

Research Report
399

SKID RESISTANCE STUDIES IN KENTUCKY
(An Overview - 1974)

by

J. H. Havens
Director of Research

J. L. Burchett
Research Engineer Principal

and

R. L. Rizenbergs
Research Engineer Chief

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

prepared for presentation to the
33rd Annual Meeting of SASHTO
October 16-19, 1974
Louisville, Kentucky

September 1974

INTRODUCTION

"To free Kentucky of slick roads" is the high goal toward which Kentucky has been striving since 1950's. A very capable fellow engineer used to say that there was more satisfaction in being able to take down a **Slippery When Wet** sign than in erecting one.

Considerable effort has been devoted to the development and adaptation of improved methods of skid resistance testing and to the standardization of testing devices (1, 2, 3, 4). Methods of tests have included the NCSA friction wheel (bicycle wheel), automobile deceleration, skewed-wheel (skewed front-wheels of an automobile), skidding automobile, and the skid-test trailer. The development and standardization of a trailer method of test in recent years represents significant progress in the measurement area.

From the outset of our skid resistance measurement program, evaluations of pavement design, construction and maintenance practices were of utmost concern. In fact, the first field tests -- made in 1953 -- resulted in changes of the design mix in the use at that time (5). Every type of pavement and sealing and deslicking treatment used in the state have been monitored and assessed as to their friction properties (1, 6, 7). Insights gained have been applied towards the development and refinements of wearing surfaces.

Skid resistance standards for maintenance and mix design purposes must be established if meaningful improvements in highway safety are to be realized. Arbitrary judgements as to minimum requirements will not suffice because the safety and economics involved are much too important to every highway user. Efforts to derive minimum skid resistance requirements in Kentucky were based on accident statistics. Critical values have been determined for rural, four-lane, controlled access roads (interstates and parkways) (8). Critical values for rural, two-lane roads (U.S. routes) are forthcoming.

Studies of pavement slipperiness have received renewed emphasis as a result of attention directed towards highway safety. Congress recognized the element of pavement skid resistance in the Highway Safety Act of 1966 and the resulting Highway Safety Program Standard 12, dated June 27, 1967. Most recently, Instructional Memorandum 21-2-73, dated July 19, 1973, stressed the importance of pavement skid resistance in providing safe highways. Kentucky has continued to progress in this vital area.

METHOD OF TEST

The Kentucky Department of Transportation has been engaged in laboratory studies of wear and frictional characteristics of aggregates since 1956 and in field testing of pavement surfaces since 1958. A variety of tests methods have been used in the course of skid-resistance studies, both in field and laboratory investigations. A two-wheeled skid-test trailer (Figure 1) was acquired in 1969. The skid tester was developed by General Motors Proving Ground and manufactured by K. J. Law Engineers, Inc., Detroit, Michigan. The Surface Dynamics Pavement Friction Tester, Model 965A, complies fully with ASTM E-274 and has several features designed for greater research flexibility which are not covered in the ASTM standards.

Factors and variables associated with the testing device and calibration and test procedures were investigated and standardized, and the trailer was adopted for routine testing (4). Kentucky trailer measurements provide both locked-wheel skid resistance, expressed as Skid Number, SN, and peak slip resistance, expressed as Peak Slip Number, PSN. Many of the tests for pavement evaluation were conducted at three test speeds (20, 40, and 60 mph (9, 18, and 27 m/s)) to evaluate the effects of velocity (7). Normally, tests were made in the left wheel path and at 1-mile (1.6-km) intervals; no less than five tests per lane were made on each construction project.



Figure 1. Skid-Test Trailer.

FRICTION REQUIREMENTS

Ideally, wet pavements should provide as much traction as dry pavement. In a practical and realistic sense, however, the question remains as to what minimum level of friction a pavement should provide to safeguard the public from undue hazards associated with wet weather driving. Little satisfaction derives from merely maintaining a friction level at or near a critical value. The critical value, however, may serve as a criterion for posting wet-weather speed restrictions and for design of surface courses providing a due margin of safety.

Investigations to establish minimum friction requirements in Kentucky have focused on analysis of accident experience as related to pavement friction. The initial study involved rural, four-lane, controlled access roads on the interstate and parkway systems (144 projects) in Kentucky (8). These highways were purposely chosen for this initial analysis because many of the usually confounding variables, such as road geometrics, access control, and speed, may be assumed to have minimal influence. Traffic characteristics (volume and density) and pavement surface conditions (wet or dry and skid resistance when wet) are, respectively, the regenerative and causative factors.

Annual average daily traffic volumes were obtained for 1971. Accident data were those reported during the calendar years 1970, 1971, and 1972. Pavement friction measurements were made between June and October 1971 on 770 miles (1240 km) of the interstate and parkway system having a posted speed limit of 70 mph (31 m/s). The test speed was also 70 mph (31 m/s).

Several different analyses of accident data were performed and the results were related to skid resistance. These included total accident rate, wet weather accident rates, wet to dry and wet to total accidents ratios, and number of wet accidents per mile. Wet surface accidents per 100 million vehicle miles (161 million vehicle kilometers) (total travel under all pavement conditions rather than wet-surface mileage) correlated best with skid resistance.

Even using the best statistical expression of accidents, scatter and spurious variability in data seem inevitable. Stratification of the data by AADT at 3000 vehicles per day minimized scatter. Averaging methods as a means of developing trends and minimizing scatter between variables were used and the "moving average" yielded more definitive results. Definite trends were established in regard to the relationship between wet-surface accident rates and Skid Numbers (Figure 2). Wet-surface accident rate decreased rapidly as the Skid Number (70 mph or 31 m/s) increased to 27; further increases in Skid Number beyond this point resulted in

only a slight reduction in accident rate. Definite trends were also evident between wet-surface accident rates and Peak Slip Numbers. The greatest change in slope of the trend lines occurred at a Peak Slip Number (70 mph or 31 m/s) of about 57.

The true accident rate for wet-surface conditions would be several times higher since pavements were wet only 13 percent of the time. Wet-surface accident rates for 2 of the 3 years considered in this study were higher during the summer-fall periods (Table 1) even though the roads were wet a lesser proportion of time. When adjusted to equal time of precipitation during December to May and June to November, wet-surface accident rates for the summer-fall periods were higher for all 3 years. Lower skid resistance of pavements during summer and fall obviously contributed to an increase in wet-surface accidents.

Analysis presently underway is to determine a relationship between accident experience and pavement friction for rural, two lane, U.S. designated roads previously signed for 60 mph (27 m/s) travel speed. Wet-surface accidents per 100 million vehicle miles (161 million vehicle kilometers) were determined for each test section, based on 1970 and 1971 accident data, and were related to skid resistance measured at 40 mph (18 m/s) during 1970. The data were stratified at 3000 AADT and at 15 access points per mile (9 access points per kilometer). Critical skid numbers of 40 to 45 were indicated.

The results are summarized in Figure 3 and includes the result from study of interstate and parkway roads when converted to 40 mph (18 m/s) test speed. Rural, two-lane US routes with more than 3000 AADT and less than 15 access points per mile (9 access points per kilometer) showed a critical value of 40. For more than 15 access points per mile (9 access points per kilometer), the critical value was about 42. Obviously, increased congestion and points of conflict tend to increase the frictional needs of traffic. For roads with less than 3000 AADT, this critical skid number was about 45. Influence of roadway geometrics, traffic congestion and roadway access on wet-surface accident rates were apparent.

Our studies, therefore, have demonstrated a relationship between accident experience and pavement skid resistance. This relationship should be used as a guide in establishing minimum friction requirements for pavements.

