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CONSTRUCTION AND EVALUATION OF RESIN MODIFIED PAVEMENT

by

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13. ABSTRACT *(Maximum 200 words)*

The US Army Engineer Waterways Experiment Station (WES) was tasked by the US Army Corps of Engineers to evaluate the current state of the art of the resin modified pavement (RMP). This type of pavement is best described as a semirigid, semiflexible pavement. The RMP is basically an open-graded asphalt concrete mixture that contains 25 to 30 percent voids which are later filled with a resin modified cement slurry grout. The RMP is a tough and durable surfacing material that combines the flexible characteristics of an asphalt concrete material with the fuel, abrasion, and wear resistance of a portland cement concrete.

A literature search and background analysis were conducted on the RMP process. It was discovered that the majority of in-service pavements constructed with this process are in Europe and heavily concentrated in France where this process was developed. Visual observations of these sites indicated that the RMP process had considerable potential for US military applications.

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The final phase of the WES study involved the construction, trafficking, and evaluation of a 150- by 50-ft test section. Trafficking included both straight passes and pivot steer turns from the M1 and M60 tanks. The Federal Highway Administration's Accelerated Loading Facility was used to traffic the RMP test section by simulating heavily-loaded, high tire pressure truck traffic. Sections of the test section were also subjected to controlled fuel and oil spillage.

The evaluation indicated that the RMP process does have potential for several pavements use. At an initial cost somewhere between asphalt concrete and portland cement concrete, the RMP provides an alternative surfacing material for many Army pavement applications. These proposed applications include tracked-vehicle roads, hardstands, and aircraft parking aprons.

PREFACE

This study was conducted by the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the US Army Corps of Engineers (USACE) under the Facilities Investigation and Studies Program. The work was conducted from October 1987 to September 1989 under the project entitled, "Fuel and Abrasion Resistant Resin Modified Filler Applied to Open-Graded Asphalt Pavement." The USACE Technical Monitor was Mr. Paige Johnson.

This pavement evaluation was conducted with the assistance of the Federal Highway Administration (FHWA). The FHWA's Accelerated Loading Facility (AFL) was used to traffic a portion of the resin modified pavement test section. Messrs. Charles Churilla and Charles Niessner provided technical assistance and coordination for the ALF services.

The study was conducted under the general supervision of Dr. W. F. Marcuson III, Chief, GL; Mr. H. H. Ulery, Jr., Chief, Pavement Systems Division (PSD), GL; and Mr. L. N. Godwin, former Chief, Materials Research Center, PSD. This report was prepared under the direct supervision of Dr. R. S. Rollings, former Chief, Materials Research and Construction Technology Branch, PSD. PSD personnel engaged in the testing, evaluating, and analysis of this project included Messrs. R. Ahlrich, G. Anderton, J. Duncan, R. Graham, H. McKnight, T. McCaffrey, D. Reed, and J. Simmons. The Principal Investigator was Mr. Ahlrich. This report was written by Messrs. Ahlrich and Anderton.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
gallons	3.785412	cubic decimetres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
quarts (US liquid)	0.9463529	cubic decimetres
square feet	0.09290304	square metres
square yards	0.8361274	square metres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

CONSTRUCTION AND EVALUATION OF RESIN MODIFIED PAVEMENT

PART I: INTRODUCTION

Background

1. Asphalt concrete pavements are very susceptible to damage when subjected to fuel and/or oil spillage and/or severe abrasion from tracked vehicles. Over 80 percent of the Army's pavements are surfaced with asphalt concrete. Because of the mission of the Army and the equipment in its inventory, Army pavements are routinely subjected to fuel spillage and severe abrasion. Tank trails and crossings, hardstands, wash facilities, motorpools, helicopter refueling pads, and aircraft parking aprons are examples of Army pavements that are susceptible to fuel and/or abrasion damage. Cost-effective surfacing materials other than conventional portland cement concrete are needed for construction and rehabilitation of Army pavements in order to assure the most economical pavement surface.

2. A resin modified pavement (RMP) was developed in France in the 1960's as a fuel and abrasion resistant surfacing material. The French construction company, Jean Lefebvre, developed this pavement process as a cost-effective alternative to portland cement concrete. The RMP process has been used on various types of pavements including warehouse floors, tank hardstands, and aircraft parking aprons. The RMP has been successfully constructed in numerous countries including Great Britain, South Africa, Japan, Australia, and Saudi Arabia.

3. The RMP is best described as a semirigid, semiflexible pavement. The RMP is a tough and durable surfacing material that combines the flexible characteristics of an asphalt concrete material with the fuel, abrasion, and wear resistance of a portland cement concrete. The RMP process is basically an open-graded asphalt concrete mixture containing 25 to 30 percent voids which are filled with a resin modified cement slurry grout as shown in Figure 1. The open-graded asphalt mixture functions as a support layer and

determines the thickness of the RMP. The slurry grout is composed of portland cement, fine aggregate, water, and a resin additive. The grout material is poured onto the open-graded asphalt mixture after the asphalt material has cooled, squeegeed over the surface, and vibrated into the voids with a small (3 to 5 ton*) vibratory roller. A curing period is required and can vary between 1 and 28 days depending on the type of portland cement used in the grout and the loading conditions.

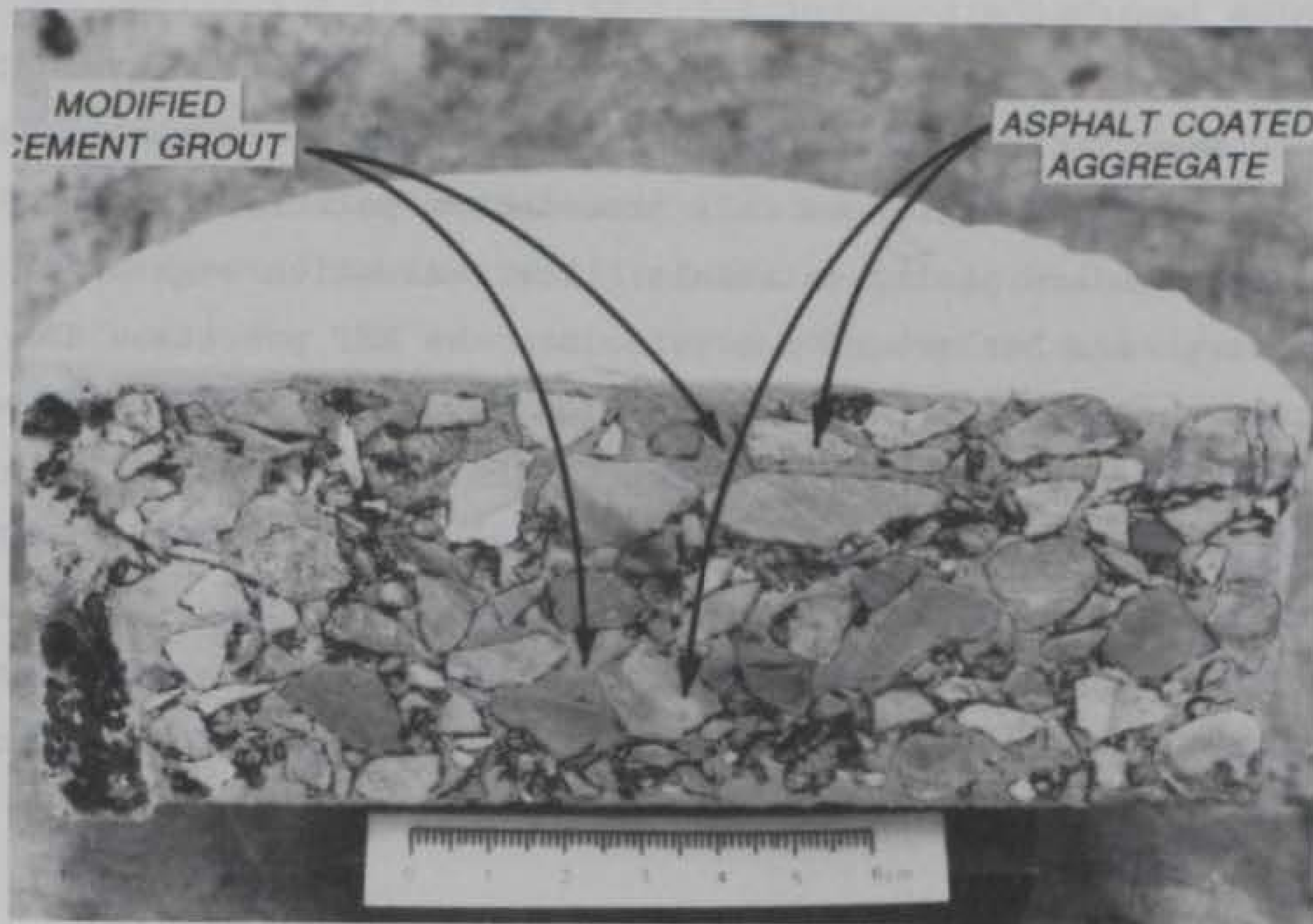

Figure 1. Cross section of RMP specimen

4. During the mid 1970's, the US Army Engineer Waterways Experiment Station (WES) evaluated the RMP (Rone 1976). A test section was constructed to evaluate the effectiveness of this special surfacing material to resist damage caused by fuel and oil spillage and abrasion from tracked vehicles. The results of this evaluation were not favorable. The test section did not resist damage caused by tracked vehicles and fuel spillage. The evaluation indicated that the effectiveness of the RMP was very construction sensitive, and if all phases of design and construction were not performed correctly, the RMP process would not work.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

