file

DRAFT - NOT FOR PUBLICATION

VOIDS AND MACROTEXTURE OF MONO, MINUS-MONO AND MULTIPLE LAYERS OF DISCONTINUOUSLY GRADED FINE AGGREGATE, SLURRY-LIKE, BITUMINOUS MIXTURES

by

C. ROBERT BENEDICT
320 Northview Road
Dayton, Ohio 45419 (513-298-6647)

A draft statement of needed research prepared for presentation to the ISSA R & D Committee meeting to be held May 3, 1978 at the Washington Hilton Hotel, Washington, D.C.

Claims are made that slurry seal is both skid resistant and durable. The fact is, only some slurry seals possess either or both of these properties.

This proposed research would study the aggregate properties and gradation design that contribute to durable skid resistance and special design problems of various layer thicknesses, especially when the application is a leveling course of discontinuously graded aggregate.

The areas of study and objectives should be at least to:

1. Search the literature, patents and field experience and report.
2. Define "slurry", the noun and the verb, "to slurry".
3. Define continuous (step), discontinuous and one-size gradation.
4. Define "mono", "minus-mono", and multiple layers of various types of aggregate gradations used in the slurry process.
5. Define macro-texture of surfaces projecting or depressing above or below a surface "horizon".
6. Define fine aggregate matrix and coarse aggregate fractions of the gradation.
7. Define surface, substrate and matrix voids (voids, void in the mineral aggregate, etc.).
8. Mathematically describe a slurry-like mixture or gradations that will exhibit uncompacted and compacted macrotextures.
9. Develop a useful field and laboratory technique for measurement of surface macrotexture.
10. Experimentally validate the mathematical description of gradations that exhibit uncompacted and compacted macrotextures.
11. Develop mathematical techniques to design specific macrotextures using a blend of two different specific gravities and particle shape aggregates.

12. Experimentally investigate differential wear rate aggregate blends and their effects on surface macrotexture as they wear by use of a traffic simulator.

13. Experimentally investigate the effect of simulated traffic compaction on multiple layers of open one-size and discontinuously graded slurry-like bituminous mixtures.

14. Define a point where "slurry" properties cease to exist.

15. Possible co-research on compaction extrusion mechanics, plastic distortion, matrix properties, coarse aggregate retention, adhesion phenomena and sound levels due to macrotexture.

OBSERVATIONS AND SOURCE MATERIALS FOR THE MACROTEXTURE STUDY

Conventional or standard ISSA A-105 (1) aggregate gradations were first proposed by R. Jiminez (2) in 1963 in a study supported by Slurry Seal, Inc., Waco, Texas. These gradations follow quarry "screenings" generally available as a by-product from the manufacture of coarser aggregates produced for hot mixed asphaltic concrete and for "chip-seal" or seal coating and penetration applications. K.E. MacConeghey (3) suggested similar gradations. Prior to this time, slurry investigators attempted to use most any fine aggregates such as quarry dusts, concrete and mortar sands with little success.

Researchers in California (4) in the 50's determined that the fines (-200) quality and quantity greatly affected the ability of a slurry to be stable; i.e., a non-draining, non-segregating fluid homogeneous mass. The addition of high surface area fillers such as Portland cement or hydrated lime in small quantities was discovered to aid in mix stability and homogeneity. More recently, the addition of thixotroping or visbuilding agents to the emulsion in very small quantities (such as bentonite clay) (5) finds use in obtaining mix homogeneity.

Many conventional slurry seal gradations will produce excellent skid prevention characteristics when applied in a "mono-layer" but these characteristics may be lost when applied in multiple layers (see Benedict: (6) (7) (8).) Some aggregate gradations may be slippery when applied in a mono-layer, but skid resistance may be dramatically improved by applying a minus-mono layer. Whitehurst (9) reports skid resistance and speed gradients as dependent on macrotexture while Rose (10) states that a minimum macrotexture of .030" (1.2 mm) is necessary to maintain satisfactory skid resistance and speed gradients.

Certain aggregate gradations when applied in mono or minus-mono layered slurries, such as occasionally experienced on start-up and shut-down operations and with hand work at intersections, will lose coarse aggregate fractions or tend to "kick-out". Young, Province and Fiock (11) state that slurry appearance is improved by limiting the percent passing the coarsest screen to 98-100 and that the next coarsest screen "should constitute 10 to 15% of the total aggregate for load bearing purposes." Sands (12) suggests that spreading slurry in a traffic opposed direction and use of burlap drags pulls up and points the aggregate toward the oncoming traffic thus improving skid resistance. This effect may not endure under the compaction of heavy traffic though certainly the initial macrotexture is improved.

