MEMO TO: A. O. Neiser, State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report (Final); "Kentucky Rock Asphalt Hot-Mix Surfaces"
KYHPR-64-10; HPR-1(4), Part II

Kentucky Rock Asphalt has served prominently on our roads for many years. At times its performance proved to be unreliable. About 1956, its use was discontinued altogether—except for some de-slicking applications. The Kentucky Rock Asphalt Company dissolved soon thereafter. W. G. Reynolds and Associates acquired extensive holdings from the old company. Eventually, interest reverted to redevelopment of the deposits as a source of bituminous paving aggregate. Two avenues of choice were apparent: one was to pre-roast the rich rock immediately prior to paving, and the other was to produce and ship lean or non-bituminous aggregate for conventional processing through hot-mix plants. Beginning in 1962, several attempts were made to use lean rock from the old quarries on traffic-bound roads in the area around Edmonson County. These were not very successful: in some cases the lean product had sufficient bitumen to cause it to bind together while in others it remained loose—and reverted to sand. Thicker applications with bituminous seals on top were also tried. Somewhat as a last resort, a compacted base course and, optionally, a hot-processed surface course or multiple seal topping was specified experimentally on the Nolin Dam Road (KY 728) in Edmonson County. Fortwith, the redevelopers made a trial run of the crushed, lean rock through a hot-mix plant and supplemented the indigenous asphalt with refinery asphalt; whereupon, they determined to pave the entire section of the project in this manner. Unfortunately, the raw, lean, aggregate base did not perform well—apparently it was too porous and unstable. Nevertheless, the project demonstrated the feasibility of processing and laying a high-type surfacing product. Thereafter, the Department undertook a series of resurfacing projects employing the processed product on an experimental basis. The report submitted herewith is largely concerned with the construction and performance of those projects.

Rock Asphalt surfaces have always been admired for their high skid resistance and quietness. Both of these qualities have persisted throughout the redevelopment experiments.

As a specific summary to our current report, I shall mention two observations: first, the bituminous binders are necessarily quite hard; second, the porosity (percentage of voids) in the compacted mixtures remains high. I believe that the latter quality is essential to skid resistance and
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that hard binders assure sufficient stability—to prevent scaling but yet permit some sacrificial wear.

For the sake of continuity among research projects, and although this is presumably the final report on this particular study, the two features of Rock Asphalt—mentioned above—are being synthesized or designed into mixtures employing other sands. In fact, these and other variables have been incorporated into a rather extensive experimental surfacing project on US 27, north of Somerset. Paving there will probably be completed before you have this report in hand. Results from those experiments will be forthcoming under KYHPR-64-24 and under KYHPR-67-44* subitems.

Mr. Florence, who prepared the manuscript for this report and was head of our Bituminous Section, resigned June 28, 1968, to accept a position with the Bureau of Public Roads in North Carolina.

Respectfully submitted,

Jas. H. Havens
Director of Research

cc's: Research Committee

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Research Report

KENTUCKY ROCK ASPHALT HOT-MIX SURFACES

FINAL REPORT
KYHPR-64-10; HPR-1(4), Part II

by
Robert L. Florence
Formerly Research Engineer

Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

The opinions, findings, and conclusions in this report are not necessarily those of the Department of Highways or the Bureau of Public Roads.

August 1968
INTRODUCTION

When this study was initiated in 1962, the objectives were disposed toward the development of Kentucky Rock Asphalt for use as a traffic-bound base and surface on rural roads near its source and toward redevelopment of the material for use as hot-mixed, hot-laid, skid-resistant surface course for higher echelon roads. Between July 1962 and August 1965, eight experimental, lean rock-asphalt bases were constructed and evaluated (1, 2, 3).

During the fall of 1965 a hot-mixed, enriched, rock-asphalt surfacing material was successfully produced through a conventional hot-mix plant and laid with a paver on a 8.4-mile section of Nolin Dam Road (KY 728) in Edmonson County. The construction and interim performance of this project has been reported previously (3). The hot-mix process consisted of crushed rock asphalt, containing approximately four percent indigenous bitumen, as the total cold-feed aggregate, heated to 250 - 300°F, and enriched with four to five percent asphalt cement. The mixture was then laid and compacted with conventional hot-mix paving equipment.

The success of the hot-mix surface on the Nolin Dam Road project renewed interest in rock asphalt for high-type surfacing and resurfacing. A series of eight resurfacing projects, totaling 92.9 miles in length, was let for the 1966 construction season. A Special Provision (dated March 1966, Appendix C) was prepared to govern this work. The developer, W. G. Reynolds and Associates, expanded their rock asphalt production operations during the spring of 1966. A company was formed under the name of Gripstop Corporation and a large capacity crushing plant was set up in the Indian Creek Rock Asphalt Quarry in Edmonson County. At the end of the 1966 construction season, three of the resurfacing projects were completed and two were partially completed. On the basis of the experience gained during the 1966 construction season, a revised Special Provision (dated March 1967, Appendix C) was prepared, and seven additional resurfacing projects -- totaling 53.5 miles in length -- were let to contract.

The major revisions in the Special Provision pertained to laying procedures. During 1966 it was found that the hot-mix rock asphalt became stiff and unworkable very quickly after placing. As a consequence, the material was difficult to hand work, and it was also difficult to grader lay the material as a leveling course. The first two projects under construction in 1966 used rock asphalt as the leveling course material. On one project (US 68, Christian County) constructed in 1966, Class I binder was used for the leveling course. Change orders were prepared for the other projects awarded in 1966 in order to use the usual hot-mix surfacing (Class I, Type A) for the leveling course. These change orders did not materially change the total cost of the contract. The contractors and the Department agreed upon a price per ton for the asphaltic concrete leveling course material. Sufficient quantities of the remaining contract materials were deducted to balance the cost of the leveling course.
The application rate of the hot-mix rock asphalt was set at 85 pounds per square yard for an estimated one inch of compacted thickness for those projects let to contract during 1966. The asphalt cement added to the mixture was set up as a separate pay item. For those projects let during 1967, the hot-mix rock asphalt application rate was set at 60 pounds per square yard, the asphalt cement was not set up as a separate pay item; and leveling course material (conventional hot-mix material) was provided.

Construction of all resurfacing projects has been completed. The Nolin Dam Road surfacing has been in service two full years, and several performance inspections have been made—some of which have been reported (3). The other 15 hot-mix surfacing projects have been in service for periods of 1-1/4 years to a few months. Two performance inspections have been made on the projects constructed during 1966 and 1967, and one inspection has been made on the most recent project (Butler County). The construction and performance of each project is presented in this report (Appendix A) in the order of the start of construction. Discussion of the Nolin Dam Road is presented in Appendix D.

A discussion of the Moutardier Boat Ramp Road is also given in Appendix D. This is one of the lean rock-asphalt base projects which was surfaced with conventional hot-mix bituminous concrete during 1966.
CONSTRUCTION INSPECTIONS, MATERIALS SAMPLING AND LABORATORY TESTING

Construction Inspections

Inspection and construction control was exercised by the Construction and Materials Divisions in the same manner as on routine resurfacing projects. Research Division personnel inspected the projects at various times during construction. The number of inspections made and the detail of the inspection was quite variable due to limitations in personnel and the number of projects under construction. Rather detailed inspections were made of the first two projects under construction. However, no construction inspections were made on five of the projects. During the inspections, notes were made of any problems experienced in producing and laying the mixtures, photographs were taken of the plant and paving operations, and samples of the material were obtained.

Materials Sampling

On the first project under construction, US 31W, Hardin-Meade Counties, samples of the cold-feed aggregate and of the finished mix were obtained in cloth bags and returned to the laboratory for testing. On succeeding projects, samples of material were taken in cloth bags and in one-gallon, sealable tins. Samples of the material were taken from cold feed, the hot bins, and the truck beds and immediately sealed in the tins. On one project, US 31W in Warren County, samples of material were taken from a few areas in the finished surface which showed distress soon after construction.

Laboratory Testing

Cold-feed material which was sampled in cloth bags was tested in the laboratory for bitumen content by benzene extraction. The samples were dried in the oven at 220°F prior to performing the extraction test. The extracted aggregate was tested for gradation.

The finished mix, sampled from truck beds and placed in cloth bags, was reheated to 280°F; and three or more Marshall specimens were prepared from each sample. A Marshall mechanical compactor was used to prepare the specimens — 50-blow compaction at 260°F. A portion of the sample was tested for asphalt content by Rotarex extraction with benzene. Gradation tests were performed on the extracted aggregate. A summary of the Marshall test results is shown in Table 1, Appendix B. The extraction test results on the cold-feed aggregate and on the finished mix are summarized in Table 2 in Appendix B.

Recoveries of the asphalt were made on samples taken in the one-gallon tins. The asphalt was extracted from the aggregate using a Rotarex extractor and reagent-grade benzene as the solvent. The effluent was centrifuged to remove the fine mineral matter and the benzene was then removed in a Cal Lab, Model C, thin film evaporator at a maximum temperature of 280°F under 15 cm of mercury pressure. All of the recovered asphalts were tested for penetration according to ASTM D 5. Selected recovered asphalts were tested for softening point by ASTM D 36, ductility by ASTM D 113, specific gravity by ASTM D 70, effect of heat and air (TFOT) by ASTM 1754, and viscosity. The
viscosity measurements were made at 77°F with a rotating coaxial cylinder viscometer. A summary of the test results on the recovered asphalts is shown in Table 3 in Appendix B.

For comparative purposes a tabulation of the sources and routine acceptance test results on the asphalt cements used for enrichment of the material on the various projects is shown in Table 4 of Appendix B. These data were obtained from the Materials Division.

Skid-test measurements were also made on eleven of the hot-mix rock-asphalt surfacings. These tests consisted of skidding an automobile with its wheels fully locked on the wetted surfaces from a velocity above 30 mph to 0 mph. From the recording of velocity and time, the coefficient of friction between 30 mph and 20 mph was calculated. Skid-test measurements were made on three of the surfaces during 1966 and tests on these surfaces were repeated in 1967. A summary of the frictional test results is listed in Table 5 in Appendix B.
During the spring of 1966, the Gripstop Corporation set up a large capacity plant for crushing and grading rock asphalt in the Indian Creek Quarry in Edmonson County (Figure 1). This quarry was the source of material used for the Nolin Dam Road surfacing and for the lean rock-asphalt traffic-bound bases. For those projects, the material was crushed to gradation at a limestone crushing plant located on the Nolin Dam Road.

The Indian Creek Quarry was operated by the Kentucky Rock Asphalt Company in the period between 1928 and 1956. The Kentucky Rock Asphalt Company hand picked material that would yield an average asphalt content of approximately seven percent, leaving the lower asphalt content material on the quarry floor. This waste material was loose and exposed to weathering for a period ranging from 10 to 38 years. The waste material ranged in size from large boulders to sand grains. This loose, weathered material was processed first and used in the first hot-mix surfacings. When this loose material was exhausted, ledge rock from a portion of the quarry floor was processed. In the spring of 1967, overburden was cleared from an area immediately adjoining the existing quarry and the freshly exposed ledge rock was quarried and processed.

During 1966 and a large part of 1967, the rock asphalt was processed over a 1/2-inch screen. The aggregate used on the last four projects constructed in 1967 was processed over a 3/8-inch screen. This change in aggregate size was made by agreement between the Department and the producer and did not require a modification of the existing gradation specification.

As previously mentioned, a revised Special Provision was prepared for the resurfacing projects let to contract in 1967. A reduction was made in the minimum natural asphalt content requirement — from 4.0 percent to 3.5 percent.

In the spring of 1968, a kiln-type drier was installed at the Indian Creek Quarry. Some of the rock asphalt used on US 231 in Butler County was pretreated by heating to 300°F at the quarry in an attempt to harden the bitumen in the crushed rock asphalt. As the rock asphalt passes the screens, it is watercooled to 130° - 150°F. Marshall tests on the heat-treated rock asphalt indicated stabilities of approximately 590 pounds and flow-values of about 6.5. Penetration tests and bitumen content values for the various materials are tabulated below:

<table>
<thead>
<tr>
<th></th>
<th>Natural Rock Asphalt</th>
<th>Heat-treated Asphalt</th>
<th>US 231</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen Content (Average)</td>
<td>3.8%</td>
<td>4.1%</td>
<td>9.3%</td>
</tr>
<tr>
<td>Penetration</td>
<td>46</td>
<td>26</td>
<td>28</td>
</tr>
</tbody>
</table>

Approximately one mile of the 11.5 miles on the US 231, Butler County, project was laid using the heat-treated rock asphalt. During an inspection on July 7, 1968, it was impossible to distinguish between this section and the remaining
Figure 1. Indian Creek Quarry and Crushing Plant in Edmonson County.
portion of this project resurfaced with rock asphalt which had not been heat treated. No difficulties were reported by the contractor in laying the heat-treated material.

Construction and Performance of Hot-Mix, Rock-Asphalt Surfacing

A general discussion and evaluation of the construction and performance of the surfacings follows. A more detailed account of the construction and performance of each surfacing project is given in Appendix A. There, the projects are presented in order of date of start of construction. Information on the project location, contract quantities and costs, and the hot-mix plants is also presented. Summaries of laboratory test data are tabulated in Appendix B.

The primary factors to be considered in evaluation of the hot-mixed rock asphalt are skid resistance, cost, uniformity (homogeneity), stability and durability. Problems associated with plant-mixing and placing and techniques to overcome these problems are also of interest.

Skid resistance. Coefficients of friction measured on eleven of the surfacings during 1967 were in the range between 0.57 and 0.72, a high level of skid resistance, and corresponds to the level of skid resistance measured on rock-asphalt surfacings in the past. Skid tests were performed on three projects in 1966 and the tests were repeated during 1967. On two projects the coefficients were lower in 1967 and on the third the coefficient was higher.

