Transportation

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Observations on Seal Coats, Tack Coats and Penetration Macadam Construction in 1950

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Among the projects let to contract during the past year, the Department included some seal coats, tack coats, and one bituminous penetration macadam job, all of which involved materials or uses of materials that were unusual. Since there was not much known about those applications, the Division of Design asked that the Research Laboratory observe and report on a group of projects that were considered representative, the object being to obtain the reactions of contractors and personnel in the field as well as the application and performance features on the roads.

This work was carried out by W. B. Drake, Research Engineer, and the results of his observations are contained in the attached report. His account of the various jobs is, of course, limited to the construction phase. The report is comprehensive and well illustrated, and I believe it makes an excellent record on which the Design Division can temporarily base judgement pending the development of performance characteristics as time goes on.

You will recall the penetration macadam job (which we inspected together on one occasion during the construction) as a neat-looking, substantial-looking pavement. Mr. Drake has illustrated the simplicity of construction there, and the satisfactory progress made despite adverse weather conditions. It remains to be seen whether the pavement will stand up under traffic and weather.

So far as the tack coats are concerned, the unique feature was the alternate provision by which a contractor on a plant-mix resurfacing project could use asphalt cement as a tack coat material, as well as for the mix itself, if he chose to do so. The object, of course, was to reduce the storage requirements on the jobs and facilitate handling of bituminous materials. If the projects in the group observed are a reliable indication, this provision was not particularly attractive to contractors for only one of the five chose to use the asphalt cement for tack, and three definitely did not take advantage of it. The remaining project is being carried over to next year. It should be noted that on the one project where the asphalt cement was used, the application seemed to be successful and practically no difficulties developed.
One of the most outstanding points implied in the report is a need for more attention to the so-called A-2 Seal Coat Treatments. It is obvious that if subsequent performance characteristics are favorable, these seal coats offer a relatively low-cost means of prolonging the usefulness of some rather high-cost bituminous pavements. However, to do this satisfactorily they should be designed for the surface being sealed, and they deserve as much care in placement on the job as any other bituminous surface. The report shows definitely that rates of application of both the bituminous materials and the aggregates should be varied on different projects to fit the surfaces being sealed, but its scope was too limited to show the rates that would be most effective. I believe that further investigation along these lines next year could establish combinations of quantities suitable for different conditions. The Division of Design may wish to have us undertake this as an extension of the study.

The specification for A-2 Seals as it now stands should be revised to include all the materials that have been used satisfactorily on this work; to require mechanical means for spreading the chips; to provide for rollers heavier than 7 tons (since 8- and 10-ton rollers are common and were the only flat-wheeled rollers used on the projects reported); and to bring other features of the Specification up to date. Also, it may be desirable to advertise some of the so-called seals as initial treatments for roads where there have been no bituminous surfaces heretofore. In a case where the "seal" is an initial treatment it is not possible to carry out some of the specification provisions such as cleaning the surface with a mechanical sweeper. Although a designation of this sort may be of little consequence so far as the field work itself is concerned, it is one of the factors which contributes to an attitude of underrating this type of project.

Because of the limited time available for preparation of this report, no attempt has been made to prepare suggested revisions in the Specification for A-2 seals, or to draw up recommendations for further study next year. We feel that both of these should be done, and we would welcome an opportunity to go into them further if interest in either one develops.

Respectfully submitted

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Assistant Director of Research

Copies to:
Research Committee Members
Mack Galbreath (3)
OBSERVATIONS ON SEAL COATS, TACK COATS AND
PERETRATION MACADAM CONSTRUCTION IN 1950

by

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Lexington, Kentucky

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INTRODUCTION

Early in the 1950 construction season the Division of Design requested that the Research Division observe some new methods and materials that were being used in bituminous construction. The projects chosen in most cases represented several of the type throughout the state. There were some instances though where the procedure or material was used in only one project.

The purpose of this investigation was to determine the effectiveness of the materials and the methods which were being used. The nature of this study required that only visual inspections be made. Particular emphasis in this report is placed upon observations of construction procedures and design requirements. When the performance data are available, they will be reported. It might be expected that some of the designs appear satisfactory during construction but not stand the test of traffic and weather. Observations of a nature that might prove essential in later performance investigations are reported.

SEAL COATS

The seal coats that were observed were of several types. The A-2 seals called for Emulsified Asphalt (RS-2), MC-5 or RC-4. A rock asphalt spinner seal over new Class F binder was included. Several seals using NAC-8 were observed, and these were called A-2 (with modifications) seals in the proposals, but in most cases they amounted to initial treatments.

