



COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

August 11, 1964

HENRY WARD
COMMISSIONER OF HIGHWAYS

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

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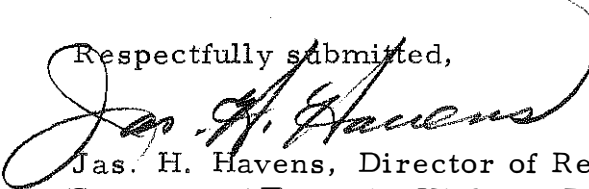
MEMORANDUM

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

SUBJECT: Annual Report, Division of Research;
HPS-HPR-1(25), Part II; Fiscal Year 1963-64

The attached report is a summary of the Research Division's activities and accomplishments during the past fiscal year. This report, in a similar way, reflects the status of each research project at the close of the year. The compilation may further serve other administrative uses within the Department and to fulfill other obligations to the Bureau of Public Roads. Copies are being distributed to our Research Committee and to the Bureau of Public Roads. Of course, constructive suggestions regarding various aspects of the program and individual projects are invited.

Respectfully submitted,



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

JHH:afj

cc: Research Committee
R. O. Beauchamp
R. L. Campbell
T. J. Hopgood
A. O. Neiser

Attachment

ANNUAL REPORT
Fiscal Year 1963-64

for
Project HPS-HPR-1(25), Part II

Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

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

132 Graham Avenue
Lexington, Kentucky

July, 1964

KYHPR-64-1

EXPERIMENTAL CONCRETE PAVEMENT
CONTAINING FLY-ASH ADMIXTURES

Fiscal Year 1963-64

In 1962 the Kentucky Department of Highways, in cooperation with the Bureau of Public Roads, began an investigation of the use of fly ash in portland cement concrete for pavements. The project was undertaken to evaluate the performance of a cement - fly ash concrete pavement to compare its performance with that of a normal cement concrete pavement.

Approximately 2 1/3 miles of urban, four-lane, divided highway on the Poplar Level Road, in Louisville, Kentucky, was chosen for the investigation. Two, parallel, 26-foot wide, dual-lane pavements 9-inches thick were placed on a 4-inch insulation course of dense-graded, crushed limestone aggregate. The project was divided into three sections: a control section and two experimental sections. The major portion of all pavement concrete was placed during the summer of 1963. Materials were dry-batched at a plant near the project and were transported in dry-batch trucks to a "Twinbatch" mixer at the site. All batches were mixed for a 1-minute period. The mixer was rated at 34 cu ft and was operated at a 10 percent overload, giving 37.4 cu ft per batch. The major portion of concrete utilized in each of the three sections was placed and finished by conventional mechanical methods. Mixtures were adjusted at the mixer to produce a slump approximately 2 1/2 inches and an air content of 4.5 percent plus or minus 1.5 percent.

Concrete placed in the Control Section was proportioned to contain six sacks of cement per cubic yard in accordance with the Department's specification for pavement concrete. A ratio of fine aggregate to total aggregate combination of 37 percent by weight was maintained. Provision for the addition of fly ash and a reduction in the cement requirement for concrete placed in the experimental sections was made through a Special Provision. Concrete placed in Experimental Section A was proportioned to contain five sacks of cement and 94 pounds of fly ash per cubic yard. All mixtures for Experimental Section A were proportioned on a solid basis, and the fly ash in excess of that required to replace one sack of cement was considered as fine aggregate. Thus, by deducting a weight of sand equal to this excess (specific gravity of sand and fly ash were equal), a ratio of fine aggregate to total aggregate combination of 37 percent by weight was maintained. Concrete placed in Experimental Section B was proportioned to contain five sacks of cement and 140 pounds of fly ash per cubic yard. The concrete was proportioned in a manner similar to the method used for Experimental Section A.

Type I normal portland cement from one producer was utilized in all mixtures. The fine aggregate was natural sand and the coarse aggregate was crushed limestone ranging from 2 1/2 inches to 1/4 inch in nominal size. The fly ash was locally supplied and met the requirements of ASTM Designation: C 350-60T. The same brand and type air-entraining admixture was added to all mixtures at the mixer. Both the cement and fly ash were supplied in bulk.

Construction supervision and inspection were in accordance with

standard, departmental procedures for all construction projects. Division of Construction personnel made necessary adjustments in mixture proportions, sampled materials and concrete, supervised construction and made routine inspections. Beams and cylinders for flexural and compressive strength testing at 3, 7 and 28 days and 6 and 12 months were cast independently by Division of Research personnel. Cylinders were also cast for 3-month compressive strength testing and beams were cast for freeze-thaw testing beginning at 14 days. Each set of specimens that was cast consisted of 18 beams and 18 cylinders. All tests were in triplicate. Four sets of specimens were cast from concrete placed in each of the three sections for the project. All beams and cylinders were cast and cured in accordance with procedures outlined under ASTM Designation: C 31, Making and Curing Concrete Compressive and Flexural Test Specimens in the Field. The cylinders were 6 inches diameter by 12 inches long and the beams were 3 inches by 4 inches by 16 inches. The fresh concrete used in casting of beams and cylinders was sieved on appropriate screens in order to comply with the aggregate size limitation for size specimens cast.

The average free-water requirement for mixtures from which beams and cylinders were cast was 30.99, 30.12 and 31.23 gallons per cubic yard respectively for the Control, Experimental A and Experimental B Sections. Slump and air-content tests were conducted four to five times per day during placement. Slumps ranged from 2 to 3 inches and averaged approximately 2 5/8 inches. Air contents ranged from 2.3 percent, an exceptional case, to 6.5 percent and averaged 4.78 per-

cent. The minimum strength of portland cement concrete for pavements as required by the Kentucky Department of Highways is 3500 psi in compression and 600 psi modulus of rupture at 28 days. Specimens from all mixtures placed in the various sections met the designated minimum strength requirements. Compressive and flexural strength tests were made in accordance with ASTM Designations: C 39-61 and C 293-59. Flexural and compressive strength test results are listed in the accompanying table.

Early strengths for concrete placed in the Experimental Sections were expected to be somewhat lower than that for the Control Section, unless a significant reduction in the water requirement could be achieved in the Experimental Sections. A significant reduction in water requirement was not achieved in production of the experimental mixtures and average strengths through 28 days for concrete placed in the Experimental Sections were less than those for the control mixtures. This observation is in accordance with the general conception that pozzolonic benefits develop slowly and do not appear within the first month. The average 3-month and 6-month strengths for the Experimental Sections were greater than those for the Control Section. Beams from all sections have shown good performance in freeze-thaw testing. Freeze-thaw tests were conducted in a manner similar to that outlined under ASTM Designation: C 310-61T.

Two performance surveys have been conducted to date. No major defects or signs of deterioration were observed in any of the sections. All sections appear to be performing equally well and minor defects were equally distributed among the three sections. Approximately 500

feet of pavement were placed in Experimental Section A on December 5, 1962. The temperature dropped below the freezing point that night and remained below freezing for several days thereafter. The section has been observed several times to date, and there is no evidence of any detrimental effects.

STRENGTH TEST DATA

	DATE PLACED	LBS. FREE WATER PER CU. YD.	COMPRESSIVE STRENGTH: PSI. AVG. OF 3 SPECIMENS					FLEXURAL STRENGTH: PSI. AVG. OF 3 SPECIMENS			
			3 DAY	7 DAY	28 DAY	3 MO.	6 MO.	3 DAY	7 DAY	28 DAY	6 MO.
CONTROL	6-13-63	252.7	3249	3806	4914	4955	5902	806	850	1050	1250
	7-17-63	264.2	2882	4082	4562	5491	6493	813	938	1125	1338
	7-24-63	255.6	2963	4073	5453	5856	6208	725	956	1075	1413
	8-8-63	260.6	3447	3776	4949	5813	6289	735	1062	1263	1425
	AVG.	258.3	3135	3935	4970	5529	6223	770	952	1128	1357
EXPR. A.	12-5-62	238.9	1958	3872	4868	5859	6455	385	813	1106	1349
	6-3-63	261.3	2952	3579	4619	6354	6170	738	988	1188	1500
	6-11-63	253.4	2330	3270	4572	5282	6428	550	700	1015	1400
	8-21-63	250.5	2896	3759	4551	5744	7014	738	900	1012	1450
	AVG.	251.0	2534	3620	4653	5810	6517	603	850	1080	1425
EXPR. B.	7-1-63	259.9	2855	3349	5208	6817	6656	719	863	1138	1487
	7-3-63	264.2	2445	4124	5496	6463	7502	687	925	1275	1521
	7-15-63	259.9	2460	3420	4622	5505	6516	756	731	1038	1440
	8-1-63	257.0	3129	3414	3788	5638	6198	773	963	1250	1508
	AVG.	260.2	2727	3577	4779	6105	6718	734	871	1175	1489

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KYHPR-64-2

CONSTRUCTION AND FINISHING TECHNIQUES-
CONCRETE BRIDGE DECKS

Fiscal Year 1963-64

The problem of durability in concrete bridge decks has become increasingly critical during the past ten years or so and is now a major concern to highway engineers throughout the northern states. Relief is being sought through improved construction techniques, air entrainment, and protective coatings of various kinds. The performance of individual slabs in a deck is sometimes markedly different from that of an adjacent slab; and, even within a particular slab, the performance of concrete within various areas may be quite variable. Such differences in performance might indicate poor concreting practices. Improper placement of concrete bridge decks automatically incurs a premature maintenance liability; thus the proper placement of deck concrete becomes even more significant.