The relationship between the qualities and quantities of finer and coarser fractions of slurry is not understood sufficiently. Field observations indicate that the -16 fraction contributes little if anything to the mechanical wear rate of a finished slurry surface but plays a very important part in holding the larger fraction.

The properties of this matrix portion (arbitrarily the -16 fraction) are very important. The effects of the "fines" (-200 and -325), both quality and quantity, may affect the adhesive properties of the asphalt emulsion both chemically and mechanically. Bituminous mastic technology as practiced in both the roofing and flooring materials industry, as well as debonding of calcareous aggregate-bituminous mixtures (13) (AAPT - 1974), should be useful. E. Jimenez, at Corsicano, Texas, is currently working on plastic distortion.

On the other hand, the size, quality and relative quantity of the +16 fractions may predict the wear rate of a finished slurry surface. The properties of this fraction become very important when considering both the durability and skid resistance of slurries.

Many studies have been made to attempt prediction of aggregate durability. Fiock (14) and Young (15) show the relative wear rates as affected by both gradation (% +16) and aggregate qualities. Benedict has commented on the levels of wear for different gradations to serve as a guide for gradation-quality selection to meet a particular design objective.

Other "shaker" wear devices have been used in attempting to determine mechanical wear, such as the Washington State ice-cream container shaker (23) and the Georgia DOT Sand Equivalent Shaker Degradation Test (24). Others are trying paint can shakers (24a).

The L.A. "Rattler" test does not correlate well with field experience. The British polishing wheel along with the British pendulum friction device does not meet with good correlations though many attempts have been and are being made such as Walker (17) at Texas, Penn DOT, and J. Fernandez del Campo at Probisa in Madrid, Kentucky DOT and others. Skog or Zube developed the shaker test in California (?). Fiock and Young have adapted its use to both slurries and slurry aggregates. Wallace (18) at Kansas DOT uses a variation for a standard slurry design tool. Lee (19) at Iowa State University compares an interesting variation of the shaker design technique with the so-called Wet Track Abrasion Test (WTAT).

Acid insolubilities have been correlated with road surface skid resistance in Virginia by Mahone and Runkle (20) (21) and the relative laboratory wear acid insolubilities and Centrifuge Kerosene Equivalent (CKE) of slurry aggregates reported by Young (15).

Measurements of surface macro and micro geometrics by use of stereo-photographs have been made by Sheaburne (22) and may be most useful in predicting skid resistance. Rose's (10) sand patch, putty impressions, and profilograph methods may also be useful in studying surface textures of slurries.

The classification of aggregate skid resistance levels (SRL) at Penn DOT by Sandlin, Howe (25) and others represents a practical approach to aggregate design for skid resistance. Dahir (26) (27) (28) at Penn State University has included much knowledge of aggregate skid in his important researches and suggests that differential wear properties of aggregates may be the best way to select optimum skid resistant aggregates.

Since the days of old John MacAdam (29) highway engineers have been concerned with aggregate gradation and its effect on field performance of all road materials. "Ideal" slurry gradations are generally thought to be linear or straight-line. Non-linear gradations such as gap-grading - Lee (30), and one-size or open-grading as promoted by many researchers as well as the FHWA (see John Carroll and many others (31)) have proven very effective in producing satisfactory macrotexture to prevent hydroplaning.

The Fuller gradation curves and other variations of same have been supplanted by the rational and novel approach of Geoffrey Lees (32) at Birmingham. Understanding void contents and the relationships of aggregate size ratios becomes quite complex as the layer thickness decreases.

Example: When adequate, conventional hot mixes are applied at 1½" to 2" the mixes are durable but as the thickness is reduced, deterioration becomes more rapid. When a mono layer is reached, the results are disastrous. Open graded mixtures with conventional AC contents ravel rather quickly. However, chip seals and slurry seals properly applied in thin layers, do not ravel. . . . Why?

I suspect that the Marshall and Hveem strength curves will be reduced exponentially as the specimen thickness is reduced. I am not familiar with work of this sort.