The A-2 seals using 0.25 gallon of RS-2 per square yard were placed under three different circumstances: over existing pavement using crushed gravel; over existing pavement using crushed stone; and over new C-1 Road Mix using crushed stone. RS-2 was used also in quantities of 0.15 gallon
### Table 1. Summary of Seal Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Length (Miles)</th>
<th>Bit. Mat. (Gallons)</th>
<th>Aggregate (Pounds)</th>
<th>Road Condition</th>
<th>Distributor</th>
<th>Spreader</th>
<th>Drag or Broom</th>
<th>Roller</th>
<th>Aggregate Appearance</th>
<th>Ft. Aggr. Retd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grant REG 4</td>
<td>21.0</td>
<td>0.25</td>
<td>20 frcr, gray, 77%</td>
<td>Broken &amp; Patched</td>
<td>Cir. Bar.</td>
<td>Tailgate</td>
<td>Chain-lk.</td>
<td>Pneum.</td>
<td>Very</td>
<td>Wet</td>
</tr>
<tr>
<td>Fendleton REG 5</td>
<td>23.1</td>
<td>0.25</td>
<td>20 %f</td>
<td>Broken &amp; Patched</td>
<td>Non-Cir.</td>
<td>Bar</td>
<td>Chain-lk.</td>
<td>8-ton</td>
<td>Wet</td>
<td>Smooth</td>
</tr>
<tr>
<td>Russell</td>
<td>10.1</td>
<td>0.25</td>
<td>20 %f</td>
<td>New Open</td>
<td>Non-Cir.</td>
<td>Bar</td>
<td>Chain-lk.</td>
<td>10-ton</td>
<td>Smooth</td>
<td>Damp</td>
</tr>
<tr>
<td>Pulaski SP 104-138</td>
<td>7.1</td>
<td>0.45</td>
<td>15 %f</td>
<td>New Pen.</td>
<td>Dbl-Cir.</td>
<td>Buckeye</td>
<td>Chain-lk.</td>
<td>8-ton</td>
<td>Wet</td>
<td>90±</td>
</tr>
<tr>
<td>Pulaski SP 100-75</td>
<td>0.9</td>
<td>0.25</td>
<td>20 %f</td>
<td>Old Bit.</td>
<td>Dbl-Cir.</td>
<td>Buckeye</td>
<td>Chain-lk.</td>
<td>8-ton</td>
<td>Wet</td>
<td>90±</td>
</tr>
<tr>
<td>Greenup RS 45-491</td>
<td>2.7</td>
<td>0.25</td>
<td>20 %f</td>
<td>New Open</td>
<td>Non-Cir.</td>
<td>Bar</td>
<td>Chain-lk.</td>
<td>8-ton</td>
<td>Wet</td>
<td>Smooth</td>
</tr>
<tr>
<td>Morgan &amp; Wolfe (88-98) (112-23)</td>
<td>11.1</td>
<td>0.25</td>
<td>20 %f</td>
<td>New Open</td>
<td>Cir.</td>
<td>Buckeye</td>
<td>Barbed</td>
<td>10-ton</td>
<td>Very</td>
<td>Wet</td>
</tr>
<tr>
<td>Anderson</td>
<td>7.3</td>
<td>0.40</td>
<td>30 %f</td>
<td>Traffic</td>
<td>Cir.</td>
<td>Buckeye</td>
<td>Chain-lk.</td>
<td>10-ton</td>
<td>Smooth</td>
<td>60</td>
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<tr>
<td>Casey</td>
<td>5.7</td>
<td>0.40</td>
<td>30 %f</td>
<td>Traffic</td>
<td>Cir.</td>
<td>Buckeye</td>
<td>Chain-lk.</td>
<td>10-ton</td>
<td>Smooth</td>
<td>80±</td>
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<td>Pulaski SP 100-215</td>
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<td>0.40</td>
<td>30 %f</td>
<td>Traffic</td>
<td>Dbl-Cir.</td>
<td>Buckeye</td>
<td>Chain-lk.</td>
<td>10-ton</td>
<td>Smooth</td>
<td>Damp</td>
</tr>
<tr>
<td>Mercer</td>
<td>8.3</td>
<td>0.07</td>
<td>10 Rock</td>
<td>Class F</td>
<td>Dbl-Cir.</td>
<td>Agr. Lime</td>
<td>Traffic</td>
<td>-</td>
<td>Only</td>
<td>-</td>
</tr>
<tr>
<td>Pulaski SP 16</td>
<td>3.6</td>
<td>0.40</td>
<td>30 %f</td>
<td>Traffic</td>
<td>Dbl-Cir.</td>
<td>Agr. Lime</td>
<td>Traffic</td>
<td>-</td>
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</table>
per square yard for sealing a new penetration macadam pavement.

The generally accepted purposes of a seal coat are (a) to seal the road surface against the entrance of moisture or air, (b) to develop a non-slip texture where the existing road surface is dangerously smooth and slippery, (c) to apply a fresh coat of asphalt which will enliven an existing dry or weathered surface, (d) to reinforce and build up an inadequate pavement section, (e) to provide a demarcation for traffic guidance between shoulder sections and traffic lanes and (f) to improve the luminosity or visibility at night. A seal may be applied to accomplish one or more of the above objectives. The first four are the major factors in Kentucky designs.

Grant County, RH Group 4 (1950) was a project using RS-2 with crushed gravel. This group consisted of three rural highways totaling 21 miles in length. Construction got under way September 2. Gravel was spread using tailgate boxes. The 0.25 gallon of RS-2 tacked down only slightly over 50 percent of the 20 pounds per square yard of the gravel. The emulsion had a tendency to run to the inside of elevated curves (See Fig. 1). Coverage of the roadway with the RS-2 was fairly uniform. The sections of road sealed were patched with cold patch material by maintenance forces about two weeks prior to sealing. Unpatched portions of the old surface were rough and alligator cracks were much in evidence. The gravel was very wet.

After placing the crushed gravel with tailgate spreader boxes and before rolling, a steel frame drag broom was tried. This broom did more damage than good, when wet chips were used. The gravel was disturbed before it had set. A light weight wire drag was more effective, assuring an even spread of the gravel. The brooming was discontinued after the first short section was placed near Folsom.
Fig. 1 A section of RH 1006 M-1 from project RH Group 4 (1950) in Grant County. A large portion of the inside of this curve was patched by maintenance forces with cold patch. The outside portion of the curve, near the front center, is an old, slick bituminous pavement. One quart of RS-2 has just been applied and is running from the dense sections of the pavement to the inside of the curve. The cold patched sections readily used up the 0.25 gallon applied. This implies that the amount of RS-2 required varies with the condition of the surface being sealed. The 0.25 gallon was retained on the pavement in all sections other than on a few of the elevated curves.
The contract permitted use of a pneumatic type roller. A wobble wheel smooth-tired pneumatic roller was provided by the contractor. This type roller was not as effective in setting the gravel, and it was thought that a conventional flat wheel roller would have been more satisfactory. However, none was tried.

