TO:  D. V. Terrell  
Director of Research

Attached you will find our second progress report on "A Bank Gravel Base Containing Calcium Chloride," by W. B. Drake. This project pertains to that portion of the Paducah-Eddyville Road (U.S. 62) extending from Kentucky Dam to Kuttawa. You are quite familiar with the road having visited it in company with Mr. Bray on August 13, this year and I believe most of the members of the Research Committee are familiar with it. Discussions following presentation of Report No. 1 on the project at our meeting last April would have accomplished that, but the road is better known for the number of failures that developed within the first year after its construction.

The present report is largely concerned with those failures. A brief review of construction features is given, but most of the report tells of things which were noted at the time of a condition survey in June, 1952, and gives an account of observations and measurements made just prior to and during the work undertaken to restore a large part of the pavement in October. As was the case in the original construction, our function was to record data and obtain samples or make tests considered necessary for the record - this to be done in cooperation with the Resident Engineer and construction forces. At the time of construction we made a number of recommendations, several of which were accepted for use on the project, and some of these had a bearing on the failures that developed.

Records indicate that high plasticity in the gravel-soil mix influenced most of the failures, but even this might not have been extremely critical had the weather during construction been more favorable. Some of the worst failures occurred where the two materials were never well mixed, rainfall prior to the mixing operations having made it impossible to get the binder material worked into the gravel. Even after the binder soil was left out entirely the difficulties were not eliminated, because some failures developed in the last 400 feet of construction on the Kuttawa end where the treated base consisted of just the bank gravel and calcium chloride. Of course, the plasticity index in the gravel alone at that stage was considerably higher than the specification limit.
Other failures were attributed to effects of the prime which accumulated in spots, and the stripping of asphalt which permitted lateral displacement of the bituminous binder and surface courses. Still other failures were dependent on subgrade material working up through the base even though at those places the base was 20 inches thick. Certainly not all the difficulties were directly associated with softening of the base, but the large majority were in that category.

I believe that no one condemns calcium chloride as such for the failures, even though the only sections without pavement distress are those without any chloride. In my opinion the road does show that the combining of calcium chloride in a mix that can not be controlled from the standpoint of gradation and plasticity is unwise. To that extent a project with calcium chloride in a bank gravel should not have been undertaken. In fact, not only this road but others where bank gravels have been used in the base show that the performance is likely to be commensurate with the cost, and we can expect a certain amount of failures from materials as variable as the bank gravels in the Purchase Area. Certainly the failures should never be nearly as great as they have been on the Kuttawa-Kentucky Dam Project, but it is evident that probably there will be many failures where we try to produce a controlled mix with an ingredient that is as variable as this pit-run material.

In a letter of December 8, to Jack Crider, Resident Engineer at Kuttawa, Mr. C. B. Owens, Director of Construction, recommended that further observations and measurements be made in a way that will correlate well with our past records. Apparently, there are evidences that still further difficulties may develop. We will cooperate with Mr. Crider in the observation on the road and make occasional reports as long as there is interest in its performance.

Respectfully submitted,

L. E. Gregg
Assistant Director of Research

LEG:cdc
Attached
cc: Research Committee Members
Mack Galbreath (3)
Commonwealth of Kentucky
Department of Highways

Report No. 2

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

December, 1952
VARIATION IN BASE

Standard design for the top 4 inches on the treated portion of the base in Lyon County consisted of two 2-inch courses each containing calcium chloride applied at the rate of 1 pound per square yard. Also, the gravel-binder soil combination was set at 90 percent bank-run gravel with 10 percent soil by weight. Exceptions to this were as follows:

1. A 6000-foot "test" section between Sta. 120/00 and Sta. 180/00 in which 2000 feet was placed without calcium chloride, 2000 feet contained the standard application, and 2000 feet received twice the normal application, or 2 pounds per square yard in each course. (See Fig. 13, Report No. 1 for locations)

2. Binder soil was not added to the gravel in the last 4100 feet of the base (Sta. -6400 to 35/00), but the regular application of calcium chloride was retained.

3. Approximately 1000 feet of base material in three sections was removed and replaced in the west-bound lane between Sta. 180/00 and Sta. 200/00 at the time the bituminous binder was laid. This was done to overcome a failure that developed during construction. Untreated gravel was used for replacement.