5. When the first test section was constructed at WES, the technical guidance was insufficient. The viscosity of the grout used in this test section was approximately twice the current recommended value. The void content of the open-graded asphalt material was between 5 and 10 percent lower than the current recommended values. The grout application rate used was nearly half of the current recommended rates. All of these differences resulted in insufficient penetration of the grout into the open-graded asphalt mixture, which caused the pavement failures in the test section.

6. In 1987, US Army Corps of Engineers tasked WES to reevaluate the RMP process. Good field performance in Europe and improved materials and construction procedures indicated this process had potential to be a viable alternative to standard paving materials. The evaluation began with a literature search and background analysis into the RMP process. The review indicated that the majority of the in-service pavements constructed with this process were in Europe, especially France. Site inspections were conducted to evaluate the field performance of several private and military RMP applications in France, Great Britain, and Australia. Visual observations of these sites indicated that the RMP process had considerable potential for US military applications. The findings of the site inspections in France and Great Britain are discussed in Appendix A.

Objective

7. The objective of this research was to determine the effectiveness of the RMP in resisting damage caused by severe abrasion from maneuvering tracked vehicles and from fuel and oil spillage. Recommendations on the potential future use of the RMP would be made based on its determined effectiveness.

Scope

8. In order to determine the effectiveness of the RMP process, a 150-by 50-ft test strip was constructed at WES by a local contractor, APAC of Mississippi. Representatives from Jean Lefebvre provided technical assistance during the construction of the RMP test strip. The RMP test strip was constructed according to the contract specifications without any problems.

The contract specifications for the RMP surfacing material are detailed in Appendix B. The test strip was allowed to cure for 28 days to obtain adequate strength before any traffic was placed on the pavement.

9. The RMP was trafficked with the M1 and M60 tanks. Straight passes and 180 deg pivot steer turns were applied with the tracked vehicles to evaluate the abrasion resistance of the RMP. Five different fuels and oils including jet aviation fuel, gasoline, diesel, synthetic oil, and hydraulic oil were spilled on the RMP. Thirty cycles of controlled fuel and oil spillage were used to evaluate the fuel resistant properties. The Federal Highway Administration's Accelerated Loading Facility (ALF) was also used to traffic the RMP. ALF simulated heavily loaded, high-tire pressure truck traffic. Data drawn from the traffic tests and fuel resistance analysis provided the basis for the recommendations made for this new pavement process.

PART II: PRECONSTRUCTION ANALYSIS

Site Evaluation and Thickness Design

10. A pavement testing area across from the Geotechnical Laboratory at WES was chosen as the construction site for the proposed 150-by 50-ft RMP test strip. Various types of asphalt concrete test pavements had been constructed in this area by WES researchers since World War II. In 1982 approximately 1-1/2-in. of asphalt concrete was placed over the entire area as a leveling course. Since that time, the area had been used occasionally to stockpile aggregates and soil samples. This site represents an extremely strong and stiff support for the test section and precluded the possibility of a base failure.

11. Since the RMP is essentially a surface course, there was a need to ensure that the underlying layers of the test strip would be structurally sound. If any load related failures were to occur during future traffic tests, a structurally sound foundation would leave no doubt that the failure was initiated in the surface course, which was the pavement layer being evaluated. A high-quality asphalt concrete mixture placed on top of this paved area was determined to be the most economical means of obtaining the structurally sound foundation needed.

12. A thickness design procedure was conducted to determine the required thickness of this asphalt concrete layer. The first step of the design procedure was to determine the strength properties of the existing pavement. Nondestructive tests (NDT) were conducted using the falling weight deflectometer (FWD). The pavement deflection data captured during these tests were input to a computerized layered-elastic program (BISDEF) which computes strength properties and predicts elastic moduli for each pavement layer. The moduli values were then input to a computerized pavement thickness design program (AIRPAVE) to determine strengthening overlay requirements. A design load near equivalent to the M1 and M60 tank loads was used in this thickness design program. The results of this exercise indicated that a total thickness of 3 in. of asphalt concrete would provide a structurally sound foundation for the 2-in.-thick RMP wearing course. Figure 2 is a diagram of the RMP test strip dimensions.

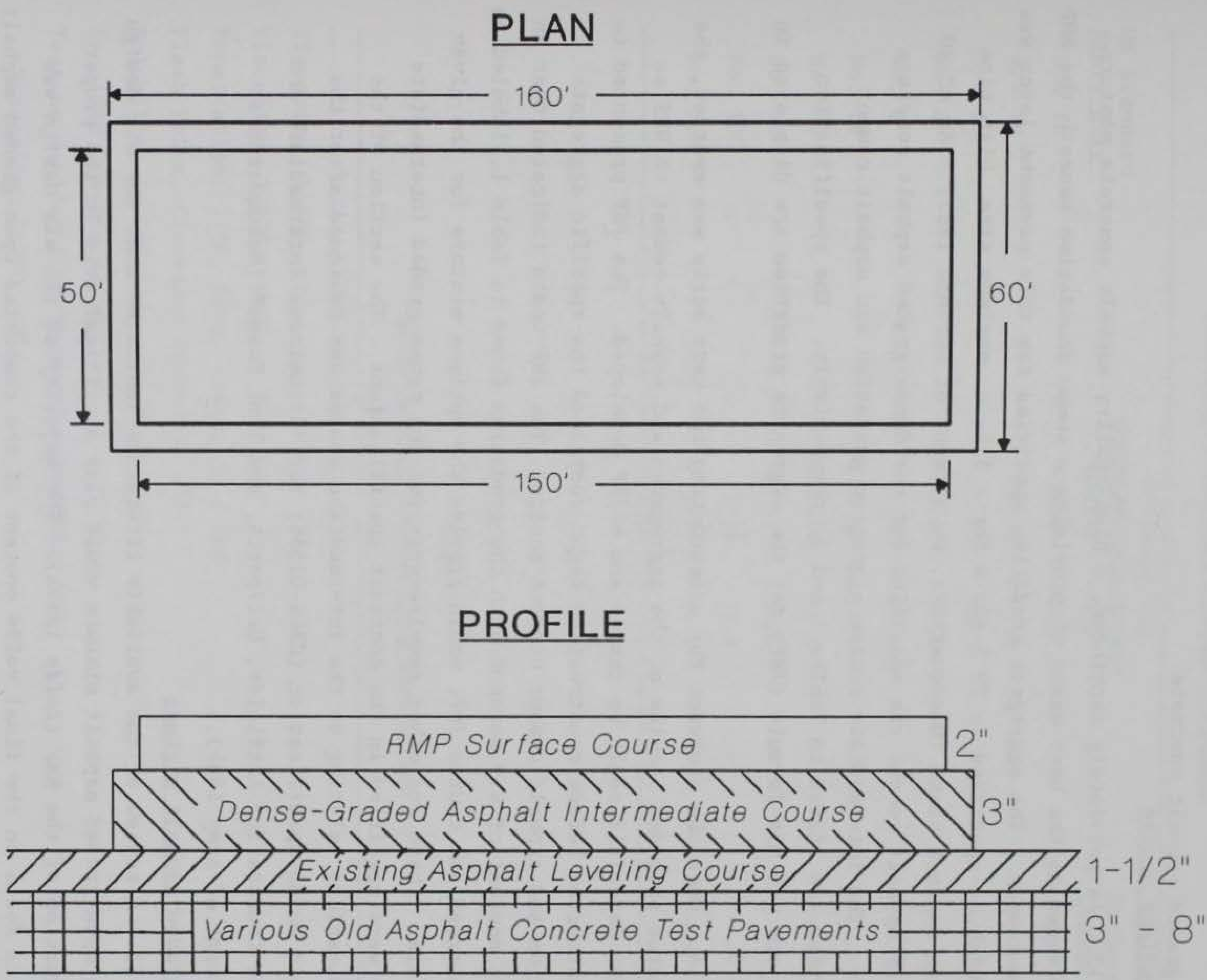

Figure 2. RMP test strip dimensions

Materials Evaluation

Dense-graded asphalt concrete intermediate course

13. As previously mentioned, a high-quality asphalt concrete mixture was selected as the best means of providing a sound foundation beneath the RMP surface course. The aggregate gradation specified for this pavement layer was that which is specified in TM 5-822-8 for a 3/4-in. maximum size, high tire pressure surface blend (Headquarters, Department of Defense 1987). An AC-30 grade of asphalt cement was specified for the dense-graded asphalt concrete mixture. The intermediate course aggregate gradation and asphalt cement properties are listed in Tables 1 and 2, respectively. The specification limits and job-mix-formula (JMF) for the aggregate gradation are displayed in Figure 3.

