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Kentucky Rock Asphalt Bases and Hot-Mix Surfaces; Experimental Construction

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MEMORANDUM

TO: W. B. Drake, Assistant State Highway Engineer
   Chairman, Kentucky Highway Research Committee

SUBJECT: Research Report (Interim); "Kentucky Rock Asphalt Bases and Hot-Mix Surfaces; Experimental Construction"; KYHPR 64-10; HPR-1(1), Part II

The attached report is the third of a series concerned with rock-asphalt experiments. The first experiments involved nominal additions of crushed, raw, lean rock-asphalt to existing traffic-bound roads; the second involved greater thicknesses of raw rock-asphalt bases and seal coats; the third and present one is concerned principally with a raw rock-asphalt base covered with a hot-mixed rock-asphalt surface. Hot-mixed rock-asphalt represents significant progress in the re-development of a high-type surfacing material. As you know, a series of eleven rock-asphalt resurfacing and de-slicking projects is planned for the 1966 season; they will undoubtedly occupy our attention during the immediate future; however, we will continue to follow the performance of each of the experimental roads already built -- those which have not performed well may require some remedial work.

Respectfully submitted,

Jas. H. Havens
Director of Research
Secretary, Research Committee

JHH:em
Attachment
cc: Research Committee
   A. O. Neiser
   R. O. Beauchamp
   R. A. Johnson
   T. J. Hopgood
KENTUCKY ROCK ASPHALT BASES AND HOT-MIX SURFACES; EXPERIMENTAL CONSTRUCTION

AN INTERIM REPORT
KYHPR-64-10; HPR-1(1)

by

Robert L. Florence
Research Engineer

Division of Research

DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

in cooperation with the
BUREAU OF PUBLIC ROADS
U. S. Department of Commerce

132 Graham Avenue
Lexington, Kentucky

April, 1966
INTRODUCTION

The objectives of this study are 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 re-development of the material for use as hot-mixed, hot-laid, skid-resistant surface course for higher echelon roads. The material is a natural asphaltic-sandstone which occurs in considerable abundance in Edmonson County and in other outcrops of Pottsville sandstones bordering the eastern rim of the Western Kentucky Coal Fields. From 1900 until the 1950's, rock-asphalt was used extensively in Kentucky and elsewhere for road surfacing and was regarded widely as a premium-grade material -- providing a soft-riding, sand-textured, skid-resistant pavement. The crushed, natural product -- traditionally containing 7.2 percent natural bitumen -- was characteristically tender for a long time after it was spread on the road; consequently, it could not reliably withstand modern traffic. In the past, several attempts were made to process and pre-roast the material to overcome this deficiency, but none proved to be wholly desirable. Production was discontinued in 1956. Re-development began in 1962 with trial uses of lower
grade (lean) materials as traffic-bound bases and surfaces on minor roads. These early experiments did not produce favorable performance; in some of the interim experiments, the material was up-graded with additions of liquid and emulsified asphalts; and, in other the raw base courses were sealed, a major development, recently, was the successful production of a hot-mixed, enriched, mixture processed through a conventional dryer, pugmill, etc. The raw aggregate consisted of crushed, graded, lean rock -- containing 4 percent or more indigenous bitumen.

This report supplements two earlier interim or progress reports (1)(2). Those reports recorded the construction and performance features of six experimental rock-asphalt roads. This report adds three case studies. In October, 1964, two additional test sections of rock-asphalt base were constructed: 1) the Moutardier Boat Ramp Road, which is designated as Test Section No. 7, and 2) the Brownsville Plant


Site Road, which is designated as Test Section No. 8,
Special Provisions, which were prepared for the construction
on the Moutardier Boat Ramp Road are shown in Appendix I.
In June, 1965, additional lean rock-asphalt base was paver-
laid on the Sunfish-Independence School Road (Test Section
No. 1) and on the Dog Creek-Union Light Road (Test Section
No. 2). Each of these paver-laid bases were then sealed
with liquid asphalt and fine-graded, lean rock-asphalt.
The Special Provisions which governed the work on the
Moutardier Road also governed the work on these projects
(Appendix I).