It is well known that the durability of concrete is enhanced by air entrainment. The more air present, the closer the air bubbles are in the paste and the more effective they are in relieving internal pressures generated by ice formation. Bridge-deck concrete is subjected to various types of finishing techniques in which a certain degree of densification of the surface occurs. The densification has a tendency to force the large sized aggregate down and bring water to the surface. The finished surface may show a decrease in bleeding with time while the layer underneath may bleed at a

relatively faster rate, resulting in a weak boundary layer forming beneath the densified surface which may lead to scaling. Deicing agents also contribute to and greatly aggravate bridge deck scaling. In an attempt to evaluate the various construction techniques used in placement of bridge-deck concrete, bridge-deck concreting practices have been observed; and a surveillance of the performance of decks placed by various methods has been maintained.

Placement of the deck on the Clays Ferry Bridge carrying southbound I-75 traffic across the Kentucky River between Fayette and Madison counties was observed on several occasions. All concrete was ready-mixed and transported from ready-mix trucks to the placement site in "Georgia buggies". Concrete was dispensed from the buggies and shoveled under and around the reinforcing steel and then vibrated. Concrete was then placed above the steel and a hand-drawn, vibrating screed mounted on rails along the plinth was pulled over the concrete. The screed was pulled over each section approximately three times. Bull floats were drawn across the deck in a transverse direction, and a wet burlap drag was drawn longitudinally for the final finish. Portions of the decks near the curb were final finished with hand trowels. All concrete was cured with wet burlap. The structure was opened to traffic in November, 1963. To date, the deck appears to be in very satisfactory condition.

Placement of a deck without the use of deck-finishing equipment was observed on the eastbound structure carrying I-64 traffic over the Cane Run Creek in Fayette County. All concrete was ready-mixed and wooden screeds were used to level the concrete. Bull floats were

drawn across the deck transversely and a wet burlap drag was pulled longitudinally for the final finish. A Chace AE-55 Air Indicator was used to determine the air content in the top 1/2 inch of deck concrete. Air contents ranged from 2.80 to 3.31 percent for samples taken from the deck concrete after final finishing. The air content of concrete dispatched from the ready-mix trucks was 3.05 percent and the air content of concrete placed in the trucks at the ready-mix plant was 5.75 percent. To date, the deck is in excellent condition.

Several bridge decks were placed in 1963 with use of a Bridwell Bridge Deck Finishing Machine. The machine is self-propelled and is mounted on pipe rails attached to forms outside the walk line. Essentially, the machine consists of two triangular frames braced horizontally, a walkway, four wheels, motor, and a finishing shoe. The finishing shoe is chain driven transversely from curb to curb and is operated back and forth longitudinally by a sprocket. Initial finishing is accomplished by use of the machine in two passes of the shoe transversely across the deck. Bull floats are then drawn over the surface transversely and a wet burlap drag is drawn longitudinally over the surface. Portions of the decks near the curb were finished with trowels.

Twelve structures, the decks of which were placed with use of the Bridwell machine, have been observed. The majority of the decks were observed to be somewhat rough and numerous ground areas were noted. Scaling was evident on all but two structures and the areas of more severe scaling were near the curb lines. It is suspected that deck scaling near the curbs is a direct result of overworking the concrete during the trowel finishing operations.



KYHPR-64-3

PROTECTIVE COATINGS FOR CONCRETE BRIDGE DECKS

Fiscal Year 1963-64

Scaling and spalling has been noted at very early ages on numerous concrete bridge decks throughout the state. No doubt, the widespread use of deicing chemicals has accelerated the development of these signs of deterioration. The concrete sustaining damage was undoubtedly over-watered, over-worked, de-aired, and segregated. The repair and protection of these decks has become an engrossing maintenance liability. Preventative maintenance of bridge decks through the application of protective coatings at early ages is in large superior and less expensive than the repair and maintenance of unprotected decks.

Many products have been claimed to effectively waterproof and to protect concrete structures which might otherwise be vulnerable to scaling and structural deterioration. In an attempt to evaluate the effectiveness of various types of protective coatings, the Department of Highways has made trial applications on existing bridge decks and has specified linseed oil treatments for a number of bridges recently completed. Specific trial applications of protective coatings have been reported in "Concrete, Bridge Decks: Deterioration, Coatings and Repairs," by Havens, J. H., and Drake, W. B., Highway Research Laboratory, Kentucky Department of Highways, February, 1963.

Surface grinding has been required on several newly constructed structures in order to provide smooth decks. The Department is re-

KYHPR-64-4

REPAIR AND MAINTENANCE OF CONCRETE BRIDGE DECKS

Fiscal Year 1963-64

During the past ten years or so, the repair and maintenance of concrete bridge decks has become an ever increasing problem. The widespread use of deicing chemicals has no doubt accelerated the development of concrete failures. The proper placement of deck concrete is perhaps the more serious aspect of the problem than repair, since improper placement automatically incurs a premature maintenance liability. The general types of failure noted in concrete bridge decks are scaling, cracking, joint spalling, surface spalling and pop-outs. In general, scaling and surface spalling are the more predominant types that have been observed to date. None of the damaged decks which have been observed thus far has shown any evidence of overloading by traffic (adjudged by the absence of any checkerboard crack-pattern on the under side of the deck).

Whereas the long-range objective of this project encompasses the entire problem of restoration of deteriorated concrete decks, the immediate objective is to provide research - type surveillance over such repairs as may be effected or attempted by the Division of Maintenance on a perennial basis and to offer recommendations and suggestions from time to time. The ultimate objective is to establish the effectiveness of various materials and systems for restoring and over-laying deck concrete. No significant bridge deck repairs have been effected during this fiscal year; therefore, no progress

has been made. A somewhat complete history of the repair and maintenance of concrete bridge decks is contained in the report "Concrete, Bridge Decks: Deterioration, Coatings and Repairs," by Havens, J. H., and Drake, W. B., Highway Research Laboratory, Kentucky Department of Highways, February, 1963.

KYHPR-64-5

SLIP-FORM PAVING

Fiscal Year 1963-64

Conventional methods of placing concrete pavement require the use of extensive systems of forming. Slip-form paving has attracted widespread attention in recent years as a construction technique which might result in great savings by eliminating the need for an elaborate system for forming the pavement. The first concrete pavement placed with use of a slip-form paver was constructed in 1949 on a section of road between Iowa 106 and U.S. 18, west of Mason City, Iowa. A description of this project was reported in "Slip-Form Streets ~~Pride~~ of Mason City," Concrete Highways, No. 253, published by the Portland Cement Association. A general description of a slip-form paver and its operation as well as general construction techniques is contained in "Construction of Concrete Pavement with the Slip-Form Paver," Portland Cement Association.

The California Division of Highways has made use of a slip-form paver on California Interstate 5-W, north of Qirwea. A brief report of the project is contained in "Electronic Slip-Form Paver on California Interstate," Concrete Highways, No. 249, Portland Cement Association. A more detailed article pertaining to California's experience with slip-form pavers is "U.S. 80 at El Cajon," California Highways and Public Works, September-October, 1961. Difficulties in obtaining a smooth surface and the remedial methods are described in the article.

To date, slip-form pavers have not been used in Kentucky.

KYHPR-64-6

FREEZE AND THAW PHENOMENA OF CONCRETE AGGREGATE

Fiscal Year 1963-64

Many test methods are being used in the laboratory to determine aggregate durability. One relatively simple method is the sodium or magnesium sulfate soundness test. However, there are many instances on record where there is disagreement between service records and the results of the soundness tests. This has led to a lack of confidence among engineers in the sodium and magnesium sulfate soundness test, and many organizations retain this test since it is simple and inexpensive.

There are a number of different laboratory freeze-and-thaw tests in use, and no single test is suitable for all conditions. These tests are time consuming and require expensive equipment, and the correlation between the laboratory tests and field performance remains unknown.

The large variance found in test methods is due to a lack of understanding of the freeze-and-thaw phenomena. Many projects are initiated yearly by various organizations to study the durability of concrete aggregates. The usual method employed in these studies is to incorporate the aggregate being investigated into a concrete mix.

This project was initiated in order to study the phenomena of freezing and thawing of concrete aggregates. This study was approached differently as it was felt that more could be learned if

each aggregate particle could be studied individually. This necessitated freezing in a media other than concrete. Mercury was selected as the media because of its low freezing point, its high thermal conductivity and its non-miscibility with water. This procedure permitted a minute examination of each aggregate particle for distress and determination of other physical properties free from contamination.

Preliminary evaluation of the test data indicated four important aspects: 1) if a saturated piece of aggregate does not show distress at the end of one freeze-thaw cycle, it will probably withstand a number of cycles, 2) contrary to prevalent belief, particle size and durability of aggregate are not related, 3) durability of saturated aggregate is related to porosity, and 4) most aggregate particles fail because of excess hydrostatic pressure.

Gravel was obtained from the bed of the Ohio River. The saturated aggregate was graded into sizes, and the physical characteristics and mineralogy were determined. Each piece of aggregate was then subjected to four freezing cycles in chilled mercury (-30°C to -35°C). The distress resulting from each freezing cycle was recorded. The conclusions reached are:

1. The quick-freezing of stream-saturated gravel induces dilating pressures which are damaging and can lead to failure of the rock fragment in a single freeze-thaw cycle.
2. The particle size of aggregate tested in an unconfined state is not related to freeze-and-thaw durability.
3. Although most failures occur in the lower specific gravity ranges, specific gravity is not the sole indicator of aggregate durability. Most failures occurred

in chert having a specific gravity of less than 2.45 and in dolomite having a specific gravity less than 2.72.

4. For saturated aggregate, absorption, or porosity, could be used as a measure of aggregate durability.
5. Gravel particles derived from igneous and metamorphic rocks are less absorptive and more resistant to freeze-and-thaw than gravel particles derived from sedimentary rocks.
6. Failure of aggregate particles can be expected at porosities of 1.0 to 2.5 percent, according to theoretical analysis.
7. The porosity at which failure actually occurs under freezing closely approximates the theoretical value.