Pendleton County RH Group 5(1950) was set up for 0.25 gallon per square yard of RS-2 with 20 pounds of crushed No. 9 stone. The condition of the 23.1 miles of rural highway was much the same as on the Grant County sections. Maintenance forces had patched the road shortly before sealing. Alligator cracks were in abundance. The emulsion went down very nicely but did have a tendency to run on the curves. It was estimated that between 60 and 70 percent of the No. 9 stone adhered to the asphalt. The stone had been stock piled and was not dry. This relatively small amount of water did not seem to have any effect on the stone adhering to the asphalt.

The 11 or 12 foot roadway was shot in one pass of the distributor. Stone was applied with tailgate spreader boxes. This required spreading one and one-half lanes in two passes, the same as in Grant County. A wire drag was used before rolling with a smooth wheel roller.

Russell County SP 104-138 was a 10.142 mile C-1 road mix that required an A-2 seal of 0.25 gallon RS-2 and 20 pounds of No. 9 stone per square yard. The road mix called for 90 pounds of No. 6 and 40 pounds of No. 9 stone per square yard. This road mix was placed during an exceptionally wet season and required considerable manipulation. The resulting mix was rather porous.

The 0.25 gallon of emulsion penetrated this open mix very quickly and as a result left very little material on the surface. An 18-foot non-circulating type bar was used on the distributor. Short sections of 600 or 700 feet were being primed as stone was made available. Priming these short distances caused the bar to become clogged with emulsion and as a result
the coverage was not too good.

It was suggested to the Resident Engineer that priming be postponed until sufficient stone was on the job to cover a distributor load of emulsion and then that the bars be cleaned after every application. This was done on the last 8 miles of the seal on the north end of the project and a uniform coverage of emulsion was obtained.

20 pounds of stone per square yard was too much for this type of road. Well over half the stone was not adhering. The quantity of stone was cut to 15 pounds per square yard. It appeared that over 30 percent of that amount did not stick.

A quart of RS-2 was not enough material to seal this open road mix.

_Pulaski County SP 100-75_ an emulsion seal using RS-2, was placed over a new penetration macadam that had been constructed with RS-1. This road was rather dense but had some fairly open sections (See Fig. 2). RS-2 in the quantity of 0.45 gallon per square yard was applied (See Fig. 3). This quantity made a very nice covering and had very little tendency to run even on curves and steep grades. The surface texture was rough enough to hold the material and the emulsion did not run through or penetrate as was the case with the road mix. Only 15 pounds per square yard of No. 9 stone was applied and this was sufficient to cover the material and prevent traffic damaging the seal (See Fig. 4). Less that 10 percent of this stone was whipped from the road.

The chips had been stock piled during a very wet season, but this did not affect their adherence to the emulsion appreciably. The emulsion was applied in 9-foot widths with a double circulating type bar. An excellent job of placing the material was accomplished. Full width of the pavement
Fig. 2 An average section of Pulaski County, SP 100-75 before the final seal coat was applied. The left lane is rather open textured while the right lane is somewhat denser. The surface in the lower foreground is much finer textured than that in the distance. The seal design for this section was 0.45 gallon of RS-2 with 15 pounds of No. 9 stone.
Fig. 3 Application of the 0.45 gallon of RS-2 for the seal over the penetration macadam on project SP 100-75, Pulaski County. Full width of both lanes was applied for a length of 1500 feet before the 15 pounds of stone per square yard was applied. This quantity of RS-2 had very little tendency to run on this project, even on the curves and steep hills.
Fig. 4 Chain-link fence type wire drag being used on the 15 pounds of No. 9 stone on SP 100-75, Pulaski County. This stone was spread with a Buckeye Spreader Box. The 15 pounds per square yard was sufficient for the 0.45 gallon of RS-2 used on this project.
was shot after the stone was on the job. Stone was spread with a Buckeye Spreader Box in a very uniform manner. Quantities of both stone and emulsion were controlled very closely.

There was a section of 0.9 mile of pavement on the south end of this job that had been paved at an earlier date. This section was patched and pretty rough. A quart per square yard of RS-2 with 20 pounds of No. 9 stone was used for this portion. The weather was hot (85° to 90°F) when this was placed and the emulsion broke rapidly. There was very little emulsion that ran off of the road on the one steep grade within this section.

Greenup County RS 145-491 was a C-1 road mix using crushed slag aggregate. The new road mix was rather open and porous. The seal called for 0.25 gallon of MC-5 with 20 pounds of No. 9 crushed slag per square yard. The MC-5 was shot, aggregate applied, and rolling completed in one of the 8-foot lanes before the second lane was started. Work in the two lanes was alternated throughout the length of a distributor load.

The MC-5 was not very tacky. It penetrated the open mix and did not fill the open voids. Slag was placed with the use of an approved mechanical spreader box. A even spread was accomplished.

Morgan and Wolfe Counties, SP 88-98 and 119-23 was set up as a RC-4 seal. The bituminous material was changed to RC-5 because RC-4 was not obtainable.

