



COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT, KENTUCKY 40601

Eugene Goss
COMMISSIONER OF HIGHWAYS

February 23, 1970

H-2-7

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

SUBJECT: Research Report; "Slurry Seal Maintenance Applications";
HPR-1(5), Part II, KYHPR 64-7

Sand-emulsion slurries became quite a novel innovation about fifteen years ago. Unlike "chip seals", which were the only type of low-cost surface treatments extensively used for many years, slurry seals offered an opportunity to utilize hard sands, for skid resistance, and to avoid loose surpluses of chips associated with conventional seals. Incompatibility between the emulsion and other materials has caused considerable despair on occasions and, in several instances, has prevented completion of the scheduled work. In 1964, in District 1, when the Department was using transit-mix trucks, the emulsion "broke" as soon as it was charged into the mixer; this produced hard balls ranging from the size of golf balls to as large as beach balls; clear water could be drained from the drum, but then the drum had to be opened and the balls removed by hand. The only remedy found there was a substitute source of emulsion. In order to avoid re-occurrence of this problem, it seemed necessary to use emulsions which were heavily dosed with soaps and other emulsifying chemicals. In some instances, very stable slurries were obtained; they were so stable, in fact, that they did not "break" or "set" for several hours after they were spread on the road. Apparently, the "set" was achieved through drying rather than a "timed" reaction. On humid days, this delay was intolerable.

Drying and curing are affected by thickness and gradation; thickness seems to be related to coarseness of the sand. Dense-graded sands together with thicknesses in the order of 0.25 of an inch, when used with non-breaking emulsions, tend to skin dry and to prevent curing underneath; with time, the asphalt tends to float to the surface and give the appearance of excess asphalt -- while beneath, evidence remains of uncured emulsion (brown coloration). Where breaking emulsions have been used, droplets of clear water have been found below the surface after several weeks. Both types of situations seemed to require a "breathing" gradation. Whereas a seal against the substrate may result from a "breathing" type of cure, further assurance of sealing the pavement surface against leakage could be obtained by priming the surface with diluted emulsion well in advance of the slurry application. Ideally, this would provide a layer of porous but well-cemented sand over a membrane seal at the interface.

Mr. A. O. Neiser

Slurry seals simulate but do not yet equal hot-mixed sand-asphalts in quality or appearance. Both workability and performance remain uncertain. Compatibility between emulsions and sands (and water) cannot be assured unless field trials are made. Price contract methods of purchasing ingredient materials as now practiced are inadequate in this respect. About a year ago, the Department invited suppliers of emulsion to express their views on a specification in which they would be required to guarantee compatibility and to "tailor" emulsions for each job. Most of them declined to do business on such terms. Thus, the burden of uncertainty remains with the Department unless the work is let to contract -- in which case the contractor is at liberty to "shop around" for his materials and to select those which are compatible.

The customary gradations of sands for slurry seals have been rather dense -- perhaps too dense. Comparatively speaking, they would suffice for a hot-mixed sand-asphalt. This type of grading has been employed by others and is the type advocated by the National Slurry Seal Association. However, the possibility remains that open-type gradations would be more favorable from the standpoint of curing on the road.

Coarse, natural sands -- containing coarse particles of quartz -- are rather rare; to meet present gradation requirements, natural sands are blended with crushed limestone sands. The crushed limestone contributes the coarse sand and the fines. Blends of 40 percent natural sand and 60 percent limestone sand, as presently employed, are not ideally suited for de-slicking purposes. Higher percentages of quartz sands would be preferable. All-limestone slurries, therefore, have rather limited uses.

In the beginning, skid resistance was not considered an essential attribute of slurry seals inasmuch as they were foreseen to have limited use with respect to volume of traffic. Certainly, slurries spread more easily and uniformly when the existing pavement is relatively smooth and unrutted; but their use on roads carrying significant volumes of traffic has undoubtedly emphasized, and perhaps brought into issue, the criticality of curing time.

Concurrently with the surveillance of construction operations and the performance of slurry seals in regard to durability, skid tests have been made; some of the data are contained in the attached report. A companion study, KYHPR-64-24, embraces the subject more fully. At this time, a progress report on "Pavement Slipperiness Studies" is pending. An excerpt therefrom follows:

SAND-SLURRY SEALS

Properly designed and placed slurry seals are reputed to be economical, skid-resistant, and reasonably durable. Slurry seals thus offer a possible method of renewing wearing surfaces and of providing protection for existing pavements which are not otherwise structurally deficient. A research report entitled "Slurry Seal Maintenance Applications", (12), dated September 1969, documents the development and performance of the slurry seal in Kentucky.

Mr. A. O. Neiser

The skid resistance of several sand-slurry seal surfaces has been monitored for the past five years, beginning in 1964, and the data are presented in Table IV in the Appendix. Several sections were sealed between 1964 and 1966. Most of the seals have worn or weathered off.

From July, 1967 through June, 1968, seventeen road sections were slurry sealed. Each of these projects were skid tested with the automobile and the results are tabulated in Table V in the Appendix. About 60 percent of the projects yielded coefficients of friction lower than 0.40 in one or both lanes. Several projects should be regarded as having skid resistances which are inadequate to sustain normal driving speeds in wet weather conditions. These surfaces appeared to be fatty and in some instances were bleeding. On the other hand, several surfaces exhibited high skid resistance, suggesting that good resistance can be attained with slurry seals provided they are properly designed and placed and if the surfaces initially showed no excess of asphalt.

The Corps of Engineers has conducted an extensive survey of the performance of slurry seals and current specifications, and their issuance of a specification is now pending.

Another item of very current interest is the re-sealing of US 60, westward from Shelbyville. There the contractor elected to use a crushed sand identified as "Georgia Granite"; a coarse gradation was permitted. Sand received on the job proved to contain excessive percentages of coarse fractions, and it appears that blending with local river sand will be necessary to comply with specifications.

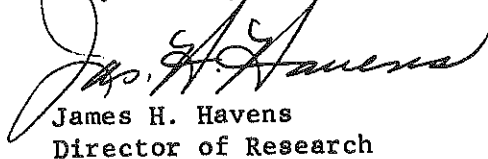
Also at this time, KY 11 (in Bath County) is being sealed by contract.

The Maintenance Division is operating two machines; and, at the present time, it appears that considerable mileage may be sealed by maintenance forces before the close of the season.

The attached report will formally conclude KYHPR-64-7, but we will surely continue to observe and to assist the Maintenance Division in their future slurry-seal programs.

Mr. Florence accepted a position with the Bureau of Public Roads in North Carolina in July 1968. Mr. Southgate completed the field work and prepared the draft of the final report.

Respectfully submitted,



James H. Havens
Director of Research

bv

Attachment

cc: Research Committee

Mr. A. O. Neiser

Research Committee:

Assistant State Highway Engineer, Research and Development
Assistant State Highway Engineer, Planning and Programming
Assistant State Highway Engineer, Pre-Construction
Assistant State Highway Engineer, Construction
Assistant State Highway Engineer, Operations
Assistant State Highway Engineer, Staff Services
Assistant Pre-Construction Engineer
Assistant Operations Engineer
Executive Director, Office of Computer Services
Executive Director, Office of Equipment and Properties
Director, Division of Bridges
Director, Division of Construction
Director, Division of Design
Director, Division of Maintenance
Director, Division of Materials
Director, Division of Photogrammetry
Director, Division of Planning
Director, Division of Research
Director, Division of Right of Way
Director, Division of Roadside Development
Director, Division of Rural Roads
Director, Division of Traffic
Division Engineer, Bureau of Public Roads
Chairman, Department of Civil Engineering, University of Kentucky
Associate Dean for Continuing Education, College of Engineering
All District Engineers

TABLE V

SAND SLURRY SEALS - FY 1968

ROUTE NUMBER	COUNTY	PROJECT NUMBER	LOCATION	CONSTR YEAR (FY)	COEFFICIENT OF FRICTION			1967 ADT
					EB NB Lane	WB SB Lane	Average	
US 60	Clark	MP 25-102-M	Lexington-Winchester	1968	0.41	0.46	0.44	3800
US 60	Clark	MP 25-22-K	Winchester-Mt. Sterling	1968	0.49	0.54	0.52	990
US 60	Montgomery	MP 87-117-J	Winchester-Mt. Sterling	1968	0.48	0.48	0.48	1070
US 60	McCracken	MP 73-172-0	Paducah-Wickliffe	1968	0.38	0.37	0.38	3700
US 227	Clark	MP 25-2-I	Winchester-Paris	1968	0.39	0.47	0.43	850
US 460	Scott	MP 105-134-H	Georgetown-Frankfort	1968	0.48	0.48	0.48	1760
KY 11	Montgomery	MP 87-97-H	Mt. Sterling-Clay City	1968	0.43	0.45	0.44	1950
KY 15	Powell	99-100-L	Stanton-Clay City	1968	0.40	0.38	0.39	2150
KY 29	Jessamine	RP 57-68-G	Wilmore-Nicholasville	1968	0.47	0.39	0.43	2490
KY 33	Jessamine	MP 57-128-B	US 68-Versailles	1968	0.70	0.61	0.65	470
KY 90	Wayne	MP 116-19-I	Monticello-Bronston	1968	0.41	0.29	0.35	2500
KY 90	Wayne	MP 116-99-L	Monticello-Clinton Co. Ln.	1968	0.36	0.53	0.44	1640
KY 152	Mercer	MP 84-3092-E	Harrodsburg	1968	0.38	0.43	0.40	
KY 152	Mercer	MP 84-92-L	Harrodsburg-Burgin	1968	0.38	0.35	0.36	2510
KY 213	Powell	99-20-H	Stanton-Mt. Sterling	1968	0.43	0.46	0.45	950
KY 1057	Powell	99-180-M	Clay City-Furnace	1968	0.33	0.30	0.32	620
Hurstbourne Lane	Jefferson	56-633-B	Hurst-KY 155	1968	0.34	0.28	0.31	

Research Report

SLURRY SEAL MAINTENANCE APPLICATIONS
KYHPR-64-7; HPR-1(5)
FINAL REPORT

by

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Former Research Engineer
and
Herbert F. Southgate
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.

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INTRODUCTION

A slurry seal mixture consists of graded fine aggregate (normally minus 3/8-inch material), mixing grade emulsified asphalt (SS-1 or SS-1H), and water. The water is added to aid in mixing and to provide a free-flowing consistency so that the mixture can be spread in thin layers on the surface of an existing pavement. After the mixture is spread, the water evaporates and the remaining material, aggregate and base asphalt, forms a thin seal on the pavement surface which resembles a fine-grained asphaltic-concrete surface. As a result of the free-flowing consistency and the fineness of the aggregate, a slurry mixture readily fills cracks, voids, small depressions, and will form a thin seal over the entire pavement surface.

Slurries were first used extensively as seals by the Road Department of Los Angeles County, California, in 1955 (1). Since that time the use of slurry seals has spread widely across the country. Present practice and specifications pertaining to slurry seals largely evolved from such experience. Slurry seals composed of a wide range of materials have been used on many types of surfaces for various purposes with variable results (2).

The Department's first experience with slurry seals was in 1962 when the Louisville Asphalt Company contracted to seal two short sections of roadway in Jefferson County and to seal the service areas of the Kentucky Turnpike (3). In addition to the work contracted, the Louisville Asphalt Company laid several "test" applications of slurry seals of varying composition. All of these slurry seals were placed with a Young Slurry Machine.

In 1963, the Department prepared "Special Specification No. 19-56, Emulsion Slurry Seal" in order that slurry seal maintenance contracts could be let by competitive bidding. The shoulders on approximately 40 miles of the Kentucky Turnpike were sealed by contract in 1963. This was the only slurry seal work let to contract by the Department until the 1969 construction season.

Also, early in 1963, the Maintenance Division purchased and constructed equipment for slurry seal operations by Maintenance forces. Two, six cubic-yard, transit-mix concrete trucks, a portable batching plan, and a twelve-foot wide spreader box were purchased. A piece of equipment for proportioning emulsion for each batch was constructed. Since then, Maintenance has added equipment and at present has the capability to keep two separate slurry operations in progress.

During the 1963 construction season, Maintenance forces sealed the front parking lots and drives of the Kentucky State Fair and Exposition Center (in excess of 225,000 square yards), a large parking lot in Frankfort, and sections of nine roadways totaling 39 miles in the Louisville and Lexington Districts. In 1964, Maintenance expanded slurry

operations and sealed approximately 100 miles of roadways of varying widths in Highway Districts 1, 3, 7, and 9. In 1965, approximately 52 miles of roadways of varying widths were sealed. For the 1966-67 Fiscal Year, Maintenance programmed in excess of 100 miles of slurry seal, 76 miles of which were in the Lexington District. Maintenance had two separate slurry seal operations in progress during the summer and fall of 1966. During 1967, they purchased two Highway Slurry Machines and used these in addition to the transit-mix truck operation.

EQUIPMENT AND PROCEDURES

Shown in Figure 1 is the portable batching plant used to proportion aggregates for each slurry batch. Aggregates were loaded into the weigh-hopper by use of a front-end loader. The weight of each aggregate for each transit-mix truck-load batch was marked on the scale dial for easy reading by the loader operator. A small hopper was included on the plant for adding mineral filler; however, the mineral filler was not weighed by the plant. Portland cement has been the only mineral filler used and was proportioned by the bag. Water was stored in a tank truck and was proportioned into each batch by a pump on the batch plant which could be preset for the quantity desired.

After the aggregate, filler, and water were proportioned into the transit mixer, the required quantity of emulsion was proportioned by the equipment shown in Figure 2. Emulsion was stored in a transport, which remains at the plant site. The emulsion was pumped from the storage transport into the measuring tank and then from the measuring tank into the transit mixers. The transit mixer then hauled the proportioned slurry mixture to the job site. A spreader box, hitched to the transit-mix trucks and shown in Figures 3 and 4, was used to apply the slurry. The pavement was wetted immediately ahead of the box by a spray bar located across the front of the box. The water for the spray bar was supplied through a hose from a storage tank on the transit-mix truck. Heavy rubber belting at the bottom of each side of the box prevents the slurry from escaping. At the rear of the box were hand screws, used to adjust for the crown of the roadway, attached to a rubber belting screed. The box was towed by a truck from one job site to another by attaching wheels at two corners. The metal pipe running down the center of the box was the drawbar and was easily detached from the box.

When the first transit-mix load of slurry arrived from the plant, the spreader box was attached to the truck and wetted with a hose from the truck. Some of the water on the truck may be used to make a final adjustment of the slurry consistency. When a project was of sufficient length, the usual procedure was to lay slurry on one lane of roadway each day. Traffic cones were used to keep vehicles off the freshly laid slurry (Figure 5). One two-lane roadways, flagmen were placed at each end of the section to be sealed, and a guide vehicle was used to lead traffic past the freshly laid material. Of course, control of vehicles crossing the freshly laid slurry from side roads and driveway entrances has been impossible. An effort was made to keep traffic off the seal until it was cured; however, curing times are dependent upon the thick-



Figure 1. View of Ross Porta-Plant used to proportion slurry seal aggregates and water.

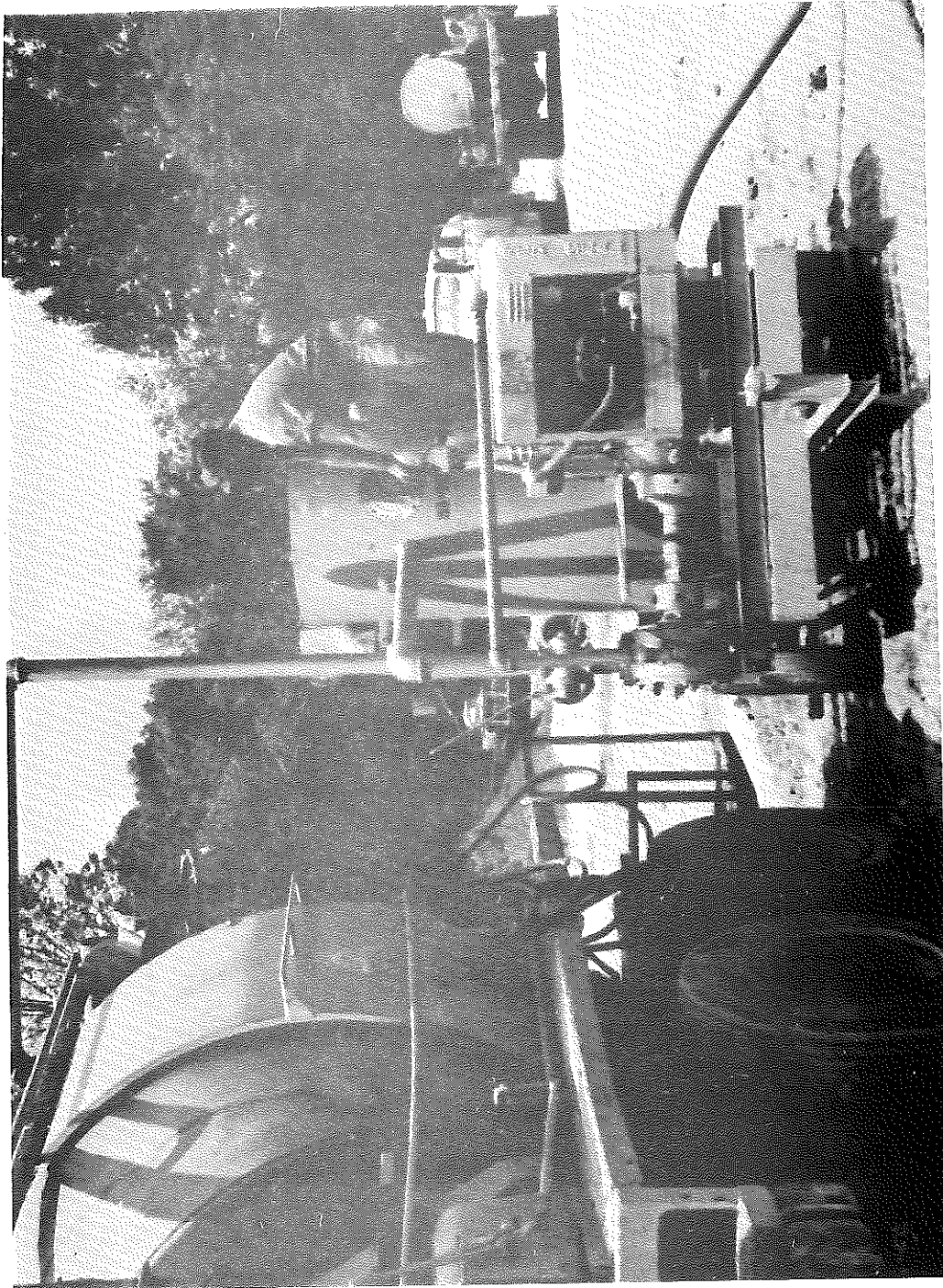


Figure 2. Equipment to proportion emulsion for slurry batches.

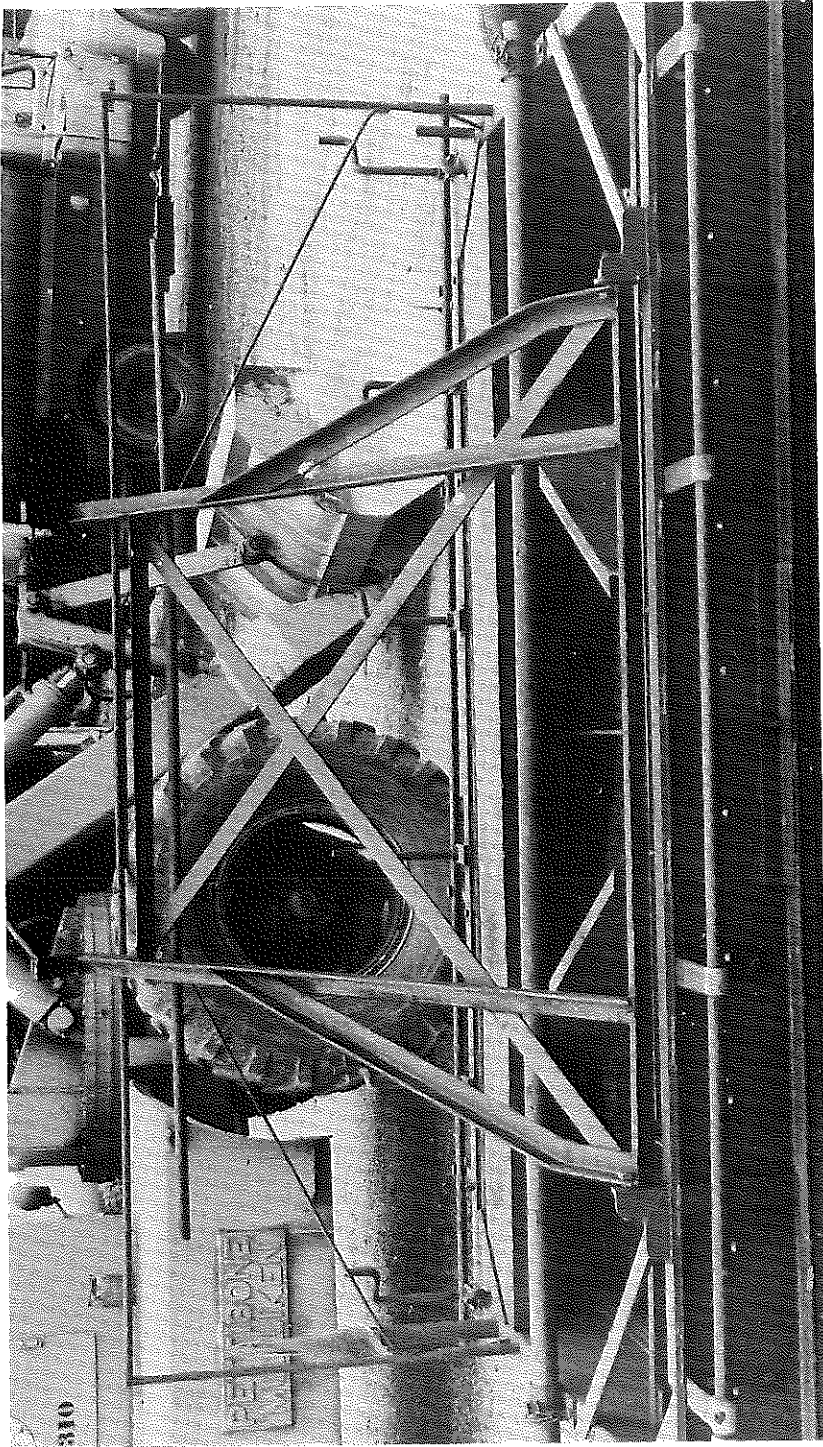


Figure 3. A front view of a slurry-seal spreader box.