Cost. Detailed cost data for each project are included in Appendix A. These data were obtained from the final Contractor's Pay Estimate for ten projects and for the remaining four projects from the most recent Contractor's Pay Estimate available. Inasmuch as these four estimates were complete except for minor adjustments, it is believed the average costs given here are reasonably accurate. For those projects let to contract during 1966, asphalt cement enrichment was a separate bid item. During 1967 the price of the asphalt cement was concomitant with the bid price of the rock-asphalt mixture. Following is a tabulation of average cost data for these projects:

For contracts let during 1966:

- Average bid price for rock-asphalt mixture: $12.25 per ton
- Average cost for rock-asphalt mixture: $11.86 per ton
- Bid price for asphalt cement: $0.14 and $0.15 per gallon
- Average cost for asphalt cement: $1.59 per ton of finished mix
- Average cost for rock-asphalt mixture with asphalt cement enrichment: $13.45 per ton

For contracts let during 1967:

- Average bid price for rock-asphalt mixture: $17.25 per ton
- Average cost for rock-asphalt mixture: $17.58 per ton
From these data it is apparent that the finished rock-asphalt mixture (cost of asphalt-cement enrichment included) cost an average of $4.13 per ton more for those projects let to contract and completed during 1967. This is approximately a 30 percent increase in cost.

**Uniformity.** In the spring of 1966, at the beginning of large scale quarry production of lean rock asphalt, there was concern about the uniformity of the natural asphalt content and gradation of the material. The material supplied to date has proven to be uniform in gradation and reasonably uniform in asphalt content. It was necessary to reject some of the very first rock asphalt supplied to the Hardin-Meade Counties project (US 31W) as a result of some oversize (plus 1/2-inch) material. Initially the material was produced to pass the 1/2-inch screen and then production was changed to the 3/8-inch screen for the last four projects constructed during 1967. For both maximum sizes, minus 1/2-inch and minus 3/8-inch, the gradation was very uniform. In the following table are the average extracted gradations for each size. Gradations of extracted aggregates from samples of the cold feed and from samples of the finished mix indicate that degradation of the aggregate during the heating and mixing process is negligible.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minus 1/2-inch</td>
</tr>
<tr>
<td>1/2-inch</td>
<td>100</td>
</tr>
<tr>
<td>3/8-inch</td>
<td>97.6</td>
</tr>
<tr>
<td>No. 4</td>
<td>88.3</td>
</tr>
<tr>
<td>No. 8</td>
<td>82.7</td>
</tr>
<tr>
<td>No. 16</td>
<td>79.9</td>
</tr>
<tr>
<td>No. 30</td>
<td>76.5</td>
</tr>
<tr>
<td>No. 50</td>
<td>39.5</td>
</tr>
<tr>
<td>No. 100</td>
<td>9.8</td>
</tr>
<tr>
<td>No. 200</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Little difficulty was experienced with variation of the natural asphalt content. The rock asphalt was tested for bitumen content by District Materials personnel as the material was delivered to the plant sites. On one project, US 31E in Barren-Hart Counties, approximately twelve loads of rock asphalt were rejected as deficient in natural asphalt (containing less than 4.0 percent). On a second project, US 31E in Nelson County, the natural asphalt content was very close to the minimum limit of 3.5 percent. Extraction test results on samples of the finished mix indicated that the variation in asphalt content was approximately one percent.

During the 1966 construction season the usual procedure was to add sufficient manufactured asphalt to maintain a total asphalt content of 8.5 percent. Based on the pay quantities, manufactured asphalt cement was added at an average rate of 4.4 percent. For those projects let to contract during 1966, the total asphalt content was required to be in the range of 7 to 10 percent and the minimum allowable asphalt content of the cold-feed material was 4.0 percent. During the 1967 construction season the total asphalt content was generally maintained between 9 and 10 percent. For those projects,
the total asphalt content was required to be in the range of 8 to 11 percent, and the required minimum asphalt content of the cold-feed material was 3.5 percent.

Considerable variation in consistency of the natural asphalt was experienced. Penetration and other laboratory tests were performed on natural asphalt extracted from stockpile material and on heat-treated natural asphalt extracted from samples of materials taken at the hot bins of the plants. The tests were also performed on blended natural and refinery asphalts extracted from samples of the finished mix. Table 3 in Appendix B is a summary of the test results obtained on these recovered asphalts. For those projects constructed during 1966 and early in 1967, the penetration of the natural asphalt ranged around 18 and the penetration of the blended natural asphalt and refinery asphalt ranged around 30. For those projects constructed during the latter part of the 1967 construction season, the penetration of the natural asphalt ranged around 55 and the blended natural and manufactured asphalt ranged around 60. The variation in consistency is related to the type of material processed at the quarry. The low penetration (18 pen) natural asphalt was from the loose waste material that was processed first. This natural asphalt was also highly oxidized as evidenced by its lower solubility in carbon tetrachloride than in carbon disulfide. The natural material in the 55 penetration range was obtained from freshly quarried ledge rock. This variation in consistency may prove to be significant in that penetrations in the range of 100 to 300 have been measured in previous studies (5).

Thin film oven tests (ASTM D 1754) were performed on four samples of recovered asphalts and these test results are summarized below:

<table>
<thead>
<tr>
<th>Asphalt Description</th>
<th>Penetration</th>
<th>% Loss</th>
<th>Penetration of Residue</th>
<th>Ductility of Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Asphalt (weathered)</td>
<td>21</td>
<td>4.57</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Natural Asphalt (weathered and heat-treated in dryer)</td>
<td>31</td>
<td>3.22</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Natural Asphalt (unweathered)</td>
<td>44</td>
<td>4.57</td>
<td>31</td>
<td>100+</td>
</tr>
<tr>
<td>Blend of Natural Asphalt (weathered) and Manufactured Asphalt (Approximately a 50-50 blend)</td>
<td>30</td>
<td>1.81</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

These data are very limited as a result of the quantity of material available for the tests, but some interesting results were observed. It may be noted that the percent loss was 4.6 percent for both samples of natural asphalt even though the samples varied in degree of weathering and penetration. Manufactured asphalt cements used to enrich the rock-asphalt mixtures had losses of less than 0.2 percent for the PAC-5 grade (85 to 100 penetration grade). Thus, these natural asphalts have a relatively high proportion of constituents that are volatile at the thin film oven test temperature (325°F). It may be noted that the weight loss was reduced, but still substantial, for the natural asphalt recovered from material sampled from the hot bin of an asphalt plant. The weight loss of the blend of refinery and natural asphalt, recovered from a sample of finished mix, was fairly predictable, inasmuch as the weight loss (1.8 percent) was intermediate between that for the manufactured
asphalt (0.0 percent) and that for the heat-treated natural asphalt (3.2 percent).

A factor of primary significance revealed by the test results on the recovered asphalts is that the consistency, as measured by penetration, of the natural asphalt in all material incorporated in the hot-mix resurfacings is harder than that encountered in previous studies of Kentucky rock asphalt. It is possible that much softer natural asphalt will be encountered in future quarrying operations and that the material may prove difficult to cure.

Stability. Marshall test values are shown in Table 1 of Appendix B. Stability of the mixture varied over an extremely large range. Inasmuch as the aggregate gradation was very uniform from project to project, this variation in stability must be attributed to variations in the consistency of the natural asphalt. Stabilities on the 1/2-inch top size material ranged from 1000 to 5000 pounds and on the 3/8-inch top size material from 380 to 1000 pounds. The stabilities of the mixtures generally decreased as production of raw material shifted from the weathered material to freshly quarried ledge rock. The minus 3/8-inch material was wholly produced from freshly quarried ledge rock. Stabilities measured on the last two projects constructed in the fall of 1967 were in the range of 300 to 700 pounds. It is apparent that further reductions in the hardness of the natural asphalt will result in instability of the finished mixtures. At present all of the surfacings are exhibiting adequate stability.

Durability. Full evaluation of the durability of the surfacings must be relegated to some future date. The various surfacing projects have been in service from a maximum of about two years to a minimum of just a few months under varied traffic volumes. At present all of the surfacings appear to be performing well. Reflection cracking has been noted in the two sections located on US 31W. Some of these cracks appear to be widening rather rapidly. Crack filler has been used in many of the cracks on the Warren County section and a few small broken areas adjacent to the cracks have been patched in the Meade-Hardin Counties section.

Plant Operations. The primary problem experienced at the hot-mix plants was that the heated rock asphalt would build up on the interior surfaces of the plants. This accumulation of material would create many problems in controlling the mixtures. At several of the plants, fires were experienced in the driers and ductwork of the exhaust systems. It was necessary for the contractors to spend considerable time in cleaning the accumulations of material from the plants during shut downs in order to operate properly. In general, satisfactory mixtures were produced on all of the projects after contractor personnel had gained experience in handling the material.

A potential problem associated with plant-mixing the rock asphalt is that of air pollution. A considerable amount of odor and soot was emitted from virtually all of the plants. The plants were operated with a variety of dust collection systems and modifications of the systems. With one exception, MaGo Construction Company at Bardstown, all of the plants used to date have been located in rural areas and few complaints were registered by local residents.

Paving Operations. Several problems were experienced in placing the rock-asphalt mixtures. On the first two projects under construction, rock asphalt
was used in the leveling course. The material became stiff and unworkable too rapidly for proper manipulation with a grader. This problem was circumvented by using conventional hot mix for leveling on the remaining projects. On several projects the paver screed would tear or scrub the surface of the mat. On one project, US 31E in Barren-Hart Counties, the paver left a small transverse bump in the mat whenever the paver stopped. The addition of silicone fluid appeared to reduce the tearing of the mat. It was found that these problems were also reduced by operating the paver as continuously as possible. Revisions were made in the Special Provision to promote continuous paver operation. On most projects, entrances, crossovers and other areas inaccessible to the paver and which required considerable handwork were paved with conventional hot-mix surface course material. This work was usually done after the main-line paving was completed.

Much of the problem in laying the material must be attributed to the high viscosity of the natural asphalt binder. The following are viscosities at 77°F for natural asphalt and blends of natural and manufactured asphalt recovered from the rock-asphalt aggregates and finished mixtures. For comparative purposes, the viscosity of a 60 penetration asphalt cement is also shown.

<table>
<thead>
<tr>
<th>Asphalt Description</th>
<th>Penetration at 77°F (0.1 mm)</th>
<th>Viscosity at 77°F (poises)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weathered natural asphalt</td>
<td>25</td>
<td>70.61 x 10^6</td>
</tr>
<tr>
<td>Blend of weathered natural asphalt and manufactured</td>
<td>30</td>
<td>23.21 x 10^6</td>
</tr>
<tr>
<td>and manufactured asphalt cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blend of natural asphalt and</td>
<td>52</td>
<td>6.87 x 10^6</td>
</tr>
<tr>
<td>manufactured asphalt cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat-treated natural asphalt (extracted from hot-bin</td>
<td>50</td>
<td>4.97 x 10^6</td>
</tr>
<tr>
<td>sample)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufactured asphalt (PAC-3)</td>
<td>60</td>
<td>3.89 x 10^6</td>
</tr>
</tbody>
</table>

The hardest asphalt cement normally used for hot-mix paving is PAC-3 (60 to 70 penetration). From the tabulation of viscosities given above, it is apparent that the blend of manufactured and weathered natural asphalts, incorporated in the first surfacings, was about five times as viscous as a 60 penetration material. The viscosity of the natural asphalt obtained from freshly quarried ledge rock is much more comparable to the PAC-3. This large variation in viscosity, of course, explains the greater difficulty experienced in laying the material on the first projects as compared to the last projects constructed.
SUMMARY OF OBSERVATIONS AND CONCLUSIONS

The prime motivation in using rock asphalt for hot-mix surfacing is its proven history of high skid resistance. Skid tests performed to date on the hot-mix, rock-asphalt surfacings have yielded coefficients in the range of 0.57 to 0.72, which is excellent in comparison to results obtained on other type surfaces.

The average cost of the rock-asphalt resurfacing was $13.45 per ton (asphalt cement included) for those contracts awarded during calendar year 1966 and $17.58 per ton for those projects awarded and constructed during calendar year 1967.

The lean, rock-asphalt aggregate was very uniform in gradation and reasonably uniform in natural asphalt content. The consistency of the natural asphalt varied over a wide range. The natural asphalt contained in the loose waste material processed first at the crushing plant was very hard, and mixtures produced with this material had very high stabilities but were difficult to place. The natural asphalt in material produced from freshly quarried ledge rock was much softer and the mixtures produced from this material had much lower stabilities and were much easier to place.

To date the surfaces have exhibited adequate stability and durability. Three of the lower-stability surfacings have not experienced hot-weather conditions. Further observations of the surfacings will be necessary to fully evaluate the stability and durability of the material.

Most of the problems associated with plant mixing the material have been minimized by thorough, daily cleaning of the plant. The soot and odor in exhaust gases presents a potential problem for plants without adequate dust collecting and washing systems.

Satisfactory-to-good results have been obtained in laying the material with pavers. Good results were generally attained on the projects constructed during 1967. It is believed that a better-appearing mat was obtained with material crushed to pass the 3/8-inch sieve.
RECOMMENDATIONS

Inasmuch as improved workability and appearance were experienced using material crushed to pass the 3/8-inch sieve, it is recommended that the Department continue to use this gradation. This size range was allowed, but not necessarily required, by the gradation limits in Special Provision No. 24-B. It is recommended that Special Provision No. 24-B be amended to include the following gradation limits for the extracted aggregate:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8-inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 16</td>
<td>80-98</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-15</td>
</tr>
</tbody>
</table>

In view of the large variation in consistency (viscosity) of the natural asphalt experienced over the 1966-67 construction seasons, it is recommended that a minimum limit of consistency be incorporated into Special Provision No. 24-B. Under present operating conditions, this consistency control can best be exercised on materials sampled from the Gripstop Corporation's stockpile. There are two alternative methods of testing for consistency of the natural asphalt. In one case this may be done by extracting and recovering the natural asphalt and testing for penetration. This method is presently specified in Special Provision No. 69 for Crushed Bituminous Sandstone Slurry Seal (Experimental). For slurry applications the consistency of the natural asphalt is limited by a maximum penetration of 75 at 77°F, 100 gm, 5 sec. The disadvantage to this method is that it is tedious and time consuming. A second method would be to specify a minimum Marshall stability on specimens prepared from material sampled from the Gripstop stockpile. A minimum Marshall stability of 300 pounds should be adequate.

