INTRODUCTION TO A STUDY FOR THE PREDICTION AND MAINTENANCE OF SLURRY SEAL SPREAD RATES

by

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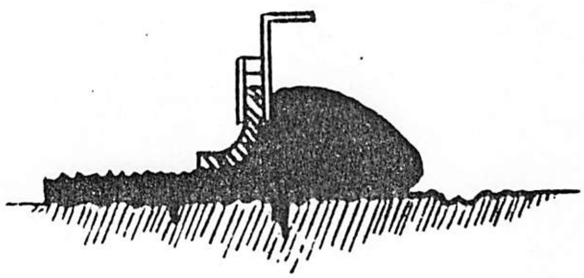

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INTRODUCTION TO A STUDY FOR THE PREDICTION AND MAINTENANCE OF SLURRY SEAL SPREAD RATES

PURPOSE: To enable design engineers and contractors to pre-determine the proper or required application rate of slurry seal for a given surface.

PROBLEM: Slurry Seal is a fluid, homogeneous mixture of asphalt emulsion, water, mineral filler and fine-graded aggregate which is applied to a pavement surface by means of a bottomless, runner supported, squeegee sealed spreader box.

The single unique property of Slurry Seal is it's inherent ability to deposit a thin bituminous mix to a variable pavement surface in accordance with the demands of the surfaces. (1) Smooth areas receive a single stone depth or "mono-layer", whereas coarse and ravelled areas will be filled completely by "multiple-layers", in a single pass of the slurry spreader.

McLeod (2) suggests that because conventional chip seals (spray bar and box surface treatment) deposit only a transversly uniform mono-layer application irrespective of the surface demand, that a light slurry seal be applied before chip seal in order to present a uniform surface for a superior chip seal!

I suggest that a properly designed and applied slurry seal can save the expense of two separate operations and do both jobs . . . . in a single pass.

The rate of application depends on many variable factors and is not well understood. Consistently successful slurry seal application rates have been achieved in the field by experimentation and observation by the contractor and with the forbearance of the customer. Since field practice and results vary widely, there is a need to understand and quantify the many complex factors involved in achievement of satisfactory spread rates and thus relieve the industry of this mystery.

PROGRAM: An ISSA R 8 D task force project is divided into three phases:

1. Outline of the variable factors involved and a laboratory study of these factors.
2. Experimental field work
3. Full scale field production studies

This paper includes the following:

Part I Outline of the variable factors that determine the spread rate of slurry seal.

Part II A simplified method for measurement of pavement surface macrotexture. . . . . The surface demand for slurry seal.

Part III The role of squeegee properties, clamp-gap settings, slurry consistency and depth of sand in the spread rate design and control of slurry seal.

Part IV The role of pavement geometry in slurry seal spread rates.

PART I – OUTLINE OF THE VARIABLE FACTORS THAT DETERMINE THE SPREAD RATE OF SLURRY SEAL

1. The PAVEMENT
   - A. SURFACE CONDITION
     1. Surface Macrotexture
     2. Surface Absorbtivity and Permeability
     3. Surface Cleanliness
     4. Surface Cracks (vs. Structural Cracks)
   - B. SURFACE GEOMETRY
     1. Crown
     2. Wheel Ruts
     3. Corrugations
     4. Severe Ravelling
     5. Structural and Joint Cracks
     6. Wedge Sections

2. The SLURRY
   - A. Slurry Properties
     1. Consistency or Mix Viscosity
     2. Aggregate Gradation
     3. Aggregate Particle Shape, Sharpness and Interlock
     4. Specific Weight of the Mix
   - B. Depth of Slurry in the Box (Hydrostatic Pressure)
   - C. Pavement Moisture, Spray Bar Moisture

3. The SPREADER BOX
   - A. Spreader Box Geometry
     1. Single or Double Compartments
     2. Lateral Divisions
     3. Hinging Arrangements
     4. Span Between Runners
     5. Distribution Augers, Size, Location, Speed
   - B. Fill Depth or "Head" or Pressure against the squeegees in front and rear compartments
   - C. Squeegee Properties
     1. Dimensions
     2. Durometer Hardness
     3. Elasticity
     4. Plasticity
     5. Composition
   - D. Squeegee Mounting
     1. Runner Setting – Distance from Clamp to Pavement
     2. Clamp Angle
     3. Stretch Tensioning
     4. Squeegee Pavement Contact Pressure
   - E. Forward Speed or Velocity
     1. Effect of dynamic planing
     2. Effect of slurry motion – rolling distribution

PART II – A SIMPLIFIED METHOD FOR MEASUREMENT OF PAVEMENT SURFACE MACROTEXTURE. . . . THE SURFACE DEMAND FOR SLURRY SEAL

Since Slurry Seal deposits a bituminous mix according to the demands of the surfaces, it becomes necessary to know what indeed the demands are. Measurement of the surface demand (quantity of slurry seal required to fill surface voids and deposit a mono-layered slurry seal) involves a description of:

A. The surface texture, and
B. The surface geometry

This paper is concerned with only the measurements of pavement surface texture.

Several methods have been developed to describe the texture of a surface. McLeod (3) followed by the Asphalt Institute (4) the Kansas Department of Transportation (5) and many others, describe pavement surface texture as follows:

B - Black
S - Smooth, Non-porous
H-1 - Slightly porous, Oxidized
H-2 - Slightly pocked, porous, Oxidized
H-3 - Badly pocked, porous, Oxidized

Jerry Rose (6) described the measurement of surface texture by means of:

a. a tracing profilograph
b. a string needle texture meter
c. sand patch measurements
d. putty flow or impression

Professor Rose's work is primarily aimed at measuring texture depths required to prevent hydroplaning and to understand the role of macrotexture in skid resistance speed gradients.

The Kentucky Department of Transportation (7) method # 64-307-74, "Measurement of Texture Depth by the Sand Patch Test" is a further example of texture measurement methods.

Schonfield (8) neatly classifies all possible pavement macro and microtextures and projection shapes by optically measuring stereo photographs of pavement surfaces. His primary purpose is to determine skid resistance photo-optically.

Though the above methods are effective for the purpose intended I should like to present a simpler method for use of our industry to determine the demand of a surface for slurry seal.

I suggest that a small wooden spreader box be filled with fine sand and drawn over the pavement to be treated and to then measure the distance travelled by a given volume of sand. Smooth surfaces should give long distances and coarse surfaces should be much shorter.

