned, it was obvious that the courses containing calcium chloride were hardly affected by passing traffic during dry weather. Of course, the influence of binder soil - and particularly the excessive P.I. which showed up later - must be taken into account on that score. However, there was a marked difference between the untreated and treated portions of the test section (outlined in Fig. 13), (Page 19), both portions being alike in all respects other than the calcium chloride addition. Raveling was far greater on the untreated than on the treated base in the test section.

Specific effort was made to get density measurements in the top course (actually extending the full 4-inch depth of the two treated courses). Results of the measurements are shown in Table 4. These results were even more variable than those representing the underlying untreated base (See Table 3), the range being from a low of 109.3 to a high of 140.7 pounds per cubic foot. In comparison the low for the untreated base was 121.0 and the high was 141.2 pounds per cubic foot. Average values of density were from approximately 2 to 8 pounds per cubic foot higher on the underlying untreated courses than on the upper treated courses.

Table 4 - Densities of Treated Base, Lyon County F 530 (6)

Station	Sample No.	Dry Density lb/cu.ft.	Design Thickness Inches
-6+00	63	116.0	12
10+00	62	133.0	12
20+00	61	125.0	12
30+00	60	128.0	12
40+00	59	137.0	12
50+00	58	133.5	12
60+00	57	127.3	12
70+00	56	109.3	12
80+00	55	124.0	12
90+00	54	121.3	12
100+00	53	137.0	12
110+00	52	124.0	12
120+00	51**	116.5	12
125+00	50**	118.3	12
130+00	49	135.0	12
135+00	48	139.8	12
140+00	47*	130.7	12
145+00	46*	134.0	12
150+00	45*	116.7	12
155+00	44*	124.0	4
160+00	43*	133.7	4
165+00	42	133.0	4
170+00	41	127.0	4
175+00	40**	138.4	4
180+00	39**	140.7	4
185+00	38	121.6	4
195+00	32	133.0	4
205+00	30	134.3	16
215+00	31	136.0	16
225+00	29	116.0	16
235+00	28	123.8	16
245+00	27	116.9	16
255+00	26	126.6	16
265+00	25	135.8	16
275+00	24	130.7	16
295+00	23	127.7	12
305+00	22	127.2	12
315+00	21	124.6	12
325+00	20	125.2	12
334+95	19	123.1	12
Average		127.4	

Note: All samples represent base with $CaCl_2$ treatment of 1 lb. per sq. yd. per 2-inch depth, except as noted:

* No $CaCl_2$ treatment

** Double $CaCl_2$ treatment

Because of differences in gradation, soil content, and other factors, a more valid comparison can be made between the untreated and treated portions in the test section. There the composition, aside from the calcium chloride additive, was not intentionally varied. Even these values do not offer much for comparison because they have a large range from minimum to maximum. Probably this is caused partially by actual variations in composition of the materials at the points of test, and partially by limitations in the accuracy of the density test.

At face value, the average density of the different parts of the test section were as follows: non-treated - 127.8 pounds per cubic foot; normal treatment - 133.7 pounds per cubic foot; and double treatment - 128.5 pounds per cubic foot. Despite these differences, it appears that density can have no particular bearing on the future performance of pavement within the test section.

One particular thing of significance was noted throughout the rolling of the stabilized courses. The contractor was unable to locate and remove more than just a small portion of the oversize material; hence, in many places it was obvious that construction of a 2-inch course was being attempted with material that had a maximum size approaching 2 inches. In effect, the tires of the pneumatic roller were supported a good portion of the time by the large pieces of gravel, and adequate compaction could not be obtained.

Another factor which had considerable influence was the change in gradation and plasticity of gravel coming from the pit. At the time of the last sampling which influenced design of the treated base mixture, the gravel, as mentioned on page 8, had only two percent passing the No. 200 sieve and no plasticity. Addition of the 10 percent silt was calculated to keep the P.I. of the mixture below 6, and the percentage passing the No. 200 sieve between 10 and 20. Unfortunately, there were no checks on the gravel until the first reports on samples taken from the treated base were available. This information, which is represented by the first six listings in Table 5, became known at the project on September 11. At that time, the first treated course had been completed to a point within 4100 feet of the Kuttawa end of the job, and the second treated course was only about 2500 feet short of that.

Both the gradation and the plasticity characteristics of the gravel had obviously changed to some extent during the period since gravel samples were last taken, which was August 6. Checks on the silt from the binder-soil pit showed a P.I. of 10, and this plus other characteristics indicated that this material remained essentially constant. Variations in properties of materials throughout a given pit are characteristic of bank gravel deposits, but changes as great as those indicated in this case were not anticipated because of the uniform appearance of material coming from the pit.

Inasmuch as the test data and conditions on the site indicated plasticity in the bank gravel, binder soil additions were discontinued on September 13. Thus, the treated base from Sta. 35+00 to the end point at Kuttawa contained just the bank gravel and calcium chloride.