REFERENCES


APPENDIX A

AND PERFORMANCE

PROJECT DESCRIPTIONS, COSTS,
Description: The Louisville-Elizabethtown Road (US 31W and US 60) from 550 feet north of KY 868 in Muldraugh (Meade County) to the south end of the Salt River Bridge at the Jefferson County line in West Point.

Length: 5.180 miles

Width: Double, 22-foot roadways (4 lanes)

Letting Date: April 22, 1966

Contractor: Warren Brothers Company and Consolidated Subsidiaries-Middle West Roads, Louisville, Kentucky

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing: 6,265 tons
- Rock-Asphalt Mixture for Leveling: 3,107 tons
- Total: 9,372 tons
- Asphalt Cement (PAC 5): 111,340 gallons
- Diluted SS-1h for Tack: 14,740 gallons

Note: Contract included removing bituminous concrete median and construction of dense-graded aggregate shoulders.

Unit Bids:
- Rock-Asphalt Mixture (Leveling and Surfacing): $11.00 per ton
- Asphalt Cement (PAC 5): $0.14 per gallon
- Diluted SS-1h: $0.20 per gallon

Total Contract Amount: $156,937.70

Pay Quantities:
- Rock-Asphalt Mixture: 8,411 tons
- Asphalt Cement (PAC 5): 75,743 gallons
- Diluted SS-1h: 25,249 gallons

Total Cost of Above Items: $108,173.72
Total Cost of Contract: $143,665.22

Surfacing Dates: August 18 through September 13, 1967

Plant Description: Warren Brothers Batch, 4000-pound capacity (Figures 2 and 3)

Plant Location: Osborn Brothers Quarry on KY 434, 1.8 miles east of intersection with US 31W

Approximate Average Haul Distance: 15-1/2 miles
Figure 2. Middle West Roads Plant, August 18, 1966. Note that the plant is exhausted through the wet collector.

Figure 3. Middle West Roads Plant, August 29, 1966. A view of the plant after an explosion collapsed the duct between the dry and wet dust collectors. An exhaust stack was erected immediately after the dry collector. Note the burned area on the dry collector.
Plant Operations: The lean rock asphalt was first hauled to the plant site on July 5, 1966. The first 200 tons of material was too coarse, a result of the producer, Gripstop, Inc., changing from a 1/2-inch square opening screen to a 1/2-inch slotted screen. This material was returned to the source. Thereafter material arriving at the plant site satisfactorily met all material requirements. The following is the average indigenous asphalt content and average gradation as indicated by District Materials reports:

<table>
<thead>
<tr>
<th>Indigenous asphalt</th>
<th>- 4.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation: Sieve Size - 1/2-inch</td>
<td>No. 4</td>
</tr>
<tr>
<td>Passing - 100%</td>
<td>85.3%</td>
</tr>
</tbody>
</table>

The bitumen content of the rock asphalt was determined by centrifuge extraction using first trichlorethylene as the solvent for two washes and then using a final wash with gasoline. The trichlorethylene was necessary as the native bitumen was found to be difficult to remove from the material using gasoline alone. This test procedure was used for all projects. After the material was dumped from trucks at the plant site, a clamshell was used to move the material to a second stockpile. The material was then loaded from the second stockpile into two cold-feed bins. In this manner thorough blending of the material was insured and a uniform asphalt content was maintained in the final mixture. Initially there was some concern that the indigenous bitumen content would be variable and thereby cause a variation in the bitumen content of the finished mix.

The dried and heated rock asphalt was scalped over a 9/16-inch screen into one hot bin. Petroleum asphalt cement (PAC 5) was added at a rate of 4 percent of the final total batch weight. The material was mixed in 3600-pound batches with 5 seconds dry-mixing time (before adding petroleum asphalt) and 40 seconds wet-mixing time (after adding petroleum asphalt). Average test values on the final mixture at the plant (data taken from the plant inspector's field reports) were as follows:

<table>
<thead>
<tr>
<th>Total asphalt content</th>
<th>- 8.8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation: Sieve Size - 1/2-inch</td>
<td>No. 4</td>
</tr>
<tr>
<td>Passing - 100%</td>
<td>87.5%</td>
</tr>
</tbody>
</table>

Some problems were experienced in producing the mixture. The heated material would build up on the walls of the hot bin and the dryer, and very fine material would build up within the ductwork of the dust collection system. It was reported that on one occasion the material cooled in the hot bins, while there was a wait for trucks, and then the material had to be removed using jackhammers. On another occasion, it was reported that the dryer foreman saturated the material accumulated on the walls of the dryer with fuel oil, and the excess fuel caused an explosion which shattered the ductwork between the dry and wet dust collectors. Afterwards the wet collector was not reconnected to the plant; the plant was exhausted through a stack immediately after the dry collector. Considerable dirt was exhausted and this discolored the plant and accumulated about the plant site. It was necessary to frequently clean the accumulations of material from the plant. The dryer was cleaned at the end of each day by running the heat up and burning out the accumulated material.

Paving Operations: The project proposal called for grader application of the rock-asphalt leveling material. A uniform tack coat of diluted SS-1h was applied before the mix was tailgated onto the road; but the mix became cool
and unworkable before it could be spread to the desired thickness (Figure 4). A Barber-Greene paver was used for the remainder of the leveling operation (Figure 5). As the outer lanes were rutted, a continuous leveling course was placed. Approximately 50 pounds per square yard was used for this continuous leveling. Spot leveling was used on the inside lanes. In some areas, a considerable thickness of leveling resulted (Figure 6). However, the material was very stable and appeared to stand up well under traffic. Approximately 2040 tons of mix and 10,300 gallons of tack (SS-1h) were used in the leveling operation. About 0.1 gallon per square yard of tack was used between the leveling and surfacing operation. In surfacing, a Cedar Rapids paver with electronic screed control was used (Figure 7). The inside lanes were placed first using a 20-foot ski which rode the outside lanes on which the full leveling course had been placed. In laying the final surface on the outside lanes, a foot rode on and matched the level of the inner lane. An application rate of approximately 91 pounds per square yard was used in the final surface course.

At the beginning of the final surfacing operation on August 29, the material was being placed at approximately 300°F, and the material pulled in the center of the mat for a distance of about 1/2 mile. The temperature was then reduced to approximately 260°F and thereafter pulling was limited to an occasional small area in the center of the mat. It was also reported that the thickness of the mat was reduced. Silicone was also used in the asphalt cement at a rate of one ounce per 1000 gallons.

A tandem roller was used immediately behind the paver and a three-wheel roller was used for back rolling. The material appeared to cool and become stable very quickly. Only a minimum amount of rolling was used on the surface course.

Performance Inspections: An inspection was made of the surface on March 14, 1967. The surface appeared to be in much the same condition as when the surfacing was completed. The surface appeared to be porous in those areas pulled by the paver screed. Cracks in the underlying cement concrete surface had reflected through the bituminous overlay (Figure 8).

The surface was inspected one year later, March 7, 1968, and found to be in good condition (Figure 9). At several locations cracking near the joints of the underlying concrete has become rather severe (Figure 10). A few bituminous patches have been placed at these locations.
Figure 4. US 31W, Hardin-Meade Counties. Leveling with a patrol grader, as shown above, was unsuccessful as the material cooled quickly and became stiff.

Figure 5. US 31W, Hardin-Meade Counties. A Barber-Greene paver was used to lay the leveling throughout the length of the project.
Figure 6. US 31W, Hardin-Meade Counties. The leveling was laid very thick in some areas. The material has high stability and appears to be performing well.
Figure 7. US 31W, Hardin–Meade Counties. A Cedar Rapids paver with electronic screed control was used to lay the surface course.

Figure 8. US 31W, Hardin–Meade Counties. Typical appearance of the surface on March 14, 1967. The dark areas are moist areas in the surface course. Note the reflection cracks from the underlying concrete.
Figure 9. US 31W, Hardin-Meade Counties, March 7, 1968. The surface was in good condition overall.

Figure 10. US 31W, Hardin-Meade Counties, March 7, 1968. Reflection cracking from the underlying concrete results in breakup at some joints.
US 31E, BARREN-HART COUNTIES
SP 5-12, SP 50-40

Description: The Glasgow-Hodgenville Road (US 31E) from the north city limits of Glasgow to the Larue County line

Length: 31.848 miles

Width: Variable width for 21.854 miles; 22 feet wide from north city limits of Canmer to the Larue County line.

Letting Date: May 5, 1966

Contractor: Henry Farris Paving Contractor, Horse Cave, Kentucky

<table>
<thead>
<tr>
<th>Contract Quantities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock-Asphalt Mixture for Surfacing</td>
<td>19,462.2 tons</td>
</tr>
<tr>
<td>Rock-Asphalt Mixture for Leveling</td>
<td>1,100 tons</td>
</tr>
<tr>
<td>Asphalt Cement (PAC 5)</td>
<td>257,380 gallons</td>
</tr>
<tr>
<td>Class I, Type A Surface for Leveling</td>
<td>1,623 tons</td>
</tr>
<tr>
<td>Diluted SS-1h for Tack</td>
<td>46,085 gallons</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit Bids</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock-Asphalt Mixture for Surfacing</td>
<td>$11.50 per ton</td>
</tr>
<tr>
<td>Rock-Asphalt Mixture for Leveling</td>
<td>$12.50 per ton</td>
</tr>
<tr>
<td>Asphalt Cement (PAC 5)</td>
<td>$0.15 per gallon</td>
</tr>
<tr>
<td>Class I, Type A Surface</td>
<td>$7.80 per ton</td>
</tr>
<tr>
<td>Diluted SS-1h</td>
<td>$0.20 per gallon</td>
</tr>
</tbody>
</table>

Total Contract Amount $298,071.50

<table>
<thead>
<tr>
<th>Pay Quantities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock-Asphalt Mixture for Surfacing</td>
<td>18,607.2 tons</td>
</tr>
<tr>
<td>Rock-Asphalt Mixture for Leveling</td>
<td>1,517.7 tons</td>
</tr>
<tr>
<td>Asphalt Cement (PAC 5)</td>
<td>235,799 gallons</td>
</tr>
<tr>
<td>Diluted SS-1h</td>
<td>37,678 gallons</td>
</tr>
<tr>
<td>Class I, Type A Surface</td>
<td>1,881.6 tons</td>
</tr>
</tbody>
</table>

Total Cost of Contract $290,535.98
Liquidated Damages $400.00

Surfacing Dates: September 9, 1966 through July 3, 1967

Plant Description: Barber-Greene 345L Continuous used in fall 1966 (Figure 11)
Hetherington-Berner Batch used in spring 1966 (Figure 12)

Plant Location: McLellan Stone Company on KY 218, 1.0 mile south of intersection with US 31W

Approximate Average Haul Distance: 9 miles
Figure 11. Henry Farris Paving Plant, September 23, 1966. This plant, a Barber-Greene continuous plant, was used to produce the mixture in the fall of 1966.

Figure 12. Henry Farris Paving Plant, June 1967. A view of the dryer of the Hetherington-Berner batch plant used to produce the rock-asphalt mixture in the spring of 1967. Paint was burned off much of the duct of the plant.
Plant Operations: This project started September 8, 1966, and paving was discontinued November 15 with approximately 1/3 of the project remaining to be completed. Paving was resumed in the spring of 1967 and the project was completed July 3, 1967. A Barber-Greene continuous mix plant was used during the fall of 1966 and a Hetherington-Berner batch plant was used in the spring of 1967.

All rock asphalt was hauled to the job site by truck and all of the material passed the specifications requirements except for approximately ten loads which were deficient in native asphalt. This material was returned to the supplier. The following is the average native bitumen content and the average extracted gradation for the stockpile materials as reported by the District Materials Engineer for the fall of 1966:

<table>
<thead>
<tr>
<th>Indigenous asphalt</th>
<th>4.8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation:</td>
<td></td>
</tr>
<tr>
<td>Sieve Size: 1/2-inch</td>
<td>No. 4</td>
</tr>
<tr>
<td>Passing: 100%</td>
<td>85.3%</td>
</tr>
</tbody>
</table>

At first, the rock asphalt would not feed through the cold-feed bins, equipped with reciprocating type feeders. After some experimentation it was found that, the material would feed with a vibrator attached to the bin. A 10-foot smoke stack was attached to the dust collector. The dust washer was not used for this project. Operation of the dryer required constant attention from plant personnel. It was reported that erratic cold feeding or fluctuating moisture content of the cold-feed material would cause temperature fluctuations as large as 100°F. It was necessary to clean the plant at several points every time the plant shut down.

Plant production was set at 71 tons per hour with asphalt cement (PAC 5) added at 4.0 percent. Data from the plant inspector's field reports, for the fall of 1966, indicated the following average extraction test results:

<table>
<thead>
<tr>
<th>Total bitumen content</th>
<th>8.9%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation:</td>
<td></td>
</tr>
<tr>
<td>Sieve size: 1/2-inch</td>
<td>No. 4</td>
</tr>
<tr>
<td>Passing: 100%</td>
<td>86.6%</td>
</tr>
</tbody>
</table>

These data, when compared to the data previously given on the stockpile material, indicate that the gradation of the material is altered very slightly in the plant processing.

Temperatures of the mix at the plant generally ranged between 250°F and 290°F. Some patching material was mixed at temperatures above 300°F in an effort to increase workability. Mix temperatures between the first week of October and when the work was discontinued were usually below 275°F. Some material was laid satisfactorily at temperatures of 240°F.

In the spring of 1967 production was continued with a Hetherington-Berner batch plant. Asphalt cement was added at 4.3 percent to 5000-pound batches. Mixing time was set for 10 seconds dry mixing and 35 seconds wet mixing. The plant was operated with the wet washer connected and the dry collector disconnected. The dryer was operated with an automatic burner. The rock asphalt would collect around the heat sensing elements, thus causing
erroneously low temperatures to be indicated and the automatic burner would operate continuously causing fires in the plant.

Paving Operation: Tacking was done with diluted SS-1h and uniform coverage was obtained. On cool days it was necessary to tack ahead for a considerable distance in order for the tack to break properly prior to applying the hot mix. When it was necessary to leave tack down overnight, it was sanded with the lean rock-asphalt aggregate.