McLeod (33) suggests the use of thicker films of softer asphalts and higher void contents to increase pavement durability. Hughes (34) at Va DOT states that inadequate compaction and consequent permeability increases results in loss of pavement life ("each 1% compaction below design optimum results in the loss of 1 year of life"). Michigan researchers, Rowan Peters (35) at Arizona, Goetz at (36) Purdue and Kendahl (37) at Penn DOT and many others all report on the deleterious effect of excess voids in bituminous mixtures.

Compacted slurries are essentially voidless or are void fillers and serve to reduce moisture, chemical and air penetration into mix matrices.

McLeod (34) has refined the Hanson (35) method of chip seal design as published by the Asphalt Institute (36), and his techniques may be useful in designing slurry gradations for maximum wear and macrotexture by substituting slurry matrix (-16) for bitumen in filling the voids in chip seal aggregates.

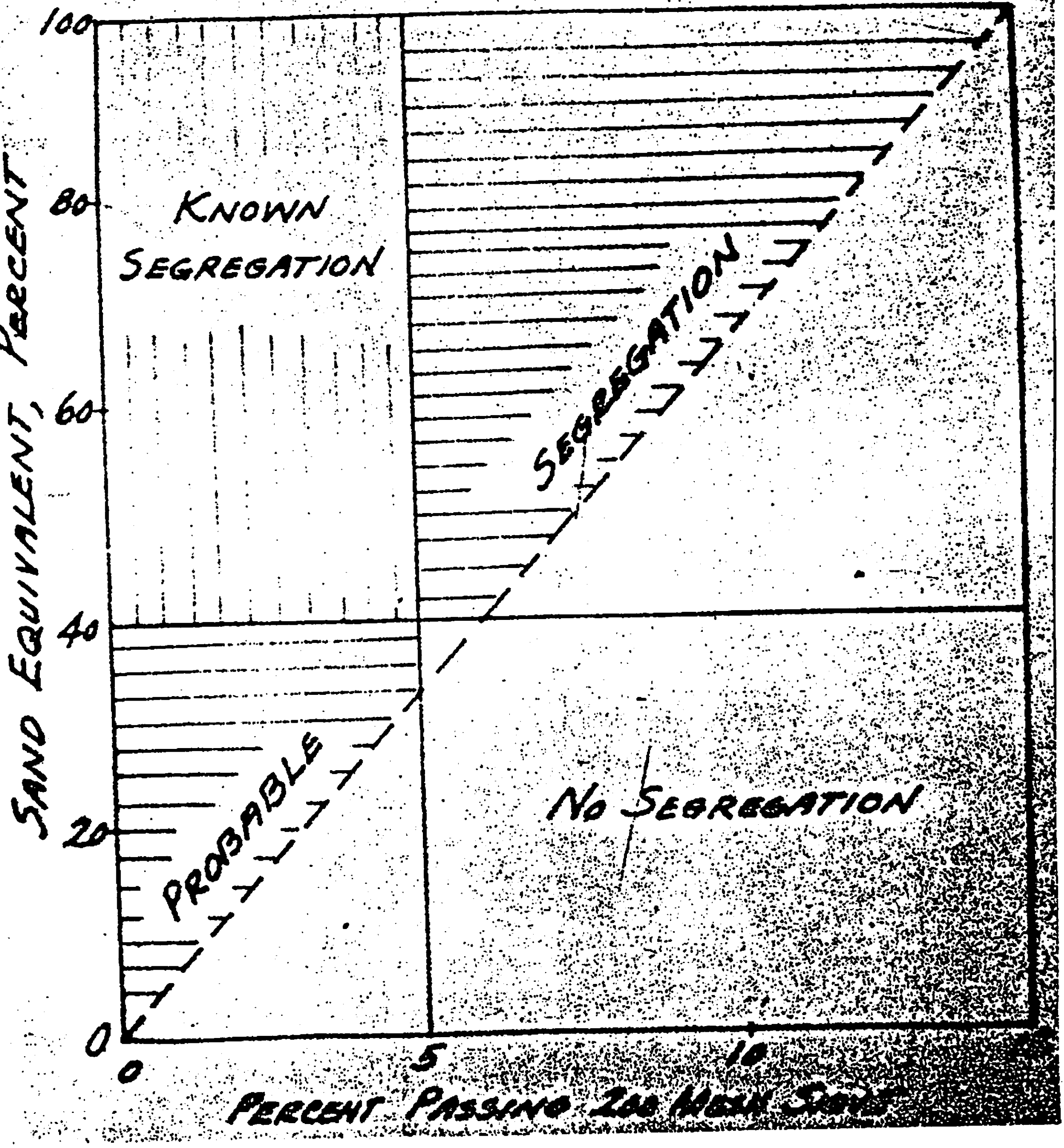
"Cape seals" or Nodular slurry" as described by Chevron (36) and Robin Campbell (37) U.K. (a coarse chip seal filled or "choked" with a fine slurry) may present a complimentary technology to the above notion.

