

March 22, 1974

H-2-66

MEMO TO: Calvin G. Grayson
Assistant State Highway Engineer

FROM: Jas. H. Havens *J. H. Havens*
Director of Research

SUBJECT: Proposed Specifications for Sand-Asphalt and
Open-Graded, Plant-Mix Seals.

At a meeting of the State Highway Engineer's staff, November 2, 1973 (cf. Research memo, November 13, 1973), Materials, Specifications and Research were assigned the development of specifications to carry forward a deliberate, surfacing program leading to the qualification of and standardization of skid-resistant, pavement surfaces. The task force mutually agreed upon a plan February 15, 1973. This submittal includes proposed specifications and recommendations toward implementation.

Two special provisions are proposed, as follows:

1. "Open-Graded Friction Courses (Plant Mix Seals)"
2. "Sand-Asphalt Surfaces"

The one 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 test late last year and are yielding very high skid-test results.

The "Sand-Asphalt" specification is very encompassing and may be used to supplant S.P. 59-C, S.P. 22-C and any others which have not been retired. It provides four types and(or) grades of sands and commensurate (presumably) levels of skid resistance. It preserves the use of common sands where high

skid-resistance is not required. Types 1 and 2 are patterned after S.P. 22-C and S.P. 59-C. They are intended to be dense, stable, durable surfaces; Type 2 is similar to the mixture placed on US 31-W, from West Point to Ky. 1638 in 1972 and 1973. Type 1 would be limited to low-traffic streets and roads. Type 2 is suitable for heavy traffic where the speed limit is 60 mph or less. Type 3 represents an attempt to utilize ultra-fine sands not allowed in Type 4. Types 3 and 4 are open-graded. The gradations for Types 3 and 4 are obtained, conceptually speaking, by splitting the gradation for Type 2 sand at the No. 30 sieve (could be physically accomplished in a wet classifier). The two fractions differ in particle size only; and mixtures made with each fraction should be similar in terms of voids and particle shape. This has been accomplished in the laboratory; however, we were unable to obtain high stabilities with the crushed conglomerate sands in the ultra-fine sizes. High stabilities were achieved by blending the fine quartz sands with fine slag and with other fine sands and fillers. Summarily, Type 3 would require about the same asphalt content as Type 4. We do not know how well it would perform on roads and streets. Second and Shelby Streets in Frankfort (1966) were composed principally of very fine sand.

The so-called "open-grading" is achieved by shortening an otherwise dense gradation. The two gradations in "Open-Graded Friction Courses...", together with Types 4 and 3 in "Sand-Asphalt..." provide a spectrum of four size ranges. We need to know the performance characteristics of each. However, we are recommending only Type 4 Sand-Asphalt for trials on high-speed, heavy-traffic roads.

For the first time, we have included stability requirements in the specifications. The purpose is twofold: 1) to provide assurances against scaling, and 2) to assure that materials supplied have those qualities which produce stable mixtures. In effect, this type of requirement is an extension of the so-called job-mix formula to meet design and end-product requirements for the mixtures.

The draft specification for "Open-Graded, Friction Courses (Plant Mix Seals)" was distributed by the Specifications staff, March 21, 1974. In order to unitize this package, a copy thereof and the cover memorandum is included herewith. This is the first attachment.

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The second attachment is the proposed specification for sand-asphalts.

The third attachment is a short treatise on porous (open-graded) sand-asphalts; it was prepared by request for presentation at the HRB meeting last January but was not offered for publication. Its more singular purpose was to accompany this submittal and to further explain porous sand-asphalts and the specifications now proposed.

The fourth attachment is a list of projects now pending or being considered for resurfacing and suggested surface types in terms of the proposed specifications.

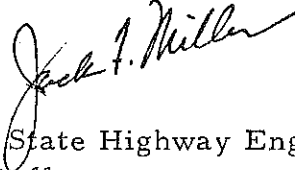
JHH:gd

Attachments

CC's: J. R. Harbison
Calvin Grayson
J. T. Anderson
G. F. Kemper
J. W. Spurrier
J. D. Witt
C. G. Cook
E. B. Gaither
C. S. Layson
J. E. McChord
A. R. Romine

MEMO

TO: J. T. Anderson
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J. H. Havens
C. S. Layson
J. E. McChord
A. R. Romine

FROM: Jack F. Miller 
Assistant to the State Highway Engineer
Specifications Staff

DATE: March 21, 1974

SUBJECT: Draft of Special Provision for
Open-Graded Friction Courses (Plant Mix Seals)

In compliance with a directive issued at the November 13, 1973 staff meeting, to the Divisions of Materials and Research and the Specifications Staff, the subject draft has been prepared and is being submitted for consideration and comments. This draft has been prepared so as to incorporate the best information available from other states and F.H.W.A. in a context compatible with Kentucky's potential aggregate sources and with our present testing procedures for angularity.

Further input from each of your offices will be appreciated.

Drafts of separate specifications for other sand-asphalt-type friction courses have also been prepared and will be submitted by Mr. Havens in the near future.

JFM:eq
Attachment

cc: J. R. Harbison

KENTUCKY BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. _____

OPEN-GRADED FRICTION COURSES (PLANT MIX SEALS)

This Special Provision shall be applicable when indicated in the plans or proposal and shall supersede any conflicting requirements of the Bureau's 1965 Standard Specifications for Road and Bridge Construction. Section and Article references herein are to the Standard Specifications.

I. DESCRIPTION

This work shall consist of constructing one course of hot-mixed, hot laid, open-graded surface mixture upon a satisfactory foundation of either new or existing pavements. The thickness of the course shall be nominally 3/4 inch thickness, or as specified on the plans and/or proposal. All 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.

II. MATERIALS

All materials for use in this work must 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 INFORMATIONAL 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 who is the successful bidder will be made to determine the acceptability of the aggregate for the work.

The contractor for the work 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 shall be considered the minimum allowable amount of aggregate necessary to be stockpiled in order that representative samples for testing may be taken therefrom.

A/ Aggregate. Except for mineral filler, aggregate for this mixture shall be crushed slag, meeting the quality requirements of Special Provision No. 102, or crushed gravel meeting the requirements of Special Provision No. 102 except that:

1. Percent Crushed - The gravel shall be a 100% crushed product with at least 95% having one or more crushed faces and at least 75% having two or more crushed faces when tested by Kentucky Method 64-603. This requirement is considered satisfied when the gravel is crushed from material of 3/4 inch sieve size or greater.

2. Silica Content - The gravel shall have a minimum silica (SiO₂) content of 75% as determined by Kentucky Method 64-224.

Crushed limestone shall not be permitted in this mixture. The Contractor may request approval for other types of aggregate. Other aggregates shall have a proven record of satisfactory friction properties acceptable to the Department and shall meet the quality requirements of the aggregates listed in Special Provision No. 102 for general uses. When lightweight aggregates are approved, the application rate and asphalt percentage shall be adjusted to achieve the approximate volume percentages used in the slag or crushed gravel mixes.

The gradation of the aggregate, including mineral filler when used, shall meet either the Type 1 or Type 2 grading when tested by Kentucky Method 64-606. Prior the start of construction, the Contractor shall specify in writing to the Engineer which grading (Type 1 or Type 2) he elects to use. He shall also submit aggregate samples and a job-mix formula consisting of a single value for percent passing on each sieve. Tolerances from the approved job-mix formula but within the master gradation range shall apply to all mixtures provided, as indicated in the table below.

<u>SIEVE SIZE</u>	<u>MASTER GRADATION RANGE</u>		<u>JOB-MIX FORMULA TOLERANCES</u>
	<u>PERCENT PASSING</u>		
	<u>Type 1</u>	<u>Type 2</u>	
1/2	100		
3/8	90-100	100	*
No. 4	25-50	50-100	+6%
No. 8	3-15	10-30	+4%
No. 16	-----	5-15	*
No. 200	2-5	2-5	*

*Master range applies

The angularity of the aggregate particles shall be such that the aggregate will have a voids content of 49% or more when subjected to the Dry-Bulking Test in accordance with Kentucky Test 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 SS-1h conforming to AASHO M 140 except the maximum penetration may be 100, RC-250 conforming to AASHO M 81, or other materials approved by the Engineer.

D/ Unless otherwise specified in the plans or on the proposal, the asphalt cement for the open-graded mixture shall be AC-20 conforming to the requirements of AASHO M 226.

E/ When required by the Engineer, Silicone shall be furnished by the Contractor and blended into the asphalt cement 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 when necessary 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 on the 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 closed even surface as a foundation for this open-graded course.

If paved shoulders are used, or if there are curb and gutter sections on the project, the open-graded mix should be higher than the shoulder or the gutter to provide the proper drainage of the mix.

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 0.2 gallon per square yard in one or more applications and with a sufficient amount of time and distance allowed in advance of the paver to insure that all of the water has escaped and evaporated before any of the 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 with a sufficient time and distance allowance in advance of the paver to insure that the volatiles have evaporated before any of the 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 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 shall 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. 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 content limits. Deviations from the established asphalt content shall not exceed 0.4 percent when the mixture is tested by Kentucky Method 64-405.

1. If the 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 gradation and voids content specified herein.

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>
Aggregate	200	260
Asphalt Cement	250	300
Mixture at Plant	200	260
Mixture when Laying	180	260

D/ Paving. 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. Any raking done should be kept to the absolute minimum.

E/ Rolling. Normal equipment for placing and compaction will apply except that rolling shall be accomplished by means of a 8-10 ton steel-wheel tandem roller. The amount of rolling shall be confined to only that 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 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 open-graded mixture and bituminous material for tack coat will be paid for in accordance with Article 306.5.0 except that any silicone or antistripping additive for the mixture and any water used for diluting the SS-1h will be considered as incidentals and will not be paid for separately.