A progress report has been prepared:

Scott, J. W. and Laughlin, G. R., "A Study of the Effects of Quick Freezing on Saturated Fragments of Rocks," Division of Research, Kentucky Department of Highways, February, 1964.

Work is continuing in an effort to determine the hydrostatic pressure generated in critically saturated rock undergoing freezing. From data derived to date, it appears that there is a definite relationship between the hydrostatic force that may be induced and porosity.



KYHPR-64-7

SLURRY SEAL MAINTENANCE APPLICATIONS

Fiscal Year 1963-64

Prior to July, 1963, the Highway Department's experience with slurry seals was limited. During the 1962 construction season, slurry seals were placed on the service areas of the Kentucky Turnpike, a short section of South Third Street in Louisville, and a short section of the Buechel By-Pass (US31-E) near Louisville. These seals were placed for maintenance purposes as the surfaces were cracked and weathered. In addition, several small demonstration or "test" applications of slurry seals of various compositions were placed. All of the aforementioned seals were placed by the Louisville Asphalt Company using a Young Slurry Machine which was developed especially for slurry seal work. Personnel of the Division of Research inspected several of the seals as they were being applied and have made periodic inspections of all of these seals. A memorandum report prepared in April, 1963, presented information relating to the composition of the slurry mixtures and to the condition of the seals at that time.

A Special Specification for Emulsion Slurry Seal was prepared and approved in May, 1963, in order that slurry seal maintenance contracts could be let by competitive bidding. The shoulders on 40 miles of the Kentucky Turnpike were slurry sealed under contract by the Louisville Asphalt Company during the 1963 construction season.

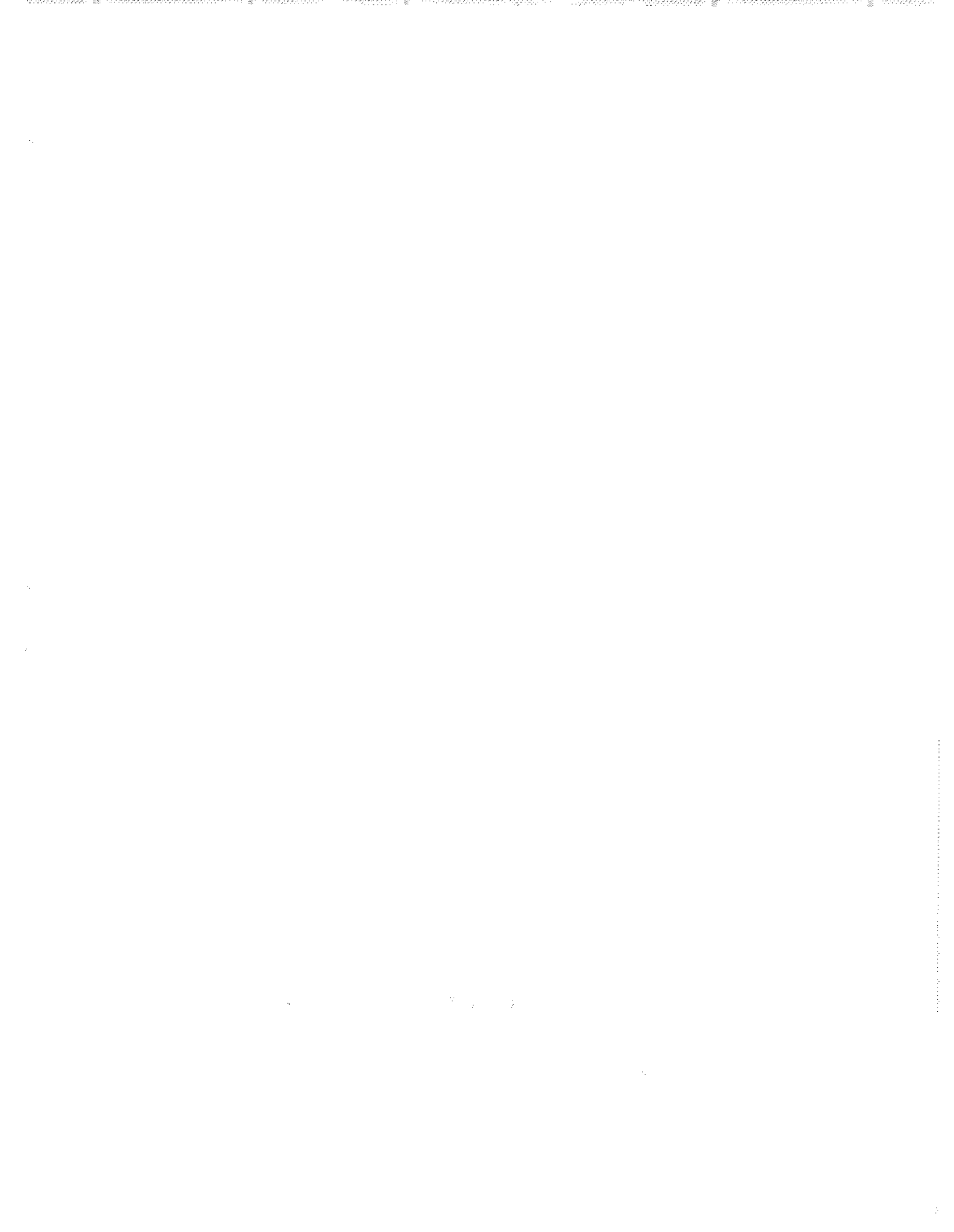
The Maintenance Division purchased two transit-mix trucks and a portable batching plant and constructed a spreader-box in order to

produce and place slurry-seal mixtures. Between the first part of July and the latter part of October, 1963, the Division of Maintenance sealed sections totaling approximately 39 miles on nine roads which are located in the Louisville and Lexington Districts and two large parking areas. Several of the seals placed in the Lexington District were applied as deslicking surfaces on sharp curves. Others were applied as preventative maintenance to cracked or weathered surfaces.

The composition of all of these slurry-seal mixtures placed during 1963 was essentially the same. The aggregate blends consisted of 55 to 60 percent limestone sand and 40 to 45 percent natural sand by weight. The emulsion content ranged from 18 to 20 percent by weight of the aggregate. Portland cement was added as filler in the proportion of approximately one percent by weight of the aggregate. The same grade (SS-1h) emulsified asphalt was used in all of the slurry-seal mixtures. The limestone aggregates were from one source in the Louisville District and from one source in the Lexington District. Natural sand used in all of the slurry-seal mixtures was medium Ohio River sand from Louisville. A neoprene, rubber latex was added to the slurry mixture placed on a portion of one surface sealed by maintenance forces.

In October, 1963, a Louisville contractor applied tar emulsion seals to several small areas of the parking lot of the Kentucky State Fairgrounds and Exposition Center. Several variables, such as a double application or adding natural sand, were incorporated into these seals.

Personnel of the Division of Research inspected several of the seals during construction and obtained samples of materials for laboratory testing. Air permeability and skid test measurements have been made on two of the seals placed during 1963. Periodic inspections of the seals which have been placed to date will be continued in order to evaluate the effectiveness of the material.



KYHPR-64-8

EXPERIMENTAL SILICA SAND-ASPHALT SURFACE

Fiscal Year 1963-64

Bituminous surface courses containing only limestone aggregate tend to become slick after a period of time under traffic. This is attributed to the susceptibility of limestone to polishing by the action of grit and vehicle tires. Kentucky has, and is using, a predominant amount of limestone aggregates; and the problem of slick pavements is one of great concern. It is the policy, therefore, to require a significant percentage of polish resistant fine aggregate in surface courses placed on highly trafficked roads.

Silica sand-asphalt surfaces are reputed to have high skid-resistance even after considerable wear. Large quantities of quartziferous (silica) aggregates such as sandstones, pit sands, river sands, gravels, and conglomerates are available in the state for use in sand-asphalt mixtures. Only limited use has been made of these aggregates in sand mixtures, and this research project will provide information leading to the proper and reliable use of such materials for this type of application.

The objective of this project is to field-test thin applications (1/2 inch or less) of silica sand-asphalts. An ever-increasing need is foreseen for a surface-renewal type of treatment for primary roads as well as the more expedient deslicking treatments for all classes of roads. Until a few years ago, this need was fulfilled largely by Kentucky Rock Asphalt. Sand-asphalts have the qualities sought for

this kind of service; however, performances, cost data, and construction experiences are needed to establish their feasibility and to establish routine practices for their use.

Specification requirements have already been proposed; additional information with regard to the following listed items is sought:

1. Acceptable quality requirements for various quartziferous (silica) sands.
2. Acceptable limits for the amount of polish-susceptible aggregate to be allowed in the mixture.
3. Acceptable method of blending sands and of controlling gradations in the hot-mix plant.

KYHPR-64-9

CLASS I BITUMINOUS MIXTURES

Fiscal Year 1963-64

For some time, the Department of Highways has been aware of certain deficiencies in the standard specifications pertaining to asphaltic concrete construction. Surface course composition requirements have been especially problematic in that the void contents of the compacted courses have tended to be too high and the stability was often low. To remedy the compositional problems and to up-date or correct other specification requirements, the Department has made extensive revisions to Section 3 of the Standard Specifications by an amendment which became effective in January, 1964.

In recent years, to alleviate the surface course compositional problem, the Department has applied special provisions to surfacing projects on roadways with 700 or more vehicles per day. During the 1963 construction season, pending the approval of the aforementioned amendment, bituminous surface courses placed on the higher traffic-volume roadways were required to meet the composition requirements of a Special Provision for Bituminous Concrete Surface, Class I, Type B, Modified. Prior to the 1963 construction season, the requirements of this Special Provision were applied to surfaces placed on Interstate Highways.

