A PROGRESS REPORT ON A STUDY OF DURABILITY AND SKID RESISTANCE OF SLURRY SEALS FOR OHIO HIGHWAYS

Prepared by

C. Robert Benedict, Chairman
ISSA Research and Development Committee
February 22, 1979

A PROGRESS REPORT ON A STUDY OF DURABILITY AND SKID RESISTANCE OF SLURRY SEALS FOR OHIO HIGHWAYS

Following the 1973 Arab Oil Embargo, the need to use energy and material efficient pavement conservation techniques became extremely important to Ohio. Relentless inflation has caused our engineers to seek alternative, more cost effective techniques of pavement construction and maintenance.

Previously, conventional slurry seal design and construction techniques fell short of the best potential of the material. At that time the Ohio Slurry Seal industry embarked on a modest research program to learn and to demonstrate the part they could play to help control Ohio highway costs and to do so safely.

THE A-B ROAD TEST

In July of 1974 our first road test was constructed on Alexandersville-Bellbrook Road (A-B Road) in West Carrollton. Samples were analyzed from 18 marked locations over the 4000 ft. length of the project. A conventional 404 hot mix was simultaneously laid on a 600 ft. intersection approach to OSR 741 and served as reference comparison.

The samples were carefully analyzed by Bowser-Morner Testing Labs and periodic skid tests were run by ODOT at the request of the City of West Carrollton.

Figure 1 shows the results of these tests after nearly 4 years and 25,000,000 accumulated two-lane traffic.

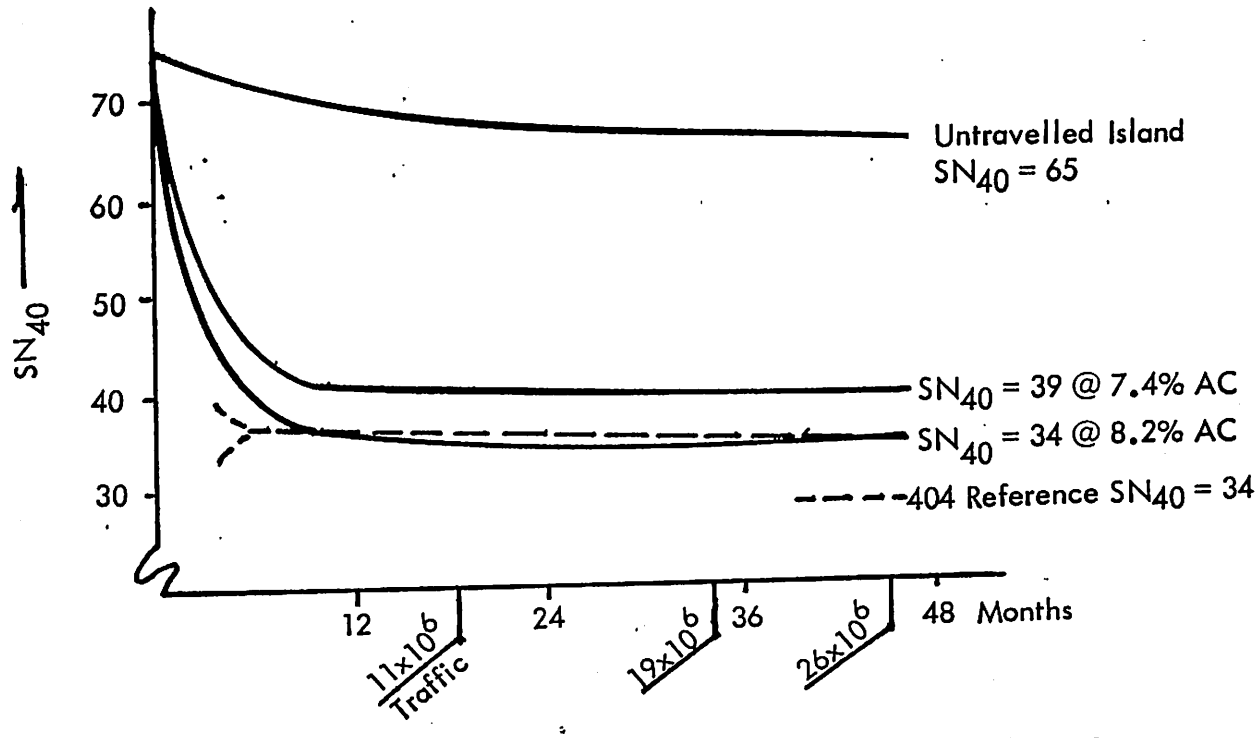
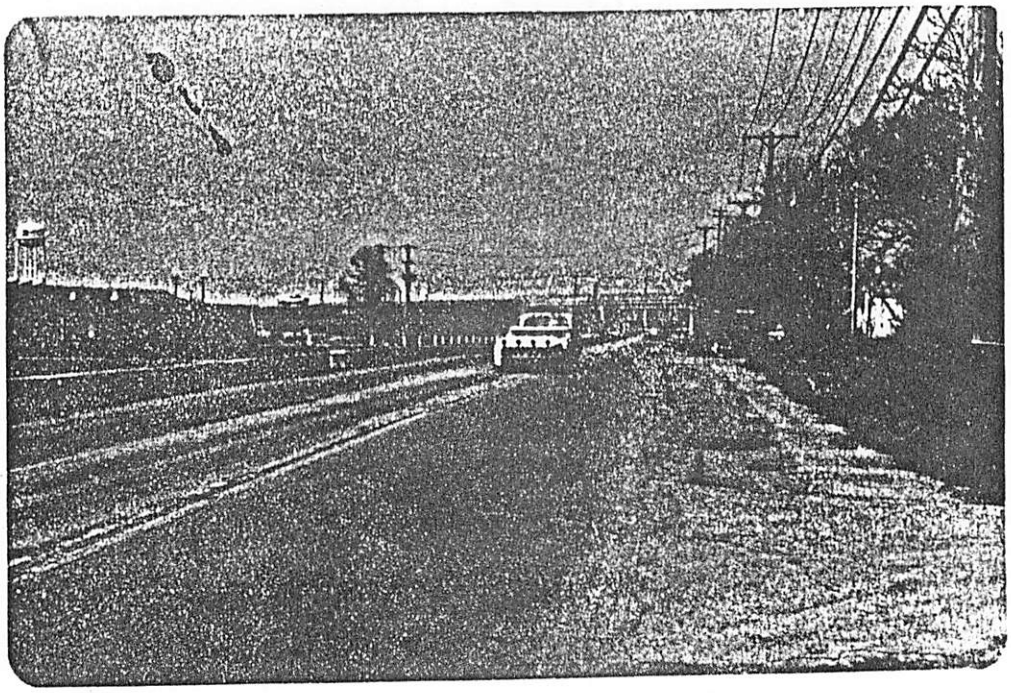
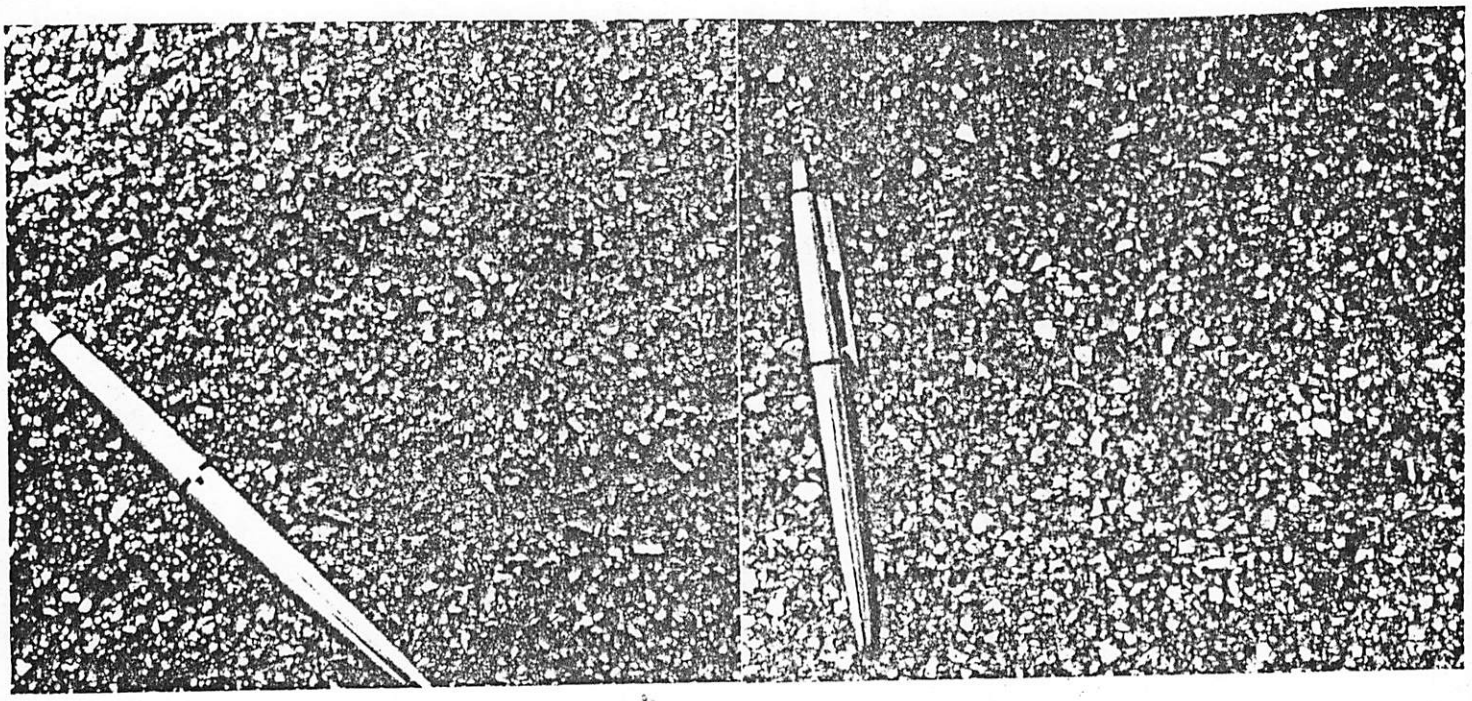