Approved _____

J. R. HARBISON
STATE HIGHWAY ENGINEER

SAND-ASPHALT SURFACES

This Special Provision shall be applicable when indicated in the plans or proposal, and shall supersede any conflicting requirements of the Department's 1965 Standard Specifications for Road and Bridge Construction. Section and Article references herein are to the Standard Specifications.

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 3/4 inch. All leveling, wedging and patching deemed necessary by the Engineer to repair an existing pavement so it will provide a smooth, uniform and satisfactory foundation shall be performed before construction of this surface course is started.

These sand-asphalt mixtures are intended to provide fine-textured, skid-resistant, wearing surfaces for vehicular traffic. Special attention shall be given to all aspects of the work to insure that only high quality materials, equipment, and workmanship are utilized at all times and that the finished surface is in conformity to the lines, grades, and sections indicated in the plans and/or proposal. These sand-asphalt mixtures are designated as follows:

Type 1 - dense-graded, for general use,

Type 2 - dense-graded, skid resistant; for moderate-speed traffic,

SAND-ASPHALT SURFACES

This Special Provision shall be applicable when indicated in the plans or proposal, and shall supersede any conflicting requirements of the Department's 1965 Standard Specifications for Road and Bridge Construction. Section and Article references herein are to the Standard Specifications.

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 3/4 inch. All leveling, wedging and patching deemed necessary by the Engineer to repair an existing pavement so it will provide a smooth, uniform and satisfactory foundation shall be performed before construction of this surface course is started.

These sand-asphalt mixtures are intended to provide fine-textured, skid-resistant, wearing surfaces for vehicular traffic. Special attention shall be given to all aspects of the work to insure that only high quality materials, equipment, and workmanship are utilized at all times and that the finished surface is in conformity to the lines, grades, and sections indicated in the plans and/or proposal. These sand-asphalt mixtures are designated as follows:

Type 1 - dense-graded, for general use,

Type 2 - dense-graded, skid resistant; for moderate-speed traffic,

SAND-ASPHALT SURFACES

This Special Provision shall be applicable when indicated in the plans or proposal, and shall supersede any conflicting requirements of the Department's 1965 Standard Specifications for Road and Bridge Construction. Section and Article references herein are to the Standard Specifications.

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 3/4 inch. All leveling, wedging and patching deemed necessary by the Engineer to repair an existing pavement so it will provide a smooth, uniform and satisfactory foundation shall be performed before construction of this surface course is started.

These sand-asphalt mixtures are intended to provide fine-textured, skid-resistant, wearing surfaces for vehicular traffic. Special attention shall be given to all aspects of the work to insure that only high quality materials, equipment, and workmanship are utilized at all times and that the finished surface is in conformity to the lines, grades, and sections indicated in the plans and/or proposal. These sand-asphalt mixtures are designated as follows:

Type 1 - dense-graded, for general use,

Type 2 - dense-graded, skid resistant; for moderate-speed traffic,

Type 3 - open-graded; skid resistant; intended for moderate traffic.

Type 4 - open-graded; skid resistant; intended for high speed, heavy traffic.

The type or types shall be designated on the plans or proposals.

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.

The Contractor for the work shall stockpile sand at the plant site for sampling at least 2 weeks before starting plant operations.

A sufficient quantity of sand to supply one day's plant operation shall be considered allowable stockpile to obtain test samples.

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. Since the angular sand 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 sand furnished by the Contractors, for informational 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 who is the successful bidder will be made to determine the acceptability of the sand for the work. The sand for the sand-asphalt mixture shall be obtained

from natural, processed, or crushed materials in whatever combinations that may be practical. The sand may consist of either quartz sand, natural sand, slag sand, ceramic sand, or combinations thereof. The combined carbonates (expressed as calcium carbonate equivalent; Ky. Test Method No. ___) for sands used in Type 1 mixtures shall not exceed 40 percent; carbonates in Type 2 sand shall not exceed 25 percent; carbonates in Type 3 and Type 4 sands shall not exceed 15 percent.

The maximum quantity of mineral filler which may be incorporated into the sand in order for the sand to conform to the specified gradation is 5 percent for Type 1 and 2 and 15 percent for Types 3 and 4. Each ingredient sand used, except mineral filler, shall have a Sand-Equivalent value of not less than 10; the blend, including mineral filler, shall have a Sand-Equivalent value of not less than 25. Deleterious substances retained on the No. 200 sieve shall not exceed the following percentages by weight of the total combined sand mixture:

	<u>Percent by Weight</u>
Clay lumps	None
Other deleterious substance such as, but not limited to, alkali, mica, shale, coated grains, soft and flaky particles	1.0

The angularity of the sand particles for use in Type 2, 3, or 4 mixtures 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 Test 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. A heat-stable, anti-stripping additive of a type and source approved by the Engineer shall be furnished, when necessary, by the Contractor and shall be 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 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. for Type 1 and 2 mixes and 0.2 gal./sq. yd. in two or more applications for Type 3 and 4 mixes. Sufficient time shall be allowed to insure that all the water has evaporated before the mixture is placed 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 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 mixture is laid on the tacked surface.

B. Seasonal and Weather Limitations. The sand-asphalt mixtures 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 clean and dry 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. A job-mix formula, determined by the Marshall Design Method, 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 finess modulus of the sand 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:

PERCENT PASSING

SIEVE SIZE	<u>Type 1 or 2</u>	<u>Type 3</u>	<u>Type 4</u>
1/4 inch	100	----	----
No. 4	---	----	----
No. 8	75-100	----	100
No. 16	60-95	----	40-65
No. 30	45-90	100	10-40
No. 50	20-65	40-65	----
No. 100	3-20	25-35	----
No. 200	2-6	5-15	5-15

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 mixtures shall be maintained within the following ranges:

Sand	265-375 ^o F
Asphalt Cement	275-350 ^o F
Mixture at Plant	265-350 ^o F
Mixture when Placed	250-350 ^o F

Marshall Design Method criteria are as follows:

Mixture	Minimum Stability(lb)	Air Voids (%)
Type 1	300	3-9
Type 2	600	3-9
Type 3	400	9-18
Type 4	1000	9-18

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 sand-asphalt 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, and/or anti-stripping additive 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.

Research Report
385

POROUS SAND-ASPHALT MIXTURES

by

Jas. H. Havens, Director of Research

BUREAU OF HIGHWAYS

Kentucky Department of Transportation

prepared for

Session 47, Sponsored by Committee A2D05

Program

on

Skid-Resistance - Corrective Measures using
Bituminous Surfaces

53rd Annual Meeting, Highway Research Board
Sheraton-Park Hotel
Washington, D. C.
January 24, 1974

ABSTRACT

Size is relative. Densely graded sand-asphalts are relatively similar to conventional, bituminous concretes. Porous sand-asphalts possess the same attributes as other porous, bituminous mixtures. Surely, sand-asphalt mixtures, can be designed to be as porous as the so-called, open-graded plantmix seals. Particle shape and texture otherwise define skid-resistance. Stability remains an assurance against scaling. Stability is assured by maximum utilization of filler-bitumen ratio and the stiffness of asphalt cement.

INTRODUCTION

Whereas others seem to have forsaken sand-asphalts in their compelling search for skid-resistant pavement surfaces, the basic principles of the relativity of particle size and packing remain as applicable to sand sizes as they are to pebble sizes. It is still possible to grade sands or silts to obtain a desired porosity. One merely shortens the gradation.

Suppose for instance, that a relatively short-graded sand with sufficient asphalt in it to prevent bulking compacts to 33 percent VMA. Suppose, also, that 15 percent voids in the final mixture is desired. For a trial mixture, one might use 13 percent asphalt cement and 5 percent mineral filler (both by volume). For 2.64-sp.g. sand, this would yield about 6.5 percent asphalt by weight. The proportions of asphalt-to-filler may be adjusted to obtain maximum stability. Stability is necessary to prevent scaling and stripping.

Sands occur in great abundance in many localities throughout the country. Not all sands are skid resistant. Shape and texture of particles are important attributes. Shape is discernible macro- and microscopically. The Goldbeck (1) bulking test is an empirical measure of order, or conversely, a measure of disorder of shape.

Perhaps the most unique feature of sand mixtures, one which has not yet been fully explored and developed, is the strong capillarity and wicking forces which may be achieved and made useful. Whereas drainage of larger, porous mixtures must depend on gravity flow, porous sand mixtures definitely blot and wick -- and may, possibly and hopefully, be designed to siphon.

Indeed, the objectives are: 1) to clear standing water from the pavement as quickly as possible, 2) minimize hydroplaning, and 3) avoid polished or polishing aggregate particles which can be lubricated by residual films of water. Field tests remain the final proof of success; however, one should retain a intuitive and scientific skepticism toward standard methods of test, such as those now used to measure skid resistance.

RESEARCH AND DEVELOPMENT

From the early 1900's, Kentucky Rock Asphalt was much admired and respected for its skid-resistant qualities. It was basically a porous sand-asphalt. The VMA ranged between 28 and 35 percent. Total voids ranged between 12 and 16 percent. It had an unforgivable weakness; it often scaled or delaminated.

The mixture had very low stability when fresh. However, a study (2) in 1955 showed an average life-expectancy of 17.29 years.