Kari (38) describes use of open graded emulsion mixes, mixed and laid in modified slurry machine travel plants. These mixes will also require sealing. Slurry seals for this purpose are reported by Benedict (39).

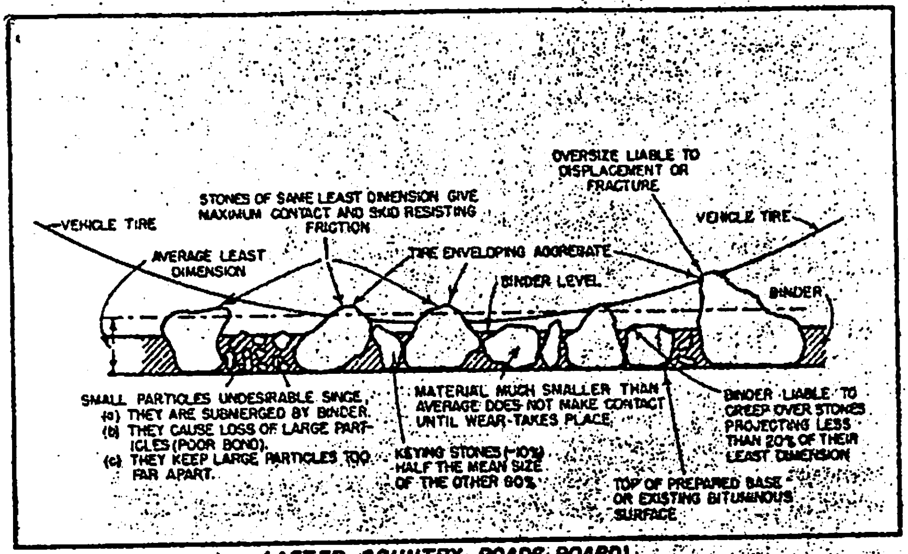
Transportation Research Record 622, "Skidding Accidents - Pavement Characteristics" and 624, "Skidding Accidents - Ancillary Papers" (40) summarizing proceedings of the Second International Skid Prevention Conference, held at Columbus, Ohio May 2-6, 1977, contains a wealth of current knowledge and practice and should be thoroughly searched for references. Also British patent No. 1393885 and U.S. patent application of Dunlop Limited should be consulted.

Machenel (41) of Vulcan Materials and NCSA has suggested selecting aggregate screenings as they occur and controlling their gradation rather closely. This approach to aggregate selection may be satisfactory in some circumstances.

RELATIONSHIP OF AGGREGATE PROPERTIES TO SLURRY SEAL SEGREGATION.



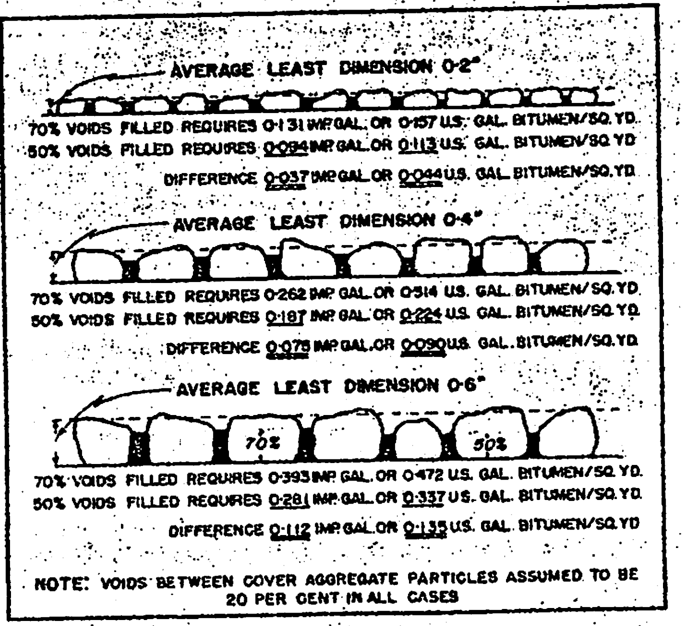
FOR SLURRY DEFINITION, ALSO ISSA TB 106
ON CONSISTENCY OF SLURRY MIXES.