14. Once the contract for constructing the test strip was awarded, the contractor provided samples of the aggregates and asphalt cement to WES so that the materials could be tested and a JMF developed. The JMF presented to the contractor before construction began contained the specific aggregate gradation and asphalt cement content desired. The JMF tests indicated that an asphalt content of 4.9 percent with the gradation found in Table 1, labeled as the intermediate course JMF, would provide the optimum mixture for the given materials. These and other requirements for the dense-graded intermediate course were specified in the contract specifications. The section of the specifications relating to the intermediate course was designed after the standard Guide Specification (CEGS-02556) for "Bituminous Intermediate and Surface Courses for Airfields, Heliports, and Tank Roads" (Headquarters, Department of Army 1984).

Open-graded asphalt mixture

15. A review of the available literature indicated that the mix design of the open-graded asphalt mixture would play a critical role in the proper construction of the RMP (Roffe 1989a). The majority of the mix design was found to focus on the final voids content of the compacted open-graded asphalt mixture. The general requirement is 25 to 30 percent voids in the compacted mixture. Any amount less than this would not allow the slurry grout to fully penetrate the open-graded mixture, resulting in a structurally unsound surface

Table 1

Aggregate Gradations, Percent Passing

US Standard Sieve Size	Dense-Graded Intermediate Course Limits	Dense-Graded Intermediate Course JMF	Open-Graded Surface Course Limits	Open-Graded Surface Course JMF
3/4 in.	100	100	100	100
1/2 in.	82-96	95.3	65-75	67
3/8 in.	75-89	88.9	50-65	44
No. 4	59-73	71.3	23-33	22
No. 8	46-60	49.8	9-17	12
No. 16	34-48	38.3	--	--
No. 30	24-38	31.6	5-10	5
No. 50	15-27	18.5	--	--
No. 100	8-18	8.9	--	--
No. 200	3-6	6.7	1-3	2

Table 2

AC-30 Asphalt Cement Test Properties

Test	Results
Viscosity, 140°F, (P)	3,182
Viscosity, 275°F, (cst)	479
Penetration, 77°F, 100g, 5 sec, (0.1 mm)	58
Flash Point, Cleveland Open Cup, (°F)	590
Solubility in Trichloroethylene, (%)	99.9
Specific Gravity at 77°F	1.023
Test on Residue from Thin Film Oven Test	
Viscosity, 140°F, (P)	7,523
Ductility, 77°F, 5 cm/min, (cm)	150+

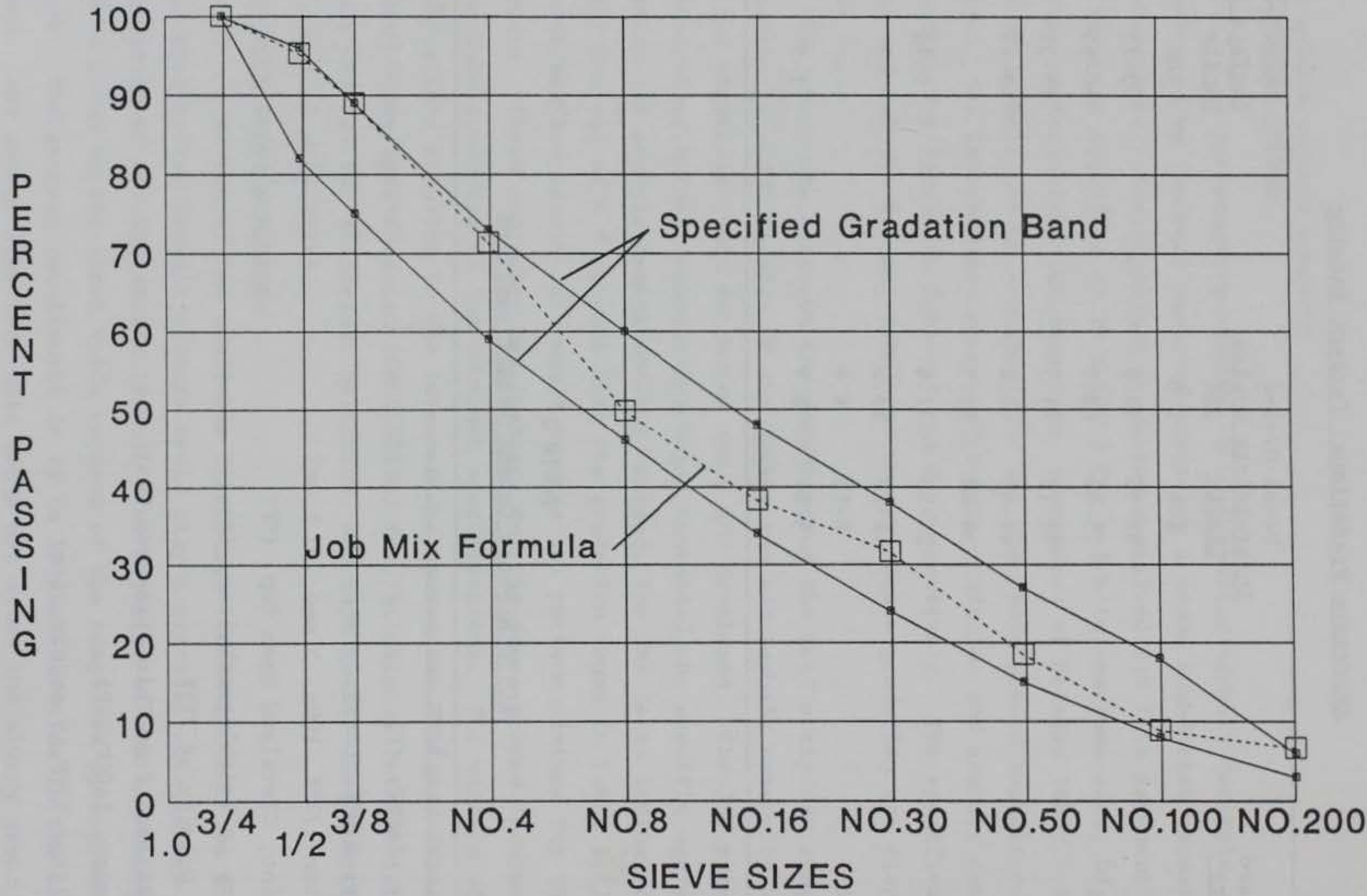

Figure 3. Intermediate course aggregate gradations

course which would likely deteriorate under traffic. Void contents greater than this amount would increase the cost of the pavement without providing any significant structural improvements and could also reduce the pavement strength by eliminating some of the aggregate to aggregate interlock.

16. The majority of the laboratory mix design guidance found in the literature was based on French methods which used nontraditional specimen sizes and compaction methods. Therefore, a preliminary analysis was first conducted in the WES laboratories to determine the proper laboratory compactive effort in terms of standard US practices. Twenty-five blows of the 6-in.-diam Marshall hand hammer are used in the French standards for compacting laboratory samples. The 25 blows are applied to only one side of the laboratory sample. The comparative analysis conducted in the WES laboratories validated this compactive effort by examining the changes in void contents versus varying levels of hand hammer compaction. The results of this analysis, shown in Figure 4, indicated that the 25-blow compactive effort would most likely produce void contents in the 25 to 30 percent target range.