Elsewhere, sand(sheet)-asphalts were used as low-cost surfacing in areas where sands were abundant. Pavement structures consisted of one or more courses of sand-asphalt or macadam base and perhaps two inches of sand(sheet) surface. Richardson (3) apparently sought angular, sharp, silica sands as early as 1896. Nicholson (4) published photomicrographs of prominent sands in 1926. A dilemma which yet persists in some degree was expressed by Gage (5) in 1926; his context is quoted:

A natural rock asphalt mixture seldom contains much over seven per cent of asphalt, yet we are all familiar with what would happen to a sheet asphalt mixture that only contains eight per cent of asphalt. I do not think there is much doubt about the durability of some rock asphalt mixtures that do not contain much over seven per cent of bitumen yet there is a grave doubt about the durability of the average sheet asphalt pavement that does not contain more than ten per cent of bitumen. The stability of a sheet asphalt mixture containing eight and one-half or nine per cent of bitumen may be greater than one containing eleven per cent, yet the durability of one will certainly exceed that of the other.

Gage (idem) apparently was recognizing not only the need for adequate stability but also the prerequisite need for coating thickness. A dense sand-asphalt having 10 percent asphalt and a unit weight of 136.67 lbs. contains 1.58 times more asphalt per cubic foot than an open-graded mixture having 7.5 percent asphalt and a unit weight of 115.68 lbs. The percentages by weight of aggregate would be 11.11 and 8.11, respectively. The ratio of the aggregate weights is 1.15:1. Surely, the ratio of the specific surface areas would be greater but not 1.58 times greater. Indeed, it appears that there has been a tendency in the past to starve rock asphalts and other sand mixtures of their due portion of asphalt or asphalt and filler. The filler-bitumen ratio (6) appears to have been neglected, and stabilities have not been maximized. Scaling and stripping have resulted. Stabilities increase with: 1) increasing angularity and texture of the sand, 2) increasing stiffness of asphalt and 3) increasing filler-bitumen ratio to optimum. Anti-stripping agents provide precautionary assurances against loss of stability in water.

The first generation of sand-asphalts in Kentucky were designed to be very dense and very stable. They did not scale; but they weren't exceptionally skid resistant; the shape of the sand was not controlled. It seemed necessary to prove that they could be designed to endure and to be as reliable in all respects as high quality, bituminous concrete.

Open-graded sand-asphalts compounded to simulate Kentucky Rock Asphalt were first subjected to road trials in 1968 (7). Sand was selected visually and, by comparison, was judged to be similar to but not quite equal to Kentucky Rock Asphalt sand. Without filler material, the surfaces scaled; with filler material, they did not. About 2 percent filler increased the stabilities from 40 to 80. Incidentally, stabilities in the range of 500 to 1200 (Marshall) are thought to be necessary to withstand very high volumes of traffic. A simulated Kentucky Rock Asphalt has now equaled and slightly exceeded the Rock Asphalt in skid resistance.

A crushed quartz conglomerate sand in a densely graded sand-asphalt constructed in 1972 and '73 compares favorably in skid-resistance with a crushed quartz conglomerate in an open-graded plantmix

seal constructed in 1973 on an abutting section of the same road.

Now, it is apparent that the shape and texture qualities sought in sands for sand-asphalts are converse to those sought for portland cement concrete and mortar sands. River sands, glacial sands, especially glacial outwash sands, and beach and blow sands tend to be rounded, frosted, and polished. Many sandstones and conglomerates yield sharp, angular sands. Crushed, manufactured, non-carbonate sands, altogether or blended with qualifying natural sand fractions may provide new opportunities to utilize local resources and indigenous material to achieve skid-resistant pavement surfaces. Controlled wear and attrition are essential. The surface, therefore, becomes sacrificial but renewable.

Scaling

Scaling, illustrated in Fig. 1, is attributed to a deficiency in the design of the mixture--that is, instability. Usually, such mixtures are deficient in asphalt and (or) filler. Failures are accompanied by stripping of asphalt from the sand particles. Coatings are thin, and asphalt menisci are not well formed at the inter-particle contacts. Persisting water or continual wetness in conjunction with loading accelerates scaling (8). Hard asphalts improve stability, minimize sponginess, and are more resistant to stripping. Anti-stripping agents may be needed with some aggregates. Kentucky Rock Asphalt surfaces showing good durable performance contained asphalt binders (after 15 years or so in service) having penetrations of about 15. No sand-asphalt or Rock Asphalt having stabilities (Marshall) of as much as 400 has scaled.



Fig. 1: Early Scaling of Sand-asphalt having Low Stability and Insufficient Asphalt.

TECHNOLOGY

Sand is defined as aggregate passing the No. 4 or No. 8 sieve. Historically, there have been two generic types of sand-asphalt surfacing mixtures: Sand-asphalts and Sand Sheet-Asphalts. Sand-Asphalts have generally been long-graded sands containing 4-14 percent passing the No. 200 sieve and 7 to 11 percent asphalt. Sheet-Asphalts have generally been finer -- containing as much as 98 percent passing the No. 16 sieve, 8 to 16 percent passing the No. 100, and 7.5 to 12 percent asphalt. The latter is merely a fine-sand mixture. A purposeful effort to open-grade and sand mixtures began in 1968 (7).

Aggregate Shape

A cubic packing of uniform spheres, regardless of size, contains 47.64 percent voids (9) (10). The rhombohedral or dense packing contains 25.95 percent voids. Although the isolation of a standard sieve series size of material provides a mixture of sizes in which the smallest particles are half the diameter of the largest, there is a high probability that a random arrangement and distribution of spherical particles in the size range will yield about 41 percent voids. Goldbeck (1) suggested a test in which the excess bulking was to be avoided in order to assure good concrete-making qualities of fine aggregates. Tests on concrete have indicated an upper limit of about 47 percent. Kentucky has used this type of requirement in its specification for crushed limestone fine aggregate for concrete for several years. Clearly, a size fraction yielding 50 percent or more voids indicates greater disorder -- that is: in shape, texture and(or) cohesion.

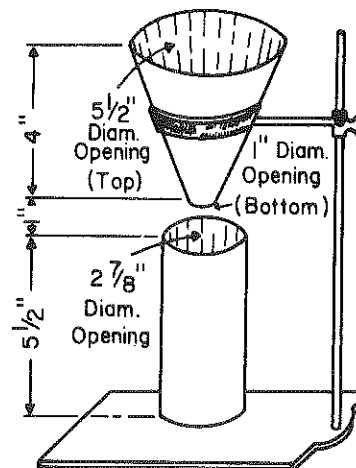
The test procedure follows:

Particle shape and texture of each sand shall be so controlled that, when subjected to the dry-bulking test, the volume of voids shall be 50 percent or greater. The dry-bulking test shall be used as a source control test and thereafter shall be conducted as often as deemed necessary by the Engineer. The specified procedure follows:

1. Balance -- a balance having a capacity of 1500 grams and a sensitivity of 0.1 gram.
2. Drying Pans -- at least 1500-gram capacity, suitable for drying samples.
3. Cylindrical Cup -- a rigid, cylindrical cup having an inside diameter of 2-7/8 inches and a height of 5-1/2 inches.
4. Funnel -- a truncated, hollow, metal cone, having an overall height of 4 inches and an inside diameter of 5-1/2 inches for the large opening and 1 inch for the small opening (as shown in the sketch).
5. Sieves -- the following sizes are required: No. 4, No. 8, No. 16, No. 30, and No. 50.
6. Steel Straightedge -- 1" x 6" x 1/16" (typical).

The sample of aggregate shall be washed thoroughly, dried to constant weight at 105° to 110°C (221° to 230°F), and separated into the following 4 sizes:

	PASSING	RETAINED
1.	No. 4	No. 8
2.	No. 8	No. 16
3.	No. 16	No. 30
4.	No. 30	No. 50



Approximately 1500 grams of each of the above sizes shall be required for the tests.

The test shall be conducted on only the specified size fractions having 5 percent or more of the aggregate by weight contained in the given specified size fraction.

A size of the aggregate shall be poured into the funnel while a stiff piece of metal is held against the bottom opening. The funnel shall be filled until the material is heaped between 1 and 2 inches above its top level; care shall be taken not to overflow the funnel or to spill material into the cylinder below. The piece of metal used to close the bottom opening of the funnel shall be quickly withdrawn in a horizontal movement and the material permitted to flow freely into the cylinder until it overflows. Then, the flow of the material onto the filled cylinder shall be cut off, and any of the material remaining in the funnel shall be allowed to flow into a pan.

The material in the cylinder shall then be carefully struck off even with the top of the cylinder with the straightedge. This is accomplished by holding the straightedge in both hands, edge down; starting at one side, strike off the material above the top of the cylinder. The straightedge is then placed along a diameter of the cylinder and the material struck off again. This is then repeated in the opposite direction. Extreme care shall be taken during the striking-off operation to avoid any downward pressure on the aggregate or any jarring of the cylinder.

After carefully removing any material that may be adhering to the outside of the cylinder, the weight of the contents shall be determined to the nearest 0.1 gram.

The aggregate in the cylinder shall then be recombined with the excess of the same size from the pan, thoroughly mixed, and two additional determinations made. An average of three determinations having a maximum variation of 4 grams shall constitute a test.

The percent voids in each size shall be determined by the following formula:

$$\text{Percent voids} = 100 \left(1 - \frac{W}{VG}\right)$$

where W = average weight of material in the cylinder,
 V = volume of cylinder in cubic centimeters, and
 G = bulk specific gravity (oven dry) of the aggregate as determined by the applicable portions of ASTM C-127.

The arithmetical average of the percent voids so determined for the tested size -- that is, the sum of the percentages divided by the number of sizes tested -- shall be reported.

Fig. 2 shows the test being performed.