The major experiment reported here is the Nolin Dam
Road (Test Section No. 9), 8.367 miles in length, which was
paved with a lean rock-asphalt base course and a hot-mix
surface course incorporating lean rock-asphalt as aggregate.
Special Provisions governing this work are presented as
Appendix II. The construction began on this project in
August, 1965, and was completed in November, 1965. This,
of course, is the longest and most elaborate of the experi-
mental sections constructed to date; it has proven to be
the most successful -- and, therefore, the most significant.
As an outgrowth of this project, interest in rock-asphalt
for high-type surfacing and resurfacing has been renewed.
A series of contract resurfacing projects (See Appendix III), utilizing more than 50,000 tons is planned for the 1966 construction season. The rate of application will be nominally 85 pounds per square yard and the mixture will contain approximately 8.5 percent asphalt. A copy of the specifications applicable to this work is included in Appendix III.

Each of the aforementioned experimental projects are described and discussed herein. A Summary of Observations pertaining to all of the experimental projects discussed in this report are presented at the end of the report.
CONSTRUCTION AND PERFORMANCE
OF
THE MOUTARDIER BOAT RAMP ROAD (TEST SECTION NO. 7)
AND
THE BROWNSVILLE PLANT SITE ROAD (TEST SECTION NO. 8)

(Experimental Lean Rock Asphalt Bases)
Figure 1. Test Section No. 7. Edmonson County
The Moutardier Boat Ramp Road (SF 31-688-181)
Test Section No. 7

County: Edmonson
Road: Moutardier Boat Ramp Road
Project: SF 31-668-1S1
Length: 0.80 miles
Width: 18 feet

Initial Condition: New grade, twenty five percent of surface area unstable.

Treatment: 504 lbs./sq. yd. of crusher-run (passing 1-in. sieve) rock-asphalt. A double seal-coat; total of 0.20 gals./sq. yd. of SS-lh covered with 28 lbs./sq. yd. of sand-size rock asphalt.

Procedure: Placed rock-asphalt on subgrade in two lifts with a Barber-Greene paver; first lift placed to a 4-inch thickness loose, second lift 2-inches loose; compacted each lift with a pneumatic roller and a three-wheeled roller.

Each seal-coat was applied by spraying the emulsion with a distributor, followed by a spinner application of fine-graded rock-asphalt and compacted with a pneumatic roller.

Date: Rock-asphalt base - October, 1964
      Seal - October, 1964

Condition: During construction, subgrade failure reflected through the base and seal-coat in twenty-five percent of the road area.

The following pictures depict the construction of the base and seal-coat operations and reflects unstable areas in the subgrade.
Figure 2. Moutardier Boat Ramp Road. Paver laying a 4-inch lift of lean rock-asphalt base.

Figure 3. Moutardier Boat Road. One of many areas of unstable subgrade in the newly constructed grade.
Figure 4. Moutardier Boat Ramp Road. Areas of unstable subgrade immediately reflected through the freshly laid rock-asphalt base.

Figure 5. Moutardier Boat Ramp Road. Application of emulsified asphalt (SS-1h) to the compacted rock-asphalt base.
Figure 6. Moutardier Boat Ramp Road. Spin-spreader application of fine-graded, lean rock-asphalt to emulsion-treated rock-asphalt base.
Figure 7. Test Section No. 8, Edmonson County Brownsville Plant Site Road.
Test Section No. 8

County: Edmonson

Road: Brownsville Plant Site Road

Length: 0.23 miles

Width: 20 feet, plus a 133-foot length extension of 16 feet

Initial Condition: New grade, forty percent of surface area unstable. Soft areas due to excessive moisture caused by permanent springs and drain field from a residential area.

Treatment: 360 lbs./sq. yd. of crushed-run (passing 1-in. sieve) rock-asphalt on the 20-foot wide section and 180 lbs./sq. yd. on the 16-foot section.

Procedure: Placed rock-asphalt on subgrade in a single lift, using a Barber-Greene paver for placing part of base. Due to softness of subgrade part of base was placed by spreading from dump trucks and reworked with a patrol grader. The 20-foot wide section was placed to a 4-inch depth. The 133-foot extension was placed to a 2-inch depth.