(AFTER COUNTRY ROADS BOARD)

Fig. 29. Illustrating Advantages of One-Size Aggregate for Seal Coats or Surface Treatments.

“HORIZON PROJECTIO



70% VOIDS FILLED REQUIRES 0·131 IMP. GAL. OR 0·157 U.S. GAL. BITUMEN/SQ. YD.
50% VOIDS FILLED REQUIRES 0·094 IMP. GAL. OR 0·113 U.S. GAL. BITUMEN/SQ. YD.
DIFFERENCE 0·037 IMP. GAL. OR 0·044 U.S. GAL. BITUMEN/SQ. YD.

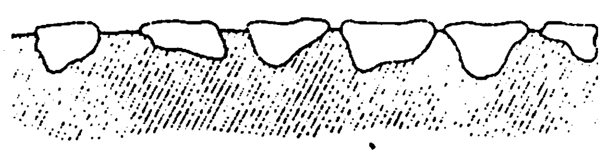
70% VOIDS FILLED REQUIRES 0·262 IMP. GAL. OR 0·514 U.S. GAL. BITUMEN/SQ. YD.
50% VOIDS FILLED REQUIRES 0·187 IMP. GAL. OR 0·224 U.S. GAL. BITUMEN/SQ. YD.
DIFFERENCE 0·075 IMP. GAL. OR 0·090 U.S. GAL. BITUMEN/SQ. YD.

70% VOIDS FILLED REQUIRES 0·393 IMP. GAL. OR 0·472 U.S. GAL. BITUMEN/SQ. YD.
50% VOIDS FILLED REQUIRES 0·281 IMP. GAL. OR 0·337 U.S. GAL. BITUMEN/SQ. YD.
DIFFERENCE 0·112 IMP. GAL. OR 0·135 U.S. GAL. BITUMEN/SQ. YD.

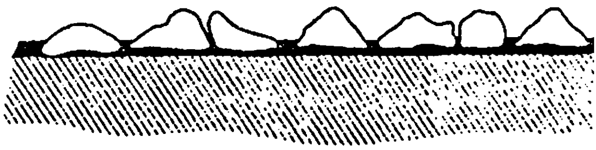
NOTE: VOIDS BETWEEN COVER AGGREGATE PARTICLES ASSUMED TO BE 20 PER CENT IN ALL CASES

Fig. 28. Influence of Cover Aggregate Size on the Critical R of Bitumen Quantity Required for a Seal Coat or Surface Treatme

Figure 7 Surface textures of hot rolled asphalt and surface dres



Hot rolled asphalt (Flat faces uppermost)



Surface dressing (Angular edges uppermost)