During the 1963 construction season, surface course mixtures, which meet the requirements of the Special Provision, were sampled from 19 surfacing projects by personnel of the Division of Research.

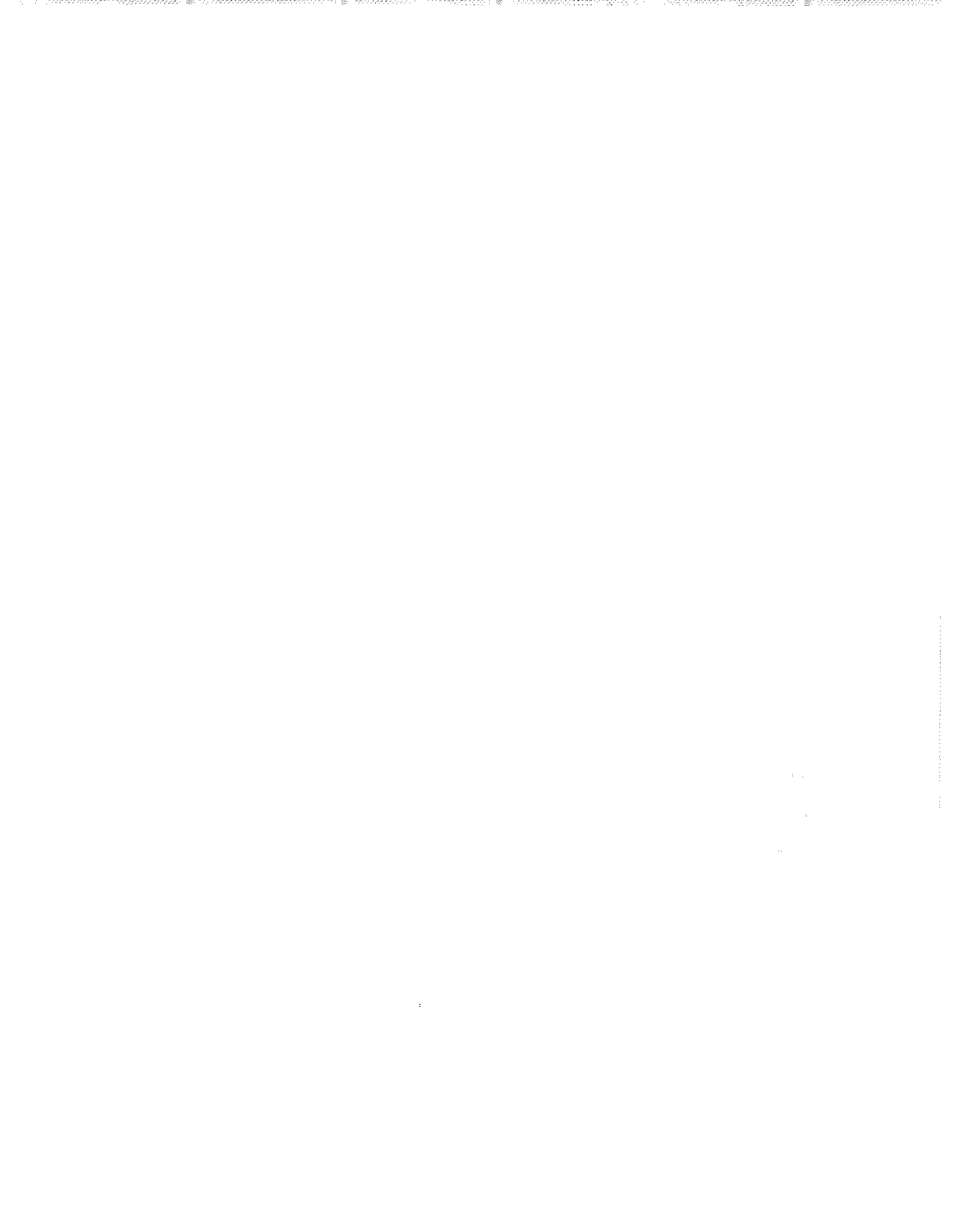
The aggregates and asphalt cements used in the mixtures were also sampled. An attempt was made to sample materials from plants widely scattered over the State and also to include all of the commonly used aggregate types. The materials sampled were then tested and evaluated in the laboratory to determine the quality of surface mixtures being produced and also to form a basis by which to compare the surface mixtures produced under the requirements of the then forthcoming amendment.

Certain provisions have been made in the specification amendment to encourage the use of locally occurring aggregates in bituminous mixtures. In Kentucky it is a common practice to ship Ohio River Sand long distances for use in bituminous surface mixtures. One of the surfacing projects, Knott County SP60-18, sampled in 1963 involved the use of a locally occurring silica-sand, on an experimental basis, in an attempt to meet the composition requirements of the then proposed amendment. To investigate the possibility of using wet-bottom-boiler slag produced at the TVA Steam Generating Plant at Paradise, Kentucky, as a hot-mix aggregate, a special provision has been prepared for surfacing requirements on the Drakesboro-Paradise Road, Muhlenberg County SP89-43, with a surface mixture incorporating the slag in lieu of natural sand. Two Marshall mix designs of surface mixtures using the slag have been tested in the laboratory.

In September and October 1963, density measurements were made on four short sections of bituminous concrete which were compacted with a varying number of passes of a Buffalo-Springfield PSR-14 Roller equipped with solid rubber tires. A Nuclear-Chicago nuclear density

apparatus was used to make the density measurements.

During April, 1964, an inspection was made on initial bituminous treatments placed during the 1963 construction season on sections of seventeen roadways. The sections which received the bituminous surface totaled 35 miles, are widely scattered over the State, and all are lightly trafficked (less than 700 vehicles per day). The treatment basically consisted of priming the existing traffic-bound base with RT-2 and then laying a hot-mix surface course containing a minimum of 6 percent PAC-9. A memorandum report on the performance of these surfaces was prepared in May, 1964.



KYHPR-64-10

KENTUCKY ROCK ASPHALT AS A TRAFFIC-
BOUND BASE AND HOT-MIX AGGREGATE

Fiscal Year 1963-64

Vast quantities of lean-to-rich bituminous sandstones exist as waste and tailings in spoil areas of the rock asphalt quarries of Western Kentucky. Because of a desire to use locally available materials in highway construction and maintenance insofar as they may be practical, economical, and otherwise advantageous, a program has been initiated to study the feasibility of using this material as a dust-free, traffic-bound base and surface and as a material for stage construction of bases on rural roads.

Five traffic-bound roads in Edmonson and Grayson Counties have been treated with rock asphalt. Of these test sections, two have been treated with a No. -610 gradation applied approximately two inches thick and sealed with an asphaltic emulsion. The three remaining sections were resurfaced with a crusher-run gradation which was applied approximately two inches thick. A sixth test section is composed of a five-inch compacted base of rock asphalt which was sealed with an asphaltic emulsion. A detailed report covering the construction phase of Test Section No. 1 has been prepared. An interim report describing the performance of these test sections has also been prepared.

1. Laughlin, G. R., "Construction Report on Experimental Use of Natural Bituminous Quartz Sandstone (Kentucky Rock Asphalt) as a Traffic-Bound Aggregate," Division of Research, Kentucky Department of Highways, 1962.

2. Laughlin, G. R., "Kentucky Rock Asphalt, Traffic-Bound Bases," Division of Research, Kentucky Department of Highways, 1964.

Although a thorough evaluation cannot be fully developed at the present, several conclusions are evident:

1. The use of rock asphalt as an aggregate in base construction is economically feasible.
2. The bases constructed thus far have given satisfactory service.
3. In contrast to traffic-bound limestone bases, there is less attrition of the aggregate and less dusting of the road surface.
4. When constructed during the summer months, rock asphalt bases become compacted, firm, and dustless.
5. When constructed during cool weather the material remains in a loose condition.
6. When proper construction methods are employed and adequate thickness is provided, rock asphalt will serve as an excellent, economical, dust-free base and surface on rural roads.
7. Where bases are constructed with full thickness, seal coating will render the surface more impervious to surface water and minimize softening of the subgrade.
8. The use of spreader boxes in placing the rock asphalt enhances the smoothness of the surface.

KYHPR-64-11

PAVEMENT-TYPE SELECTION BASIS

Fiscal Year 1963-64

The objective of this study is to study those design factors which alter the pavement cross-section (i.e., total thickness of pavement and the thickness of individual courses within the pavement) and the manner in which these factors affect pavement construction costs. The long term objective is to develop a working plan for selection of pavement type (flexible or rigid) based upon the best engineering judgement and experience available. A realistic plan for selection of pavement type is contingent upon a thorough understanding of the factors which affect first costs (construction costs). This study attempts to isolate those factors.

Generically pavements are classified as being "flexible" or "rigid", these terms alluding to bituminous concrete and to portland cement concrete, respectively. Assuming that design criteria are sufficiently reliable and assuming that equivalent load-carrying capacities are sought in each of the two pavement types, the selection of the type becomes wholly a matter of comparative costs rather than an arbitrary preference. That is not to say that preferences and opinions are altogether invalid but rather that such preferences should be substantiated in terms of economic benefits, safety, and overall service.

Basically there are two methods of determining pavement type:

1. Alternative Bidding - Engineers design comparable pavements

and advertise for bids on each; the lowest bid determines the type.

2. Engineer's Cost Estimate - Engineers estimate the cost of equivalent pavements and advertise for bids on the type for which their estimate was the more favorable.