Date: Rock-asphalt base - October, 1964

Condition Survey: The areas of unstable subgrade immediately reflected through the base material during construction.

The following pictures depict the construction of the base and reflect the unstable areas of the subgrade.
Figure 8. Brownsville Plant Site Road. Area of Unstable Subgrade

Figure 9. Brownsville Plant Site Road. A failure in the newly constructed rock-asphalt base resulting from instability in the subgrade.
Figure 10. Brownsville Plant Site Road. Completed lean rock-asphalt base placed on an area of stable subgrade.
Discussion and Performance

Inasmuch as the Moutardier Boat Ramp Road and the Brownsville Plant Site Road were constructed on new subgrades with considerable areas of instability in each, it was anticipated that settlement and consolidation would occur and reflect through the rock-asphalt bases for several months.

The Brownsville Plant Site Road received a 2-inch thick course of bituminous concrete surfacing on November 12, 1964. The rock-asphalt base was laid in October, 1964. During placement of the bituminous concrete surface the unstable subgrade conditions were evident; failures were reflected through the pavement surface (Figures 11, 12). Coarse-graded limestone aggregate was used to stabilize some of the soft areas prior to laying the asphaltic concrete surface.

Considerable maintenance of the Moutardier Boat Ramp Road was necessary in the Spring of 1965. This work was done by the Developer, W. G. Reynolds and Associates, at their own expense. A complete photographic survey was made of the roadway on August 4, 1965. A brief inspection was made of the roadway surface on March 23, 1966.
Figure 11. Brownsville Plant Site Road. Placing 2-inch lift of hot-mix asphaltic concrete surface, November 12, 1964. Note the failed area reflecting through the asphaltic concrete beneath the raker.

Figure 12. Brownsville Plant Site Road. Completed asphaltic concrete surfacing on the left lane.
Considerable repair work was done on the road­way by the Developer in the Spring of 1965.
Figure 14. Moutardier Boat Ramp Road, Typical Appearance March 23, 1966. This same section is shown in Figure 13. The advancement of deterioration is very apparent.
CONSTRUCTION AND PERFORMANCE

OF

ADDED TRAFFIC-BOUND BASE AND SEAL COAT

ON

THE SUNFISH–INDEPENDENCE SCHOOL ROAD (TEST SECTION NO. 1)

AND

THE DOG CREEK–UNION LIGHT ROAD (TEST SECTION NO. 2)
In the fall of 1964 plans were made to pave lay an additional 2-inches of rock-asphalt and a double, rock-asphalt seal on Test Sections 1 and 2. It had been concluded that the original application of rock-asphalt on these roads was too light to yield satisfactory performance. It had also been concluded that seal-coats helped greatly in preserving the integrity of the rock-asphalt material by preventing moisture from saturating the base and subgrade. Thus, it was believed that this stage construction technique would upgrade these rock-asphalt bases to a satisfactory level of performance.

As the Nolin Dam Road was scheduled to be the principal base and seal experimental section, some cursory experimentation with a cold-mix and a seal coat incorporating AE-200 liquid asphalt was performed on a short section of the Dog Creek-Union Light Road.
Figure 15. Test Section No. 1. Edmonson County
Sunfish-Independence School Road
Test Section No. 1

County: Edmonson
Road: KY 238, Sunfish-Independence School Road
Project: MP 31-298-B
Length: 3.27 miles
Width: 16 feet
Initial Condition: July 1962, Traffic-bound limestone base, 0-in. to 3-in. thick, 1 1/2-in. average thickness.

Treatment: Base: 225 lbs./sq. yd. of a No. 610 gradation of rock-asphalt. 1500 ft. at the eastern end of test section-primed with 0.3 gal./sq. yd. of RT-2 before placement of rock asphalt base.

Seal: 500 ft. located one mile from western end of test section-0.05 gal./sq. yd. of RS-2 overlain with 4.5 lbs./sq. yd. of a sand-size rock asphalt.

Treatment: 2-inches, paver-laid and compacted rock-asphalt (June, 1965) Quantity: 2857 tons total; 171 lb./sq. yd.