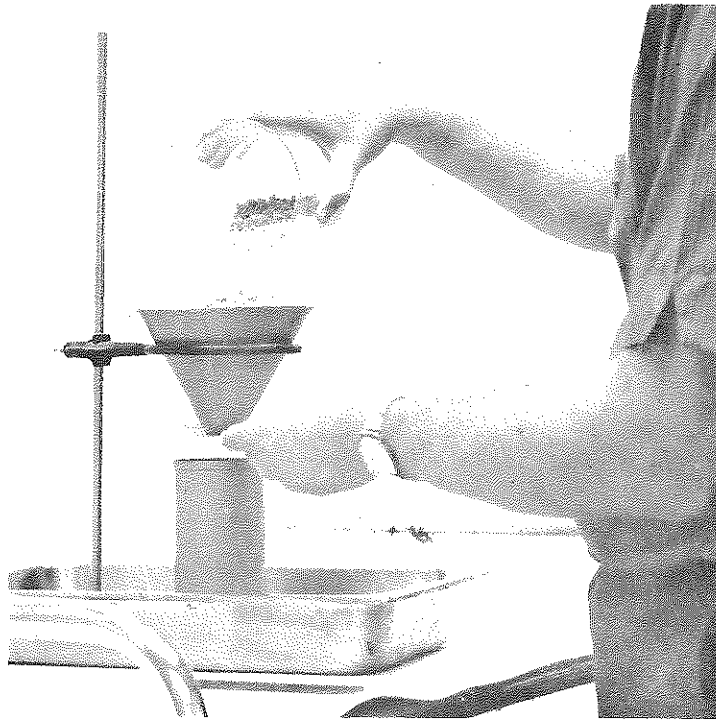


Fig. 2: Bulking Test; for Control of Aggregate Shape.

Figs. 3 through 6 illustrate, by association, the relationship between the bulking value and particle shape (11). The test is subject to some error when the aggregate is highly vesicular. The errors arise from inherent inability to determine the true, oven-dry, bulk, specific gravity.

The bulk specific gravity of slag larger than the No. 4 sieve may be about 2.30; fine slag sand passing the No. 30 or No. 50 sieve may exceed 3.00. Expanded shale fines may range 2.59 and 2.84. Quartz grains approach 2.64. All approach zero percent absorption as the size diminishes. The specific gravity of powdered material is equivalent to that of a voidless mass.

Porosity and Capillarity

A relatively dense sand-asphalt gradation divided at the No. 30 sieve will provide a coarse and fine sand, each of which will yield about twice the VMA in asphalt mixtures as the original sand. The coarser fraction would not contain filler; the filler would have to be added. Such sorting might be accomplished in a wet classifier. All filler could be removed and proportioned back into each of the sands at the hot-mix plant. The two mixtures would be very much alike in terms of total voids (porosity) but have very different pore sizes. Capillary rise and wicking would be greater in the finer mixture if the voids remain open and if the internal surfaces are wettable. Both the coarse and fine mixture would exhibit wicking capabilities. Wicking is merely capillary forces at work in a porous medium.

Capillary rise, capillary siphoning, and wicking are illustrated in Fig. 7. Height H must be sufficient to overcome the tensions holding the drop at the tip of the tube before efflux will occur. A wick may substitute for or extend a capillary tube, as shown.

Suppose the capillary rise is 1 cm. in a surface course which is 2 cms. thick; if the surface course were inundated by rain surface flow and some internal flow would carry the excess water to a lower elevation; the free-water surface would then subside into the surface course; ordinary gravity drainage would cease at some point; shallow basins would siphon (by capillary action) into lower basins and emerge laterally or surface at low points; water which can form concave surfaces (menisci) having shorter radii than the pores causing capillary rise will not drain, the hydrostatic law does not apply; as drying progresses the menisci recede, but blotting capacity remains high; additional water cast onto the surface is absorbed readily.

Clogging of Pores

Soil and road scum intrusions affects the porosity and surface texture of various types of bituminous surfaces. Dust tends to adhere to fresh asphalt until the asphalt becomes de-tackified; interior surfaces also retain dust; this mineralizing process improves wettability with respect to water and gives rise to capillary action. Permanent clogging may occur, but the pumping action induced by passing tires during rainy periods tends to flush and clear pores in the wheel paths.

Fig. 8, left, illustrates a dense, sand-asphalt surface, outside the wheel paths, which is clogged and not readily wettable. The righthand view shows the same drop of water after the addition of a wetting

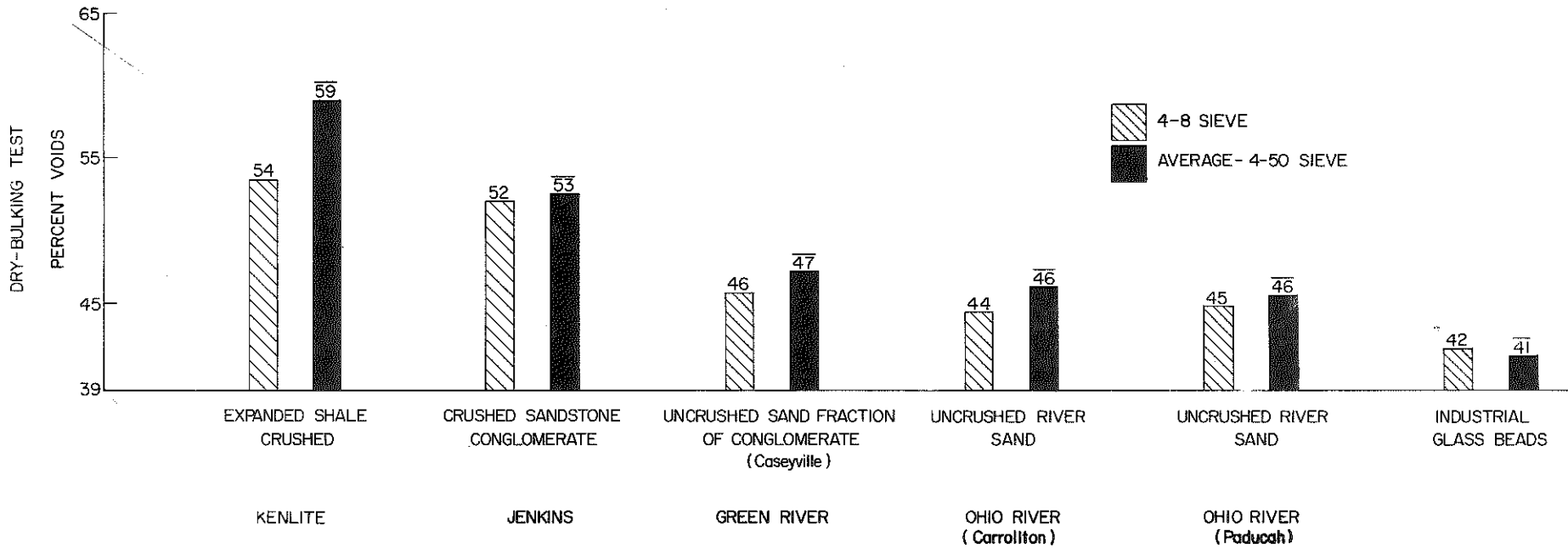
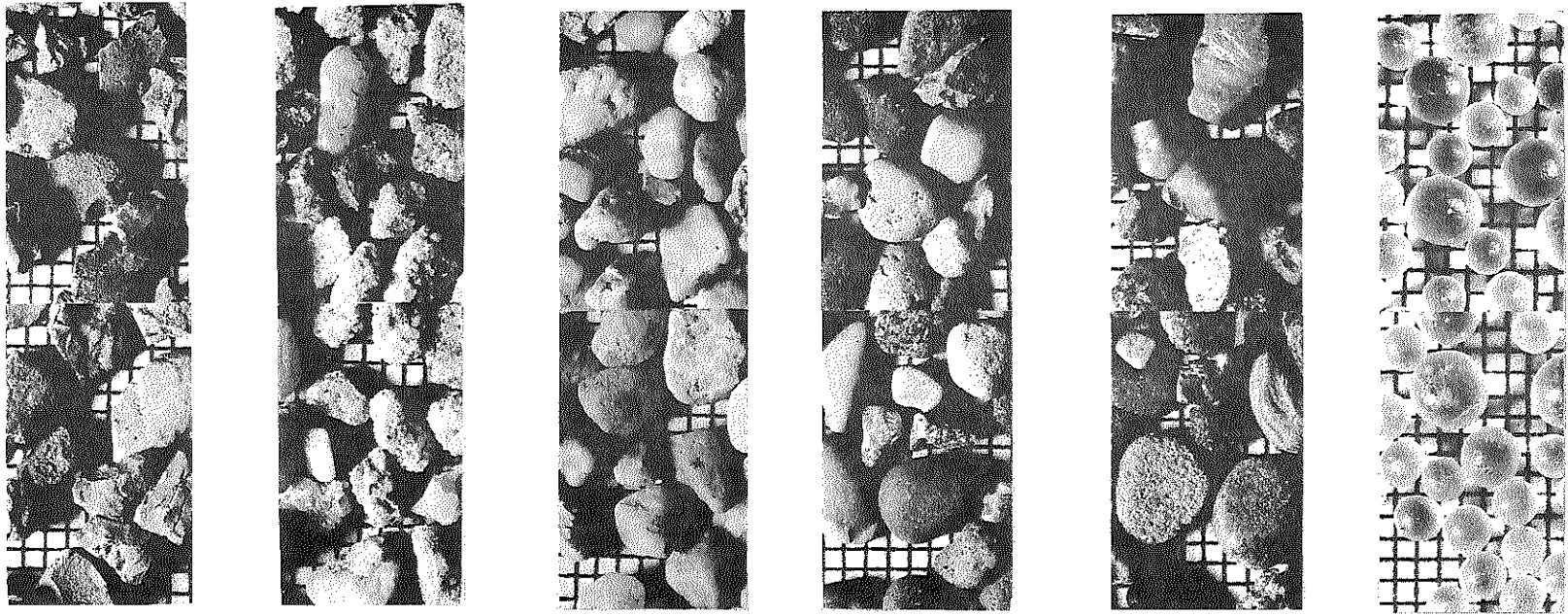