As a simple trial of the method, we constructed from common furring strips (5/8" x 1-3/4" pine) a "sand box" (Figure 1) of about 17 x 44 x 82 mm inside dimensions and containing about 60 cc volume. The box is placed on the pavement, one open side down, filled with -50, +100 mesh silica sand, struck off level full, weighted to 3 pounds (1.3 Kg.) and drawn along the surface until the sand is exhausted. The length of travel is measured and reported an "____ feet, 60 cc sand box texture".

The results of several comparative measurements follows:

--SAND BOX MACROTEXTURE--

Distance Required to Spread 60 cc, -50 mesh sand, with 3 lb., 17mm box

1.	Figure 2	Steel finished concrete		16 ft. ± 5%	4.9 m
2.	Figure 2	Roofing felt, outside edge		16	4.9
3.	"	Roofing felt, inside		18	5.5
4.	Figure 3	Two-Year Hot Mix, oil soaked	Wheel track	12.5	3.8
5.	"	Same	Transverse	12.5	3.8
6.	"	Same, Oil free	Wheel track	10.0	3.1
7	"	Same	Transverse	9.5	2.9
8.	Figure 1	Board finished concrete		8.5 ft. ± 5%	2.6
9.	Figure 4	Old Hot Mix Parking Lot		6.0	1.8
10.	"	Same with single coat Tar Emulsion		8.0	2.4
11.	Figure 5	Adjacent 2-month old Hot Mix		10.5	3.2
12.	Figure 6	5-Year Shoulder Mix 5.5, 8.0, 6.6 avg.		6.5	2.0
13.	"	Same	Transverse	7.1	2.2
14.	Figure 7	7-Year Type 2 slurry. . .	Longitudinal	4.3	1.3
15.	"	Same	Transverse	3.7	1.1
16.	"	10-Year Hot Mix.	Longitudinal	4.8	1.5
17.	"	Same	Transverse	3.5	1.1

Comment: Do not confuse sand-box macrotexture as measurements of skid resistance. In general, sand box macrotexture measurements of more than 10-12 feet (3 to 3.5 metres) is subjectively judged as a suspicious lack of adequate macrotexture to prevent hydroplaning.

This sand box method for the measurement of pavement macrotexture offers, after development, standardization and field correlation, a method for the common understanding of the demand of a pavement surface for Slurry Seal.

From the above data, it is clear that a relationship exists between the macrotexture and the amount of sand required to fill the surface voids (equals "surface demand"). To predict precisely the application rate of a given slurry will require study of other variables such as spreader box set-up, squeegee properties, slurry consistency and depth of slurry carried in the box during spreading operations.