17. Once the proper mix design method had been determined, an estimate of the optimum binder content was made using a French procedure based on aggregate properties (Roffe 1989b). This procedure is outlined below:

$$\text{Optimum binder content} = (\alpha)(K)(\sqrt[5]{\Sigma})$$

where

$\alpha = \dfrac{2.65}{\gamma_G}$ where γ_G = apparent specific gravity of the combined aggregates

K = richness modulus having a value of 3 to 3.5 depending upon maximum aggregate size and gradation

Σ = conventional specific surface area

$= 0.25G + 2.3S + 12s + 135f$

G = percentage of material retained on 1/4 in. sieve

S = percentage of material passing 1/4 in. sieve and retained on No. 50 sieve

s = percentage of material passing No. 50 sieve and retained on No. 200 sieve

f = percentage of material passing No. 200 sieve

Therefore, for the materials and conditions of the WES test section, the following estimate was made:

$$\alpha = \frac{2.65}{\gamma_G} = \frac{2.65}{2.648} = 1.0008$$

$$K = 3.25$$

$$\Sigma = 0.25G + 2.3S + 12s + 135f$$

$$= 0.25(0.64) + 2.3(0.32) + 12(0.02) + 135(0.02)$$

$$\Sigma = 3.836$$

$$\therefore \text{ Optimum binder content} = (\alpha)(K)(\sqrt[5]{\Sigma})$$

$$= (1.0008)(3.25)(\sqrt[5]{3.836})$$

Optimum binder content = 4.26 percent

18. The asphalt cement used in the laboratory study and actual construction was the same type as that used in the dense-graded intermediate course, an AC-30 grade. The aggregate gradation specified was taken from the literature as the standard gradation for heavy-duty pavement applications. The selected gradation is found in Table 1, labeled as the limits of the open-graded surface course. The JMF gradation was recommended by the Jean Lefebvre representative. The coarser gradation was recommended to ensure that the final void content would be sufficient enough to allow full penetration of the grout. The specification limits and JMF are shown in Figure 5.