There was no calcium chloride nor binder soil used in the top 4 inches of base in Livingston County, and gravel for this portion of the project came from an entirely different pit.
PAVEMENT CONDITION

Pavement condition surveys have been made at three different times, and the results from one of these (February 19, 1952) were included in Report No. 1. At that time three failures of the pavement in Lyon County were noted. Two of these were illustrated in Figs. 21 and 23 on page 40 of Report No. 1.

June 17, 1952. Much more extensive records of failures and greater photographic coverage were required at the time of the second inspection. Fifteen locations, showing pavement cracking or displacement were found. The lengths of failures at these locations are given in Table 1.

Figure 1 shows a displacement of about 1 inch at Sta. 15/83. The pavement was cracked and rutted for a distance of 38 feet. The base for this section was 12 inches of compacted bank gravel, the top 4 inches of which contained 2 pounds per square yard of calcium chloride and no binder soil. Two failures were noted in this type of base.

Near Sta. 44 where the pavement lay on about a 5 percent grade, considerable failure was noted. Some loss of surface and binder was in evidence. Figures 2 and 3 were taken near Sta. 44.

The maximum pavement displacement noted was in the vicinity of Sta. 182. None of the surface or binder was missing, even though there was rutting in excess of 2 inches. Figure 4 illustrates the condition at Sta. 182/25.
Table 1. Pavement Failures (Cracking or Displacement) June 17, 1952.

<table>
<thead>
<tr>
<th>Station*</th>
<th>Length in Feet</th>
<th>10% Binder Soil Added</th>
<th>CaCl₂ Content Lb/Sq.Yd.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left Lane</td>
<td>Right Lane</td>
<td></td>
</tr>
<tr>
<td>15/400</td>
<td>38</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>35/400</td>
<td>1000</td>
<td>-</td>
<td>Part of Sec.</td>
</tr>
<tr>
<td>50/400</td>
<td>50</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>55/400</td>
<td>50</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>62/400</td>
<td>50</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>122/75</td>
<td>-</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>182/25</td>
<td>100</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>186/50</td>
<td>-</td>
<td>50</td>
<td>Yes</td>
</tr>
<tr>
<td>205/400</td>
<td>-</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>217/400</td>
<td>-</td>
<td>1600</td>
<td>Yes</td>
</tr>
<tr>
<td>255/75</td>
<td>-</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>259/400</td>
<td>200</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>263/400</td>
<td>-</td>
<td>10</td>
<td>Yes</td>
</tr>
<tr>
<td>299/400</td>
<td>-</td>
<td>250</td>
<td>Yes</td>
</tr>
<tr>
<td>310/400</td>
<td>-</td>
<td>10</td>
<td>Yes</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1488</td>
<td>1955</td>
<td></td>
</tr>
</tbody>
</table>

* Approximate Beginning
Figure 5 shows pavement cracking and displacement near Sta. 217. The earliest failure noticed was near this spot. This failure was recorded in Fig. 21, Report No. 1, page 40.

An extensive failure was found on the fill to the Cumberland River Bridge between Sta. 303 and Sta. 306. This failure is shown in Fig. 6.

October 20, 1952. An inspection was made just prior to the time that removal and replacement of material at the failures was started. Some of the failures had become more extensive and new cracking was noted. The worst cracking and displacement was concentrated in 12 locations totaling more than 2900 square yards of pavement. These locations had been marked for removal and replacement operations. Some short sections of pavement had minor rutting or indication of displacement. A considerable portion of the pavement that did not show any cracking was slated for resurfacing.

Two failures were noted in the 6000-foot test section. One at Sta. 122/80 had been recorded during the June 17 survey. This was in the double chloride-treatment base and is shown in Fig. 7. The other failure was in the single-application portion at Sta. 135/60 and is shown in Fig. 8. This condition was first noted on October 20, 1952, therefore, it was not scheduled to receive any attention from the standpoint of removal or resurfacing. The portions to be restored were set up in August.

The displacement at Sta. 182/25 remained about the same through the summer months. This large displacement was accompanied by minor cracking (See Fig. 9).
The longest and most pronounced failure began at Sta. 218/.70. First difficulties with movement of the binder course occurred in this vicinity (See Fig. 10).

The condition of the pavement near Sta. 303 remained about the same as it was in June. A small quantity of cold patch material had been placed in the openings (See Fig. 11).
Through a supplemental agreement change order the Department arranged to have certain sections of the pavement and base removed and replaced. This work was begun late in October, 1952.