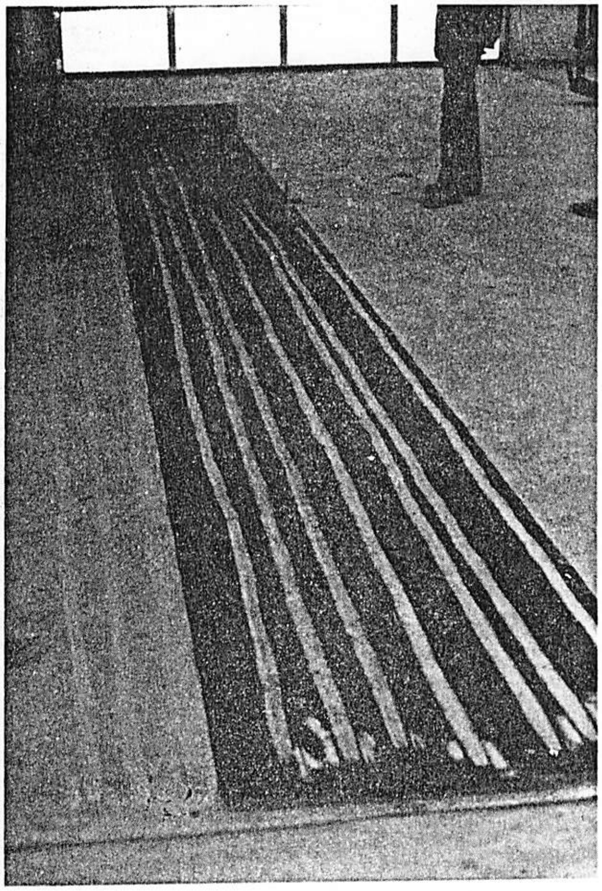

FIGURE 2

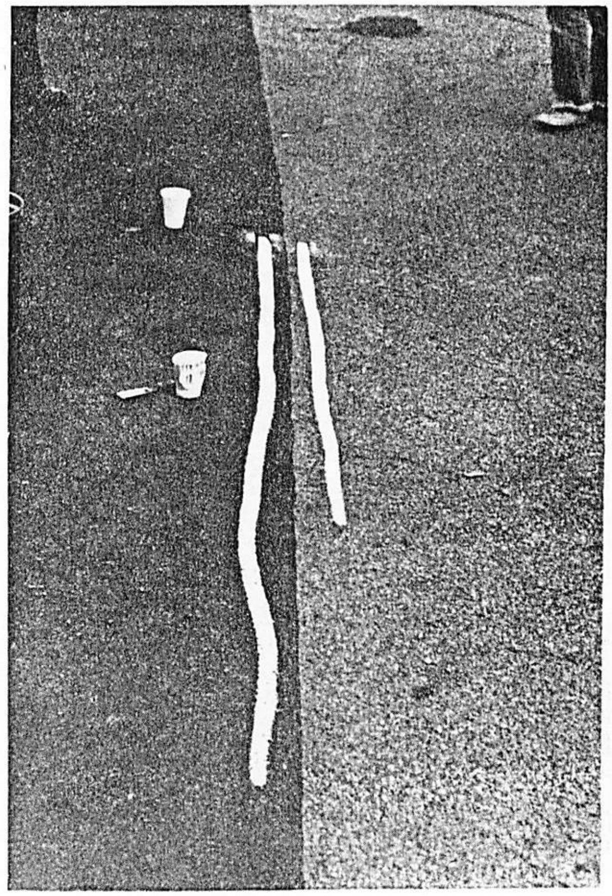

FIGURE 4

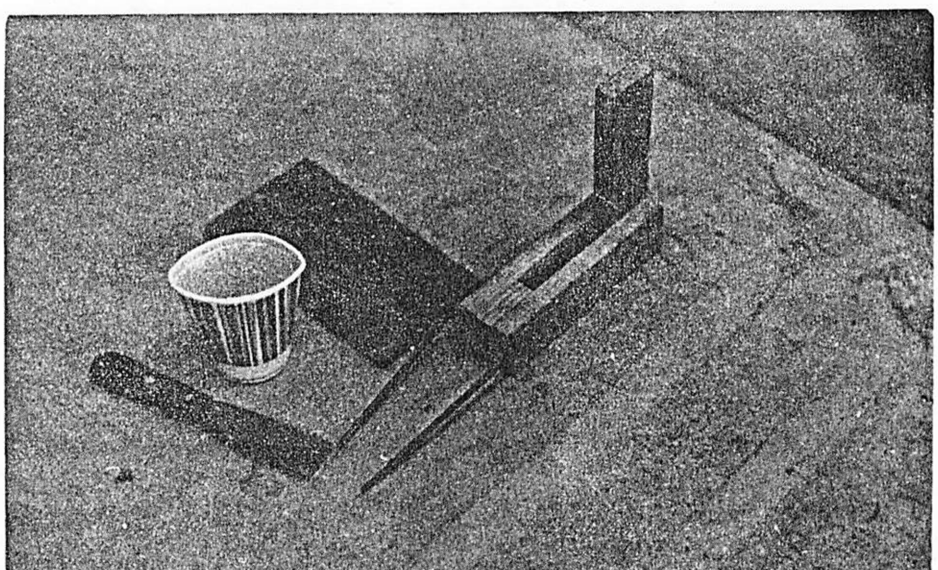

FIGURE 1

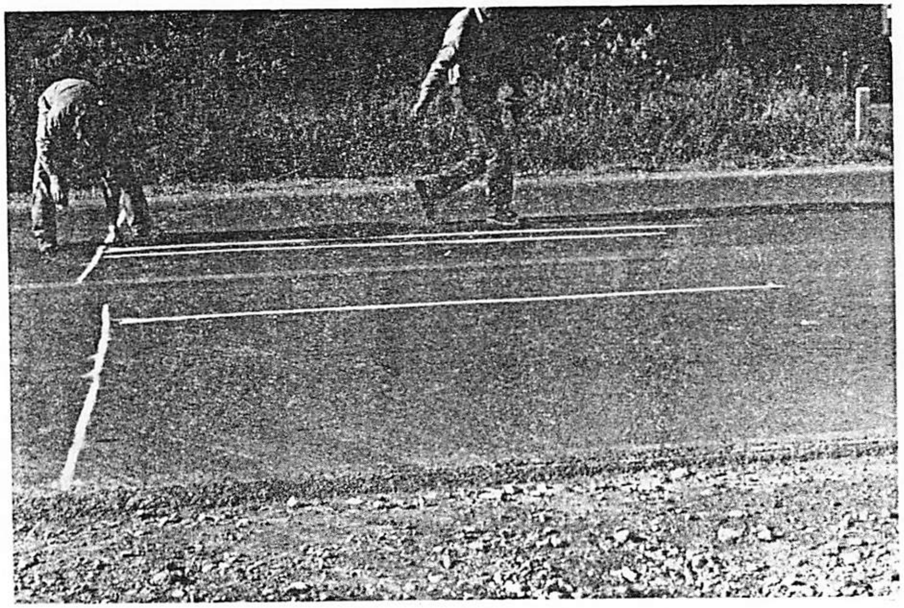

FIGURE 3

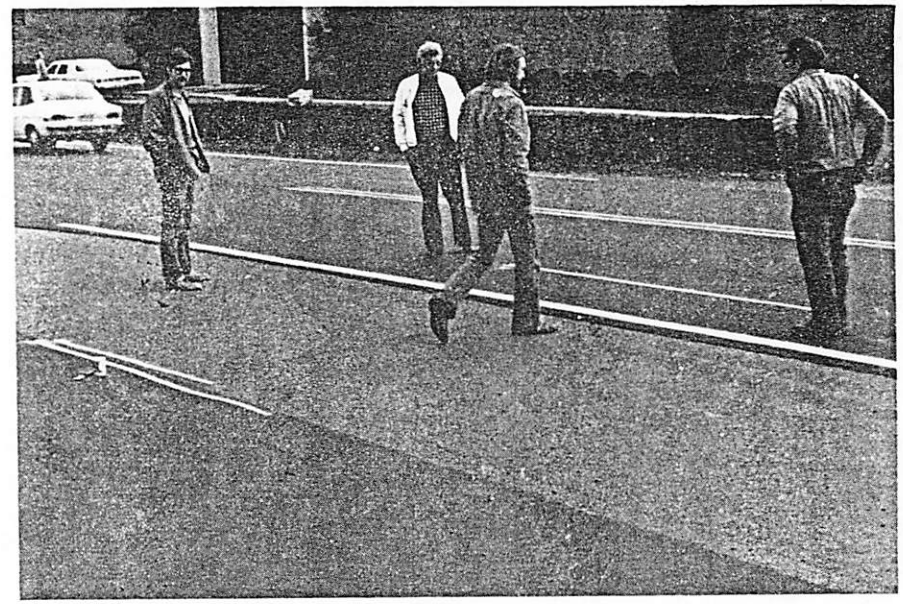

FIGURE 5

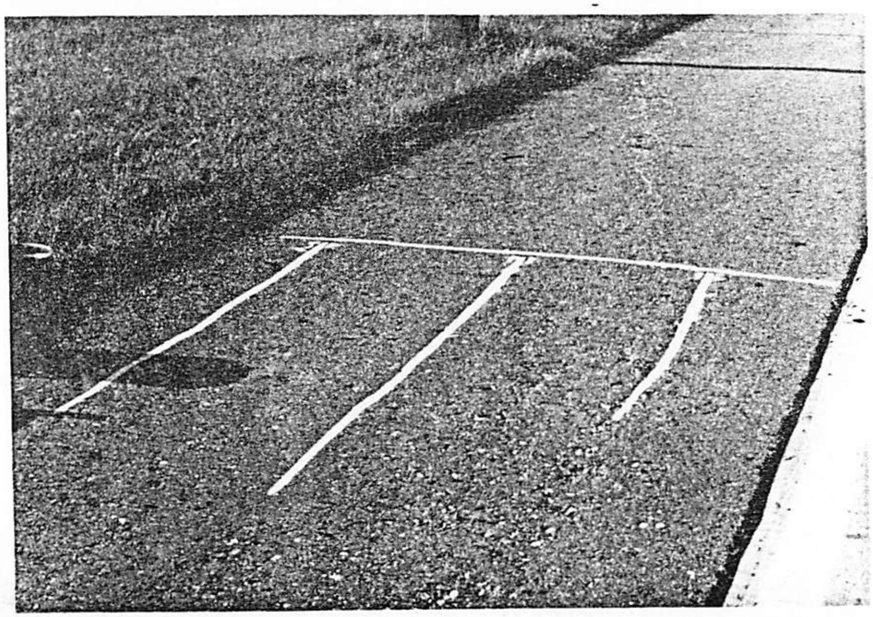

FIGURE 6

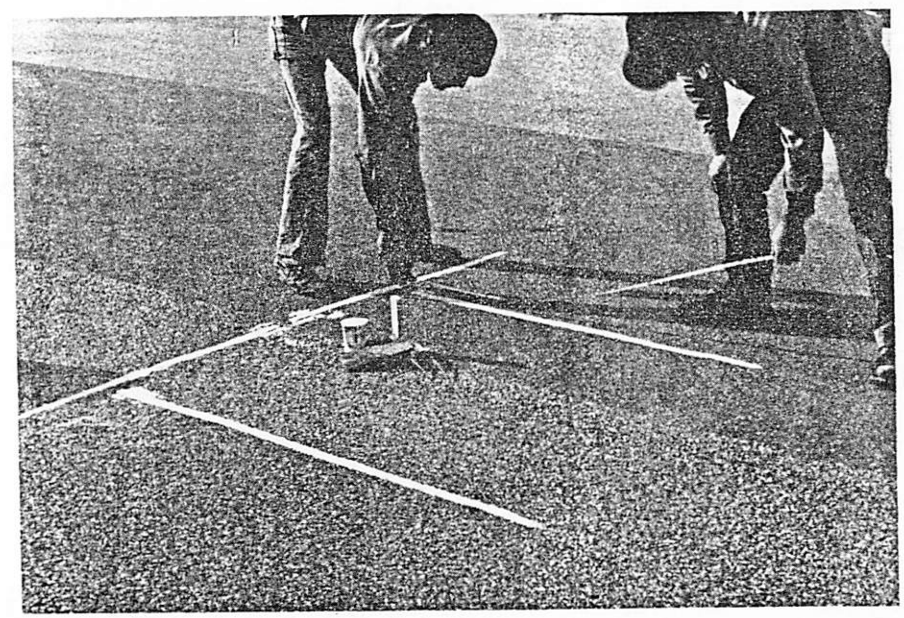

FIGURE 7

PART III – THE ROLE OF SQUEEGEE PROPERTIES, CLAMP-GAP SETTINGS, SLURRY CONSISTENCY AND DEPTH OF SLURRY IN THE SPREAD RATE DESIGN AND CONTROL OF SLURRY SEAL

At least 33 factors affecting the spread rate of slurry seal have been identified. The degree of success of a particular slurry seal application is judged by its initial appearance and its long term durability. Neither quality can be fully achieved without an understanding of what the spread rate should be and how to achieve it in the field.

In order to understand the mechanics of slurry seal spread rates, all factors should be studied and evaluated. However, for present purposes, this paper will deal in a preliminary, experimental way, only with the following factors:

1. Properties of the strike-off squeegee – dimensions, properties etc.
2. Measurement of squeegee-pavement contact pressure relative to squeegee hardness and runner settings (clamp distance to pavement or clamp gap)
3. Measurement of application rates to smooth, textureless surfaces by varying the:
   a. Squeegee contact pressure
   b. Slurry mix consistency
   c. Depth or "head" pressure of the slurry

The experimental procedure adopted here involves the measurement of pavement, static contact pressures or weights at 3 settings of 11, 6" long squeegees mounted in a conventional 90^{o} clamp. Two squeegees were then selected and mounted on a 1 liter spreader box. The box was then filled with 1000 or 2000 grams of a Type 2 slurry and drawn over pre-weighed 30 cm. (12") smooth textured, continuous sections of roofing felt. After air drying, the slurried sections of roofing felt were weighed and the grams per square cm. application rate were calculated.

Table No. 1 describes the properties and contact pressures of the squeegees used. The 6" long squeegees ranged in Durometer hardness (1) from 78 to 38. The dimensions ranged from 1/2" to 1/4" (1.3 to .75 cm) thick. Contact pressures ranged from 38 to 7.5 pounds per lineal foot (550 to 110 grams/lineal centimeter) of squeegee contact. Figures 1 and 2 show the scale and clamp apparatus used to obtain the squeegee pressure values shown in Table No. 1.