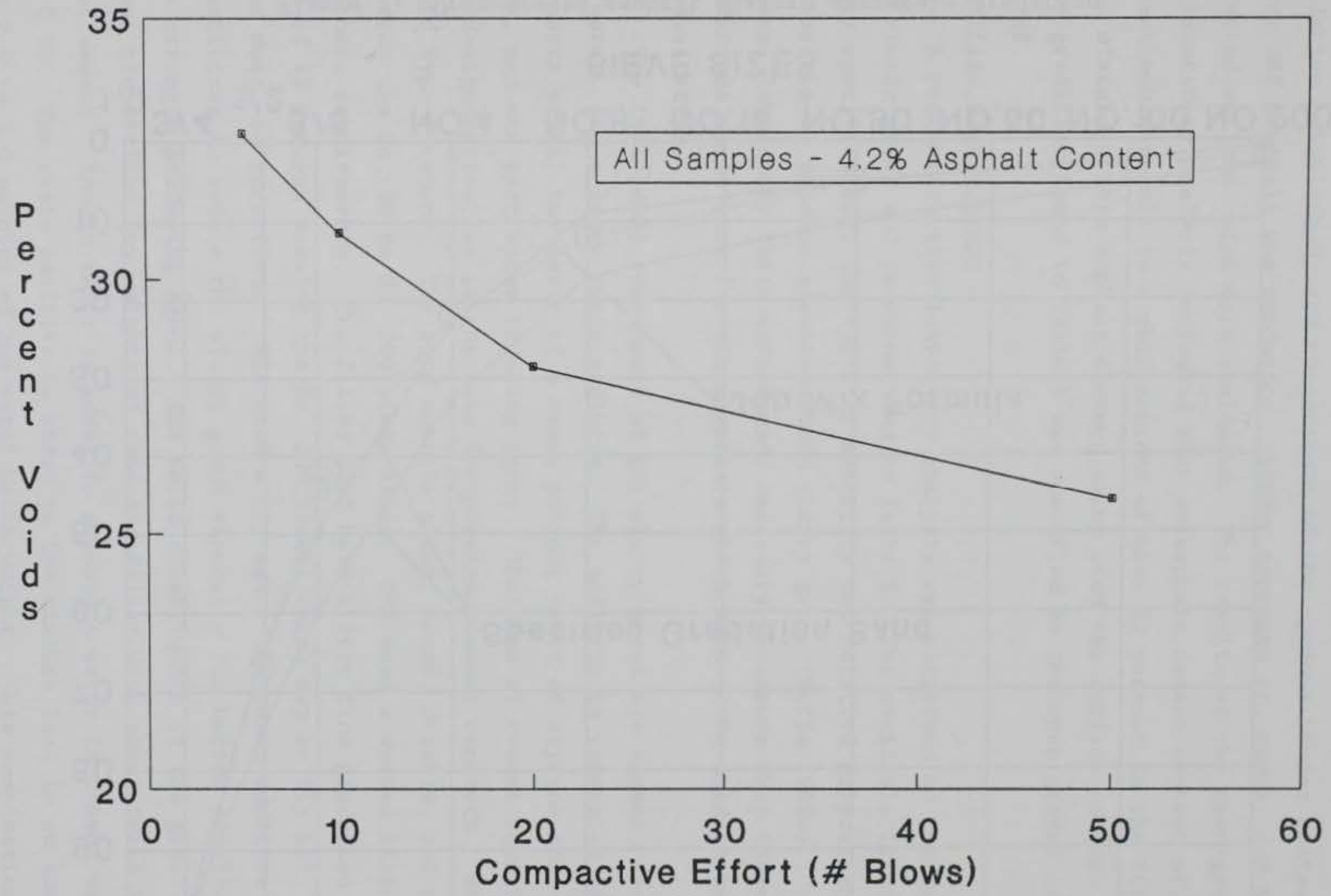

Figure 4. Hand hammer compactive effort analysis

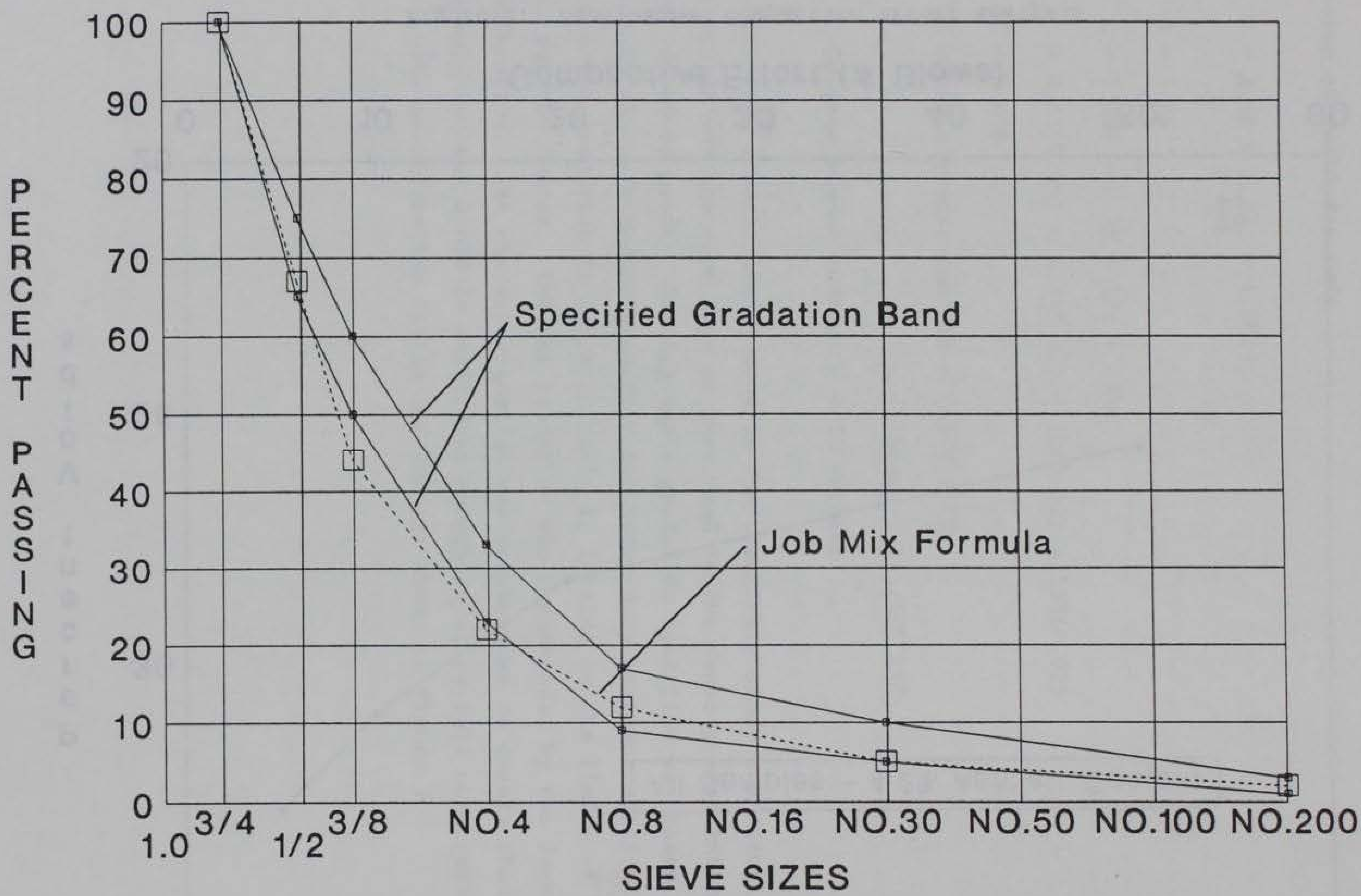

Figure 5. Open-graded asphalt mixture aggregate gradation

19. With all of the aggregate and binder materials in hand, an aggregate gradation established, and an estimate of the optimum binder content, a laboratory JMF analysis was conducted. Binder contents at, above, and below the estimated optimum value were evaluated. The results of the open-graded mixture laboratory analysis indicated that an asphalt cement content of 4.2 percent would result in a void content of near 30 percent in the final compacted mixture. This asphalt content along with the surface course aggregate gradation found in Table 1 was specified as the open-graded asphalt mixture JMF.

Resin modified slurry grout

20. A preconstruction laboratory analysis was performed on the resin modified slurry grout and is summarized in Table 3. The available literature was fairly specific about the types of materials and relative proportions of these materials to produce a satisfactory slurry grout (Roffe 1989b). Nonetheless, laboratory tests were deemed necessary to ensure that these recommendations would work for the materials which were to be used in the WES RMP test strip.

21. The individual components of the slurry grout are cement, sand, filler, water, and a latex resin additive. The additive is generally composed of five parts water, two parts of a cross polymer resin of styrene and butadiene, and one part water reducing agent. The type of cement used is purely a design option, as is the case for portland cement concrete. WES used a standard Type I cement. The sand must be clean, sound, durable, and range in size from the No. 30 to No. 200 sieve sizes. WES used a washed silica sand to meet these requirements. The filler must have a very fine gradation (minimum of 95 percent passing the No. 200 sieve) which may be fly ash, limestone dust, or rock flour. WES used a fly ash. The resin additive acts as a plasticizer to reduce the slurry grout viscosity for better penetration and as a strength producing agent. The solid constituents of the grout are near equal proportions (by weight) of sand and filler with about twice that amount of cement. Enough water is added to produce a water to cement ratio of 0.60 to 0.70. The resin additive is added to the mixture last in an amount equal to 2.0 to 3.0 percent of the total batch weight. This combination of ingredients produces a slurry grout which is very fluid and only slightly more viscous than water.

22. The laboratory analysis conducted at WES on the slurry grout consisted of varying the mix proportions within the recommended allowances to determine the best mix formula. The single acceptance criterion for the slurry grout is a Marsh flow cone viscosity of 7.0 to 9.0 sec immediately after mixing. For comparison, water has a Marsh flow cone viscosity of 6.0 sec. Because this viscosity range is relatively narrow, slight variations of the water to cement ratio and amount of resin additive were used to obtain a slurry grout mix formula of the proper viscosity. The Marsh flow cone dimensions and test procedure are described in Appendix C.

23. After 10 different slurry grout formulations were mixed and tested in the laboratory (Table 3), a final formula was derived which was found to produce a slurry grout viscosity of just over 7 sec. It was thought that a slurry grout in the lower end of the acceptable viscosity range combined with an open-graded support layer in the upper end of the acceptable voids range would help to ensure full penetration of the grout during construction. The final slurry grout formulation used on the test strip is listed in Table 4.

Table 3

Slurry Grout Laboratory Analysis

Trial	Type 1 Cement wt(g) [%]	Sand wt(g) [%]	Filler wt(g) [%]	Water wt(g) [%]	Resin Additive wt(g) [%]	Marsh Flow Cone Viscosity* (sec.)
1	1835 [36.7]	920 [18.4]	920 [18.4]	1190 [23.8]	135 [2.7]	11.0
2a	1820 [36.4]	910 [18.2]	910 [18.2]	1225 [24.5]	135 [2.7]	9.7
2b	1820 [36.2]	910 [18.1]	910 [18.1]	1250 [24.9]	135 [2.7]	9.0
2c	1820 [36.3]	910 [18.1]	910 [18.1]	1225 [24.4]	150 [3.0]	9.0
3a**	1810 [36.2]	905 [18.1]	905 [18.1]	1240 [24.8]	140 [2.8]	7.2
3b	1810 [36.3]	905 [18.1]	905 [18.1]	1230 [24.6]	140 [2.8]	7.1
3c	1810 [36.2]	905 [18.1]	905 [18.1]	1240 [24.8]	135 [2.7]	7.2
4a	1800 [36.0]	900 [18.0]	900 [18.0]	1250 [25.0]	150 [3.0]	6.7
4b	1800 [36.1]	900 [18.0]	900 [18.0]	1240 [24.8]	150 [3.0]	6.6
4c	1800 [36.1]	900 [18.0]	900 [18.0]	1250 [25.0]	140 [2.8]	7.1

* Results shown are average of three viscosity tests.

** This formula chosen as specified by JMF.

Table 4

Resin Modified Slurry Grout Formula

Material	Weight, percent
Type I Cement	36.2
Fly Ash	18.1
Sand	18.1
Water	24.8
Cross Polymer Resin	2.8

PART III: CONSTRUCTION

Dense-Graded Asphalt Concrete Intermediate Course

24. Prior to the construction of the RMP test strip, a 10-by 40-ft trial test section of dense-graded asphalt concrete was constructed. This test section was tested and evaluated to ensure that the asphalt mixture and construction procedures would conform to all of the specified requirements. Quality control tests conducted on the asphalt concrete mix included asphalt extractions, aggregate gradations, and field compaction. These tests indicated that the construction of the trial test section was acceptable. The results of the quality control tests for the test section are listed in Tables 5 and 6.

25. The construction of the RMP test strip began with the dense-graded asphalt concrete mixture. The existing surface was swept clean, and a light tack coat of Type SS-1 asphalt emulsion was sprayed on the clean surface by a distributor truck. The tack coat was used to bond the new dense-graded asphalt mixture with the existing asphalt surface. This tack coat was applied during the afternoon and before construction of the intermediate course began to allow for enough curing time and to prevent construction delays the next morning.

26. With the construction equipment already in place, the intermediate course construction was completed in less than 1 day. The hot mix was spread with a mechanical paver and compacted with a 10-ton rubber-tired roller and a 10-ton steel-wheeled roller. Samples of the hot mix were taken at several intervals during the day for determination of mixture properties by WES laboratory personnel. These laboratory quality control tests along with data obtained from field cores cut out of the test strip early the next day indicated that both the mix and construction procedures were satisfactory. The results of the quality control tests are listed in Tables 5 and 6. A final thickness of approximately 3 in. was laid across a 160-by 60-ft area. These dimensions were designed to provide the sound foundation required for the 2-in.-thick, 150-by 50-ft resin modified surface course.