Fig. 3: Bulking Value of Sands Associated Visually with Particle Shape; No. 4

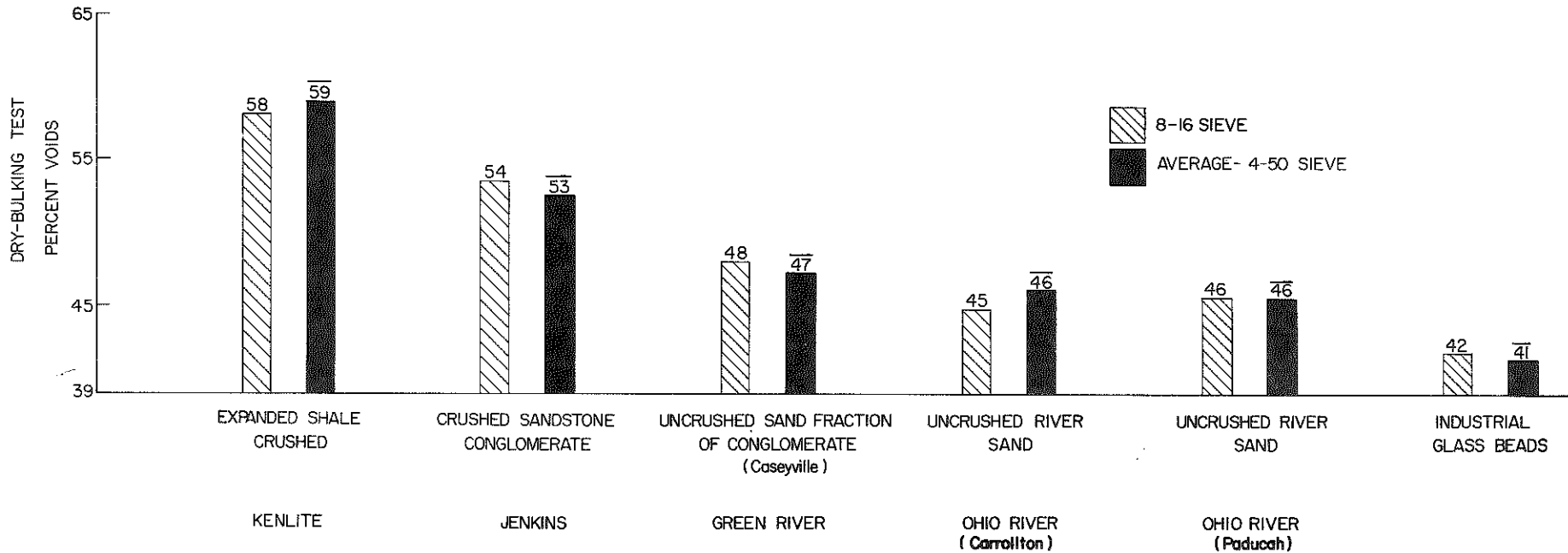
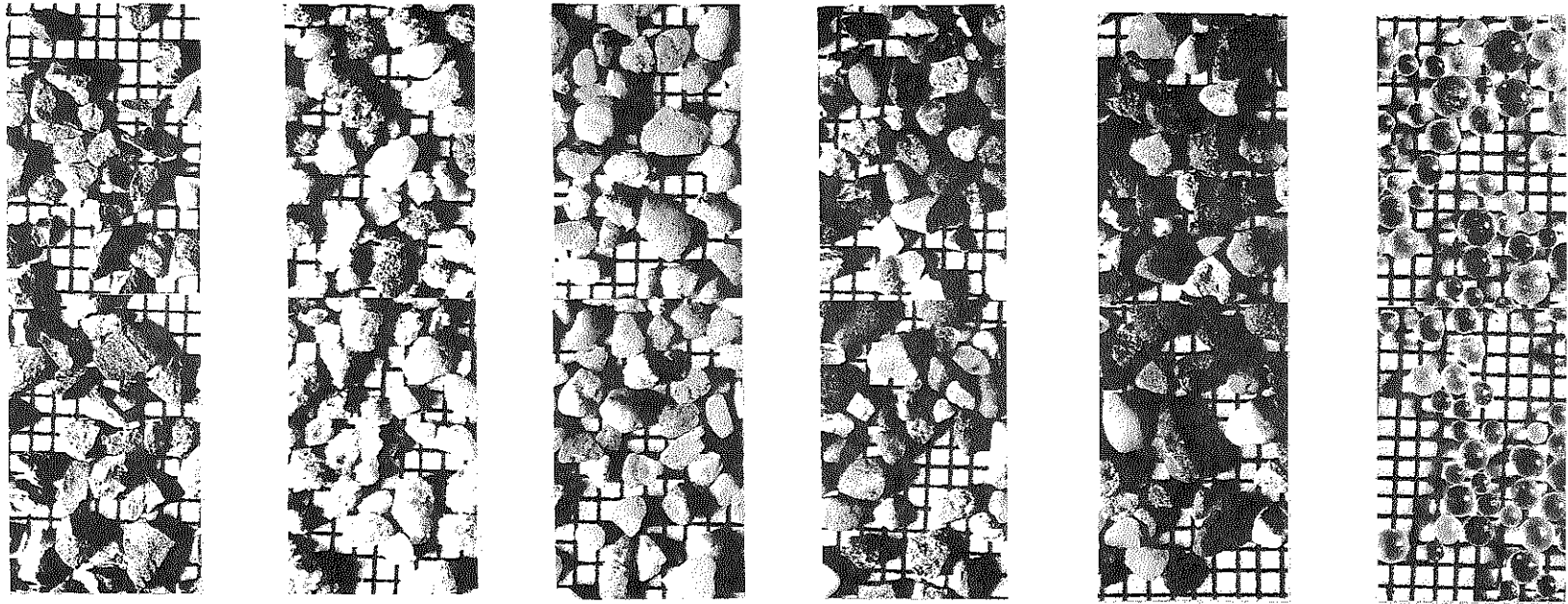


Fig. 4: Bulking Value of Sands Associated Visually with Particle Shape; No. 8 to No. 16 Sieve Sizes.

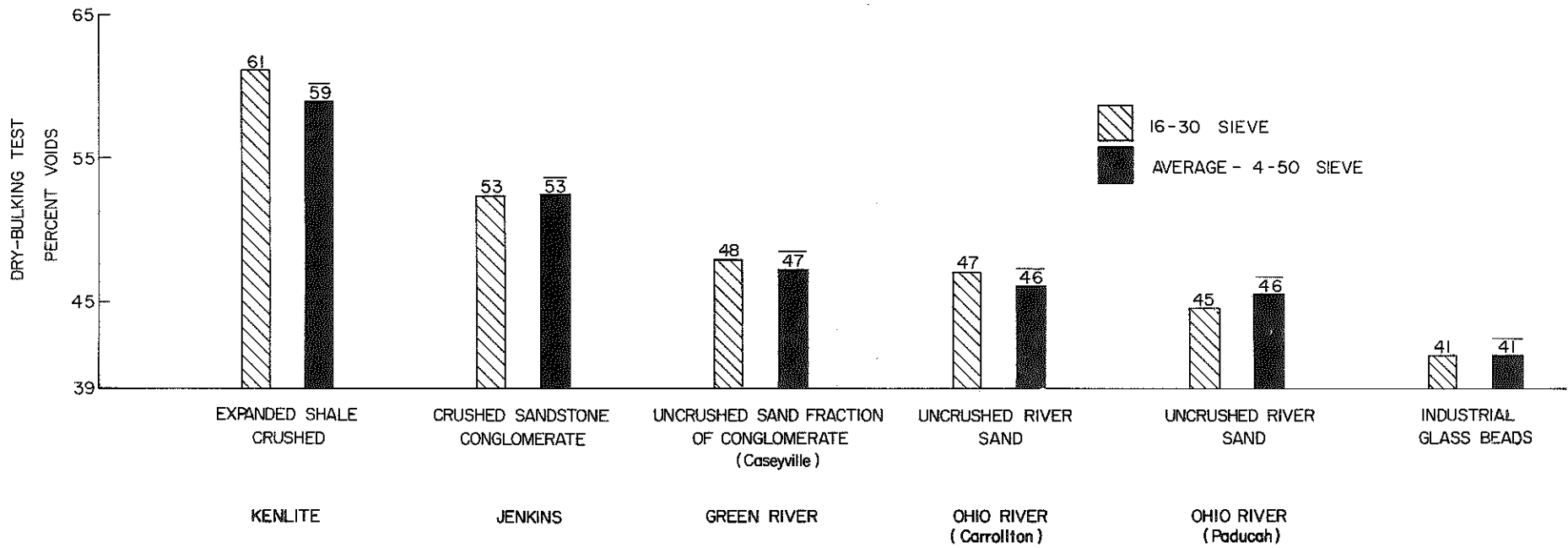
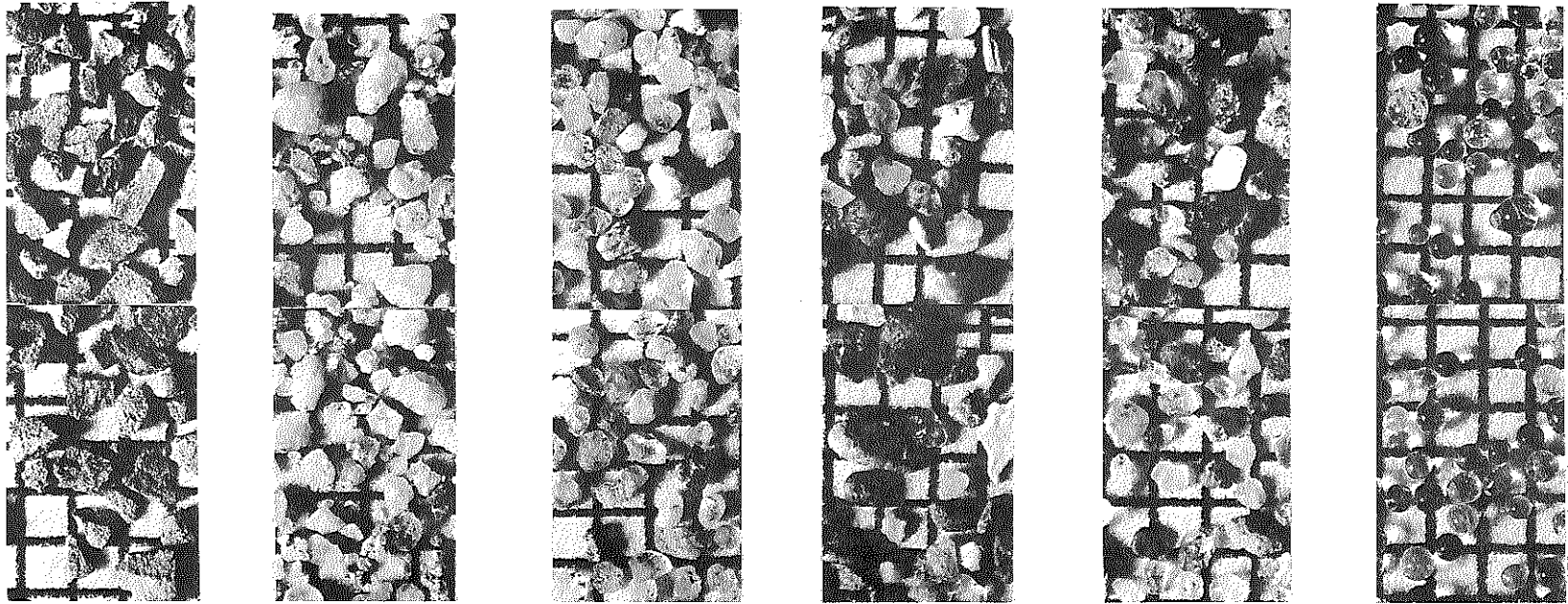