Seal: A single seal of SS-1h and fine-graded rock asphalt

Condition Survey: A complete photographic survey of the roadway was conducted August 4, 1965, approximately 1-1/2-months after completion of the resurfacing treatment. Cracking and potholes were quite numerous through out the length of the project. The performance of the treatment was very disappointing for the short time it was in service. Photographs of the roadway, taken in August, 1965, are shown in Figures 16 and 17.
A second survey was made of the roadway March 23, 1966. The condition of the sealed rock-asphalt base was obviously poor as shown in Figures 18 and 19. There were many large areas in which the rock-asphalt completely lost its bond and reverted to a loose sandy condition. Alligator cracking of the base and seal coat were obvious throughout the length of the project.
Figure 16. Sunfish-Independence School Road. Appearance of the roadway at the eastern end of the project August 4, 1965,
Figure 17. Sunfish-Independence School Road. Appearance of the roadway 2.75 miles from the eastern end of the project, August 4, 1965.
Figure 18. Sunfish-Independence School Road. Appearance of the roadway at the eastern end of the project, March 23, 1966. This same section is shown in Figure 16.
Figure 19. Sunfish-Independence School Road. Appearance of the roadway 2.75 miles from the eastern end of the project, March 23, 1966. This same section is shown in Figure 17.
Figure 20. Test Section No. 2. Edmonson County
Dog Creek-Union Light Road
Test Section No. 2

County: Edmonson

Road: Dog Creek-Union Light Road, beginning at MP 31-328-A extending northward.

Project: RSR 31-528-451

Length: 2.7 miles

Width: 16 to 18 feet

Initial Condition:

- **Southern portion**: Stable limestone averaging 1/2-in. thick
- **Northern portion**: Unstable metal averaging 1/2-in. thick

**Comparative Section** (One-mile section to north of project): No. 610 limestone, 2-in. thick.

Treatment:

- **Base**: 216 lbs./sq. yd. of No. 610 gradation of rock-asphalt
- **Seal**: 0.15 gal./sq. yd. of RS-2 covered by 10 lbs/sq. yd. of sand-size rock-asphalt.

Procedure:

- **1963**
  - Shaping existing roadway
  - Spreading aggregate on roadway with dump trucks
  - Shaping to line and grade with patrol grader
  - Sealing operation

- **June, 1965**
  - **Quantity**: 1900 Tons total; approximately 141 lbs./sq. yd.
  - **Seal**: A single seal of SS-1h and fine-graded rock-asphalt.

**Cold-mix**: 50 tons of material were grader-mixed with AE-200 at the crushing plant site. AE-200 was added to the rock-asphalt at a rate of 9 gal. per ton—brining the total asphalt content to approximately 6.2 percent. This work and material was furnished by the Reynolds Interests at no extra cost to the Department. The AE-200 cold-mix was then paver-laid approximately 0.75 miles from the southern end of the project. A short section of a double seal coat was placed, incorporating AE-200 liquid asphalt.
Condition Surveys: A complete photographic survey of the roadway was conducted August 3, 1965, approximately one month after completion of the resurfacing. Cracking and potholes were numerous throughout the length of the roadway. Over-all the seal coat appeared to be lighter than that applied on the Sunfish-Independence School Road. Photographs of the roadway, taken in August, 1965, are shown in Figures 21 and 23.

A second survey was made of the roadway March 23, 1966. The roadway was in a very poor condition as illustrated in Figure 22. The short section of base which received a heavy seal incorporating AE-200 liquid asphalt is shown in Figure 24.
Figure 21. Dog Creek-Union Light Road, August 3, 1965. In the foreground, the base received a heavy seal of AE-200 and fine-graded rock-asphalt. In the background, a short section of the roadway was paved with a cold-mix incorporating AE-200 liquid asphalt.
Figure 22. Dog Creek-Union Light Road, March 23, 1966. The same section is shown in Figure 21.
Figure 23. Dog Creek-Union Light Road, August 3, 1965. View of the extreme northern end of the project.
Figure 24. Dog Creek-Union Light Road, March 23, 1966. This same section is shown in Figure 23. The large failed area has deteriorated to the consistency of loose sand. Note the alligator cracking pattern in the foreground. This type cracking is prevalent throughout the length of the project.
CONSTRUCTION AND PERFORMANCE
OF
TRAFFIC-BOUND BASE AND HOT-MIX ROCK ASPHALT SURFACE
ON
KY 728, THE NOLIN DAM-DEMUNBURNS STORE ROAD