Twelve sections comprising a total of 2,904 square yards were designated for removal. At these locations the surface and binder course and 4 inches of the base (or the entire depth treated with calcium chloride) was involved. Figures 13 and 14 show this material being taken out.

After the removal was completed, the remaining (untreated) base was rolled and primed lightly with RT-2. Restoration was carried out in three steps as illustrated in the accompanying diagram:

A - Class I base mix was placed and compacted in two layers of 2-3/4 inches each.

B - The remaining 1-1/2 inch of the opening was filled with Class I, Type B surface mix.

C - A new 1-1/2-inch surface course was applied in all locations except one. This new surface was placed for the entire 22-foot width of the road regardless of the width of the patch, and always the new surface extended beyond the ends of the patch.
In two instances, and for a total distance of 400 feet, new surface was placed on the existing pavement even though there had been no removal and replacement. At those two locations, the pavement was obviously weak but there was no rutting or serious fracture of the surface.

Table 2 is a summary of the entire removal, replacement, and resurfacing operations divided according to locations and quantities involved. It will be noted that some of the patches, such as the one at Sta. 15/23 illustrated in Fig. 15, were too narrow for adequate compaction of the mix with a tandem roller. In those cases a pneumatic tamper was used along with the tandem roller for compaction.

**Observed Base Conditions.** During the removal of the surface and base particular effort was made to determine if unmixed soil and gravel were present. At one location near Sta. 182/50 a layer of unmixed binder soil was encountered. Figure 12 shows this layer of unmixed material and gives some of the reasons for its existence. Undoubtedly the extreme displacement of the surface shown in Figure 4 and 9 can be attributed to the segregation of materials, even though results of field tests and laboratory tests on materials taken from this location do not indicate excessive moisture contents or unusually high plasticity characteristics.

All observations confirmed the fact that there was practically no penetration of the RT-2 prime into the treated base. The depth of penetration was seldom greater than 1/4 inch. In conjunction with this there were several places where the asphalt was stripped from the bottom of the binder course, as evidenced by limestone aggregate that was practically white. This was particularly true at spots where there was evidence
Table 2. Sections Replaced by Change Order, October, 1952.

<table>
<thead>
<tr>
<th>Location (Station)</th>
<th>Base* Length and Width</th>
<th>Binder** Length and Width</th>
<th>Surface*** Length and Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/83 to 16/23</td>
<td>40 x 5</td>
<td>40 x 5</td>
<td>--</td>
</tr>
<tr>
<td>35/00 to 85/00</td>
<td>--</td>
<td>--</td>
<td>5000 x 22</td>
</tr>
<tr>
<td>35/00 to 35/55</td>
<td>37 x 14</td>
<td>37 x 14</td>
<td>--</td>
</tr>
<tr>
<td>39/50 to 40/15</td>
<td>26 x 5</td>
<td>26 x 5</td>
<td>--</td>
</tr>
<tr>
<td>43/75 to 44/41</td>
<td>44 x 11</td>
<td>44 x 11</td>
<td>--</td>
</tr>
<tr>
<td>49/88 to 50/25</td>
<td>36 x 10</td>
<td>36 x 10</td>
<td>--</td>
</tr>
<tr>
<td>57/40 to 57/50</td>
<td>40 x 11</td>
<td>40 x 11</td>
<td>--</td>
</tr>
<tr>
<td>61/36 to 62/36</td>
<td>53 x 11</td>
<td>53 x 11</td>
<td>--</td>
</tr>
<tr>
<td>121/40 to 124/60</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>166/40 to 200/40</td>
<td>--</td>
<td>--</td>
<td>3100 x 22</td>
</tr>
<tr>
<td>181/41 to 182/91</td>
<td>100 x 11</td>
<td>100 x 11</td>
<td>--</td>
</tr>
<tr>
<td>211/40 to 231/40</td>
<td>--</td>
<td>--</td>
<td>2300 x 22</td>
</tr>
<tr>
<td>214/89 to 215/40</td>
<td>25 x 7</td>
<td>25 x 7</td>
<td>--</td>
</tr>
<tr>
<td>217/40 to 231/92</td>
<td>133 x 11</td>
<td>133 x 11</td>
<td>--</td>
</tr>
<tr>
<td>24/8 to 25/45</td>
<td>36 x 13</td>
<td>36 x 13</td>
<td>--</td>
</tr>
<tr>
<td>26/25 to 32/45</td>
<td>24 x 14</td>
<td>24 x 14</td>
<td>--</td>
</tr>
<tr>
<td>269/40 to 263/50</td>
<td>224 x 11</td>
<td>224 x 11</td>
<td>--</td>
</tr>
<tr>
<td>299/40 to 303/40</td>
<td>--</td>
<td>--</td>
<td>1715 x 22</td>
</tr>
<tr>
<td>303/40 to 306/40</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>341/33 to 342/33</td>
<td>--</td>
<td>--</td>
<td>100 x 22</td>
</tr>
</tbody>
</table>