Figure 1. Effect of Asphalt Content on A-B Road Test Skid Numbers after 45 Months and 25,000,000 Accumulated Traffic



Final skid tests being performed on the A-B Road after 25,000,000 accumulated traffic. ODOT type B.



A-B Road untravelled texture close-up ($SN_{40} = 70$)

A-B Road type B texture at end of test ($SN_{40} = 39$)

The following observations were made:

1. This slurry has a very high initial skid resistance (SN_{40} = 70+) but is quickly compacted by traffic to a stable skid number dependent upon the AC content.

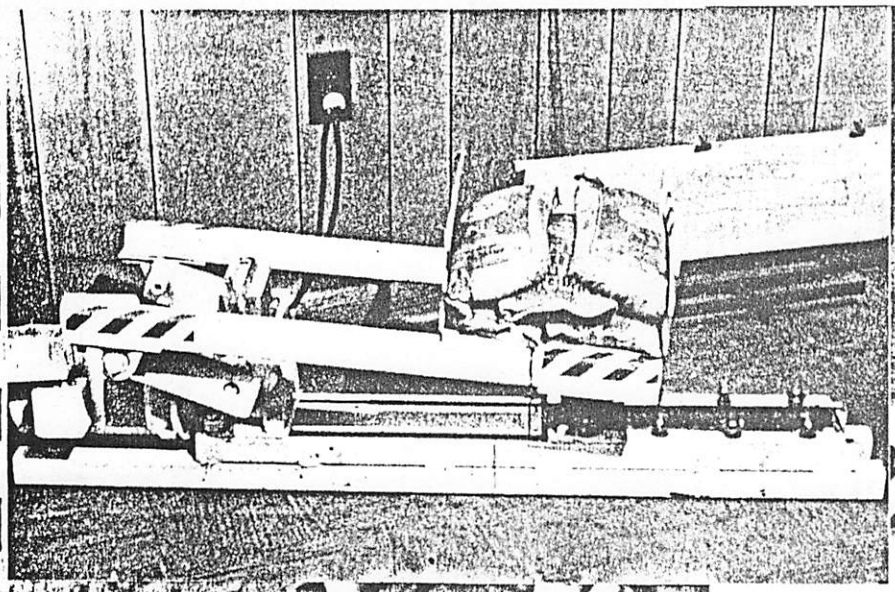
2. When the AC content is low (7.4%), the skid resistance is adequate.

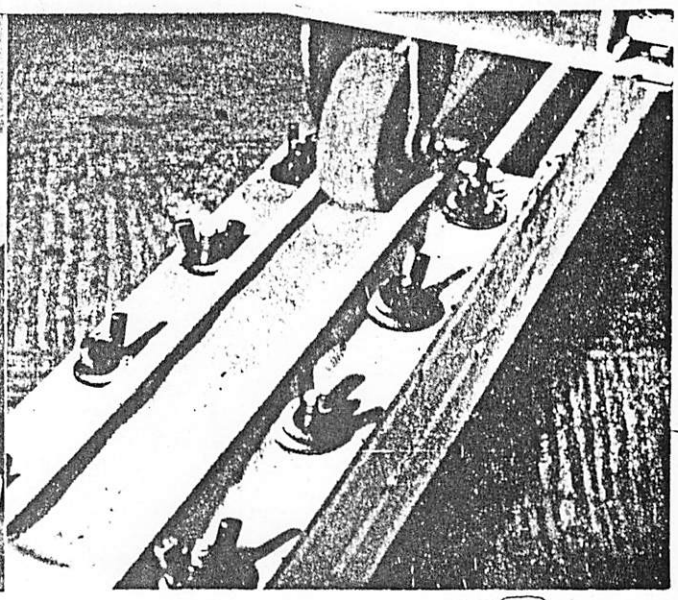
3. When the AC content is high (8.2%), the skid resistance is low.

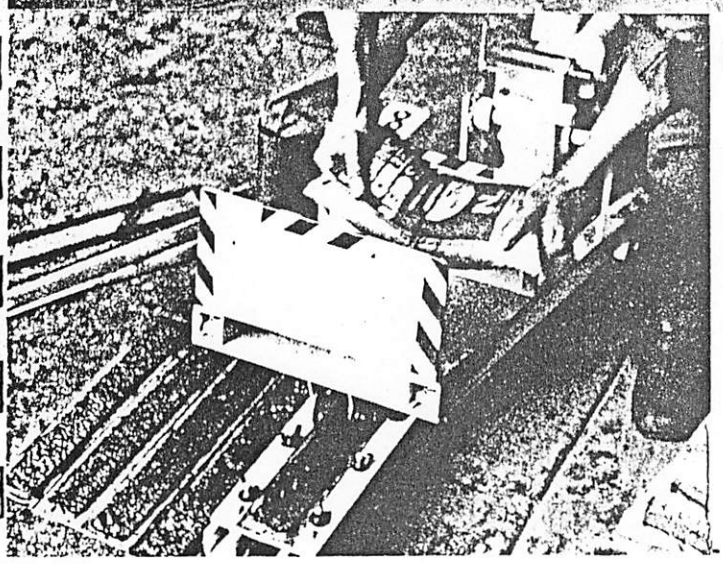
4. At low levels of AC and when this Xenia type 2 gradation is applied at 14.3 lbs/SY, adequate durability and skid resistance is maintained for at least 25,000,000 accumulated traffic.

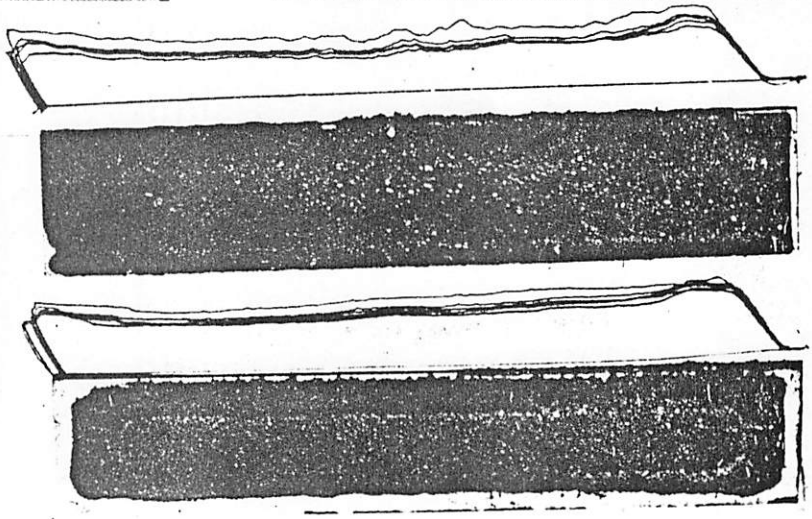
5. The 404 hot mix maintained a consistently lower skid number than did the adjacent slurry.