Leveling was accomplished with a small grader (Figure 13). Many of the leveled areas were rough as the material becomes unworkable very quickly as it cools.

The final surface course was started at the northern end of the project in Hart County. Transverse bumps can be observed in the surface at regular intervals. These were caused by the paver screed "riding over" cool material after the paver was stopped for several minutes. Four different pavers were used on the project during the fall. The first was an old clutch operated, Barber-Greene; the second a Cedar Rapids; the third a small Blaw-Knox; and the last a larger Blaw-Knox (Figure 14).

When work ceased in the fall of 1966, the surfacing was completed from the Hart-Larue County line south to approximately 300 feet north of its intersection with KY 218, an approximate distance of 19.8 miles. The roadway was also completed on the southern end from the north city limits of Glasgow to a point approximately 3.25 miles north.

Performance Inspections: A performance inspection was made of the surfacing completed in the fall of 1966 on April 12, 1967 (Figure 15). In the first two miles below the Larue County line, many transverse bumps were left by the paver screed, and there were also many shallow, pulled areas in the southbound lane. From a point approximately 0.2 miles north of the Green River bridge to the southern end of the northern section the appearance improved noticeably. The only section showing serious distress was the northbound lane of the southern section (Figure 16). Ravelling was apparent at eleven locations in the northbound lane and at one location in the southbound lane. These ravelled areas were confined to the lane width and varied from about 25 to 75 feet in length. It is suspected that these ravelled areas were the result of insufficient compaction of the material in cool weather. These ravelled areas were more concentrated in location toward the northern end of the southern section. These areas were repaired with overlays in the spring of 1967.

The surfacing was last inspected March 7, 1968. Overall the surfacing appeared to be in very good condition (Figure 17). The transverse bumps left by the paver screed were still noticeable at the northern end of the project. It was observed that the surface texture appeared to be somewhat improved since the surfacing was first laid.
Figure 13. US 31E, Barren-Hart Counties, September 20, 1966. All of the leveling on this project was grader-laid. The grader could make about three passes over the material before it became too stiff to work properly.

Figure 14. US 31E, Barren-Hart Counties, June 1967. A view of the Blaw-Knox paver with electronic screed control which was used to lay most of the surface.
Figure 15. US 31E, Barren-Hart Counties, April 12, 1967. An overall view of the rock-asphalt surface near Glasgow.

Figure 16. US 31E, Barren-Hart Counties, April 12, 1967. A view of one of the ravelled areas in the northbound lane of the southern section paved in the fall of 1966.
Figure 17. US 31E, Barren-Hart Counties, March 7, 1968. An overall view of the surface 4.0 miles north of Glasgow.
US 41, HENDERSON COUNTY  
SP 51-299, SP 51-99

Description: The Henderson-Sebree Road (US 41) from 0.311 miles south of KY 54 to KY 136 at Anthoston

Length: 5.089 miles

Width: 22 feet

Letting Date: May 6, 1966

Contractor: Dixie Pavers Inc., Hopkinsville, Kentucky

Contract Quantities:  
- Rock-Asphalt Mixture for Surfacing: 2,745 tons  
- Asphalt Cement (PAC 5): 63,140 gallons  
- Class I, Type A Surface for Leveling: 5,260 tons  
- Diluted SS-1h for Tack: 7,225 gallons

Note: Class I, Type A Surface substituted for rock-asphalt mixture for leveling by change order.

Unit Bids:  
- Rock-Asphalt Mixture for Surfacing: $14.60 per ton  
- Asphalt Cement (PAC 5): $0.15 per gallon  
- Class I, Type A Surface: $7.50 per ton  
- Diluted SS-1h: $0.15 per gallon

Total Contract Amount: $88,153.75

Pay Quantities:  
- Rock-Asphalt Mixture: 2,820.6 ton  
- Class I, Type A Surface: 5,753.1 tons  
- Asphalt Cement (PAC 5): 29,641 gallons  
- Diluted SS-1h: 8,036 gallons

Total Cost Contract: $90,056.16

Surfacing Dates: October 18, 1966 through October 31, 1966

Plant Description: Hetherington-Berner Batch, 5000-pound capacity

Plant Location: Just off US 41, Henderson, Kentucky

Approximate Average Haul Distance: 3 miles

Plant Operations: The rock asphalt was shipped to the plant site in railroad cars and considerable difficulty was experienced in unloading the cars. After some trials, the material was successfully unloaded by warming the material with diesel fuel in five-gallon buckets prior to and during unloading. In loading the cars, care was exercised to prevent the material from packing over the discharge shutes. A vibrator was also used in the unloading operation.
Average test results on the stockpile material as reported by the District Materials Engineer were as follows:

<table>
<thead>
<tr>
<th>Gradation:</th>
<th>Sieve Size</th>
<th>Passing</th>
<th>No. 4</th>
<th>No. 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigenous asphalt</td>
<td>4.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradation:</td>
<td>1/2-inch</td>
<td>100%</td>
<td>85.0%</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

Production of the hot-mix rock asphalt began October 25, 1966 and continued through October 29, 1966. The mixture was produced in 4000-pound batches and asphalt cement was added at 4.2 percent. The mixing time was set for 3 seconds dry mixing and 42 seconds wet mixing. Dow-Corning silicone fluid was added to the asphalt cement. During the first day of production, some oversize material was found in the mix. The plant was equipped with a 9/16-inch scalper screen which did not completely cover the three hot bins. The mixture was produced at a temperature of 275°F ± 15°F. The following is an average of the field tests on the plant's production:

<table>
<thead>
<tr>
<th>Gradation:</th>
<th>Sieve Size</th>
<th>Passing</th>
<th>No. 4</th>
<th>No. 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total asphalt content</td>
<td>9.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradation:</td>
<td>1/2-inch</td>
<td>100%</td>
<td>85.5%</td>
<td>11.0%</td>
</tr>
</tbody>
</table>

Paving Operation: The contract required leveling and patching to be done with the rock-asphalt mixture. A change order permitted leveling with Class I, Type A surface. The surface was tacked with SS-1h diluted with an equal volume of water and applied at a rate of 0.1 gallon per square yard. Flagmen were used to keep traffic off the tack coat until the tack cured. Curing time varied from 25 minutes to 1-1/2 hours, depending upon weather conditions. Excellent tack coverage was obtained. A Cedar Rapids electronic leveling control paver, equipped with a 20-foot skid was used to lay the leveling course. The leveling course was then compacted with a 10-ton, 3-wheel roller and a 10-ton tandem roller. This leveling course greatly improved the riding qualities of the surface but some long longitudinal dips remained. A land leveler with a 40-foot rigid wheel base was used to remove these long dips. The machine was pulled by a farm tractor and was equipped with a blade to spread material which has been dumped on the roadway. The electronic leveling controls were not used in laying the final surface course. A full day's run was laid on one lane before setting the paver back for the following day's work. The longitudinal joint was tacked before the adjacent mat was placed. The paver was run as continuously as possible. Entrances and intersections were constructed with Class I, Type A surface course material. The surface course was compacted with a 10-ton, 3-wheel roller and a 10-ton tandem roller.

Performance Inspections: A performance inspection was made of the surface on April 3, 1967. The surfacing was in generally good condition (Figure 18) except for several ravelled and pulled areas (Figures 19 and 20). The ravelled areas, primarily located at the ends of bridges (Figure 21) or at the extreme ends of the project, are apparently related to the non-continuous operation of the paver and hand working. The cross-section and riding quality of the surfacing is very good.

The surface was inspected a second time on March 6, 1968, and the surface was still in good condition. The ravelled areas had been repaired and these areas are no longer noticeable.
Figure 18. US 41, Henderson County, March 16, 1967. An overall view that is typical of the generally good appearance of the surfacing.

Figure 19. US 41, Henderson County, March 16, 1967. A ravelled area at the extreme northern end of the northbound lane.
Figure 20. US 41, Henderson County, March 16, 1967. There were a few areas, such as shown above, in which the surfacing was apparently pulled by the paver screed.

Figure 21. US 41, Henderson County, March 16, 1967. There were several ravelled areas at the ends of bridge decks and at the extreme ends of the project.
US 68, CHRISTIAN COUNTY
SP 24-65, SP 24-525

Description: The Hopkinsville-Elkton Road (US 68) from approximately 0.7 miles east of junction of US 68 and US 41 to the Todd County line

Length: 9.356 miles

Width: The contract involved base widening to a uniform 24-foot width. The existing pavement was 20 and 22 feet in width.

Letting Date: May 5, 1966

Contractor: Hopkinsville Stone Company, Inc., Hopkinsville, Kentucky

Contract Quantities:

Rock-Asphalt Mixture for Surfacing 6,587 tons
Class I Binder for Leveling 9,357 tons
Diluted SS-lh for Tack 6,586 gallons
Asphalt Cement (PAC 5) 78,255 gallons

Note: The project involved base widening; only quantities for rock-asphalt surfacing and leveling with Class I binder are given.

Unit Bids:

Rock-Asphalt Mixture $12.50 per ton
Class I Binder $6.90 per ton
Asphalt Cement (PAC 5) $0.14 per gallon
Diluted SS-lh $0.14 per gallon

Total Contract Amount $399,950.04

Pay Quantities:

Rock-Asphalt Mixture 5,235.7 ton
Class I Binder 12,695.5 ton
Diluted SS-lh 4,995 gallons
Asphalt Cement (PAC 5) 53,600 gallons

Total Cost of Above $161,248.50
Total Cost of Contract $376,212.07

Surfacing Dates: October-November 1966

Plant Description: Hetherington-Berner Batch, 4000-pound capacity

Plant Location: Hopkinsville Stone Company's Quarry on US 41 at Hopkinsville

Approximate Average Haul Distance: 12 miles

Plant Operations: No difficulties were reported in the plant operation. The average gradation and bitumen content for the stockpile material was as follows:
Indigenous asphalt - 4.8%
Gradation: Sieve Size - 1/2-inch
Passing - 100%
No. 4 No. 100
79.8% 9.9%

Asphalt cement (PAC 5) was added to the mix at a rate of 4.2 percent.

Performance Inspection: Inspections were made of the finished pavement on November 17, 1966, and March 16, 1967. Overall the surface looked very good (Figure 22). The center of the pavement appeared open-textured throughout the length of the surfacing, reportedly the result of the mix pulling under the paver screed extension. The appearance of the surface was about the same on each inspection. There were three cracked areas in the eastbound lane (Figures 23 and 24), located about 4.0 miles from the western end of the project, which were apparently due to batches of mix which were overheated (burned) or deficient in asphalt.

A third inspection was made of the surfacing on March 6, 1968, and the surface was found to be in good condition (Figure 25). The pulled areas in the center of the surface were not as noticeable as on the previous inspections. The condition of the surfacing in the cracked areas had deteriorated considerably and these areas will soon require extensive maintenance.
Figure 22. US 68, Christian County, March 16, 1967. A view of the surface near the eastern end of the project at Fairview.

Figure 23. US 68, Christian County, March 16, 1967. There were three cracked and deteriorated areas in the eastbound lane, in close proximity, located about four miles from the western end of the project. Apparently these are batches of material which were burned and/or deficient in added asphalt.
Figure 24. US 68, Christian County, March 6, 1968. A view of the same area as shown in Figure 22. The deterioration of the area is apparent.

Figure 25. US 68, Christian County, March 6, 1968. A view of the surface approximately 2.8 miles from the western end.
US 31W, WARREN COUNTY
SP 114-68

Description: The Bowling Green-Cave City Road (US 31W) from the south end of the Barren River Bridge at the old northeast city limits of Bowling Green extending northeasterly

Length: 6.46 miles

Width: Variable

Letting Date: May 5, 1966

Contractor: R. E. Gaddie Inc., Bowling Green, Kentucky

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing: 9,045 tons
- Asphalt Cement (PAC 5): 107,455 gallons
- Diluted SS-1h for Tack: 20,275 gallons
- Class I, Type A Surface for Leveling: 600 tons

Unit Bids:
- Rock-Asphalt Mixture: $11.00 per ton
- Asphalt Cement (PAC 5): $.14 per gallon
- Diluted SS-1h: $.25 per gallon
- Class I, Type A Surface: $7.60 per ton

Total Contract Amount: $119,607.45

Pay Quantities: (Based on estimate of July 13, 1967, not a final estimate)
- Rock-Asphalt Mixture: 8,576 tons
- Asphalt Cement (PAC 5): 93,190 gallons
- Diluted SS-1h: 14,918 gallons
- Class I, Type A Surface: 740 tons

Total Cost of Contract: $116,736.10
Liquidated Damages: $5,600.00

Surfacing Dates: October 19, 1966 through June 7, 1967

Plant Description: Hetherington-Berner Batch, 400-pound capacity (Figure 26)

Plant Location: Old Kyrock plant site on KY 259 near Sweeden, Kentucky

Approximate Average Haul Distance: 20 miles

General Comments: Construction of the hot-mix surfacing began October 19, 1966, and was discontinued November 14, 1966 - the usual cutoff date for hot-mix construction. During this period the northernmost 4.9 miles, the section with four lanes and depressed median, were paved. Considerable difficulty was
Figure 26. R. E. Caddie's Batch Plant, October 18, 1966. Note the long conveyor belts from the drier to the hot bins and from the hot bins to the mixer.
experienced in both the plant and placement operations and distressed areas were apparent in the newly placed surfacing. Construction was resumed in the spring of 1967 and the surfacing was completed June 7, 1967. Repairs were made on the surfacing placed in the fall. Class I surface was permitted by change order for leveling the remaining section (curb and gutter section) to be surfaced and for paving aprons. No difficulties were experienced during the spring of 1967.