The seal was placed over an exceedingly course textured C-1 road mix. The aggregate was very tightly bound for this type mix and a smooth surface was obtained.

A quart of RC-5 was called for and the application varied from 0.2 to 0.3 gallon per square yard. At the application temperature of 150°F, the prime appeared to seal the surface relatively well.
Aggregate was spread with a Buckeye box and application was erratic in some places because of inexperienced truck drivers. Stone received on the project was wet with surface water. The wet stone adhered very poorly to the RC-5. Occasionally a dry load of stone would be secured from the crusher fines and placed. The location of these loads are very evident in that a greater portion of the stone was tacked down. On the project as a whole less than 50 percent of the 20 pounds per square yard adhered to the RC-5. Due to the fact that so much stone was lost, flat areas can be expected.

A barbed wire drag was used and seemed to be effective. After the aggregate was allowed to surface dry, 4 passes of a 10-ton, three-wheel roller were made. In some locations several passes were tired in addition to normal rolling. This greatly reduced the size of the aggregate, and somewhat helped the aggregate retention.

Anderson County, SP 3-291 was 7.25 miles in length and the width varied from 12 to 14 feet. The road was traffic bound limestone and the specified quantities required 0.5 gallon of tar per square yard prime (See Fig. 5). After the prime had set up 0.4 gallon of NAC-8 was applied. The design called for 40 pounds of No. 8 stone per square yard for chips. This quantity proved to be too much and 30 pounds was used. Of this 30 pounds only a little over half was tacked to the asphalt.

The NAC-8 and stone were applied in two courses over the first 0.2 mile on the east end, each application being 0.2 gallon and 15 pounds per square yard. The remainder of the project was one application of 0.4 gallon and 30 pounds.

Stone was spread with a Buckeye box. A wire drag was used before rolling the surface with a smooth wheel 10-ton roller.
Fig. 5 A section of project SP 3-291 in Anderson County. The dark portion in the foreground is traffic bound base with 0.5 gallon of HT-2 per square yard. The light section of road has been sealed with 0.4 gallon of NAC-8 and 30 pounds of No. 8 stone.
Casey County, SP 23-201 was very much different from any of the other NAC-8 seals. One-half gallon of RT-2 was used for prime, then 0.8 gallon of MC-4 was specified for mixing with the floater in a road-mix type of construction. It was found after a short section had been mixed that there was not sufficient floater material to even attempt to cover the roadway with one thickness of rock, so 1200 tons of stone was added. It was calculated that approximately 75 pounds of floater per square yard was obtained with the additional stone.

After the floater was mixed, spread, and rolled, many fat spots were in evidence. In some places the tar prime bled through the thin surface mix.

This surface was then sealed with 0.4 gallon of NAC-8 and 30 pounds of No. 8 stone. It was estimated that 25 pounds of this No. 8 stone would have been sufficient for the seal even over the very fat places. Approximately 80 percent of the stone did adhere to the bituminous material. Stone was spread with a Buckeye Box and was wet.

Laurel County, SP Group 47 (1950) was another of the NAC-8 seals. This project was 3.645 miles in length, of which about one half was over traffic bound base and the remainder over existing bituminous pavement. The traffic bound section was worked over very thoroughly with a patrol grader prior to priming with 0.5 gallon of RT-2. The Sublemity Street section, within the city limits of London, was in very good condition (See Fig. 6) prior to sealing. The remainder of the paved section was patched considerably and had numerous alligator cracks (See Fig. 7).

The project called for 0.4 gallon NAC-8 per square yard with 30 pounds of No. 8 stone. These materials were placed in these quantities on all of
Fig. 6 Sublimity Street in London, Laurel County, SP Group 47 (1950). This portion was in good condition and fairly dense before sealing with 0.4 gallon of MAC-8. The size of the chips was changed from No. 8 to No. 9 for this street.
Fig. 7 A portion of College Street in London on Laurel County SP Group 47 (1950). This surface received a seal of 0.4 gallon of NAC-8 with 30 pounds of No. 8 stone.
the sections except Sublemity Street in London. On that section the stone size was changed to No. 9 because the existing surface was rather dense and it was believed that the larger stone would not adhere and would produce a very rough riding surface. The stone was damp but there was not an excessive amount of free water. A Buckeye Box was used to place the stone. An even job of spreading was accomplished with both bituminous material and stone. A wire drag was used prior to rolling with a 10-ton, three-wheel roller. Some of the stone did not adhere but no estimate of the percentage was made.

Pulaski County, SP 100-215 was a NAC-8 seal over a traffic bound base. There was 0.2 of a mile of bituminous pavement at the east end of this project which did not require the tar prime. An unusually rainy season prior to priming caused the contractor to work the traffic bound material with a patrol grader in order to dry it. This extended over a period of several days and left the traffic bound material in very good shape.

The contractor that sealed the Laurel County Project, SP Group 47 (1950) did this job. Two double circulating bar type distributors were used to accomplish a very uniform distribution of the 0.4 gallon of NAC-8.

A Buckeye Spreader Box was used to place the 30 pounds of No. 8 stone. A very good primed surface was obtained from the tar priming (See Fig. 8). In order not to tear up the prime with the heavy rock trucks, sealing was begun at the east end of the job nearest the supply of stone. The stone trucks were very effective rollers and did help to roll the No. 8 stone into the road.