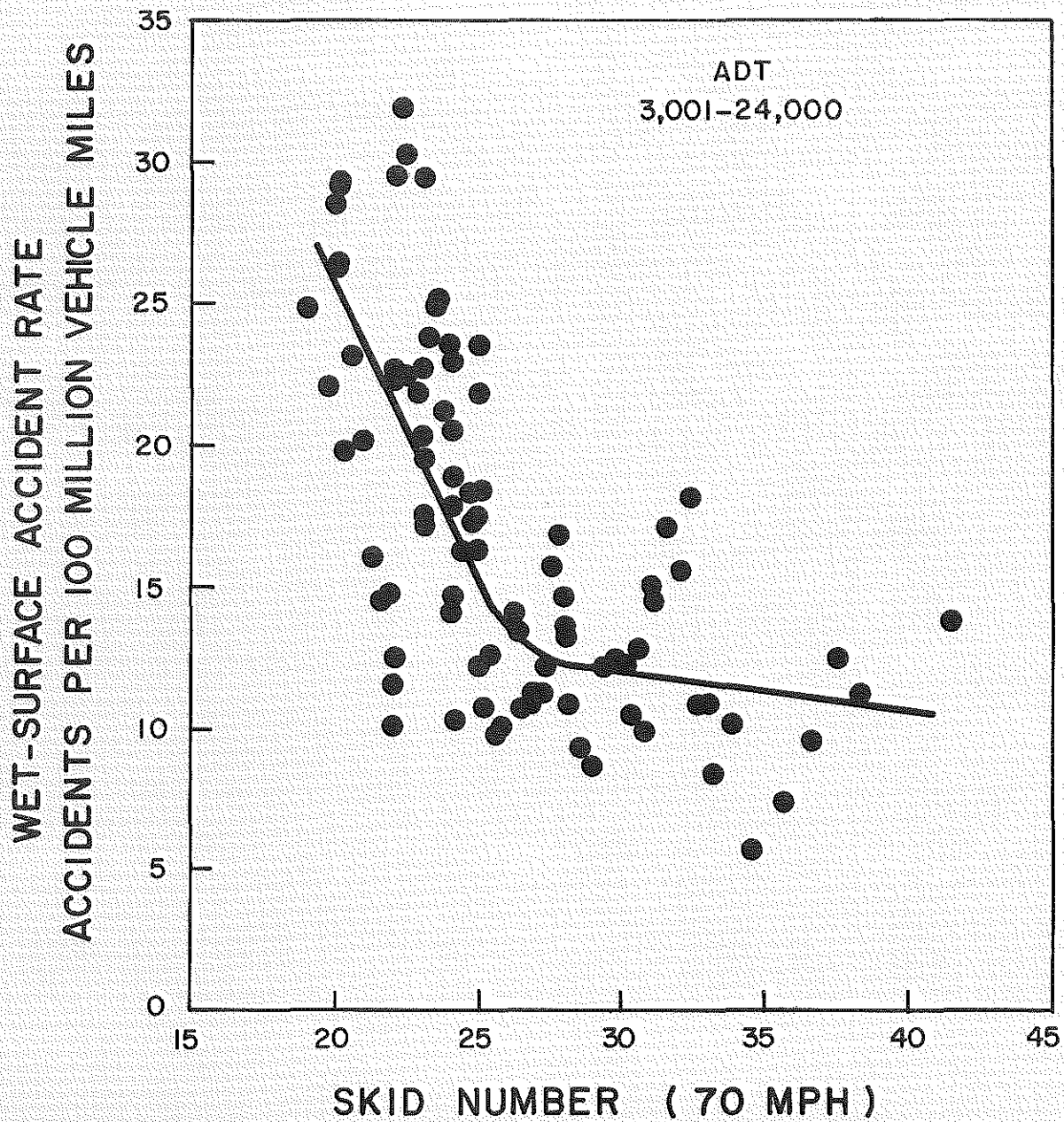


Figure 2. Rural, Four-Lane Controlled Access Roads (Interstate and Parkway): Wet-Surface Accident Rate versus Skid Number with Volume Stratification at AADT of 3000. Five-Point Moving Average.

TABLE 1
SEMIANNUAL ACCIDENT SUMMARY

YEAR	PERIOD	WET-SURFACE ACCIDENTS		PRECIPITATION (PERCENT)**	ACCIDENT RATE PRECIPITATION
		NUMBER	RATE*		
1970	Jan - May, Dec	166	15.9	13	1.2
	Jun - Nov	221	16.8	10	1.7
1971	Jan - May, Dec	160	15.3	13	1.2
	Jun - Nov	229	17.4	10	1.7
1972	Jan - May, Dec	280	26.8	18	1.5
	Jun - Nov	278	21.2	12	1.8
1970	Jan - May, Dec	606	19.3	15	1.3
1972	Jun - Nov	728	18.5	11	1.7

*Accidents per 100 million vehicle miles (161 million vehicle kilometers) (all pavement conditions).

**Percent of total time with precipitation (trace or more) in the Lexington area.

Periods of snow or ice not included.

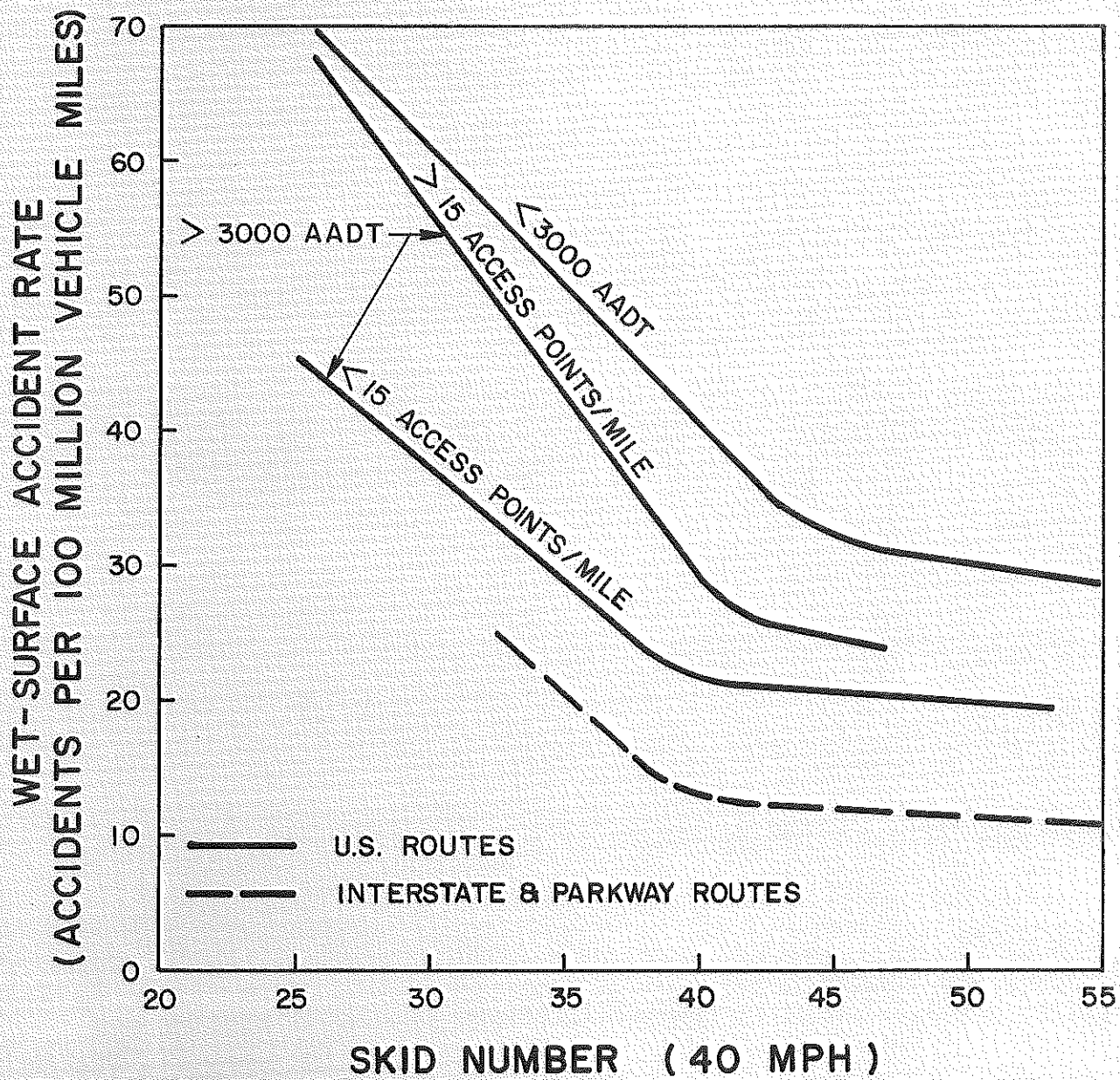


Figure 3. Relationship between Wet-Surface Accident Rate and Skid Numbers.

SKID RESISTANCE INVENTORY

Measurements on the interstate and parkway system and on the U.S. designated routes during 1970 and 1971 provided an accurate indication of total pavement skid conditions within the state. On 110 test sections of the interstate and parkway system (Figure 4), 58, or more than 52 percent, had a Skid Number less than the critical value of 27. On 296 test sections of the U.S. designated route (Figure 5), 149, or just over 50 percent, had a Skid Number less than the lowest critical value of 40. Thus, in Kentucky -- with its preponderance of limestone aggregate -- much of the major road system does not provide desirable levels of skid resistance.

PAVEMENT PERFORMANCE

Past Efforts

Some skid test in 1953 showed Class I, Type B surfaces containing all limestone aggregate to be very slippery (5). Kentucky rock asphalt and sandstone were outstanding. Class I, Type B, containing natural sand, was superior to all-limestone surfaces. The decisive action was to require natural sand in Type B surfaces if the traffic exceeded 700 vehicles per day. There was some hope then that Kentucky rock asphalt and sandstone aggregate would develop and supply skid-resistance surfacing superior to Type B. Sandstone was specified as an alternate to limestone for several years in eastern Kentucky; a few sandstone resurfacing projects materialized (9), but, the alternative was dropped about 1963 because contractors were not bidding it. Kentucky rock asphalt encountered performance problems (scaling) and, after an adverse report on a test road constructed in 1955 (5), the company liquidated its assets in 1958. Sometime later they were acquired by another company and two thrusts were made to develop serviceable materials, one in 1963 and another in 1966 (10). However, because of several problems -- including air pollution resulting from pre-roasting the materials -- Kentucky rock asphalt is not now used.

At the beginning of interstate surfacing (Clark-Montgomery Counties), difficulties arose with the Class I, Type B surface. Kentucky's Class I, Type B surface admitted either limestone or natural sands. Natural sands (dredges) were usually void of fines, and the addition of fines (filler) was normally not required. These Type B surfaces containing 8-10 percent voids, tended to ravel. The gradation was changed to allow addition of limestone sands to supply the needed fines. This Type B (Modified) mix was used from 1961 to 1963. During this period the Division of Research

undertook studies to improve the mixture. This work resulted in Class I, Type A (11). This was very dense, very stable, bituminous concrete. More recently after field evaluations of many projects, it was concluded that the mixture was perhaps too dense. Class I, Type A (Modified) resulted. Although as much natural sand was crowded into these mixtures as could be (perhaps more than we should have from the standpoint of stability), it became apparent that a high degree of skid resistance would never be achieved -- because of polishing of limestone coarse aggregate (Figure 6). Also, the definition of natural sand provided no assurances concerning shape or composition.

Until the Kentucky Turnpike was built (1955) and the beginning of interstate surfacing, very few miles of concrete pavement had been built in Kentucky for a long time. Now the surface of most of the completed interstate and parkway system is PCC. Until 1970 and 1971, no indication of serious-slipperiness of PCC pavements has been found. Tests at that time indicated low skid resistance on much of the concrete surfaces of the interstate system, especially at the higher speeds (7). Wear induced by studded tires and seasonal polishing are believed to be significant influences.

Meanwhile, when it appeared that Kentucky rock asphalt might pass away, the Research Division undertook development of sand asphalts. Between 1958 and 1966 several sections of sand-asphalts were laid and evaluated (12, 13, 14). In 1968, four sections of sand asphalt (one simulated Kentucky rock asphalt) and one section of Kentucky rock asphalt were laid (experimentally) on US 27 near Somerset (15). This was intended to demonstrate a higher skid resistance for 100 percent quartz sands than is obtainable with a blend of 50 percent quartz and 50 percent limestone sand. It was also intended to demonstrate differences in skid resistance between dense sand asphalts and porous sand asphalts.