Table 5

Asphalt Concrete Intermediate Course Analysis

Sieve Size	Specified Limits	JMF	Trial Test Section	Test Strip S-1	Test Strip S-2	Test Strip S-3
3/4 in.	100	100	100	100	100	100
1/2 in.	82-96	95.3	97.9	96.0	93.8	97.1
3/8 in.	75-89	88.9	90.2	90.3	86.5	89.0
No. 4	59-73	71.3	67.1	72.3	68.6	69.7
No. 8	46-60	49.8	47.8	52.3	49.8	50.9
No. 16	34-48	38.3	36.3	39.5	37.5	39.1
No. 30	24-38	31.6	29.3	32.0	30.3	32.3
No. 50	15-27	18.5	18.2	19.9	18.9	19.8
No. 100	8-18	8.9	9.2	10.5	10.1	10.0
No. 200	3-6	6.7	6.7	8.1	7.7	7.7
Asphalt content		4.9	4.4	4.9	4.4	4.6
Marshall stability, lb	1,800 min	2,232	2,853	2,540	2,473	2,309
Flow, 0.01 in.	16 max	12	10	12	12	12
Percent voids total mix	3-5	3.6	3.6	2.8	3.9	3.9
Percent voids filled	70-80	76.2	74.5	80.7	72.9	73.6
Unit weight, pcf		150.4	152.1	152.2	151.7	151.2
Theoretical density, pcf		155.9	157.8	156.6	157.8	157.3

Table 6

Asphalt Concrete Intermediate Course Field Density Analysis

Location	Core No.*	Thickness in.	Unit Weight pcf	Compaction percent
Trial Test Section	M-1	3	148.3	97.5
	M-2	2-3/4	148.3	97.5
	M-3	3	148.7	97.8
	M-4	2-3/4	146.3	96.2
	M-5	2-3/4	148.4	97.6
	AVG	2-7/8	148.0	97.6
RMP Test Strip	M-1	3-1/4	149.7	98.7
	M-2	3	150.0	98.9
	M-3	3	148.2	97.7
	M-4	3	148.2	97.7
	M-5	2-1/2	148.9	98.2
	M-6	3	149.7	98.7
	M-7	2-7/8	146.2	96.4
	AVG	3	148.7	98.0
	J-1	2-7/8	147.5	97.2
	J-2	2-1/4	148.9	98.2
	J-3	3-1/4	147.7	97.4
	AVG	2-3/4	148.0	97.6

Lab Unit Weight - Test Section - 152.2 pcf
Test Strip - 151.7 pcf

* M=Mat Core, J=Joint Core.

Resin Modified Pavement

Open-graded asphalt mixture

27. After completion of the intermediate course, a trial section for the open-graded asphalt mixture was constructed. Several batches of material were produced at the batch plant prior to placement of the material. After visually observing slight asphalt drainage of the open graded material, the asphalt content was decreased to 4.0 percent based on the recommendation of the Jean Lefebvre representative. This change in asphalt content was to ensure that the mixture had enough void structure to allow full penetration of the slurry grout.

28. The open-graded asphalt mixture trial section was constructed on top of the dense-graded intermediate course trial section. The asphalt material was tested for specification conformance. The test results listed in Table 7 indicated that the production of the open-graded material and construction procedures used to place the material were satisfactory.

29. The open-graded asphalt mixture for the RMP test strip was placed on top of the dense-graded asphalt concrete intermediate course 1 week after the intermediate course was placed. A light tack coat was sprayed onto the intermediate course using the same type of asphalt emulsion and application rate as before. The tack coat was allowed to cure for a few hours before the open-graded mixture construction began.

30. Similar to the quality control techniques used during the construction of the intermediate course, samples of the hot open-graded mix were taken from the haul trucks at several intervals during the day. Laboratory tests were conducted on these materials to determine the asphalt content, aggregate gradation, and most importantly, the final void content. The results of the quality control tests are listed in Table 7. Additionally, core samples were cut out of the hardened test strip the following morning to check these same properties. All loose mix samples and core samples indicated that the open-graded mix was placed with satisfactory material properties and construction techniques.

31. The open-graded mixture was spread with the same mechanical paver that was used for placing the intermediate course (Figure 6). Under normal circumstances, open-graded mixes tend to cool off quickly because of their

high internal voids and low mixing temperatures (265°F). This means that the required compaction usually must follow closely behind the paver that is placing the mix. Because the ambient temperatures were so high during the

Table 7

Open-Graded Asphalt Mixture Analysis

Sieve Size	Specified Limits	JMF *	Trial Test Section	Test Strip S-1	Test Strip S-2	Test Strip S-3
3/4 in.	100	100	100	100	100	100
1/2 in.	65-75	67	68.3	74.1	79.4	72.8
3/8 in.	50-65	44	42.2	50.4	52.8	47.2
No. 4	23-33	22	17.9	19.7	21.8	20.5
No. 8	9-17	12	10.2	8.2	9.5	9.0
No. 30	5-10	5	4.7	2.9	3.6	3.0
No. 200	1-3	2	1.1	0.8	1.3	0.8
Asphalt content		4.0	3.5	3.4	3.5	3.4
Percent voids total mix	French**	30.8	31.2	32.4	31.2	32.6
	Corps†	33.8	34.5	35.9	34.6	35.9
Percent voids filled	French**	17.2	15.2	14.1	15.2	14.0
	Corps†	15.9	14.0	12.9	13.9	12.9
Unit weight(pcf)		102.8	102.1	100.1	101.9	100.0
Theoretical density (pcf)		154.6	154.9	156.1	155.8	156.1
Temperature (°F)		265	250	240	250	275

* Gradation recommended by Jean Lefebvre representative.

** French Method - $VTM = [1 - (\frac{WTair - WTwater}{volume}) \times 100]$.

† Corps Method - $VTM = [1 - \frac{WTair}{volume} (\frac{1}{SG_T})] \times 100$.

VTM = Voids Total Mix.

WTair = Dry weight of specimen.

WTwater = Weight of specimen in water after soaking for 15 min.

Volume = $\pi/4\ D^2\ H$ (measured).

SG_T = Theoretical specific gravity.

construction of the test strip, rapid heat loss of the asphalt mix was not a problem. To the contrary, the afternoon temperatures which reached well over 100^0 F forced the construction crews to wait several hours before rolling so that the roller would not cut and shove the hot asphalt mixture.

32. As is the case for most open-graded asphalt mixes, compaction during construction was not used to achieve any density requirements, but merely to "seat" the asphalt coated aggregates and smooth over the rough surface. A relatively small 3-ton steel-wheeled roller was used to roll the open-graded mix (Figure 7). The static, light-weight steel-wheeled roller was used as opposed to the more traditional heavier models (8 to 10 tons) to ensure that a minimal loss in voids would result during the rolling process.

33. Once the open-graded asphalt mixture had cooled for several hours, a single pass of the small steel-wheeled roller in the static mode was made over the entire 150-by 50-ft area. Small cut marks were left along the edge of the roller wheels after this process. Therefore, after another hour of cooling, another pass of the small roller was used to roll out these marks. After these final passes of the roller, the construction of the open-graded asphalt layer was complete.

34. Due to the high percentage of voids and the modest slope of the test section, a sand asphalt material was placed on the edges of the open-graded material to prevent seepage of the fluid grout. The entire freshly paved area was covered with polyethylene sheeting for the night to prevent contaminants such as dirt and sand from blowing onto the pavement surface and falling into the open voids.

Resin modified slurry grout

35. A trial application for the resin modified slurry grout was conducted the day after the open graded trial section was completed. One batch of slurry grout was produced according to the recommended mixture proportions. The slurry grout had the proper viscosity, but the sand material settled out before placement was completed. It was recommended by the Jean Lefebvre representative that the amount of sand be decreased to avoid any problems of settling. The final mixture proportions for the resin modified slurry grout are listed in Table 8.