Contractors' bids provide the more realistic cost information; however, it is limited solely to "first costs" or cost of construction and does not take into account any of the maintenance costs. The engineer's cost estimate may also be limited, by choice, to "first cost," but it is not necessarily so limited. The engineer's cost estimate could include both construction and maintenance costs, particularly so if maintenance costs could be estimated reliably.

Construction cost or "first cost" is the primary criterion and often, as the result of financial limitations, the only criterion used in selection of pavement type; hence, a thorough understanding of the manner in which various factors affect first cost is of considerable significance. Although the nature of this study is exploratory, it will aid in clarifying the manner in which those factors influence first costs. It is recognized that a complete pavement-type selection study must take into account such factors as maintenance cost, effective pavement life, and salvage value. A study which includes these factors must be relegated to some future date when sufficient factual information becomes available.

KYHPR-64-12

TREATED DENSE-GRADED AGGREGATE BASE INVESTIGATION

Fiscal Year 1963-64

The objective of this project is to determine the structural equivalences of unbound dense-graded aggregate base (DGA), cement-treated DGA base, bituminous-treated DGA base, bituminous concrete base courses, and various chemically-treated base courses. Since the inception of dense-graded, limestone-aggregate base materials in Kentucky in about 1952, there have been various conjectures regarding "auto-cementation" and "setting" to explain the exceptionally high strengths they have exhibited, on occasions, when compacted and cured. Although the associated mechanism has not been satisfactorily explained, the strength phenomena has been observed on the road as well as in the laboratory.

Cemented or so called bound-base courses are regarded as a means of providing inherent strength at depths within a pavement. Conceptually, the contribution of bound-base courses to the strength of the pavement is greater than the contribution of an equal thickness of unbound base. The ratio of these contributions to strength or performance of a pavement is viewed as a structural equivalency, and the specific contribution is viewed as a structural index (see "The AASHO Road Test Report 5" Special Report 61E, Highway Research Board, 1962).

Although a judicious equivalency ratio between these standard materials was an inherent part of the Kentucky design criterion prior to the AASHO Test Road, the equivalencies deduced from the test road

are more favorable to the high-type, bound bases than the equivalencies previously perceived or adjudged on the basis of in-service performance histories. Thus, the extent to which high-type, bound base courses may be advantageously employed in pavements has not been fully exploited. Moreover, the extent to which unbound bases might be enhanced, by cements or binders, and employed intermediately within the pavement offers further avenues for study and experiment. Altogether, such studies and experiments are encompassed within the scope of AASHO Road Test satellite studies, i.e., studies dedicated by the state highway departments to the adaptation of the Test Road findings to local conditions and to the furtherance of a nationwide concept of pavement design.

KYHPR-64-13

ENGINEERING PROPERTIES OF SOILS

Fiscal Year 1963-64

Engineering soil maps are proving desirable in the planning stage of many types of structures. Problems associated with soil behavior may be recognized during the preliminary location through the use of adequate soil maps.

Two general approaches to compiling engineering soil maps are available. One method is to prepare engineering maps from actual field explorations. The agricultural soil scientists, however, have developed a classification and mapping system and have mapped many areas. Thus, the second method to obtain engineering soil maps is to add the necessary engineering data to existing pedological maps. This method has an advantage in that the mapping has already been done and it is only necessary to perform engineering tests on samples of the various soils.

In about 1955, the Division of Research began adapting existing U.S. Department of Agriculture soil maps by adding engineering data to the pedological classifications. This work resulted in preparation of three departmental reports summarizing information on soil classification as well as specific engineering properties of pedologically mapped soils in several counties in Kentucky. For several years, the Division of Research has obtained engineering soils data for numerous samples submitted by the Soil Conservation Service, U.S. Department of Agriculture. Samples were obtained by SCS personnel

and submitted to the Division of Research for testing as part of a co-operative soil mapping program undertaken by the SCS, Bureau of Public Roads, and Kentucky Department of Highways. Through these efforts, considerable data have been obtained.

The aims of this project are to determine engineering properties of soil samples submitted by the SCS and to aid in the preparation of the engineering chapter of the US Department of Agriculture county soil reports. Approximately 70 soil profile samples from Kenton, Campbell, Boone, McCreary and Grayson Counties were obtained by the SCS and submitted to the Highway Research Laboratory for testing. The following tests were performed on each sample:

- 1) Specific Gravity - ASTM Designation: D854
- 2) Grain Size Analysis - ASTM Designation: D422
- 3) Liquid and Plastic Limits - ASTM Designation: D423
- 4) Proctor Compaction - ASTM Designation: D698
- 5) CBR - Kentucky Method
- 6) X-ray Diffraction

Some clay mineralogy data obtained by x-ray diffraction have been supplemented by Differential Thermal Analysis. A general sample preparation procedure for x-ray diffraction tests was used on all samples. In this way semi-skilled technicians could obtain generally reliable results.

The soils were classified by the AASHO and Unified Classification systems, and tabulations of the results have been submitted to the Bureau of Public Roads for review.

KYHPR-64-14

INVESTIGATION OF DESIGN, CONSTRUCTION, AND
EROSION CONTROL METHODS FOR USE IN WINDBLOWN SILTS

Fiscal Year 1963-64

The objectives of this project are to evaluate designs, construction techniques, and erosion control methods used in windblown silts and to discern methods which will assure future successful construction in such deposits in Kentucky. Certain types of silty soils often require special techniques in design and construction. Such soils cover extensive areas along the Ohio River in Western Kentucky and in the Jackson Purchase area. These soils are predominantly windblown silts. The deposits along the Ohio River are thought to be associated with the glacial advances that extended to near the river. In the Jackson Purchase area, the silt deposits are the same as those on the eastern bank of the Mississippi River from the Gulf of Mexico to the Ohio River. These deposits, however, are somewhat different from the Ohio River deposits in that the silt is not derived from glacial material.

Ordinary construction practices frequently induce a "quick" condition in silty earth or otherwise induce widespread instability and erosion problems. Certain precautionary practices should be invoked in these areas, and the areas should be defined sufficiently to alert all unwary parties.

A preliminary investigation has been made of a construction project (grade and drain, and portland cement pavement) near Henderson, Kentucky. The soil encountered there was a windblown silt; and num-

erous problems were recognized while excavating cuts, compacting embankments and subgrade, and in controlling erosion. The project was beset by numerous delays, repairs, and damages to abutting property.

There have been instances where immediate mulching and seeding of slopes might have prevented costly repairs due to erosion damage. A research project is being proposed to investigate the establishment and maintenance of woody and herbaceous plants and turfgrass for the control of erosion and the beautification of right of ways (Ref. KYHPR-65-33).

KYHPR-64-15

RELATION BETWEEN SOIL SUPPORT VALUE AND KENTUCKY C.B.R.

Fiscal Year 1963-64

The foundation soil throughout the AASHO Test Road was uniform and, therefore, did not constitute a design variable. Hence, the Test Road results do not provide a direct basis for the establishment of a complete design criterion.

Langsner, Huff, and Liddle conceived a scheme whereby the AASHO performance equations could be adjusted so as to include a soil support parameter, and on that basis they derived a set of design equations. Although the test-road soil provided only one point of reference (given a value of 3.0), data from Loop 4, having the greatest thickness of crushed stone base, were analyzed from the standpoint of performance of asphaltic concrete surfacing on a soil having a support value equal to that of crushed stone (given a value of 10). A linear scale was drawn between these reference points and projected to zero. On this basis, a Kentucky CBR of 5 corresponds to a soil support value of 3.

The objective of this study is to discern significant relationships between the soil support values, as derived from the AASHO Road Test, and the Kentucky CBR. This objective is being approached by making numerous pavement designs based on actual traffic data using both the Kentucky and AASHO design procedures. It is planned to correlate Kentucky CBR and AASHO soil support by determining, for each design using a Kentucky CBR, an appropriate soil support value such

that an equal or equivalent design will result from the AASHO design procedure.

A considerable quantity of traffic data has been collected from files of the Highway Department as a part of another project (KYHPR-64-21). These data may also provide the traffic parameters necessary for this study.

KYHPR-63-16

DEVELOPMENT OF A PRACTICAL METHOD OF LOCATING
AND TRACING SEEPAGE WATER IN UNSTABLE SLOPES

Fiscal Year 1963-64

Recurrence of movement in slide areas during wet weather is indicative of troublesome underground seepage which is often associated with stratified shales in side-hill cuts and benched, side-hill embankments. In order to evaluate such situations and to methodically undertake corrective repairs, it is essential that the source of the seepage be located and diverted. A systematic investigation of each slide would thus obviate trial-and-error methods which are often expensive and disheartening. The subject project is primarily a field study of existing slides to develop a procedure for determining the source of seepage water associated with unstable slopes.

Some six side-hill embankment slides have been mapped and are being observed. Three of the largest and most serious of these slides have been subjected to more extensive investigations. These are:

1. I-75, south of Covington, Kenton County
2. West Kentucky Parkway, east of Princeton, Caldwell County
3. U.S. 23, north of Louisa, Lawrence County

I-75, Kenton County

In the springs of 1962 and 1963 several holes were drilled in the median and along the shoulders in the vicinity of the landslide. Large quantities of water were used to remove the cuttings which, of course, made identification and assignment of depths rather difficult. Additional subsurface data were obtained by vertical augering

methods during June and July of 1963. Since no water was used during the augering, identification of the soil material and depths to water-bearing layers was much more definite. Sufficient data were obtained to plot five soil profiles.

Two extremely wet, soft layers of clay were detected which are thought to be rather extensive in the vicinity of the slide. Both layers dip to the east, the direction of sliding, on about a 10 percent grade; and there may be a direct connection between these layers and the lower portion of the deep, mucky clay in the bottom of a lake which lies to the west of the highway.