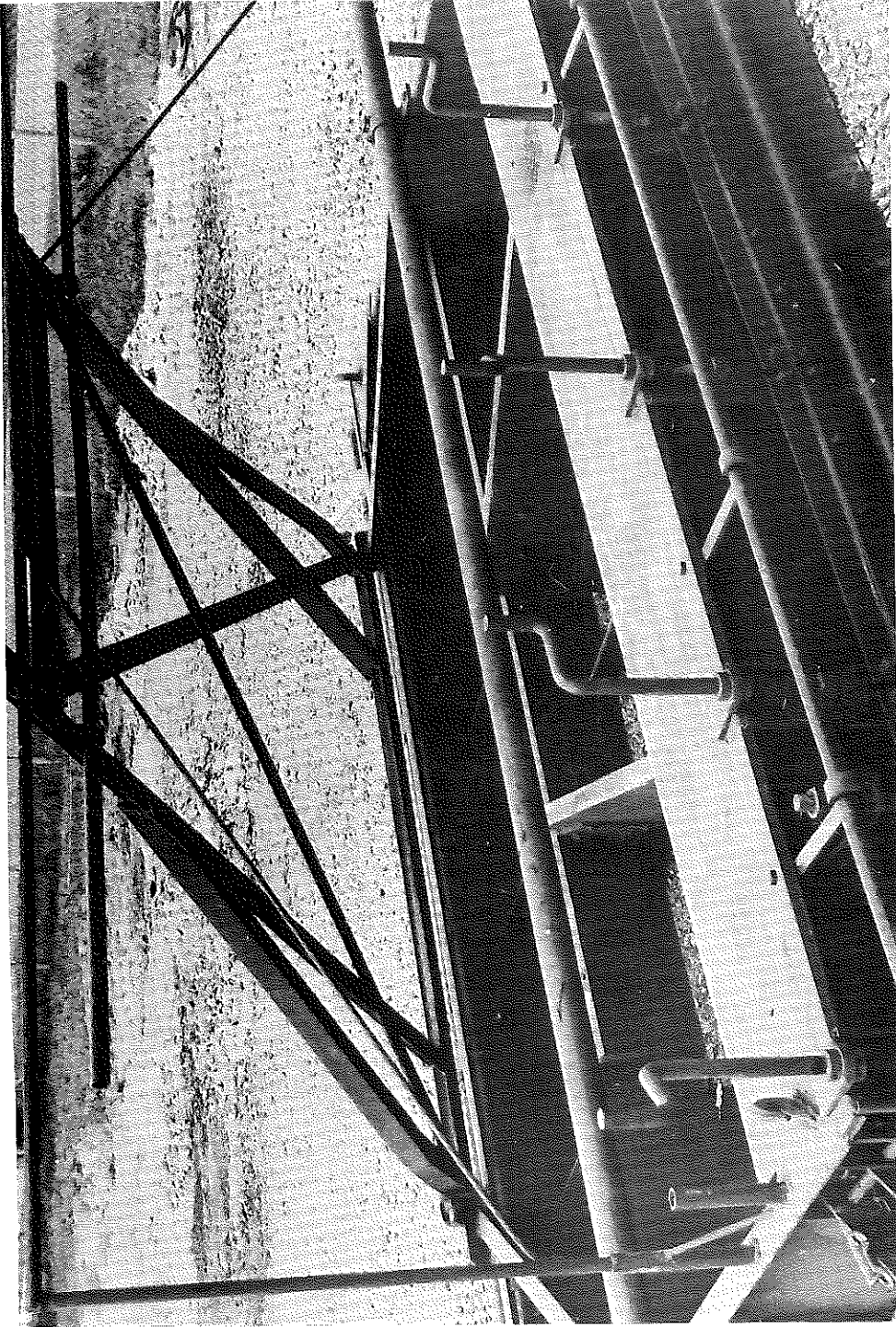


Figure 4. A rear view of a slurry-seal spreader box.



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Figure 5. An example of traffic cones placed to keep traffic off a fresh application. Note the tire marks in the seal from side entrance traffic and the wetter appearance of the seal in areas that were laid thicker.

ness of the seal and climatic conditions. Curing times have varied from as little as 1-1/2 hours to well over 4 hours.

The purchase and use of the Highway Slurry Machines resulted in a more efficient operation. The Highway Slurry Machines are self-contained units, mounted on trucks, that store the raw ingredients in separate hoppers and bins and proportion, mix, and spread the slurry seal in one operation. Adjustment of any ingredient in the mix can be readily and easily accomplished during the laying of the seal. This has the immediate advantage of being able to make changes after a very limited quantity of material has been laid. The Highway Slurry Machine returns to the aggregate storage area for recharging of the various raw ingredients.

MATERIALS

Personnel of the Research Division aided in determining the composition of the first slurries placed by Maintenance in July 1963. When the Research Division first proposed to observe and report on the slurry applications and performance, it was anticipated that slurries would only be applied on parking areas, bituminous shoulders, and low trafficked areas. As Maintenance also intended use on high trafficked surfaces, it was decided that a sizable proportion of the aggregate should be sharp grained, polish resistant, natural (quartziferous) sand to impart skid-resistant qualities to the seals.

The first slurry seal placed by Maintenance was on the State Fair and Exposition Center's front parking lots and drives in Louisville. After some exploration of available aggregates in the Louisville area, a medium Ohio River sand and a limestone sand were found which could be blended to meet the slurry seal gradation requirements set out in Special Specification No. 19-56. The first batches were formulated for a six cubic-yard, transit mix truck, and after some trials it was found that the trucks could haul and mix a "four-ton" batch. These first batches were formulated as follows:

Sand Blend:	45 percent natural sand	- 3600 pounds
	55 percent limestone sand	- 4400 pounds
Portland Cement:		- 94 pounds
Total Aggregate Weight:		- 8094 pounds
Emulsified Asphalt (SS-1H):		
	173 gallons (62.5% base asphalt)	- 902 pounds
Mixing Water:	Variable 85 to 100 gallons per batch	

It may be noted in the above proportioning that the moisture content of the stockpile was not taken into consideration in the aggregate weights and that the "four-ton" batch was based only on the weight of the sands. The moisture content of the stockpiles was not considered of importance in that water was added on the basis of judgment to yield the proper

slurry consistency. This proportioning procedure may result in some variation of the base asphalt content of the cured seal as a result of variations of moisture in the stockpiled aggregates, but the variation is not believed to be of serious magnitude unless the stockpiles are very wet. On many projects, the stockpiles were covered with plastic for protection from rain. An advantage in using the aforementioned batching procedure was that the scale dial can be marked for clear reading by the pay-loader operator, and it was not necessary to change the scale markings with variations in stockpile moisture contents.

Since the first sealing operation in 1963, the types (limestone and Ohio River sands) and proportions of sands used were not changed until the 1966 construction season. The base asphalt content has varied over an extreme range of 0.8 percent (from 9.3 to 10.1 percent), and the portland cement content has not changed. Slow setting anionic emulsion, type SS-1H, has been the only type of emulsion used except for some limited use of a cationic fast-setting emulsion, type SS-1K, in some experimental sections placed in 1966. As a result of purchasing procedures, the sources of materials have been subject to change when the sealing operation was moved from one county to another -- and even for counties within the same highway district. This resulted in some variation in the physical properties of the emulsion and aggregates. The source of the portland cement was not changed on any project.

The special specification requires that the plasticity index of the aggregates be less than five and that the sand equivalent value be greater than 35. Laboratory testing for plasticity index and sand equivalent was abandoned after the first few projects in 1963, because these types of aggregates are nonplastic and have sand equivalent values well in excess of 35. Sand equivalent values were determined for some of the aggregates used in trial slurries in 1966.

During the 1966 construction season, various trial mixtures incorporating high silica-content sands in varying proportions of 45 to 100 percent of the aggregate were placed. These sands were investigated to determine if they would impart greater skid resistance to the seal. Some trial slurries which incorporated hydrated lime and cationic fast-setting emulsion were made. These materials were used in an effort to decrease the curing time of the slurry.

CONSTRUCTION AND PERFORMANCE

Inasmuch as many miles of slurry seal have been placed by Maintenance forces and by contract, only the performance of selected projects will be discussed in this report. At least one inspection was made by Research Division personnel on all but a few of the slurry seals placed to date. The condition of the bituminous surfaces prior to sealing were quite variable. On many projects, the objectives in using slurry seal included deslicking as well as sealing.

Samples of the aggregates were taken on many of the projects and tested for gradation in the laboratory. Skid tests and air permeability

tests were performed at intervals on several of the seals. Measurements were made of the application rates for several of the seals. Cost data were carefully compiled by the Maintenance Division of five slurry seal projects constructed in 1963 and 1964. Most of the evaluation of construction and performance of the slurry seals is based on visual observation.

Slurry Seals Placed in 1963

STATE FAIR AND EXPOSITION CENTER

Two parking areas, each approximately 1000 feet by 1000 feet and approximately 4000 feet of variable width drives were slurry sealed in July 1963. The original surface was approximately eight years old and was wavy as a result of the depressions left between successive paver passes. The surface was approximately 1-1/2 inches thick and was cracked in several areas. Prior to sealing, some small, hot-mix patches were made.

The slurry seal mix was comprised of the following:

- 55% limestone sand -- Okolona Stone Co. and Derby Road Building
- 45% medium Ohio River sand -- E. T. Slider, Louisville, Kentucky
- 18% SS-1H (173 gallons) -- Kentucky Asphalt Sales
- 1.2% portland cement -- Kosmos Cement Co.

Limestone sand from Derby Road Building was used for only a few days because oversized particles marred the finished seal. The combined aggregate gradation including the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
No. 4	100.0
No. 8	96.7
No. 16	81.9
No. 30	58.3
No. 50	25.8
No. 100	13.0
No. 200	7.9

The sand equivalent value of the Okolona limestone sand and the medium Ohio River sand were 46.3 and 98.6, respectively. Both sands were non-plastic as determined by the plasticity index.

As a result of the wavy condition of the surface of the parking lots, a nonuniform thickness of slurry was placed. The slurry was laid thicker in depressed areas than on the raised areas, as shown in Figure 6. The spreader box was run perpendicular to the direction the hot-mix paver had taken in laying the original surface.

Initially a tandem steel-wheeled roller was used to roll the seal. This practice was soon abandoned because there was no apparent benefit from the rolling.

The application rate was checked very accurately for three loads and found to be 5.3 pounds per square yard of solid material (aggregate and asphalt) on the average. This figure is believed to be slightly low because the lot was fairly smooth in the area the application rate was checked. Nevertheless, the thickness of solid material averaged less than 1/16 inch.

Substantially the same area of the lot is shown in Figures 6, 7, 8, and 9, and the progressive rate of wear of the seal is quite evident. The percentage of the lot area still visibly covered by slurry seal was estimated at 50 percent in 1966. A closer view of an area typical of the surface in 1966 is shown in Figure 10.

Air permeability readings were taken on sealed and unsealed areas of the lot in 1964 and again in 1966 with a Soiltest Asphalt Paving Meter, Model AP 400-A. In 1964, the sealed lot was found to be impermeable and the unsealed area was found to average 1.1 milliliters per second of air flow. In 1966, the sealed area was tested at three locations and values of 0.20, 1.92, and 0.95 milliliters per second were obtained. The unsealed lot was tested at two locations and air flow of 1.39 and 1.40 milliliters per second values were observed. These air permeability values indicate that the slurry seal was effective in sealing the lot, but the permeability has increased as the seal has worn away.

Skid test measurements were made on the surface of the sealed lot approximately two months after sealing. Coefficients of friction were determined on the wetted pavement by the British Portable Tester (4). The following are the average coefficients of friction obtained:

Before Sealing	After Sealing
0.82	0.90

A visual inspection in July 1969, revealed that all of the slurry seal had been covered except for one 120-foot by 300-foot area in the east parking lot. In that one area, 30 percent of the slurry seal had worn off.

US 60, SHELBYVILLE TO MIDDLETOWN

The project consisted of 14.5 miles of 22-foot, two-lane roadway from the east city limits of Shelbyville to Eastwood and 5.6 miles of double 24-foot pavement from Eastwood to the west city limits of Middletown. The hot-mix surfacing was approximately seven years old and badly



Figure 6. State Fair and Exposition Center, July 1963. The slurry laid thicker in depressed areas as a result of the wavy condition of the surface. Note the hot-mix bituminous patches elsewhere on the surface.

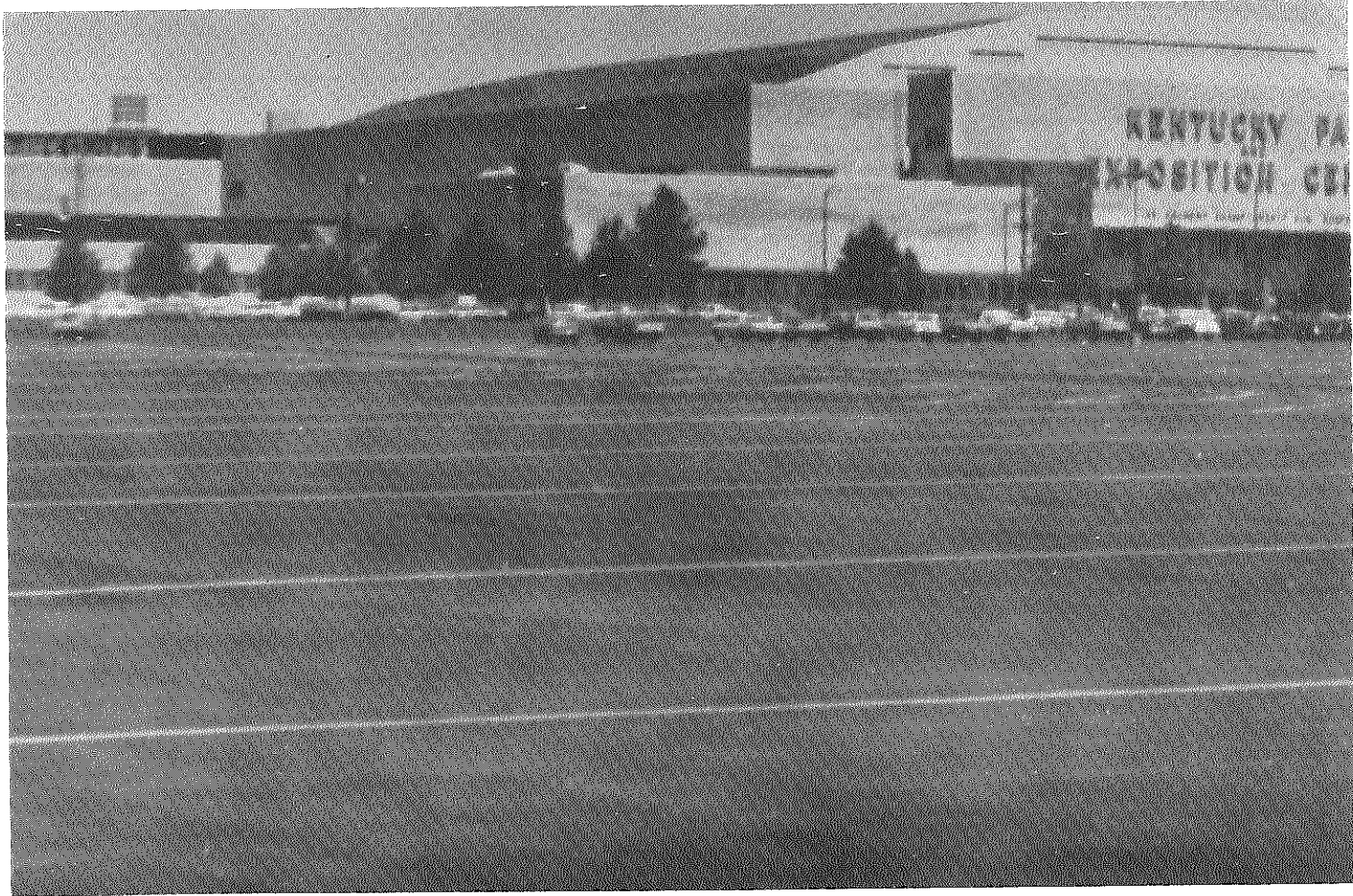


Figure 7. State Fair and Exposition Center, August 1963. An overall view of the western parking lot immediately after sealing.

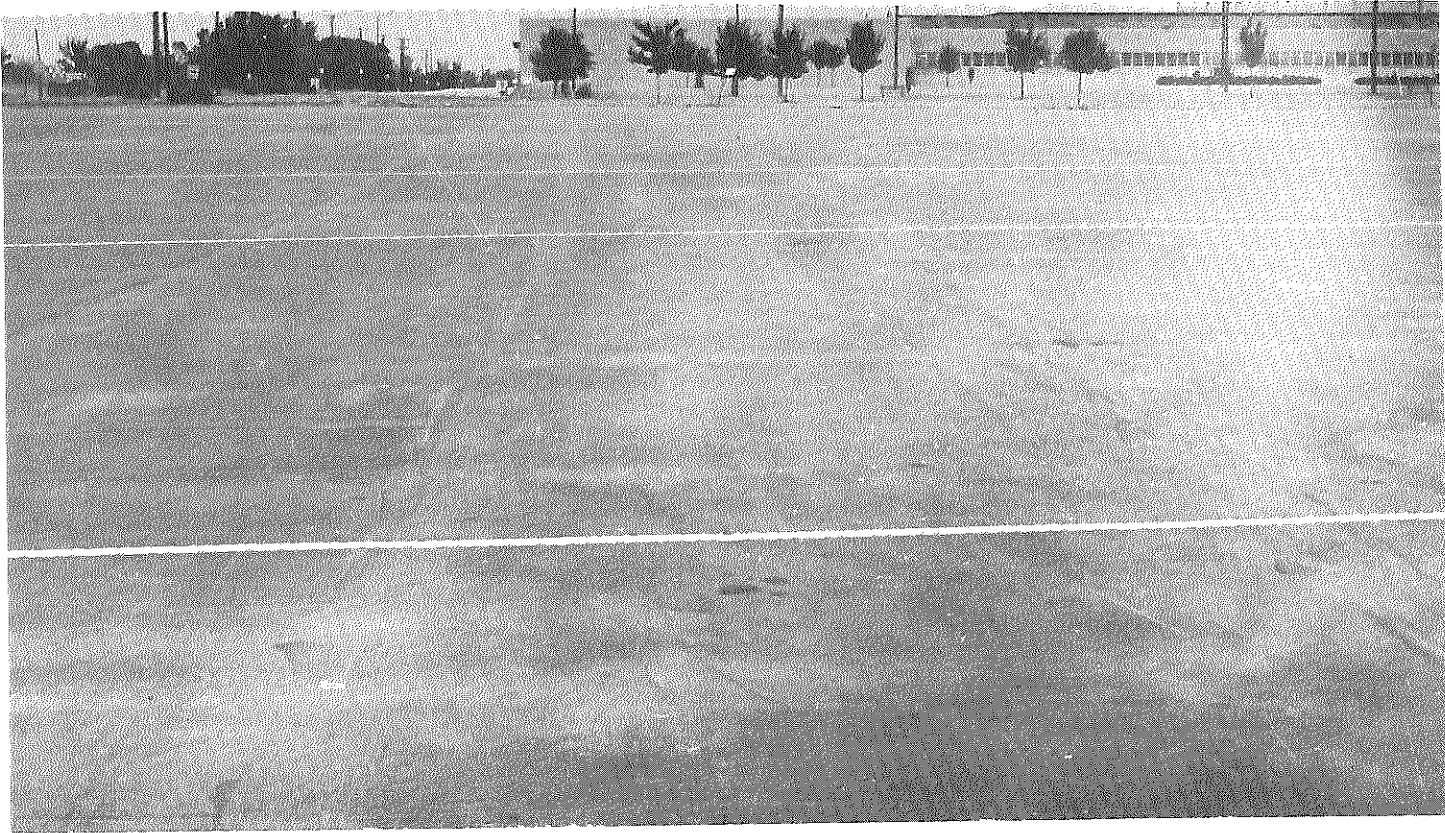


Figure 8. State Fair and Exposition Center, June 1964. An overall view of the western parking lot approximately one year after sealing.