Figure No. 8 shows graphically the difference between the various squeegees at clamp-to-pavement distances (runner settings) of 1-1/2", 2" and 3" (3.8, 5.1 and 7.6 cm). For example, the number one squeegee, when set at a 1-1/2" (3.8 cm) runner setting and spanning pavement ruts of 1-1/2" (3.8 cm) deep, will exert pavement contact pressures ranging from 38 lbs/lineal foot (550 grams/lineal centimeter) to 19 lbs/lineal foot (270 grams/lineal centimeter) depending on rut depth.

Figure No. 3 shows the one liter spreader box with a squeegee clamped in the 1-1/2" setting. Figure No. 4 shows a completed 5 cm. cone flow consistency test (2). Figures No. 5, 6 and 7 show the spreading operation and completed spread on the roofing felt panels.

A graph of the data for 3/8" squeegees in Table 1 is shown in Figure No. 8. Figure No. 9 shows the graph for the 1/2" squeegees and one 4-ply transmission belt. As might be expected softer rubber exerts less pressure. The closer the clamp mounting to the pavement (runner setting), the greater the contact pressure. It is interesting to note that the slope of the pressure curves - softer rubber has a flatter curve than harder rubber. The contact pressure of 3/8" (1.0 cm) thick, hard rubber is roughly equal to 1/2" (1.3 cm) soft rubber. Shorter projections yield greater contact pressures.

Figure No. 10 shows the effect of consistency. Drier or stiffer mixes spread more slurry (from 10 to 30% more over the range of 5 to 2.5 cm consistency).

Figure No. 11 shows the effect of an increase in box fill depth or "head" due to hydrostatic pressure of the slurry against the squeegee. A 2" (5 cm) increase in depth increased the spread rate by 10 to 12%.

We observed that for this particular series that much better looking spreads were obtained with this aggregate with softer squeegees, lower contact pressures and the stiffer mixes. There was better matrix formation, large aggregate contact and less tendency for abrasion loss or "kick-out".

Much more data is required to add certainty to the foregoing. I am aware that 2 points, a graph does not make, and offer this limited data to stimulate thought and criticizm of the method.