Fluorescent dyes have been deposited in the lake in an attempt to verify the connection between the lake and the wet clay layers and dyes have been placed in other suspected sources of seepage water. These attempts have been unsuccessful to date.

Work has been started to develop a technique of using an electrical resistivity method to locate and trace seepage water in a landslide. For this preliminary work, a two-probe resistivity method has been used. One electrode is placed in a fixed position while the other is moved from point to point. Readings of both current and potential are obtained for each position of the movable probe. This approach to the problem of locating and tracing seepage water appears to offer a great deal of promise. More work is planned to develop techniques of obtaining and analyzing the data.

The investigations of the I-75 landslide area have resulted in two status reports* which describe the conditions of the slide area and subsurface data in detail. Possible corrective considerations have also been included.

*Deen, R. C., "Development of a Practical Method of Locating and Tracing Seepage Water in Unstable Slopes," Status Report on Landslide Area on I-75, Covington, Kentucky, Highway Research Laboratory, Kentucky Department of Highways, May 15, 1963.

Deen, R. C., "Development of a Practical Method of Locating and Tracing Seepage Water in Unstable Slopes," Part II, Status Report on Landslide Area on I-75, Covington, Kentucky, Highway Research Laboratory, Kentucky Department of Highways, August 1, 1963.

West Kentucky Parkway, Caldwell County

A surface exploration of the landslide and surrounding area indicated several out-croppings of fissured and jointed sandstone and surface water was observed entering the fissures south of (above) the landslide. From roadway cuts in the vicinity of the slide, it could be observed that the sandstone was on the order of ten feet thick, was overlain by approximately five feet of soil, and was resting on blue shale. Numerous small faults, the various strata dipping up to approximately 30 degrees, were exposed in the cut areas.

After heavy rains in February and early March of 1964, wet weather springs were observed near the toe of the slide area. Fluorescent dye placed in the surface water, just before disappearing underground, was detected at the wet weather springs.

In March and April of 1964, several holes were drilled in the median and shoulders in the vicinity of the slide. No extremely wet or weak material was encountered, and all of the holes were dry immediately after drilling. Water seeped into the holes along the south shoulder overnight, however.

A four-probe electrical resistivity method is being used in an attempt to determine the extent of a seepage area above the landslide. Neither the resistivity data nor the drill-hole data have been completely analyzed. Preliminary indications are, however, that four-

probe resistivity data may be used to trace water as well as geologic strata with only a minimum of drill-hole data for reference.

U.S. 23, Lawrence County

Surface exploration of this small slide indicated that a wet seepage area in the roadway ditch above the landslide may be admitting water to the failed area. Fluorescent dye deposited in the suspected source has not yet been detected in the failure area. Observations are continuing, however, since the seepage rate seems to be slow.

On May 27, 1964, six holes were drilled in the shoulders in the vicinity of the slide. Sandstone was found at approximately 20 feet in all six holes; a very wet (soupy) clay was detected in one hole. Drill-hole data have not been completely analyzed, and there are plans to make four-probe electrical resistivity measurements of the entire area.

KYHPR-64-17

SETTLEMENT OF BRIDGE APPROACHES

Fiscal Year 1963-64

Differential settlement occurring between bridges and their approach embankments has become a serious problem in highway maintenance. On modern roads, this defect has become a hazard to high-speed traffic; and remedial work is expensive and causes considerable inconvenience to road users.

The objectives of this project are to determine the causes of settlement of bridge approaches and to develop methods of design and construction whereby settlement may be prevented. This investigation may be divided into two parts. The first phase consists of a survey of existing bridges to determine to what extent the approaches have settled and whether this settlement may be correlated with the type of bridge abutment, physical conditions at the bridge site, etc. The second phase of this investigation is a study of the settlement of bridge approaches to newly constructed bridges to determine if the settlements are occurring within the foundation soil or within the embankments. Settlement plates will be installed in each bridge approach chosen for this phase of the project.

Both phases of this investigation have begun. In connection with the first phase, several hundred bridges throughout the state have been surveyed. Observations concerning the amount of settlement, type of bridge abutments, physical conditions at the site, and other factors influencing the settlement of the approaches have been made.

The data represents bridge approaches in several of the physical regions of Kentucky.

Approximately thirteen new bridge sites have been investigated as possible locations for settlement plates. Arrangements are being made to install settlement plates at these locations. The locations were chosen so as to give as wide a range of physical conditions, type of bridge abutments, height of embankment, and foundation material as possible. Measurements of settlement both during and after construction of the embankment will be made by means of these settlement plates.

KYHPR-64-18

PLASTIC STRIPING PAVEMENT SURVEY

Fiscal Year 1963-64

During and following World War II, the Road Research Laboratory in England developed and tested a hot-melt compound consisting generally of gum-rosin, plasticising oil, pigment, and filler. The Engineering Experiment Station, Texas Agricultural and Mechanical College, conducted experiments with the compound used as a pavement striping material and found it to be unsatisfactory. The original compound was later improved through the addition of an alkyd resin. Similar materials were used on a trial basis in Frankfort and Lexington, Kentucky, in 1957 and 1958. The performance on these trials was not completely satisfactory, and the cost of the material was greatly disproportionate to the cost of striping with paint.

Further improvements were made in the compound, and it was decided to use the improved material on an experimental basis. A proposal for construction of experimental projects using thermo-plastic striping material was approved by the Bureau of Public Roads in the fall of 1962. The principal objectives of the project were:

1. To evaluate the performance characteristics of hot-melt plastic pavement striping materials known commercially as Catatherm and Perma-Line.
2. To compare the performance of these materials with the performance of painted stripes applied and renewed according to the current practices of the Kentucky Department of Highways.
3. To evaluate the economics of these striping materials in terms of cost-per-mile-per-day of useful life.

The project is described more fully in:

- 1) "Proposal for Experimental Use of Thermo-Plastic Pavement-Striping Materials," by Jas. H. Havens, Highway Research Laboratory, Kentucky Department of Highways, November 2, 1961.
- 2) "Pre-Construction Report, Experimental Use of Thermo-Plastic Pavement-Striping Materials," by Jas. H. Havens, Highway Research Laboratory, Kentucky Department of Highways, September 19, 1962.

Four test sites selected were: 1) a portland cement concrete pavement in an urban area (I264-1(25)20, Jefferson County), 2) a portland cement concrete pavement in a rural area (I64-3(14)34, Franklin-Shelby Counties), 3) a bituminous concrete pavement in an urban area (I264-1(24)16, Jefferson County), and 4) a bituminous concrete pavement in a rural area (I64-5(16)93, Clark-Montgomery Counties). Construction began October 12, 1962, and was completed on April 26, 1963. Kentucky paint, Catatherm thermo-plastic, and Perma-Line thermo-plastic were applied in the form of edge, center-skip, and transverse lines. Construction dates, methods of application, quantities and costs are reported in:

- 1) "Interim Construction Report, Experimental Use of Thermo-Plastic Pavement-Striping Materials," Report No. 2, by Jas. H. Havens, Highway Research Laboratory, Kentucky Department of Highways, April, 1963.
- 2) "Final Construction and Interim Performance Report, Experimental Use of Thermo-Plastic Pavement-Striping Materials," Report No. 3, by Jas. H. Havens and J. W. Scott, Highway Research Laboratory, Kentucky Department of Highways, May 15, 1964.

Evaluation of the test lines has been based primarily on both day and night observations. Records have been maintained in regard to bonding qualities, spalling, cracking, over-all appearance, and material out of service. Due to damages incurred during the winter

of 1962-63, extensive repairs were required in the spring of 1963. Approximately 38,546 ft. or 17.41 percent of the Catatherm line and 18,505 ft. or 8.36 percent of the Perma-Line line was reworked. Inspections during the spring of 1964 revealed 8.45 percent of the **Catatherm line** as unsatisfactory and 0.82 percent of the Perma-Line line as unsatisfactory. In accordance with the Catatherm warranty provisions, 4,001 ft. of Catatherm line are to be replaced. The Perma-Line warranty is not as encompassing and repairs cannot be required under provisions of their warranty.

Several of the center and transverse lines of the Kentucky paint were repainted during the spring of 1962 and spring of 1963. Repainting of other lines is anticipated this year. An exact analysis of the cost-per-mile-per-day of useful life is not possible at this time. Inspections and surveys are to be continued, and a complete cost analysis is to be made at a later date.

KYHPR-64-19

DURABILITY OF TRAFFIC PAINT ON PORTLAND
CEMENT CONCRETE PAVEMENTS

Fiscal Year 1963-64

Traffic paints used in Kentucky within the past several years have been largely the alkyd-resin type; and, historically, they have proved to be less durable on portland cement concrete pavements than they have been on bituminous surfaces. This disparity is seemingly more evident on new concrete surfaces than on the older concrete surfaces having surface laitance weathered away. Laitance and the highly alkaline nature of concrete are thought to be the principal causes of difficulties encountered. It is estimated that the cost of striping is in the order of \$40 per mile of continuous line, and it is expected that any type of pretreatment might equal or exceed this value. The cost of pretreatment must thus be weighed against the frequency of restriping deemed necessary.

This project was established as a means of determining the most favorable methods of pretreating portland cement concrete pavements to enhance the durability performance of alkyd-type traffic paints and to determine, comparatively, the durability performance of alternate types of paints on concrete pavements. To date, several samples of tars, varnishes, epoxies, and paints have been secured. Additional samples are to be secured in the near future. A series of test lines, either transversely or diagonally, are to be applied. Various pretreatments such as sandblasting, acid washes, etc. and primers such as tars, asphalt poly-styrenes, co-polymers of styrene and butadiene, acrylics, and other lacquers and varnishes will be applied.