McLEOD/AAPT
&
AI VERSIONS.
FOR SLURRY
DESIGN
VARIATION

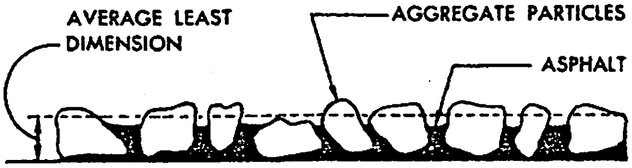


Figure C-1—Aggregate Particles Dropped by Spreader Lie in Unarranged Positions

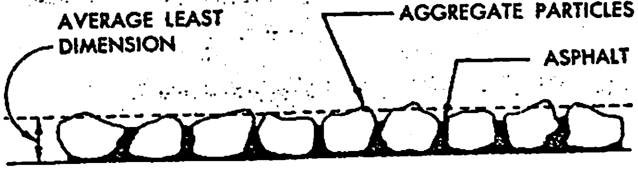


Figure C-2—After Being Set by Traffic, Particles Lie on Flattest Side

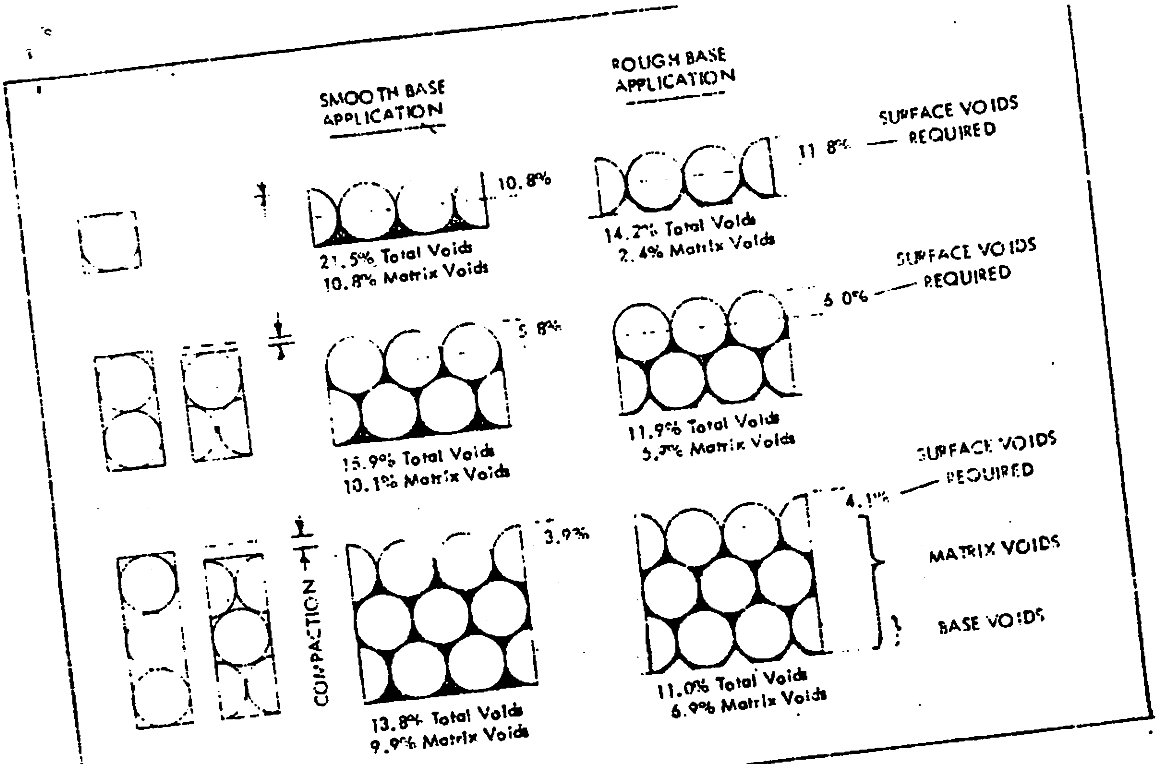


Figure 5. HYPOTHETICAL VOID STRUCTURE REQUIRED TO MAINTAIN ADEQUATE SURFACE MACROTEXTURE (50%) IN MONO AND MULTIPLE LAYERED ONE-SIZE SPHERICAL AGGREGATE PAVEMENTS.