(Test Section No. 9)
SF 31-328-6S1
SF 31-958-4S1
Plans were made in the Spring of 1965 to use the recently constructed Nolin Dam Road in Edmonson County as an experimental rock-asphalt surfacing project (Figure 25). The standard to which the grade and drain was constructed was inducement to construct the highest type surfacing achievable, under the prevailing circumstances, with the lean rock-asphalt. The experimentation on the earlier constructed test sections had indicated that improved performance was gained by using a good thickness of traffic-bound rock-asphalt base and by protecting the base from water intrusion and traffic abrasion. Double seals had proved to be uncertain in the protection offered the base course. Some exploratory, laboratory testing had indicated that liquid asphalts might be added to the lean rock-asphalt to produce mixtures with adequate resistance to water intrusion and traffic-abrasion. As previously indicated some cold-mix, incorporating AE-200 liquid asphalt, was paver-laid on the Dog Creek-Union Light Road.

On July 24, 1965, two truck loads of fine graded lean rock-asphalt were put through a Barber-Greene Continuous hot-mix plant at Tompkinsville. The arrangements for this work was made by the Developer. The material was successfully dried and heated in the plant without any apparent difficulties.
Figure 25. Test Section No. 9, Edmonson County
Molin Dam-Deminbruns Store Road, KY 728
Asphalt cement (PAC-5) was mixed with a portion of the dried and heated material. Subsequent to this experimentation the Developer purchased a small (30 ton per hour) Barber-Greene Continuous hot-mix plant for experimentation with the lean rock-asphalt as a hot-mix aggregate.

The purchase of the hot-mix plant by the Developer and the desire to place as high a type surfacing on the Nolin Dam Road as the prevailing circumstances would allow, caused the Department to change to the following plan for the project. A traffic-bound lean rock-asphalt base, 3 1/2-inches thick, was to be paver laid for the full length of the project. This was to be covered with a rock-asphalt surface course, 1 1/2-inches thick, with added bituminous material. On the western-most 0.92 miles of the project, a hot-mix rock-asphalt with added asphalt cement was to be laid. The rock-asphalt surface for the remaining portion of the project was to be cold-mixed, incorporating various percentages of AE-200 liquid asphalt. Special Provisions (Appendix II) were prepared which allowed considerable flexibility in the manner of preparing and applying the surface-course mixture. The surface-course mixtures, cold-mix and hot-mix, were to
be purchased in place on the roadway at a unit price of $6.21 per ton. The base course material was to be supplied in place at $2.99 per ton. Preparation of the existing surface and compaction of the lean rock-asphalt base and surface courses was to be done by District Maintenance forces with Department equipment. The tack coat material was to be supplied and applied by the Department.

When the first hot-mix rock-asphalt was produced at the plant, a few loads were laid on the southern-most end of the Dog Creek-Union Light Road. The results of the first placements of the hot-mix material were very encouraging. As it was desired to construct as high a type rock-asphalt surfacing on the Nolin Dam Road as the prevailing circumstances would allow, an agreement was made with the Developer to use the hot-mix rock-asphalt surface throughout the length of the project. This created no extra cost to the Department as the hot-mix and cold-mix were to be supplied at the same unit price.
Construction of Lean Rock Asphalt Traffic Bound Base
Nolin Dam Road

Construction of the lean rock-asphalt, traffic-bound base began August 4, 1965. An overall view of a section of the Nolin Dam Road, prior to placing the lean rock-asphalt base, is shown in Figure 26. The existing traffic-bound limestone surface, averaging approximately two inches in thickness, was prepared for surfacing by wetting, grading, and rolling-in the floater stone.