The field quantities and designs were reproduced in the laboratory and subjected to a new ISSA developed traffic simulating device called the Loaded Wheel Tester (LWT) which can simulate the compactive effort of 1,000,000 vehicles in 25 minutes. From the LWT data, a new design technique was developed to define maximum AC limits for safe, thin layer design.









OHIO DOT APPLICATIONS - SR 42, XENIA

In late 1976, Willis B. Gibboney, of ODOT, was assigned to work with the slurry seal industry to write a new specification that would incorporate mix design procedures and overcome the problems associated with acceptance sampling and testing of the slurry by centrifuge extraction.

The new specification has been applied successfully to four state jobs to date, notably SR 42 southwest of Xenia.

The new specification, of the quality assurance type, provides for:

1. The contractor to design the slurry in accordance with ISSA Technical Bulletins.
2. Materials to be tested and approved prior to use.
3. Acceptance of the slurry proportioning and spread rate by lots of 15,000 SY each on the basis of the engineer's account of the quantity of aggregate and emulsified asphalt used.
4. Acceptance tolerances with penalties for non-conforming, both in spread rate and emulsified asphalt proportion.
5. Use of single, continuously self-loading travel plants for work on appropriate roadway types.

Self-propelled continuous slurry machine applying ODOT type C slurry to Ohio SR 42 near Xenia. Late August - 1977.

Re: Project No. 738: SR 42; Xenia, Ohio

LABORATORY DESIGN FOR FIELD CONTROL OF SLURRY APPLICATION

			Control Quantities	Tolerances
a.)	Aggregate	100.0%	--	--
b.)	Filler (1) - Type PC-IA	1.0%	20 lbs./ton	±4 lbs/ton
c.)	Mix Water (2)	8.0%	19.2 gal/ton	--
d.)	Cone Flow Consistency	2.5%cm.	--	±0.5 cm
e.)	AC Target Extraction	7.8%	--	--
f.)	Emulsion @ 62.5% Res. AC	12.5%	30 gal/ton	±4.0 gal/ton

(1) Percent added to the dry weight of the aggregate.

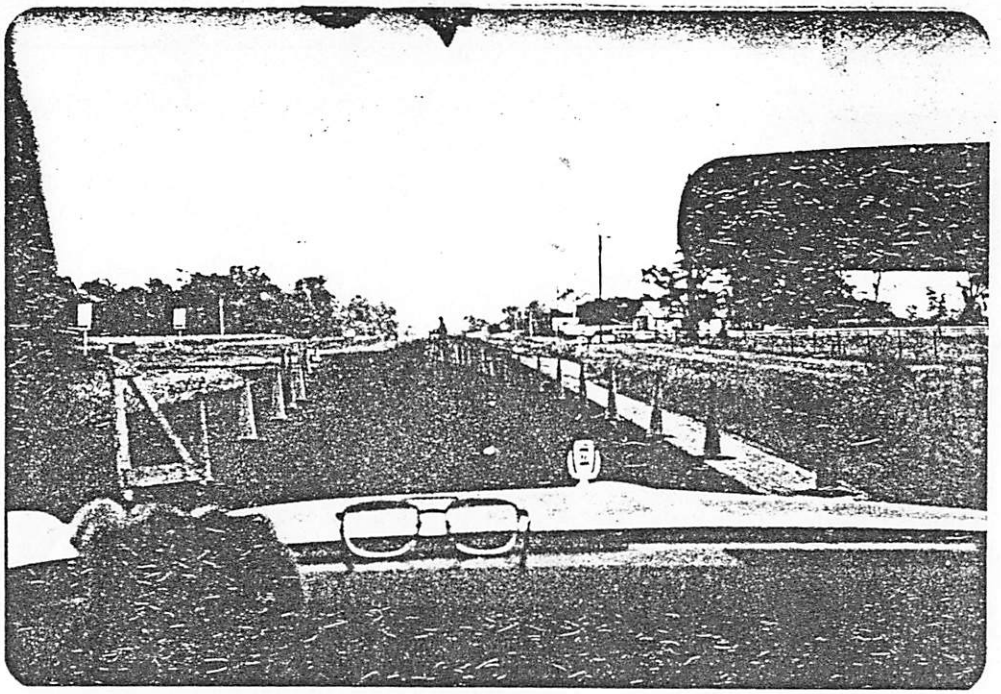
(2) This value is approximate, and is based on an aggregate moisture of approximately 2.0%. Actual water demand should be controled by the cone flow consistency.

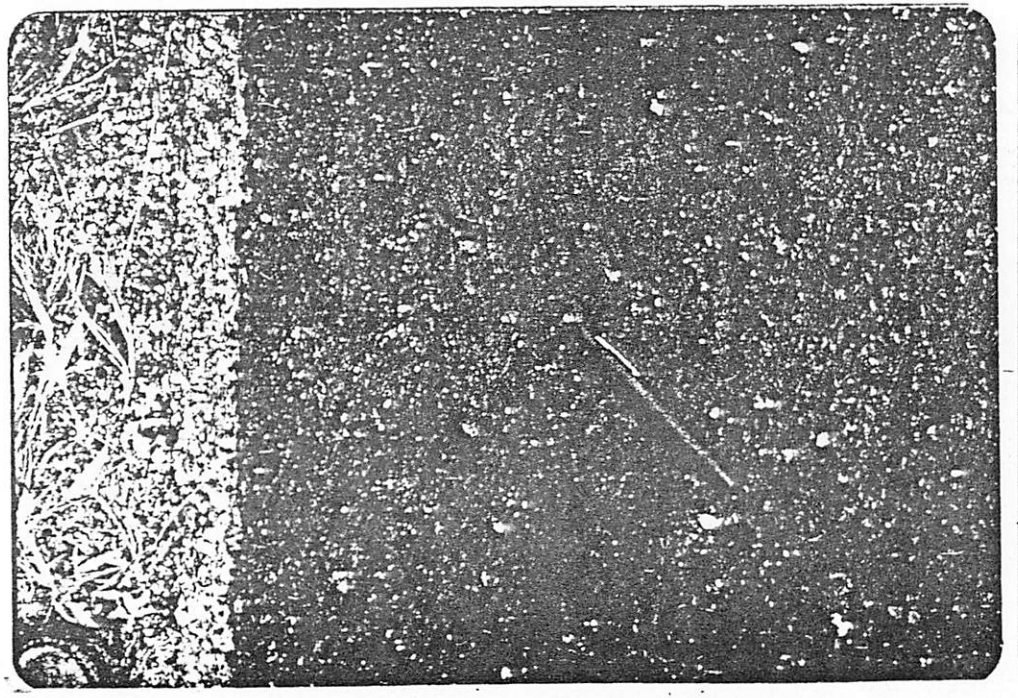
Table 1. Laboratory Design and Control limits for ODOT project no. 738-77 on OSR 42.