Plant Operation: Only a small stockpile of rock asphalt was maintained at the hot-mix plant site, located only a few miles from the crushing plant. Material was hauled to the hot-mix plant at approximately the rate it was being used. The following average extraction and gradation test results were determined on the stockpile material:

<table>
<thead>
<tr>
<th>Indigenous asphalt</th>
<th>4.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation:</td>
<td></td>
</tr>
<tr>
<td>Sieve Size - 1/2-inch</td>
<td>100%</td>
</tr>
<tr>
<td>Passing</td>
<td>80.5%</td>
</tr>
<tr>
<td>No. 4</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

The mix was produced in 3750-pound batches. The asphalt cement enrichment was set for 4.3 percent. Mixing time was 5 seconds dry mixing and 46 seconds wet mixing. The dry and wet dust collectors were disconnected and a 20-foot smoke stack was erected at the mouth of the dryer. The temperature of the dryer aggregate fluctuated as much as 100°F, inasmuch as a blower was not provided. Batch temperatures as low as 225°F and as high as 325°F were observed. Some loads were rejected at 400°F. In order to properly lay the material, construction personnel believed that the mix had to arrive at the paver at a temperature of 280°F. In order to do this, the rock asphalt had to be heated to near 325°F, the upper specification limit, at the plant. The plant had long conveyor belts between the dryer and hot bins and between the hot bins and pugmill. Due to this arrangement of the plant, a decrease in temperature up to 25°F occurred between the dryer and pugmill.

On October 31, 1966, the dust collectors were reinstalled in the plant. Temperatures at the boot of the dryer were then generally maintained between 275°F and 300°F. The asphalt cement enrichment was increased from 4.3 percent to 4.5 percent on October 31. During the afternoon of October 26 the asphalt cement enrichment was 4.8 percent. Beginning on October 29, silicone liquid (Dow-Corning 200 fluid) was added to the asphalt cement at a rate of one ounce per 1000 gallons of asphalt cement.

The following are average test data obtained from the plant inspector's daily field reports:

<table>
<thead>
<tr>
<th>Total asphalt</th>
<th>9.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation:</td>
<td></td>
</tr>
<tr>
<td>Sieve Size - 1/2-inch</td>
<td>100%</td>
</tr>
<tr>
<td>Passing</td>
<td>82.2%</td>
</tr>
<tr>
<td>No. 4</td>
<td>8.7%</td>
</tr>
</tbody>
</table>

When production was resumed in the spring of 1967, the asphalt cement enrichment was initially set at 4.5 percent and then reduced to 4.2 percent. No further special problems were reported in plant control or operation.

Paving Operation: Paving started at the northern end of the project on the southbound lanes. No leveling was required on the section paved in the fall of 1966. The tack coat material was diluted SS-1h applied at a rate of 0.1 gallon per square yard. A large amount of tearing of the mat by the paver screed
was experienced. In an attempt to repair these areas, material was broadcast over the mat by hand. This material did not blend into the mat when rolled and presented a rough textured and ragged appearance. Many of these areas wore excessively after a short time under traffic.

When construction was resumed in the spring of 1967, repairs were made to the areas showing distress which were paved in the fall of 1966. A thin course of hot-mix rock asphalt was used to overlay 2000 feet of the sections showing the most severe distress. A seal coat was used to cover areas showing slight distress. Rock-asphalt aggregate, material processed through the dryer of the plant but with no added asphalt cement, was used as the cover stone for the seal coat.

Class I surface course material was used to level the curb and gutter section of the project, approximately 1.6 miles, and to pave aprons. No difficulties were reported in placing the material during the spring of 1967.

Performance: A detailed inspection of the completed surface was performed on November 17, 1966, a few days after terminating construction. There were numerous areas showing various degrees and types of distress throughout the length of the surfacing. As mentioned previously, there were areas, some rather extensive in length, in which the surface had an open texture, which was apparently the result of the material pulling under the paver screed. There were other areas, usually 30 to 75 feet in length, in which severe wear was apparent. It is believed that most of these areas were undercompacted as a result of the material arriving at the paver too cold. In a few instances the wear had progressed through or very nearly through the full depth of the course, as shown in Figure 27. Samples of the surfacing were taken from two such areas on the roadway and the asphalt contents were found to be 5.4 percent and 4.8 percent. Thus it appears that a few batches of mix were produced which were extremely deficient in asphalt cement and which escaped detection when produced or laid (Figure 28). There were also areas of the roadway in which small holes, less than 1/4 square foot in area, were worn deep into the mat (Figure 29). It is probable that these were agglomerations of rock asphalt that had formed by cooling on inside surfaces of the plant and which subsequently broke loose and remained intact while in the pugmill. On the southermmost 0.5 miles of the northbound lane, there were several lengths of ravelled longitudinal joint.

Although there were distressed areas throughout the length of the surfacing, the distress was most prevalent in the northermmost 2.7 miles of the southbound lanes—the portion of the roadway paved first. It appears that much of the problem was the result of the contractor’s inexperience in handling the material at the plant and on the roadway. The frequency of occurrence and the severity of the distress decreased as the job progressed. When construction was resumed in the spring of 1967, repairs were made to the distressed areas, and the remaining portion of the project was completed with no unusual difficulties.

A second performance inspection was made on April 13, 1967. The surface was, in general, the same condition as on the previous inspection except that the wear had progressed further (Figures 30 and 31). A hot-mix patch was placed in the most severely worn areas.
Figure 27. US 31W, Warren County, April 13, 1967. The area of pavement is the same as shown in Figure 28. Note that a bituminous concrete patch was placed in the area. In the inner wheel path the course has been worn through to the underlying surface.

Figure 28. US 31W, Warren County, November 17, 1966. An area of pavement in which a load of hot-mix rock asphalt deficient in asphalt cement was placed.
Figure 29. US 31W, Warren County, November 17, 1966. Holes were formed from cold agglomerations of non-enriched rock asphalt.

Figure 30. US 31W, Warren County, April 13, 1967. A view of a typical section of the surface.
Figure 31. US 31W, Warren County, April 13, 1967. A view of the southern end of the resurfacing in the northbound lanes. Note the open longitudinal construction joint.
A third performance inspection was made March 6, 1968 (Figure 32). Many long cracks were noted in the surfacing. These cracks appeared to be randomly located and oriented. Most of the cracks had been sealed by Maintenance (Figure 33). The overlay placed on the distressed areas in the southbound lanes appeared to be performing satisfactorily. Other than the cracks previously mentioned, the surface appeared to be in good condition.
Figure 32. US 31W, Warren County, March 6, 1968. A typical view of the pavement.

Figure 33. US 31W, Warren County, March 6, 1968. A close-up view of a sealed crack.
KY 80, ADAIR-METCALFE COUNTIES
SP 1-30, SP 85-24-5

Description: The Columbia-Edmonton Road (KY 80) from the new, west city limits of Columbia to US 68 at the old, north city limits of Edmonton

Length: 21.51 miles

Width: 18 feet

Letting Date: May 5, 1966

Contractor: Marion Contracting Company, Lebanon, Kentucky

Contract Quantities:

- Rock-Asphalt Mixture for Surfacing: 10,469 tons
- Class I, Type A Surface for Leveling: 1,745 tons
- Asphalt Cement (PAC 5): 124,348 gallons
- Diluted SS-1h for Tack: 31,218 gallons

Unit Bids:

- Rock-Asphalt Mixture: $12.65 per ton
- Class I, Type A Surface: $8.00 per ton
- Asphalt Cement (PAC 5): $0.15 per gallon
- Diluted SS-1h: $0.25 per gallon

Total Contract Amount: $172,849.55

Note: Type A Surface substituted for rock asphalt for leveling by change order.

Pay Quantities:

- Rock-Asphalt Mixture: 10,422.7 tons
- Class I, Type A Surface: 1,971.2 tons
- Asphalt Cement (PAC 5): 116,907 gallons
- Diluted SS-1h: 16,086 gallons

Total Cost of Contract: $169,174.31

Liquidated Damages: $2,500.00

Surfacing Dates: May 8 through June 9, 1967

Plant Description: Barber-Green Continuous, 80 tons per hour capacity

Plant Location: Montgomery and Company Quarry, Knob Lick, Metcalfe County

Approximate Average Haul Distance: 20 miles

Plant Operation: Production of the surface mix began May 8, 1967. Asphalt cement was added to the mixture at the rate of 4.5 percent, bringing the total asphalt content to 9 percent. Silicone liquid was added to the asphalt cement. Paving began on the eastern end of the project near Columbia.
Paving Operation: No undue difficulties were reported in the paving operation.

Performance: Inspections were made of the finished surface on October 10, 1967 and March 8, 1968. On both inspections, the surface appeared in good condition (Figure 34). It was noted that the appearance of the surfacing generally improved as one progressed over the surfacing from east to west.

Figure 34. KY 80, Adair-Metcalf Counties, March 8, 1968. A typical view of the surfacing near Edmonton.
US 127, RUSSELL COUNTY
SP 104-78-9

Description: The Jamestown-Albany Road (US 127) from KY 619 near the south city limits of Jamestown to KY 55 south of Sewellton

Length: 5.150 miles

Letting Date: May 5, 1966

Width: 20 feet

Contractor: R. E. Gaddie Inc., Bowling Green, Kentucky

Contract Quantities: Rock-Asphalt Mixture for Surfacing 2,763 tons
Class I, Type A Surface for Leveling 712 tons
Asphalt Cement (PAC 5) 32,816 gallons
Diluted SS-1h for Tack 8,654 gallons

Unit Bids: Rock-Asphalt Mixture $13.50 per ton
Class I, Type A Surface $8.90 per ton
Asphalt Cement (PAC 5) $0.15 per gallon
Diluted SS-1h $0.25 per gallon

Total Contract Amount $50,723.20

Pay Quantities: Rock-Asphalt Mixture 2,734.9 tons
Class I, Type A Surface 722.4 tons
Asphalt Cement (PAC 5) 30,643 gallons
Diluted SS-1h 2,612 gallons

Total Cost of Contract $48,599.96
Liquidated Damages $3,600.00

Surfacing Dates: June 1 through June 20, 1967

Plant Description: Hetherington-Berner Batch

Plant Location: Columbia, Kentucky

Approximate Average Haul Distance: 18 miles

Plant and Paving Operations: No inspections were made by Research Division personnel during construction; however, no difficulties were reported. The asphalt content was set at a minimum of 8.5 percent.

Performance: An inspection was made of the surface on October 10, 1967, and the surface was found to be in good condition. The surface was also inspected on March 8, 1968. A few randomly located transverse cracks were noted, but overall the surface was in good condition (Figure 35).
Figure 35. US 127, Russell County, March 8, 1968. A typical view of the surface near Jamestown.
KY 101 and KY 259, EDMONSON-WARREN COUNTIES
SP 114-48-1, SP 31-138-2, SP 31-98-2

Description: The US 31W-Brownsville Road (KY 101 and KY 259) from its intersection with US 31W in Warren County extending northerly to its junction with KY 70 east of Brownsville in Edmonson County

Length: 8.291 miles

Width: KY 101, 18 feet; KY 259, 19 feet

Letting Date: September 23, 1966

Contractor: R. E. Gaddie Inc., Bowling Green, Kentucky

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing
- Class I, Type A Surface for Leveling
- Asphalt Cement (PAC 5)
- Diluted SS-1h for Tack

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock-Asphalt Mixture</td>
<td>4,175 tons</td>
</tr>
<tr>
<td>Class I, Type A Surface</td>
<td>2,430 tons</td>
</tr>
<tr>
<td>Asphalt Cement (PAC 5)</td>
<td>49,595 gallons</td>
</tr>
<tr>
<td>Diluted SS-1h for Tack</td>
<td>9,360 gallons</td>
</tr>
</tbody>
</table>

Unit Bids:
- Rock-Asphalt Mixture $11.00 per ton
- Class I, Type A Surface $0.50 per ton
- Asphalt Cement (PAC 5) $0.14 per gallon
- Diluted SS-1h $0.25 per gallon

Total Contract Amount $75,863.30

Pay Quantities: (Based on estimate of July 13, 1967, not a final estimate)

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock-Asphalt Mixture</td>
<td>3,975 tons</td>
</tr>
<tr>
<td>Class I, Type A Surface</td>
<td>2,588 tons</td>
</tr>
<tr>
<td>Asphalt Cement (PAC 5)</td>
<td>41,453 gallons</td>
</tr>
<tr>
<td>Diluted SS-1h</td>
<td>9,925 gallons</td>
</tr>
</tbody>
</table>

Total Cost of Contract $74,007.67

Liquidated Damages $200.00

Surfacing Dates: June 1967

Plant Description: Hetherington-Berner Batch, 4000-pound capacity

Plant Location: Old Kyrock plant site on KY 259 near Sweeden, Kentucky

Approximate Average Haul Distance: 9 miles

Plant and Paving Operations: Asphalt cement was added to the mix at 4.2 percent. No problems, such as were experienced in the fall of 1966, were encountered at the plant or at the paver. Reportedly, good temperature control was maintained. Considerable time was spent each day in chipping rock asphalt off the inside surfaces of the dryer, hot bins, etc.
Performance: A performance inspection was made of the surfacing on August 31, 1967, and the surface was found to be in good condition. Inspections were repeated in October 1967 and in March 1968. In March 1968 the surface was still in good condition (Figures 36 and 37).

Figure 36. KY 259, Edmonson County, March 7, 1968.

Figure 37. KY 101, Warren County, March 7, 1968.
US 79, TODD COUNTY
SP 110-126-2

Description: The Russellville-Guthrie Road (US 79) from the Logan County line extending southwesterly to the end of the cement concrete pavement

Length: 6.673 miles

Width: 20 feet

Letting Date: April 21, 1967

Contractor: Kapco Inc., Russellville, Kentucky

Contract Quantities: Rock-Asphalt Mixture for Surfacing 2,590 tons
Class I, Type A Surface for Leveling 3,545 tons
Diluted SS-1h for Tack 8,220 gallons

Unit Bids: Rock-Asphalt Mixture $19.40 per ton
Class I, Type A Surface $8.20 per ton
Diluted SS-1h $0.30 per gallon

Total Contract Amount $81,781.00

Pay Quantities: Rock-Asphalt Mixture 2,588.3 tons
Class I, Type A Surface 3,540.0 tons
Diluted SS-1h 6,804 gallons

Total Cost of Contract $81,282.22

Surfacing Dates: June 19, 1967 through July 14, 1967

Plant Description: Cedar Rapids, 5000-pound batch (Figure 38)

Plant Location: US 431 just south of Russellville, Kentucky

Approximate Average Haul Distance: 16 miles

Plant and Paving Operations: Initially asphalt cement was added to the mix at 4.5 percent. This was changed to 4.8 percent about midway through the project in an effort to maintain the total bitumen content near 9.5 percent. Some difficulty was experienced with temperature control of the mix. The plant was operated without a dust collector.