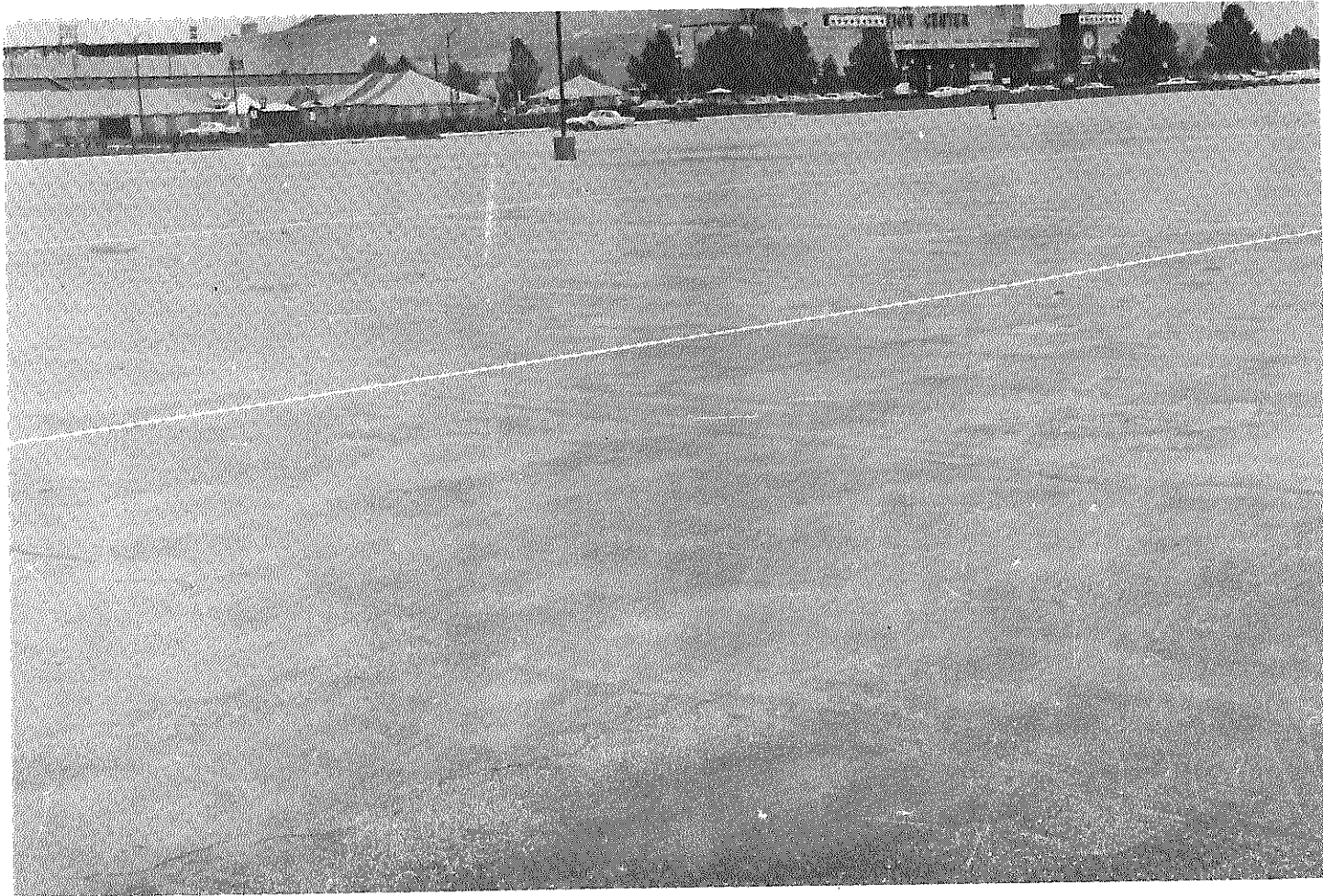


Figure 9. State Fair and Exposition Center, August 1966. An overall view of the western parking lot three years after sealing.

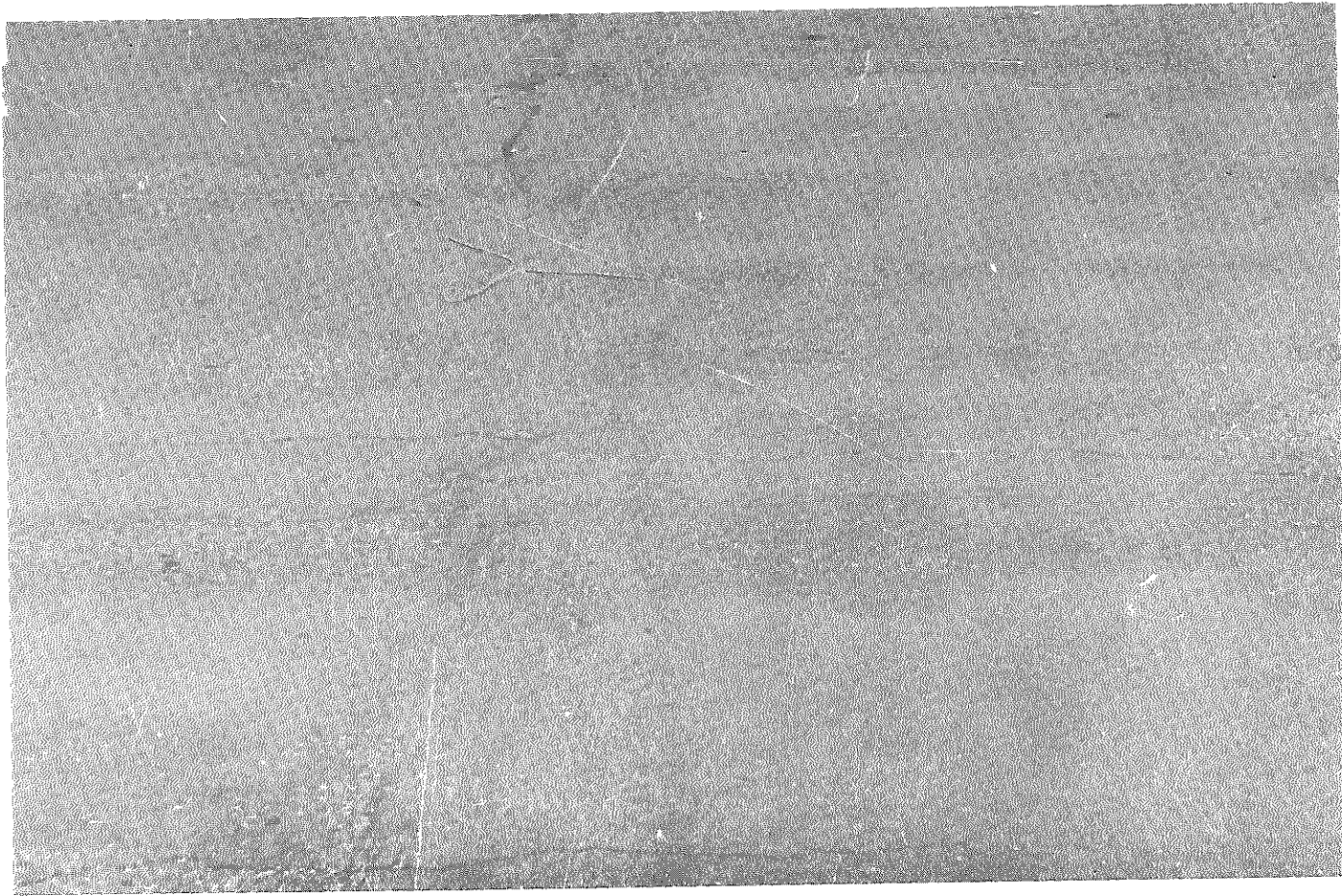


Figure 10. State Fair and Exposition Center, August 1966. A closer view of the surface of the parking lot.

weathered. Typically, the fine aggregate was eroded from around the coarse aggregate particles. Approximately 19.5 miles of this section of roadway had been bypassed by I 64. Views of the existing surface are shown in Figures 11 and 12. The two-lane section and two lanes of the four-lane section were underlaid by portland cement concrete. A patrol grader was used to shave excess bituminous material, both crack filler and mix, off the rough transverse joints which had reflected through the bituminous mat. Many of the larger cracks had been recently sealed with crack sealer.

Just prior to moving the sealing equipment from the State Fair project, one load of slurry seal was laid on Watterson Expressway in Louisville. The slurry was of the same composition as that laid at the Fairgrounds, but the material laid was between 1/4 inch and 1/2 inch thick. The asphalt in the seal was flushed to the surface when traffic was allowed on the seal. Inasmuch as the seal was obviously slick and traffic volumes were very heavy, it was necessary to cover this section of seal with a thin hot-mix sand type mixture the following day. As a result of this, it was decided to reduce the emulsion proportion per batch by 13 gallons for the US 60 project.

The slurry seal was placed on US 60 between August 2 and September 10, 1963. The composition and material sources were the same as for the Fairgrounds, except that the emulsion content was reduced to 160 gallons and the emulsion for the Shelby County portion of the project was obtained from American Bitumuls Co. There was also some variation in the gradation of the aggregate, the combined aggregate gradation, including the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
No. 4	100.0
No. 8	87.0
No. 16	69.7
No. 30	45.1
No. 50	20.8
No. 100	13.1
No. 200	8.9

During the first week of construction, 160 gallons of emulsion per batch were used. The slurry was laid on the two-lane section of roadway (Shelby County) first. The location of the batching equipment was changed once to shorten the haul distance.

The application rate was measured for 45 loads of material and found to average 6.0 pounds of base asphalt and aggregate per square yard. District Maintenance personnel estimated the application rate at 7.6 pounds of dry aggregate per square yard for the whole project. This figure is



Figure 11. US 60, Shelbyville to Middletown, August 1963. A typical view of the appearance of the surface before sealing. Note the area where excess bituminous material was shaved off a rough transverse joint.

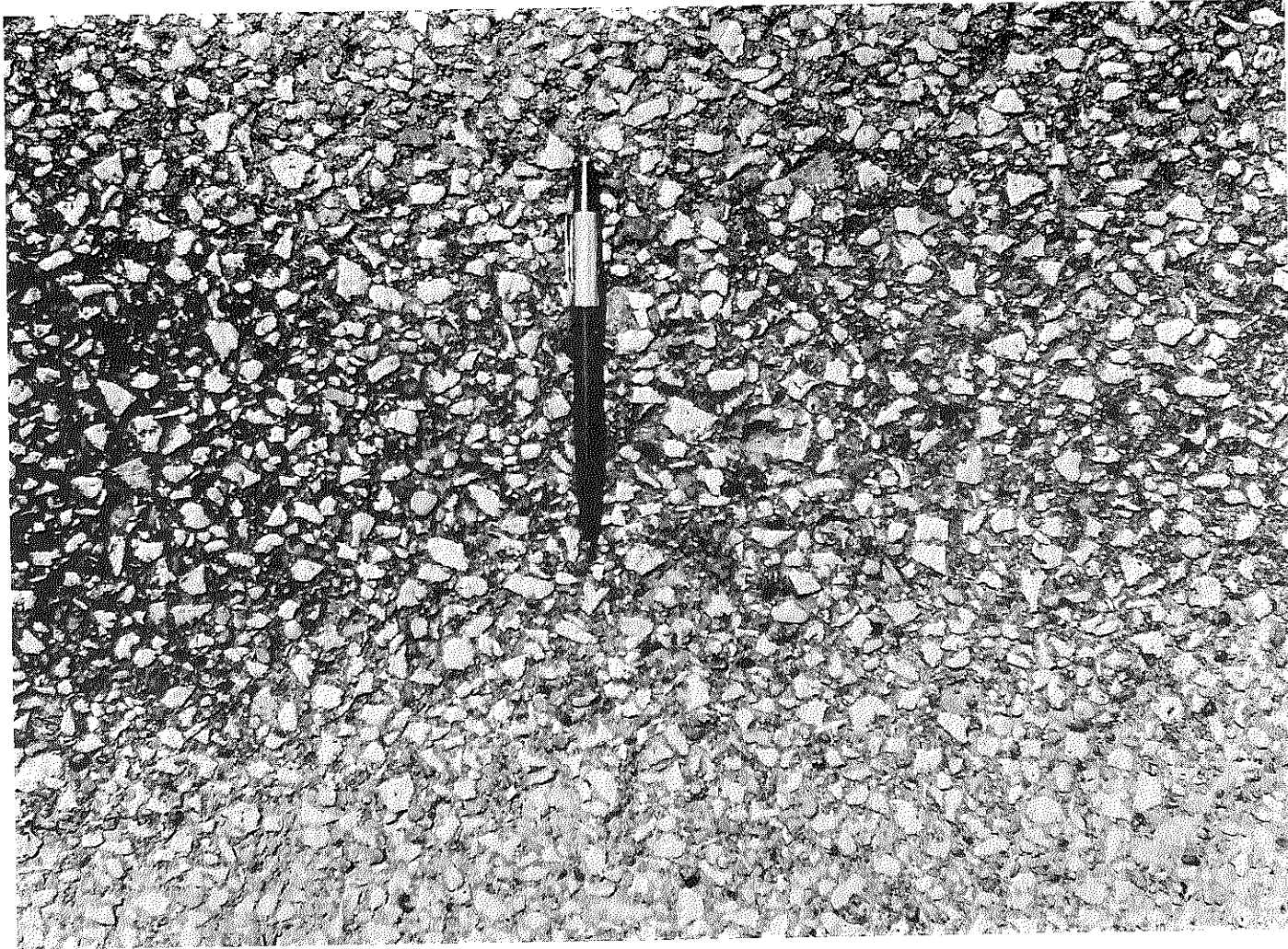


Figure 12. US 60, Shelbyville to Middletown, August 1963. A closer view of the existing, weathered surface.

believed to be high because it was calculated using the square yards of pavement covered and the total amount of aggregate ordered. Rain washed out some areas of freshly laid slurry, and these areas were replaced. Several loads of slurry seal were wasted because of interruption by rain and various other causes. It also neglects numerous median crossovers and turning lanes. The thickness of the application, using either application rate, averages less than 1/16 inch of solid materials.

The following itemized cost breakdown was made by District Maintenance personnel for the project:

Labor	\$ 8,302
Equipment	4,812
550 tons -- River Sand	1,134
680 tons -- Limestone Sand	1,120
33,500 gallons SS-1H Emulsion	4,390
Portland Cement	<u>672</u>
Total	\$20,430

Using these figures, the cost of applying the slurry was calculated to be \$.063 per square yard. This included the cost of all problems associated with applying slurry seal, such as rain, equipment breakdown, handling of traffic, and considerable handwork on median crossovers.

Curing time for the slurry seal varied from about 1-1/2 to 4-1/2 hours, depending upon weather conditions. In certain areas, the pavement was rough and the slurry was laid at a variable thickness. The thicker areas of seal required a much longer curing time prior to opening to traffic.

Views of the slurry seal in September 1963, June 1964, and September 1966 are shown in Figures 13, 14, and 15, respectively. The progressive wear of the seal is quite evident. This section of roadway had a traffic count above 5000 ADT (average daily traffic). It is estimated that slurry seal covered approximately 40 percent of the surface area in August, 1966.

Air permeability readings were taken on this pavement at six locations in January, 1963 and again at the same locations in August 1966. The average reading was 0.263 milliliters per second in 1963, and 0.378 milliliters per second in 1966. No tests were made on the pavement before sealing.

Coefficients of friction were measured in 1964, 1965, and 1966 by a skidding automobile with its wheels fully locked on the wetted pavement (4). From a recording of velocity and time, the coefficient of friction between 30 mph and 20 mph was determined to be 0.54 in 1964, 0.50 in 1965, and 0.52 in 1966. It appears that the seal maintained a satisfactory and uniform level of skid resistance during the two-year period. Frictional



Figure 13. US 60, Shelbyville to Middletown, September 1963. A view of a section of the four-lane pavement shortly after sealing.



Figure 14. US 60, Shelbyville to Middletown, June 1964. A view of a section of the pavement nine months after sealing.

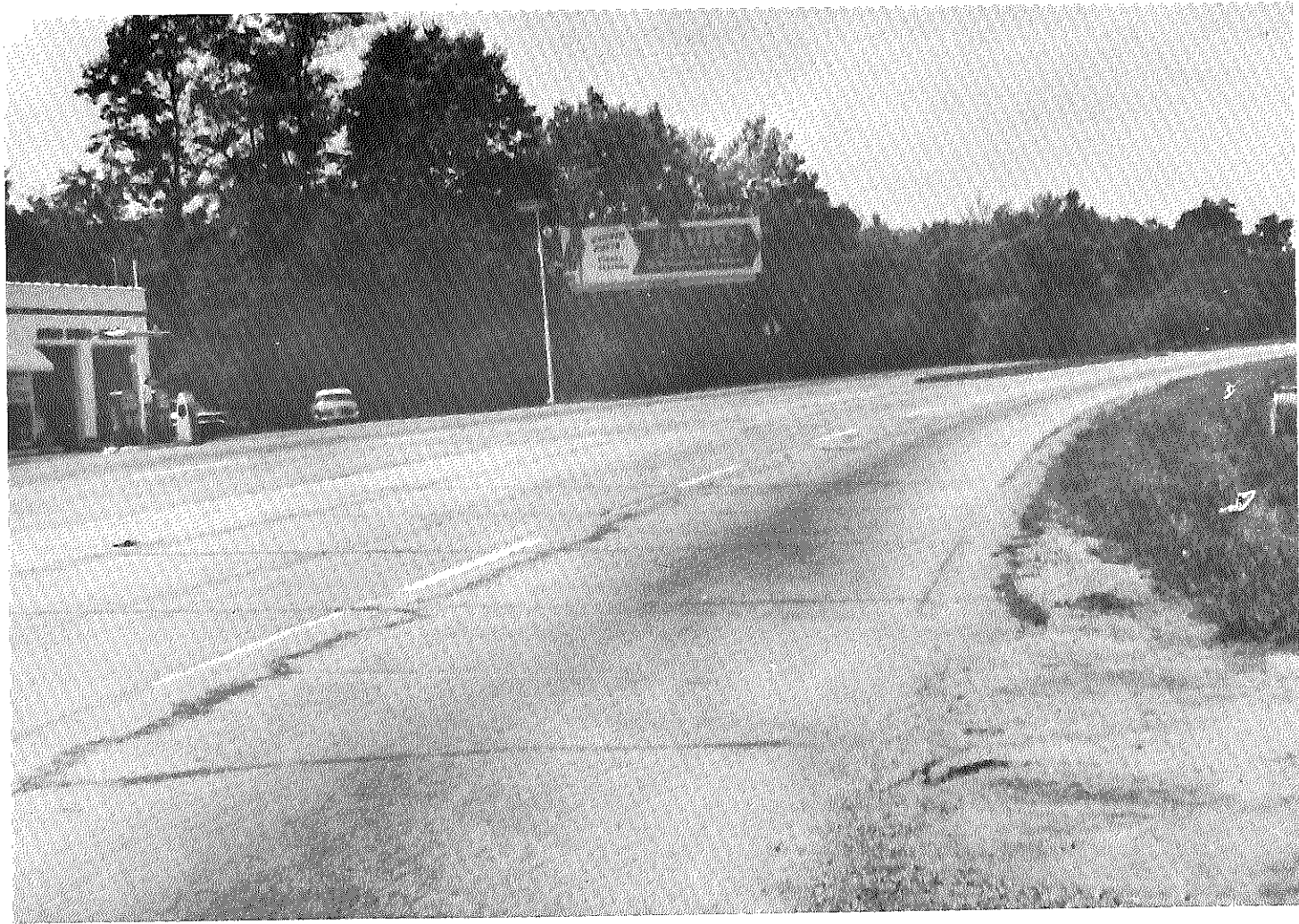


Figure 15. US 60, Shelbyville to Middletown, September 1966. A view of the same section shown in Figures 13 and 14, three years after sealing.

test measurements were made by means of the British Portable Tester just prior to sealing and shortly after sealing. The tests indicated that the slurry seal increased the skid resistance of the pavement as follows:

Before Sealing	After Sealing
0.47	0.57

The after-sealing value was obtained approximately two weeks after the section of pavement was sealed and opened to traffic.