Lot. No.	Gals.	Lbs/SY	Gals/ton	SY
1	3618	*12.09 (a)	68.0 (a)	8,796
2	5570	28.09	29.35	13,517
3	8478	23.0	32.0	22,780
4	4953	20.0	32.0	15,118
5	7161	19.0	32.0	24,255
6	5050	19.49	28.21	18,376
7	2794	*18.93	27.0	10,936
8	3492	*18.63	27.28	13,760
9	3749	19.00	27.00	14,770
10	940	31.00 (a)	26.10	2,280
Average (valid)		20.77	28.99	
Design		20#	30.0 ± 5	

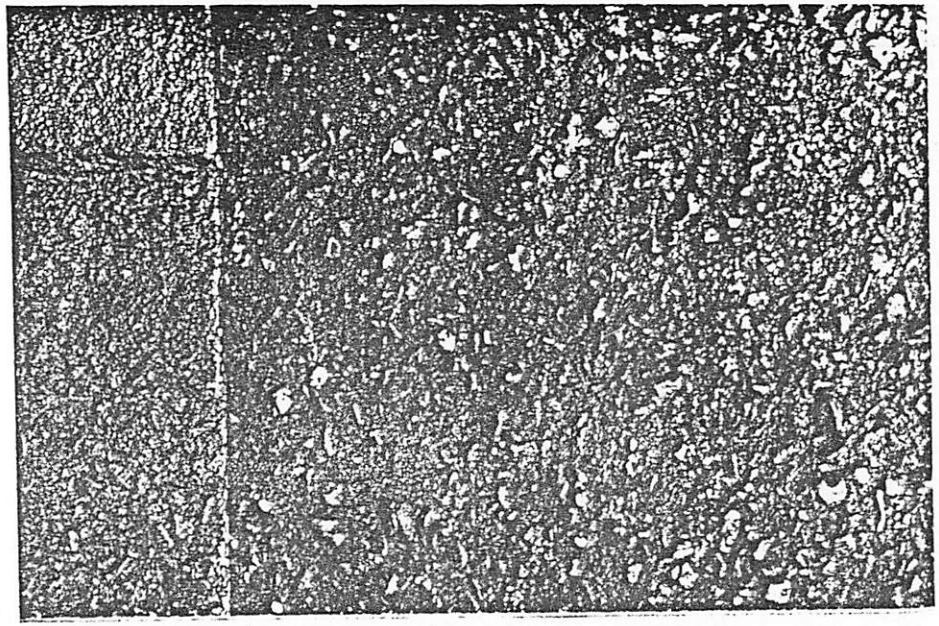
* Penalty (a) Vagary

Table 2. Summary of the inspector's report of the acceptance lots of the OSR 42 job.

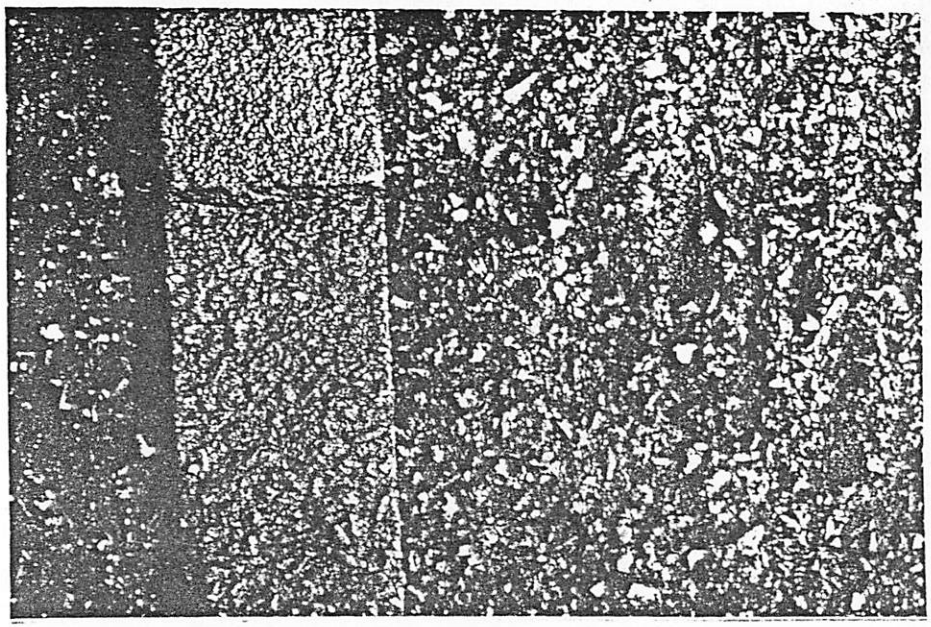




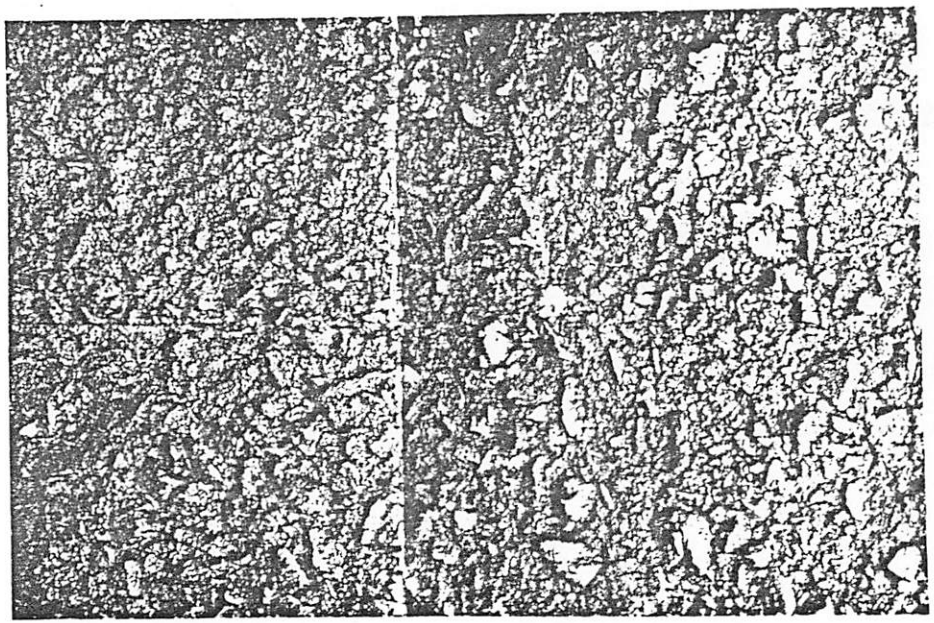
OSR 42 - Xenia. Final Day of ODOT Type C Slurry Seal Construction - Late August, 1977



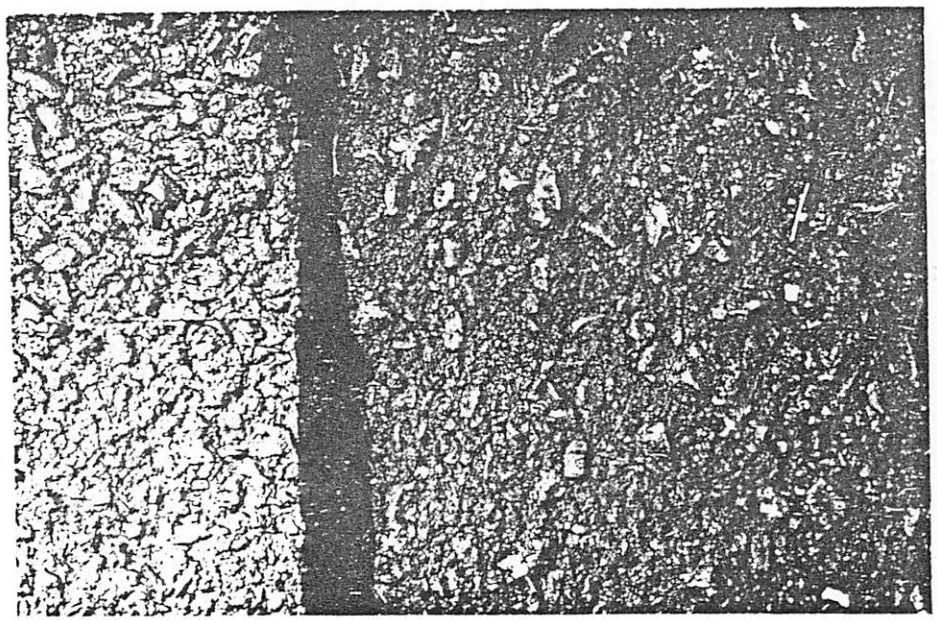
NB - 3 27 Lbs./SY (Multiple Layer)



NB-4 18 Lbs./SY (Minus-mono Layer)



NB - 3 Close-up



SB- 2 22 Lbs./SY (Mono Layer)

ODOT Type C Slurry Seal Textures - OSR 42, Xenia - 3 Weeks After Completion (Compare ODOT Types A & B)

Three series of skid tests have been made to date and show that, after one year of 2,000,000 accumulated traffic, excellent skid numbers are maintained and that the design and application were highly successful. Figure 2 shows these initial results. Continued testing is planned.