Fig. 5: Bulking Value of Sands Associated Visually with Particle Shape; No. 16 to No. 30 Sieve Sizes.

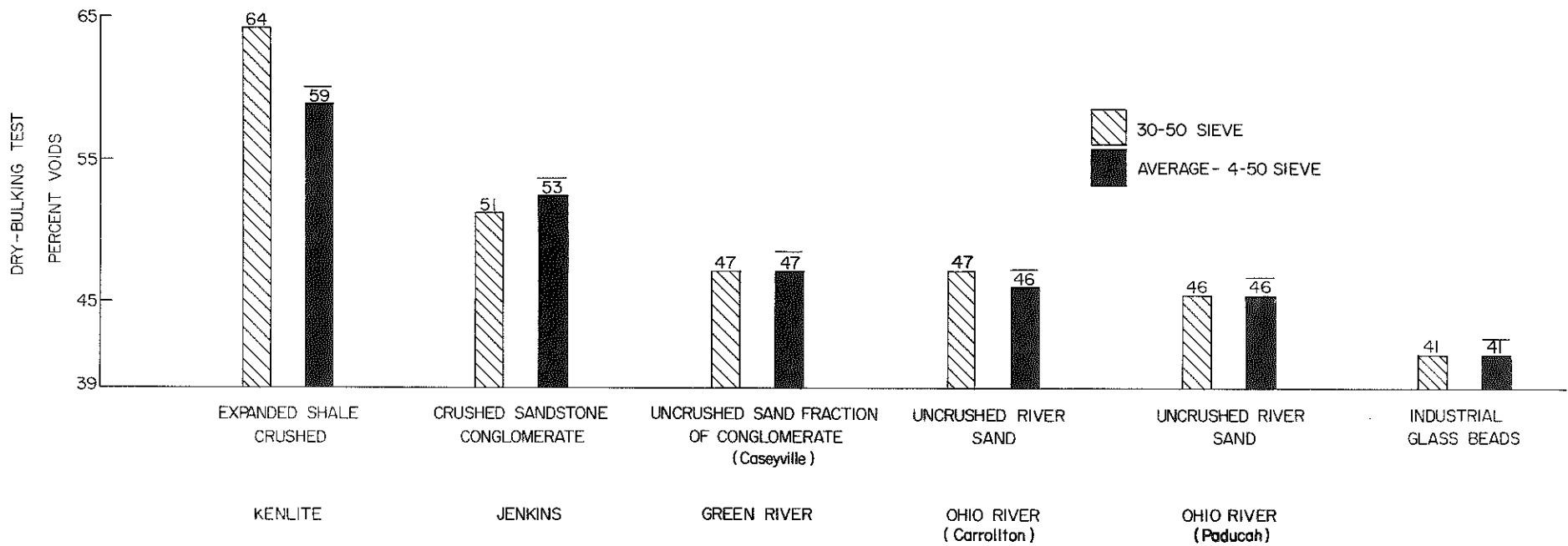
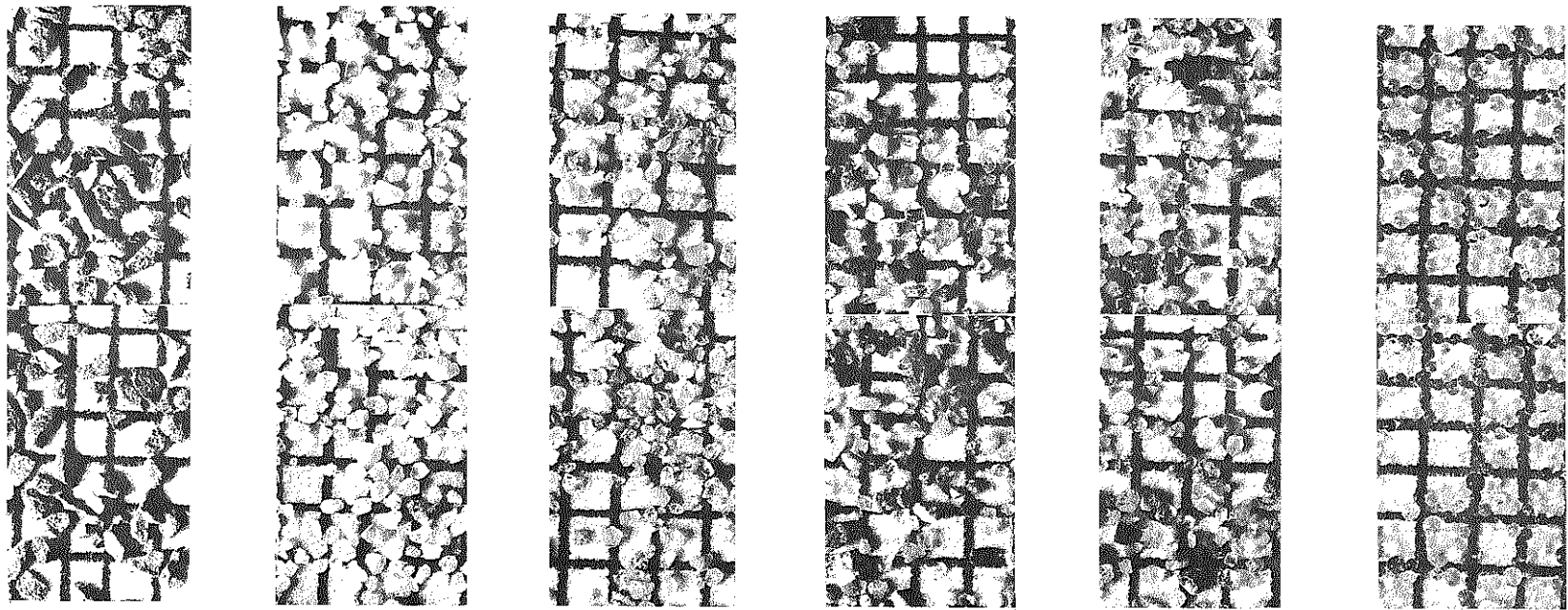


Fig. 6: Bulking Value of Sands Associated with Particle Shape; No. 30 to No. 50 Sieve Sizes.