An inspection in July 1969 showed that all of the slurry seal had disappeared.

SHOULDERS, KENTUCKY TURNPIKE

Bituminous shoulders on the Kentucky Turnpike, extending a distance of 40.4 miles were slurry sealed between September 6 and October 22, 1963. The project was let by contract to the Louisville Asphalt Company. The bituminous shoulders were approximately seven years old, were weathered and had considerable longitudinal cracking (Figures 16 and 17). In areas, there was considerable map cracking and settlement of the shoulders. The 10-foot wide, outer, paved shoulder and the 4-foot wide, inner, paved shoulder were sealed. The thickness of the original surfacing on the shoulders was one inch. The shoulders in many areas had previously been sealed with a tar sealer.

The slurry composition and material sources were as follows:

- 60% limestone sand -- Okolona, Kentucky
- 40% Ohio River sand -- Utica, Indiana
- 1-1/2% portland cement
- 20% SS-1H emulsion -- American Bitumuls

The combined aggregate gradation, excluding the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
No. 4	100.0
No. 8	95.3
No. 16	69.5
No. 30	46.0
No. 50	21.9
No. 100	12.7
No. 200	7.4



Figure 16. Kentucky Turnpike, Louisville to Elizabethtown, September 1963. A typical view of an outer shoulder just prior to sealing.

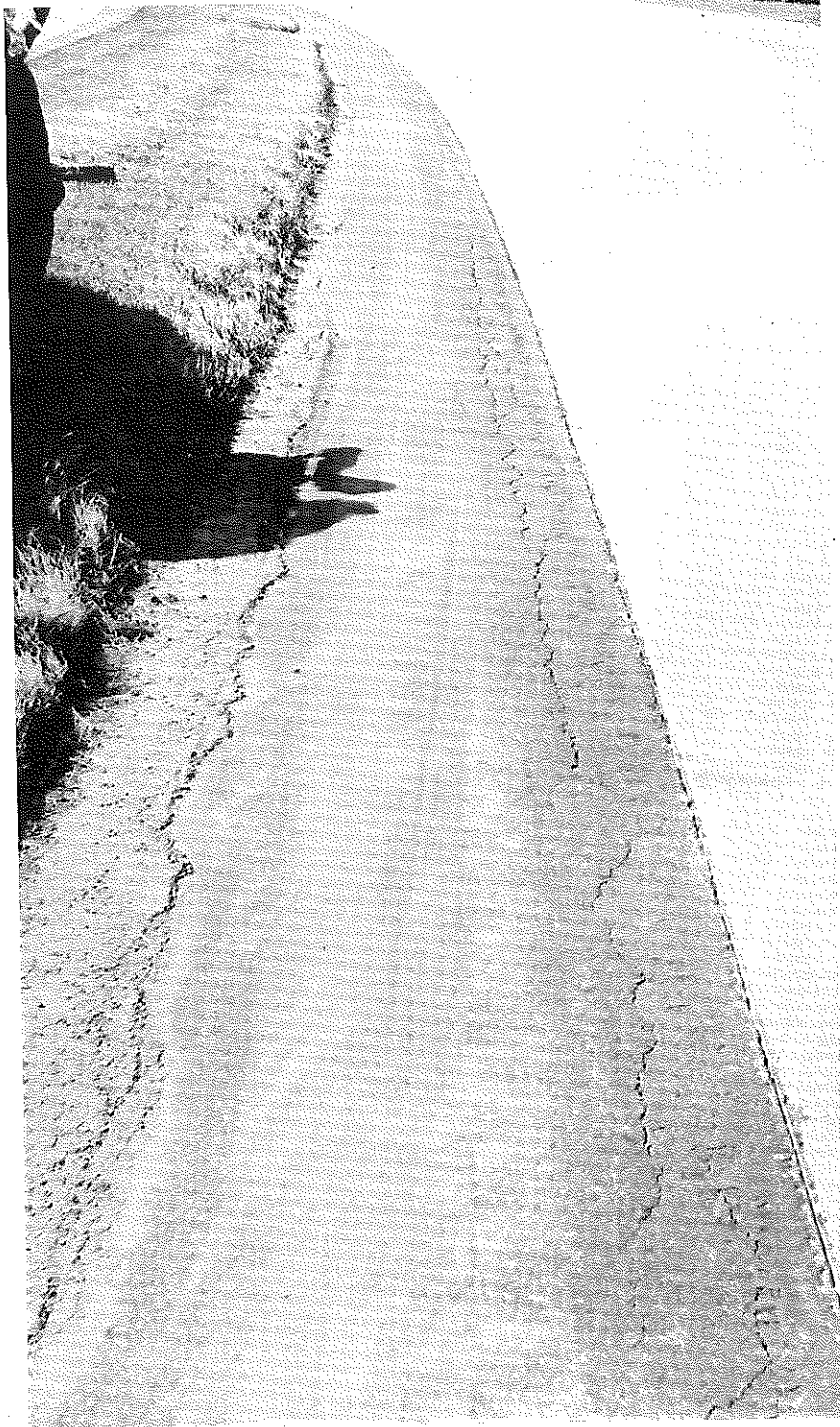


Figure 17. Kentucky Turnpike, Louisville to Elizabethtown, September 1963. A typical view of the inner shoulder prior to sealing.

This was the average gradation (two samplings) of the blended aggregate stockpile on the project. The limestone sand and river sand were blended by use of a high-lift loader, i.e., three scoops of limestone sand to two scoops of medium Ohio River sand. Special Specification for Emulsion Slurry Seal required that 40 percent of the aggregate be quartz sand (natural sand).

The project was bid at \$18.00 a ton for aggregate and \$0.16 a gallon for SS-1H emulsion. The total bid price for the project was \$84,831.60.

Two Young Slurry Seal Machines were used to seal the shoulders at a rate of ten pounds per square yard. Because the trucks were equipped with a single aggregate hopper, it was necessary to blend the sands in the stockpile. The Young Slurry Machine is a truck-mounted unit consisting of a large aggregate hopper, water and emulsion storage tanks, filler hopper, mixing unit, and a spreader box (Figure 18). The machine works on a continuous-mix principle. Aggregate is metered to the mixer by a belt feed (volumetric control). Each time the belt makes one revolution, a pump delivers one gallon of emulsion to the mixer. Filler is fed continuously to the mixer from the filler hopper. The amount of filler delivered can be varied by use of interchangeable cogs. Water is added to the mixer at a rate to give the slurry the proper laying consistency. The slurry flows continuously through the mixer and into the spreader box. A spray bar, mounted beneath the truck, lightly wets the pavement just in front of the spreader box.

A difficulty in laying the slurry was observed on super-elevated sections of roadway where the slurry tended to run off the shoulder onto the concrete pavement (Figure 19). Care also had to be exercised to prevent splattering and discoloration of the guardrail. A special spreader box was constructed to lay the four-foot inside shoulder.

The performance of this seal was very good up to the summer of 1968. Since that time, the shoulders have been chip sealed.

Slurry Seals Placed in 1964

US 68, BOYLE COUNTY

Slurry seal was applied in June 1964 to eleven miles of 18-foot pavement, extending from the Boyle-Mercer County line to the Boyle-Marion County line. The surface had been chip sealed the entire length of the section (Figure 20). There were fatty areas in the surface due to skin patches predominantly located at the outer edges of the surface. Overall the surface was rough with some rutting in the wheel tracks.

The slurry composition and material sources were as follows:

55% limestone sand -- Caldwell Stone Co., Danville, Kentucky

45% natural sand -- R. W. Green Co., Louisville, Kentucky

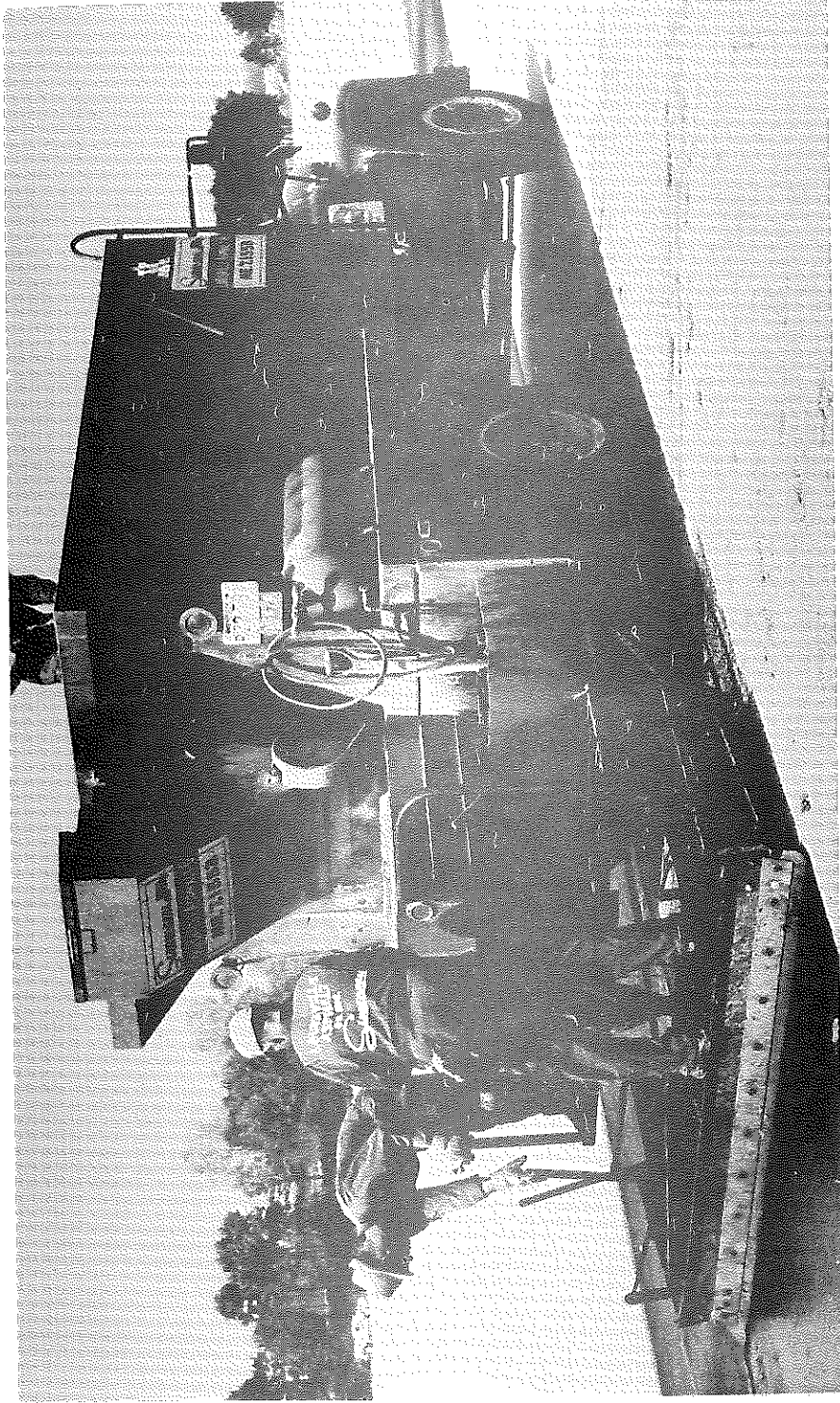


Figure 18. A Young Slurry Seal Machine.

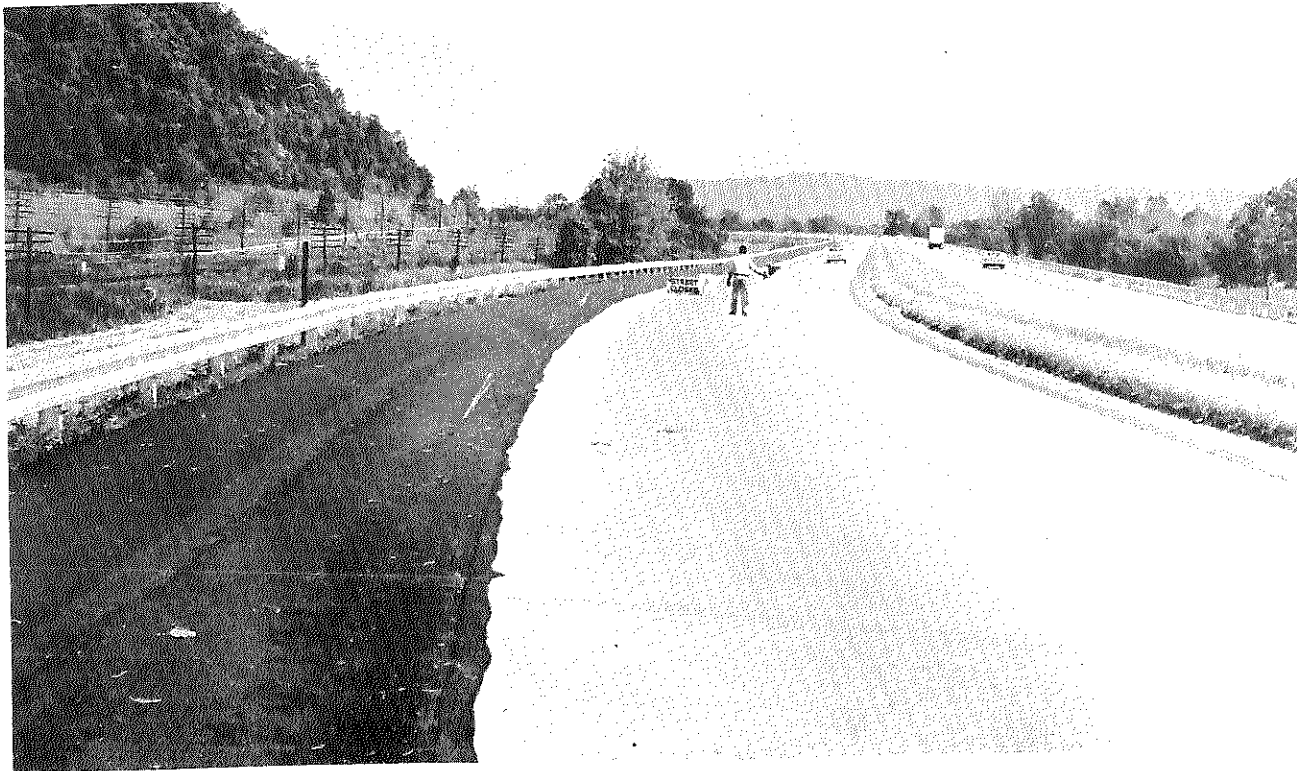


Figure 19. Kentucky Turnpike, Louisville to Elizabethtown, September 1963. On super-elevated curves, the slurry had a tendency to run onto the concrete pavement.



Figure 20. US 68 at the Boyle-Mercer County line, June 1964. Typical appearance of the roadway prior to sealing.

1.2% portland cement -- Kosmos Cement Co., Kosmosdale, Kentucky

16% SS-1H emulsion -- American Bitumuls, Columbia Park, Ohio

The combined aggregate gradation, including the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
3/8-inch	100.0
No. 4	99.7
No. 8	91.9
No. 16	72.8
No. 30	49.7
No. 50	19.7
No. 100	11.8
No. 200	8.8

Air permeability measurements indicated that the chip sealed pavement was impermeable before slurry sealing. Obviously, deslicking of the surface was the primary objective on this project. The roadway had many sharp curves and, as previously noted, there were fatty areas in the surface.

The slurry application rate varied between 8.5 and 11.0 pounds per square yard, depending upon the roughness of the pavement. When the pavement was rough, or rutted, a heavier application of slurry was used because the rubber screed allowed more slurry to discharge into depressed areas. A view of the seal shortly after it was laid is shown in Figure 21.

Inspections were made of the roadway in September 1965, April 1966, and December 1966 (Figures 22 and 23). Rich areas and cracks in the chip sealed surface reflected through the slurry seal shortly after it was laid. In December 1966, it was estimated that the slurry seal still covered very nearly 100 percent of the surface. The 1965 average daily traffic was 970 vehicles per day on this roadway. In terms of surface coverage, the slurry seal was wearing better than those placed in 1963 on the Fairgrounds lot and on US 60; however, it should be recognized that the average applications rate was heavier, and the traffic count was lighter than on US 60. By July 1969, the slurry seal had been covered with a Class I overlay.

KENTUCKY STATE HOSPITAL GROUNDS

An application of slurry seal was made in June 1964 to 1.9 miles of 18-foot wide drives on the Kentucky State Hospital grounds. The main drive, from KY 33 to the main hospital building, was badly weathered and

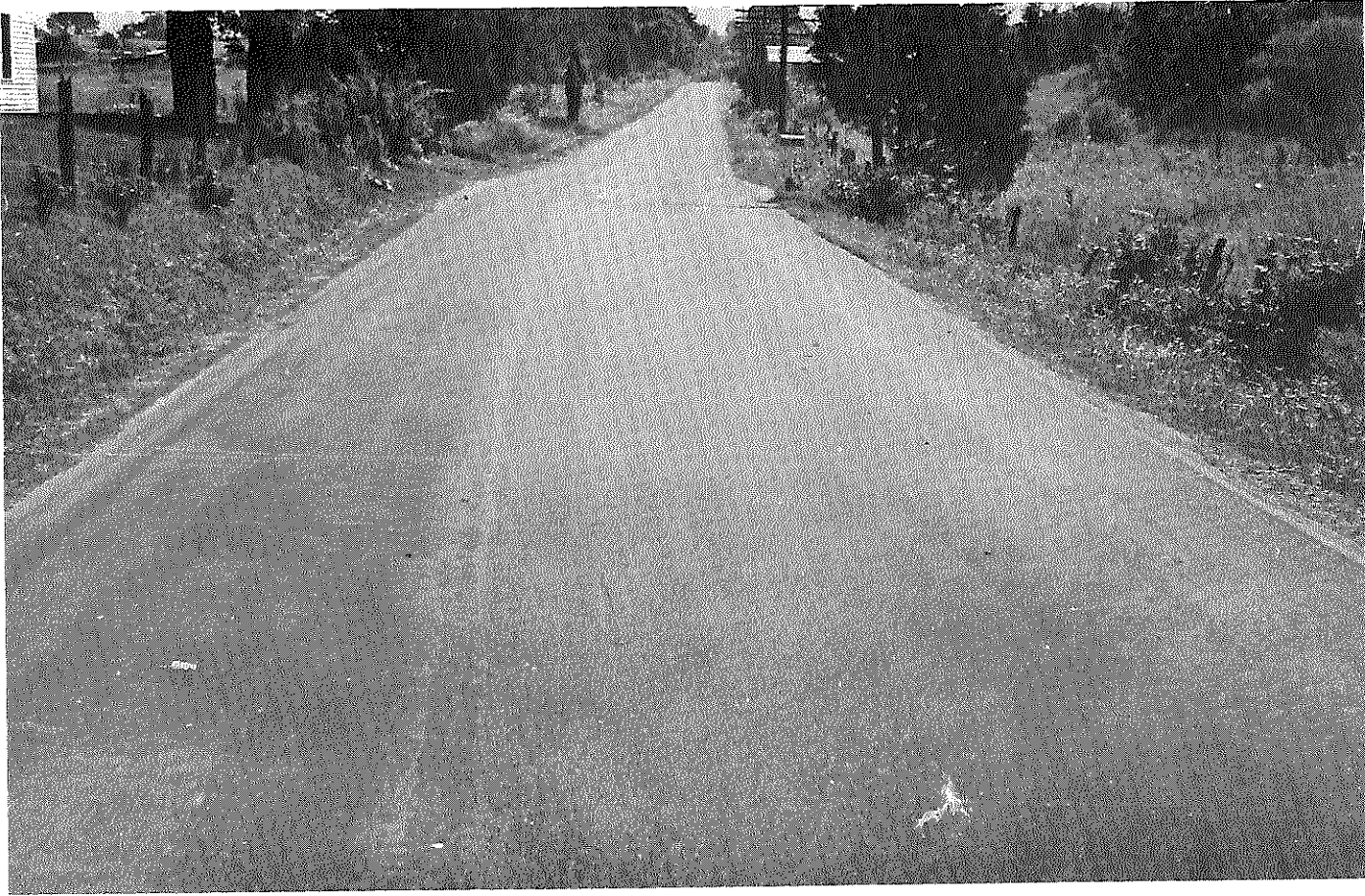


Figure 21. US 68, June 1964. Appearance of the surface shortly after sealing.