Figure 6. Placing open-graded asphalt material

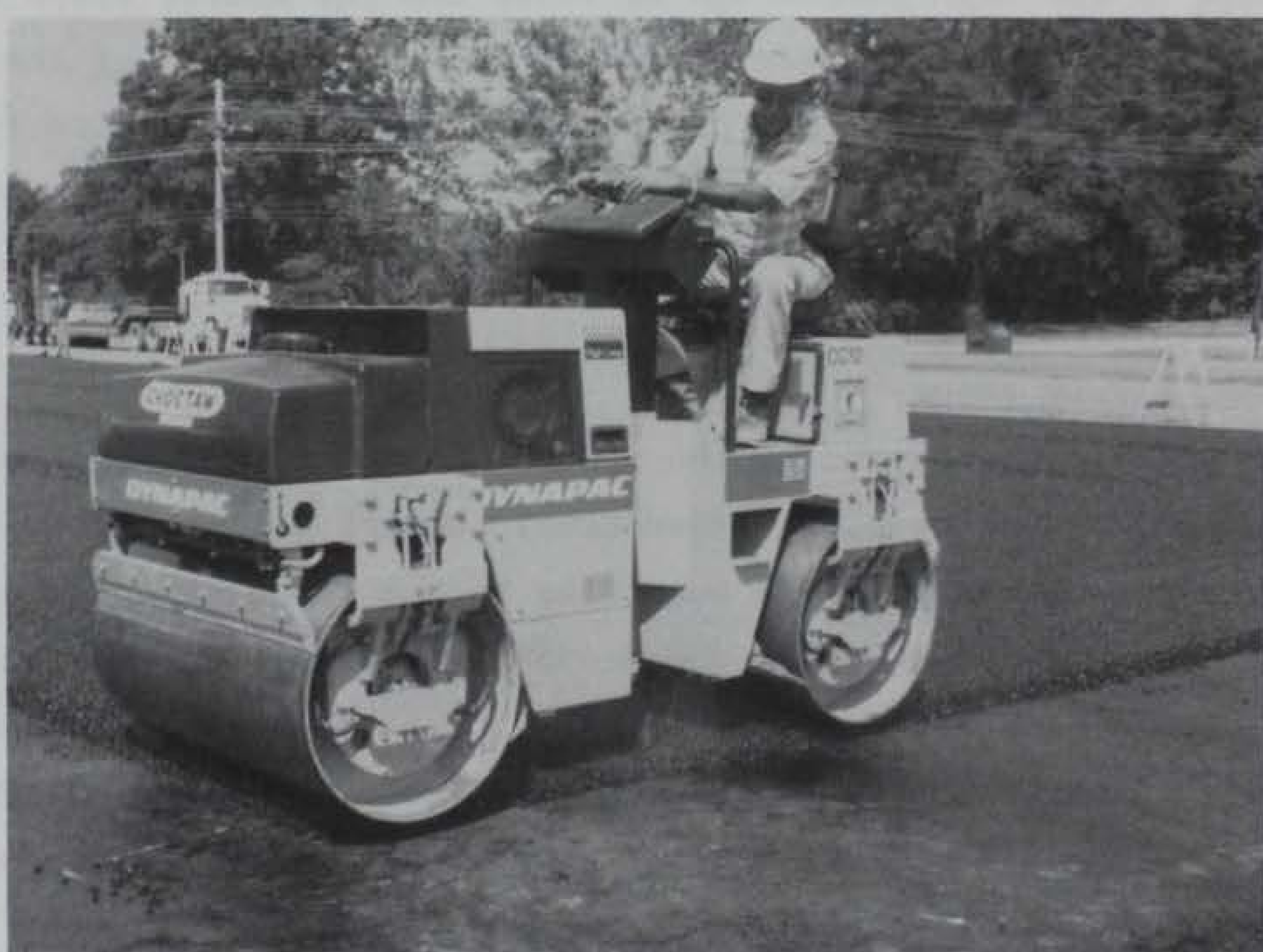

Figure 7. A 3-ton steel-wheel roller

Table 8

Revised Resin Modified Slurry Grout Formula and Viscosity Test Results

Material		Batch Percentage by Weight
Type I cement		38.2
Fly ash		19.1
Sand		13.3
Water		26.7
Cross polymer resin		2.7
Marsh flow cone		--
Viscosity test,	No. 1 - 6.2 sec	--
	No. 2 - 7.0 sec	
	No. 3 - 7.0 sec	
	No. 4 - 7.0 sec	

36. The resin modified slurry grout was added to the open-graded asphalt pavement 2 days after the open-graded mix was placed. The slurry grout used in the construction of the test strip was made at a local concrete batch plant. The dry cement, sand, and fly ash were mixed in the plant's pugmill for several minutes before dumping into the transient mixer truck. Then the water was dumped into the transient mixer truck, and the resulting slurry grout was mixed in the rotating mixing drum for several minutes. At this point, the cross polymer resin additive was poured into the mixing drum and the truck operator was allowed to leave the plant site for the test strip jobsite while the mixing truck continuously rotated intransit.

37. Once at the test strip jobsite, the transient mixing trucks were allowed to position themselves directly on the open-graded asphalt pavement which had hardened overnight. A sample of the slurry grout was first taken and the Marsh flow cone viscosity was checked on the test strip jobsite to ensure that the grout was of the proper viscosity (Figure 8). Samples were taken from each transient mixer truck at the test strip jobsite and approved before the grout was placed. Viscosity test results are listed in Table 8.

Figure 8. Testing slurry grout with Marsh flow cone

38. The grout was to be placed in the same 10-ft wide longitudinal lanes as were used during construction of the open-graded asphalt pavement. This pattern gave a sense of order to the grout application and prevented over-working the hand working crew. This crew consisted of four people working broom-handled squeegees behind the transient mixer truck. The slurry grout was slowly poured onto the open-graded asphalt surface, and when an area became saturated with grout, the squeegees were used to pull the grout along the surface to undersaturated areas. The grout was poured onto the pavement surface after traveling down a pivoting delivery chute. As the grout was slowly poured onto the pavement, one person continuously directed the chute to dry areas of the pavement. Once an area of a lane was completely saturated with grout, the truck driver slowly moved the truck forward. After a short time at the beginning of the grout application, the squeegee operators, chute operator, and truck driver were able to continue the grouting procedure in an efficient, controlled manner. Figure 9 is a typical view of the grout application procedure used on the test strip.

Figure 9. Resin modified slurry grout being applied to open-graded asphalt mixture

39. Immediately behind the grouting operation, the small 3-ton steel-wheeled roller made several passes over the grout filled pavement in the vibratory mode in order to ensure that all subsurface voids were being filled. Because the void content of the open-graded asphalt pavement and the slurry grout viscosity were within the specified ranges, the vast majority of the internal voids were filled with grout simply by saturating the pavement when the grout was poured over the surface. There did seem to be, however, a small amount of internal voids isolated from the initial grout application as evidenced by small air bubbles which appeared behind the vibratory roller as it passed. These air bubbles usually appeared only after the first pass of the vibratory roller, indicating that all voids were being filled with grout.

40. After each of the five 10-ft lanes had been saturated with grout and vibrated, all excess grout remaining on the surface was removed by continually pulling the hand squeegees in one direction. This process also served to fill any possible undersaturated areas. After this final step, the grout application was complete.

41. To evaluate whether full penetration of the slurry grout had occurred, random 4-in. cores were taken throughout the RMP test strip and examined. All cores indicated that the slurry grout material had penetrated the total thickness of the open-graded layer. The results of the field cores are listed in Table 9.

Table 9

Resin Modified Pavement Test Strip Field Cores

Location	Core Number	Thickness in.	Unit Weight pcf	Grout Penetration percent
Trial test section	1	1-3/8	140.6	100
	2	2-1/2	140.5	100
	3	2-3/4	139.7	100
	4	2-3/8	141.0	100
	AVG	2-1/4	140.5	100
RMP test strip	1	2-9/16	139.0	100
	2	2-1/4	138.3	100
	3	2-1/8	138.8	100
	4	2-1/2	140.8	100
	5	2-1/8	138.0	100
	6	2	139.0	100
	AVG	2-1/4	139.0	100

Curing

42. After the grout application was completed, a curing compound was sprayed over the surface of the wet, grout-filled pavement (Figure 10). The material used was a white pigmented concrete curing compound which is commonly used in curing Type I portland cement concrete. The white pigments are used to reduce maximum pavement temperatures during the curing period. This in turn reduces the expansion and contraction stresses resulting from extreme temperature changes. An overabundance of these stresses can lead to shrinkage cracking during the curing period. The curing compound was applied by a pressurized, hand operated sprayer wand with a fan type nozzle. A light coating of the curing compound (200 sq ft per gal) over the entire test strip completed the construction process. The pavement was allowed to cure with no traffic applied for 28 days before traffic testing began.

Figure 10. Applying curing compound

PART IV: EVALUATION

43. In order to determine the effectiveness of the RMP, a series of tests and evaluations were conducted on the pavement surface. A layout of the testing areas is shown in Figure 11. To evaluate the abrasion resistant characteristics of the RMP, tracked vehicle maneuvers were conducted. Controlled fuel and oil spills were conducted to evaluate the fuel resistant properties. The ALF was used to evaluate the RMP under heavy rubber-tired vehicular traffic.

Tracked Vehicle Traffic

44. As previously mentioned, the RMP test strip was allowed to cure for 28 days before any traffic was allowed on the pavement. This cure time was allowed to ensure that the RMP had plenty of time for adequate strength gain. The effectiveness of the RMP greatly depended on its performance during the tracked vehicle trafficking.