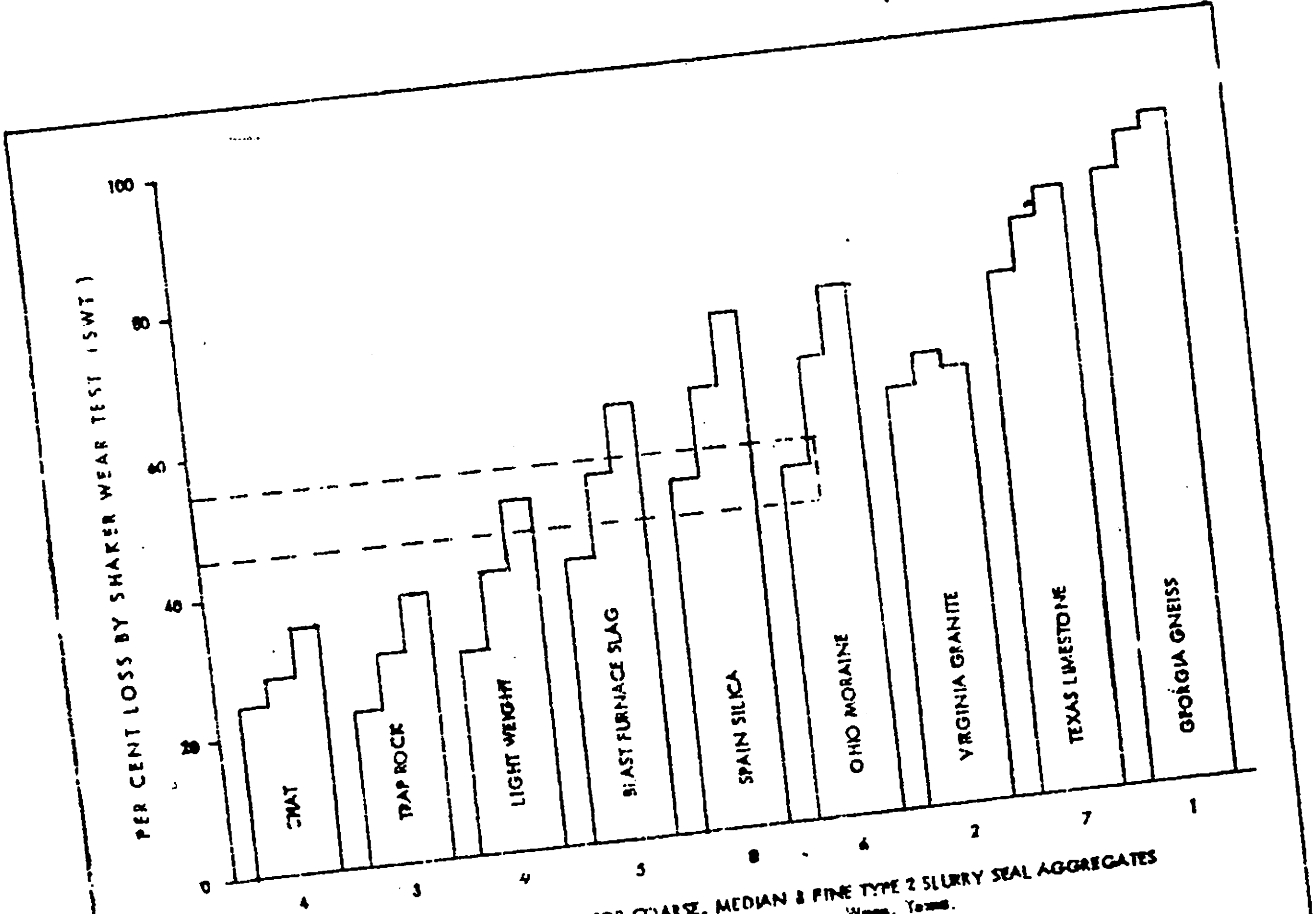


Figure 6. COMPARATIVE LEVELS OF WEAR FOR COARSE, MEDIAN & FINE TYPE 2 SLURRY SEAL AGGREGATES BY THE SHAKER WEAR TEST (SWT) Slurry Seal, Inc., Waco, Texas.