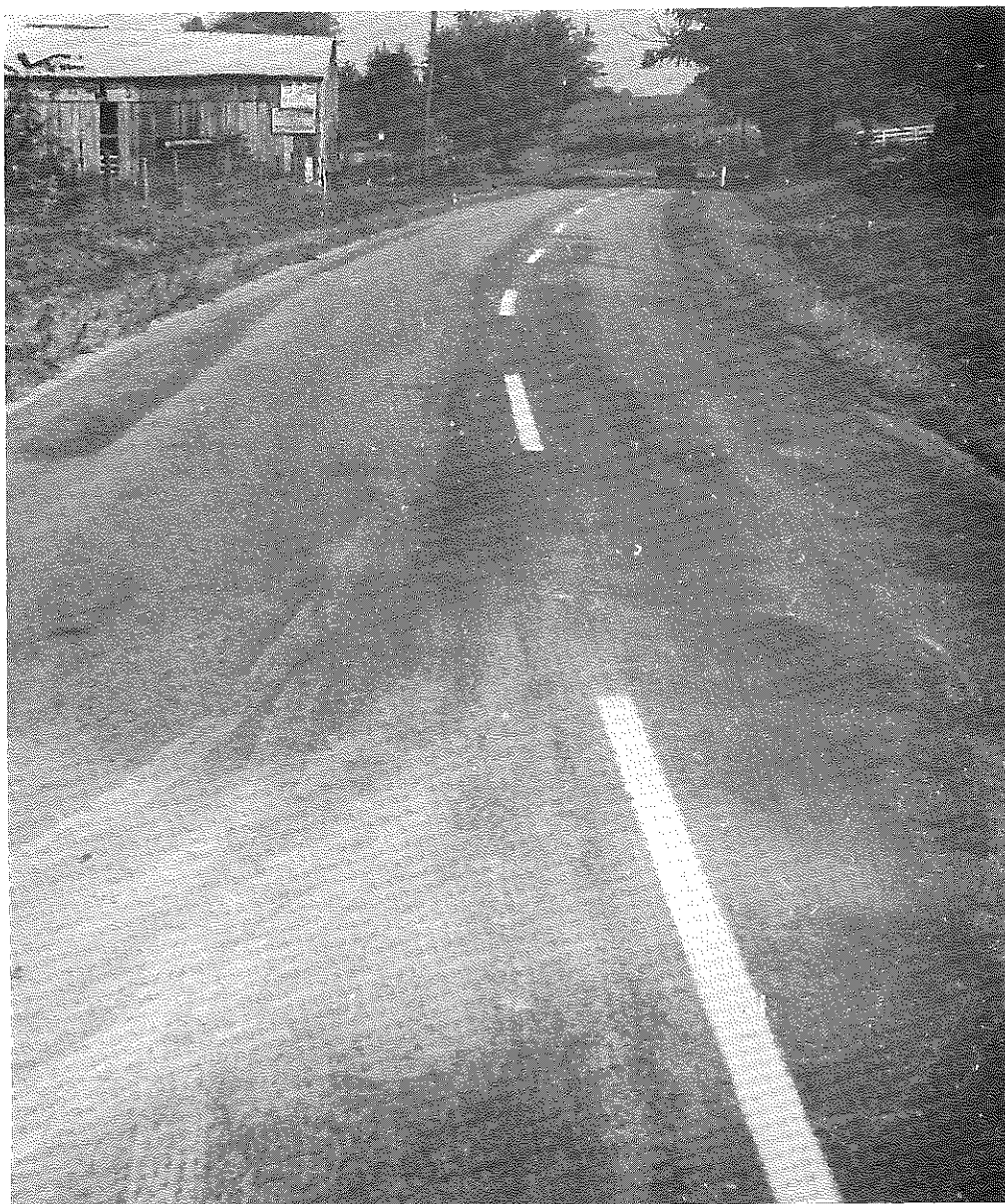


Figure 22. US 68, September 1965. Typical appearance of the roadway one year after sealing.



Figure 23. . US 68, December 1966. Typical appearance of the roadway two and one-half years after sealing.

showed rutting and cracking. Some hot-mix patches had been placed on the more seriously distressed areas.

The slurry composition and material sources were as follows:

- 55% limestone sand -- Caldwell Stone Co., Danville, Kentucky
- 45% natural sand -- R.W. Green Co., Louisville, Kentucky
- 1.2% portland cement -- Kosmos Cement Co., Louisville, Kentucky
- 16% SS-1H emulsion -- American Bitumuls, Columbia Park, Ohio

The combined aggregate gradation, including the portland cement filler, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
3/8-inch	100.0
No. 4	99.9
No. 8	92.6
No. 16	75.1
No. 30	49.1
No. 50	18.4
No. 100	8.7
No. 200	4.9

Because the traffic on the drives was all low speed, the primary objective in the slurry application was to seal and protect the surface. The application rate varied between 8.0 and 9.2 pounds per square yard of solids (asphalt and aggregate).

Air permeability readings were taken at six locations 25 feet apart on the loop section of the drive before sealing (June 2, 1964), immediately after sealing (June 8, 1964), and again in 1966 (July 8). Following is a tabulation of these readings, all obtained with an air pressure of 0.25 inches of water.

<u>Location</u>	<u>Reading in milliliters per second</u>		
	<u>June 2</u>	<u>June 8</u>	<u>July 8</u>
2.5 feet from pavement edge	1.15	0.74	0.13
4.5 feet from pavement edge	1.00	0.44	impermeable
6.5 feet from pavement edge	0.46	impermeable	impermeable

(Cont.)

<u>Location</u>	<u>Reading in milliliters per second</u>		
	<u>June 2</u>	<u>June 8</u>	<u>July 8</u>
2.5 feet from pavement edge	0.49	0.51	impermeable
4.5 feet from pavement edge	0.36	impermeable	impermeable
6.5 feet from pavement edge	1.00	impermeable	impermeable

It is readily seen from examination of these data that the seal was effective after two years of service. However, traffic volume on the drive was light and the slurry seal application has lasted very well. In December 1966, the slurry still covered the entire surface area. By July 1969, all but 0.3 miles of the slurry seal had been covered with a chip-seal application. The 0.3 miles of slurry seal was still in good condition.

US 25, GEORGETOWN TO WILLIAMSTOWN

Slurry seal was applied to US 25 from Georgetown to Williamstown, approximately 30 miles of 20-foot pavement, in June - August 1964. The condition of the existing surface varied within the 30-mile section as follows: A chip-sealed surface, a fine grained, hot-mix surface, a coarse grained, hot-mix surface, and an extensive length of pavement which had numerous skin patches. The section which was surfaced with the coarse-grained mix was of particular interest because shaley-limestone coarse aggregate had popped out, leaving the surface very pitted. Skid tests performed on this section in the fall of 1963 had indicated that the surface was slick.

The composition and material sources were as follows:

55% limestone sand -- Nally and Gibson Quarry, Georgetown, Kentucky

45% medium Ohio River sand -- Louisville Sand and Gravel, Louisville, Kentucky

16% SS-1H emulsion -- American Bitumuls, Columbia Park, Ohio

1.2% portland cement -- Kosmos Cement Co., Kosmosdale, Kentucky

The combined aggregate gradation, including the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
3/8-inch	100.0
No. 4	99.8
No. 8	89.9

(Cont.)

<u>Sieve</u>	<u>Percent Passing</u>
No. 16	73.0
No. 30	51.8
No. 50	18.7
No. 100	11.7
No. 200	8.5

To investigate the effect of thickness of seal coat on the life of the seal, two layers of slurry seal were placed on approximately 1600 feet of the pitted section. The application rate of solids (asphalt and aggregate) varied between 8.1 and 10.9 pounds per square yard for the five loads used in the first layer of seal. The average application was 9.4 pounds per square yard. For the second layer, the application rate varied between 7.5 and 9.7 pounds per square yard. The average application rate was 8.5 pounds per square yard. Thus, the total application for this section of pavement was 17.9 pounds of solids per square yard.

Some difficulty was experienced in the application of the slurry mixture when the limestone aggregate formed balls.

Air permeability measurements were made at three sites on the roadway before sealing and the surface was found to be impermeable at all three sites.

A view of a sealed section of the roadway is shown in Figure 24. The slurry seal had approximately 100 percent coverage in both the single and double applications sections in July 1966 and was performing satisfactorily.

The following skid-test values for the sealed surface were determined at intervals after sealing with the interim standard method of test using an automobile (4).

Coefficient of Friction [f(30-20)]

<u>Date</u>	<u>Southbound Lane</u>	<u>Northbound Lane</u>
1964	0.59	----
1965	0.54	0.57
1966	0.53	0.57

The coefficient of friction may be decreasing with time; however, the values indicate a satisfactory level of skid resistance. In August 1963, this section of roadway was tested for skid resistance with a British



Figure 24. US 25, Georgetown to Williams-
town, April 1965. This area had received
a double application of slurry seal.

Portable Tester and the average coefficient was found to be 0.40. The British Portable Tester results cannot be directly correlated to the tests results given above, but the 0.40 value indicated a hazardous condition. This section of roadway was signed "slippery when wet".

By July 1969, 50 percent of the slurry seal had disappeared on the section from Georgetown to Corinth. From Corinth to Williamstown, 75 percent of the slurry seal had been covered with patching materials and 75 percent of the remaining 25 percent of the slurry seal had worn off.

KY 440, WICKLIFFE TO MAYFIELD (Now designated as KY 121)

Difficulty was experienced with the SS-1H emulsion initially used in the slurry mixture on the project in September 1964. The emulsion would break too quickly after being introduced into the transit-mix truck. A trial run was made in which two bags of cement were used instead of the usual one. The emulsion broke immediately after being introduced into the mix. A second trial was made in which the cement was omitted altogether and the slurry persisted for about three or four minutes. Within five minutes, the slurry could not be discharged from the truck. The emulsion apparently met all requirements of the Department's Standard Specifications. This problem was overcome by changing the source of the emulsion.

The slurry seal lasted for eighteen months. By 1967, the deteriorated pavement condition required a Class I mix overlay.

KY 34, US 27 TO HERRINGTON LAKE BRIDGE

The 2.62-mile section of roadway had a very fat surface (excess asphalt) prior to placing the slurry seal in May 1964. The excess asphalt was the result of two applications of chip seal in which the cover stone of each application had been lost. An unsuccessful attempt was made to remedy this situation by applying additional cover stone. The slurry seal was applied more or less experimentally in an attempt to deslick the surface. The composition of the slurry was the same as given previously for the US 68 project. The excess asphalt soon bled through the slurry seal application. By July 1969, a Class I mix overlay covered the slurry seal.

Slurry Seals Placed in 1965

KY 5, BOYD COUNTY

Difficulty was experienced with a premature break of the SS-1H emulsion on this project. Adjustments were made in the emulsion and the project was completed using the same source of emulsion; however, the finished seal was rough and nonuniform in appearance. A view of the finished seal is shown in Figure 25. The slurry seal lasted one winter and was resurfaced with a Class I mix in 1967.

US 60, SHELBYVILLE TO FRANKFORT

Slickness developed on certain sections of this roadway shortly after sealing in the summer of 1965. Other sections of the seal appeared to have



Figure 25. KY 5, Boyd County, August 1965. A view of the roadway shortly after sealing. Difficulty was experienced with a premature break of the emulsion.

adequate skid resistance. The composition of the slurry seal was basically the same as for other slurry sealed roadways. A steep hill on the west side of Frankfort was particularly problematic because traffic volume is over 5000 vehicles per day, and the roadway has sharp curves. It has been reported that heavy trucks were slipping in travelling up the hill when the pavement was wet. A view of this sealed section of roadway is shown in Figure 26. The slickness was apparently the result of allowing traffic on the slurry seal before it was sufficiently cured. In Figure 27, the result of allowing traffic on the slurry seal before sufficient curing is shown very clearly. To remedy this slickness problem on the hill, a grader was used to shave most of the slurry seal off the surface. This area was paved with a sand asphalt in the summer of 1966.

Skid test measurements were made at two locations on this section of roadway, Frankfort to Shelbyville, prior to slurry sealing in 1964, and after slurry sealing in 1965 and 1966. The following coefficients of friction were obtained:

<u>Year</u>	<u>Test Location</u>	<u>Lane</u>	<u>Coefficient of Friction</u>
1964	at Clay Village	Eastbound	0.48
		Westbound	0.43
1965	at Clay Village	Eastbound	0.46
		Westbound	0.49
1966	at Clay Village	Eastbound	0.51
		Westbound	0.49
1964	Franklin County	Eastbound	0.46
		Westbound	0.44
1965	Franklin County	Eastbound	0.42
		Westbound	0.45
1966	Franklin County	Eastbound	0.44
		Westbound	0.47

These data indicate that the slurry seal did not materially change the skid resistance of the pavement at the locations tested. It appears that the seal maintained the same level of skid resistance during the year it was in service. By July 1969, only 20 percent of the slurry seal remained.

Slurry Seals Placed in 1966

US 27, NEAR NICHOLASVILLE

This 0.7 mile long section of pavement was scheduled for a hot-mix resurfacing in the summer of 1966. The seal was placed in May to determine if any benefits might result from slurry sealing shortly before paving. The existing chip-sealed surface had some rutting and cracking in the wheel

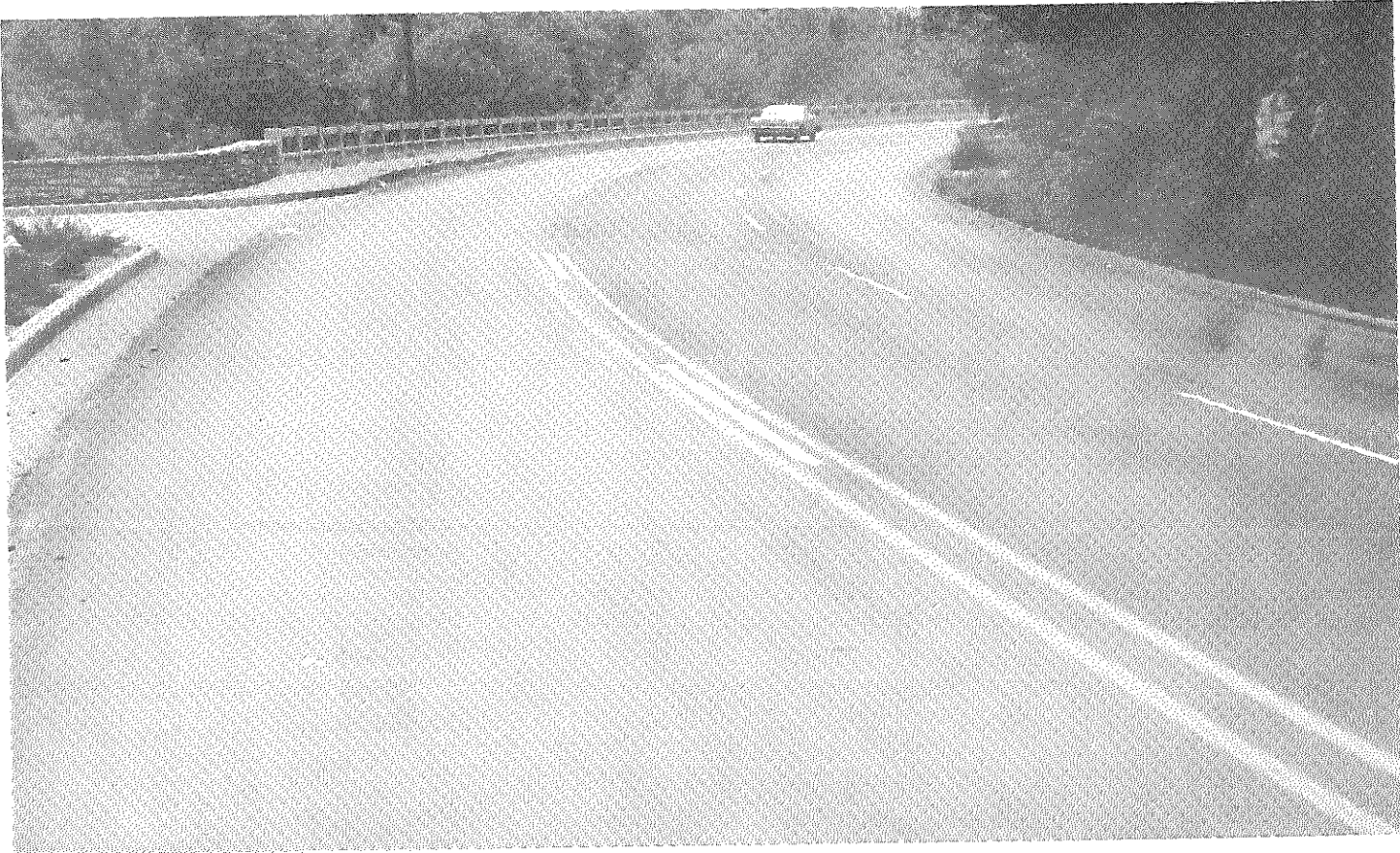


Figure 26. US 60, at Frankfort, July 1965.
A view of the pavement shortly after seal-
ing. Note the glazed appearance of the outer
lanes.



Figure 27. US 60, Shelbyville to Frankfort,
July 1965. Note the glazed appearance in
the wheel tracks of the outer lanes.

paths. The basic formulation of the slurry was the same as for other projects; however, the slurry seal crew was somewhat inexperienced in slurry seal work. Slurry seal was laid on the southbound lane first. After approximately two hours of curing, traffic was routed over the southbound lane while the northbound lane was sealed. Excess asphalt became evident shortly after allowing traffic onto the seal. The surface became very tacky and had a glazed appearance (Figure 28). In spots the sticky slurry was picked up by vehicle tires (Figure 29). Subsequent to sealing this section, it was found that a large excess of emulsion had been used as a result of a faulty valve on the emulsion proportioning equipment.

By July 1969, 0.1 mile was all that remained of the slurry seal and 50 percent of that length was badly worn.

SHOULDERS OF I 75, FAYETTE COUNTY

A slurry seal was placed on approximately 1.7 miles of the outside, northbound shoulder and on 1.0 mile of the outside, southbound shoulder on I 75 in Fayette County in August 1966. The bituminous shoulder had settled as much as two inches below the concrete pavement in this area. The purpose in placing this slurry was to provide a smooth transition from the pavement to the shoulder. Some difficulty was encountered in keeping the slurry off the concrete pavement. A view of a section on the sealed shoulder is shown in Figure 30. A small spreader box was constructed by Maintenance personnel for this work and is shown in Figure 31. The slurry seal did not fully eliminate the vertical displacement at the pavement edge because slurry seal shrinks considerably when placed in thick layers.

By July 1969, the shoulders had settled to a level of at least one inch below the mainline pavement surface. Thirty percent of the slurry seal was badly worn.

Experimental Slurry Seals Placed in 1966

The experience of the Maintenance Division with slurry seals has indicated that the greatest problems are the curing time and the slickness of the seals. It is believed that slickness of the seals placed in Kentucky is related to curing time, i.e., traffic allowed on an uncured seal will tend to bring the emulsion to the surface causing a rich, slick surface.

A slurry seal is cured when traffic may be turned upon it without causing displacement of the slurry seal or a glazing of the surface. Observation has indicated that a slurry seal is not cured until virtually all the water has evaporated. The rate of cure, or evaporation, is affected by several variables. Weather conditions such as low humidity, high temperatures, and high winds are conducive to a fast cure. Shaded areas of slurry take much longer to cure than areas in the direct rays of the sun. Thicker applications also take longer to cure. It is believed that



Figure 28. US 27 at Nicholasville, May 1966. An excess of emulsion in this mixture was a result of a leaking valve in the asphalt proportioning equipment. The seal was cured two hours before allowing traffic onto the surface.