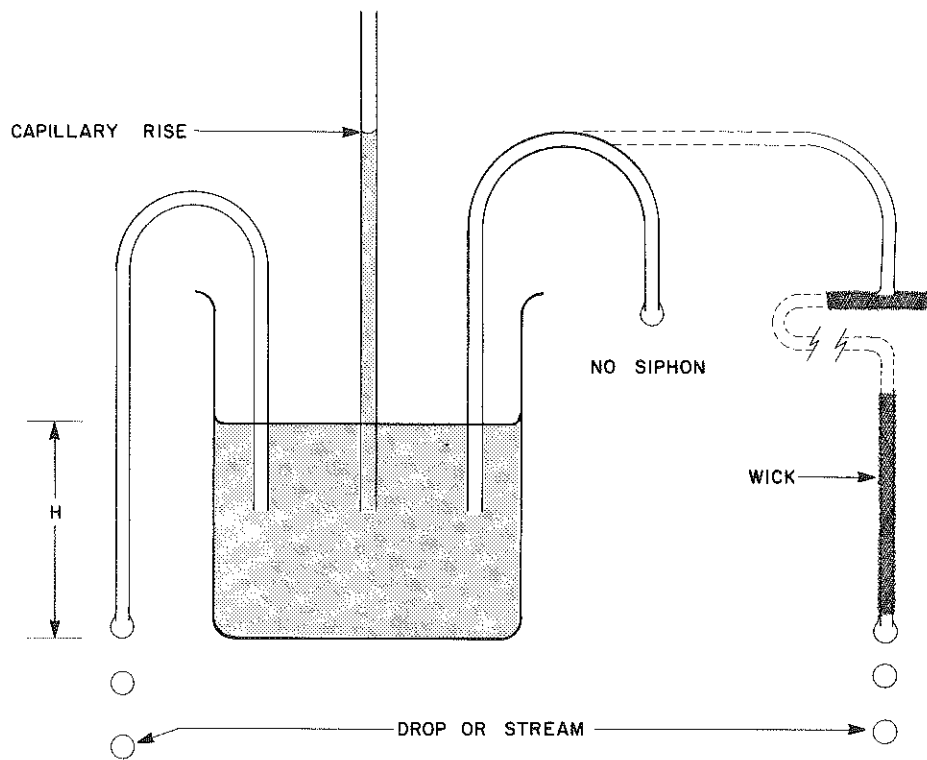


Fig. 7: Illustration of Capillary Rise, Capillary Siphoning and Wicking.

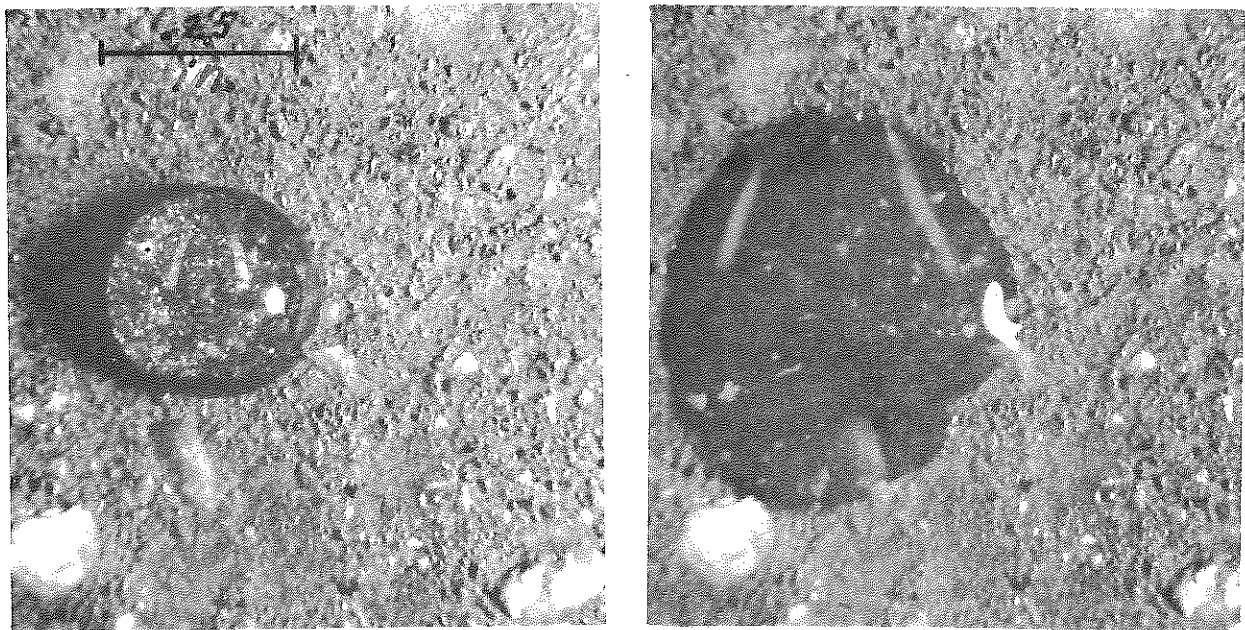


Fig. 8: Quarter-Inch Diameter Bead of Water (left) on Dense, Clogged Sand-Asphalt Surface not readily Wetted; Wetting Agent Induces Wetting (right) without Blotting.

agent. The surface wetted, but there was no in-rush or blotting. In contrast, Fig. 9 shows a drying porous sand-asphalt (Kentucky Rock Asphalt) which has been fully wetted and flushed clean in the wheel paths. Blotting occurs readily. Traffic assists the wetting process if the surface is somewhat hydrophobic at first and also hastens the de-saturation process.

Tack Coat

Porous sand-asphalts have a high blotting capacity toward asphalt used in the tack coat. An abundant tack application seems necessary to prevent delaminations and to seal the underlying pavement. It is usually prudent to subtract an equivalent amount of asphalt from design asphalt content of the mixture. This adjustment becomes very significant when the sand surface course is very thin.

Particle Orientation and Surface Texture

Particles having one or more flat sides tend to be positioned in the surface during compaction so that they present a flat side rather than an acute angle or cutting edge toward the tire. In this position, the edges, if they remain sharp contribute to tractive resistance. The micro-texture of the flat surface may be lost through wear and polishing. Certainly, micro-texture is obscured by asphalt when the surface course is new. Skid-resistance should improve rapidly for a brief time and then diminish gradually to a more-or-less constant value. Attrition or loss of particles from an open-graded, plantmix seal would present an impression of ravelling; attrition from a sand surface would be desirable if it occurs uniformly and at a rate commensurate with the life expectancy of surface course. Indeed, a steady wearing away becomes an assurance against eventual polishing of sand grains at the surface. Finer sands appear to be more favorable from this point of view than coarse sands. Admittance of finer sands also permits a higher size-reduction ratio and consequently provides greater angularity when manufacturing sharp sands by crushing coarse sands or pea gravel. No. 4 to No. 8 size do not appear to be essential to the performance of sand mixtures.

Orientation of particles of fine, crushed quartz sand, oiled and compressed lightly against a flat surface, is shown in Fig. 10.

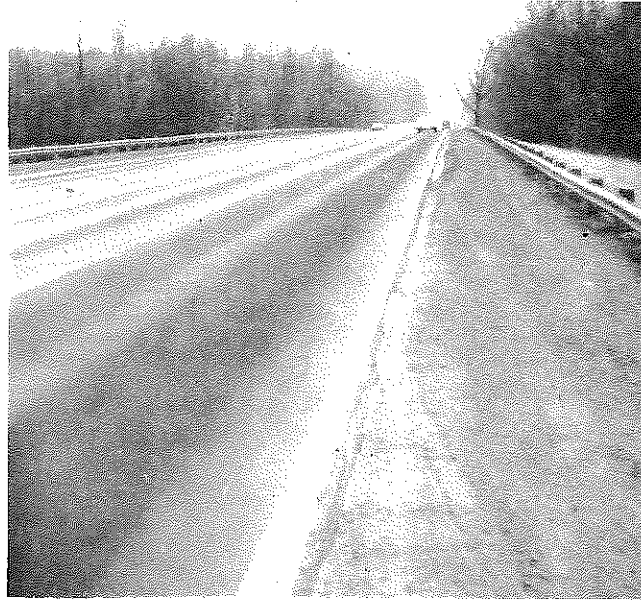


Fig. 9: Porous Sand-Asphalt (Kentucky Rock Asphalt, after Rain; Showing Cleansing of Wheel Paths; Surface Blots readily.

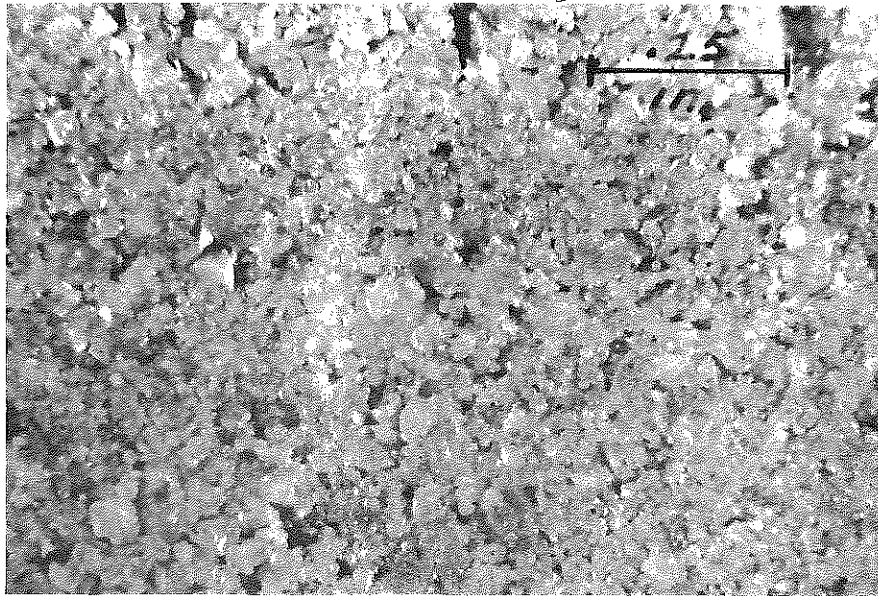


Fig. 10: Particle Orientation of Compressed Fine Sand; Flat Sides Tend to be Horizontal.



Fig. 9: Porous Sand-Asphalt (Kentucky Rock Asphalt, after Rain; Showing Cleansing of Wheel Paths; Surface Blots readily.