Table 5. Results of Tests on Mixtures Taken From The Top Four Inches of Base, Lyon County F 530 (6)

Station	Sample No.	Course	Plasticity Characteristics		Gradation Factors Percentage Passing	
			L.L.	P.I.	No. 40	No. 200
39/00	17	1	26.3	16.2	14.0	23.1
64/00	18	1	24.0	14.0	16.4	29.2
89/00	11	1	28.2	18.3	15.3	21.5
100/00	21	2	21.4	11.4	9.4	30.9
114/00	7	1	27.9	16.2	9.6	18.9
125/00	22	2	21.7	12.8	9.5	29.2
139/00	6	1	20.3	8.4	12.1	20.4
150/00	23	2	27.0	15.8	16.4	42.0
175/00	20	2	25.3	15.5	15.8	33.8
179/00	10	1	20.8	12.0	14.2	26.9
184/50	9	1	24.8	14.4	11.1	22.9
195/00	14	2	20.0	10.8	12.1	29.3
209/50	8	1	23.2	13.3	19.3	34.3
220/00	15	2	25.6	14.9	14.3	27.5
230/50	5	1	28.7	17.9	11.5	29.9
245/00	19	2	25.0	14.7	12.0	27.1
259/00	1	1	23.4	15.1	11.7	26.1
270/00	16	2	27.6	17.7	12.2	25.0
284/50	3	1	24.5	13.3	14.2	30.4
295/00	12	2	21.7	13.7	12.0	23.6
309/50	2	1	26.8	16.5	21.2	39.9
320/00	13	2	23.4	13.1	14.7	28.7
334/50	4	1	28.0	16.5	15.7	34.2
Average			24.6	14.4	13.7	28.5

All of the several influences in combination led to either severe erosion or rutting of the base in several places after two periods of heavy rainfall. The first of these developed during the rain of August 27-28, at which time the edges of the base on fills between Sta. 230+00 and the Cumberland River Bridge (Sta. 350+00) were eroded in several places. One of these locations is illustrated in Fig. 16. Also, the day following this concentrated rain, construction forces on the Bridge projects attempted to move a bulldozer outfit on a lowboy over the base. This load was supported quite well even on the recently completed stabilized course, but at about Sta. 195+00 where the first treated course had not yet been placed, the truck mired down in the untreated base.

The base was cut and rutted severely in the attempts to move the lowboy, and it was necessary to leave the rig set until the following day when the base became firm enough to support the load. Some additional passes of a grader and the three-wheel roller were required to bring the base back to shape. For restoration of the eroded base, premixed treated material was picked up about Sta. 212+00 where construction was in progress, and this material was taken by trucks to the spots needing replacement. This treated mix was used regardless of whether the material which had been eroded was treated or untreated. The three-wheel roller was used to recompact the base in these spots.

When the rainfall of September 10, occurred many of the workers and some equipment at the Bridge Project were on the job. The rain caused a shut down for the day, and the several vehicles making the trip out during the rain caused extensive rutting on the surface - particularly on the

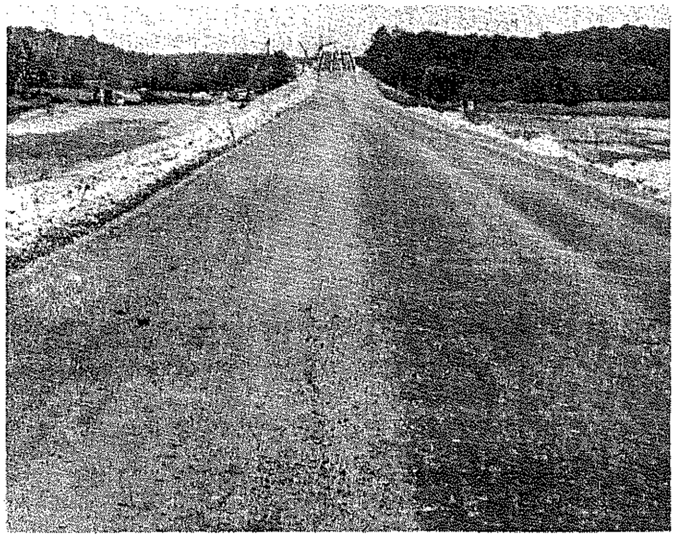


Fig. 15. A finished section of the first 2-inch stabilized course. Very little traffic had used this section at the time. Within the next two days, severe erosion of the edges occurred following a heavy rainfall (See Fig. 16).

Fig. 16. Erosion of bank gravel base and shoulders following the heavy rainfall of August 28. Only the top 2 inches of base had been treated at the time, and water removed both treated and untreated material as shown. Eroded places were refilled with stabilized gravel and recompacted.

Fig. 17. A section of completed base following a rainfall of 2.40 inches within the preceeding 77 hours (September, 10-13). This portion of the base had cured for one week before the heavy rain occured. There was only slight evidence of softening of the base at this point, although a considerable amount of traffic to and from the Cumberland River Bridge project passed over this base during and following the rain.

Fig. 18. A freshly laid section of base at Sta. 115+00 which was severely rutted by passing traffic after the rainfall of September 10. Further rutting occurred during and after the rain of September 12-13. Softening was much in evidence with considerable rutting of the uncured portions. Material shown was placed just two days prior to the first rainfall.

treated base. Damage to the surface was somewhat in proportion to the length of time the material had been in place, or the time it had cured. In the sections nearest the bridge, which had been down almost one week, the damage was limited as shown in Fig. 17. In contrast, those portions of the treated base which had been in place no more than two or three days were rutted and gouged to the extent that in some spots the road was almost impassible for a few hours. One of the more heavily damaged sections of treated base is shown in Fig. 18.