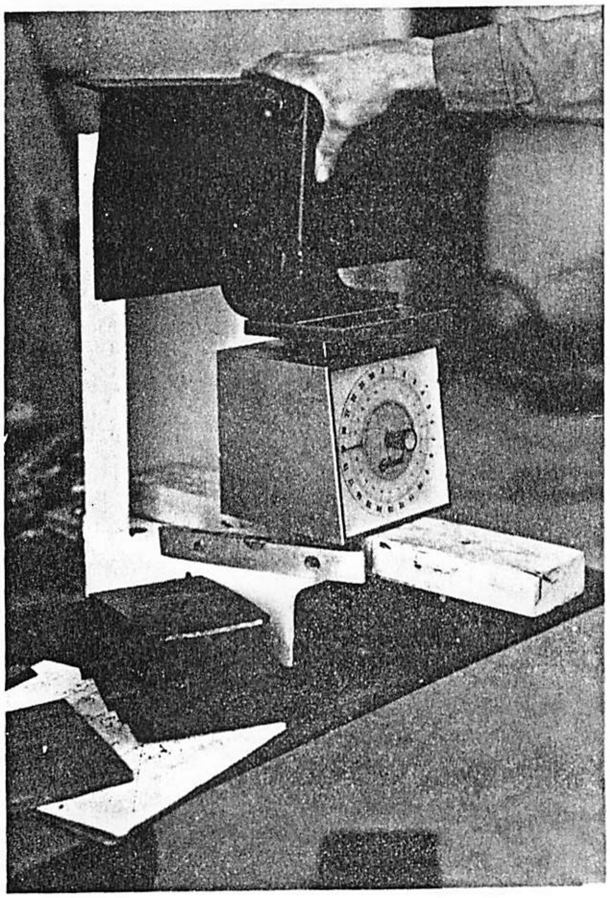

FIGURE 1
CONTACT PRESSURE DEVICE

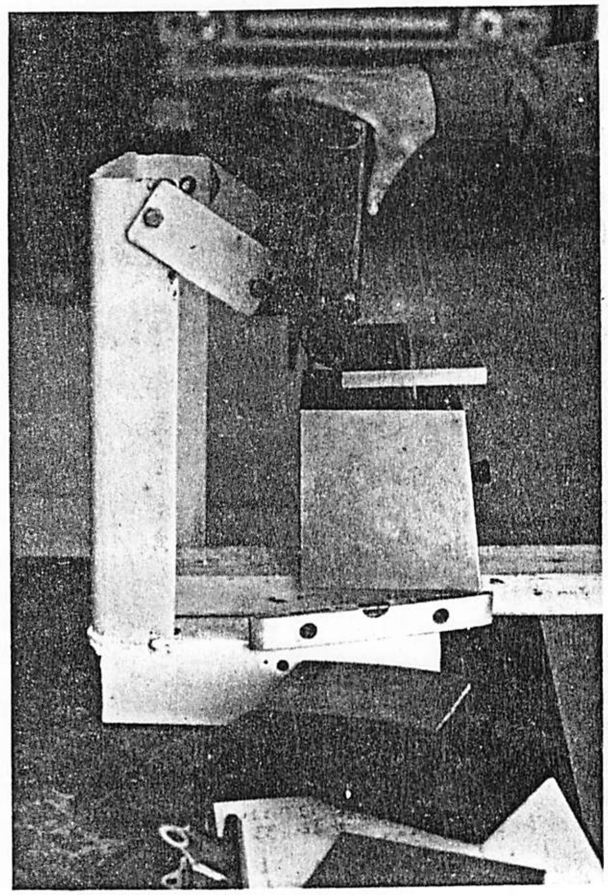

FIGURE 2
SIDE VIEW - CLAMP & SCALE

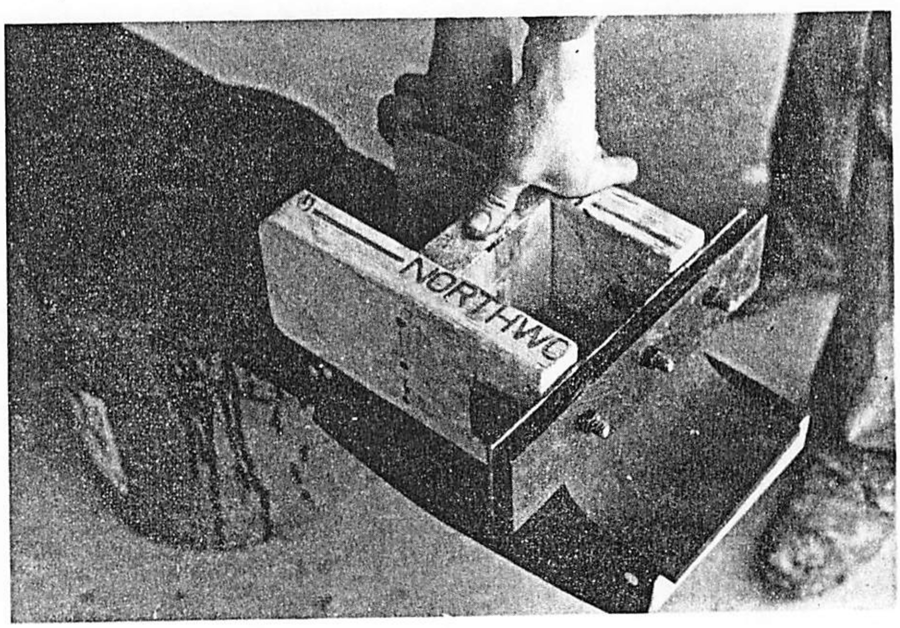

FIGURE 3
1 LITER SPREADER BOX - 6" SQUEEGEE
CLAMPED AT 1-1/2" INCH SETTING

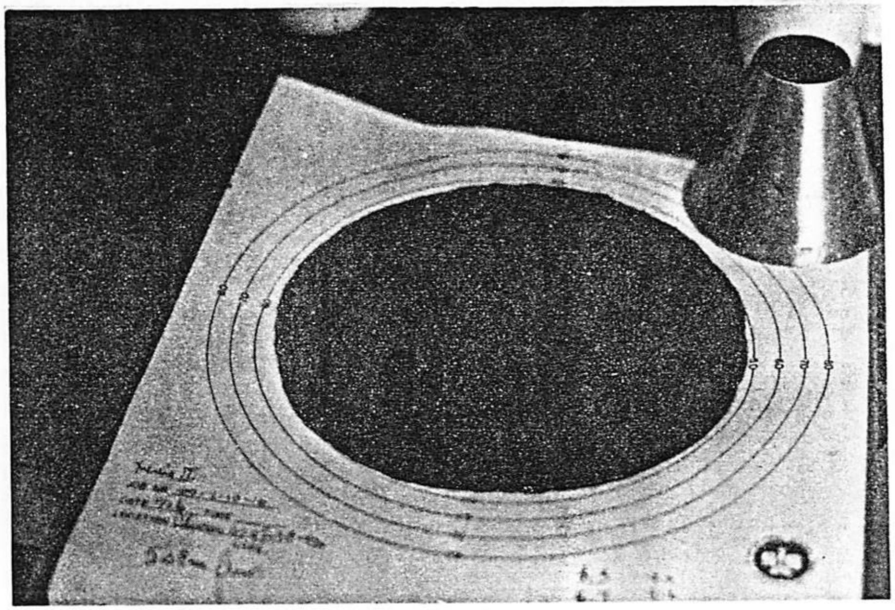

FIGURE 4 – 5 CM SLURRY CONSISTENCY

FIGURE 5 – FILLING THE BOX

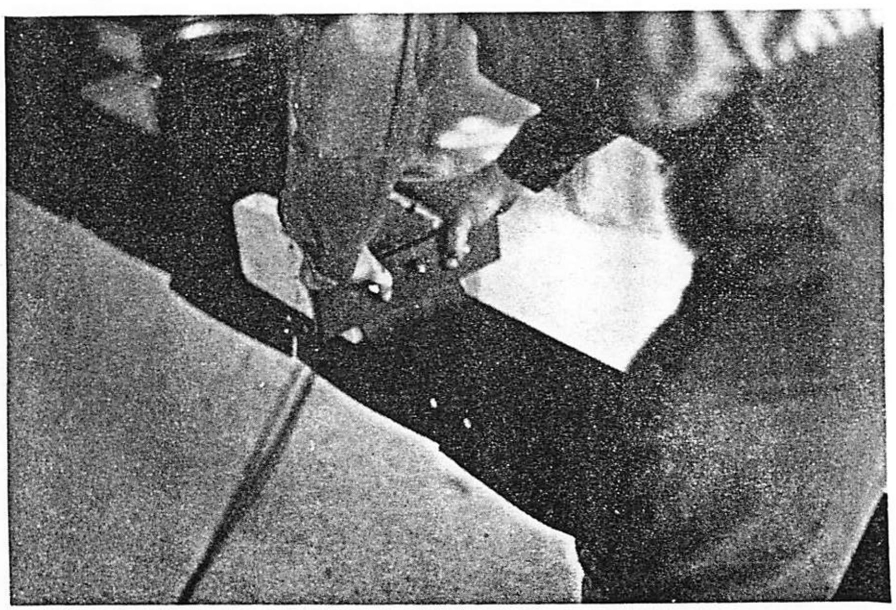

FIGURE 6 – MAKING THE SPREAD

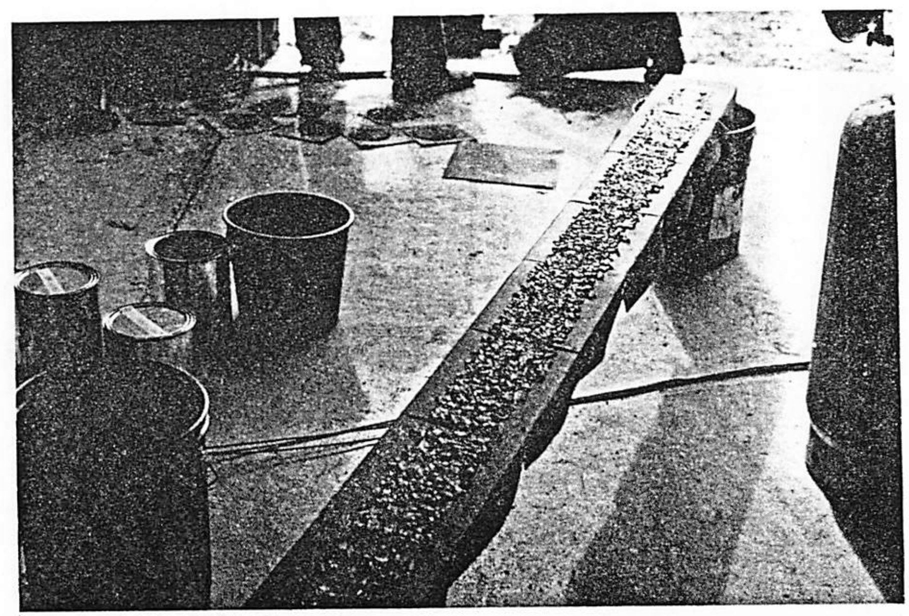

FIGURE 7 – COMPLETED SPREAD

RUBBER TYPE	DURO-METER	NOMINAL DIMENSIONS	PROJECTION FROM CLAMP	90°- STATIC CONTACT PRESSURE @ CLAMP DISTANCE TO SCALE 1.5"	2"	3"
1. Armorlite	77	3/8 x 6 x 5 in.	1.0 x 9.7 cm.	lbs. 18.94 Kg. 8.59 (564)	12.19 5.53 (363)	9.75 4.42 (290)
2. Neoprene	61	3/8 x 6 x 5-1/2 in	.9 x 11.2 cm	8.13 3.69 (242)	6.19 2.81 (184)	5.75 2.61 (171)