Measurements made about 5 years after construction (December 1973) ranked the pavements in the order anticipated (Figure 7) (7). Regular sand asphalts exhibited the lowest friction and Kentucky rock asphalt the highest. Both surfaces seemed to be rather comparable to similar pavements constructed elsewhere. As expected, the open-graded, high-silica pavement yielded higher skid resistance than the open-graded, medium-silica section. However, the frictional levels achieved were disappointing. Limestone sand obviously reduced the skid resistance of sand asphalts.

Results from the most recent Department study on the skid-resistant attributes of sands indicated that the term "Natural Sand" and its definition given in Section 611 of the Standard Specifications ... (16) permits but does not assure skid-resistant materials. Indeed, certain

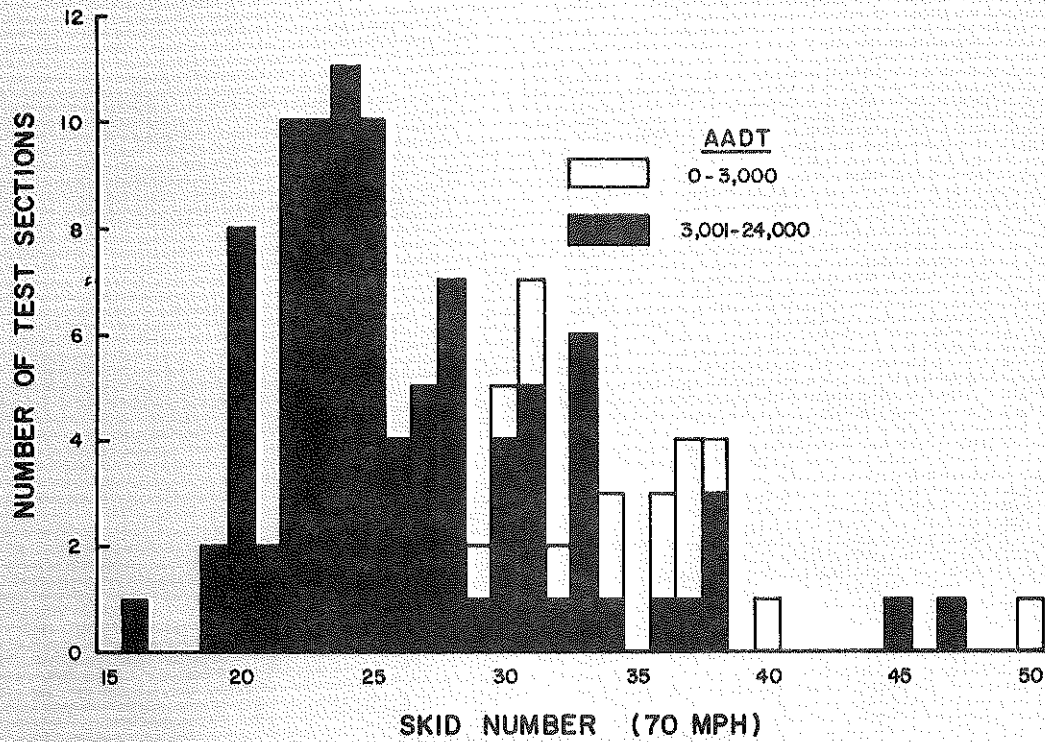


Figure 4. Skid Number Distribution for 110 Test Sections of Rural Interstate and Parkway Routes.

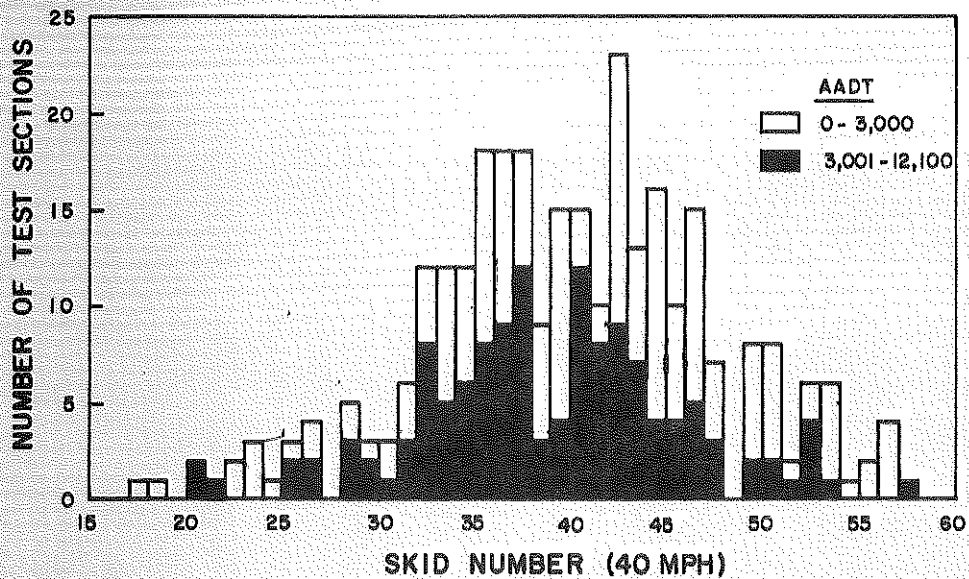


Figure 5. Skid Number Distribution for 296 Test Sections of Rural US Routes.

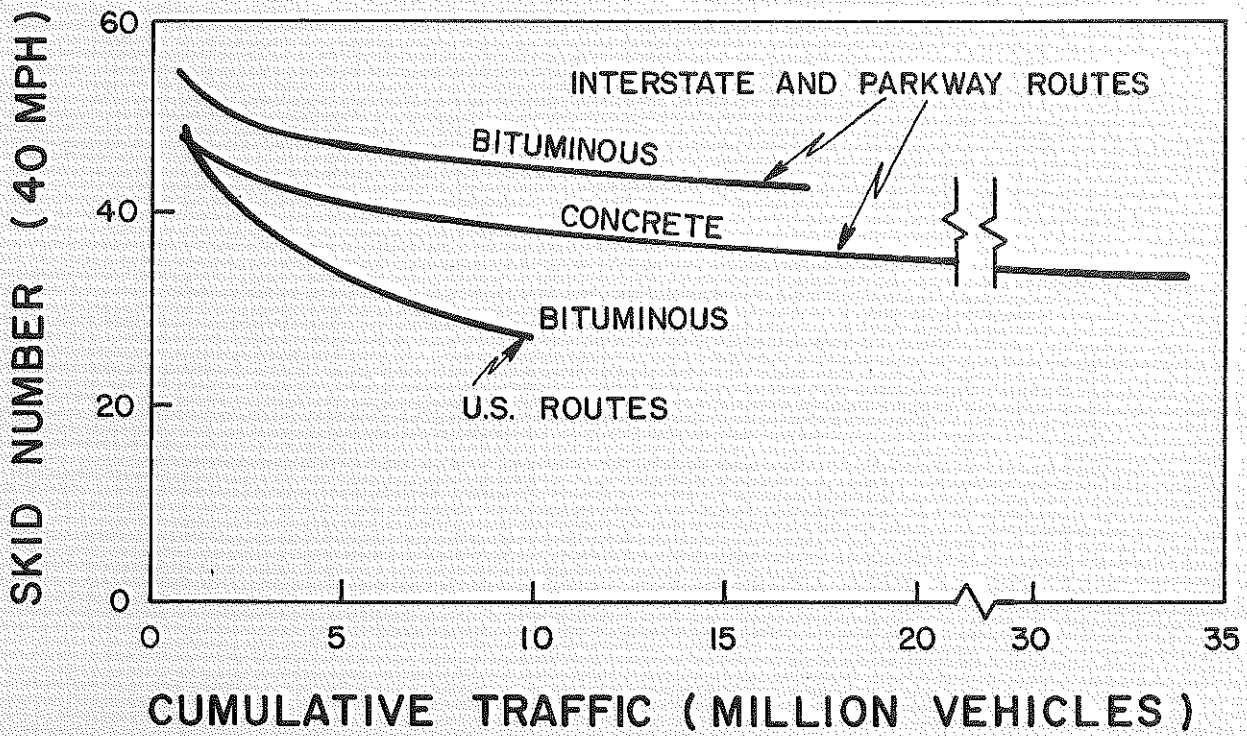


Figure 6. Effects of Traffic on Bituminous and Concrete Surfaces.