A Cedar Rapids paver with automatic leveling controls was used to lay the mixture. There was some scuffing of the mat by the paver screed (Figure 39).

Performance: Inspections were made of the surface in October 1967 and in March 1968. The surface was found to be in good condition. Many areas which had been scuffed by the paver screed were still visible but the damage appeared superficial (Figure 40). A severely cracked area was noted in the southbound lane about 1/2 mile from the northern end of the project (Figure 41).
Figure 38. Kapco's Hot-Mix Plant, June 1967. The dust collectors on the plant were by-passed, as shown above.

Figure 39. US 79, Todd County, June 1967. Some scuffing of the mat by the paver screed occurred throughout the length of the project.
Figure 40. US 79, Todd County, March 6, 1968. A view of the surfacing near the southern end of the project. Note that scuff marks left by the paver screed are still apparent.

Figure 41. US 79, Todd County, March 6, 1968. An area of the southbound lane, near the northern end of the project, in which the mix was deficient in asphalt and/or was overheated.
Description: The Brownsville-Cave City-Sulphur Well Road (KY 70) from US 31W in Cave City extending easterly to the east city limits of Hiseville.

Length: 8.550 miles

Width: 20 feet from US 31W to US 31E, 18 feet from US 31E to the east city limits of Hiseville.

Letting Date: April 21, 1967

Contractor: Henry Farris Paving Contractor, Horse Cave, Kentucky.

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing: 3,170 tons
- Class I, Type A Surface for Leveling: 4,480 tons
- Diluted SS-1h for Tack: 10,074 gallons

(Contract included construction of DGA Shoulders)

Unit Bids:
- Rock-Asphalt Mixture: $16.00 per ton
- Class I, Type A Surface: $8.75 per ton
- Diluted SS-1h: $0.20 per gallon

Total Contract Amount: $114,548.30

Pay Quantities:
- Rock-Asphalt Mixture: 3,062.2 tons
- Class I, Type A Surface: 4,549.3 tons
- Diluted SS-1h: 9,087 gallons

Total Cost of Above Items: $90,623.35
Total Cost of Contract: $113,334.87

Surfacing Dates: August 1967

Plant Description: Hetherington-Berner Batch

Plant Location: McLellan Stone Company on KY 218, 1.0 mile south of intersection with US 31W

Approximate Average Haul Distance: 8.5 miles

Plant and Paving Operations: No difficulties in plant operation were reported during the period of this project. Asphalt cement was added to the mix at a rate of 4.8 to 5.0 percent to bring the total asphalt content to 9.5 percent.

The mix appeared to be more workable than that used on previous projects. The finished surface had a fine-textured, pleasing appearance. It was noted that there was some dragging of coarse aggregate particles by the paver screed.
Performance: The surface was inspected in October 1967 and in March 1968. The surface was in good condition, having a uniform appearance and fine texture (Figure 42).

Figure 42. KY 70, Barren County, March 7, 1968.
Description: The Bardstown-Louisville Road (US 150 and US 31E) from Forest Street in Bardstown to Cox's Creek

Length: 5.300 miles

Width: 24 feet

Letting Date: April 21, 1967

Contractor: Mago Construction Company, Bardstown, Kentucky

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing: 2,465 tons
- Class I, Type A Surface for Leveling: 2,655 tons
- Diluted SS-1h for Tack: 7,835 gallons

Unit Bids:
- Rock-Asphalt Mixture: $17.50 per ton
- Class I, Type A Surface: $8.40 per ton
- Diluted SS-1h: $0.30 per gallon

Total Contract Amount: $67,790.00

Pay Quantities:
- Rock-Asphalt Mixture: 2,438.6 tons
- Class I, Type A Surface: 2,706.3 tons
- Diluted SS-1h: 7,790 gallons

Total Cost of Contract: $67,745.42

Surfacing Dates: Mid-August 1967

Plant Description: Batch

Plant Location: Geoghegan and Mathis Quarry on US 62 at Bardstown

Approximate Average Haul Distance: 4 miles

Plant and Paving Operations: No difficulties were experienced at the plant or on the roadway on this project. The rock-asphalt aggregate was freshly quarried material crushed to pass the 3/8-inch sieve. The natural bitumen content on some samples ran below the minimum requirement of 3.5 percent. Initially the added asphalt content was set at 5.0 percent and then was raised to 6.0 percent in an effort to keep the total asphalt content near 9.5 percent. The temperature of the mix was generally maintained between 280 and 300°F.

Performance: An inspection was made of the surfacing on August 24, 1967. The surface had a fine texture and very pleasing appearance. Inspections of the surface were repeated in October 1967 and March 1968. In March 1968 the surface was in good condition (Figure 43). Lateral cracks had developed at regular intervals and at a few locations a longitudinal crack had developed along the centerline.
Figure 43. View of US 31B, Nelson County, March 7, 1969.
Description: The Cloverport-McQuaddy Road (KY 105) from US 60 in Cloverport to KY 992

Length: 7.394 miles

Width: 18 feet

Contractor: Charles R. Allen Company, Inc., Louisville, Kentucky

Letting Date: April 21, 1967

Contract Quantities: Rock-Asphalt Mixture for Surfacing 2,585 tons
Class I, Binder for Leveling 7,185 tons
Class I, Type A Surface for Leveling 2,550 tons
Diluted SS-1h for Tack 8,200 gallons

Unit Bids: Rock-Asphalt Mixture $ 17.00 per ton
Class I Binder $ 7.60 per ton
Class I Type A Surface $ 7.80 per ton
Diluted SS-1h $ 0.25 gallon

Total Contract Amount $132,563.00

Pay Quantities: Rock-Asphalt Mixture 2,250.3 tons
Class I Binder 7,847.2 tons
Class I, Type A Surface 2,612 tons
Diluted SS-1h 7,597 gallons

Total Cost of Above Item $120,371.87
Total Cost of Contract $132,315.87

Surfacing Dates: August 1967

Plant Description: Hetherington-Berner Batch, Barber-Greene cold feed, Barber-Greene dust collector.

Plant Location: KY 992 near Hardinsburg, Kentucky

Approximate Average Haul Distance: 6 miles

Plant and Paving Operations: The rock-asphalt aggregate was freshly quarried material passing the 3/8-inch sieve. Asphalt cement (PAC 7) was added to the mix at a rate of 5.5 percent. Some difficulty was experienced with temperature control and appeared to be the result of frequent shutdowns when trucks were not available. A few loads of material out of the temperature tolerance were rejected the first day surface mix was produced. The plant foreman indicated that it was necessary to spend considerable effort in cleaning accumulations of material from the plant, when it was shutdown, in order to operate properly.
The existing roadway surface was badly deformed and considerable material was estimated for leveling. Leveling material overran the contract quantities and a reduction was made in the surface course thickness to keep the costs down. As a result, the surface course is very thin in some areas.

Performance: Inspections were made of the surface in October 1967 and in March 1968. Overall the surface was in good condition, having a fine texture and pleasing appearance (Figure 44). A few areas of base failure were noted about midway through the project. The edge of the surfacing was cracked at intervals throughout the length of the project.

Figure 44. KY 105, Breckinridge County, March 6, 1968.
KY 54, DAVIESS-OHIO COUNTIES
SP 30-57, SP 92-44

Description: The Owensboro-Fordsville Road (KY 54) from 0.234 miles northwest of Whitesville to the west city limits of Fordsville

Length: 10.116 miles

Width: 18 feet, 20 to 30 feet within Whitesville

Letting Date: April 21, 1967

Contractor: State Contracting and Stone Company, Inc., Hartford, Kentucky
(Subcontracted to Corum and Edwards, Inc.)

Contract Quantities: Rock-Asphalt Mixture for Surfacing 3,809 tons
Class I Binder for Leveling 8,995 tons
Class I, Type A Surfacing for Leveling 742 tons
Diluted SS-lh for Tack 11,420 gallons
(Project also included shouldering materials)

Unit Bids: Rock-Asphalt Mixture $17.50 per ton
Class I Binder $7.95 per ton
Class I, Type A Surface $8.50 per ton
Diluted SS-lh $0.25 per gallon

Total Contract Amount $180,736.75

Pay Quantities: (Based on estimate of October 27, 1967, not a final estimate)

Rock-Asphalt Mixture 3,554.7 tons
Class I Binder 9,435.8 tons
Class I, Type A Surface 1,091.9 tons
Diluted SS-lh 6,699 gallons

Total Cost of Above Items $148,177.75
Total Cost of Contract $188,161.76
Liquidated Damages $1,550.00

Surfacing Dates: September 1967

Plant Description: Barber-Greene Continuous, 160 tons per hour capacity

Plant Location: KY 54 near junction with KY 261

Approximate Average Haul Distance: 6 miles

Plant and Paving Operation: No difficulties were encountered at the plant in producing the mix. The cold feed was minus 3/8-inch material produced from
freshly quarried ledge rock. Asphalt cement (PAC 5) was added to the mix at a rate of 5.5 percent—maintaining the total bitumen content near 9.5 percent. Dow-Corning 200 fluid (silicone) was added to the asphalt cement at a rate of one to two ounces per 5000 gallons of asphalt cement.

Good temperature control was maintained at the plant. The material left the plant at a temperature of 245°F-285°F. The dryer was equipped with a steam generated burner and its operation was constantly monitored.

Initially some difficulty was experienced in laying the material. A Ceder Rapids paver was first used to lay the material. A deep continuous tear was left in the center of the mat. The paver screed was changed and this reduced the severity of the tear. The problem was fully eliminated when a Barber-Greene paver with a tamping bar was used.

Performance: Inspections were made of the surface in October 1967 and in March 1968. The surface was in good condition and had a fine-textured, pleasing appearance (Figure 45). The tears made by the paver screed were still apparent. The torn areas were limited to the westernmost 1.5 miles at Whitesville.

Figure 45. KY 54, Daviess-Ohio Counties, March 6, 1968.
US 431, McLEAN COUNTY
SP GROUP 15 (1967)
SP 75-202, SP 75-122

Description: The Central City-Owensboro Road (US 431) from the northeast city limits of Island to the east city limits of Livermore

Length: 3.107 miles

Width: 22 feet, 20 feet in Livermore

Letting Date: April 21, 1967

Contractor: State Contracting and Stone Company, Inc., Hartford, Kentucky
(Subcontracted to Corum and Edwards Inc.)

Contract Quantities: Rock-Asphalt Mixture for Surfacing 3,130 tons
Class I, Type A surface for Leveling 1,873 tons
Diluted SS-1h for Tack 4,164 gallons
(Project also included shouldering materials)

Unit Bids: Rock-Asphalt Mixture $ 19.00 per ton
Class I, Type A Surface $ 8.25 per ton
Diluted SS-1h $ 0.25 per gallon

Total Contract Amount $55,562.75

Pay Quantities: (Based on estimate of October 27, 1967, not a final estimate)

Rock-Asphalt Mixture 1,294.6 tons
Class I, Type A Surface 1,943.5 tons
Diluted SS-1h 2,136 gallons

Total Cost of Above Items $41,165.28
Total Cost of Contract $53,251.03
Liquidated Damages $ 1,350.00

Surfacing Dates: October 1967

Plant Description: Barber-Greene Continuous

Plant Location: KY 54 near junction with KY 261

Approximate Average Haul Distance: 31 miles
Plant and Paving Operations: The same plant and paving equipment were used on this project and on the KY 54 project in Daviess-Ohio Counties. No problems in plant or paving operations were reported.

Performance: Inspections were made of the project in October 1967 and in March 1968. The surface had a fine-textured, pleasing appearance and was in good condition throughout its length (Figure 46). Reflection cracks from the underlying concrete pavement were apparent within Livermore.

Figure 46. US 431, McLean County, March 6, 1968.
Plant and Paving Operations: The same plant and paving equipment were used on this project and on the KY 54 project in Daviess-Ohio Counties. No problems in plant or paving operations were reported.

Performance: Inspections were made of the project in October 1967 and in March 1968. The surface had a fine-textured, pleasing appearance and was in good condition throughout its length (Figure 46). Reflection cracks from the underlying concrete pavement were apparent within Livermore.

Figure 46. US 431, McLean County, March 6, 1968.
US 231, BUTLER COUNTY
SP 16-156, SP 16-296

Description: The Morgantown-Bowling Green Road (US 231) from the old northwest city limits of Morgantown to the Warren County line

Length: 11.331 miles

Width: 19 feet, 20 feet in Morgantown

Contractor: R. E. Gaddie Inc., Bowling Green, Kentucky

Contract Quantities:
- Rock-Asphalt Mixture for Surfacing: 4,225 tons
- Class I, Type A Surface for Leveling: 6,704 tons
- Diluted SS-1h for Tack: 20,115 gallons

Unit Bids:
- Rock-Asphalt Mixture: $15.35 per ton
- Class I, Type A Surface: $8.85 per ton
- Diluted SS-1h: $0.25 per gallon

Total Contract Amount: $129,212.90

Pay Quantities: (Based on estimate of July 17, 1968, not a final estimate)

- Rock-Asphalt Mixture: 4,074 tons
- Class I, Type A Surface: 6,622 tons
- Diluted SS-1h: 8,709 gallons

Total Cost of Above Items: $123,317.85
Total Cost of Contract: $133,417.65

Surfacing Dates: June 1968

Plant Description: Hetherington-Berner Batch, 4000-pound capacity

Plant Location: Gary Brothers Quarry on US 231 near the Warren County line

Approximate Average Haul Distance: 6 miles

Plant and Paving Operations: No difficulties were reported in plant-mixing or placing the material. This particular plant was used on two previous rock-asphalt surfacings--US 31, Warren County, and KY 101 and KY 259, Edmonson-Warren Counties. Considerable difficulty was experienced on the US 31W project but experience in handling the material apparently eliminated the problems. The general comment has been that this is the best appearing hot-mix, rock-asphalt surfacing placed to date. Asphalt cement was added at a rate of 4.7 percent.