Base Removal .................................. 2904.1 Square Yards  
Class I Base ...................................... 798.6 Tons  
Class I Binder .................................... 218.0 Tons  
Class I Surface ................................... 2441.2 Tons

* Removed Surface and 4 Inches of Gravel Base and Replaced With 5½ Inches of Class I Base, 550 Pounds Per Square Yard.

** Used 1 ½ Inches of Class I Type B Surface Mix For Binder.

*** 1 ½ Inches of Class I Type B Surface, 150 Pounds Per Square Yard.
of green tar or puddles of prime. Apparently, the binder had been placed before the prime had cured, and when the prime could not penetrate it accumulated in puddles. Evidently, the liquid tar cut the asphalt from the binder. This condition was very prominent between Sta. 217 and Sta. 232.

A minimum curing period of 10 days was established and followed for the stabilized base courses. This 10-day period was required after placement of base to permit the excess moisture to leave before priming. Inasmuch as this waiting period did sometimes delay paving, no definite curing period for the prime was maintained. Some sections of binder were placed the same day the gravel was primed.

Field and Laboratory Tests. At the time the excavations were open for replacement, moisture content and density tests were made at fourteen locations. Eight of these represented untreated base because in the removal operations material in the treated course was disturbed and intermixed with the old bituminous pavement. At six locations it was possible to make valid tests on the top 1-inch course containing the calcium chloride before material in that course was broken up and removed.

Results of these tests are listed in Table 3. For both tests the data were quite variable, so that averages have little meaning. At face value the average density of the treated course was 126.5 compared with 126.5 pounds per cubic foot for the untreated base. With regard to moisture contents, which ranged from 5.1 to 11.1 percent, the average for the course containing calcium chloride was 6.1 percent whereas the average for the untreated base was 7.1 percent.
Samples of base material were taken from the locations where density and moisture tests were made, and also from six additional locations. These samples were brought to the laboratory and tested for gradation and for plastic and liquid limits. Results of these tests are listed in Table 4. Here, too, the results were quite variable, the plasticity indexes, for example, ranging from 0 to 15.2, and the material passing the No. 200 sieve running from 5.8 to 28.0 percent.
SUMMARY

Significant features of the observations and tests are:

1. Field moisture contents in October, 1952, ranged from about 1/3 to 2/3 the value of the corresponding plastic limits of the -4O material in the base material removed during the replacement of failures. For the 14 samples taken and tested, the average values were:

   MC = 7.7 percent; P.L. = 15.1 percent.

2. Tests for total gradation and plasticity characteristics of -40 material in the top 4 inches of base indicates little difference between conditions at the time of construction and at the time of restoration of failures. Variations in the data and in the locations represented by the samples limit the significance of comparisons, however, the relationship of averages for treated base were:

   23 Samples, 1951    9 Samples, 1952
   P.I. .................... 14.4    13.1
   Pct. Passing 200 Sieve 13.7    11.5

3. Failures were associated with all but one of the combinations of materials placed in the top 4 inches of base. These were as follows:

   Distance   Failures
   In Ft.*    Restored

(a) Gravel, binder soil, and CaCl₂ at rate of

   1 lb. per sq. yd. ................. 25,000    Numerous

* Approximate
(b) Gravel, binder soil, and CaCl₂ at rate of
2 lbs. per sq. yd. 2,000 2
(c) Gravel, binder, no CaCl₂ 2,000 none
(d) Gravel, CaCl₂ and no binder soil 4,100 2
(e) Gravel, no binder soil and No CaCl₂ 1,000 minor
(one lane) (last resurfaced)

The last group represents original replacement made at the time of construction (See Fig. 19, Report No. 1).