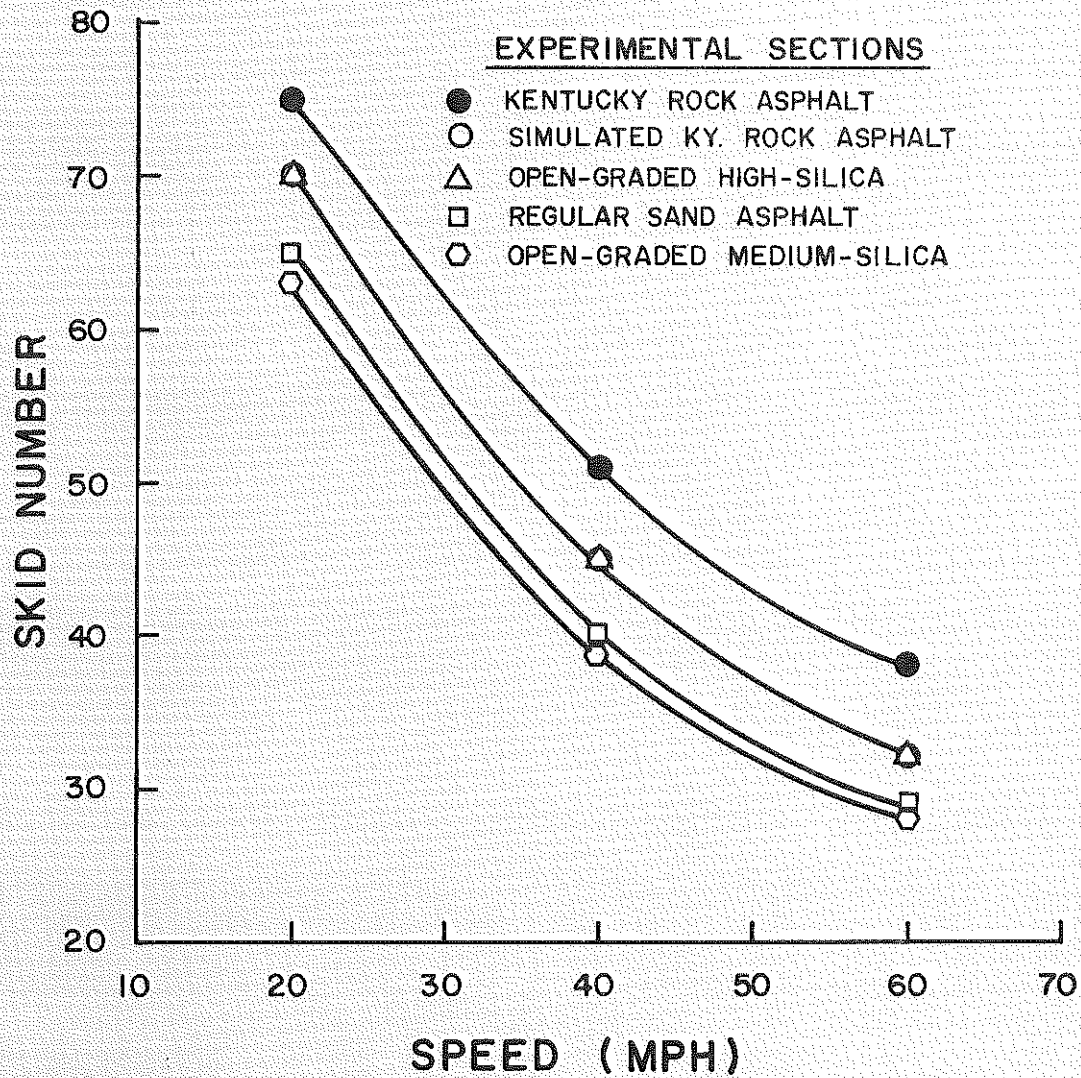


Figure 7. Skid Resistance of Experimental Sand-Asphalt Sections on US 27 near Somerset (December 1973).

reforms were needed. Sands should be selected in terms of mineral composition, gradation, and particle shape (17). Sand Asphalt (skid resistant), Special Provision 59-B, resulted. This was a dense mix. Recommendations put forward for an open-graded sand asphalt (18) remain in suspense.

Present Efforts

The need for thin-layered asphaltic surface courses remains, and the demand for them will grow, particularly as concrete pavements require deslicking. Such surfaces, in contrast to the asphaltic concrete surface courses, must meet the following criteria: (1) superior skid resistance, especially at the higher traffic speeds, (2) wear rates commensurate with the desired service life, and (3) competitive cost per square yard of material. However, conditions may warrant higher expenditures to achieve desired friction levels.

Present criteria for specifying a bituminous wearing surface encompass four pavement designs. These criteria are as follows (normal operating speed is previously marked speed and not speed marked for temporary periods):

- 1) **Projects with less than 750 ADT** -- Specify Bituminous Concrete Class I Type A Modified Surface wherein the natural sand requirement would be waived.
- 2) **Projects with 750 ADT or greater and a normal operating speed of 45 MPH (21 m/s) or less** -- (a) in locations where natural sand or slag sand is readily available, specify Special Provision No. 22-D, Sand Asphalt Surface Type I. (b) In areas where natural sand or slag sand is not readily available, specify Bituminous Concrete Class I Type A Modified Surface with natural sand required.
- 3) **Projects with 750 ADT or greater and normal operating speed of 45 mph (21 m/s) but not greater than 60 mph (27 m/s)** -- Specify alternate wearing surfaces of Special Provision No. 59-D, Sand Asphalt Surface (Skid Resistance Type II) or Special Provision No. 109, Open-Graded Friction Courses (Plant Mix Seals).
- 4) **Projects with 750 ADT or greater and a normal operating speed in excess of 60 mph (27 m/s)** -- Specify Special Provision No. 109, Open-Graded Friction Courses (Plant Mix Seals).

Special Provision Numbers 22-D, 59-D and 109 are presented in Appendix A.

The design for "Open-Graded Friction Courses" is entirely new. It admits crushed, siliceous gravels and crushed slag. Both aggregates (crushed, quartz gravel and slag) were put to on-road tests during 1973. An

Open-Graded Friction Course using slag aggregate was placed on a short section of US 23 south of Ashland. Another, longer section (4.7 miles (7.6 kilometers)), using crushed, quartz gravel aggregate was placed as a demonstration project on the southbound lanes of US 31W just north of Elizabethtown. The most recent skid resistance data are presented in Figure 8. The cumulative traffic on the Ashland section was 1.2 million vehicle passes. The cumulative traffic on the Elizabethtown section was 1.5 million vehicle passes in the outside lane.

The design for "Sand Asphalt Surface (Skid Resistant Type II)" is similar to the mixture placed in 1972 and 1973 on US 31-W from West Point to US 60 south of Muldraugh. The mixture for these two projects was Sand Asphalt (skid resistant), Special Provision 59-B and the aggregate was crushed, quartz gravel. The latest skid resistance data of the project placed in 1972 are presented in Figure 8. Cumulative traffic was 3.4 million vehicle passes. Skid resistance performance history to date, of this project is presented in Figure 9. The effects of traffic are becoming evident. Seasonal influence is apparent, but data points for the same months show a downward trend.

The design for "Sand Asphalt Surface (Type I)" is patterned after and supplants Special Provision 22-C. The primary change is gradation.

Not including the Class I Type A Modified Surface, approximately ten surfacing projects using one of the three other bituminous wearing surface designs were scheduled for this year. All projects will be routinely measured for skid resistance for the next several years to determine their performance equations and, thereby, to qualify them to meet skid resistance requirements.

Texturing of freshly placed concrete surfaces has been recognized to be important. The added macrotexture, or macroroughness, improves tire-pavement friction and reduces the potential for hydroplaning. The texture depth (amplitude), spacing (pitch) between adjoining ridges, wear rates, and direction of texturing are important considerations in choosing a method or style.

Texturing of freshly placed concrete surface in Kentucky has been mostly limited to burlap drag. First attempts at broom texturing were in 1971 on short sections of the Daniel Boone Parkway. However, because of equipment and other problems, the resulting texture was not satisfactory. Several bridge decks on Interstate 64 between Lexington and Frankfort were plastic grooved during latter part of 1971 and the first half of 1972. The skid resistance of these decks are being evaluated. To date, the values remain good. A short length of US 421 A in Franklin County was grooved during late 1973. More recently, about 20 miles (32 kilometers) of construction on Interstate 24 in Christain

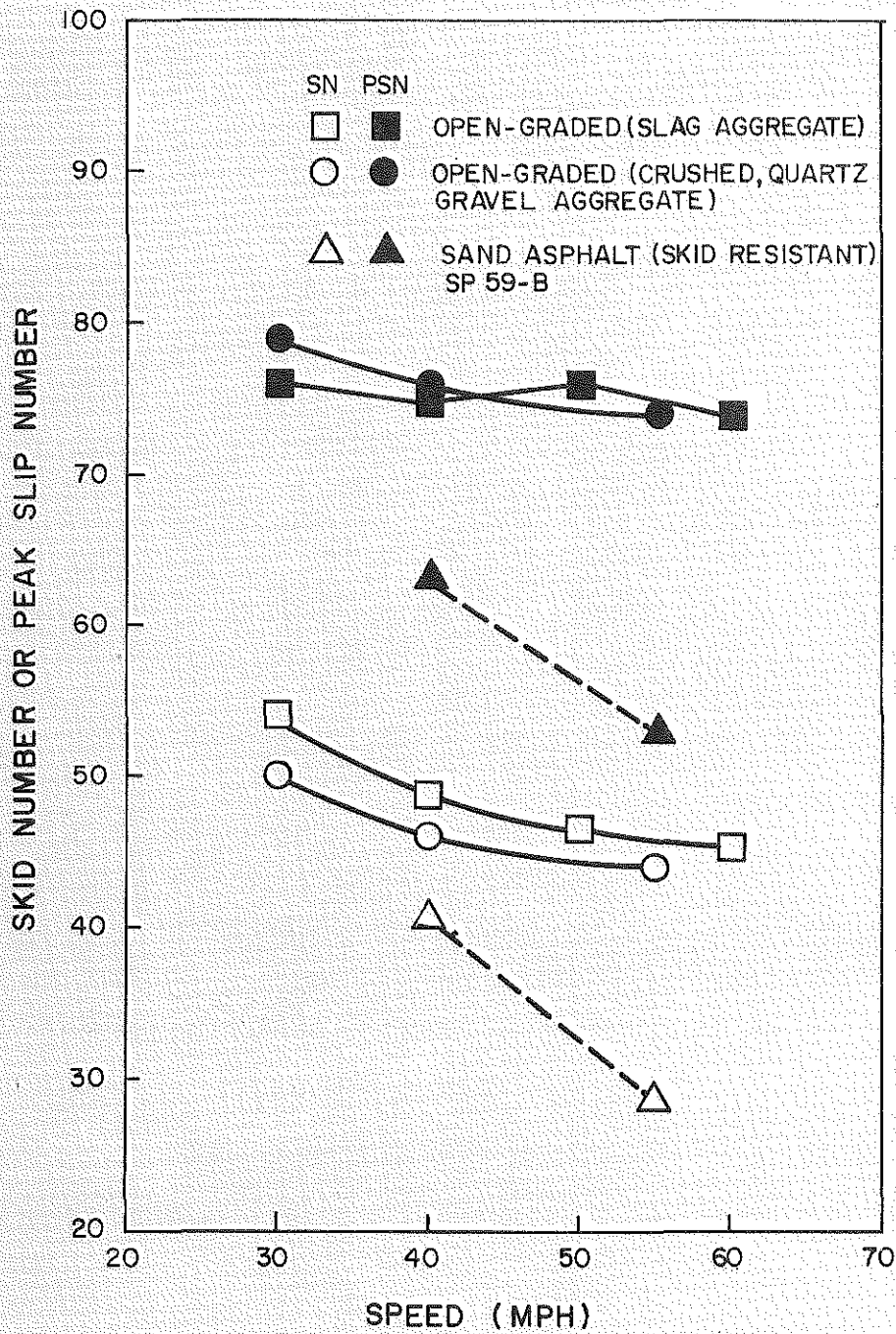


Figure 8. Skid Resistance of Open-Graded Friction Courses on US 23 near Ashland (slag aggregate) and US 31 W at Elizabethtown (crushed, quartz gravel aggregate) -- and Sand Asphalt (Skid Resistant), Special Provision 59-B on US 31W at Muldraugh.