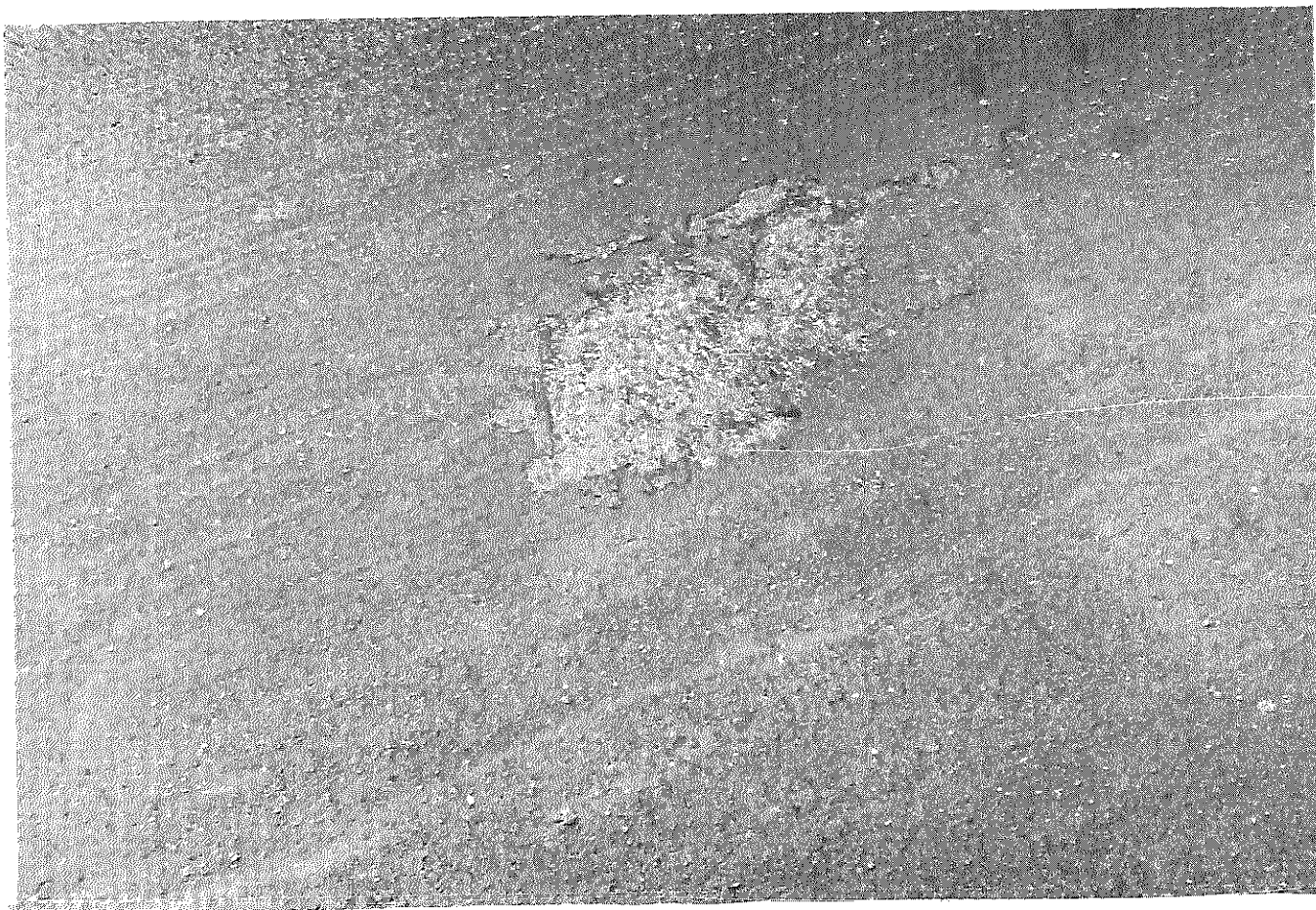


Figure 29. US 27 at Nicholasville, May 1966. A view of an area where the rich slurry seal was picked up by vehicle tires.



Figure 30. I 75, Fayette County, July 1966. The sealed area was approximately three feet in width.



Figure 31. Spreader box constructed by Maintenance forces for sealing bituminous shoulders.

chemically active fillers, such as portland cement and hydrated lime, can decrease the curing time of anionic emulsion slurries. These fillers cause the emulsion to break, thus freeing the water in the emulsion for fast evaporation.

Long curing periods result in higher labor costs and increased hindrance in traffic flow and control. At times the slurry crew has had to stop work in the early afternoon in order to allow the last batches placed to cure adequately prior to opening a roadway to peak afternoon traffic. This results in greater costs and in inefficiency as a result of a limited work day.

During 1966, several experimental measures were tried to alleviate these problems of long cure time and slickness. In an effort to decrease the curing time, hydrated lime, calcium chloride, and cationic emulsion were used. In an effort to provide more skid resistant slurries, high proportions of sharp-grained quartz sands were also used in some mixtures.

US 60, LEXINGTON TO WINCHESTER

Hydrated lime and calcium chloride were used on short sections of US 60, Lexington to Winchester, in August 1966. Dry, hydrated lime was dusted on two short sections of pavement ahead of the sealing operation. There was no noticeable difference between the curing time for these sections and the curing time of the adjoining slurry seal. A strong solution of calcium chloride was also applied on a short section of a lane ahead of the slurry application. This section of slurry seal was noticeably wetter than the adjoining seal for a period of several hours. After all of the seals had cured, there was no difference in the appearance of the treated and untreated areas. Hydrated lime was again added to slurry in October 1966. The lime, in 50-pound bags, was added to three 8000-pound batches at the job site. Lime was added by hand to each of three batches in a transit-mix truck; then the batches were mixed several minutes prior to depositing the slurry into the spreader box and placing on the roadway. Approximately 1/4, 3/4, and 1-1/2 bags were added to each batch, respectively. The lime did not disperse through the loads inasmuch as much of the lime formed balls in the mixture. These balls of lime were caught by a screen over the spreader box as the slurry was dumped. There was no noticeable difference in curing time between the batches containing hydrated lime and those without the hydrated lime. The usual amount of cement was added to all batches.

By July 1969, 20 percent of the slurry seal had worn off. The wear was most noticeable in the inner wheel track. This is most likely the result of a high crown, which permitted the slurry seal to move toward the outside, resulting in only a thin layer of slurry in the inner wheel track.

US 460, FRANKLIN COUNTY

Slurry seal which contained a higher proportion of natural sand (55% of the aggregate) than had been used in the past was laid on US 460

in Franklin County in June 1966. The aggregates came from the same sources as used on the US 60, Shelbyville to Frankfort project, and it will be remembered that portions of the slurry seal placed on that project became slick. It was believed that a higher proportion of polish-resistant natural sand would impart additional skid resistance to the seal.

This slurry was of the following composition:

55% medium Ohio River sand -- Standard Materials

45% limestone sand

17.2% SS-1H emulsion -- Chevron Asphalt Co., Columbia Park,
Ohio

1.2% portland cement -- Kosmos Cement Co., Kosmosdale, Kentucky

The combined gradation, including the portland cement, was as follows:

<u>Sieve</u>	<u>Percent Passing</u>
3/8-inch	100.0
No. 4	99.9
No. 8	99.0
No. 16	87.1
No. 30	77.1
No. 50	35.6
No. 100	16.2
No. 200	12.3

The usual construction procedures were used in mixing and placing this slurry. Skid tests were performed on the seal shortly after placing and the following coefficients of friction were obtained:

Eastbound lane - 0.44

Westbound lane - 0.47

The average daily traffic on the roadway was over 3120 vehicles per day in 1965. Only 20 percent of the slurry seal remains as of July 1969.

US 460, SCOTT COUNTY

Test batches of slurry seals containing large proportions of quartz sands were laid on US 460 in Scott County on October 6, 1966. The first

batch of slurry laid contained Kentucky rock asphalt as the total aggregate. Kentucky rock asphalt is an asphalt-impregnated sandstone currently being commercially produced under the trade name of Gripstop. The material contains approximately 4.5 percent native asphalt. The composition of this batch of material follows:

- 12,000 pounds Kentucky rock asphalt -- Gripstop Corporation,
Edmondson County, Kentucky
- 247 gallons SS-1H emulsion -- Kentucky Asphalt Sales, Louisville,
Kentucky
- 1-1/2 bags portland cement -- Kosmos Cement Co., Kosmosdale,
Kentucky

The following is an approximate combined gradation of the Kentucky rock asphalt and portland cement filler:

<u>Sieve</u>	<u>Percent Passing</u>
1/2-inch	100.0
3/8-inch	95.1
No. 4	80.7
No. 8	63.4
No. 16	48.6
No. 30	34.3
No. 50	21.9
No. 100	9.3
No. 200	3.2

Difficulty was experienced in laying this batch of slurry due to the large proportion of material coarser than a No. 4 screen. A screen was used over the spreader box to retain coarse aggregate which would otherwise catch against the rubber screed and mar the appearance of the finished seal. A large amount of material from this batch blocked the screen and delayed laying the batch to such a degree that much of the mixture had to be disposed of after only 200 to 300 feet of slurry seal was laid.

A second section was sealed with a slurry of the following composition:

- 6000 pounds Kentucky rock asphalt -- Gripstop Corporation
- 6000 pounds limestone sand -- Nally and Gibson Quarry,
Georgetown, Kentucky

273 gallons SS-1H emulsion -- Kentucky Asphalt Sales,
Louisville, Kentucky

1-1/2 bags portland cement -- Kosmos Cement Co., Kosmosdale,
Kentucky

The following is the combined aggregate gradation:

<u>Sieve</u>	<u>Percent Passing</u>
1/2-inch	100.0
3/8-inch	97.5
No. 4	90.3
No. 8	73.0
No. 16	53.1
No. 30	46.5
No. 50	23.9
No. 100	13.0
No. 200	7.6

This batch also clogged the screen and had to be disposed of after approximately 300 feet of slurry seal was laid.

A third batch with the following composition was prepared and laid:

5400 pounds Kentucky River sand -- Gilley Co., Lexington,
Kentucky

6600 pounds limestone sand -- Nally and Gibson Quarry,
Georgetown, Kentucky

247 gallons SS-1H emulsion -- Kentucky Asphalt Sales,
Louisville, Kentucky

1-1/2 bags portland cement -- Kosmos Cement Co., Kosmosdale,
Kentucky

The following is the combined aggregate gradation:

<u>Sieve</u>	<u>Percent Passing</u>
3/8-inch	100.0
No. 4	99.8

(Cont.)

<u>Sieve</u>	<u>Percent Passing</u>
No. 8	90.7
No. 16	77.8
No. 30	66.7
No. 50	41.6
No. 100	12.4
No. 200	7.7

The Kentucky River sand had a sand equivalent value of 58.9. This slurry mixture was placed on the roadway without any delays or difficulties.

The coefficients of friction measured on the three test sections and the control section were:

<u>Aggregate Blend</u>	<u>Coefficient of Friction</u>
100% rock asphalt	0.50
50% rock asphalt and 50% limestone sand	0.42
55% limestone and 45% Kentucky River sand	0.59
55% limestone and 45% Ohio River sand	0.48 (usual slurry)

By July 1969, 75 percent of the slurry in Scott County had worn off.

US 127, ANDERSON COUNTY

Four test strips of slurry seal were placed on the southbound lane of US 127 between Alton and the intersection with KY 425 south of Alton on October 26 and 27, 1966. A fifth test strip was placed in Alton on KY 151 on the southbound lane. These test strips were laid 1) to investigate the use of certain available, high silica content aggregates, 2) to investigate the use of a fast-setting cationic emulsion, and 3) to demonstrate the Rex commercial slurry seal machine. The existing pavement had been slurry sealed earlier in the year, but the outer edges of the pavement had a glazed appearance in many areas. Glazing was caused by excess bitumen from bituminous patches placed to repair the edges of the roadway.

At the request of District Maintenance personnel, skid tests were performed on the pavement in September 1966. A coefficient of friction

of 0.46 was measured on the southbound lane. On the northbound lane, the coefficient of friction was 0.29, which must be regarded as hazardous. In this particular case, the situation was further aggravated since the skid resistance differs greatly between the inner and outer wheel tracks. This presented some difficulty in testing this lane because the rear of the test automobile would skid off the pavement shortly after the wheels were locked. As a result of these skid tests, it was decided to place a second application of slurry seal on the roadway. All of the trial mixtures of the second application were laid with the Rex commercial machine.

The sands used in the various mixtures had the following gradations and sand equivalent values:

<u>Sieve</u>	<u>Percent Passing</u>			
	<u>Walker's</u>	<u>Ohio River</u>	<u>Limestone</u>	<u>Kentucky Rock Asphalt</u>
3/8-inch				86.6
No. 4			100	76.4
No. 8	100	100	98	69.4
No. 16	95	97	77	64.9
No. 30	83	77	52	57.3
No. 50	38	30	37	21.0
No. 100	6	6	25	1.8
No. 200	2	2	17	0.2
Sand Equivalent	47.6	-	50.3	-

Walker's sand, a high silica content sand, is a crushed sandstone. The sandstone is weathered and readily crushes to grain size. The Kentucky rock asphalt sand, furnished by Gripstop Corporation and used in one trial section, was an impregnated sandstone with approximately 4.5 percent natural asphalt, and crushed to pass a 1/2-inch screen. This material differed from that used earlier on a trial basis on US 460 in Scott County in that the rock asphalt was "dry heated" by putting the material through a dryer of a hot-mix plant. This process hardened the natural bitumen and the resulting material was friable and black in color.

Trial mixtures of the following compositions were used to seal five test sections:

Mix A
49% Ohio River sand
49% limestone sand
2% portland cement
16% SS-1H emulsion

Mix B
49% Walker's sand
49% limestone sand
2% portland cement
16% SS-1H emulsion

Mix C
49% Walker's sand
49% limestone sand
2% portland cement
18% SS-1K -- Bitucote

Mix D
49% Ohio River sand
49% limestone sand
2% portland cement
18% SS-1K -- Bitucote

Mix E
98% Kentucky rock asphalt
2% portland cement
18% SS-1K -- Bitucote

Mix A, which was very similar to the usual mix placed by Maintenance forces, was placed with some difficulties. There was some coarse aggregate (3/4-inch to 1-inch) particles in the limestone sand stockpiles. These coarse particles would lodge against the rubber screed at the rear of the spreader box and cause thick lifts of slurry to be laid in areas where the coarse particles exerted sufficient pressure to raise the screed. These particles would also mar the seal. The slurry application varied in thickness from 1/32-inch to 5/8-inch. The slurry cured much slower in the thicker areas. The finished and cured slurry seal presented a rough riding surface.

These same problems were encountered in placing Mix B. Much more water was necessary with this mix to achieve the proper slurry consistency. This mix was placed at 2:30 PM and had not cured by 9:00 PM. A grader was used at 9:00 PM to remove the seal from the roadway. On the following morning it was found that the material removed from the roadway was still soft and that the emulsion could be brought to the surface by mechanically patting the surface. It was suspected that portland cement was not added to this mix because the shear pin on the cement feeder shaft of the mixer was found to be sheared the following morning.

Mixes A and B were placed October 26 and mixes C, D, and E were placed October 27. After placing mixes A and B, all of the aggregates were passed through a 1/4-inch screen to remove the large aggregate particles.

No problems were encountered in placing mixes C and D. The thickness of Mix C varied from 1/4-inch to 3/8-inch. Mix D varied in thickness from 1/16 to 1/8-inch. Mix E thickness varied from about 1/8-inch to 1/4-inch. Larger particles in Mix E were caught by the screed and streaked the slurry surface.

A shorter length of slurry Mix E was laid than had been planned because of a mechanical failure on the Rex machine. Operations ceased when the water-level glass burst and sprayed water over the newly laid slurry mix. It appeared that the cationic emulsion had a shorter curing time than the anionic emulsion; however, the curing time varied considerably with the thickness of the seal.

Mixes A and B were covered with hot-mix patching material in mid-November 1966. By July 1969, Mixes C and D had been covered with hot-mix patching material and 20 percent of the Mix E had worn off in the wheel tracks.

Slurry Seals Placed in 1967

KY 229, LAUREL COUNTY

Slurry seal was applied on 12.3 miles of KY 229, starting at London and extending to the Knox County line in the summer of 1967. The cationic emulsion, SS-1K, was supplied by Bitucote. One truck load of Kentucky rock asphalt aggregate was used; however, more problems occurred with this aggregate than with the normal silica sand-limestone aggregate used on the remainder of the job. A visual inspection in July 1969, showed that 40 percent of the slurry seal had worn off and some patching had been placed. The Laurel County maintenance foreman reported that the patching was required because of base failure and was not a slurry seal failure.

The Laurel County maintenance foreman has been most pleased with slurry seal as a method to reduce pavement slipperiness. He reported that prior to the placement of this slurry seal, one to six traffic accidents per year could be attributed to a slippery pavement. Since placement of the slurry seal, no accidents attributable to a slippery pavement have occurred. This same pavement is scheduled to receive another slurry seal application during the 1969 construction season.

Slurry Seals Placed in 1968

KY 90, Monticello

Slurry seal was applied to KY 90 from five miles east of Monticello to five miles west of Monticello in the summer of 1968. The slurry was

applied on alternate lanes rather than both lanes. The cationic emulsion, SS-1K, was supplied by Ashland Oil Company and considerable difficulty in placement and breaking time was encountered. As of July 1969, 50 percent of the slurry seal had worn off.

KY 210, LARUE COUNTY

Slurry seal was placed in the summer of 1968 on KY 210 in Larue County, starting at the south city limits of Hodgenville and extending 9.5 miles to the west side of Ball Hollow, at which point the stock of materials was depleted. Chevron Oil Company supplied the cationic SS-1K emulsion. Initially, problems were encountered with the mix breaking in the pugmill. This was overcome by adding a Chevron admixture, which sufficiently retarded the breaking time to allow the pugmill to mix and discharge the slurry but which did not retard the breaking time after placement. It is reported that approximately 20 percent of the slurry seal has worn off and there are some problems with the MC asphalt patching material bleeding through the slurry seal. The slurry seal has sealed the surface and has reduced surface ravelling and cracking.

Slurry Seals Placed in 1969

US 119, HARLAN COUNTY

A 5.0-mile length of slurry seal was laid in the spring of 1969 on US 119, starting at Baxter and extending toward Cumberland. A considerable problem arose in determining the proportional amounts of silica sand versus crushed limestone sand to be applied under Special Provision 47-C. Once this was resolved, problems arose with the slurry mixture using Vulcan's anionic emulsion. In an attempt to solve this problem, Vulcan supplied a cationic emulsion which broke in the pugmill. The last two miles of slurry seal that was laid was lifted from the pavement by a hard rain. Apparently, the slurry seal had not had sufficient time to cure prior to the rain.

District 11, Manchester, had scheduled 65 miles of pavement to be slurry sealed. After the first 5.0 miles was laid on US 119, a decision was made to move the equipment to Monticello where it is located as of July 31, 1969.

KY 90, WAYNE COUNTY

As of July 31, 1969, maintenance forces are presently applying another layer of slurry seal on 11 miles of KY 90 from Monticello to the Wayne-Clinton County line. It is interesting to note that the Bitucote SS-1K emulsion presented no problems when mixed with aggregates hauled from Harlan County; however, problems with the emulsion breaking in the pugmill were immediately apparent when Wayne County aggregates were used.

SUMMARY OF FINDINGS AND OBSERVATIONS

The following is a summary of the general findings and observations of the slurry seals placed in Kentucky and reported herein:

1. District Maintenance forces in five districts kept careful cost records on five of the larger slurry seal projects placed during the 1963 and 1964 construction seasons. Cost figures ranged from a low of \$0.063 per square yard to a high of \$0.090 per square yard. These figures include the cost of labor, equipment, and materials. The average cost for the five projects was \$0.076 per square yard. Because cost records were kept on larger projects (four were in excess of 17 miles and one was approximately 6.7 miles), it is possible that the figures are slightly low for generalized slurry seal work. The cost of a conventional A-2 Seal (chip seal), as estimated by District 7 Maintenance, is \$0.09 per square yard.

2. Visual observations, supplemented somewhat by air permeability readings, have indicated that slurry seals are effective in sealing bituminous surfaces. However, it has been observed that slurries are not effective, for the most part, in sealing cracks in the surfaces. Cracks reflect through the slurry seal in a short time after application, although the width of the crack is often diminished.

The useful service life of the seals was quite variable. Light applications of slurry seal (five to six pounds per square yard), placed on sharp curves primarily for deslicking purposes, have an effective life of one year or less. It is estimated that the seals placed on the Fairgrounds lot and on US 60 Jefferson-Shelby Counties had an effective life of between two and three years. The application rate for those seals varied between 5.5 and 7.5 pounds per square yard. Slurry seals which were laid somewhat heavier than this show promise of having an effective service life of three years or more.

3. Skid-test measurements performed to date indicate that properly proportioned and cured slurry seals will improve the skid resistance of slick bituminous surfaces. Natural sand has comprised approximately 45 percent of the total aggregate in all slurry seals placed by Maintenance forces through 1968 construction season. During the 1969 construction season, the natural sand content has been increased to 55 percent.

Certain sections of slurry-sealed pavements, US 60 near Frankfort and US 127 near Alton, have become slick. However, it appears that glazing, or slickness, was the result of excess asphalt on the surface before sealing (US 127 at Alton) or a result of allowing traffic on the seal before it was properly cured (US 60 at Frankfort). It is doubtful that slurry seal will materially improve the skid resistance of surfaces initially showing an excess of asphalt.

4. The long curing time is perhaps the major difficulty encountered in constructing slurry seals. The use of cationic fast-setting emulsions show promise of reducing curing time. Premature breaking in the pugmill may be overcome by the addition of an admixture.

When a heavy application of slurry is desired, it is recommended that the slurry be placed in two or more applications, allowing each application to cure thoroughly. Application rates for a single application of slurry have varied between 5.5 and 11.0 pounds of solid materials per square yard.