The crushing plant, material stockpiles, and the hot-mix plant were located in a limestone quarry on the Nolin Dam Road approximately 1.5 miles from KY 259. Construction of the base began at KY 259 and proceeded toward the dam. When the base was constructed to the dam, the equipment was moved to the eastern end of the project; and the base was constructed back to the dam. In this manner, construction traffic on the freshly laid base was held to a minimum. A Model 879-A, Barber-Greene paver was used to lay the lean rock-asphalt base in a single 3 1/2-inch lift (Figure 27). The base material is bulked by moisture and has a dark color when freshly laid. As the material dries, the color becomes lighter and the material bonds together. A Buffalo-Springfield, pneumatic-
Figure 26. Nolin Dam Road. A typical view of a section of the traffic-bound limestone base.
Figure 27. Nolin Dam Road. A Model 879-A Barber-Greene paver was used to lay the rock-asphalt base in a single lift.
Figure 28. Nolin Dam Road. The Buffalo-Springfield pneumatic-tired roller could compact the base material immediately behind the paver.
Figure 29. Nolin Dam Road. Roller marks were quite prominent upon first compaction. The base course develops bond as the moisture dries out.
tired roller was used to compact the base course (Figure 28). One-half days run would be laid in one lane and then the paver would drop back and bring the other lane up even, to complete the full roadway width at the end of each day. After initial compaction from the pneumatic roller, the base was further compacted, as the moisture dried out, by construction and local traffic. A section of the finished base course is shown in Figure 30. The base course was finished for the full length of the project before any hot-mix surfacing was laid.

The following is an average gradation of the traffic-bound base material on the project:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Average Gradation</th>
<th>Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2-inch</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1-inch</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td>3/4-inch</td>
<td>80.0</td>
<td>75-100</td>
</tr>
<tr>
<td>1/2-inch</td>
<td>68.2</td>
<td>40-80</td>
</tr>
<tr>
<td>No. 4</td>
<td>47.3</td>
<td>35-65</td>
</tr>
<tr>
<td>No. 100</td>
<td>0.4</td>
<td>0-10</td>
</tr>
</tbody>
</table>

The average, native bitumen content was 5.3 percent (as determined by ignition test).

A total of 14,000 tons of lean rock-asphalt traffic-bound base was laid on the roadway, at a total cost of $42,128.66. This calculates out to an application rate of approximately 285 lbs. per square yard.
Figure 30. Nolin Dam Road. A view of the compacted base course just prior to placing the hot-mix surface course.
Plant Production of Hot-Mix Rock-Asphalt Surfacing (Nolin Dam Road).

Production of the hot-mixed rock-asphalt began in mid-September after the base had been completed. The asphalt plant was an old Barber-Greene Continuous having a capacity of 30 tons per hour. It was necessary to assemble, calibrate, and make certain modifications in the plant. An over-all view of the hot-mix plant is shown in Figure 31.

The lean rock-asphalt has pronounced tendency to bridge across and block narrow openings -- i.e., because of its high internal friction, moisture bulking, and bitumen content. Openings at the top of the cold-elevator and in the hot-elevator systems had to be enlarged. The partition between the fine and intermediate bin was cut-out. At first it was necessary to keep a laborer at the cold-feed bin to break up bridging of the material in the bin and thus assure a uniform feed to the dryer. Later a vibrator was attached to the cold-feed bin. Many of the initial problems encountered with the plant were largely a result of the small capacity of the plant. The gradation unit was more intricate than was necessary for the process. A large-capacity plant would probably not exhibit the aforementioned problems.
Figure 31. Barber-Greene Continuous Mix Plant -- 30 Tons per hour capacity. The plant is made up of a dryer, Model 839; gradation unit, Model 863; and a mixer, Model 843.
Temperature control was one of the principal items of concern in setting up the plant. After some trials, it was found that the best control was achieved by placing a thermocouple at the dryer discharge. Of course one of the principal questions to be answered by this experimental project was to determine if the lean rock-asphalt could be dried and heated without undue coking or caking of the material in a conventional, hot-mix plant dryer. No apparent caking occurred in the dryer. The moisture content was reduced to zero or to a negligible level by heating the material to approximately 250°F. The asphalt cement (PAC-5) was heated to 325°F. The finished mix averaged approximately 190°F when it left the plant.
Construction of Hot-Mix Rock-Asphalt Surface Course
(Nolin Dam Road)

The first hot-mixed material was placed in mid-September, beginning at the eastern end of the project near Demunbrun's Store. Paving proceeded westward to the dam and then from KY 259 back to the dam. A tack coat was used throughout the length of the project, with the exception of 1/2-mile of the west-bound lane at the extreme eastern end of the project. The tack coat consisted of RS-2 applied at a rate of 0.2 gal. per sq. yd.