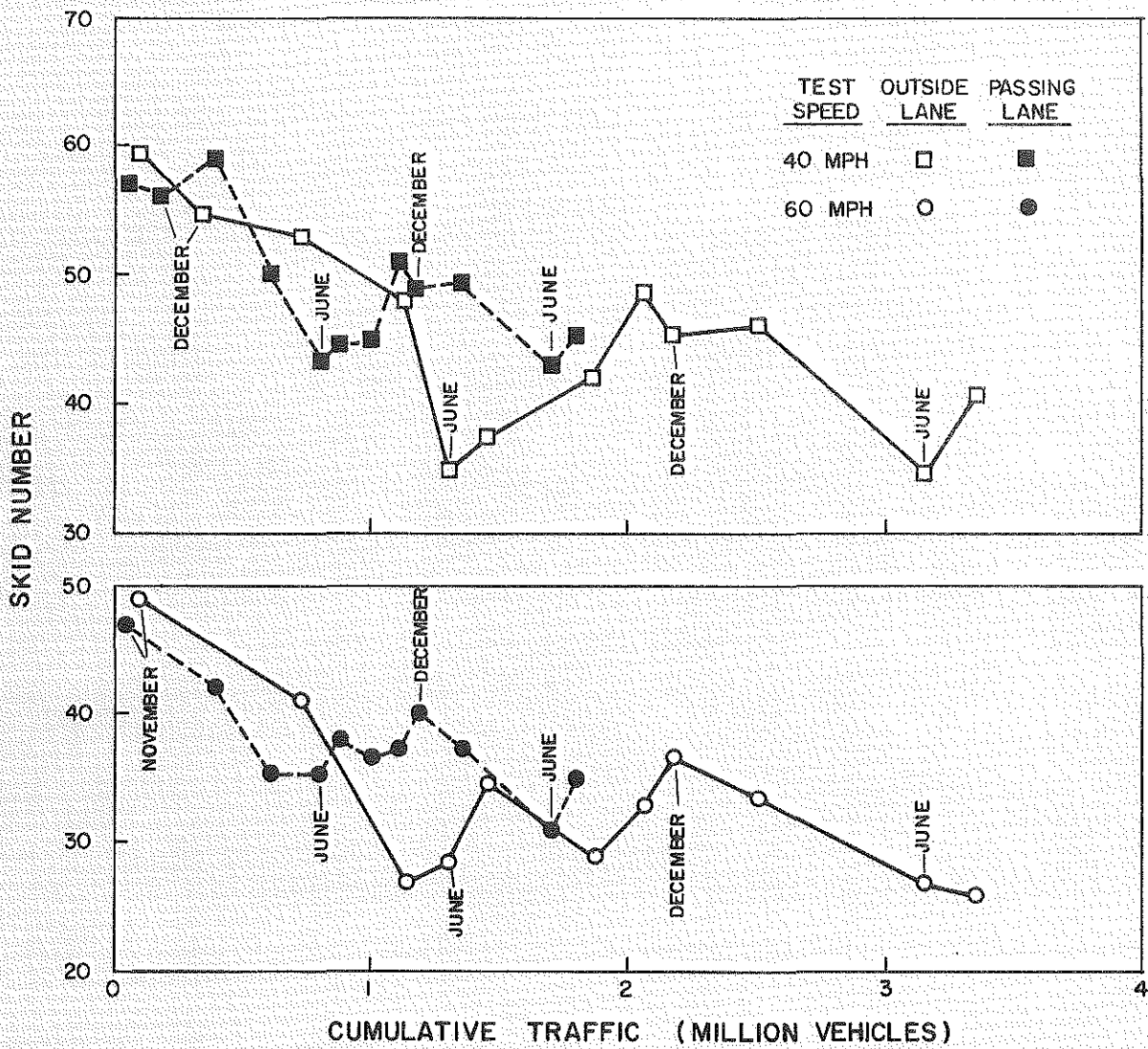


Figure 9. Effect of Traffic on Sand Asphalt Surface (Skid Resistant), S.P. 59-B, placed on US 31W at Muldraugh.

County was grooved this summer (Figure 10). Special notes for grooving requirements are presented in Appendix B. Additional projects are planned.

Other efforts presently underway include evaluation of pavement design procedures and specifications. Increasing the crown slope to 1/4 inch per foot (21 mm per meter) (previously 1/8 inch per foot (10 mm per meter) to provide better drainage is being implemented.

A permanent speed limit of 55 mph (25 m/s) (for fuel conservation) would surely reduce accident rates and death on the highway and is likely to alter skid resistance requirements. Conventional surfaces might qualify to a higher degree of confidence. Measurements from the interstate and parkway inventory, presently under way, will be evaluated to establish an updated critical value for these roads. The same analysis will be applied to US routes during 1975.

SUMMARY

Kentucky studies relating to pavement slipperiness extend over a long period of time and have recently received renewed emphasis as a result of attention directed towards highway safety. Considerable effort has been devoted to development of better methods of skid resistance testing and to standardization of testing devices. Commercially fabricated trailers became available and a two-wheeled trailer and towing vehicle was acquired. The development and standardization of a trailer method of test represented significant progress in measurement techniques.

Before meaningful improvements in highway safety are to be realized, skid resistance requirements for maintenance and mix design purposes must be established. To this end, considerable effort has been expended to related skid resistance data to accident statistics for Kentucky highways. Measurements have been completed on rural, interstate, parkway, and primary routes. Relationships between wet-surface accidents and skid resistance were established and indicated that surfaces with skid resistance less than a "critical" value have disproportionately higher wet accident rates.

The development of skid-resistant surface courses to operational status has become more and more

compelling. Kentucky rock asphalt had always been praiseworthy for its skid resistance; other problems besetting this material have not been completely resolved. Class I, Type A, asphaltic concrete surface courses containing limestone coarse aggregate and non-descript, natural sands have not provided the degree of certainty and confidence now sought from the standpoint of the skid resistance needed for high-speed and high-volume traffic. Specifications for bituminous concrete now include requirements that the aggregate contain minimum amounts of highly skid-resistance quartz sand.

In the latter 1950's, the Department undertook the development of a more generic and inclusive surfacing mixture -- namely, a sand asphalt in which full reliance for skid resistance would be given to hardness, sharpness and angularity of quartz sand -- this was a recognizable and specific attribute of Kentucky rock asphalt and sandstone aggregates excelling in skid resistance. The surface course (nominally 0.5 inch (13 mm)) would be regarded as sacrificial but renewable. Blends of quartz sand with crushed limestone were admitted. At that time, there was persuasive evidence that some limestone in sand sizes would not affect skid resistance significantly if the wear rate was satisfactory. Unfortunately, it appears now that such a balance is unachievable. Conceptually, the alternative is to regulate the limestone aggregates to bituminous concrete structural layers and to employ skid-resistance sands in a relatively thin, wearing course on top.

Pavement design alternatives using materials indigenous to and (or) produced in Kentucky appear to be: (1) Sand Asphalts typified by special provision No. 59-D and (2) Open-graded friction courses (plant-mix seal) as specified by special provision No. 109. Aggregate incorporated in these mixes must be angular and resistant to polishing. These aggregate includes: (1) crushed, quartz gravel, (2) slag, (3) light weight (expanded shale), and (4) sandstones (possibly).

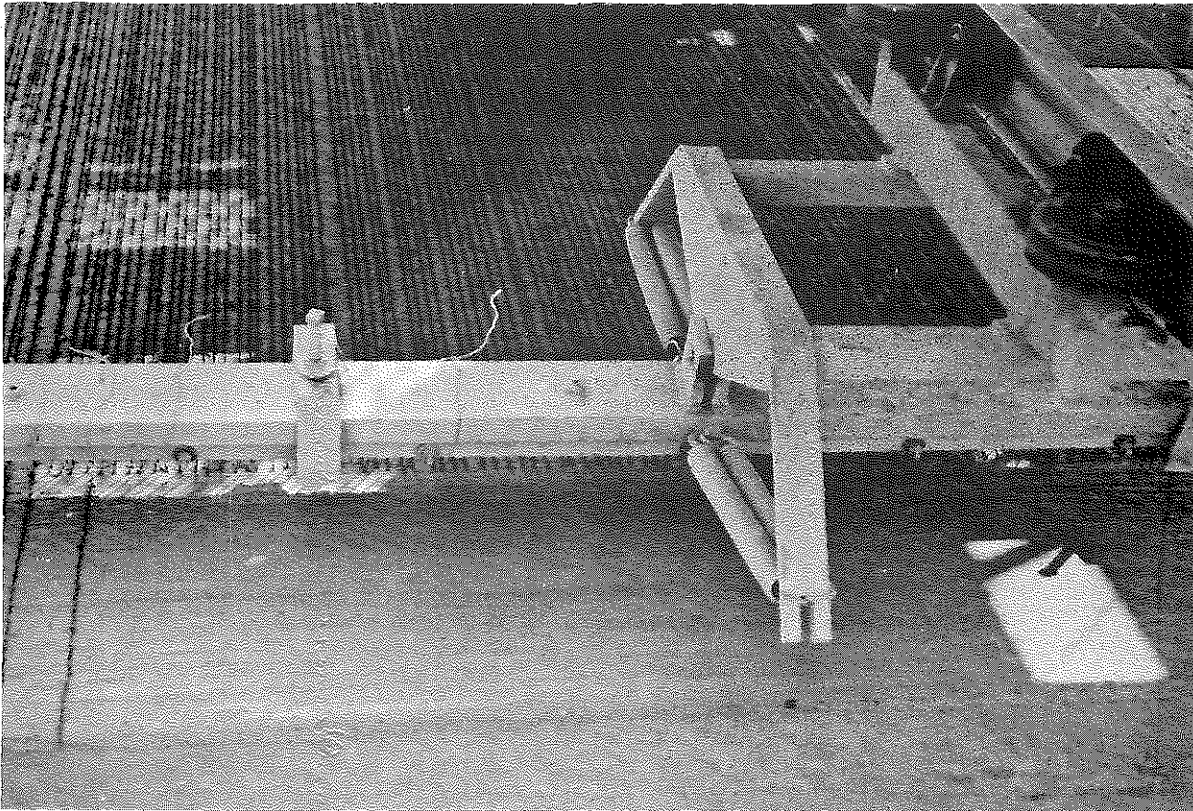


Figure 10. Transverse Grooving of Plastic Concrete on Interstate 24.