Despite this severe damage, it is possible that the base benefited from the kneeding action of traffic during this period. Working the mix in this manner could have conceivably increased the final density of the base particularly in view of the oversize material and the tendency toward point support of the pneumatic roller as previously mentioned in the discussion of construction procedures. At any rate, when the moisture content of the displaced material was once again reduced during the succeeding period of fair weather, the base was reshaped and recompacted with the grader, pneumatic roller, and the three-wheel roller in the usual sequence. Within a few days time the bituminous binder course was started, and no further rutting of this magnitude occurred in the exposed base although there were some cases where localized reshaping and recompaction were required following other rains in the period of September 21-24.

Another prominent instance of difficulty originated with the heavy rainfall of August 27-28. This situation, which developed between Sta. 180+00 and Sta. 195+00, was attributed to the fact that binder soil was laid in the north lane on August 27, but before it could be mixed with the gravel rain began to fall some time that afternoon. Within the next 36 hours, 4.56 inches of rain was recorded at the nearby weather station. When mixing operations were resumed two days later, the soil was still wet and could not be well distributed throughout the gravel. Some of it remained concentrated in the north lane where it had been placed originally.

After two days of operations with the grader, in an attempt to aerate and mix the soil and gravel, the treated base mixture was completed, spread, shaped, and rolled to a condition that appeared satisfactory. However, when the bituminous paving had been started, and the binder course had been laid from Sta. 350+00 down to about Sta. 195+00, the rains of September 21-24, set in. At that time, the prime had been shot some distance past Sta. 180+00 in the direction of Kuttawa.

Trucks loaded with the plant mix, while passing over this section on September 25, caused such serious shoving in some spots on the north lane it was necessary to take corrective measures. Accordingly, three strips of base in this lane were cut out with a blade grader to a depth of from 2 to 8 inches and for a width of approximately 8 feet. The total length of the three strips was almost 1000 feet.

Before replacement was started, the subgrade or subbase exposed by the cut was rolled with the pneumatic roller until it was firm. Bank gravel direct from the pit was hauled to the spots, tail-gated, and rolled continuously with the pneumatic roller. Immediately after the base replacement was completed, the bituminous binder course was laid over the entire 1500-foot section and on toward Kuttawa. The finished pavement, which is illustrated in Fig. 19, showed no further evidence of weakness in this section.

Fig. 19. Finished pavement at about Sta. 190+00 as it appeared on October 8, 1951. A section of the finished base under the left (North) lane was soft and shoved under loads at the time of bituminous binder-course construction. This condition existed in three spots totaling about 1000 feet in length. Upon examination it was found that the binder soil and gravel in the first 2-inch course of stabilized base had not been properly mixed and that lenses of binder soil were present. Records showed that this binder soil had been placed on the road and became very wet while in a windrow, and it remained wet at the time of mixing with the gravel.

Before the bituminous binder was laid, base material to a depth of from 2 to 8 inches and for a width of 8 feet was removed in the left lane. Prior to replacement, the exposed surface was rolled until firm, after which the excavations were refilled with bank-run gravel which was rolled continuously as it was spread. The bituminous binder course followed immediately. Forms shown here were used later in the construction of a lip curb.

One instance of base weakness was not particularly associated with rainfall, and it apparently had no connection whatsoever with the treated base. A plan note called for the trenching of existing traffic-bound gravel and subgrade to a depth of 0.7 foot between Sta. 195+00 and Sta. 275+00. Total thickness of the base for this 8000-foot section was to be 16 inches (of which 12 inches would be untreated). The trench was made, and the base between Sta. 227+00 and Sta. 234+00 was soft from the time it was started. The underlying soil (See Table 8, in the Appendix) described as blue clay and classified as A-6(11), began to work through to the surface. Within a short time, the base was softened to the extent that it was necessary to reduce speed and sometimes shift to a lower gear on the loaded trucks carrying gravel for the top course of untreated base near the Cumberland River Bridge.

Because of this condition, it was decided that an additional 4-inch course of untreated base be placed in the 700-foot section thus affected. Even after the untreated base to a depth of 16 inches had been finished, and the 4-inch course of treated base placed on top, there was still evidence of weakness. Deflections under load continued, and shortly after the bituminous binder course was laid allegator cracks developed in some of the weaker spots. When the application of the bituminous surface course had carried up to these spots, further effort was made to correct the condition.

In five or six localized areas both bituminous binder and base material was removed to a depth of 6 or 8 inches. This was done entirely by hand, the area affected being so limited that cutting and replacement operations could not be carried out with equipment. Material from the excavations was wasted on the shoulder, and the entire depth in all cases was refilled with bituminous surface course by end dumping from trucks. The bituminous mix was raked and rolled, and then the surface course was placed over the top with the finishing machine. One of the spots where bituminous replacement was used (Approximately Sta. 220/00), is illustrated in Fig. 20.