The mixture was laid with a Model 879-A, Barber-Greene paver and was compacted with a 10-ton tandem roller. The haul distance was short, and the material lost very little heat in transportation and was laid at 190°F. Delays were experienced between delivery of each truck load of material. A rough area was left in the finished mat by the paver screed at each point where the paver was stopped to wait for material.

Laboratory tests, on samples of the mixture taken during construction of the surface, gave the following, average test results:

Bitumen Content of Stockpile Material, by Ignition - 5.5 percent
Bitumen Content of Stockpile Material, by Extraction - 4.4 percent
Figure 32. Nolin Dam Road, Hot-Mixed Rock-Asphalt Surface. The material was laid at approximately 190°F. The roller could compact the material immediately behind the paver. Note the rippled condition of the compacted surface.
Bitumen Content of Hot-Mix Surface, by Ignition - 9.0 percent
Bitumen Content of Hot-Mix Surface, by Extraction - 8.8 percent

These data indicate that the indigenous asphalt content ran about 4.4 percent, which was slightly higher than was anticipated. The intent was to lay a mixture having 8.25 percent total bitumen content from the east end of the project to the dam. From the dam to KY 259, the total bitumen content was increased to approximately 10 percent. Some difficulty was experienced in controlling the asphalt content of the mixture. Less than 2 percent asphalt was added to the mixture laid on approximately 450 feet of the east-bound lane, 4.1 miles from KY 259.

The hot-mix surface course was completed in November. A total of 7,267 tons (148 lbs. per sq. yd.) of hot-mix rock-asphalt surfacing was laid on the project -- at a total cost of $46,481.91. A view of the completed pavement is shown in Figure 33.
Figure 33. Molin Dam Road, November, 1965.
Performance Inspection of Nolin Dam Road

An inspection was made of the roadway February 14, 1966. Over-all, the rock-asphalt surface appeared to be in good condition structurally. In the full length of the roadway, there were areas of longitudinal cracking and alligator cracking in the outer wheel tracks at approximately ten locations. Virtually all of these failures appeared to be the result of subgrade instability. No failures were noted which could be attributed to deficiencies in the composition or construction of the surfacing. A few of these failures occurred at the time of construction and were patched with hot-mix rock asphalt. Many of the cracks were sealed with asphalt cement. The surface course has a rippled finish throughout the length of the project. Rough areas left by the paver screed were apparent throughout the length of the roadway. These rough areas were a result of the material cooling under the paver screed during delays caused by the small capacity of the plant.

Samples of the surface course material were taken at eight locations throughout the length of the project. The laboratory test results obtained on these samples are shown in Table 1. These tests indicate that the surfacing
TABLE 1
TEST RESULTS ON ROCK ASPHALT SURFACE COURSE SAMPLES

<table>
<thead>
<tr>
<th>Sample Location*</th>
<th>Bitumen Content (%) by Extraction</th>
<th>Bitumen Content (%) by Ignition</th>
<th>Penetration of Recovered Bitumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7 mi. -EB</td>
<td>9.9</td>
<td>10.9</td>
<td>40</td>
</tr>
<tr>
<td>1.7 mi. -WB</td>
<td>9.4</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>3.1 mi. -EB</td>
<td>8.3</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>6.1 mi. -WB</td>
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<td>7.1 mi. -EB</td>
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<td>9.3</td>
<td>37.5</td>
</tr>
<tr>
<td>8.1 mi. -WB</td>
<td>8.3</td>
<td>8.6</td>
<td>38.5</td>
</tr>
<tr>
<td>Average</td>
<td>8.5</td>
<td>9.3</td>
<td></td>
</tr>
</tbody>
</table>