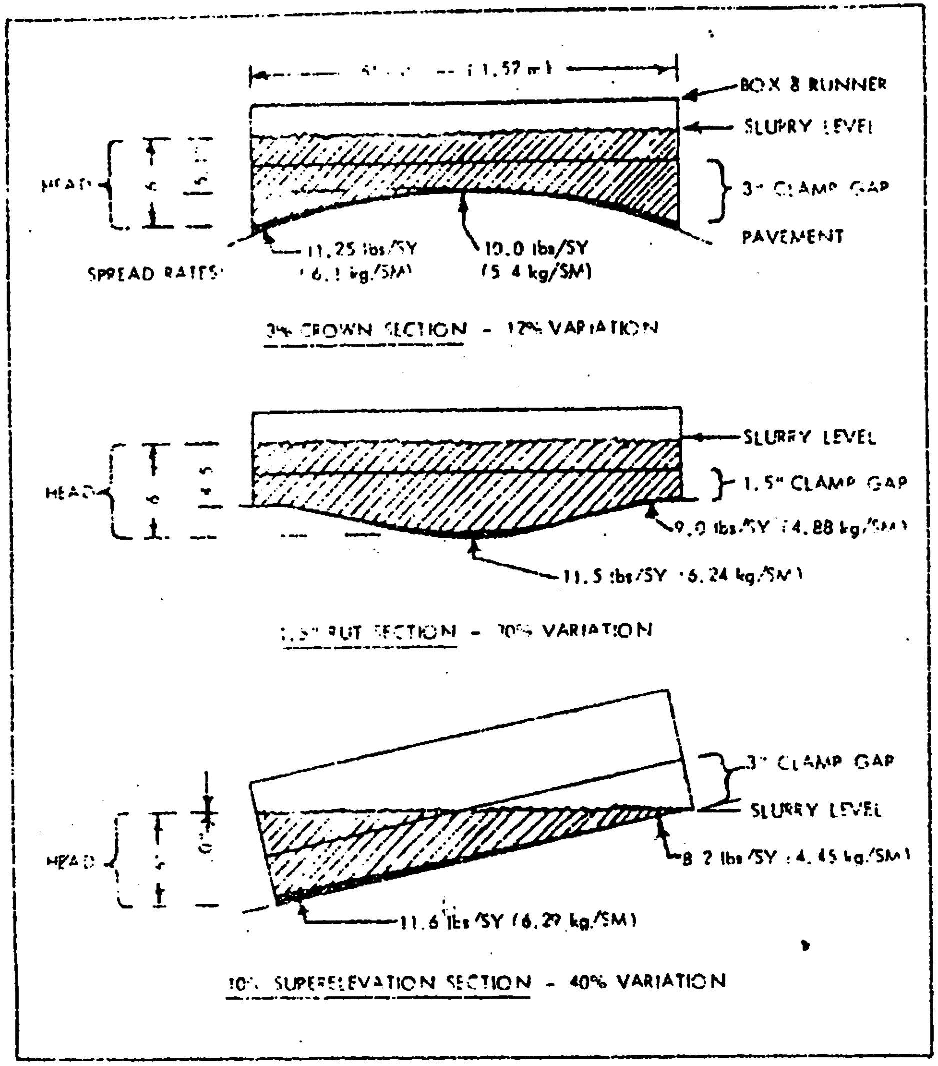


Figure 3. THEORETICAL SPREAD RATE VARIATIONS DUE TO PAVEMENT GEOMETRY
(Smooth Surface, 2.5 cm Consistency)

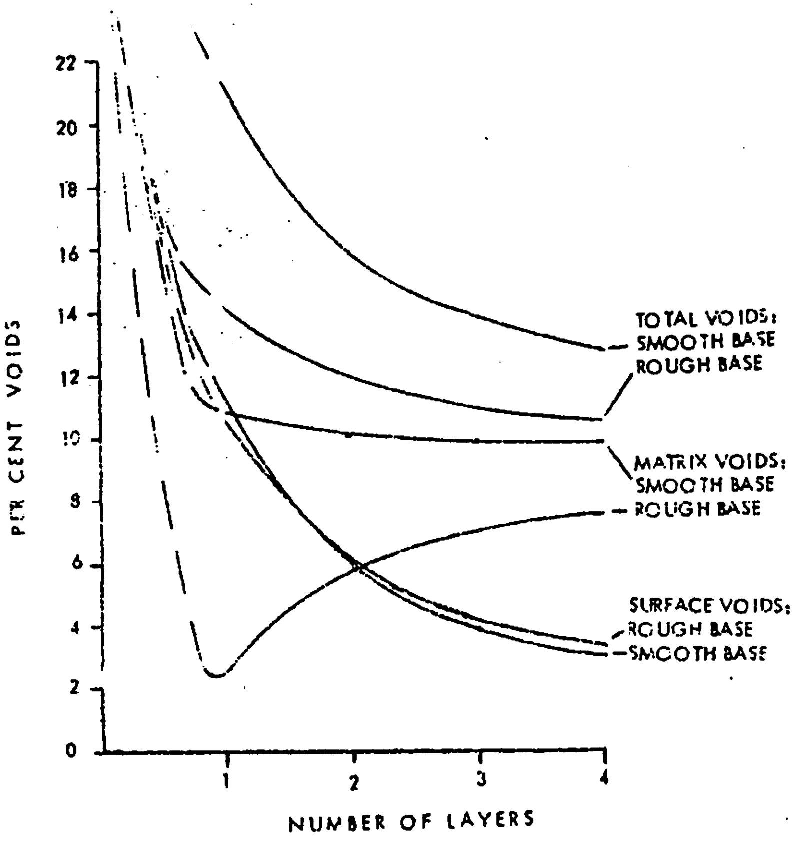


Figure 5. RELATIONSHIP OF TOTAL, SURFACE AND MATRIX VOIDS OF A HYPOTHETICAL MONO AND MULTILAYERED PAVEMENT
(Surface macrotexture remains constant)

Figure 5.