A wire drag was used prior to rolling with a 10-ton, three-wheel roller (See Fig. 9). The contractor had a very efficient organization and an ex-
Fig. 8 A section of tar prime on SP 100-215 in Pulaski County. The two weeks prior to placement of this prime were very rainy and the traffic bound base was in good shape for blading. The contractor kept his petrol grader on the 4.7 mile section for the two week period and did an excellent job of shaping the roadway and filling the holes. The prime of 0.5 gallon of RT-2 was applied in two applications. The first was 0.35 gallon and the remaining 0.15 gallon was used as needed.
Fig. 9 A section of SP 100-215 receiving its final rolling with a 10-ton, three-wheel roller. The 30 pounds of No. 8 stone are adhering pretty well to the 0.4 gallon of NAC-8.
cellent job of sealing was accomplished (See Fig. 10).

Mercer County, SP Group 16 (1950) was a plant mix, Class F type binder, with a rock asphalt spinner seal, 8,313 miles in length. The binder was a fairly open type mix of 150 pounds per square yard (See Fig. 11). This new binder was shot with approximately 0.07 gallon of RC-2 for prime.

Rock asphalt in the quantity of 10 pounds per square yard was applied with agricultural lime spreaders of the spinner type. Several passes of the spinners were required, usually at least five applications. Traffic was not allowed over the fresh prime before at least one application of rock asphalt had been completed.

A wire mesh (chain-link fence) drag was used at the beginning of the operation on the north end (See Fig. 12). This type of drag was not very effective in breaking up any lumps of rock asphalt that were present. Those were practically impossible to break with the drag if traffic compacted them before the drag was used. As a result, the first section of seal did have some rough spots (See Fig. 13). In view of this unsatisfactory condition, the contractor began to investigate a better type of drag. A discarded crusher screen about 8 x 12 feet with approximately 1-inch openings was obtained (See Fig. 14). This screen was constructed of fairly rigid mesh with bars of 3/8 inch steel. It was very effective in breaking the lumps of rock asphalt.

Traffic was used to compact the rock asphalt, and a very good seal with excellent riding qualities and an excellent appearance was obtained (See Fig. 15). It was evident that care must be exercised so as not to apply too much prime for this type of seal, otherwise, the RC-2 will bleed through and cause fat spots or streaked sections.
Fig. 10  A section of completed MAC-8 seal on SP 100-215 in Pulaski County. This section has carried the 10-ton stone trucks for approximately 4 days. The stone is well tacked and the appearance is good.
Fig. 11 A portion of the plant mix class F binder on Mercer County SP Group 16 (1950). The 150 pound binder was rather course-textured, as shown, and very receptive to the rock asphalt spinner seal.
Fig. 12 Chain-link fence type of drag used on the first section of Mercer County SP Group 16 (1950). This drag was not very effective in breaking up the lumps of rock asphalt.
Fig. 13 Beginning section of spinner seal placed on Mercer County SP Group 16 (1950). The chain-link fence type of drag was used for this location. The drag did not break up the lumps of rock asphalt.
Fig. 14 The crusher screen that was effectively used on Project SP Group 16 (1950) in Mercer County. This drag was heavy and rigid enough to break up any of the lumps that formed, even after traffic had compressed them.
Fig. 15 A finished section of rock asphalt seal on Mercer County SP Group 16, 1950. One tenth of a gallon of RC-2 with 10 pounds of rock asphalt were used. The pavement has exceptionally good riding qualities. The road is not slick when wet.
TACK COATS

The primary item that was investigated in the tack coat line was the use of PAC (not cut back). The projects concerned were set up for the same grade of asphalt cement as was used in the plant mix. This material for tack was placed in the proposal as an alternate to RC-2 for the discretion of the contractor.

Five projects that were easily accessible and contained the PAC alternate were chosen to observe and obtain the reaction of the field engineer and contractors.

Adair and Metcalf, SP Group 27 (1950) was set up for RC-2 or PAC-7. The contractor on this project preferred to use RC-2 and did so. This project was begun late in the season (August 22) and was not completed this year. No observations were made since the asphalt cement was not involved.

Boone, Grant and Kenton, SP Group 28 (1950) had a PAC-5 or RC-2 alternate for tack. The contractor had not begun the project.

Fleming, Nicholas and Bath, SP Group 3 (1950) was a PAC-7 or RC-2 project. The contractor used RC-2 which was the preference of the Assistant District Engineer of Construction.

The Construction Engineer felt that PAC (not cut back) is too heavy an asphalt for prime over road mix, rock asphalt, or sand seal - particularly if traffic is allowed over the tack. The traffic will tear up the existing surface. A PAC tack would be excellent for a concrete resurfacing job. He suggested that tack material be placed at approximately design quantities in the outside 4 feet of each lane and then the remainder of the pavement be shot with a very light application. If PAC is to be used, he
would prefer to cut it back with at least 20 percent of kerosene.

Garwood and Lincoln, SF Group 29 (1950) was a PAC-5 or RC-2 project. The contractor preferred to use the PAC-5. This necessitated only one set of storage tanks for bituminous material. The distributor was used to transport PAC-5 from rail to plant.

The surface being primed was 15-year-old rock asphalt that had been cold patched and skin patched over most of its length. One-tenth gallon of PAC-5 per square yard was allowed for the tack. Only 0.045 gal. per square yard was actually used. This was applied with a single "fog nozzle" (See Fig. 16). The asphalt hit the pavement in small droplets. Automobiles had to be shielded from this fog, as it would blow and cause considerable damage. The tack would track and cover the surface pretty well. Five passes of the distributor were required to cover the entire width of pavement.

In some instances the old rock asphalt was pulled up under the action of traffic (See Fig. 17). A very tacky prime resulted if the surface remained intact.