3. *Armorlite	78	3/8 x 6 x 6 in.	1.0 x 12.4 cm.	*14.44 6.54 (429)	*11.19 5.40 (354)	8.88 4.03 (264)
4. Neoprene	61	1/2 x 6 x 5 in.	1.3 x 9.8 cm.	13.75 6.24 (409)	12.63 5.73 (376)	9.19 4.17 (274)
5. *Neoprene	60	1/2 x 6 x 5-1/2 in	1.3 x 11.1 cm	14.13 6.41 (421)	11.25 5.10 (335)	6.88 3.12 (204)
6. Neoprene	60	1/2 x 6 x 6 in.	1.3 x 12.4 cm.	12.18 5.52 (362)	9.13 4.14 (272)	7.88 3.57 (234)
7. *Gum Rubber	38	3/8 x 6 x 5-1/4	1.0 x 9.1 cm.	*5.75 2.61 (171)	4.69 2.13 (140)	3.75 1.70 (112)
8. 4-Ply Belt	63	1/4 x 6 x 4-1/4	.75 x 8.7 cm.	8.76 3.97 (261)	6.18 2.80 (184)	3.94 1.79 (117)
9. Neoprene	67	3/8 x 6 x 5 in.	.95 x 9.9 cm.	9.88 4.48 (294)	9.00 4.09 (268)	6.00 2.72 (178)
10. Neoprene	67	3/8 x 6 x 5-1/2	.95 x 11.0 cm.	10.75 4.88 (320)	7.63 3.46 (227)	6.63 3.01 (197)
11. Neoprene	63	3/8 x 6 x 6 in.	1.0 x 12.2 cm.	10.25 4.65 (305)	7.75 3.52 (231)	5.75 2.61 (171)