A portion (166 tons) of the cold-feed material had been pre-roasted by the Gripstop Corporation in a dryer at their plant site in Edmonson County.
Thus this material was heated twice before mixing with asphalt cement. The following test results were obtained by District Maintenance:

**Cold Feed Material**

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<th>Percent Passing</th>
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Bitumen Content—4.8%

**Finished Hot-Mix**

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Bitumen Content—8.8%

The material was heated to a temperature of 300 to 320°F. No differences were noted in laying or handling between the pre-roasted and the usual cold-feed material. This material was laid on the northbound lane between Sta 52+00 and Sta 100+00. Station 0+00 is at the Warren County line.

**Performance:** On July 7, 1968 an inspection was made and it was noted that the overall condition was good. A slight bumpiness was noted, but it is anticipated that this will smooth out under traffic. Approximately one mile of the 11.5 miles consisted of the heat-treated rock asphalt (Figure 47). It is not possible to distinguish this section from the remaining portion.
Figure 47. US 231, Butler County, July 7, 1968.
APPENDIX B

LABORATORY TEST RESULTS AND
SKID TEST RESULTS OF
TABULATIONS
### TABLE 1

**SUMMARY OF MARSHALL TEST RESULTS**

<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Asphalt Content (percent)</th>
<th>Stability (pounds)</th>
<th>Flow (0.01 inch)</th>
<th>Unit Weight (lbs/cu ft) in Mix</th>
<th>Weight in Aggregate</th>
<th>Percent Void in Mix</th>
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*Sample overheated, not included in average for project.*
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<th>Ductility at 77°F (%)</th>
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<td>1.52</td>
<td>16</td>
</tr>
</tbody>
</table>

Notes:

1 Penetration at 77°F, 100 cm = 1 sec.
2 Two specimens were obtained from each truck sampled.
3 Specific gravity at 77°F = 1.054; Ash content = 0.35%
4 Percent asphalt extracted from 50-gram samples of cold-feed material using Carbon Disulfide = 4.05%
5 Carbon Tetrachloride = 3.70%
6 Benzene = 92%
7 Viscosity test performed on a blend of bitumen recovered from truck samples obtained on August 16 and 17, 1967.
8 Viscosity test performed on a blend of bitumen recovered from hot-bin samples obtained on August 25 and 28, 1967.
9 Viscosity test performed on combined bitumen recovered from all material sampled on June 20, 1967.
### TABLE 5

**SUMMARY OF SKID-TEST RESULTS**

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Lane</th>
<th>Coefficient of Friction</th>
<th>1965 ADT</th>
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</tr>
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<td>Both</td>
<td>0.70</td>
<td>0.62</td>
</tr>
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<td>0.64</td>
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<td>US 41</td>
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<td>5900</td>
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<td>0.62</td>
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<td>Christian County</td>
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<td></td>
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<td>2380</td>
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<td>0.68</td>
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<tr>
<td>Warren County</td>
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<td></td>
<td></td>
<td>1170</td>
</tr>
<tr>
<td>KY 80, Adair-Metcalfe Counties</td>
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<td>0.66</td>
<td>0.70</td>
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<tr>
<td>US 79</td>
<td>Todd County</td>
<td>Both</td>
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<td>0.64</td>
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<tr>
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<td>KY 1827</td>
<td>Edmonson County</td>
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<td>0.64</td>
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<tr>
<td>(Rollin Dam Road)</td>
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APPENDIX C

SPECIAL PROVISIONS

FOR

CRUSHED BITUMINOUS SANDSTONE SURFACE
(KENTUCKY ROCK ASPHALT)

1. Special Provision Dated March 29, 1966
2. Special Provision No. 24-A, Dated March 20, 1967
COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 24

FOR

CRUSHED BITUMINOUS SANDSTONE SURFACE
(KENTUCKY-ROCK-ASPHALT)
(Experimental)

These Special Provisions shall be applicable only when indicated on proposals or bid invitations and, when so indicated, shall supersede any conflicting requirements of the Department's 1965 Standard Specifications ..., and are complemented with the applicable provisions of Section 306 thereof.

I. DESCRIPTION

This work shall consist of furnishing and placing paving mixtures complying with the material requirements and processed as hereinafter described, without alternate types of materials or processes, for use in the construction of surface courses on existing bases or pavements as set forth in prefacing plans, proposals, or bidding invitations. The mixture shall consist essentially of crushed, bituminous sandstone (Kentucky Rock Asphalt) enriched with an optimum quantity of asphalt cement. Construction procedures and finished work shall conform with the further stipulations respectively listed hereunder. A brief summary follows:

1. The aggregate shall be heated to not less than 240° F. nor hotter than 325° F.

2. Asphalt cement shall be heated to not less than 225° F. nor hotter than 325° F.

3. Asphalt and aggregate shall be combined in optimum proportions while hot and shall be blended together uniformly.

4. The mixture shall be spread on the road and compacted while hot and workable.

5. The finished work shall conform to the lines, grades, and cross-sections specified.
6. The work shall also include the surfacing of approaches at road and street intersections and approaches or aprons at entrances when and as directed by the Engineer.

II. MATERIALS

A. Aggregate. The aggregate shall consist of crushed, bituminous, quartzy sandstone having uniform quality and hardness. It shall be free of dirt and debris and shall meet the following requirements.

1. Bitumen Content: The raw aggregate shall contain not less than 4 per cent natural bitumen by weight. Bitumen content may be determined by extraction.

2. Gradation: The size-gradation shall comply with the following-listed requirements:

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<thead>
<tr>
<th>Sieve Size</th>
<th>*Per Cent Passing</th>
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<tbody>
<tr>
<td>1/2-in.</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>40 - 100</td>
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<tr>
<td>No. 100</td>
<td>0 - 15</td>
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</table>

*Based on extracted sample

Note: Closer tolerances than these may be required in order to establish a suitable job-mix formula.

B. Asphalt Binder. Unless noted otherwise, asphalt cement enrichment shall consist of PAC-5 (Article 621.4.0).

C. Bituminous Tack Coat. Tack coats, when required, shall be of the type and in the quantities designated in the plans or proposals for the work and shall be applied in the manner described in Section 301 of the "Standards" and as prescribed by the Engineer. If the type and quantities are not designated elsewhere, to be otherwise, tack materials shall be SS-1h (Article 621.6.0) diluted with an equal volume of potable water. The diluted emulsion shall be applied at a nominal rate of 0.1 gallon per square yard of surface; however, the Engineer may adjust the proportions and rate of application on the site as needed or require reapplication.

D. Paving Mixture. The optimum proportions of aggregate and asphalt and the mixture formula shall be determined and established by the Engineer. The asphalt content shall be not less than 7 per cent and not more than 10 per cent by weight of the mixture and shall be controlled within these limits as directed by the Engineer.
III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. (Article 306.3.1)

B. Plant and Equipment. (Article 306.3.2, as applicable)

C. Preparation of Mixtures. (Article 306.3.3, as applicable--excluding Paragraphs A and B thereof.)

D. Preparation of Existing Surfaces. (Article 306.3.5, as applicable)

E. Spreading and Finishing. (Article 306.3.6, as applicable)

F. Compaction. (Article 306.3.7, as applicable)

IV. METHOD OF MEASUREMENT

The crushed bituminous sandstone mixture will be weighed in accordance with Article 1.9.1 and the weight of the added asphalt cement will be deducted therefrom.

The asphalt cement and the bituminous tack material will be measured in gallons as specified in Section 621.

V. BASIS OF PAYMENT

The accepted quantities thus measured will be paid at contract unit price bid per ton for "Bituminous Concrete Mixture" exclusive of the added asphalt cement, per gallon for "Asphalt Cement," and per gallon for "Bituminous Tack Material" as blended with water, which payment shall be full compensation for furnishing, hauling and placing all materials, for cleaning and all necessary preparations of base, the burning and necessary preparation of old bituminous pavements adjacent to the new construction, for the making of proper joints, for the disposal of all surplus materials, for furnishing, processing, placing, and rolling of the bituminous mixtures and materials, and for all labor, equipment, tools and incidentals necessary to complete the work specified.

APPROVED  March 29, 1966

A. O. NEISER
PROJECT MANAGEMENT ENGINEER
COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 24-A

FOR

CRUSHED BITUMINOUS SANDSTONE SURFACE
(KENTUCKY ROCK ASPHALT)
(Experimental)

These Special Provisions shall be applicable only when indicated on proposals or bidding invitations and, when so indicated, shall supersede any conflicting requirements of the Department's 1965 Standard Specifications for Road and Bridge Construction, and are complemented with the applicable provisions of Section 306 thereof.

I. DESCRIPTION

This work shall consist of furnishing and placing paving mixtures complying with the material requirements and processed as herein-after described, without alternate types of materials or processes, for use in the construction of surface courses on existing bases or pavements as set forth in the plans, proposals, or bidding invitations. The mixture shall consist essentially of crushed, bituminous sandstone (Kentucky Rock Asphalt) enriched with an optimum quantity of asphalt cement. Construction procedures and finished work shall conform with the further stipulations listed herein.

The work shall also include the surfacing of approaches at road and street intersections and approaches or aprons at entrances, when and as directed by the Engineer. If not specified and unless otherwise directed by the Engineer, the bituminous mixture for this work shall be Bituminous Concrete Surface, Class I, which shall conform to Section 306. Fine aggregates may be natural, crushed, or conglomerate sands meeting the requirements of Section 611 for quality.

II. MATERIALS

A. Aggregate. The aggregate shall consist of crushed, bituminous, quartzy sandstone having uniform quality and hardness. It shall be free of dirt and debris and shall meet the following requirements:

1. Bitumen Content: The raw aggregate shall contain not less than 3.5 per cent of natural bitumen by weight. Bitumen content shall be determined on the aggregate.
as produced (without additional crushing or fracturing) by extraction with trichloroethylene used as the solvent.

2. Gradation: The size-gradation of the extracted aggregate sample shall comply with the following requirements:

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<thead>
<tr>
<th>Sieve Size</th>
<th>Per Cent Passing</th>
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<tbody>
<tr>
<td>1/2 inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>40-100</td>
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<tr>
<td>No. 100</td>
<td>0-15</td>
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</tbody>
</table>

3. Silica: The extracted aggregate shall contain not less than 90 per cent Silica (SiO₂) as determined by chemical analysis.

B. Asphalt Binder. Asphalt cement enrichment shall consist of PAC-5 (Article 621.4.0) as specified on the plans or proposals.

C. Bituminous Tack Coat. Tack coats shall be of the type and in the quantities designated in the plans or proposals for the work and shall be applied in the manner described in Section 301 and as prescribed by the Engineer.

D. Admixture. A moisture controlling admixture such as silicone fluid (dimethyl siloxane polymer) shall be furnished by the Contractor to be blended with the mix when and as directed by the Engineer. The silicone shall be of a type approved by the Department and shall be from a source approved by the Department.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. No rock asphalt surface shall be placed between September 30 and May 1, nor when the air temperature is below 60° F., except by written permission of the Engineer. No rock asphalt shall be placed when the underlying course is wet or when other weather conditions are unsuitable.

B. Plant and Equipment. Article 306.3.2, except as noted below:

1. Screens: Only one screen, a scalping screen of the necessary size, will be required.

2. Bins: The plant shall include a storage bin of sufficient capacity to supply the mixer, when it is operating at full capacity, with no undue periods of waiting for aggregate. The outlet gate on the bin shall cut off quickly and completely and shall be designed and constructed so there will be no leakage when closed.
3. Thermometric Equipment: Article 306.3.2-C-8, excluding paragraphs c. and d., therefore which shall read as follows:

c. A certified thermometer, visible to the plant operator responsible for controlling the aggregate temperature, shall be installed at the aggregate discharge from the drier.

d. A recording thermometer or pyrometer shall be installed with the actuator at the aggregate discharge from the drier and the recording device mounted free of vibration.

4. Dust Collectors: The plant shall be equipped with an effective dust collector. Material collected must be returned to the mix unless wasting is permitted by the Engineer.

5. Field Laboratory: Article 306.3.2-I. In addition, each field laboratory where rock asphalt will be tested shall be provided with a hood and exhaust fan arrangement to remove harmful solvent fumes and to provide adequate ventilation.

C. Preparation of Mixture.

1. Composition of Mixtures: The rock asphalt aggregate and asphalt cement shall be combined in such proportions that the total bitumen content will be not less than 8 per cent and not more than 11 per cent. The asphalt cement enrichment shall be not less than 4 per cent nor more than 6 per cent. No direct payment shall be made for the asphalt cement enrichment. A minimum total bitumen content within the specified limits shall be established by the Engineer for each project. Mixtures which contain less than the minimum total bitumen content as established by the Engineer shall be adjusted by increasing the asphalt cement enrichment.

2. Preparation of Aggregate: The aggregate shall be deposited in the cold elevator at a rate to insure correct and uniform temperature control of the heating and drying operation. The aggregate shall be heated to a uniform temperature between 240° F. and 325° F. as measured at the point of discharge from the drier. Any aggregate heated in excess of 325° F. shall be rejected.
3. Preparation of Asphalt Cement: Article 306.3.3-C

4. Preparation of Mixtures: Article 306.3.3-D as applicable.

5. Temperature Requirements: Article 306.3.3-E

D. Preparation of Base. The existing surface shall be swept clean of all foreign material by means of hand brooms and mechanical sweepers. Patching, wedging, and leveling courses of bituminous concrete (Class I) shall be applied as directed by the Engineer and in the quantities as stated on the contract plans and proposals. Bituminous tack coat shall be applied in accordance with Section 301.

E. Spreading and Finishing. Spreading and finishing shall be in accordance with Article 306.3.6, except as hereinafter provided.

1. Continuous Paver Operation: The plant procedure and the power speed shall be synchronized in such a manner which will permit the paver to travel in a uniform continuous forward speed. The paver shall engage the hauling trucks while traveling forward. Every effort shall be made to keep the paver moving continuously. The paver should be permitted to stop only when a plant or paver breaks down or when some emergency or unavoidable condition exists.