The tack applied at this rate by the fog nozzle was not a traffic hazard when wet. A one-half mile section of this tack was left open over the July 4, weekend. There was rain during that time but no accidents were reported. The section was checked for slickness by the Resident Engineer. Brakes were applied on the wet prime and no excessive skidding occurred.

The Division of Research requested that a section of this 150 pound plant mix surface be placed over the old rock asphalt without any tack material. The request was granted by the Division of Construction and a
Fig. 16 Applying PAC-5 with a "fog nozzle" type applicator on Lincoln County SP Group 29. The PAC-5 strikes the pavement in very small droplets and does not tend to cause slickness when wet. Traffic tends to track the droplets into a uniform tack.
Fig. 17 Close up of a section of SP Group 29 in Lincoln County, where the action of traffic over the PAC-5 tack pulled up a part of the old rock asphalt surface. This condition was not widespread but seemed to occur at locations where the tack was relatively heavy and the old surface very thin.
section was placed from the intersection with US 27 South in Stanford, eastward approximately one mile to a concrete bridge. About half of this section lay within the city of Stanford. The condition of this section was variable. A picture record with photos for each five station sections was made. A portion of the road in the town had been ditched for utility pipes. For three blocks, from the Court House to the intersection with U.S. 27 (south), the existing pavement was in very good shape before resurfacing. Other portions were skin-patched considerably.

The no-tack section was completed about the first week of August, and up to December it showed no signs of surface failure. There is one location outside the city limits where a water pipe broke and water seeped through the pavement. A soft spot occurred with a resulting pavement deflection. Photographs were taken on August 10, while the water company was repairing the pipe.

Harrison County, SP Group 41 (1950) was set up as an RC-2 or PAC-5 tack. Construction orders changed the tack to RS-1 emulsion. This project was located between Cynthania and Georgetown on US 62 and was 10.215 miles in length.

The existing surface was rock asphalt that had been in service for 15 years and had numerous skin patches and edge patches. Four miles on the west end of the project, beginning at the Harrison-Bourbon County Line, was placed between August 17, and August 23. The reason for closing down the project at that time was to allow the contractor to use the plant for mixing binder and surface for a project on US 27 south out of Cynthania. The quarry and plant were located on the Russell Cave Pike a short distance from US 62, and had this surface in the SP Group been completed, all of the heavy
traffic carrying stone and plant mix to US 27 and another project in Nicholas County would have traveled over this now 125 pound Class I Surface.

The surfacing was resumed about the first of October and completed October 7. The material was working nicely at the air temperature of 45° at that time. The emulsion was shot in one-lane width of 8 feet or less in lengths equal to one days paving. The quantity applied was in the order of 0.04 gallon per square yard. Traffic, which consisted mainly of trucks hauling mix to the paver, tracked this material into a very nice tack. The emulsion broke readily and became sticky.

Franklin County, SP Group 39, (1950) was set up for 0.15 gallon per square yard of RS-1 to tack a 150 pound plant mix Class I Surface with a binder of 150 pounds only at designated places. This project was begun very late in the season and only the binder was placed this year. No observations were made on the tack.

**PENETRATION MACADAM**

Pulaski County, SP 100-75 was a penetration macadam type construction using RS-1 as the bituminous material. The project was 8 miles in length and located on SR 39, just north of Somerset. The first 0.9 of a mile was over an existing bituminous surface and had only an A-2 type seal with 0.25 gallon per square yard and 20 pounds of No. 9 stone. The second section of 7.1 miles was over a traffic bound base and had 300 pounds of stone with 2 gallons of RS-1 per square yard for the penetration macadam. A seal for this second section required 0.25 gallon of RS-2 and 15 pounds of No. 9 stone per square yard. The total quantities for the penetration macadam
Table 2

Quantities of Materials per Square Yard on Pulaski County SP 100-75 Penetration Macadam

<table>
<thead>
<tr>
<th>Material</th>
<th>Regular Section</th>
<th>Test Section No. 1</th>
<th>Test Section No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sta. 10b-11h East Lane</td>
<td>Sta. 76-88 East Lane</td>
</tr>
<tr>
<td>No. 4 Stone (lb.)</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>No. 9 Stone (lb.)</td>
<td>-</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>First Application RS-1 (gal.)</td>
<td>0.80</td>
<td>1.00</td>
<td>0.80</td>
</tr>
<tr>
<td>No. 9 Keystone (lb.)</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Second Application RS-1 (gal.)</td>
<td>1.20</td>
<td>1.50</td>
<td>1.20</td>
</tr>
<tr>
<td>No. 9 Keystone (lb.)</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Seal Coat RS-2 (gal.)</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>No. 9 Stone (lb.)</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total Aggregate (lb.)</td>
<td>315</td>
<td>315</td>
<td>330</td>
</tr>
<tr>
<td>Total Emulsion (gal.)</td>
<td>2.45</td>
<td>2.95</td>
<td>2.45</td>
</tr>
</tbody>
</table>
section were 315 pounds of stone and 2.45 gallons of emulsion per square yard. (See Table 2)

The traffic bound base was in fair shape. There were some locations at which ledge rock was present at road elevation. Drainage was very poor at many locations, chiefly because of right-of-way problems. A 60-foot way was guaranteed by the County but had not been secured in some cases. Plans called for an 18-foot surface with 3-foot shoulders on each side. The 18-foot surface was placed and in practically all cases the shoulder was obtained. Prior to placing any stone, the contractor cleaned the ditches and shaped up the roadway.