Marshall Test Results**

<table>
<thead>
<tr>
<th>Stability (lbs.)</th>
<th>Flow (0.01-in.)</th>
<th>Unit Weight (lbs. per cu. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7 mi. -EB</td>
<td>2145</td>
<td>9</td>
</tr>
<tr>
<td>1.7 mi. -WB</td>
<td>2811</td>
<td>8</td>
</tr>
<tr>
<td>3.1 mi. -EB</td>
<td>1963</td>
<td>9</td>
</tr>
<tr>
<td>4.1 mi. -WB</td>
<td>2049</td>
<td>8</td>
</tr>
<tr>
<td>5.1 mi. -EB</td>
<td>3090</td>
<td>7</td>
</tr>
<tr>
<td>6.1 mi. -WB</td>
<td>1619</td>
<td>7</td>
</tr>
<tr>
<td>7.1 mi. -EB</td>
<td>2748</td>
<td>9</td>
</tr>
<tr>
<td>8.1 mi. -WB</td>
<td>2720</td>
<td>10</td>
</tr>
<tr>
<td>Average</td>
<td>2393</td>
<td>8</td>
</tr>
</tbody>
</table>

*The mileage indicated is the distance from Ky. 259. EB and WB indicate the east-bound and west-bound lanes respectively. All samples were taken from the extreme edge of the pavement.

**50-blow compaction; test temperature 140°F.
Figure 34. Nolin Dam Road, February 14, 1966. A typical view of the roadway. Note the transverse marks left by the power screed.

Figure 35. Nolin Dam Road, February 14, 1966. A failed area resulting from poor subgrade. Note that the failure occurred during construction and was patched with hot-mixed material.
Figure 36. Nolin Dam Road, February 14, 1966. An example of a cracked area in the outer wheel-track which had been sealed with asphalt cement.

Figure 37. Nolin Dam Road, February 14, 1966. The photograph was taken shortly after a light rain. The dark areas in the foreground are caused by moisture within the pavement.
material has a very high stability -- attributable to its high internal friction and as a result of hardening of the indigenous asphalt in the heating process. The asphalt was recovered from three of the surface course samples, and the penetration of the recovered asphalt averaged 38.5.

A brief inspection was also made of the roadway surface on March 23, 1966. Cracked areas in the outer wheel-tracks were much more extensive than was noted on the earlier inspection. It was noted again that the failures tended to be concentrated in areas of poor subgrade support, primarily cut-sections. At two locations, which had considerable superelevation, the surface course was cracked and sliding on the tack coat. At the time of this inspection the Developer had sealcoated most of the cracked areas with a fine rock-asphalt as shown in Figure 38.

Skid-test measurements were made at two locations on the roadway March 2, 1966. The test consisted of skidding an automobile with its wheels fully locked on the wetted pavement from a velocity above 30 m.p.h. to 0 m.p.h. From the recording of velocity and time, the coefficient of friction between 30 m.p.h. and 20 m.p.h. was determined
to average 0.68 for the two locations tested. This, of course, is an excellent frictional value in comparison to values measured on other road-surface types by the same test method.
Figure 38. Nolin Dam Road, March, 1966. Sealing cracked areas in the outer wheel-track with fine-graded rock asphalt.
SUMMARY OF OBSERVATIONS

The following observations are based on the performance of the various test sections to date.

1) When lean rock-asphalt is used as an exposed traffic-bound surface, the indigenous bitumen content is too low to provide sufficient bond to withstand traffic and weather. These bases are porous and saturate readily.

2) Seal coats on lean rock-asphalt bases improve resistance to deterioration from traffic and weather; however, the sealed bases built to date have deteriorated too rapidly. Whereas the seals shed water, they also prevent drying and binding of the base.

3) The hot-mixed rock-asphalt placed on the Nolin Dam Road has excellent stability and skid-resistance. The surface is quite porous (13 to 15 percent voids) and, therefore, has great capacity for water. Unless the base was adequately primed and sealed before surfacing, rain water may permeate the base and underlying soil also. High porosity is thought to be in essential quality for good skid-resistance.