2. Entrances and Crossovers: Entrances, crossovers, and other areas inaccessible to the paver which must be spread by hand, whether constructed of crushed bituminous sandstone surface or of other surface mixture, shall be constructed as a separate operation. The material for these areas shall be placed directly from the traveling trucks. The paver shall not be stopped side plates removed, and the material for these areas allowed to spill out to the side, or the paver shall not be stopped and material for these areas shoveled from the hopper.

F. Compaction. Compaction shall be in accordance with Article 306.3.7, as applicable, except that entrances, crossovers, and other inaccessible areas spread by hand may be compacted with a roller weighing not less than three tons.

G. Leveling and Patching. Leveling and patching shall be performed in a manner, with the designated equipment and with the materials, as prescribed on the plans or in the proposal, or as directed by the Engineer.
H. Surface Tolerances. Surface tolerances shall be in accordance with Article 306.3.9 as applicable.

I. Maintenance and Protection. Maintenance and protection shall be in accordance with Article 306.3.10.

IV. METHOD OF MEASUREMENT

The crushed bituminous sandstone and bituminous concrete mixtures shall be weighed in accordance with Article 1.9.1.

The bituminous tack material shall be measured in gallons as specified in Section 621.

V. BASIS OF PAYMENT

The accepted quantities thus measured will be paid for at the contract unit price per ton for "Bituminous Concrete Mixture" for patching, wedging, and leveling and for "Crushed Bituminous Sandstone Mixture" for the surface course, complete in place, and per gallon for "Bituminous Tack Material," which payment shall be full compensation for furnishing, hauling and placing all materials, for cleaning and all necessary preparations of base, the burning and necessary preparation of old bituminous pavements adjacent to the new construction, for the making of proper joints, for the disposal of all surplus materials, for furnishing, processing, placing, and rolling of the bituminous mixtures and materials, and for all labor, equipment, tools and incidentals necessary to complete the work specified.

APPROVED March 20, 1967

A. O. Neiser
STATE HIGHWAY ENGINEER
COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 24-B

FOR

CRUSHED BITUMINOUS SANDSTONE SURFACE
(KENTUCKY ROCK ASPHALT)

This Special Provision shall be applicable only when indicated on
the plans, in the proposal, or in the bidding invitation and, when
so indicated, shall supersede any conflicting requirements of the
Department's 1965 Standard Specifications for Road and Bridge Con­
struction, and is complemented with the applicable provisions of
Section 306 thereof.

I. DESCRIPTION

This work shall consist of furnishing and placing paving mixtures
complying with the material requirements and processed as herein­
after described, without alternate types of materials or processes,
for use in the construction of surface courses on existing bases or
pavements as set forth by the plans, proposal, or bidding invita­
tion. The mixture shall consist essentially of crushed bituminous
sandstone (Kentucky Rock Asphalt), enriched with an optimum quantity
of asphalt cement. Construction procedures and finished work shall
conform with the further stipulations listed herein.

The work shall also include the surfacing of approaches at road
and street intersections and approaches or aprons at entrances, when
and as directed by the Engineer. If not specified and unless other­
wise directed by the Engineer, the bituminous mixture for this work
shall be Bituminous Concrete Surface, Class I, which shall conform
to Section 306. Fine aggregate for the bituminous concrete may be
natural, crushed, or conglomerate sand meeting the requirements of
Section 611 for quality.

II. MATERIALS

A. Aggregate. The aggregate shall consist of crushed, bituminous,
quartzy sandstone having uniform quality and hardness. It shall be
free of dirt and debris and shall meet the following requirements:

1. Bitumen Content: The raw aggregate shall contain not
   less than 3.5 per cent of natural bitumen by weight.
   Bitumen content shall be determined on the aggregate
as produced (without additional crushing or fracturing) by extraction with trichloroethylene used as the solvent.

2. Gradation: The size-gradation of the extracted aggregate shall comply with the following requirements:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Per Cent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>40-100</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-15</td>
</tr>
</tbody>
</table>

3. Silica: The extracted aggregate shall contain not less than 90 per cent Silica \( (\text{SiO}_2) \) as determined by chemical analysis.

B. Asphalt Binder. Asphalt cement enrichment shall consist of PAC-5 (Article 621.4.0) as specified on the plans or in the proposal.

C. Bituminous Tack Coat. Tack coats shall be of the type and in the quantities designated on the plans or in the proposal for the work and shall be applied in the manner described in Section 301 and as prescribed by the Engineer.

D. Admixture. A moisture controlling admixture such as silicone fluid (dimethyl siloxane polymer) shall be furnished by the Contractor to be blended with the mix when and as directed by the Engineer. The silicone shall be of a type approved by the Department and shall be from a source approved by the Department.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. No crushed bituminous sandstone surface shall be placed between September 30 and May 1, nor when the air temperature is below 60° F., except by written permission of the Engineer; neither shall it be placed when the underlying course is wet or when other weather conditions are unsuitable.

B. Plant and Equipment. Article 306.3.2, except as noted below:

1. Screens: Only one screen, a scalping screen of the necessary size, will be required.

2. Bins: The plant shall include a storage bin of sufficient capacity to supply the mixer, when it is operating at full capacity, with no undue periods of waiting for aggregate. The outlet gate on the bin shall cut off quickly and
completely and shall be designed and constructed so there will be no leakage when closed.

3. Thermometric Equipment: Article 306.3.2-C-8, excluding paragraphs c. and d., which are replaced with the following paragraphs:

c. A certified thermometer, visible to the plant operator responsible for controlling the aggregate temperature, shall be installed at the aggregate discharge from the drier.

d. A recording thermometer or pyrometer shall be installed with the actuator at the aggregate discharge from the drier and the recording device mounted free of vibration.

4. Dust Collectors: The plant shall be equipped with an effective dust collector. Material collected must be returned to the mix unless wasting is permitted by the Engineer.

5. Field Laboratory: Article 306.3.2-I. In addition, each field laboratory where rock asphalt will be tested shall be provided with a hood and exhaust fan arrangement to remove harmful solvent fumes and to provide adequate ventilation.

C. Preparation of Mixture.

1. Composition of Mixtures: The rock asphalt aggregate and asphalt cement shall be combined in such proportions that the total bitumen content will be not less than 8 per cent and not more than 11 per cent. The asphalt cement enrichment shall be not less than 4 per cent nor more than 6 per cent. No direct payment shall be made for the asphalt cement enrichment. A minimum total bitumen content within the specified limits shall be established by the Engineer for each project. Mixtures which contain less than the minimum total bitumen content as established by the Engineer shall be adjusted by increasing the asphalt cement enrichment.

2. Preparation of Aggregate: The rock asphalt aggregate shall be deposited in the cold elevator at a rate to insure correct and uniform temperature control of the heating and drying operation. The aggregate shall be heated to a uniform temperature between 240° F. and 325° F. as measured at the point of discharge from the drier. Any aggregate heated in excess of 325° F. shall be rejected.
D. Preparation of Base. The existing surface shall be swept clean of all foreign material by means of hand brooms and mechanical sweepers. Patching, wedging, and leveling courses of bituminous concrete (Class I) shall be applied as directed by the Engineer and in the quantities as stated on the plans or in the proposal. Bituminous tack coat shall be applied in accordance with Section 301.

E. Spreading and Finishing. Spreading and finishing shall be in accordance with Article 306.3.6, except as hereinafter provided.

1. Continuous Paver Operation: The plant procedure and the paver speed shall be synchronized in such a manner which will permit the paver to travel in a uniform continuous forward speed. The paver shall engage the hauling trucks while traveling forward. Every effort shall be made to keep the paver moving continuously. The paver should be permitted to stop only when a plant or paver breaks down or when some emergency or unavoidable condition exists.

2. Entrances and Crossovers: Entrances, crossovers, and other areas inaccessible to the paver which must be spread by hand, whether constructed of crushed bituminous sandstone or other surface mixture, shall be constructed as a separate operation. The material for these areas shall be placed directly from the traveling trucks. The paver shall not be stopped to remove the side plates to allow the material for these areas to spill out the side, neither shall the paver be stopped and material for these areas shoveled from the hopper.

F. Compaction. Compaction shall be in accordance with Article 306.3.7, as applicable, except that entrances, crossovers, and other inaccessible areas spread by hand may be compacted with a roller weighing not less than three tons.

G. Leveling and Patching. Leveling and patching shall be performed in a manner, with the designated equipment and with the materials, as prescribed on the plans or in the proposal, or as directed by the Engineer.
H. Surface Tolerances. Surface tolerances shall be in accordance with Article 306.3.9 as applicable.

I. Maintenance and Protection. Maintenance and protection shall be in accordance with Article 306.3.10.

IV. METHOD OF MEASUREMENT

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The bituminous tack material shall be measured in gallons as specified in Section 621.

V. BASIS OF PAYMENT

The accepted quantities thus measured will be paid for at the contract unit price per ton for "Bituminous Concrete Mixture" for patching, wedging, and leveling and for "Crushed Bituminous Sandstone Mixture" for the surface course, complete in place, and per gallon for "Bituminous Tack Material," which payment shall be full compensation for furnishing, hauling, and placing all materials; for cleaning and all necessary preparations of base; for the making of proper joints; for the disposal of all surplus materials; for furnishing, processing, placing, and rolling of the bituminous mixtures and materials; and for all labor, equipment, tools and incidentals necessary to complete the work specified.

APPROVED August 15, 1967

A. O. Neiser
STATE HIGHWAY ENGINEER
MOUNTARDEER BOAT RAMP ROAD
AND
NOLIN DAM-DEMUNBRUN'S STORE ROAD
PERFORMANCE REPORT

APPENDIX D
The Nolin Dam Road, constructed during the summer and fall of 1965, was the first hot-mix, rock-asphalt surfacing project. An account of the construction and performance through March 1966 has been reported (3). The project involved construction of a lean rock-asphalt base (no added petroleum asphalt) 3-1/2 inches thick and a hot-mixed, enriched, rock-asphalt surface course 1-1/2 inches thick placed on the existing traffic bound surfacing.

The last previously reported performance inspection was made March 23, 1966. At that time rather extensive cracking had occurred in the outer wheel tracks. It was noted then that the cracking tended to be concentrated in areas of poor subgrade support, primarily cut sections. The developer, Reynolds and Associates, had sealed most of the cracked areas with a fine-graded rock asphalt.

Further performance inspections were made in June and October 1966 and in March and September 1967. Following is a discussion of the condition of the surface and of the repairs made at the time of each inspection:

June 1966: Many of the cracked areas (Figure 48) had broken up. The Developer was then engaged in making repairs to the failed areas. Repairs were made by removing the rock-asphalt base and surface courses and a portion of the soft subgrade. The excavated areas was then filled with crushed limestone to the level of the top of the base course. Hot-mix rock asphalt was then used as the surfacing. These repairs were generally too limited in extent and proved to be inadequate. Many of the patched areas deformed badly and additional failures occurred immediately adjacent to the repairs.

October 1966: During the fall months, District Maintenance made temporary repairs to the larger failed areas (Figure 49) by removing the hot-mix surface, scarifying the balance of the base and allowing it to dry out, and then applying No. 610 limestone aggregate to the level of the finished surface. These repairs were made to keep the roadway in a reasonable riding condition until more extensive repairs could be performed the following construction season.

March 1967: A rather detailed inspection was made to determine the extent and general location of the failures (Figure 50). It was determined that approximately 18 percent of the surface area was badly cracked or broken up. The areas repaired during the fall of 1966 were, of course, included in the estimate as failed areas.

September 1967: In the fall of 1967, District Maintenance made extensive repairs to the roadway. The broken areas were scarified and excavated. Drains were constructed in some of the excavated areas. The area was then primed. Cold-mix base course, consisting of No. 7 limestone and emulsion, was then placed at a rate of 150 pounds per square yard. A
Figure 48. Nolin Dam Road, June 14, 1966. Note the deformed and cracked areas near the edges of the pavement.

Figure 49. Nolin Dam Road, October 17, 1966.
cold-mix surface course, consisting of No. 9 limestone and emulsion, was then applied to bring the repaired area up to the level of the surrounding surface. A chip seal was then placed on all of the roadway surface which had not been repaired (Figure 51). To allow the cold mixes ample time to cure, the repaired areas were not sealed. It is planned to seal the full surface area during the 1968 construction season.

The performance of this experimental surfacing, as a whole, was poor. The apparent cause of the severe distress was water, both subsurface and surface water, entering the lean rock-asphalt base course and thereby causing the base course material to lose cohesion and bearing strength. The lean rock-asphalt base, bitumen content 4.4 percent, is very porous and saturates readily. Initially, the distress (deformation of the pavement and cracking of the surface) tended to be concentrated along the outer wheel tracks of the pavement and in cut sections. It is postulated that surface water initially entered the base course at the pavement edge and subsurface water entered the base course by drainage along rock strata in the cut sections. Once the surface was cracked in these areas, the damage progressed in extent with further infiltration of water.
Figure 50. Nolin Dam Road, March 22, 1967. The broken sufracing was removed and replaced with limestone aggregate.

Figure 51. Nolin Dam Road, March 7, 1968. During the fall of 1967, the failed areas were repaired with cold mix and a seal coat was placed over the area which was not repaired.
MOUTARDIER BOAT RAMP ROAD

The Moutardier Boat Ramp Road was constructed in October 1964 when a lean rock-asphalt base (504 pounds per square yard) was placed on the newly constructed grade. The compacted base was immediately sealed with SS-1h emulsion and fine-graded lean rock asphalt. A report on the construction of this base and its performance through March 1966 has been made (3). During the 1966 construction season, a Class I, Type A surfacing was placed on the roadway by contract. An inspection was made of the surface in April 1967 and the roadway surface was in good condition. There was one small area of cracking as shown in Figure 52. An overall view of the roadway is shown in Figure 53.

A recent inspection was made in March 1968. The westernmost 0.1 mile of the project was badly cracked and beginning to break up. In the remaining 0.7 mile of the roadway, minor rutting was observed and there was one limited area of cracking.
Figure 52. Moutardier Boat Ramp Road, April 1967. This was the only cracked area in the surface.

Figure 53. Moutardier Boat Ramp Road, April 1967.