KYHPR-64-20

FLEXIBLE PAVEMENT STUDY USING
VISCOELASTIC PRINCIPLES

Fiscal Year 1963-64

In the past the majority of flexible pavement design criteria has been based upon empiricism. In recent years, however, emphasis has been shifted to studies more fundamental in nature. The more fundamental studies have utilized elastic concepts which appear to suffice as an approximation particularly for low ranges of stress, short durations of loading, and limited strains or deflections. The practical application to flexible pavement design is questionable since theory fails to make provision whereby the time element may be included. Since the constituent materials which comprise a flexible pavement system are known to exhibit time-dependent stress-strain characteristics, there appears to be a major restriction limiting the use of the elastic theory. A resurgence of research activity among the various highway agencies has thus been directed toward the adaptation of the theory of viscoelasticity.

The ultimate objective of this project is to determine fundamental mechanical properties of bitumens and bituminous mixtures when subjected to conditions of static and dynamic stresses at various temperatures and to use the resultant data to establish stress-strain, time-temperature relationships that may prove applicable to flexible pavement design. A preliminary study initiated prior to July 1, 1963, was completed as a portion of this project. The original study involved the rheological investigation of an as-

phalt cement and two rubberized asphalt cements. Creep data were obtained with use of a rotating, co-axial cylinder viscometer. Analysis of the data and results of the study were submitted in the report, "A Rheological Investigation of Asphaltic Materials," by W. A. Mossbarger, Highway Research Laboratory, Kentucky Department of Highways, January, 1964. In addition to the analysis and results, a review of linear viscoelastic theory and other basic principles of general rheological theory concerning creep testing were included.

On the basis of experience gained from this preliminary study, revisions were undertaken in the design of the rotating, co-axial cylinder viscometer and a new apparatus was constructed. Electronic equipment for use in monitoring loads and deformations purchased to date consists of: 1) oscillographic recorder, 2) oscillator, 3) power amplifier, 4) pre-amplifier, 5) linear variable differential transformers, and 6) rotating variable differential transformer.

A brief description of the asphalts presently under investigation is presented in Table I. In addition to these asphalts, two samples of material derived from cracking of petroleum fuel stocks for production of ethylene are under study. All asphalts have been subjected to the following tests:

1. ductility at 77°F and 39.2°F
2. penetration at 77°F and 39.2°F
3. specific gravity
4. softening point
5. Durol viscosity
6. thin-film oven test

Creep testing is presently in progress.

Data is being analysed by means of graphical techniques.

Attempts are also being made to prepare a program for computer anal-

ysis. The preliminary computer program has been written and continuing efforts are being directed toward development of dynamic test methods and equipment. Mathematical expressions for dynamic response of materials are being studied in light of their adaptation to dynamic loading in a rotating, co-axial cylinder viscometer.

TABLE I
ASPHALTS BEING STUDIED

Asphalt No.	Crude Source	Penetration Grade	Manufacturing Process
1	Mexico	85-100	Steam Distillation
2	Venezuela	85-100	Vacuum & Steam Dist.
3	Arkansas	85-100	Vacuum & Steam Dist.
4	Texas	85-100	Steam Dist. with Blowing
5	Midcontinent	85-100	Vacuum Dist. with Blowing
6	Texas	85-100	Vacuum Distillation
7	Midcontinent	85-100	Propane Solvent Extraction, Vacuum Dist. & Blowing
8	Oklahoma	85-100	Propane Solvent Extraction, Vacuum Dist., Blowing, & Fluxing
9	Texas	85-100	Propane Solvent Extraction, Vacuum Dist. & Blowing
10	California	85-100	Vacuum & Steam Dist.
11	Wyoming	85-100	Vacuum Distillation
12	Venezuela	60-70	Vacuum & Steam Dist.
13	Venezuela	120-150	Vacuum & Steam Dist.

KYHPR-64-21

DETERMINATION OF TRAFFIC PARAMETERS FOR THE
PREDICTION, PROJECTION, AND COMPUTATION OF E.W.L.'s

Fiscal Year 1963-64

The thickness design of pavements is closely related to and dependent upon the EWL's the pavement is expected to support during its lifetime. The design life of a pavement is largely dependent upon the reliability of projected EWL's. It is necessary, therefore, that the design engineer be able to predict and project the characteristics of future traffic trends in order to properly evaluate the EWL's or axle loads for which he must design.

In 1948, Kentucky, as a result of a comprehensive study, revised California's empirical CBR design curves to better fit Kentucky conditions and soils. The original EWL factors developed by California were retained however; and various parameters, such as percent trucks and average axles per truck, were developed for predicting future EWL's.

In 1959, a re-evaluation study of the 1948 Kentucky design curves was made to determine if they should be revised in the light of additional traffic data and observed pavement performance. Actual total accumulated EWL's from the time each project was constructed were computed and compared with design EWL's. There was close agreement between actual and predicted EWL's for the average of all projects, but extreme variations were found for individual projects. This study is expected to provide additional insight into methods for fitting various traffic parameters to these local conditions.

This project consists of two parts. The first part is the col-

lection of appropriate traffic data from files of the Highway Department. The second part is a statistical analysis of this data. Part one of the investigation is well underway, the following data having been assembled and punched on cards:

- 1) Vehicle classification data from permanent loadometer stations for 1950 through 1963
- 2) Vehicle classification data from a special survey at 24 rural stations made in the summer of 1957.
- 3) Automatic Traffic Recorder data for 1956 through 1962
- 4) Axle load data from the permanent loadometer stations for 1950 through 1963
- 5) Axle load data from a special survey at 24 rural stations made in the summer of 1957.

The second phase (data analysis) has begun. From the vehicle classification data, the following computations have been made:

- 1) Average Daily Traffic
- 2) Total Trucks
- 3) Total Busses
- 4) Percent Trucks
- 5) Percent Busses
- 6) Total Truck Axles
- 7) Average Axles Per Truck

Trends in the above values are being determined using statistical procedures for different groupings of data as follows:

- 1) All main rural roads
- 2) Main roads grouped according to direction
- 3) Main roads grouped according to geographic region
- 4) All secondary roads
- 5) Secondary roads grouped according to region
- 6) All roads grouped according to traffic volume
- 7) Interstate roads
- 8) Urban roads

KYHPR-64-22

FOURTH ANNUAL PERFORMANCE SURVEY OF REINFORCED
CONCRETE PIPE CULVERTS

Fiscal Year 1963-64

This performance survey is a continuation of a series of performance surveys which was inaugurated in specific response to the Bureau of Public Roads' Circular Memorandum 22-42, dated November 12, 1959. C.M. 22-42 has reference to C.M. 22-40, dated April 4, 1957, which outlined a stylized, rational criterion for the structural design and installation of reinforced concrete pipe culverts developed by the Bureau of Public Roads in cooperation with Prof. M. G. Spangler of Iowa State College and the American Concrete Pipe Association. The criterion was intended to bring together and simplify methods for computing the pipe strengths required under various fill heights and conditions of bedding.

Highway agencies were urged to adopt the criterion for use on all Federal-aid projects, and accordingly, the Kentucky Department of Highways issued specification amendments and standard drawings faithfully patterned after the criterion outlined by the Bureau of Public Roads. Included were some practical modifications, which, for the most part, were incidental to the transformation of the design criterion into specification style. Class B bedding, with its B_1 modification for high fills, was adopted as standard.

In order to evaluate the design and installation criterion, the Bureau of Public Roads requested (C.M. 22-42) that a number of reinforced concrete pipe culverts, designed and installed in accordance

with the outlined procedures, be inspected periodically and reported at the end of each calendar year. Early in 1960, a group of 113 reinforced concrete pipe culverts was selected for these inspections. The culverts selected are located in Jefferson, Shelby, Franklin, Clark, Montgomery, Scott, Grant and Kenton Counties on Interstate Routes I-64 and I-75. Each culvert was inspected during the summers of 1960, 1961, 1962 and 1963. Effective July 1, 1963, the project, with which the fourth performance survey is concerned, became identified with the Department's cooperative Planning and Research Program, HPS-HPR-1(25).

Previous reports covering the first-, second-, and third-year performance surveys, respectively, are:

1. "Performance Survey of Reinforced Concrete Pipe Culverts," by R. C. Deen and R. D. Hughes, Highway Research Laboratory, Kentucky Department of Highways, March, 1961.
2. "Second Annual Performance Survey of Reinforced Concrete Pipe Culverts," by R. D. Hughes, Highway Research Laboratory, Kentucky Department of Highways, February, 1962.
3. "Third Annual Performance Survey of Reinforced Concrete Pipe Culverts," by R. D. Hughes, Highway Research Laboratory, Kentucky Department of Highways, January, 1963.

The fourth survey report by R. D. Hughes is dated January, 1964.

Other reports related to but not directly a part of this series of performance-survey reports are:

1. "Performance of a Reinforced Concrete Pipe Culvert, with Standard and B₁, High-Fill Bedding, Under Rock Embankment (Scott County, I-75-6(5)123)," by Ralph R. Taylor, Highway Research Laboratory, Kentucky Department of Highways August, 1963.
2. "Some Effects of Fabrication Practices on the Strength Characteristics of Reinforced Concrete Culvert Pipe," by R. C. Deen and Jas. H. Havens, Highway Research Laboratory, Kentucky Department of Highways, February, 1963 (presented at the 43rd Annual Meeting of the Highway Research Board).

3. "Camber Design Study, for Concrete Pipe Culverts," by Aubrey D. May, Highway Research Laboratory, Kentucky Department of Highways, February, 1960.

Results of the four annual inspections are presented pictorially by appropriate symbols and various colors in the Appendix of the fourth report. Design and construction data for each installation are also included in the Appendix. During the first survey, several culverts were found to be in serious distress and repairs were recommended. Those sections of pipe which were in most serious distress were lined with corrugated metal pipe and grouted. Less serious cracks were patched with epoxy. The patching proved rather ineffective in that cracks reflected through the epoxy.