TABLE 1. Contact Pressure, Description, Dimensions and Mounting of Various 6 inch long Strike-off Squeegee Rubbers
* Used for Spread Data
(Bracket numbers are Grams/lineal centimeter)

RUN NUMBER	1	2	3	4	5	6
Squeegee Contact Pressure	429	354	429	170	170	170
Slurry Consistency - cm	5	5	2.5	5	2.5	2.5
Slurry Aggregate - grams	1000	1000	1000	1000	1000	2000
Slurry Depth (Head) cm	5	5	5	5	5	11
Spread - Gr/cm^2 (#2,3 panels)	.362	.399	.397	.449	.543	.611
Spread Rate-lbs/SY	6.7	7.4	7.3	8.3	10.0	11.3
Spread Rate-Kg/SM	3.62	3.99	3.97	4.49	5.43	6.11

TABLE 2. Tabulation of one liter spreader box experimental spread rates vs. squeegee contact pressure, consistency and head.

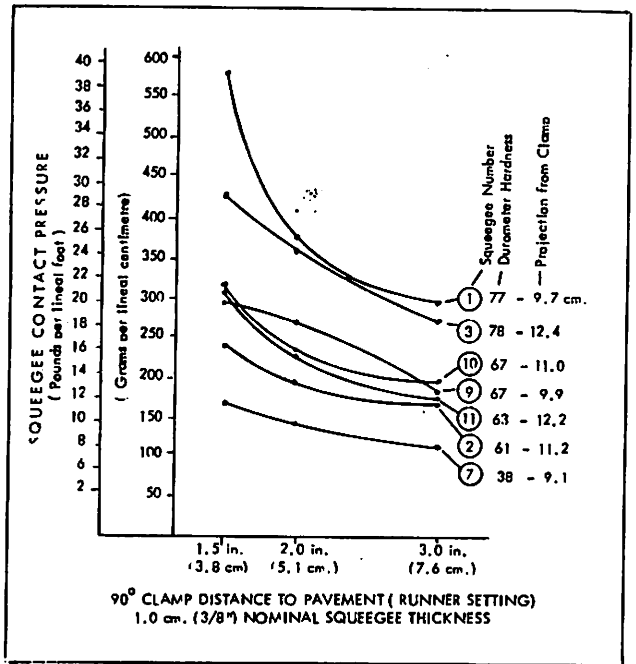

Figure 8 EFFECT of DUROMETER HARDNESS, PROJECTION LENGTH and RUNNER SETTING (CLAMP GAP) on SQUEEGEE CONTACT PRESSURE

-12a-

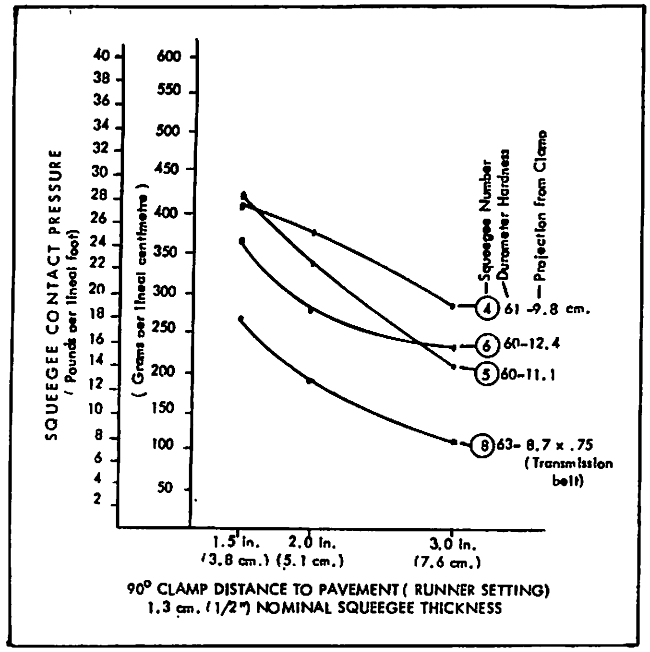

Figure 9. EFFECT of DUROMETER HARDNESS, PROJECTION LENGTH and RUNNER SETTING (CLAMP GAP) on SQUEEGEE CONTACT PRESSURE

-12b-

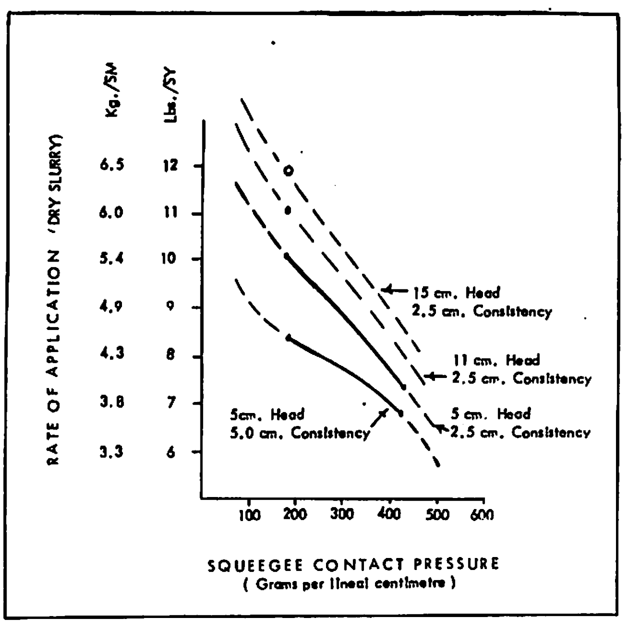

Figure 10. EFFECT of CONSISTENCY, HEAD and CONTACT PRESSURE on the SPREAD RATE for a MEDIAN TYPE 2 SLURRY SEAL