5. Oversized aggregate in the stockpile has been a problem frequently encountered. The oversized aggregate, plus No. 4 sieve material, marks the finished surface of the seal. All of the Ohio River sand and limestone sand blends used made acceptable slurry, with the exception of the oversized material previously mentioned. However, many of these blends failed, or very nearly failed, the lower gradation limit on the No. 8, No. 50, and No. 100 sieves.

6. Premature breaking of the emulsion has also been a problem, possibly as a result of an incompatibility of the aggregate and emulsion. Present purchasing procedures commit the Department to a source of aggregate materials for a given county. This could result in costly delays, particularly if the emulsion breaks prematurely and the supplier cannot correct the early break.

7. There have been projects where aggregates obtained from outside the local county have proven to make an acceptable slurry; however, problems immediately arose when local aggregates were used. It is recommended that aggregates be used that have been proven to make an acceptable slurry mix rather than to restrict a given project to the use of local aggregates. It is admitted that transportation costs will raise the unit cost; however, the quality of the end product should be greatly improved and most of the presently encountered "guess work" could be eliminated.

REFERENCES

1. Hokin, F., "Slurry," Rural Roads, June 1960.
2. "Experience with Slurry-Seal Applications," Better Roads, December 1965 and February 1966.
3. Florence, R. L., "Memorandum Report on Slurry Seal Maintenance and Test Applications of 1962," Kentucky Department of Highways, April 1963.
4. Rizenbergs, R.L. and Ward, H.A., "Skid Testing With An Automobile," Kentucky Department of Highways, February 1966.

APPENDIX

1. Special Specification No. 19-56, Emulsion Slurry Seal
2. Special Provision No. 47, Slurry Seal
3. Special Provision No. 47-A, Slurry Seal
4. Special Provision No. 47-B, Slurry Seal
5. Special Provision No. 47-C, Slurry Seal
6. Special Provision No. 69 (Experimental), Crushed Bituminous Sandstone Slurry Seal (Kentucky Rock Asphalt)

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL SPECIFICATION NO. 19-56

EMULSION SLURRY SEAL

This Special Specification shall be applicable only when so indicated on the plans, in the proposals, or on bidding invitations. Specification references are to the Department's 1956 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the preparation of slurry seal mixtures and their application to existing pavement surfaces. The slurry seal mixture shall consist basically of emulsified asphalt, fine aggregate, and water. All work shall be in accordance with these specifications or as otherwise specially provided.

II. MATERIALS

The bituminous material shall be emulsified asphalt, Type SS-1 or Type SS-1h, as may be specified in plans or proposal. Type SS-1 shall meet the requirements of Article 7.7.6. Type SS-1h shall meet the same requirements for Type SS-1, except that the penetration of the residue at 77° F (100 grams, 5 seconds) shall be within the 40 to 90 penetration range.

Mineral aggregate shall consist of fine limestone sand, quartziferous sand, ceramic slag sand, and other approved materials, or blends thereof. Unless otherwise provided on the plans or the proposals, the aggregate shall contain not less than 40 per cent quartz sand. The plasticity index shall not exceed 5, and the sand-equivalent shall not be less than 35. When tested in accordance with the Department's standard methods, the aggregate shall conform to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing</u>
No. 4	100
No. 8	85-100
No. 16	60-85
No. 30	35-65
No. 50	20-45
No. 100	10-28
No. 200	4-12

Water shall be potable and free of harmful salts.

If filler is required in order to meet the grading requirements, it shall comply with the requirements of Article 7.3.6.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1 nor when the atmospheric temperature is less than 45 degrees F. nor when the air temperature has been 35 degrees F. or less during the preceding 24 hours except by written permission from the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is menacing, or when drying and curing conditions are otherwise unfavorable.

B. Equipment

1. General. All equipment herein required of the Contractor for the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools such as may be essential to the satisfactory completion of the work.

2. Mixing Equipment.

a. Method A.

Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow, mixing unit and shall be capable of accurately delivering and proportioning the aggregate, asphalt emulsion, and water to the mixer. It shall thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader, independently of the forward speed. Calibrated controls shall be provided, and they shall be capable of accurately metering the materials into the mixer. The machine shall be capable of operating at a speed of 60 feet per minute and shall not be allowed to exceed 180 feet per minute. Sufficient capacity to properly mix, store, and apply at least 5 tons of slurry per charge shall be provided.

The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment. This equipment shall be capable of applying .05 gallon of water per square yard.

b. Method B.

Batching Plant. The batching plant shall provide for weight-proportioning of emulsion, aggregate, and water and shall be equipped with devices which will permit easy readjustment of any part of the weighing mechanism so that it will function properly and accurately. The weighing devices shall be set so as to charge the required amount of each material.

Mechanical Mixer. The mechanical mixer shall be a transit-type concrete mixer which meets the truck-mixer requirements of ASTM C94, and it shall be capable of thoroughly and uniformly mixing a rated-capacity batch of the material. It shall be equipped with a chute and a control gate through which the slurry may be discharged and dispensed to the spreader.

3. Spreading Equipment. The spreading equipment shall consist of a towed, drag-type, spreader-box or distributor which is equipped with flexible squeegees or strike-off blades. It shall spread the slurry uniformly and to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set. Arrangements for steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, any soil, loose pebbles, or dirt shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. When required, old crack seal and loose, spalled material in or adjacent to cracks or joints shall be removed. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface. Scrubbing of such areas with high potency detergent may be required if the oil and grease are not sufficiently absorbed to provide positive adhesion of the slurry coat. When required, paint stripes or markers shall be removed.

D. Composition of Mixture. The asphaltic emulsion shall be blended with the pre-wet aggregate in the proportion of 9 to 12 percent base asphalt (15 to 20 percent emulsion) by dry aggregate weight. Water shall be added as necessary to obtain a fluid, homogeneous mixture. The water may be varied slightly in the mixture for various surface conditions. The Contractor shall make trial batches, at his expense, to determine the quantities of aggregate and asphaltic binder to be used for the best results. The final blend shall be subject to approval by the Engineer. Where wholly siliceous aggregates are used, hydrated lime or portland cement shall be added in order to obtain the desired dispersion and working characteristics of the slurry. Such additions shall not exceed three percent by weight of aggregate and shall be similarly subject to the approval of the Engineer.

E. Application of Slurry. The surface shall be fogged with water directly ahead of the drag distributor. The slurry shall be at or near the desired consistency when it is discharged into the spreader box; however, minor amounts of re-tempering water may be added there in order to obtain good spreading characteristics. The total time of mixing shall not exceed 4 minutes. A sufficient amount of the slurry shall be carried in the spreader-box to provide proper spreading and the speed of travel shall be not more than 180 feet per minute nor less than 60 feet per minute. The thickness of the completed seal coat shall be nominally 1/8-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/16-inch.

Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.7, 1.7.8 and 1.7.12 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first two hours after application nor thereafter until such time as the seal coat will not be damaged. Traffic moving over the slurry seal within four hours after application shall be held to not more than 15 miles per hour.

IV. METHOD OF MEASUREMENT

The fine aggregate and mineral filler shall be measured in tons in accordance with Article 1.9.1-(d).

The emulsified asphalt shall be measured in gallons in accordance with Article 7.7.2-B.

The water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities thus measured shall be paid for at the contract unit prices bid per ton for "Aggregate" and per gallon for "Bituminous Material", which payment shall be full compensation for cleaning the existing pavement surface; for furnishing, mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED MAY 15, 1963

D. H. BRAY
STATE HIGHWAY ENGINEER

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 47

FOR

SLURRY SEAL

This Special Provision shall be applicable only when so indicated on the plans, in the proposals, or on bidding invitations. Specification references are to the Department's current Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the preparation of slurry seal mixtures and their application to existing pavement surfaces. The slurry seal mixture shall consist basically of emulsified asphalt, fine aggregate, and water.

II. MATERIALS

The bituminous material shall be emulsified asphalt, Type SS-1 or Type SS-1h, as specified on the plans or in the proposal, and shall meet the applicable requirements of Article 621.6.0.

Mineral aggregate shall consist of fine limestone sand, quartziferous sand, ceramic slag sand, and other approved materials, or blends thereof. Unless otherwise provided on the plans or the proposals, the aggregate shall contain not less than 40 percent quartz sand. The plasticity index shall not exceed 5, and the sand-equivalent shall not be less than 35. When tested in accordance with the Department's standard methods, the aggregate shall conform to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing</u>
No. 4	100
No. 8	85-100
No. 16	60-85
No. 30	35-65
No. 50	20-45
No. 100	10-28
No. 200	4-12

Water shall be potable and free of harmful salts.

Mineral filler, if required in order to obtain the grading requirements, shall comply with the requirements of Article 611.5.0.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1 nor when the atmospheric temperature is less than 45 degrees F. nor when the air temperature has been 35 degrees F. or less during the preceding 24 hours except by written permission from the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is threatening, or when drying and curing conditions are otherwise unfavorable.

B. Equipment.

1. General. All equipment required of the Contractor for the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools such as may be essential to the satisfactory completion of the work.

2. Mixing Equipment.

a. Type A.

Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow, mixing unit and shall be capable of accurately delivering and proportioning the aggregate, asphalt emulsion, and water to the mixer. It shall thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader, independently of the forward speed. Calibrated controls shall be provided, and they shall be capable of accurately metering the materials into the mixer. The machine shall be capable of operating at a speed of 60 feet per minute and shall not be allowed to exceed 180 feet per minute. Sufficient capacity to properly mix, store, and apply at least 5 tons of slurry per charge shall be provided.

The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment. This equipment shall be capable of applying .05 gallon of water per square yard.

b. Type B.

Batching Plant. The batching plant shall provide for weight-proportioning of emulsion, aggregate, and water and shall be equipped with devices which will permit easy readjustment of any part of the weighing mechanism so that it will function properly and accurately. The weighing devices shall be set so as to charge the required amount of each material.

Mechanical Mixer. The mechanical mixer shall be a transit-type concrete mixer which meets the truck-mixer requirements of ASTM C94, and it shall be capable of thoroughly and uniformly mixing a rated-capacity batch of the material. It shall be equipped with a chute and a control gate through which the slurry may be discharged and dispensed to the spreader.

3. Spreading Equipment. The spreading equipment shall consist of a towed, drag-type, spreader-box or distributor which is equipped with flexible squeegees or strike-off blades. It shall spread the slurry uniformly and to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set. Arrangements for steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, any soil, loose pebbles, or dirt shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. When required, old crack seal and loose, spalled material in or adjacent to cracks or joints shall be removed. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface. Scrubbing of such areas with high potency detergent may be required if the oil and grease are not sufficiently absorbed to provide positive adhesion of the slurry coat. When required, paint stripes or markers shall be removed.

D. Composition of Mixture. The asphaltic emulsion shall be blended with the pre-wet aggregate in the proportion of 9 to 12 percent base asphalt (15 to 20 percent emulsion) by dry aggregate weight. Water shall be added as necessary to obtain a fluid, homogeneous mixture. The water may be varied slightly in the mixture for various surface conditions. The Contractor shall make trial batches, at his expense, to determine the quantities of aggregate and asphaltic binder to be used for the best results. The final blend shall be subject to approval by the Engineer. Where wholly siliceous aggregates are used, hydrated lime or portland cement shall be added in order to obtain the desired dispersion and working characteristics of the slurry. Such additions shall not exceed three percent by weight of aggregate and shall be subject to the approval of the Engineer.

E. Application of Slurry. The surface shall be fogged with water directly ahead of the drag distributor. The slurry shall be at or near the desired consistency when it is discharged into the spreader box; however, minor amounts of re-tempering water may be added there in order to obtain good spreading characteristics. The total time of mixing shall not exceed 4 minutes. A sufficient amount of the slurry shall be carried in the spreader-box to provide proper spreading and the speed of travel shall be not more than 180 feet per minute nor less than 60 feet per minute. The thickness of the completed seal coat shall be nominally 1/8-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/16-inch.

Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.8, 1.7.9 and 1.7.13 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first two hours after application nor thereafter until such time as the seal coat

will not be damaged. Traffic moving over the slurry seal within four hours after application shall be held to a speed of not more than 15 miles per hour.

IV. METHOD OF MEASUREMENT

The fine aggregate and mineral filler shall be measured in tons in accordance with Article 1.9.1-F.

The emulsified asphalt shall be measured in gallons in accordance with Article 621.2.0.

The water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities thus measured shall be paid for at the contract unit prices bid per ton for "Aggregates" and per gallon for "Bituminous Material", which payment shall be full compensation for cleaning the existing pavement surface; for furnishing, mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED MARCH 15, 1967

A.O. NEISER
STATE HIGHWAY ENGINEER

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 47-A

FOR

SLURRY SEAL

This Special Provision shall be applicable only when so indicated on the plans, in the proposals, or on bidding invitations. Specification references are to the Department's current Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the preparation of slurry seal mixtures and their application to existing pavement surfaces. The slurry seal mixture shall consist basically of emulsified asphalt, fine aggregate, and water.

II. MATERIALS

A. Bituminous Material. The bituminous material shall be an anionic emulsified asphalt Type SS-1 or Type SS-1h or a cationic emulsified asphalt Type CSS-1h as specified for the project.

1. Anionic Emulsified Asphalt. Anionic emulsified asphalt Type SS-1 or Type SS-1h, when specified, shall meet the applicable requirements of Article 621.6.0.

2. Cationic Emulsified Asphalt. The emulsified asphalt, Type CSS-1h, when specified, shall show no separation of asphalt after thorough mixing within 30 days after delivery, except when separation has been caused by freezing or contamination, and shall meet the requirements hereinafter specified.

a. Properties.

Viscosity, Saybolt-Furol, 60 ml @ 77°F.,	
sec.	20-100
Residue by distillation, pct. min.	57
Sieve, pct. retained 20 mesh, max.	0.10
pH, max.	5
Particle Charge.	Positive
Slurry Mixing Test	Pass
Slurry Setting Test, max	One Hour
Tests on Residue from Distillation:	
Penetration @ 77°F., 100 gr., 5 sec.	40-90
Solubility in CCl ₄ , pct. min	97.5
Ductility @ 77°F., cm., min.	40
Ash, pct., max	2

b. Sampling and Testing.

(1) Sampling. A sample of cationic emulsified asphalt shall be not less than one gallon. The samples shall be stored in clean, airtight, sealed containers at a temperature of not less than 40 degrees Fahrenheit until tested. The containers for all emulsion samples shall be glass, black iron, or plastic. The material shall be sampled in accordance with the current Method of Sampling Bituminous Materials, AASHTO T-40.

(2) Testing. All tests shall be conducted in accordance with the current Methods of Testing Emulsified Asphalts, AASHTO T-59 except as hereinafter provided.

(a) Sieve Test - Replace the Sodium Oleate Solution (2%) with distilled water. Use distilled water in all operations, including wetting and subsequent washing of the wire cloth.

(b) pH Test - Use ASTM Method for determination of pH of Aqueous solution with the Glass Electrode, Designation E-70.

(c) Particle Charge Test - This test is made by an electroplating process using a suitable source of D.C. electricity (potential should be adequate to give a milliammeter reading of 4 or more during testing). Metal plates 1 inch by 3 inches, number "1" and "2", are connected respectively to the known positive and negative terminals of the D.C. current supply.

The plates shall be immersed to a depth of 1 inch in the emulsion sample. When the switch is closed, a current of 4 milliamperes or more should flow through the circuit.

After one minute, open switch and remove plates. Gently wash plates, if necessary, with distilled water to remove unbroken emulsion and then examine.

An appreciable layer of deposited asphalt on the negative (No. 2) plate with a relatively clean asphalt-free positive (No. 1) plate signifies a positive particle charge.

(d) Slurry Mixing Test - The Standard Reference Aggregates shall be Ohio River Sand with a silica (SiO_2) content of at least 65 percent and Tyrone limestone sand. The aggregates shall be combined with Portland Cement in the following percentages: 70% Ohio River Sand, 28% Tyrone Limestone Sand and 2% of Portland Cement.

To 200 grams of the reference aggregates, add enough water to yield a well wetted stone (usually about 15%, by weight, (30 grams), based on the dry aggregate). To this wetted aggregate add 20%, by weight (40 grams), of CSS-1h emulsified asphalt. This mixture shall be capable of forming a free flowing, smooth, creamy, homogeneous slurry with hand stirring (spoon or spatula) for a period of two minutes mixing time.

(e) Slurry Setting Test - The above mix, when spread out on a section of asphaltic saturated roofing felt to a thickness of approximately 1/8 inch, shall be dry to the touch in one hour at 60° F. minimum temperature placed in outside air.

B. Aggregates. Mineral aggregate shall consist of fine limestone sand, quartziferous sand, ceramic slag sand, and other approved materials, or blends thereof. Unless otherwise provided on the plans or in the proposals, the aggregate shall contain not less than 40 percent quartz sand. The plasticity index shall not exceed 5, and the sand-equivalent shall not be less than 35. When tested in accordance with the Department's standard methods, the aggregate shall conform to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing</u>
No. 4	100
No. 8	85-100
No. 16	60-85
No. 30	35-65
No. 50	20-45
No. 100	10-28
No. 200	4-12

C. Water. Water shall be potable and free of harmful salts.

D. Mineral Filler. Mineral filler, if required in order to obtain the grading requirements, shall comply with the requirements of Article 611.5.0.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1 nor when the atmospheric temperature is less than 45 degrees F. nor when the air temperature has been 35 degrees F. or less during the preceding 24 hours except by written permission from the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is threatening, or when drying and curing conditions are otherwise unfavorable.

B. Equipment.

1. General. All equipment required of the Contractor for the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools such as may be essential to the satisfactory completion of the work. Equipment described as Type A may be used with either cationic or anionic emulsified asphalts. Equipment described as Type B shall be limited to the use of anionic emulsified asphalts only.

2. Mixing Equipment.

a. Type A.

Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow, mixing unit and shall be capable of accurately delivering and proportioning the aggregate, asphalt emulsion, and water to the mixer. It shall thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader, independently of the forward speed. Calibrated controls shall be provided, and they shall be capable of accurately metering the materials into the mixer. The machine shall be capable of operating at a speed of 60 feet per minute and shall not be allowed to exceed 180 feet per minute. Sufficient capacity to properly mix, store, and apply at least 5 tons of slurry per charge shall be provided.

The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment. This equipment shall be capable of applying .05 gallon of water per square yard.

b. Type B.

Batching Plant. The batching plant shall provide for weight-proportioning of emulsion, aggregate, and water and shall be equipped with devices which will permit easy readjustment of any part of the weighing mechanism so that it will function properly and accurately. The weighing devices shall be set so as to charge the required amount of each material.

Mechanical Mixer. The mechanical mixer shall be a transit-type concrete mixer which meets the truck-mixer requirements of ASTM C-94, and it shall be capable of thoroughly and uniformly mixing a rated-capacity batch of the material. It shall be equipped with a chute and a control gate through which the slurry may be discharged and dispensed to the spreader.

3. Spreading Equipment. The spreading equipment shall consist of a towed, drag-type, spreader-box or distributor which is equipped with flexible squeegees or strike-off blades. It shall spread the slurry uniformly and to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set. Arrangements for steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, any soil, loose pebbles, or dirt shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. When required, old crack seal and loose, spalled material in or adjacent to cracks or joints shall be removed. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface. Scrubbing of such areas with high potency detergent may be required if the oil and grease are not sufficiently absorbed to provide positive adhesion of the slurry coat. When required, paint stripes or markers shall be removed.

D. Composition of Mixtures. The asphaltic emulsion shall be blended with the pre-wet aggregate in the proportion of 9 to 12 percent base asphalt (approximately 15 to 20 percent emulsion) by dry aggregate weight. Water shall be added as necessary to obtain a fluid, homogeneous mixture. The water may be varied slightly in the mixture for various surface conditions. The Contractor shall make trial batches, at his expense, to determine the quantities of aggregate and asphaltic binder to be used for the best results. The final blend shall be subject to approval by the Engineer. Where wholly siliceous aggregates are used, hydrated lime or portland cement shall be added in order to obtain the desired dispersion and working characteristics of the slurry. Such additions shall not exceed three percent by weight of aggregate and shall be subject to the approval of the Engineer.

E. Application of Slurry. The surface shall be fogged with water directly ahead of the drag distributor. The slurry shall be at or near the desired consistency when it is discharged into the spreader box; however, minor amounts of re-tempering water may be added there in order to obtain good spreading characteristics. The total time of mixing shall not exceed 4 minutes. A sufficient amount of the slurry shall be carried in the spreader-box to provide proper spreading and the speed of travel shall be not more than 180 feet per minute nor less than 60 feet per minute. The thickness of the completed seal coat shall be nominally 1/8-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/16-inch. Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.8, 1.7.9 and 1.7.13 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first two hours after application nor thereafter until such time as the seal coat will not be damaged. Traffic moving over the slurry seal within four hours after application shall be held to a speed of not more than 15 miles per hour.