REFERENCES

1. Havens, J. H. and Rizenbergs, R. L. *Pavement Slipperness Studies*, Division of Research, Kentucky Department of Highways, February 1962.
2. Rizenbergs, R. L. and Ward, H. A., *Skid Testing with an Automobile*, Record No. 187, Highway Research Board, 1967.
3. Rizenbergs, R. L. *Florida Skid Correlation Study of 1967 - Skid Testing with Automobiles, STP-456 - Highway Skid Resistance*, American Society for Testing and Materials, 1969.
4. Rizenbergs, R. L., Burchett, J. L. and Napier, C. T., *Skid Test Trailer: Description, Evaluation and Adaptation*, Kentucky Department of Highways, August 1972.
5. Havens, J. H. and Williams, E. G., *A Study of the Properties and Performance of Kentucky (Natural Sandstone) Rock Asphalt*, Kentucky Department of Highways, February 1956.
6. Burchett, J. L. and Rizenbergs, R. L., *Pavement Slipperness Studies*, Kentucky Department of Highways, March 1970.
7. Rizenbergs, R. L., Burchett, J. L., and Napier, C. T., *Skid Resistance of Pavements*, Kentucky Department of Highways, July 1972. Also in *Skid Resistance of Highway Pavements*, ASTM STP 530, American Society for Testing and Materials, 1973.
8. Rizenbergs, R. L., Burchett, J. L., and Napier, C. T., *Accidents on Rural Interstate and Parkway Roads and Their Relation to Pavement Friction*, Kentucky Department of Highways, October 1973.
9. Williams, E. G., *A Test Road for Evaluation of Sandstone as an Aggregate in Plant-Mix Bituminous Pavements*, Kentucky Department of Highways, April 1952.
10. Florence, R. L., *Kentucky Rock Asphalt Hot-Mix Surfaces*, Kentucky Department of Highways, August 1968.
11. Florence, R. L., *Class I Bituminous Mixtures*, Kentucky Department of Highways, September 1966.
12. Florence, R. L., *The Design of Thin, Silica Sand-Asphalt Wearing Surfaces for Highway Bridge Decks*, Kentucky Department of Highways, July 1959.
13. Florence, R. L., *Bridge Resurfacings with Silica Sand-Asphalt Mixture*, Kentucky Department of Highways, March 1961.
14. Florence, R. L., *Construction and Interim Performance of Silica Sand-Asphalt Surfacing*, Kentucky Department of Highways, February 1965.
15. Florence, R. L. and Southgate, H. F., *Experimental Sand-Asphalt Surface*, Kentucky Department of Highways, October 1970.
16. **Standard Specifications for Road and Bridge Construction**, Edition of 1965, Kentucky Department of Highways.
17. Rose, J. G. and Havens, J. H., *Aggregate Shape and Skid Resistance*, Kentucky Department of Highways, September 1971.
18. Havens, J. H., *Porous Sand-Asphalt Mixtures*, Kentucky Department of Transportation, Bureau of Highways, January 1974 (Presented at the Annual Meeting of the Transportation Research Board, January 1974).

APPENDIX A

SPECIAL PROVISIONS

- No. 22-D, SAND ASPHALT SURFACE (TYPE I)**
- No. 59-D, SAND ASPHALT SURFACE (SKID RESISTANT) (TYPE II)**
- No. 109, OPEN-GRADED FRICTION COURSES (PLANT MIX SEALS)**

KENTUCKY DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. 22-D

SAND ASPHALT SURFACE
(Type I)

This Special Provision will apply to a project when indicated in the contract plans or proposal. Section and Article references herein are to the Bureau's 1965 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the construction of one course of hot-mixed, hot-laid Sand Asphalt Surface mixture upon a satisfactory foundation of either new or existing pavements. The thickness of the course shall be approximately $\frac{5}{8}$ -inch and the sand-asphalt mixture shall be laid at the approximate rate of 65 lbs./sq.yd. All leveling, wedging, and patching deemed necessary by the Engineer to repair an existing pavement so it will provide a smooth uniform satisfactory foundation shall be performed before the construction of this surface course is started.

This sand-asphalt mixture is intended to provide a thin fine-textured wearing surface produced from aggregates generally available from commercial sources.

II. MATERIALS

All materials for use in this work must be sampled, tested, and approved prior to starting production of the mixture.

The Contractor for the project shall stockpile aggregate at the plant site for sampling at least 1 week before starting plant operations. Either 500 tons or enough of the aggregate to supply one-half of the tonnage of mixture specified in the contract, whichever is least, shall be stockpiled.

A. The bituminous material for the tack coat shall conform to the requirements in the plans and proposal.

B. The asphalt cement for the surface mixture shall conform to the requirements in the plans and proposal.

C. The aggregate for the sand asphalt mixture shall contain either 50 percent SiO_2 or 50 percent crushed slag sand, or an approved combination of SiO_2 material and crushed slag sand. SiO_2 determination will be made in accordance with Kentucky Method 64-224. The remaining portion of the aggregate may consist of either natural sand, limestone sand, slag sand, or combinations thereof, except that not more than 25 percent of the total sand by weight shall be limestone sand. A maximum of 5 percent mineral filler may be incorporated into the sand in order for the sand to conform to the specified gradation. Each ingredient sand used, except mineral filler, shall have a minimum sand-equivalent value of 10 as determined by AASHTO T 176, and the total combined sand including mineral filler shall have a minimum sand-equivalent value of 35.

D. Mineral filler, if used, shall conform to the quality requirements of Article 611.5.0 and shall not be fly ash.

E. Silicone shall be of a type and source approved by the Engineer, and shall be furnished and used as directed by the Engineer.

III. CONSTRUCTION METHODS

Every requirement contained in Articles 306.3.1 through 306.3.10 that is applicable to this type of work shall be in force except as provided herein and in the plans and proposal.

The materials, equipment, and methods for leveling, wedging, and patching shall be those designated in the proposal. The leveling and wedging shall be constructed as specified in Article 306.3.8 and shall be constructed to within plus or minus $\frac{1}{4}$ inch of the desired elevation as determined by a stringline measurement or by a template. The Contractor shall furnish any templates in accordance with Article 306.3.2. The leveling, wedging, and patching operations are particularly significant to the satisfactory performance of this type of surface mixture, and every reasonable effort shall be made to provide a uniform, stable, and even surface as a foundation for this sand-asphalt course.

A. Tack Coat. When SS-1h is furnished for the tack coat, it shall be diluted with an equal amount of water conforming to Section 603 and thoroughly mixed prior to application. The diluted SS-1h shall be applied at the approximate rate of 0.1 gal./sq.yd. and a sufficient time and distance in advance of the paver to insure that all the water has escaped and evaporated before any of the surface mixture is laid on the tacked surface. The surface mixture shall not be laid on the tacked surface until authorized by the Engineer. When RC-250 is furnished for the tack coat, it shall be applied at an approximate rate of 0.1 gal./sq.yd. and a sufficient time and distance in advance of the paver to insure that the volatiles have evaporated before any of the surface mixture is laid on the tacked surface.

B. Weather Limitations. The surface mixture shall be laid only at times when all weather conditions are very favorable in the judgment of the Engineer, when the atmospheric temperature is above 60° F. and when the underlying pavement is dry and clean except for the tack coat.

C. Preparation of the Sand-Asphalt Mixture. The sand and asphalt cement shall be combined in the proportions established by the Engineer. The percentage by weight of asphalt cement in the mixture will be established between 6 and 10 percent. A job-mix formula within the specified gradation and asphalt content limits will be established by the Engineer for each project. Deviations from the established asphalt content shall not exceed 0.5 percent, and the fineness modulus of the aggregate shall not vary more than 0.2 from the value established by the job-mix formula. The gradation of the mixture by dry sieving shall be as follows:

<u>Sieve Size</u>	<u>Percent Passing</u>
1/4 inch	100
No. 8	75-100
No. 16	60-90
No. 30	45-75
No. 50	15-45
No. 100	5-15
No. 200	2-6

The mixture will be designed by the Engineer in accordance with the Marshall Density and Air voids criteria in Kentucky Method 64-411.

1. If the sand for the mixture is a blend of two or more materials, the materials shall be supplied from individual cold bins in the proportions established by the Engineer.
2. The temperatures of the materials and the mixture, in degrees Fahrenheit, shall be maintained within the following ranges:

	<u>Minimum</u>	<u>Maximum</u>
Sand	265	350
Asphalt Cement	275	325
Mixture at Plant*	265	325
Mixture when Laid	250	325

* The mixture shall be maintained within a range of $\pm 25^{\circ}$ F. from the temperature designated by the Engineer.

D. Insofar as practical, the paver shall be operated at a constant forward speed that will produce a smooth uniform mat free from tears, open areas, and other imperfections.

E. All intersections, approaches, entrances, aprons, mailbox turnouts, and other incidental areas that are to be surfaced as a part of the work shall be surfaced either before or after the laying of the sand-asphalt surface course on the mainline, so as not to detract from nor interfere with the paver operations in any manner while this course is being applied to the traffic lanes.