Even with all these corrective measures, deflections under load continued in some places, and within a few days time prominent cracks were in evidence. These were limited to very short distance (5 or 10 feet) longitudinally, and they were located at two places within the 700-foot distance where trouble from soft subgrade originated. All the replacements of material and all the cracks were confined to the north lane where construction traffic was always heaviest. The cracks that developed shortly after the surface was completed were, of course, still in evidence when the 4-month performance data were taken. However, as shown in Figs. 21 and 23, maintenance forces (presumably) had made an effort to protect the road with patches even though the project had not yet been accepted.

Untreated Base - Livingston County.

Because of the fact that calcium chloride treatment was discontinued shortly after the untreated base construction was started in Livingston County, the observations on that portion of the project were

Fig. 20. Weak spot within the 8000-foot section where existing traffic-bound material was trenched 0.7 foot, prior to base construction. Subgrade soil worked up through the base in several spots and kept the base weak even after the bituminous binder was placed. When the surface course reached this section, material was excavated by hand at all the locations showing signs of failure, the openings were backfilled with surface mix, and the pavement finished. Note excavated material on the shoulder.

Fig. 21. Location shown in Fig. 20 after four months. The cracked pavement has been patched with a thin layer of porous cold patch. There was very little bond between the patch and the pavement. The failure is confined to the right wheel track of the north lane for a distance of 15 to 20 feet.

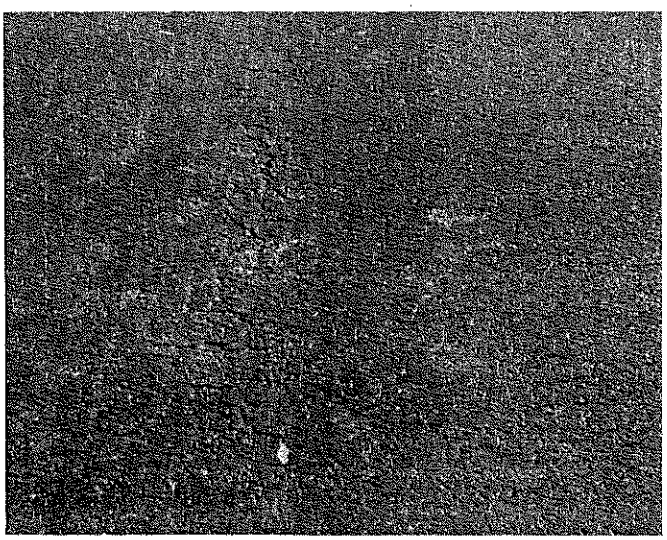


Fig. 22. Cracks in the finished surface that appeared just after paving near Sta. 233+00. This failure occurred at a point where the base was originally 20 inches in depth, a part of which was removed and replaced as described in Fig. 20 above.

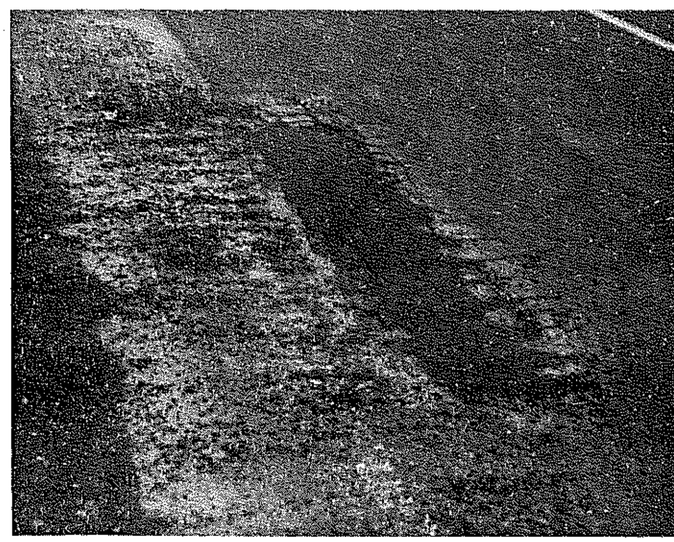


Fig. 23. Location shown in Fig. 22 after four months. The thin porous cold patch was raked from the failure of this picture.

very much reduced. In fact, a representative from the Research Division was on the job only four days during the base construction in Livingston County. A few records on this part of the work were kept, and they are presented here as a pertinent part of the over-all observations which may have a bearing in the interpretation of future performance.

When the base was started in Livingston County, gravel was taken from the Young Pit which lay between the rivers. This source as noted in the discussion of mix design, had material running as large as five inches in size, and the clay content was relatively high. High plasticity was characteristic of the fine fractions. An entire 4-inch course and about half of the second 4-inch course of the Livingston County base was laid with this material. Construction procedures were the same as those used on the untreated base in Lyon County. Results, from the standpoint of raveling on exposed surfaces, are illustrated in Fig. 24.

Following the conference of October 9, the contractor was requested to move to the Bohannan Pit in Marshall County where the qualities of the gravel were better suited to the construction. From that point on, the sheepsfoot roller (See Fig. 25) was introduced with a view toward "setting" the gravel before it was subjected to the pneumatic roller. Actually, the sheepsfoot roller seemed to be of little value, and most of the compaction was accomplished with the pneumatic roller followed by the three-wheel for final finish. Even though there was no mixing involved, the blade graders were used for shaping the top course of base before and during the pneumatic roller operations.