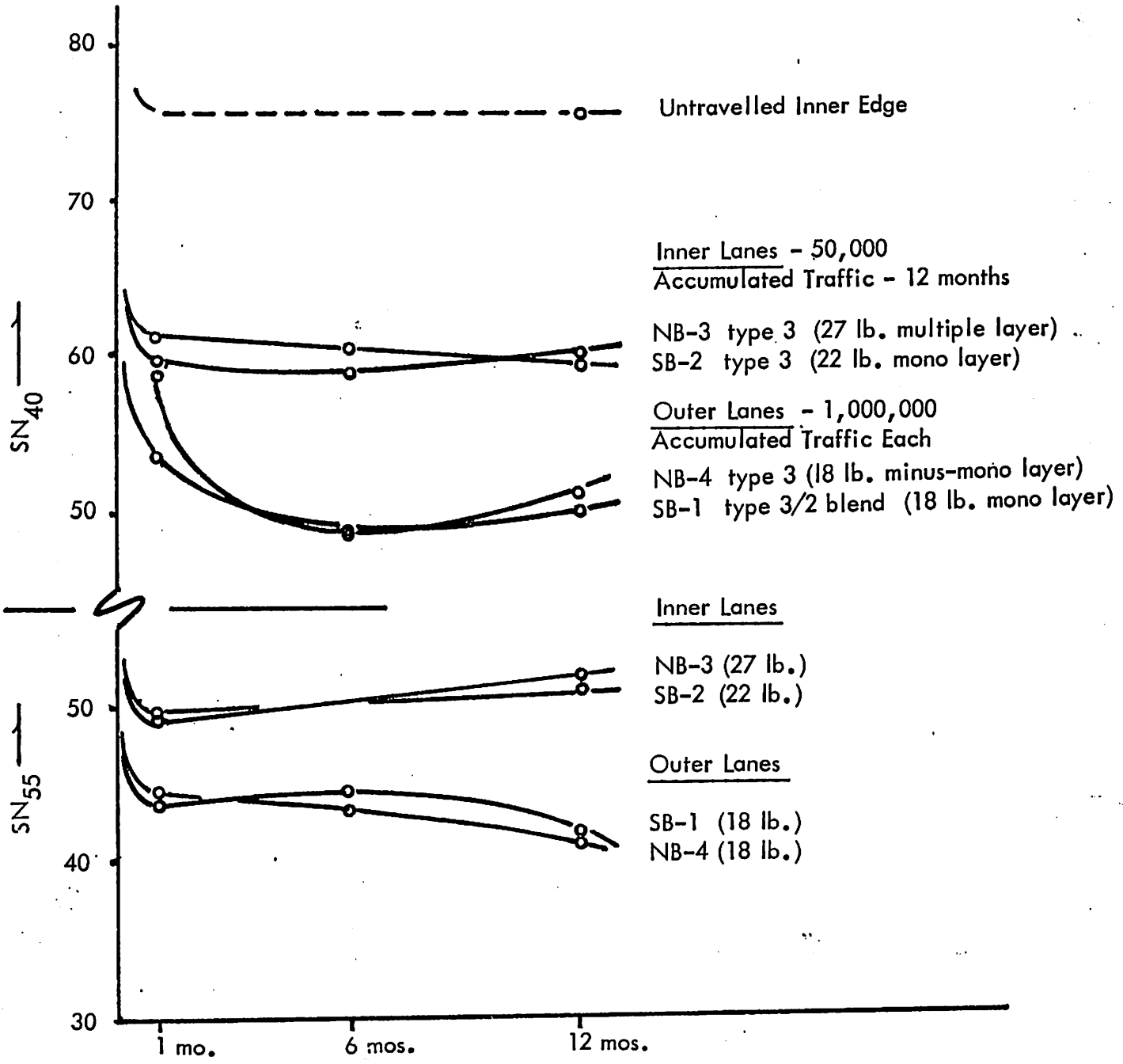
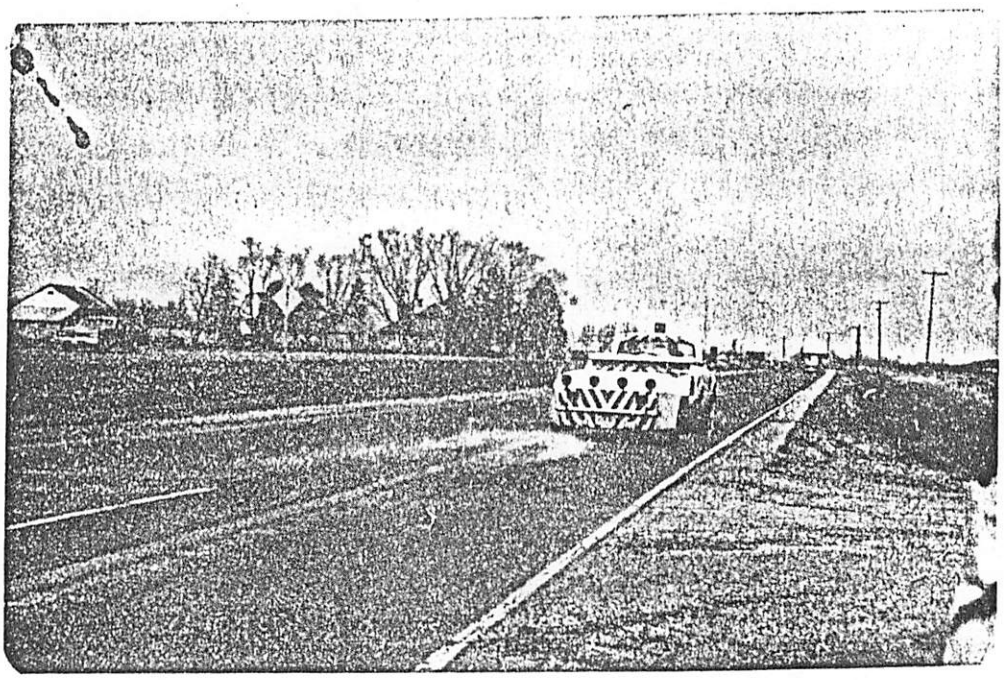
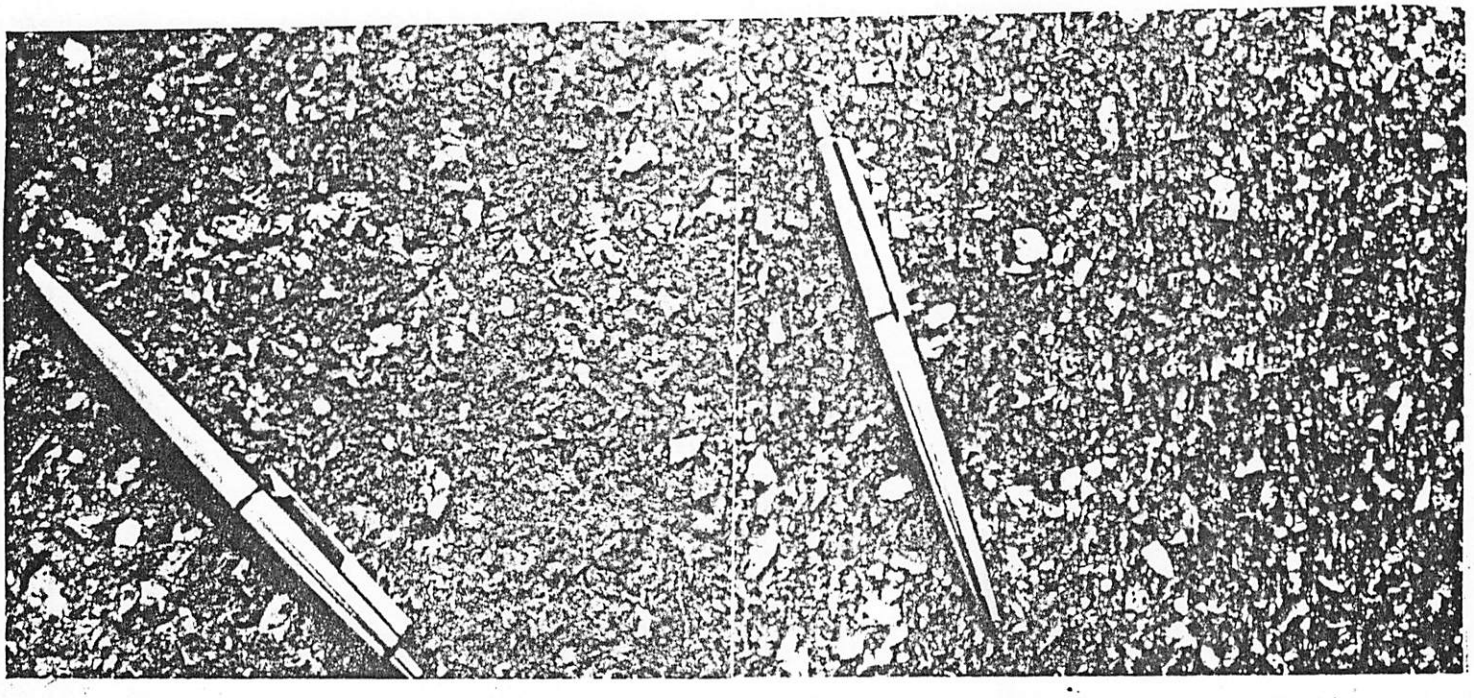


Figure 2. ODOT project no. 738-1977. Coarse type C (III) slurry seal skid analysis after 12 months and 2,000,000 accumulated traffic.