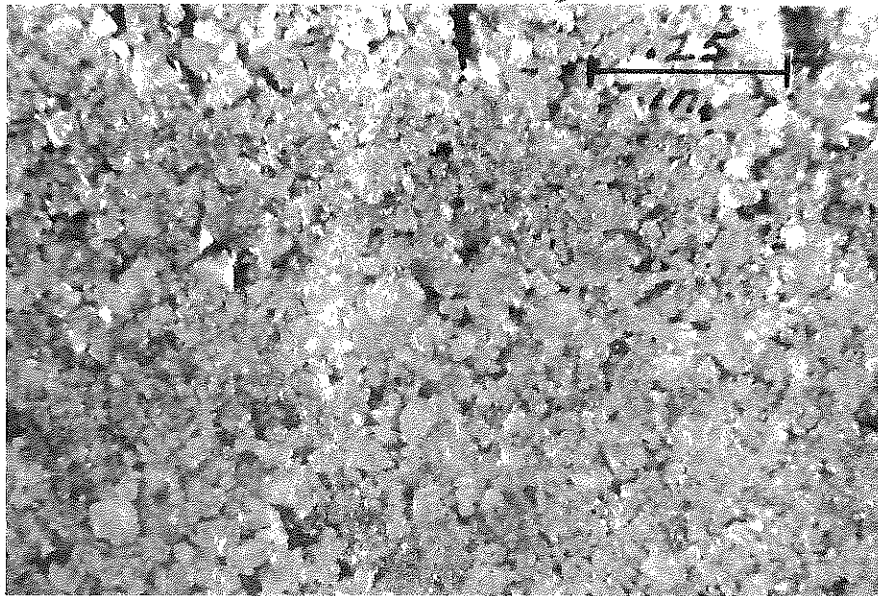


Fig. 10: Particle Orientation of Compressed Fine Sand; Flat Sides Tend to be Horizontal.

SUMMARY

Skid Resistance

Thus far, dense sand-asphalts containing blends of crushed limestone sands and natural sands have performed about equivalent to bituminous concretes containing natural sands and crushed limestone coarse aggregates. All-limestone sand-asphalts have performed about the same as all-limestone bituminous concretes. Sand-asphalts containing all-natural sands have tended to exhibit higher skid resistance; variability in shape, texture, and composition has affected performance; a crushed quartz sand in a dense sand-asphalt is showing very good skid resistance after a year under severe traffic. A porous sand-asphalt containing selected quartz sand less angular than crushed sand has shown superiority over the same sands in denser mixtures. The ultimate combination of high porosity and sharp angular (crushed quartz) sands or other hard vesicular sands such as slags, scoria or expanded shales have not been field tested. Performance equations indicating statistical confidence limits with respect to time and accumulated traffic are yet to developed. Performance equations are needed to qualify types of surfaces and materials to meet minimum standards or criteria for skid resistance.

Porous sand-asphalts may be considered to possess almost all of the attributes of a popcorn mix or an open-graded plantmix seal. They do not have comparable pore sizes. For instance, unless a porous sand-asphalt surface is pre-wetted before making an ASTM E 274 skid test, the water sprayed in front of the test wheel has not significant time to wet or be blotted into the surface. The effect on the Skid Number might be about the same as if the test were made on a dense, non-wetting surface. On the other hand, a fully-wetted, but unsaturated porous sand-asphalt may imbibe the sprayed water very quickly.

Other Attributes

Sand-asphalt surfaces, and more especially the more porous ones, generate a minimum of tire noise and tend to damp other noises generated by a vehicle. Under-car noise caused by splash and spray in wet weather is reduced. More significantly, perhaps, the spray generated by vehicles is reduced unless water is ponded or the surface is otherwise flooded.

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LIST OF PROJECTS
AND
SUGGESTED SURFACE TYPES

Paducah Beltline, MP 73-6332-G; E. curblin of Ky 994 to W. curblin of Bridge St.; U. S. 68, 62, & 60; 2.00 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2; or, Sand-Asphalt Surface, Type 2 or Type 4.

Paducah-Brookport Landing, MP 73-6012-N; N. curblin of Jefferson St. to WCL (300' E. of Jct. U. S. 45 and N. 8th St.); U. S. 45; 1.7 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2, or Sand-Asphalt Surface, Type 2 or Type 4.

Mayfield-Tenn. Line, MP 42-4128-C; S. curblin of E. South Street in Mayfield to SCL of Mayfield at Farthing St., Ky 121, 0.800 mi.

Recommended Surface: Sand-Asphalt, Type 1.

Paducah-Smithland, MP 73-6032-K; S. curblin of Jefferson St. in Paducah to S. side of Beltline at Bridge St., U. S. 68, 62 and 60, 2.250 mi.

Recommended Surface: Sand-Asphalt, Type 2 or Type 4.

Elizabethtown-Leitchfield, portion of MP 47-199-R; from Ky 84 to Grayson Co. line, U. S. 62; 4.750 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2 or Sand-Asphalt, Type 2 or Type 4.

Brandenburg-Louisville, MP-1023-K; Jct. of High St. to SECL of Brandenburg, Ky 448, 0.487 mi.

Recommended Surface: Sand-Asphalt, Type 1 or Type 2.

Brandenburg-Louisville, MP 82-23-L; SECL of Brandenburg to 2780' N.W. of L&N RR, Ky 448, 1.780 mi.

Recommended Surface: Sand-Asphalt, Type 1 or Type 2

Brandenburg-Louisville, MP 82-23-C, 2730' N.W. of L&N RR to 1820' S. of L&N RR at Brandenburg Station, KY 448, 0.861 mi.

Recommended Surface: Sand-Asphalt, Type 1 or Type 2.

Brownsboro Rd., MP 56-18-U; W. side of Rudy Lane to end of 4-lane section, U.S. 42, 6.300 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Frankfort-Shelbyville Rd., MP 37-5145-R; Second St. in Frankfort, from Capital Ave. to Lafayette Drive, U. S. 60, 1.350 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Jackson St. (in Louisville), 56-8808-C; from Ormsby St. to St. Catherine St., Ky 61, 0.300 mi.

Recommended Surface: Sand-Asphalt, Type 1 or Type 2.

High St. (in Frankfort), MP 37-5305-E; from N. curb on Main St. to S. curb of Metro St., U. S. 127, 0.250 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Main St. (in Frankfort), MP 37-5205-C; from W. curb of Ann St. to E. Capitol Ave., 0.200 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Alexandria-Newport, portion of MP 19-6011-AI; SCL, Newport to SCL, Ft. Thomas, U. S. 27, 2.533 mi.

Recommended Surface: Sand-Asphalt, Type 2 or Type 4.

Alexandria-Newport, MP 19-kk-AB; SCL, Ft. Thomas to NCL, Highland Hts., U. S. 27, 0.084 mi.

Recommended Surface: Sand-Asphalt, Type 2 or Type 4.

Alexandria-Newport, MP 19-1011-AD; NCL, Cold Spring to SCL, Cold Spring, U. S. 27, 1.200 mi.

Recommended Surface: Sand-Asphalt, Type 2 or Type 4.

Bolivar Street, in Lexington, U. S. 68-U. S. 27 Connector; MP 34-7924-C; S. Broadway to Upper, 0.152 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Lexington-Frankfort, portion of MP 34-7184-J, W. side of Southern RR Br. to WCL of Lexington (Forbes Rd.); U. S. 421, 0.248 mi.

Recommended Surface: Open-Graded Friction Course Type 1 or Type 2.

Note: Continue to near Moors Mill Road.

Paris-Lexington, Main St. in Paris, portion of MP 9-4kk9-K; from Hillcrest Drive to Eighth St., U. S. 27 & U. S. 68, 1.332 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Paris-Carlisle, Main St. in Paris, portion of MP 9-4059-2; from Eighth St. to W. end of br. over Stoner Cr., U. S. 68, 0.440 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Mt. Vernon-Richmond, MP 102-17-J; MCL of Mt. Vernon to Madison Co. line, U. S. 25, 6.278 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2.

Fullerton-Olive Hill, portion of MP 45-171-R; from Carter Co. line NE to Little White Oak Br., Ky 7, 12.000 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2.

Ashland-Grayson, MP 10-165-AI; Jct. Ky 180 to Carter Co. line; U. S. 60, 4.060 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2

Maysville-Paris, portion of MP 81-175-T; end of PCC pavement, S to new U. S. 68, 3.326 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2.

Grayson-Olive Hill-Morehead, MP 22-148-AD; from Ky 82 to 0.8 mi. W of Ky 1947, U. S. 60, 4.450 mi.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2.

Main Street, Harlan, MP 48-3088-R; NCL to SCL, U. S. 421, 1.410 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Clover St., Cumberland Ave., Walnut St., in Harlan, MP 48-3348-B; Main St. to Main St., U. S. 421, 0.439 mi.

Recommended Surface: Sand-Asphalt, Type 2.

London-Corbin, MP 63-111-2; from Little Laurel River Br. to Dixie St. in London, U. S. 25, 2.51 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Note: Continue to 13th St. in London.

Corbin-Cumberland Falls, MP 118-4220-I; from Ky 26 in Corbin to SWCL of Corbin; U. S. 25, 1.60 mi.

Recommended Surface: Sand-Asphalt, Type 2.

Note: Continue to 1400' east of I 75.

I 65-1(13)13, from Jct. U. S. 231 near Bowling Green, S. to I 65-1(17)6 at Warren-Simpson Co. line, then S. to vicinity of Hillsdale.

Recommended Surface: Open-Graded Friction Course, Type 1.

I 75, from Ohio River Br. at Covington, S. to Jct. of I 275.

Recommended Surface: Open-Graded Friction Course, Type 1 or Type 2; or, Sand-Asphalt, Type 4.