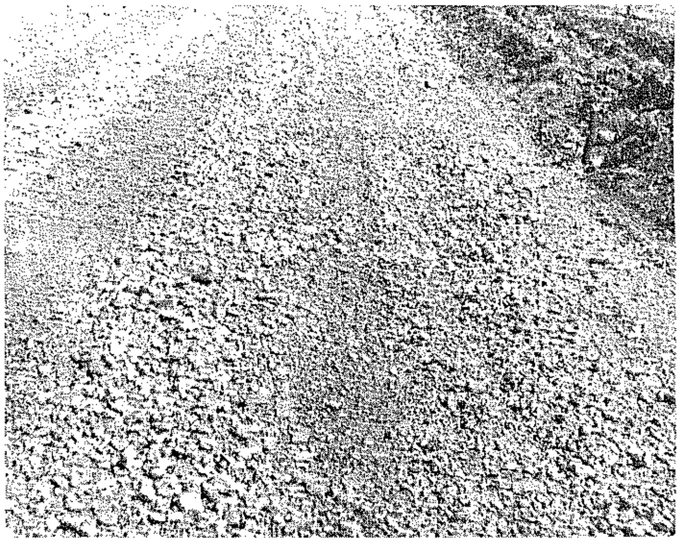


Fig. 24. Raveling of the initial 4-inch base course in Livingston County. A large quantity of gravel 4-inches and larger was contained in this material from the Young pit located between the rivers.

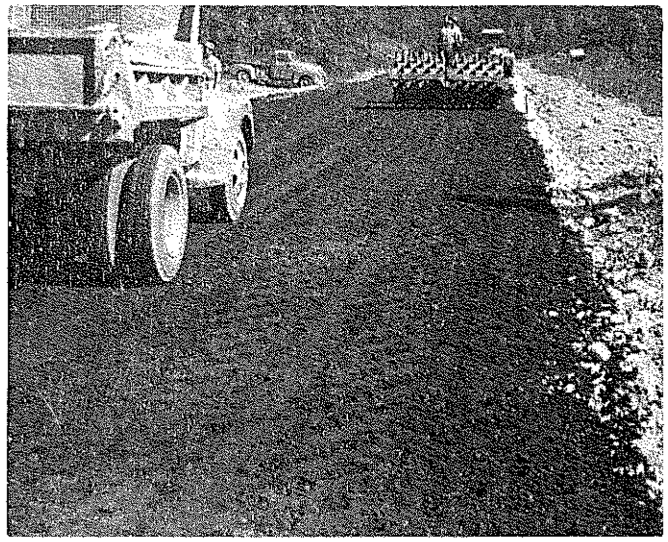


Fig. 25. The sheepsfoot roller being used on the top course of base gravel in Livingston County. The gravel was from the Max Bohannon pit in Marshall County.

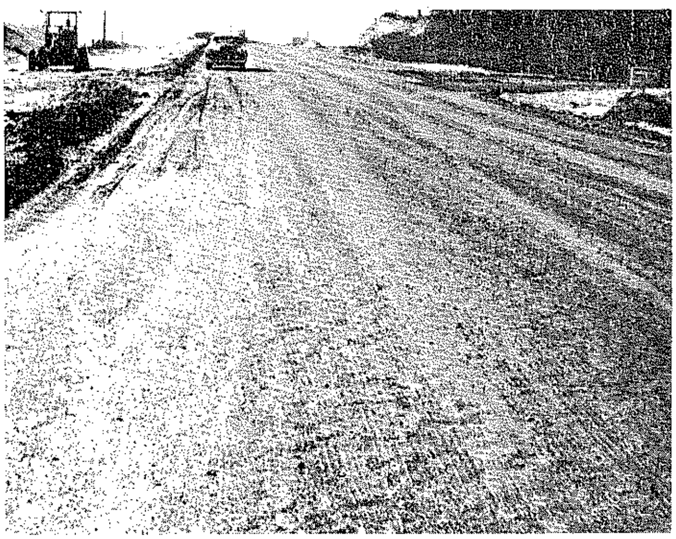


Fig. 26. A section of non-plastic base in Livingston County looking west toward station 450/00. The gravel was from the Max Bohannon pit, and was exceptionally sandy at this point. Note the evidence of non-consolidated material.

Fig. 27. Patched binder course at the location of the non-consolidated base in Fig. 26. The dark section in the center of the pavement is not a patch but was caused by a badly cracked condition. Conditions shown existed about four months after the binder course was laid. Final surfacing of this portion of the road will be carried out during the 1952 season.

Gravel from Marshall County went down well and in general compacted well, although there were a few spots where the material could not be bonded or densified sufficiently. At those spots the base remained essentially unstable even after the bituminous binder course was placed. One of these conditions, which developed in the south lane near Sta. 450+00, is illustrated in Figs. 25 and 26. Even though there were no specific tests to detect changes, it was evident that the material coming from the Marshall County pit varied somewhat, particularly from the standpoint of the percentage fines. Otherwise, the differences in binding qualities of the gravel would not have existed. There was some possibility that clay in underlying gravel from the Young pit in Livingston County worked through to help bind the looser surface gravel.