F. Tandem rollers weighing not less than 5 nor more than 8 tons shall be used for the compaction of the mixture and the surfacing of the incidental areas.

G. Vehicular traffic shall not be permitted to use the compacted mixture until it has cooled sufficiently to withstand the traffic within any damage. Intersections and any other areas which must be reopened to traffic soon after the mixture has been compacted shall be thoroughly sprayed with water so as to hasten the cooling of the compacted mixture to atmospheric temperature before it is subjected to traffic. Any adjacent areas to receive the sand-asphalt course which are wetted by the water shall be allowed to thoroughly dry before the course is laid.

IV. METHOD OF MEASUREMENT

The sand-asphalt mixture will be measured in tons in accordance with Article 1.9.1. The bituminous material for tack coat will be measured in gallons in accordance with Section 621.

V. BASIS OF PAYMENT

The accepted quantities of sand-asphalt mixture and bituminous material for tack coat will be paid for in accordance with Article 506.5.0 except that any silicone for the mixture and the water for diluting the SS-1h and for cooling the pavement will be considered as incidentals and will not be paid for separately.

APPROVED: 5-30-74


L. R. HARBISON
STATE HIGHWAY ENGINEER

KENTUCKY DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. 59-D

SAND ASPHALT SURFACE (SKID RESISTANT)
(Type II)

This Special Provision will apply to a project when indicated in the contract plans or proposal. Section and Article references herein are to the Bureau's 1965 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the construction of one course of hot-mixed, hot-laid sand-asphalt surface mixture upon a satisfactory foundation of either new or existing pavements. The thickness of the course shall be approximately 5/8 inch and the sand-asphalt mixture shall be laid at the approximate rate of 65 lbs./sq.yd. All leveling, wedging, and patching deemed necessary by the Engineer to repair an existing pavement so it will provide a smooth uniform satisfactory foundation shall be performed before the construction of this surface course is started.

This sand-asphalt mixture is intended to provide a fine-textured, skid-resistant, wearing surface for vehicular traffic. Special attention shall be given to all aspects of the work to insure that only top-quality materials, equipment, and workmanship are utilized at all times, and that the finish surface is in close conformity to the lines, grades, and sections indicated in the plans and/or proposal.

II. MATERIALS

All materials for use in this work must be sampled, tested, and approved prior to starting the production of the sand-asphalt mixture.

Since the angular high-silica sand permitted for this work is a select material, the Bureau, upon request by Contractors qualified to bid on the work, will test a reasonable number of source samples of sands furnished by the Contractors, for information purposes only, prior to the date of the opening of bids for the contract. However, tests of the actual sand subsequently stockpiled at the plant site by the Contractor for the project will be made to determine the acceptability of the sand for the work.

The Contractor for the project shall stockpile sand at the plant site for sampling at least 1 week before starting plant operations. Either 500 tons or enough of the sand to supply one-half of the tonnage of mixture specified in the contract, whichever is least, shall be stockpiled.

A. The bituminous material for the tack coat shall conform to the requirements in the plans and proposal.

B. The asphalt cement for the sand-asphalt mixture shall conform to the requirements in the plans and proposal.

C. The sand for the sand-asphalt mixture shall be either crushed slag sand or a select angular high-silica material containing at least 75 percent SiO₂. The SiO₂ determination will be made in accordance with Kentucky Method 64-224, and will be made on the portion of the sand retained on all sieves down to and including the No. 100 sieve, exclusive of any mineral filler in that portion. The SiO₂ sand shall preferably be the product of crushed siliceous material, but may be comprised either of natural materials or crushed materials, or a combination of both, provided that the gradation and angularity of the sand are consistently uniform and conform to the specified requirements.

The gradation of the sand by dry sieving shall be as follows:

Sieve Size	Percent Passing
1/4-inch	100
No. 8	60-90
No. 16	35-65
No. 30	20-45
No. 50	10-30
No. 100	3-20
No. 200	2-6

The mixture will be designed by the Engineer in accordance with the Marshall Density and Air voids criteria in Kentucky Method 64-411.

The angularity of the sand particles shall be such that the sand will have a voids content of 49 percent or more when subjected to the Dry-Bulking Test in accordance with Kentucky Method 64-609.

D. Mineral filler, if used, shall conform to the quality requirements of Article 611.5.0 and shall not be fly ash.

E. Silicone shall be of a type and source approved by the Engineer, and shall be furnished and used as directed by the Engineer.

F. An anti-stripping additive of a type and source approved by the Engineer shall be furnished by the Contractor and shall be used as directed by the Engineer to prevent stripping of the asphalt from the aggregate.

III. CONSTRUCTION METHODS

Every requirement contained in Articles 306.3.1 through 306.3.10 that is applicable to this type of work shall be in force except as provided herein and in the plans and proposal.

The materials, equipment, and methods for leveling, wedging, and patching shall be those designated in the proposal. The leveling and wedging shall be constructed as specified in Article 306.3.8 and shall be constructed to within plus or minus 1/4 inch of the desired elevation as determined by a stringline measurement or by a template. The Contractor shall furnish any templates in accordance with Article 306.3.2. The leveling, wedging, and patching operations are particularly significant to the satisfactory performance of this type of surface mixture, and every reasonable effort shall be made to provide a uniform, stable, and even surface as a foundation for this sand-asphalt course.

A. Tack Coat. When SS-1h is furnished for the tack coat, it shall be diluted with an equal amount of water conforming to Section 603 and thoroughly mixed prior to application. The diluted SS-1h shall be applied at an approximate rate of 0.1 gal./sq.yd. and a sufficient time and distance in advance of the paver to insure that all the water has escaped and evaporated before any of the mixture is laid on the tacked surface. The sand-asphalt mixture shall not be laid on the tacked surface until authorized by the Engineer. When RC-250 is furnished for the tack coat, it shall be applied at an approxi-

mate rate of 0.1 gal./sq.yd. and a sufficient time and distance in advance of the paver to insure that the volatiles have evaporated before any of the mixture is laid on the tacked surface.

B. Weather Limitations. The sand-asphalt mixture shall be laid only at times when all weather conditions are very favorable in the judgment of the Engineer, when the atmospheric temperature is above 60°F., and when the underlying pavement is dry and clean except for the tack coat.

C. Preparation of Sand-Asphalt Mixture. The sand-asphalt mixture shall be prepared by combining the approved sand with asphalt cement in the percentages established by the Engineer. The percentage by weight of asphalt cement in the mixture will be established between 6 to 10 percent. The gradation limits for the mixture are the same as those specified for the sand and the Engineer will establish a job-mix formula within the specified sand gradation and asphalt content limits. Deviations from the established asphalt content shall not exceed 0.5 percent, and the fineness modulus of the sand shall not vary more than 0.2 from the value established by the job-mix formula.

1. If the sand for the mixture is a blend of two or more materials, the materials shall be supplied from individual cold bins in the proportions established by the Engineer.
2. The temperatures of the materials and the mixture, in degrees Fahrenheit, shall be maintained within the following ranges :

	<u>Minimum</u>	<u>Maximum</u>
Sand	265	350
Asphalt Cement	275	325
Mixture at Plant*	265	325
Mixture when Laid	250	325

* The mixture shall be maintained within a range of $\pm 25^{\circ}$ F. from the temperature designated by the Engineer.

D. Insofar as practical, the paver shall be operated at a constant forward speed that will produce a smooth uniform mat free from tears, open areas, and other imperfections.

E. All intersections, approaches, entrances, aprons, mail-box turnouts, and other incidental areas that are to be surfaced as a part of the work shall be surfaced either before or after the laying of the sand-asphalt surface course on the mainline, so as not to detract from nor interfere with the paver operations in any manner while this course is being applied to the traffic lanes.

F. Tandem rollers weighing not less than 5 nor more than 8 tons shall be used for the compaction of the sand-asphalt surface mixture and the surfacing of the incidental areas.

G. Vehicular traffic shall not be permitted to use the compacted sand-asphalt mixture until it has cooled sufficiently to withstand the traffic without any damage. Intersections and any other areas which must be reopened to traffic soon after the sand-asphalt mixture has been compacted shall be thoroughly sprayed with water so as to hasten the cooling of the compacted mixture to atmospheric temperature before it is subjected to traffic. Any adjacent areas to receive the sand-asphalt course which are wetted by the water shall

be allowed to thoroughly dry before the sand-asphalt course is laid.

IV. METHOD OF MEASUREMENT

The sand-asphalt mixture will be measured in tons in accordance with Article 1.9.1. The bituminous material for tack coat will be measured in gallons in accordance with Section 621.

V. BASIS OF PAYMENT

The accepted quantities of sand-asphalt mixture and bituminous material for tack coat will be paid for in accordance with Article 306.5.0 except that any silicone for the mixture and the water for diluting the SS-1h and for cooling the pavement will be considered as incidentals and will not be paid for separately.

APPROVED 5-30-74


J. R. HARBISON
STATE HIGHWAY ENGINEER

**KENTUCKY DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. 109**

OPEN-GRADED FRICTION COURSES (PLANT MIX SEALS)

This Special Provision will apply when indicated in the contract plans or proposal. Article and Section references herein are to the Bureau's 1965 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This work shall consist of the construction of one course of hot-mixed, hot laid, open-graded surface mixture upon a satisfactory foundation provided by either new or existing pavements. The thickness of the course shall be approximately 3/4 inch. The leveling, wedging, and patching deemed necessary by the Engineer to repair an existing pavement shall be performed before the construction of this surface course is started.

This open-graded mixture is intended to provide a coarse-textured, well-draining, skid-resistant, wearing surface for vehicular traffic. Special attention shall be given to all aspects of the work to insure that only top-quality materials, equipment, and workmanship are utilized at all times and that the finished surface is in close conformity to the lines, grades, and sections indicated in the plans and/or proposal.

All materials for use in this work shall be sampled, tested, and approved prior to starting the production of the open-graded mixture.