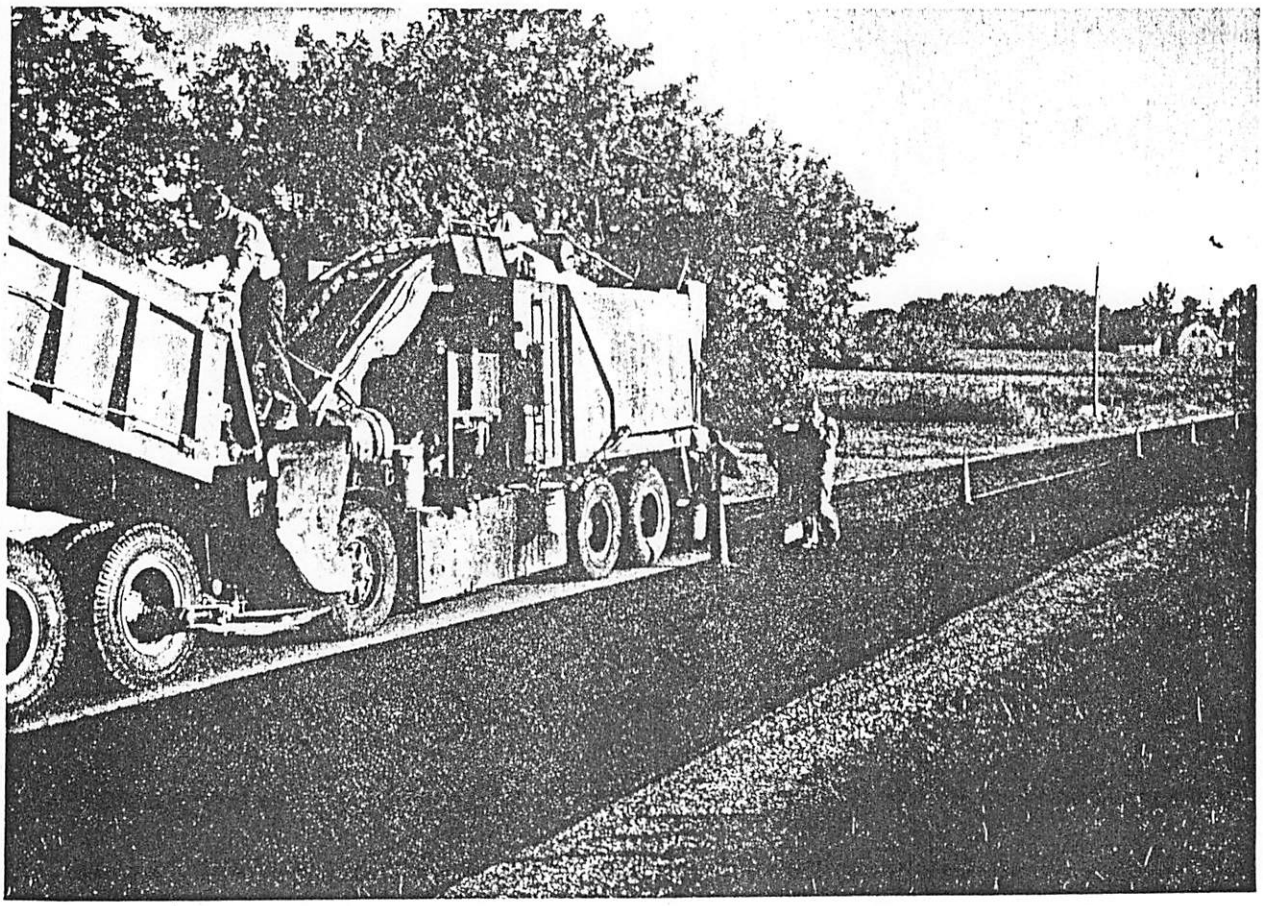


(SB-2) Close-ups of surface texture on SR 42 after first winter. (SB-1)

The shoulders of SR 35F and park roads and lots of Goodyear Park jobs have not been studied, but, in both cases, design, construction and acceptance was successful and satisfactory to all parties.

ODOT APPLICATIONS - SR 65, LIMA

A further test of the design and control method was conducted in 1978 on Ohio SR 65 south of Lima under project number 563-78.



ODOT Type C Slurry Seal Application to SR 65 north of Auglaize Co. line.

The contractor selected and used a quality local limestone. After the design (following) was completed, he was concerned that the laboratory AC content was too low in his judgment. Permission was received to raise the design AC from 7.4% to 9.7%.

The initial skid tests, Figure 3, show clearly that because an excess AC above the recommended design was used, the maximum potential skid numbers for this aggregate gradation were not achieved. (Compare the A-B Road, SR 42 and SR 65 gradations, Figure 4, with the skid numbers for those jobs.)

The SR 65 job however, represents an opportunity to study the effects of a wide range of traffic counts (8000 to 2000) and the effects of asphalt and aggregate ageing under these conditions.

Laboratory Design For
Field Control of Slurry Applications

Re: Project No.: 563-78

Materials: Aggregate - Western Ohio Stone, Lima.
Emulsion - Bitucote Corporation
Filler - Portland Cement, Type I.

	Laboratory Design	Control Quantities	Control Tolerances
a.) Aggregate	100%	----	----
b.) Filler	2 ± 0.5%	40 lbs.	30-50 lbs/ton
c.) Mix Water*	7±1%	16.8 gal/ton	14.4-19.2gal/t
d.) Cone Flow Consistency	2.5±0.5 cm	2.5±0.5 cm	2.5±0.5 cm
e.) AC Target Extraction	7.4%	----	6.5-8.3%
f.) Emulsion @ 64% AC	11.5±1.5%	27.5 gal/ton	23.8-31.0gal/t
g.) Spread rate	17 lbs/sy	117.6 sy/ton	±2 lbs/sy 105-133 sy/ton

*This value is approximate, and is based on an aggregate internal moisture of 3%. Actual water demand should be controlled by the cone flow consistency in the field.

Table 3. Recommended design and control limits established by the ODOT/ISSA design techniques.

Date	Lot No.	Temp.	Spread Rate
9/26	1	--	105.11 SY/ton
	2	--	111.66 SY/ton
	3	55-80° F	109.28 SY/ton
	4	50-70° F	113.11 SY/ton
	5	50-73° F	121.00 SY/ton
	6	50-70° F	124.00 SY/ton
	7	47-68° F	127.97 SY/ton
	8	45-68° F	114.76 SY/ton
10/5	9	Patching - 17.05 tons	

Square yards:	62,468	Gallons/ton- actual:	35.72
Gallons AE used:	19,982	Approved	
Tons aggregate used:	559.41	Gallons/ton- design:	36.00

Spread rate - actual: 17.26 lbs/SY (15.63/19.03)
Spread rate - design: 17.00 lbs/SY (15.00/19.00)