IV. METHOD OF MEASUREMENT

The fine aggregate including mineral filler other than portland cement, when required, will be measured in tons in accordance with Article 1.9.1-F.

Portland cement, when required, will be measured in barrels.

The emulsified asphalt will be measured in gallons in accordance with Article 621.2.0.

The water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities thus measured shall be paid for at the contract unit

Spec. M. No. 276

prices bid per ton for "Aggregate", per barrel for "Portland Cement", and per gallon for "Bituminous Material", which payment shall be full compensation for cleaning the existing pavement surface; for furnishing, mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED MAY 29, 1967

A. O. NEISER
STATE HIGHWAY ENGINEER

KENTUCKY DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 47-B
SLURRY SEAL

This Special Provision shall be applicable when indicated on the plans, in the proposal, or in the bidding invitation. Article references herein are to the Department's 1965 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of furnishing, preparing, and applying slurry seal mixtures to pavement surfaces. Slurry seal mixtures shall basically consist of emulsified asphalt, fine aggregate, portland cement, and water.

II. MATERIALS

A. Emulsified Asphalt. The emulsified asphalt specified in the proposal shall be used.

B. Fine Aggregate. The fine aggregate shall consist of limestone sand, quartziferous sand, ceramic slag sand, and other approved materials, or blends thereof. Unless otherwise provided on the plans or in the proposal, the fine aggregate shall contain not less than 40 percent quartz (SiO₂). The plasticity index shall not exceed 5, and the sand equivalent value shall not be less than 35. When tested in accordance with the Department's standard methods, the fine aggregate (with or without mineral filler) shall conform to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing</u>
3/8	100
No. 4	95-100
No. 8	80-95
No. 16	60-85
No. 30	35-65
No. 50	20-45
No. 100	10-28
No. 200	4-12

C. Water. Water shall be potable and free of harmful salts.

D. Mineral Filler. Mineral filler, if required in order to obtain the grading requirements, shall comply with the requirements of Article 611.5.0.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1 nor when the atmospheric temperature

is less than 50 degrees F. nor when the air temperature has been 35 degrees F. or less during the preceding 24 hours except by written permission from the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is threatening, or when drying and curing conditions are otherwise unfavorable.

B. Equipment.

1. General. All equipment required of the Contractor for the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools such as may be essential to the satisfactory completion of the work.

2. Mixing Equipment.

a. Proportioning Bins. The various ingredients that may be required in the blending of the fine aggregate shall be accurately proportioned from bins. The Engineer shall check and approve the quantities of each ingredient to assure that the fine aggregate uniformly and continuously meets the gradation and chemical properties specified in paragraph II-B.

b. Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow mixing unit and shall be capable of accurately delivering and proportioning the aggregate, emulsified asphalt, portland cement, and water to the mixer by calibrated controls. It shall be of sufficient capacity to thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader. The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment. This equipment shall be capable of applying .05 gallon of water per square yard.

3. Spreading Equipment. The spreading equipment shall consist of a towed drag-type spreader-box or distributor which is equipped with flexible squeegees or strike-off blades. It shall spread the slurry uniformly and to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set. Arrangements for steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, any soil, loose pebbles, or dirt shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. When required, old crack sealing material and loose spalled material in or adjacent to cracks or joints shall be removed. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface. Scrubbing of such areas with high potency detergent may be required if the oil and grease are not sufficiently absorbed to provide positive adhesion of the slurry coat. When required, paint stripes or markers shall be removed.

D. Composition of Mixture. The emulsified asphalt shall be blended with the pre-wet aggregate in the proportion of 15 to 20 percent of the dry aggregate weight. Portland cement shall be added in order to obtain the desired dispersion and working characteristics of the slurry. Such additions shall not exceed 3 percent of the weight of the aggregate and shall be subject to the approval of the Engineer. Additional water shall be added as necessary to obtain a fluid homogeneous mixture. The water may be varied slightly in the mixture for various surface conditions. The Contractor shall make trial batches, at his expense, to determine the blend of aggregate and emulsified asphalt to be used for the best results. The final blend shall be subject to approval by the Engineer.

E. Application of Slurry. The surface shall be fogged with water directly ahead of the spreading equipment. The slurry shall be thoroughly mixed and shall be at the desired consistency when it is discharged into the spreading equipment. A sufficient amount of the slurry shall be carried in the spreader to provide for proper spreading and the speed of travel shall be not more than 180 feet per minute nor less than 60 feet per minute. The thickness of the completed seal coat shall be nominally 3/16-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/8-inch. Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.8, and 1.7.9, and 1.7.13 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first two hours after application nor thereafter until such time as the seal coat will not be damaged. Traffic moving over the slurry seal within four hours after application shall be held to a speed of not more than 15 miles per hour.

IV. METHOD OF MEASUREMENT

The fine aggregate, including mineral filler, will be measured in tons in accordance with Article 1.9.1-F.

Portland cement will be measured in barrels.

The emulsified asphalt will be measured in gallons in accordance with Article 621.2.0.

The water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities thus measured shall be paid for at the contract unit prices per ton for "Aggregate", per barrel for "Portland Cement", and per gallon for "Emulsified Asphalt", which payment shall be full compensation

for cleaning the existing pavement surface; for furnishing, mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED APRIL 8, 1969

A. O. NEISER
STATE HIGHWAY ENGINEER

KENTUCKY DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 47-C
SLURRY SEAL

This Special Provision shall be applicable when indicated on the plans, in the proposal or in the bidding invitation. Article references herein are to the Department's 1965 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of furnishing, preparing, and applying slurry seal mixtures to pavement surfaces. Slurry seal mixtures shall basically consist of emulsified asphalt, fine aggregate, portland cement, and water.

II. MATERIALS

A. Emulsified Asphalt. The emulsified asphalt specified in the proposal shall be used.

B. Fine Aggregate. The fine aggregate shall consist of limestone sand, quartziferous sand, ceramic slag sand, and other approved materials, or blends thereof. Unless otherwise provided on the plans or in the proposal, the fine aggregate shall contain not less than 40 per cent quartz (SiO₂). The plasticity index shall not exceed 5, and the sand equivalent value shall not be less than 35. When tested in accordance with the Department's standard dry sieving methods, the fine aggregate (with or without mineral filler) shall conform to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing</u>
3/8"	100
No. 8	80-100
No. 16	60-85
No. 50	15-45
No. 200	4-12

C. Water. Water shall be potable and free of harmful salts.

D. Mineral Filler. Mineral filler, if required in order to obtain the grading requirements, shall comply with the requirements of Article 611.5.0.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1 nor when the atmospheric temperature is less than 50 degrees F. nor when the air temperature has been 35 F. or less during the preceding 24 hours except by written permission from

the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is threatening, or when drying and curing conditions are otherwise unfavorable.

B. Equipment.

1. General. All equipment required of the Contractor for the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools such as may be essential to the satisfactory completion of the work.

2. Mixing Equipment.

a. Proportioning Equipment. The various ingredients that may be required in the blending of the fine aggregate shall be accurately proportioned and thoroughly mixed by equipment and methods approved by the Engineer. The Engineer shall check and approve the quantities of each ingredient to assure that the fine aggregate uniformly and continuously meets the gradation and chemical properties specified in paragraph II-B.

b. Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow mixing unit and shall be capable of accurately delivering and proportioning the aggregate, emulsified asphalt, portland cement, and water to the mixer by calibrated controls. It shall be of sufficient capacity to thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader, independently of the forward speed of the spreader. The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment. This equipment shall be capable of applying .05 gallon of water per square yard.

3. Spreading Equipment. The spreading equipment shall consist of a towed drag-type spreader-box or distributor which is equipped with flexible squeegees or strike-off blades. It shall spread the slurry uniformly and to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set. Arrangements for steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, any soil, loose pebbles, or dirt shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface.

D. Composition of Mixture. The emulsified asphalt shall be blended with the pre-wet aggregate in the proportion of 15 to 20 percent of the dry aggregate weight. Portland cement shall be added in order to obtain the desired dispersion and working characteristics of the slurry. Such

additions shall not exceed 3 percent of the weight of the aggregate and shall be subject to the approval of the Engineer. Additional water shall be added as necessary to obtain a fluid homogeneous mixture. The water may be varied slightly in the mixture for various surface conditions. The Contractor shall make trial batches, at his expense, to determine the blend of aggregate and emulsified asphalt to be used for the best results. The final blend shall be subject to approval by the Engineer.

E. Application of Slurry Patches and Slurry Seal. The surface shall be fogged with water directly ahead of the spreading equipment. The slurry shall be thoroughly mixed and shall be at the desired consistency when it is discharged into the spreading equipment. A sufficient amount of the slurry shall be carried in the spreader to provide for proper spreading and the speed of travel shall be not more than 180 feet per minute.

All areas of the existing surface that are excessively porous, cracked or otherwise open shall be patched by coating the surface in a manner to fill the openings with the slurry seal mixture. These areas to be patched shall be those designated by the Engineer and shall be thoroughly cleaned before being patched. All patching shall be completed prior to beginning the slurry sealing operations for the entire surface. The patched areas shall have completely "set-up" or hardened before being overlaid with the slurry seal surface treatment.

The thickness of the completed seal coat shall be nominally 3/16-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/8-inch. Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.8, 1.7.9, and 1.7.13 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first 30 minutes after application nor thereafter until such time as the seal coat will not be damaged. Traffic moving over the slurry seal within four hours after application shall be held to a speed of not more than 15 miles per hour. The Contractor shall repair all areas of the slurry seal that are damaged by traffic or other causes during the construction of this project. Any damage caused by applying the seal during unfavorable conditions, improper control and maintenance of traffic, or negligence in the protection of the slurry seal by the Contractor shall be repaired by the Contractor at his own expense.

IV. METHOD OF MEASUREMENT

The fine aggregate, including mineral filler, will be measured in tons in accordance with Article 1.9.1-F.

Portland cement will be measured in barrels.

The emulsified asphalt will be measured in gallons in accordance with Article 621.2.0.

The water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities thus measured shall be paid for at the contract unit prices per ton for "Aggregate", per barrel for "Portland Cement", and per gallon for "Emulsified Asphalt", which payment shall be full compensation for cleaning the existing pavement surface; for furnishing, mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED JUNE 10, 1969

A. O. NEISER
STATE HIGHWAY ENGINEER

KENTUCKY DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 69
(EXPERIMENTAL)
CRUSHED BITUMINOUS SANDSTONE SLURRY SEAL
(KENTUCKY ROCK ASPHALT)

This Special Provision shall be applicable only when so indicated on the plans, in the proposal, or in the bidding invitation. Specification references are to the Department's current Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the preparation of slurry seal mixtures and their application to existing pavement surfaces. The slurry seal mixtures shall consist basically of (1) emulsified asphalt, (2) dry-heated, crushed, bituminous sandstone, (Kentucky Rock Asphalt), (3) portland cement, and (4) water.

II. MATERIALS

A. Bituminous Material. The bituminous material shall be cationic emulsified asphalt, Type CSS-1h.

1. Cationic Emulsified Asphalt. The emulsified asphalt, Type CSS-1h, shall show no separation of asphalt after thorough mixing within 30 days after delivery, and shall meet the requirements hereinafter specified.

a. Properties.

Viscosity, Saybolt-Furol, 60 ml @ 77°F., sec.	20-100
Residue by distillation, pct. min	57
Sieve test, pct. retained, max.	0.10
pH, max	5
Particle Charge	Positive
Slurry Mixing Test.	Pass
Slurry Setting Test, max.	One Hour
Tests on Residue from Distillation:	
Penetration @ 77°F., 100 gr., 5 sec	40-90
Solubility in CCl ₄ , pct. min.	97.5
Ductility @ 77°F., cm., min	40
Ash, pct., max.	2

b. Sampling and Testing.

(1) Sampling. A sample of cationic emulsified asphalt shall be not less than one gallon. The samples shall be stored in clean,

airtight, sealed containers at a temperature of not less than 40 degrees Fahrenheit until tested. The containers for all emulsion samples shall be glass, black iron, or plastic. The material shall be sampled in accordance with the current Method of Sampling Bituminous Materials, AASHTO T-40.

(2) Testing. All tests shall be conducted in accordance with the current Methods of Testing Emulsified Asphalts, AASHTO T-59 except as hereinafter provided.

(a) Sieve Test - Replace the Sodium Oleate solution (2%) with distilled water. Use distilled water in all operations, including wetting and subsequent washing of the wire cloth.

(b) pH Test - Use ASTM Method for determination of pH of Aqueous solution with the Glass Electrode, Designation E-70.

(c) Particle Charge Test - This test is made by an electroplating process using a suitable source of D.C. electricity (potential should be adequate to give a milliammeter reading of 4 or more during testing). Metal plates 1 inch by 3 inches, number "1" and "2", are connected respectively to the known positive and negative terminals of the D.C. current supply.

The plates shall be immersed to a depth of 1 inch in the emulsion sample. When the switch is closed a current of 4 milliamperes or more should flow through the circuit.

After one minute, open switch and remove plates. Gently wash plates, if necessary, with distilled water to remove unbroken emulsion and then examine.

An appreciable layer of deposited asphalt on the negative (No. 2) plate with a relative clean asphalt-free positive (No. 1) plate signifies a positive particle charge.

(d) Slurry Mixing Test - The Standard Reference Aggregate for the mixing test shall be a combination, by weight, of 98 percent of the dry-heated, crushed bituminous sandstone (Kentucky Rock Asphalt) meeting the requirements of paragraph II-B, and 2 percent of portland cement.

To 200 grams of the standard reference aggregate, add enough water to yield a well wetted stone (usually about 15 percent, or 30 grams). To this wetted aggregate add 22 grams of CSS-1h emulsified asphalt, which is 11 percent, by weight, of the dry aggregate. Sufficient inhibitor shall be added to produce a free flowing, smooth, creamy, and homogeneous slurry mixture when hand stirred with a spoon or spatula for a period of two minutes mixing time.

(e) Slurry Setting Test - The above mixture, when spread out on a section of asphaltic saturated roofing felt to a thickness of approximately 1/8 inch, shall be dry to the touch in one hour at

60 degrees F. minimum temperature, when placed in the outside air.

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

1. Dry Heating: The raw crushed aggregate shall be dry-heated to an appropriate temperature and cooled in a manner that will cause the aggregate to remain in a free-flowing condition, without damaging the natural asphalt it contains.

2. Asphalt Content: The dry-heated aggregate shall contain not less than 3.0 percent of natural asphalt by weight. The natural asphalt content shall be determined by extraction on the dry-heated aggregate as furnished (without additional crushing or fracturing during testing), with trichlorethylene used as the solvent.

3. Penetration: The residue obtained from extraction and distillation of the natural asphalt in the dry-heated aggregate shall show a penetration at 77° F., 100 g., 5 sec. not greater than 75.

4. Silica: The extracted aggregate shall contain not less than 90 percent Silica (SiO_2) as determined by chemical analysis.

5. Gradation: The size-gradation of the dry-heated aggregate shall comply with the following requirements:

<u>Sieve Size</u>	<u>Percent Passing</u>
No. 4	100
No. 30	60-90
No. 100	1-10

C. Water. Water shall be potable and free of any ingredients harmful to the mixture.

D. Inhibitor. The inhibitor shall be one certified by the manufacturer as being compatible for use with Cationic Emulsified Asphalt, Type CSS-1h and shall be supplied in standard containers properly labeled with brand name, contents, and recommended usage rate.

III. CONSTRUCTION METHODS

A. Seasonal and Weather Limitations. Slurry seal work shall not be permitted between October 31 and May 1, nor when the atmospheric temperature is less than 45 degrees F., nor when the air temperature has been 35 degrees F. or less during the preceding 24 hours, except by written permission from the Engineer. Slurry seal work shall be suspended during periods of high humidity, when rain is threatening, or when drying and curing conditions are otherwise unfavorable.

B. Equipment.

1. General. All equipment to be used in the performance of the work shall be subject to the approval of the Engineer before construction is permitted to begin and shall be maintained in a satisfactory operating condition. In addition to the equipment described herein, the Contractor shall furnish squeegees and other small tools that may be essential to the satisfactory completion of the work.

2. Mixing Equipment.

Continuous-Flow Mixer. The slurry seal mixing machine shall be a continuous-flow mixing unit and shall be capable of accurately delivering and proportioning the aggregate, portland cement, asphalt emulsion, water, and inhibitor to the mixer. It shall thoroughly mix and discharge the product in a continuous flow and at a uniform rate as required for the area covered by the spreader, independently of the forward speed. Calibrated controls shall be provided, and they shall be capable of accurately metering the materials into the mixer. The machine shall be capable of operating at a minimum speed of 60 feet per minute and shall not be allowed to exceed 180 feet per minute. Sufficient capacity to properly mix, store, and apply at least 5 tons of slurry per charge shall be provided.

The mixing machine shall be equipped with a fog-spray water system which is capable of thoroughly dampening the pavement surface ahead of the slurry spreading equipment, and capable of applying .05 gallon of water per square yard.

3. Spreading Equipment. The spreading equipment shall consist of a towed drag-type spreader-box or distributor which is equipped with flexible squeegees or strike-off blades, which shall be capable of spreading the slurry uniformly to the desired thickness. It shall prevent loss of slurry on varying grades and shall have adjustments whereby the crown and depth may be set, and devices for accurate steering and guiding shall be provided.

C. Preparation of Existing Surface. Prior to the application of the slurry, loose pebbles, dirt, and all debris shall be removed from the existing pavement surface. Cleaning shall be accomplished by brooming, washing, or by blowing with compressed air. When required, old crack sealer and loose spalled material in or adjacent to cracks or joints shall be removed. Oily or greasy areas shall be covered with fine sand or other absorbent material for a period of one hour prior to cleaning the surface. Scrubbing of such areas with high potency detergent may be required if the oil and grease are not sufficiently absorbed to provide positive adhesion of the slurry coat. When required, paint stripes or markers shall be removed.

D. Composition of Mixture. The asphaltic emulsion shall be blended with the pre-wet aggregate in the proportion of 6 to 8 percent asphalt (approximately 10 to 12 percent emulsion) by dry aggregate weight. Inhibitor may be added to the aggregate as necessary to obtain a fluid homogeneous mixture. The amount of inhibitor and water may be varied slightly in the mixture for various surface and atmospheric conditions. The Contractor shall make trial batches, at his expense, to determine the quantities of aggregate, inhibitor, water, portland cement and emulsified asphalt to be used for the best results. The final blend shall be subject to the approval of the Engineer. The necessary quantity of portland cement, not exceeding

3 percent of the weight of the aggregate, shall be added in order to obtain the desired dispersion and working characteristics of the slurry.

E. Application of Slurry. The surface shall be fogged with water directly ahead of the drag distributor. The slurry shall be at or near the desired consistency when it is discharged into the spreader box; however, minor amounts of re-tempering water may be added there in order to obtain good spreading characteristics. The total time of mixing shall not exceed 4 minutes. A sufficient amount of slurry shall be carried in the spreader-box to provide for proper spreading, and the speed of travel of the spreading equipment shall be not more than 180 feet per minute nor less than 60 feet per minute. The thickness of the completed seal coat shall be nominally 1/8-inch, shall not exceed 1/4-inch, and in no instance shall the thickness be less than 1/16-inch. Hand tools, lutes, and squeegees shall be used to spread slurry in areas which are not accessible to the slurry spreader.

F. Protection. The Contractor shall provide the necessary barricades, flagmen, and warning signs as specified in Articles 1.7.8, 1.7.9 and 1.7.13 and shall otherwise provide for the safety and convenience of the public.

Traffic shall not be permitted over the slurry seal within the first hour after application nor thereafter until such time as the seal coat will not be damaged.

IV. METHOD OF MEASUREMENT

The crushed bituminous sandstone will be measured in tons in accordance with Article 1.9.1-F.

Portland cement will be measured in barrels. One barrel being equal to 376 pounds.

The cationic emulsified asphalt, Type CSS-1h, will be measured in gallons in accordance with Article 621.2.0.

The inhibitor and water will not be measured for payment, but shall be considered as incidental to the work.

V. BASIS OF PAYMENT

The quantities, thus measured, shall be paid for at the contract unit prices per ton for "Crushed Bituminous Sandstone", per barrel for "Portland Cement", and per gallon for "Bituminous Material", which payment shall be full compensation for cleaning the existing pavement surface; for furnishing (including dry-heating of the aggregate), mixing, hauling, and placing all materials; for protecting the treated surface and controlling traffic; and for furnishing all labor, equipment, tools, and incidentals necessary for the satisfactory completion of the work.

APPROVED APRIL 8, 1968

A.O. NEISER
STATE HIGHWAY ENGINEER