Since the angular aggregate required for this work is a select material, the Bureau, upon request by Contractors qualified to bid on the work, will test a reasonable number of source samples of aggregates furnished by the Contractors, FOR INFORMATION PURPOSES ONLY, prior to the date of the opening of bids for the contract. However, tests of the actual aggregate subsequently stockpiled at the plant site by the Contractor for the project will be made to determine the acceptability of the aggregate for this work.

The Contractor for the project shall stockpile aggregate at the plant site for sampling at least two weeks before starting plant operations. Enough aggregate for one day's plant operation will be considered the minimum allowable quantity of aggregate necessary to be stockpiled in order that representative samples for testing may be obtained therefrom.

A. Aggregate. Except for mineral filler, aggregate for this mixture shall be either lightweight aggregate, crushed slag, or crushed gravel.

Lightweight aggregate shall have a maximum compact unit weight of 65 pounds per cubic foot when tested by Kentucky Method 64-613. Lightweight aggregate shall also conform to the following requirements when tested by the indicated Kentucky Methods.

	<u>Max. Pct. by Wt.</u>
Friable Particles (Ky 64-611)	1.0
Wear (Ky 64-614)	40
Loss after 5 cycles of Sodium Sulfate Soundness Test (Ky 64-610)	12

Crushed slag shall conform to the applicable requirements of the current edition of Special Provision No. 102.

Crushed gravel shall conform to the applicable requirements of the current edition of Special Provision No. 102, except that the gravel shall be a 100% crushed product with at least 95% having one or more fractured faces and at least 75% having two or more fractured faces when tested by Kentucky Method 64-603, and shall have a minimum silica (SiO₂) content of 75% as determined by Kentucky Method 64-224.

Crushed limestone will not be permitted as any part of the aggregate for the open-graded mixture, except as mineral filler.

The gradation of the aggregate, including mineral filler when used, shall conform to the following requirements for either Type 1 or Type 2 when tested by Kentucky Method 64-406. Prior to the start of construction, the Contractor shall designate in writing which gradation he elects to furnish. He shall also submit aggregate samples and a proposed job-mix formula consisting of a single value for the percent passing each sieve. During the operation of the plant, tolerances from the approved job-mix formula will be permitted as indicated in the following table, except that the gradation shall be within the master gradation at all times.

Sieve Size	Master Gradation Range		Job-Mix Formula Tolerances
	Percent Passing		
	<u>Type 1</u>	<u>Type 2</u>	
1/2 in.	100	----	
3/8 in.	90-100	100	*
No. 4	25-50	50-100	±6%
No. 8	5-15	10-30	±4% **
No. 16	----	5-15	*
No. 200	2-5	2-5	*

* Master gradation range applies.
** (Type 2 only)

The angularity of the aggregate particles for the Type 2 gradation shall be such that the aggregate will have a voids content of 48% or more when subjected to the Dry-Bulking Test in accordance with Kentucky Method 64-609.

B. Mineral filler, if used, shall conform to the quality requirements of Article 611.5.0.

C. The bituminous material for the tack coat may be either SS-1h conforming to AASHO M 140 except the maximum penetration may be 100, RC-250 conforming to AASHTO M 81, or other materials approved by the Engineer.

D. The asphalt cement for the open-graded mixture shall be AC-20 conforming to the requirements of AASHO M 226.

E. Silicone shall be furnished by the Contractor and blended into the asphalt cement when and as directed by the Engineer. The silicone shall be of a type and from a source approved by the Engineer.

F. An anti-stripping additive of a type and source approved by the Engineer shall be furnished by the Contractor and shall be used as directed by the Engineer to prevent stripping of the asphalt from the aggregate.

III. CONSTRUCTION METHODS

Every requirement contained in Articles 306.3.1 thru 306.3.10 which is applicable to this type of work shall be in force except as provided herein and in the plans and proposal.

The materials, equipment, and methods for leveling, wedging, and patching shall be those designated in the proposal. The leveling and wedging shall be constructed as specified in Article 306.3.8 and shall be constructed to within plus or minus 1/4 inch of the desired elevation as determined by a stringline measurement or by a template. The Contractor shall furnish any templates in accordance with

Article 306.3.2. The leveling, wedging, and patching operations are particularly significant to the satisfactory performance of this type of surface mixture and every reasonable effort shall be made to provide a uniform, stable, dense, and even surface as the foundation for this open-graded course.

This open-graded course should always be constructed higher in elevation than the shoulders and gutters in order to provide for proper lateral drainage of water through the course.

A. Tack Coat. When SS-1h is furnished for the tack coat, it shall be diluted with an equal volume of water conforming to Section 603 and thoroughly mixed prior to application. The diluted SS-1h shall be applied at an approximate rate of 0.2 gallon per square yard in one or more applications for a sufficient time and distance in advance of the paver to insure that all of the water has escaped and evaporated before any of the open-graded mixture is laid on the tacked surface. When RC-250 is furnished for the tack coat, it shall be applied at an approximate rate of 0.1 gallon per square yard and for a sufficient time and distance in advance of the paver to insure that the volatiles have evaporated before any of the open-graded mixture is laid on the tacked surface. The open-graded mixture shall not be laid on the tacked surface until authorized by the Engineer.

When other tack coat materials are approved by the Engineer, they shall be applied as directed by the Engineer.

B. Seasonal and Weather Limitations. The mixture shall be placed only when the pavement surface is clean and dry and when the pavement surface temperature is 50° F or greater. The air temperature shall be at least 50° F and rising. No seasonal limitations will apply.

C. Preparation of Open-Graded Mixture. The mixture shall be prepared by combining the approved aggregate with asphalt cement in the percentages established by the Engineer. The percentage by weight of asphalt cement in the mixture will be established between 5.5 and 8.5 percent of the total mixture when either crushed slag or crushed gravel is the aggregate used, and between 9.0 and 15.0 percent when lightweight aggregate is used. The gradation limits for the mixture are the same as those specified for the aggregate and the Engineer will approve a job-mix formula within the specified aggregate gradation and asphalt cement limits. Deviations from the established asphalt content shall not exceed 0.4 percent when the mixture is tested by Kentucky Method 64-405.

When the total aggregate for the mixture is a blend of two or more materials, the materials shall be supplied from individual cold bins or stockpiles in the proportions required to meet the specified gradation and voids content.

The temperatures of the materials and the mixture, in degrees Fahrenheit, shall be carefully maintained within the following ranges:

	Temperature	
	Minimum	Maximum
Aggregate	200	260
Asphalt Cement	250	300
Mixture at Plant	200	260
Mixture when Laying	180	260

Temperatures higher than those listed can cause the asphalt cement to drain from the mixture and should be avoided at all times.

D. Paving. The spreading of the open-graded mixture to provide the specified thickness of approximately 3/4 inch shall be at the following rates, depending upon the type of the aggregate used for the mixture.

Crushed Gravel or Slag Aggregate	70 lb./sq.yd.
Lightweight Aggregate	45 lb./sq.yd.

Insofar as practical, the paver shall be operated at a constant forward speed which will produce a smooth uniform mat free from tears, open areas, and other imperfections. Any hand raking of the mixture should be kept to the absolute minimum.

E. Rolling. Normal equipment for placing and compaction will be required except that rolling shall be accomplished by means of an 8 to 10 ton steel-wheel tandem roller. The amount of rolling shall be confined to only the minimum necessary for consolidating the bituminous mixture and bonding it to the underlying surface. Excessive rolling shall be avoided.

IV. METHOD OF MEASUREMENT

The open-graded mixture will be measured in tons and the bituminous material for tack coat will be measured in gallons in accordance with Article 306.4.0.

V. BASIS OF PAYMENT

The accepted quantities of open-graded mixture and bituminous material for tack coat will be paid for in accordance with Article 306.5.0 except that the silicone and anti-stripping additives for the mixture and water used for diluting the SS-1h will be considered as incidentals and will not be paid for separately.

APPROVED

5-13-74



J. R. HARBISON
STATE HIGHWAY ENGINEER

APPENDIX B

**SPECIAL NOTES FOR TRANSVERSE GROOVING
PLASTIC CEMENT CONCRETE PAVEMENT**

**SPECIAL NOTES FOR
TRANSVERSE GROOVING OF PLASTIC
CEMENT CONCRETE PAVEMENT**

Contrary to Article 307.3.10-F, final finish with a burlap drag will not be required for the cement concrete pavement constructed in accordance with these Special Notes.

The final finish for the cement concrete pavement shall be a transverse grooved finish which is accomplished by mechanized equipment using either a vibration beam roller or a comb made with steel tines, or other approved device. The grooves shall be formed in the plastic concrete at an appropriate time during the stiffening of the concrete, so that in the hardened concrete, the grooves will be between 0.09 to 0.13 inch in width, between 0.12 to 0.19 in depth, and be spaced at intervals between 0.5 and 1.0 inch. The grooves shall be relatively smooth and uniform in all aspects, and shall be formed without tearing the surface and without bringing pieces of the coarse aggregate to the top of the surface.

The transverse grooves shall be formed within the above specified size limits so that a minimum average texture depth of 0.030 inch is provided when determined by the Bureau's current Sand Patch Method. Any area of pavement which exhibits a value of less than 0.025 inch shall be check tested as necessary to determine the extent of the area. If check tests confirm that the size of the area with the low reading is 200 square yards or larger, then the area will be considered deficient and require corrective work as hereinafter specified.

Manual tools such as fluted floats or rakes with spring steel tines may be used for forming the transverse grooves in areas such as ramps, connections, and other miscellaneous sites where the mechanized grooving equipment cannot be utilized. Careful attention shall be given to the manual workmanship in order to achieve grooves which conform to the same requirements as those specified for the grooves formed by the mechanized equipment.

Areas of the hardened grooved pavement which do not conform to these requirements, either because of a deficiency in the grooving or because of a rough or open texture of the surface, shall be corrected by the cutting of acceptable grooves in the hardened pavement with an approved mechanical grinder or cutting machine.

No direct payment will be made for the work required by these Special Notes, as all costs related to the acceptable transverse grooving of the pavement will be considered incidental to the contract unit price per square yard for Cement Concrete Pavement.