Table 4. Summary of inspector's field notes. Project no. 563-78, OSR 65, Lima

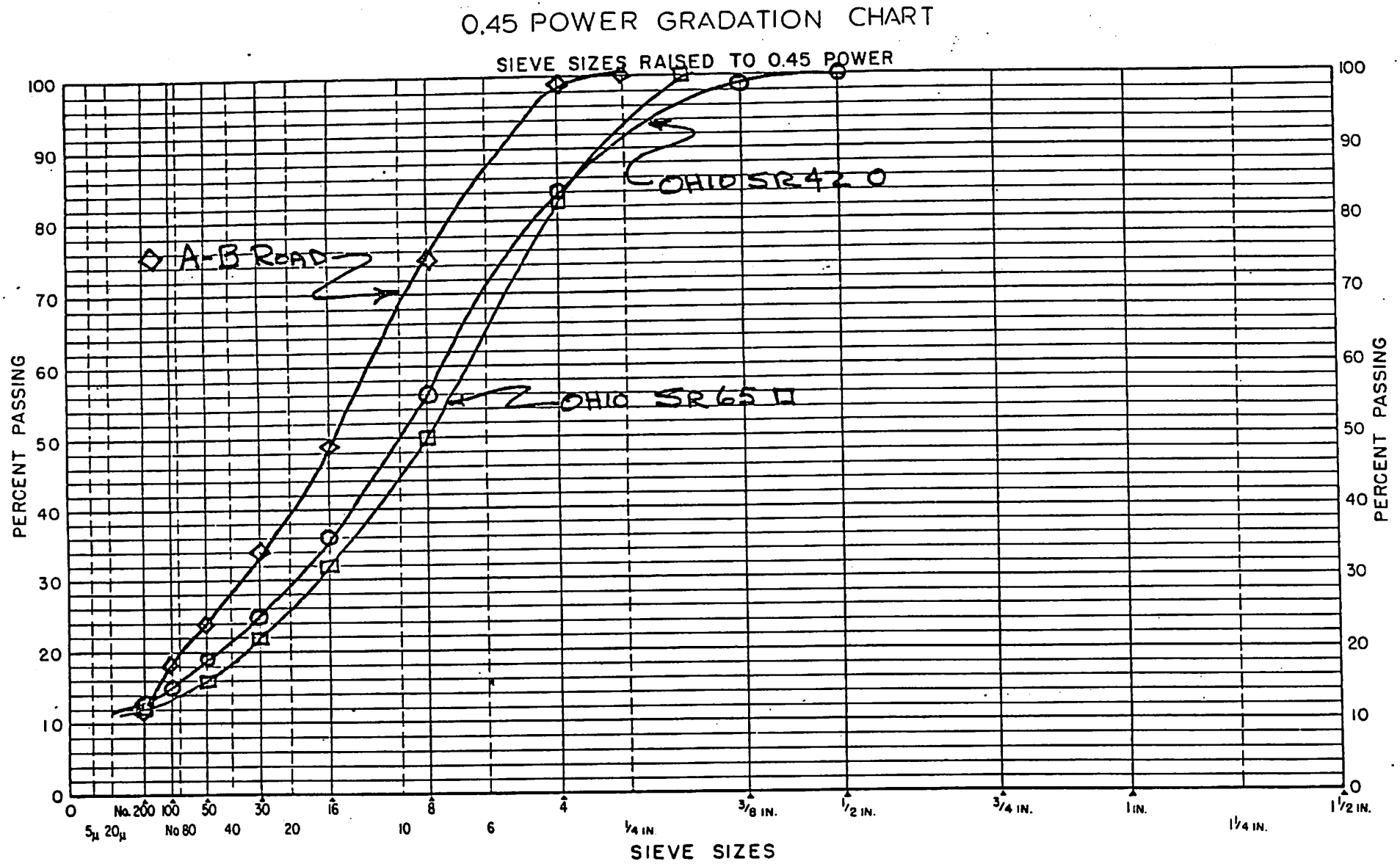


Figure 4.

▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:
OHIO TEST ROADS
AB-1974; SR42-1977; SR65-1978

GENERAL CONCLUSIONS

1. A method of slurry design for durable, safe surfaces is field proven on Ohio's highways.
2. A method of slurry construction for uniform, volume production is field proven on Ohio's highways.
3. The new ODOT specifications for slurry are workable and field proven.
4. Aggregates, emulsions, design services, construction services and equipment are all available from Ohio sources.
5. Slurry Seal for a variety of purposes can be used to safely and economically protect and conserve Ohio's highways.
6. Slurry Seal is a part of Ohio's paving industry and merits extended use and development.

SUGGESTED USES FOR SLURRY SEAL ON OHIO'S HIGHWAYS

1. To improve skid resistance levels.
2. To safely seal highways, shoulders, park roads and airports.
3. To safely seal Roto-milled surfaces.
4. To safely seal Heater Scarified surfaces.
5. To screed or hone wheel ruts.
6. For combination center-joint edge-joint repair and stripe delineation.
7. As mass, solventless surface preparation for overlay.
8. As a construction seal over variably compacted leveling courses and thin sections.
9. As a construction seal over a highly variable surface texture; e.g., after Roto-mill.
10. To correct moderate flushing and variable skid resistance.
11. As a construction seal to provide skid numbers not available in the local aggregate.
12. As a construction seal for open graded 405 mixes.

SPECIAL APPLICATIONS

1. Latex fortified bridge-deck seals.
2. Compaction resistant latex rut mixes.
3. To meet severe friction requirements at high accident locations.
4. Special aggregate combinations and blends to meet specific requirements of skid resistance, speed gradients, sight and sound requirements.
5. Corrugated paint stripe backgrounds.

Form AU-76
Rev. 10-72

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

INTER-OFFICE COMMUNICATION

County of _____ Dist. _____

S. H. _____ Sec. _____

Date January 17, 1978

To R. L. Zook, Engineer of Maintenance Attention: W. B. Gibboney

From Leon O. Talbert, Engineer, Research and Development by F. E. Behn

Subject Skid Resistance of Slurry Seal Pavement, GRE US 42 Log 3.50 to 8.00

File R:Su-FB1

The above pavement was tested for skid resistance before and after resurfacing with a slurry seal mix. The treatment improved the skid resistance significantly, raising the measured skid numbers from a low and highly variable range to a consistently high level in all lanes. The results are shown in the attached table and straight line sketch.

The initial readings were taken on June 13, 1977. The results indicate a highly variable condition from friction, with the inside lanes probably adequate but the outside lanes not. The worst condition was in lane 1, southbound traffic lane, in which SN_{40} readings as low as 12 were found. Field notes indicate that the lowest values were on surfaces which had been treated with MC-3000 material in an effort to seal cracks.

The new slurry seal surface was tested on September 13. The results show SN_{40} values ranging from 49 to 76, with an average of 53 in lane 1 and about 60 in the other lanes. This is an excellent level of skid resistance, and if typical of the mix design used, would justify additional field experimentation with this paving method.

FEB

FEB:maf

cc: L. O. Talbert
R. A. Luce
J. K. Henry
K. M. Miller

SKID RESISTANCE TEST RESULTS

GRE US 42 3.5-8.0

Date Tested	Test Speed mph		Results of Skid Tests			
			Southbound		Northbound	
			Lane 1	Lane 2	Lane 3	Lane 4
6-13-77 Before Resurfacing	40	n	14	10	13	12
		R	12-36	43-56	23-58	23-40
		Avg SN_{40}	26.6	52.1	40.8	34.7
		Std. Dev.	9.26	4.51	13.68	4.52
	55	n	12	11	12	11
		R	6-33	39-54	13-51	24-35
		Avg SN_{55}	26.2	47.8	37.9	31.1
		Std. Dev.	8.79	4.85	15.12	2.91
		Speed Gradient G	.03	.29	.19	.24
9-13-77 After Resurfacing	40	n	14	9	13	12
		R	49-56	56-68	51-76	56-62
		Avg SN_{40}	52.7	60.9	60.0	58.8
		Std. Dev.	2.56	4.57	5.89	1.70
	55	n	12	11	12	11
		R	40-47	46-53	43-60	41-48
		Avg SN_{55}	43.6	48.7	49.2	44.1
		Std. Dev.	2.02	2.41	4.39	2.21
		Speed Gradient G	.61	.81	.72	.98

GRE US 42

N

TESTED 6-13-77 BEFORE SLURRY SEAL APPLICATION

AVG SN_{40}

34 29 19 18 36 12 36 12 32 28 15 34 32 35 32 — 26.6

43 57 55 56 56 49 49 52 49 55 40 — 52.1

SLM 4 5 6 7 8

53 23 53 53 58 35 25 44 54 51 23 26 32 31 — 40.8

36 23 34 39 40 36 38 36 34 34 36 30 38 — 34.7

US 42 Log 3.5

END SLURRY SEAL

US 42 over US 35F Log 7.89

US 42 Log 7.99 XENIA CORP

TESTED 9-13-77 ON SLURRY SEAL APPLICATION

AVG SN_{4}

51 49 51 55 51 51 53 55 56 56 49 55 51 55 33 — 52.7

68 68 60 63 56 56 60 58 59 47 — 60.9

SLM 4 5 6 7 8

64 62 62 61 58 59 51 60 58 58 76 56 55 47 — 60.0

59 59 62 58 58 58 58 62 56 59 59 58 39 — 58.8

Item Special—Slurry Seal Coat—

Description—This work shall consist of constructing, on a prepared surface, a slurry seal coat wearing surface composed of a mixture of emulsified asphalt, aggregate, mineral filler if needed, and water in accordance with these Specifications and in reasonably close conformity with the lines shown on the Plans or established by the Engineer.