On July 17, the contractor began placing No. 4 stone in the quantity of 255 pounds per square yard at the north end. An Airmun Spreader (See Fig. 18) was used to spread this stone uniformly. Following this, the No. 4 stone was rolled with a three-wheel 10-ton roller. The first application of 0.8 gallon per square yard of RS-1 was then applied (See Fig. 19). Thirty pounds of No. 9 stone per square yard was then spread using a Buckeye Box Spreader (See Fig. 20). The special specifications covering this project called for brooming before rolling this first application of keystone. It was found that brooming disturbed the No. 4 base stone at that time. Rolling with an 8-ton Tandem Roller (See Fig. 21) before brooming was found to be more effective.

The brooming immediately followed this operation and the section was again rolled before applying the second application of 1.20 gallon per square yard of RS-1. Following this application, 15 pounds of No. 9 stone per square yard was spread with the box. This stone was rolled, broomed and rolled again (See Fig. 22). Traffic was not allowed on the rolled No. 4 stone.
Fig. 18 Admun spreader used to spread the 255 pounds per square yard of No. 4 stone for Project SP 100-75 in Pulaski County. With this spreader a very uniform thickness of stone was obtained. It is essential in a penetration macadam type construction to have and keep the base stone at design thickness. Only with a high type mechanical spreader, that allows positive control of the thickness of spread, can this be accomplished.
Fig. 19 Applying the first application of RS-1 at the rate of 0.8 gallon on Pulaski County SP 100-75. The first course of the penetration macadam, consisting of 255 pounds of No. 4 stone has been rolled and it easily supports the weight of the distributor without rutting. A uniform application of the emulsion was obtained. The left lane has been completed and is ready for the seal.
Fig. 20 Spreading the 30 pounds of keystone (No. 9) with a Buckeye Box on SP 100-75, Pulaski County. The lane being covered is 9 feet in width, which requires that one foot of the 10-foot box be blocked off. The heavy rear wheels of the truck are well over one foot from the edge of the stone base and only one pass of truck and box are required for each application. Using tailgate spreaders, two passes of the truck were required with the wheels of the truck running over and disturbing the edges of the base. For this type of construction a spreader such as shown is an absolute necessity.
Fig. 21 Rolling the first application of 30 pounds of keystone on Pulaski County Project SP 100-75 prior to brooming. An 8-ton tandem roller was used and was very effective.
Fig. 22 Brooming the first application of 30 pounds of keystone after rolling, on SP 100-75 in Pulaski County. The brooming worked the keystone into the larger No. 4 stone without tearing up the mat. Brooming before rolling had a tendency to pull the No. 4 stone from the mat.
An effort was made to finish a section through the second application of keystone before allowing traffic the use of the lane. In some cases it was not possible to complete a section in one day because of rain, shortage of material, or other factors. At these times traffic would be allowed to use a section after the first application of 30 pounds of keystone had been completed. In all instances the lane was opened to traffic before the seal coat was applied. The sealing operation was covered in the seal coat section of this report, on page 4.

This project was constructed during an exceptionally wet season. During the period from July 17 to August 25, the U.S. Weather Bureau Station at Somerset reported rain on 20 out of the 35 work days. A total rainfall of 5.88 inches for the period was reported.

It was found that wet aggregate did not affect this type of construction. Much of the stone was stockpiled. The emulsion could be applied to wet stone as long as there was not excessive water present to cause the emulsion to run off the stone. For one section an attempt was made to apply the second application of RS-1 just after a shower on Thursday, July 20. Enough water was present to cause the RS-1 to run from the material. Wet chips or keystone worked well as long as the stone would feed through the Buckeye Box in the desired quantities.

The emulsion can be damaged if rain occurs before it has broken or changed color. Water will dilute the material while it is still emulsified. After the emulsion has broken or changed color from brown to black, it will not be washed out by ordinary rainfall. The setting period varies with climatic conditions. With dry stone and hot windy weather the emulsion broke within 4 or 5 minutes. When the stone was wet and the weather damp
this time was extended to 2 or 3 hours. A section of the macadam was examined 24 hours after placement during one of the wet periods and brown material was found near the bottom of the No. 4 stone.

It was requested by the Construction Division that the quantity of emulsion be increased in a special test section. This section of 1,000 feet was in the east lane between Stations 104 and 114. The quantities used are listed under Test Section 1 in Table 2. The west lane was placed using the regular construction quantities.

The only difference between the two lanes was in the quantities used. The first application of RS-1 was 1,00 gallon per square yard which was applied August 11. A very small quantity of this material ran from the stone. Before the second application of RS-1 was made, 0.2 inch of rain fell. The second application of 1.50 gallons per square yard of RS-1 was made on August 12. The road had dried out considerably but was not thoroughly dry. A large percentage of the RS-1 used in the second application ponded on the edge and ran out and into the ditch (See Fig. 23). With the quantity of stone being used it appears that 2,50 gallons of RS-1 was too much emulsion.

A test section No. 2 was set up at the suggestion of the Division of Research for 1,000 feet in the east lane between Stations 78 and 88. There, 15 additional pounds of No. 9 stone was used. This additional amount was placed over the No. 4 stone prior to the first emulsion shot. The stone was rolled and the chips had a tendency to penetrate down through the No. 4 material. The west lane of this section was constructed by standard methods using specification quantities. Both of these test sections are marked with appropriate signs (See Fig. 24).
Fig. 23 Test Section No. 1 just after the second application of 1.5 gallons of RS-1 on Pulaski County, SP 100-75. The emulsion is ponding at the edge and running into the ditch. A view of the completed test section is shown in Fig. 24.
Fig. 24. Completed section of penetration macadam pavement in Pulaski County, SP 100-75. This view is toward the north. The east or right lane, for 1000 feet between the two signs, is test section No. 1. The west lane was constructed to design specifications.
CONCLUSIONS

The conclusions that follow apply only to the materials and construction, since performance characteristics usually do not become evident until several months after the work is done. The winter thus far has provided severe exposure, and therefore, any outstanding deficiencies may show up within the first year of use.