Densities of the Livingston County base are listed in Table 6. All tests were made on base courses containing the Marshall County gravel. Once again, the lower of the two courses had the higher average densities, even though there was no possibility of compaction on the top course influencing the course beneath. The first was tested before the second was placed. There was very little difference in the average densities of the lower courses in the two counties, but the range of density values was much greater in the base made with the gravel from Lyon County than with the gravel from Marshall County. Conditions with respect to the upper courses in the two counties were somewhat the same. In brief, the maximum, minimum, and average values of densities measured in these untreated bases were as follows:

Table 6. Densities of Untreated Base, Livingston County F 530 (6)

Middle Course				Top Course			
Station	Sample No.	Dry Density lb/cu.ft.	Design Thick-ness Inches	Station	Sample No.	Dry Density lb/cu.ft.	Design Thick-ness Inches
360+00	9	132.5	12	350+00	10	130.7	12
375+00	8	136.0	12	360+00	11	123.8	12
400/00	7	140.0	12	370+00	12	133.7	12
415+00	6	135.0	12	380+00	13	133.2	12
430+00	5	136.0	12	390+00	14	140.0	12
445+00	4	141.0	12	400+00	15	132.3	12
455+00	3	143.5	12	410+00	16	145.4	12
465+50	2	135.6	12	420+00	17	132.5	12
475+50	1	140.0	12	430+00	18	139.2	12
				440+00	19	130.7	12
				450+00	20	132.1	12
				465+00	21	134.3	12
				475+00	22	135.4	12
Average		137.7		Average		134.1	

Note: Entire base prepared without $CaCl_2$ treatment in Livingston County

	Density in lb. per cu. ft.			
	Upper Course		Lower Course	
	Lyon	Livingston	Lyon	Livingston
Maximum	138.1	145.4	141.2	143.5
Minimum	121.0	123.8	125.4	132.5
Average	129.1	134.1	135.5	137.7

Perhaps some of the increased density in the Livingston County base could be attributed to the sheepsfoot roller, but it is more likely that superior gradation and a smaller maximum size in the gravel accounted for this relationship.

Four Month's Performance.

The pavement was inspected again in February. Both sections had been subjected to limited traffic since the Cumberland River Bridge had not been completed. The principle traffic over the Lyon County portion had been the hauling of materials for the bridge floor, while the Livingston County Section was subjected to quarry traffic.

No specific differences could be seen in any parts of the test sections. The entire 6000 feet was in excellent condition. A photographic record was made of each part.

Particular effort was made to examine the weak spots recorded during construction. The locations represented by Figs. 21 and 23, were two of the three failures noted in Lyon County. All were in the 8000-foot section where the subgrade was trenched at the beginning of construction.

No failures were noted in the surface course in Livingston County.

The patches shown in Fig. 27 are in the exposed binder course and are at the same location as the soft spots shown in Fig. 26. Here the base gravel was sandy and did not set up.

Fig. 28 was taken at approximately the same location as Fig. 18, and apparently the restoration of this rutted base was successful. The riding qualities of the finished pavement are excellent. Fig. 29 shows the completed pavement at about the same location as Fig. 17. An excellent cross-section was obtained throughout.

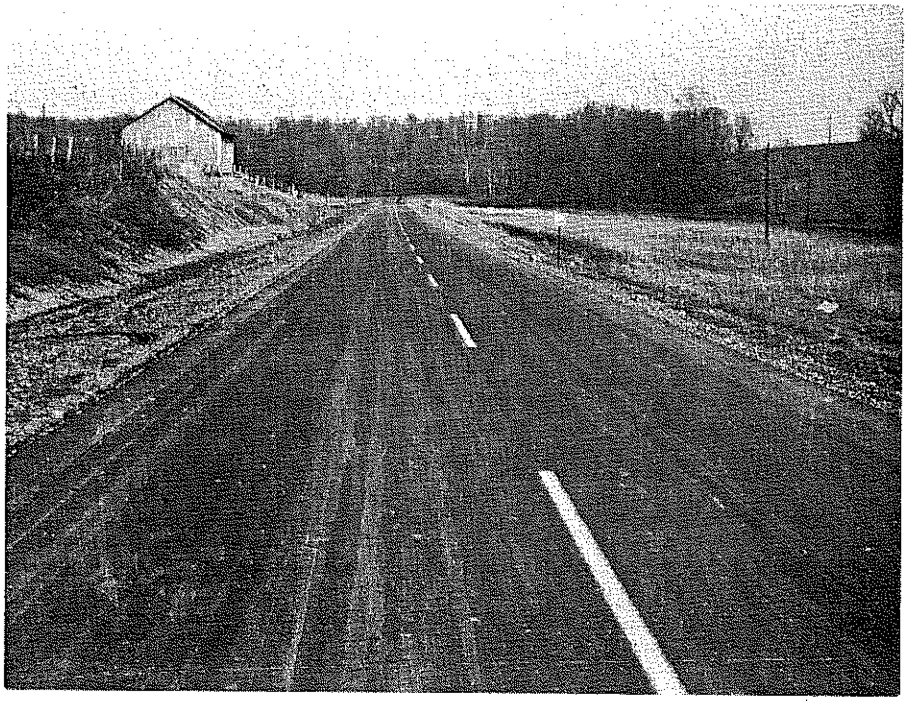


Fig. 28. Finished pavement at the same location shown in Fig. 18. Excellent riding qualities were obtained. The photograph was taken four months after construction.