4. Penetration of the RT-2 prime was poor, and in many instances this material accumulated in puddles. Insufficient curing of the prime and its influence in softening the original bituminous binder course was noticeable at some of the failures.

5. There was no evidence of maintenance or need for maintenance to overcome base weakness on the Livingston County portion of the project at the time correction of failures was undertaken on the Lyon County portion in October, 1952.

* Approximate
Fig. 1. Pavement displacement and cracking at Sta.15+83. The measured displacement in the inside wheel track was 1 inch on June 17, 1952. This failure was located in a section having 12 inches of gravel base. The top 4 inches contained 2 pounds per square yard of calcium chloride without the addition of any binder soil. The pavement was cracked for a length of 38 feet at that time.
Fig. 2. Pavement rutting, cracking, and potting near Sta. h4. A displacement of 2 inches was measured here despite the down-hill position on a grade, approximately 5 percent. This was a 12-inch gravel base with binder soil and calcium chloride. (June 17, 1952)

Fig. 3. Close up of failure at Sta. h4 shown in Fig. 2. (June 17, 1952)
Fig. 4. A maximum displacement exceeding 2 inches was measured at Sta. 182/25. None of the bituminous surface or binder was missing, and only slight cracking was noted. The design for this section was 4-inches of bank gravel containing binder soil and calcium chloride. (June 17, 1952)
Fig. 5. Cracking near Sta. 217. This portion of the road was the first to show signs of distress. Cracking and movement of the binder course was noted even before the surface was placed. A section of the binder and unstable base was removed as shown in Fig. 20 of Report No. 1. This material was replaced with surface mix. The base thickness at this station was 16 inches. Traffic-bound gravel was trenched for shoulder material here. (June 17, 1952)
Fig. 6. Failure on fill to Cumberland River Bridge near Sta. 303. This had a 12-inch gravel base with the top 4 inches containing calcium chloride and binder soil. (June 17, 1952)
Fig. 7. Failure at Sta. 122/80. This location is in the test section having a double application of calcium chloride. At the time this photo was taken (June 17, 1952) the pavement was cracked and rutted to a depth of 1 1/2 inch.
Fig. 8. Cracking at Sta. 139/60 was first noted and photographed October 20, 1952. The pavement at this failure, which is in the single or regular-application portion of the test section was not resurfaced.
Fig. 9. Displacement at Sta. 182+25 on October 20, 1952. Fig. 4 shows the same location June 17, 1952. Very little pavement cracking was noted despite the 2 inch displacement. The pavement has been cut along the center line for removal of the left lane. A 100-foot section of pavement and base was replaced here.
Fig. 10. Failure near Sta. 218/70. Fig. 5 was taken near this spot June 17, 1952. The pavement of the right lane was removed for a total length of 1432 ft. (October 20, 1952).
Fig. 11. Failure near Sta. 303 on October 20, 1952. Three hundred feet of surface and base in the right lane was removed and replaced. See Fig. 6 for condition 4 months earlier.
Fig. 12. A layer of unmixed binder soil that was encountered at Sta. 18250 when the surface was removed on October 21, 1952. Design quantities required this material spread at the rate of 52 pounds per lineal foot of base or 10 percent by weight of total gravel mix. As a construction procedure, the soil first was placed on the road in an 8-foot land or at a loose depth of about 1 inch. Immediately following this it was to have been thoroughly mixed with the gravel. An exceptionally heavy rain fell (On August 28, 1951) while this unmixed soil was on the road, and calcium chloride was placed while the soil and gravel were still wet. Following this, it was impossible to thoroughly mix the wet soil and gravel. Evaporation during the mixing was very slow because of the affinity of calcium chloride for water.
Fig. 13. Preparing surface and base for removal with a patrol grader. The ripper was used to break up the pavement after it had been cut with a pavement spade on an air hammer. The base was loosened and removed to a depth of 4 inches below the surface.

Fig. 14. Removing pavement and base with an Athey Loader.
Fig. 15. Replacing the gravel base with Class I base. Prior to placing this bituminous mix the remaining gravel base was rolled thoroughly with a 7-ton tandem roller. The gravel was primed lightly with RT-2 then the 5 1/2-inch black base was placed and compacted in two equal layers. Widths of base removed varied from 5 to 15 feet.