Seal Coats

Existing specifications and practices fail to take into account variations in the surface which is being sealed, and a flat rate of 0.25 gallon per square yard of bituminous material is not proper in all cases. Also, the tendency is invariably toward application of excessive amounts of chips even when the rate of bituminous application is greater than 0.25 gallon.

Over old bituminous surfaces, 0.25 gallon of the RS-2 was about the proper amount, but on open graded surface mixes which were new, the quantities should have been increased substantially in order to compensate for the bitumen that penetrated into surface voids. On the penetration macadam construction, 0.45 gallon of RS-2 did very well. NAC-8 in the quantity of 0.4 gallon may prove to be too much for the sections of existing pavements. This material did set up well and the stone retention was excellent, however, there is good possibility that bleeding will be serious upon the return of warm weather. MC-5 and RC-5 were not used over existing pavements, so there was no possibility for judging rates of application there.

Where only 0.25 gallon of bituminous material was applied, 20 pounds per square yard of chips was excessive, regardless of the surface being sealed. Similarly, 40 pounds of No. 8 stone placed over NAC-8 applied at
the rate of 0.4 gallon was too much. Even 30 pounds per square yard provided more than could adhere to the NAC-8 when applied at 0.4 gallon over porous surfaces.

RS-2 as a seal material was capable of retaining wet chips, and so far as the uses covered in this report are concerned, a greater percentage of crushed limestone than crushed gravel was retained on the surface. On the slopes of horizontal curves in the Rural Secondary projects having existing bituminous surfaces, the material ran toward the inside when applied at 0.25 gallon per square yard. However, in the penetration macadam surface, there was no tendency toward run-off on steep curves and hills even though the rate of application was 0.45 gallon per square yard.

For seal work the prime should be applied to the full width of the pavement before any chips are applied. This eliminates overlap at the center and development of a rough ridge down the middle of the road. Much better distribution and better aggregate retention can be accomplished when good mechanical spreader boxes are used. These are also good protection against poor workmanship.

Dragging with wire mesh drags was satisfactory, and if the distribution of aggregate is well done in the application, light dragging is preferable to several passes.

Although performance characteristics are needed to verify this observation, it appears that a seal coat with as much as 0.40 gallon per square yard of NAC-8 over a traffic bound surface may give satisfactory performance under light traffic. However, there should be sufficient traffic bound material to make an adequate base, and the thorough working and shaping of this material with a patrol grader in advance of the seal is an advantage. This operation is necessary, of course, if the surface has pot holes and
rough spots. The No. 8 stone worked very well with NAC-8 over the traffic bound base, but it was much too large for sealing an existing bituminous pavement. The resulting surface was rough and annoying to a driver passing over it.

Rock asphalt spinner seals make an excellent riding surface. A smooth application of the rock asphalt is very important and it appears possible to get this by having the material well pulverized and by making several passes with the spinner. A crusher-screen drag proved to be most effective in breaking any lumps that form. This could not be accomplished with the ordinary type chain-link fence drag. Careful, uniform application of the RC-2 prime is essential to this type seal. The rate of about 0.07 gallon per square yard for the RC-2 seems satisfactory, and compaction of the seal under traffic can be well done.

The use of flat-wheeled, 8- or 10-ton rollers seems preferable to the use of pneumatic rollers on all the seals but the rock asphalt. There was only one case where a pneumatic roller was used (excepting the wheels of traffic on the rock asphalt), and there pneumatic rolling was unsatisfactory.

Tack Coats

PAC materials make excellent tack coats but can be very destructive to existing flexible pavements. The old material pulls up under traffic before the new surface is placed. Care must be taken in the application to avoid shooting the surface too heavy and causing a safety hazard when the surface is wet. An excellent method of application is a single fog nozzle. The rate of 0.04 gallon per square yard seems to be sufficient to produce a uniform tack.
From the standpoint of contractors preference, the advantage of single storage may be off-set by difficulties in application and other considerations. The contractor on only one of the five projects on which PAC was allowed actually used it. One asked to substitute RS-1; two of the others chose to use RC-2.

The RS-1 proved to be an easily applied tack with excellent tacking properties when applied in quantities less than 0.1 gallon per square yard.

Penetration Macadam

Construction of the penetration macadam project proceeded well despite an exceptionally wet season. The RS-1 was used under climatic conditions that would close down most bituminous construction. Wet aggregate worked very well.

An essential factor to penetration type construction is the placement of base stone in uniform thicknesses. This is best accomplished by a self-propelled, accurately controlled type of spreader or paver. It is also important to guard against rutting or tearing up this base with the trucks applying keystone. Tailgate spreader boxes cause the trucks to drive too near the edge of the prepared coarse stone, and this lower course becomes torn up. A full lane spread can be accomplished without any damage to the underlying material by using a Buckeye-type spreader box. This places the wheels of the truck further from the edge of the road and requires only one pass of the truck and box for each application of chips.

The quantities of material and the construction procedures specified for Pulaski County Project, SP 100-75 — with the exception of brooming before rolling the first application of keystone — seemed to be satisfactory and provided a compact, neat appearing pavement.