-12c-

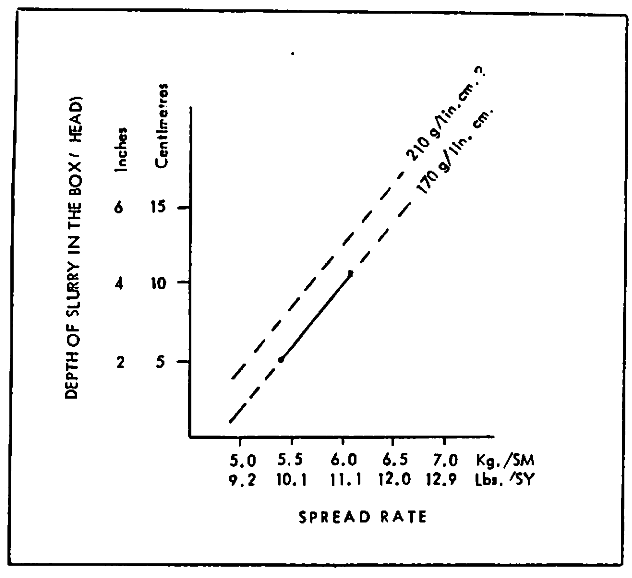

Figure 11. EFFECT OF SLURRY DEPTH ("HEAD") ON THE SPREAD RATE (Median Type 2 Slurry-- 2.5 cm. Consistency-- 170 g/lin.cm. squeegee contact pressure--applied to a smooth surface.)

-12d-

Finally, the 10% Super Elevation Section shown gives a uniform clamp gap of 3 inches resulting in a uniform squeegee contact pressure of 210 g/lin. cm. However, the depth of slurry or "head" varies from 6 inches (15.2 cm.) on the low side to zero at the top side. Extrapolating from the limited data shown in Figure 11, Part 3, the spread rate varies from 11.6 lbs./SY (6.29 kg/SM) to 8.2 lbs./SY (4.45 kg/SM) or a variation of about 40%.

The problem of up-grade and down-grade spread rates involves a study of dynamics. Cross-sectional of transverse grades also require studies of distribution levels of slurry in the box and dynamic flows. Analysis of these and the even more complex situations of corrugations and wedge sections require much more study than presented here.

Summary:
The important point shown in these essays is that spread rates of slurry seal vary over a surface due to many complex factors. Spread rates may range from a "skinned" condition through a perfect "mono" layer to heavy multiple layers.

These conditions do exist and their effect on the surface voids, total voids, asphalt content, surface texture, durability, appearance and suitability in a particular situation should be considered in studying the design, construction and control of slurry seal spread rates.

Acknowledgment:
I wish to acknowledge the assistance of Marshall Mayfield, Gregg Hamilton and Harold Meier in the preparation of the laboratory data included in this paper.

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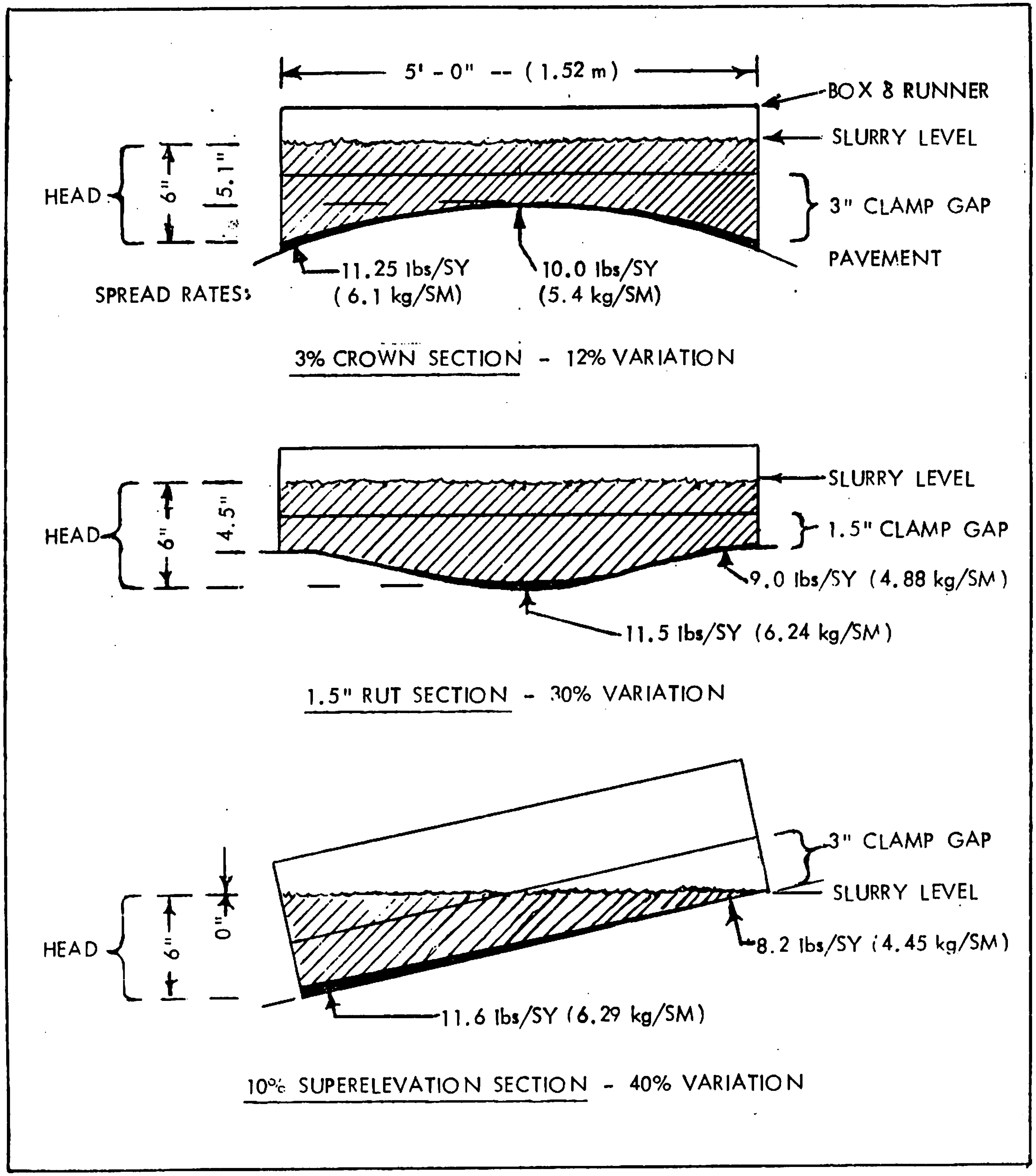

FIGURE 1. THEORETICAL SPREAD RATE VARIATIONS DUE TO PAVEMENT GEOMETRY
(Smooth Surface, 2.5 cm Consistency)