Fig. 29. Completed pavement near the location of Fig. 17, as it appeared on February 18, 1952. The cross section, as illustrated in this photograph, was excellent throughout the project.

APPENDIX

Data From Files of Division of Design

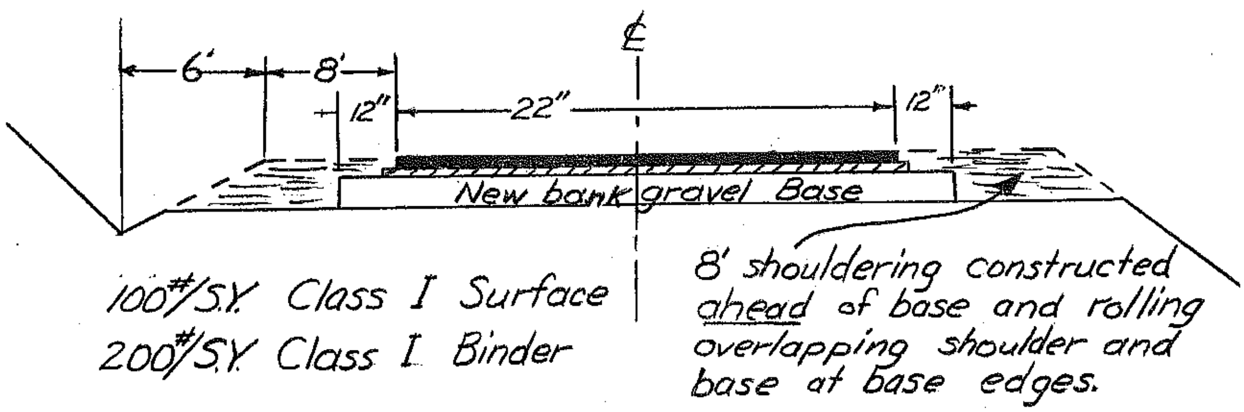
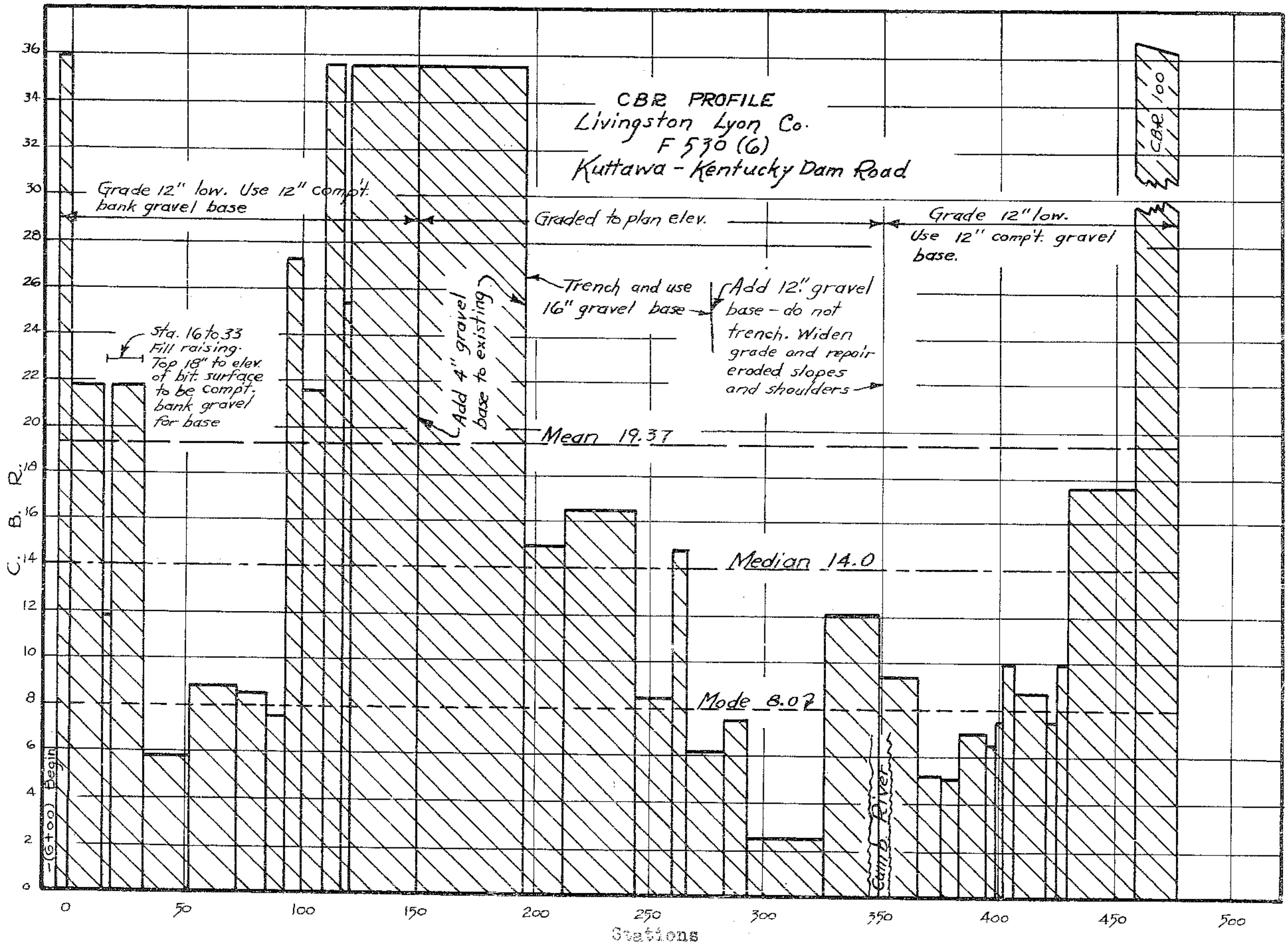