Materials—Materials shall be:

Emulsified Asphalt—702.04, SS-1h or CSS-1h, with the cement mixing test waived.

The Contractor, at his option, may require the emulsified asphalt to meet the additional requirements in Technical Bulletin No. 116 published by the International Slurry Seal Association. Under this option, the Contractor shall perform the additional tests in conjunction with the laboratory work required under Mixture Formulation.

Aggregate—Gravel crushed from material retained on the ½ inch sieve, crushed carbonate stone, or crushed air-cooled blast-furnace slag meeting the quality requirements of 703.05, Fine Aggregate. Aggregate shall have a sand equivalent of greater than 45 when tested in accordance with ASTM D-2419.

Mineral Filler—Portland cement 701.01, limestone dust 703.07, or hydrated lime 712.04(b).

Water—Potable and free from harmful soluable salts.

The aggregate-mineral filler blend shall meet the following gradation limits:

Sieve Size	Percent Passing Type A	Type B	Type C
½	100	100	100
⅜	100	100	100
No. 4	100	85–100	82–94
No. 8	90–100	65–90	45–65
No. 16	65–90	45–70	25–46
No. 30	40–60	30–50	15–35
No. 50	25–42	18–35	10–25
No. 100	15–30	10–25	
No. 200	10–20	5–15	5–15

Aggregate acceptance shall be determined prior to incorporation into the mixture based on samples taken from stockpiles. The gradation analysis of the mineral filler will be added to the gradation analysis of the aggregate stockpile samples for determining acceptance.

Mixture Formulation — The Contractor shall formulate the slurry seal mixture on the basis of a laboratory analysis of trial mixtures using job materials. The analysis shall include the performance of the following current test methods published by the International Slurry Seal Association:

(1) Technical Bulletin No. 106, Measurement of Slurry Seal Consistency.

(2) Technical Bulletin No. 109, Measurement of Excess Asphalt in Bituminous Mixtures by Loaded Wheel Tester and Sand Adhesion.

(3) Technical Bulletin No. 100, Wet Track Abrasion of Slurry Seals.

The proportion of mineral filler and the mixing water requirement shall be based on the results of the consistency test. The residual asphalt content in percent by weight of the dry aggregate shall be established so as to produce a durable, textured wearing surface using the results of the wet track abrasion and the loaded wheel test as a guide along with the anticipated traffic volume.

The proposed materials and the mixture formulation also shall be selected with consideration given to set time. The proposed formulation shall be translated into job-mix proportions in terms of quantities of mineral filler, emulsified asphalt, and mixing water to be added per ton of dry aggregate.

The results of the laboratory analysis supporting the selection of the formulation with materials properly identified including the gradation of the aggregate-mineral filler blend used in the tests, the test results, and the job-mix proportions shall be incorporated into a certified report which shall be submitted to the Engineer for approval not less than 10 days prior to starting the work. At the same time, test specimens shall be made available to the Engineer for his examination.

The materials shall be proportioned in accordance with approved job-mix proportions unless a change is approved by the Engineer due to unsatisfactory results.

Equipment — The materials shall be proportioned and mixed in a self-propelled slurry seal machine which shall be capable of thoroughly mixing predetermined proportions of aggregate, mineral filler, water and emulsified asphalt on a continuous flow basis. When required on the Plans, self-loading equipment shall be

used to charge the slurry seal machine while it is in place on the pavement, without interrupting the production and spreading operations of the machine. The mineral filler shall be introduced at the same point as the aggregate by means of a separate proportioning device. The water shall be introduced so as to wet the aggregate and mineral filler prior to the introduction of the emulsified asphalt. A pressurized water spray bar shall be provided on the machine to permit controlled, uniform dampening of the existing surface without causing free water to accumulate ahead of the slurry mixture in the spreader box.

The slurry mixture shall be spread by means of a spreader box, equipped with flexible material to contact the pavement and prevent loss of slurry from the box. It shall be adjustable for crown and varying grades to assure uniform depth of spread. The box shall have a flexible strike-off and shall be equipped with a mechanical steering device.

Suitable power equipment for cleaning the existing surface, hand squeegees, shovels, and other incidental equipment shall be provided.

Equipment and the operation thereof shall at all times be subject to the Engineer's approval based on the results being obtained and to the requirements of 108.05.

Weather Limitations — The asphalt emulsion slurry treatment shall be placed only when the temperature of the pavement surface is 55°F. or above. The mixture shall not be placed if impending weather conditions are such that proper spreading and ample curing may not be obtained.

Surface Preparation — Prior to dampening the existing surface and spreading the mixture, the existing surface shall be cleaned thoroughly of loose material and loose or bound foreign material. Removed material shall be disposed of as directed by the Engineer.

Proportioning, Mixing and Spreading — The slurry seal machine shall be calibrated to permit predetermined proportioning of materials in accordance with the approved job-mix proportions. The materials shall at all times be proportioned and mixed so as to produce a uniform mixture free from visible defects in composition when spread onto the existing surface. Should such defects occur, they shall be corrected promptly in a manner satisfactory to the Engineer.

The spread rate specified on the Plans shall be the number of pounds of aggregate, on the basis of dry weight, to be placed per square yard of pavement surface. The mixture shall be placed at the rate required to yield the specified quantity of aggregate.

The rate of mixing shall be matched with forward progress so as to carry a reasonably constant quantity of mixture in the spreader box and the spreader box shall be kept free of build-up of cured mixture. Longitudinal and transverse joints shall have no objectionable overlap of mixture.

Proportioning and Spread Rate, Control and Acceptance — Aggregate delivered to the slurry seal machine shall be weighed and emulsified asphalt shall be measured in accordance with 109.01. In addition, suitable means approved by the Engineer shall be provided for periodically determining the quantity of emulsified asphalt incorporated into the mixture.

The Contractor shall maintain continuous control of emulsified asphalt to dry aggregate proportioning to conform to approved job-mix proportions within a tolerance of plus or minus 5 gallons per ton and shall control spread rate to place not less than the specified quantity of aggregate per square yard on the basis of dry weight.

The Contractor shall perform the cone consistency test periodically and at the request of the Engineer. A uniform consistency shall be maintained and corrective action shall be taken should the test show excess water or segregation of the materials.

Acceptance as regards to emulsified asphalt-aggregate proportioning and spread rate shall be based on the Engineer's summary of quantities used in constructing lots of approximately 15,000 square yards. When the square yard is the unit of measurement and basis of payment, a lot will be approved and accepted providing the Engineer's summary indicates conformance with the above control requirements for proportioning and spread rate. When gallons of emulsified asphalt and tons of aggregate are the units of measurement, a lot will be approved and accepted providing the summary indicates conformance with the requirements for proportioning only.

In the event a lot is not approved, the disposition of the lot shall be as provided in 105.03. Should the determination under this section be to accept the work included in the not-approved lot, the contract price adjustment shall be determined by multiplying the unit bid price by the ratio of the deficient to the approved asphalt-aggregate proportion, or by the ratio of the deficient to the specified spread rate except that no price adjustment will be made for spread rate deficiencies amounting to less than one pound per square yard. In case both factors are deficient, the unit bid price shall be multiplied by both ratios. When the slurry seal is placed on shoulders, the Engineer may waive a price adjustment due to an excess of emulsified asphalt.

Protection of Completed Work — The Contractor shall be responsible for the care of the slurry seal mixture during the curing period and until final acceptance as provided in 107.16.