The more serious signs of distress developed within the first year after installation. Progressive signs of distress were noted during the second, third, and fourth surveys; however, no distresses requiring repair were noted during the last surveys. It is significant to note that the cracking and shear failures observed do not appear to be related to the adjudged, as-built, factor of safety. This suggests the possibility that damage could have been caused by heavy earth-moving equipment or by failure to conform with the plans -- that is, failure to undercut rock and failure to provide a yielding cushion under the pipe. A few instances of misunderstanding of plans and specifications have been disclosed, but no instance of damage attributable directly to construction equipment has been witnessed.

It is essential to the evaluation, from the standpoint of the design criterion and otherwise, to have tenable proof of the cause

of failure. Discovery of distress at some remote time following completion of construction does not provide adequate proof that the burden of the embankment was too great -- this would indeed be true if the pipe had actually been damaged by construction equipment and if the damaged remained undetected until the completion of the embankment. The most meaningful information and that most needed is concerned with the circumstances coincident with the first appearance of distress. With this objective in mind, all project engineers have been urged to make daily inspections of all large-size culverts during construction of embankments. Monthly reports of performance are required to be submitted.

KYHPR-64-23

STUDY OF RUNOFF FROM SMALL DRAINAGE AREAS

Fiscal Year 1963-64

Extensive records are available in reference to the rainfall-runoff relationships for the larger watersheds throughout the state; however, little data is available in regard to these relationships for the smaller watersheds. The major portion of expenditures for drainage facilities on most highway projects goes toward provision for drainage from the smaller areas. It is thus desirable to obtain reliable rainfall-runoff relationships for the smaller areas and to develop a design criterion on the basis of these relationships. Intensity-duration curves are available for the entire state; and, with minor revisions to correct for the greater years of records presently available, they should be incorporated into a criterion developed as mentioned.

Early in 1951, studies of rainfall-runoff characteristics for small drainage areas were undertaken by the Department. Observations on existing structures were made, and attempts were made to obtain a reasonable amount of data concerning their operation under varying storms. Results from these studies are reported in:

1. West, E. M., and Cornell, J. O., "Report No. 1 on a Study of Runoff from Small Drainage Areas and the Openings in Attendant Drainage Structures," Highway Research Laboratory, Kentucky Department of Highways, April, 1952.
2. West, E. M., and Sammons, W. H., "Report No. 2 on a Study of Runoff from Small Drainage Areas and the Openings in Attendant Drainage Structures," Highway Research Laboratory, Kentucky Department of Highways, July, 1955.

Various methods for determining runoff from small area have been developed over a period of time. Some of these methods are discussed in:

1. "Basic Principles of Highway Drainage," Bureau of Public Roads, Information Circular No. 1, September, 1951.
2. "Special Problems in Drainage," Bureau of Public Roads, Hydraulics Information Circular No. 2, September, 1951.
3. "Surface Drainage of Highways," Highway Research Board, Research Report No. 6-B, December, 1948.
4. West, E. M., "An Interpretation of Runoff on the Basis of Hydrologic Records for Six Drainage Areas in Kentucky," MSCE Thesis, Graduate School, University of Kentucky, Lexington, Kentucky, 1953.
5. Highway Drainage Manual, Bureau of Public Roads, July, 1953.
6. Manual of Drainage, Kentucky Department of Highways, August, 1964.
7. Manual of Instructions for Drainage Design, Kentucky Department of Highways, September, 1960.
8. Stream Flow in Kentucky, Kentucky Department of Economic Development, 1960.
9. McCabe, J. A., Floods in Kentucky, Magnitude and Frequency, U.S. Geological Survey, July, 1962.

KYHPR-64-24
PAVEMENT SLIPPERINESS STUDIES
Fiscal Year 1963-64

Several test methods are currently being used in skid testing of pavement surfaces and in evaluating polishing and wear characteristics of aggregates and paving mixes. Particular emphasis is being placed on the development of field methods of testing, since the evaluation of a particular mix or design ultimately depends upon its performance on the roadway.

The trailer and the stopping-distance methods of testing are the most commonly used field tests. The trailers used in skid testing may consist of one or two wheels and the mode of skid resistance detection and recording varies. The ASTM Committee E-17 is proposing standardization of the skid trailers and general guidelines for construction of the trailer and associated instrumentation, as well as suggested procedures for calibration and testing, are available. The stopping-distance test involves the measurement of the distance it takes for the vehicle to come to a stop from a given velocity or the measurement of deceleration of the vehicle. Commonly, the stopping-distance measurement is made from a chalk-gun indicated skid distance or with a stopmeter. The deceleration of a vehicle is measured by a mechanic pendulum, the Dopler tester, or an electrical transducer. With the latter devices, the vehicle can either be permitted to skid for a short distance or come to a full stop in measuring the friction.

The Kentucky Department of Highways has used several methods of skid testing in the last few years. The most useful of these methods has been the decelerometer test utilizing an electrical transducer. However, due to the inability to maintain the transducer in a level position during the skid, the decelerometer test has indicated greater skid resistance of the surface than was actually encountered. The vehicle suspension was neutralized in order to prevent the vehicle from pitching.

Complementary test methods are being used in conjunction with the deceleration test. A fifth wheel speedometer was acquired to measure velocity during the skid. The "observed stopping distance" and the stopping distance obtained with a brake activated magnetic distance counter are also measured. Coefficients of friction are computed by the stopping-distance, velocity-versus-time, and the decelerometer methods.

By fall of 1963, the necessary modifications in the skid-test vehicle were not completed, and the additional equipment to conduct the various proposed field tests had not been acquired. To provide some degree of continuity in skid testing from the 1962 field test series, the projects under study were retested with the British Portable Tester. Several road sections which were suspected of being slippery were also tested. Sand-slurry-sealed surface frictional properties were investigated with the British Portable Tester and the decelerometer method of testing. It is recognized, however, that the British Portable Tester is not a suitable skid testing device for fine-textured surfaces such as found in Kentucky.

KYHPR-64-25

ROAD ROUGHNESS AND SERVICEABILITY INVESTIGATIONS

Fiscal Year 1963-64

Roller-type straightedges have been used extensively as a means for measuring pavement-surface irregularities in construction tolerance control. Numerous devices have been patterned after the roller-type straightedge and attempts have been made to correlate pavement roughness (as measured by use of the various devices) with riding quality. For the past several years, the Division of Research has been actively engaged in the development and useful application of equipment for measuring and recording the riding qualities of pavement surfaces. It has been found that even when accurate measurements are made and control limits are applied to construction, the riding quality may still be fair to poor. In view of this, efforts have been directed toward the measurement and evaluation of the effect of pavement-surface characteristics on the comfort of passengers rather than the measurement of localized irregularities in the surface itself.

During the early stages of development, a triaxial-acceleration method of testing was utilized. This method involved the monitoring of accelerations experienced by a test passenger in a moving vehicle. Vertical accelerations experienced by the test passenger are analyzed and converted to an index number which serves as an indication of the riding quality of the pavement surface. During the 1963 construction season, approximately 870 lane-miles of new pavement were placed.

the underside of the bridge deck and beams received an application of spray-in-place urethane foam in October, 1962. The two-component urethane material was supplied and applied by the Dow Chemical Company. The Research Division of the Highway Department installed thermocouples at several strategic locations in the bridge deck and approach slabs and collected temperature data for the winters of 1962-63 and 1963-64. No analysis of the data has been made as of this date.

KYP-64-3

CORROSION RESISTANCE OF CULVERT MATERIALS

Fiscal Year 1963-64

Beginning in 1949, the Research Division became involved in an investigation of culvert failures on U.S. 60 near Ashland. Cause of failure was attributed to damage by acid waters. As a result of this investigation, a survey of the condition of culvert pipe in the state was undertaken. The Eastern Kentucky Coal Field Region and the Western Kentucky Coal Field, encompassing 19 counties, are considered as potential acid water areas.

For a number of years, an experimental culvert installation near Mortons Gap has been under observation. In 1951 the first of several types of pipe was installed. As new methods and new materials of pipe construction have become known, additional pipe sections have been installed at the test site for evaluation. Performance data has been collected concerning the effectiveness of various coating materials with regard to resistance to the corrosive action of the acid water.

The structures in acid water areas on the Western Kentucky Parkway are also under observation. Information obtained from the Mortons Gap installation has been used to design protective measures for most of the structures.

deck concrete, laboratory tests were conducted on specimens cast from concrete containing the admixture. Specimens were cast from control mixtures for comparative purposes. All mixtures were proportioned to contain six sacks of Type I portland cement and were adjusted at the mixer for a slump of approximately 2 1/2 inches. The experimental mixtures contained 0.3 pounds of silicone per sack of cement. On the basis of flexural and compressive strength tests, the silicone admixture had little effect upon the 28 day strengths. The admixture did retard the set significantly. Freeze-thaw tests are in progress and data is insufficient at this time in regard to the effect of the silicone upon the freeze-thaw resistance of the concrete.

Salt-Treated Granular Bases with Multiple Seals

During February 1964 an inspection was made of twelve traffic-bound bases which were salt-treated and sealed during the 1962 and 1963 construction seasons by the Maintenance Division. All of the projects were on rural roads in the Somerset Highway District and the work involved intermixing salt (calcium chloride or sodium chloride) and additional stone with the existing traffic-bound material on the roadway, compacting the base, and then applying a double chip seal. Several of the bases constructed during 1962 received a third chip seal in 1963. The bases constructed during 1963 are scheduled to receive a third seal in 1964. A memorandum report on the condition of these treated bases was prepared in March, 1964.