Fig. 30. Typical Section.



CBR PROFILE
Livingston Lyon Co.
F 530 (6)
Kuttawa - Kentucky Dam Road
Grade 12" low. Use 12" comp't. bank gravel base
Graded to plan elev.
Grade 12" low. Use 12" comp't. gravel base.
Sta. 16 to 33 Fill raising. Top 18" to elev. of bit. surface to be compt. bank gravel for base
Add 4" gravel base to existing
Trench and use 16" gravel base
Add 12" gravel base - do not trench. Widen grade and repair eroded slopes and shoulders
Mean 19.37
Median 14.0
Mode 8.07
CBR 100
Begin (6+00)
Cumb. River
C. B. R.
Stations

Fig. 30

Table 7. Design Soil Test Data Before Construction

Station	Optimum Moisture Content	Maximum Dry Density	Liquid Limit	Plasticity Index	Calif. Bearing Ratio
-3+00	22.4	97.8	40.8	20.1	2.0
-4+00	14.6	109.6	26.6	11.0	50.1
18+00	15.1	115.1	31.6	11.8	21.8
38+00	20.1	104.6	48.0	29.4	4.1
49+00	16.7	112.0	33.2	15.9	9.6
65+00	18.8	107.5	43.1	25.8	7.5
82+00	17.8	111.1	38.2	20.9	9.7
98+00	15.0	110.4	30.0	12.0	35.7
160+00	17.8	108.7	43.4	21.3	37.2
166+00	16.4	111.8	33.4	16.3	18.1
190+00	16.0	112.5	32.6	13.9	42.7
200+00	15.6	110.1	27.8	7.7	14.9
229+00	15.9	109.3	33.4	11.8	16.5
247+00	18.0	106.5	41.9	18.4	8.5
275+00	19.5	105.4	42.6	18.9	6.1
290+00	15.0	113.4	27.2	9.0	7.7
308+00	17.9	107.6	38.7	16.5	2.5
335+00	15.3	111.4	27.8	9.6	12.1
354+50	16.7	113.2	34.9	17.8	9.4
357+00	16.8	107.6	27.5	5.4	16.9
359+00	17.0	104.1	29.5	7.9	25.7
359+00	17.0	110.5	31.9	9.7	16.6
372+00	17.8	105.2	40.5	21.9	5.1
380+00	22.8	100.3	57.6	34.6	4.1
385+00	16.6	109.5	33.5	14.2	10.0
431+00	11.3	118.9	20.9	3.4	17.7
434+00	16.6	108.1	32.3	10.5	0.9
435+00	14.8	106.1	Non-Plastic		14.5
440+00	14.7	109.7	30.3	12.9	101.6
448+00	12.3	117.6	23.5	5.9	128.0
471+00	15.1	112.9	33.7	13.6	1.1

Table 8. Soil Test on Subgrade During Construction

Station	Optimum Moisture Content	Maximum Dry Density	Field Density	Liquid Limit	Plasticity Index	Calif. Bearing Ratio
25+00	14.1	112.8	--	32.0	13.1	30.5
59+30	20.0	105.5	109.8	41.7	26.4	4.2
111+00	14.0	115.2	121.7	31.4	14.6	13.9
131+00	14.9	111.8	125.4	30.7	14.8	16.5
138+00	16.9	108.4	113.6	33.1	15.3	15.3
148+00	16.0	110.6	111.7	32.8	16.8	10.8
202+00	16.1	108.5	112.3	29.7	13.3	19.2
212+00	15.8	111.1	111.7	31.3	15.4	8.7
217+00	16.6	110.0	109.2	35.1	19.6	10.7
227+00	17.1	116.1	104.2	35.6	18.1	9.8
287+00	19.0	106.4	107.3	40.0	24.2	4.4
292+00	18.0	109.6	108.0	37.6	19.8	6.2
302+00	16.2	110.9	109.8	32.9	17.0	5.0
312+00	15.2	114.0	111.7	35.2	19.3	6.0
317+00	16.2	109.4	108.0	32.4	15.3	14.5
329+00	15.4	112.2	114.2	31.6	17.6	7.9
334+00	15.2	116.0	116.7	27.2	27.2	12.8