45. Tracked vehicle traffic on the RMP test strip consisted of the M1 and M60 tanks and gross weights of 113,000 and 100,000 lb, respectively. Six hundred 180 deg pivot steer turns at the same point (Figure 12) and 5,000 straight passes were applied with the tracked vehicles to the test strip. Excessive wear of the tank track rubber pads was noticed during the initial trafficking of the RMP. During the initial stage of trafficking, the RMP withstood the abrasive action of the pivot steer turns very well; only excess grout was worn off (Figures 13 and 14). As the tank track turned during the pivot steer, the track pads would drag across the RMP surface. After 420 turns at the same location, the tracked vehicle produced enough rough abrasion and high stresses to start surface raveling (Figure 15). The surface raveling began without any warning. Once the raveling started, the deterioration increased rapidly because the loose debris that had been dislodged was now being dragged and scraped across the RMP surface causing further damage.

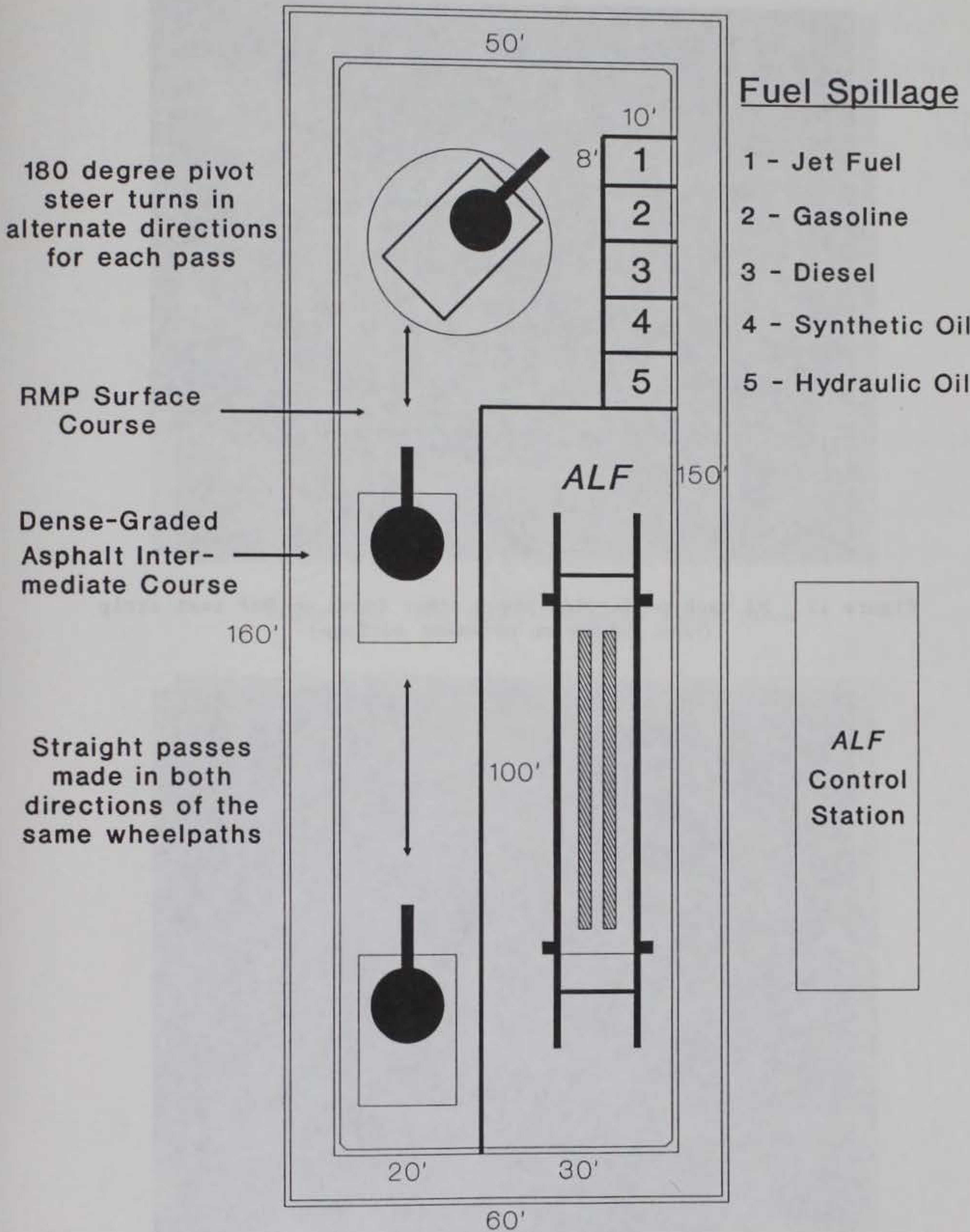

Figure 11. Layout of test areas on RMP test strip

Figure 12. M1 tank performing pivot steer turns on RMP test strip (note rubber on pavement surface)

Figure 13. RMP after 100 pivot steer turns

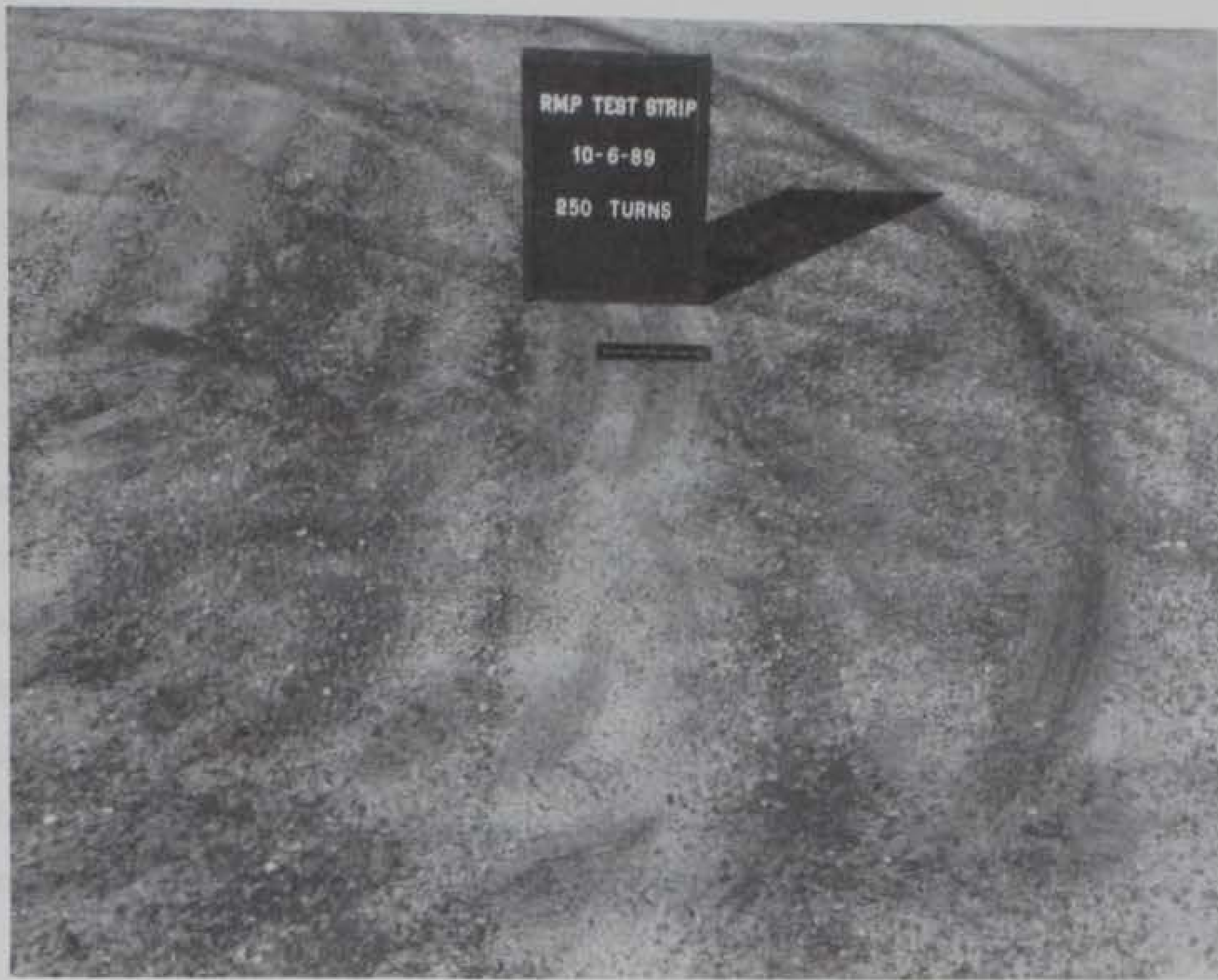

Figure 14. RMP after 250 pivot steer turns

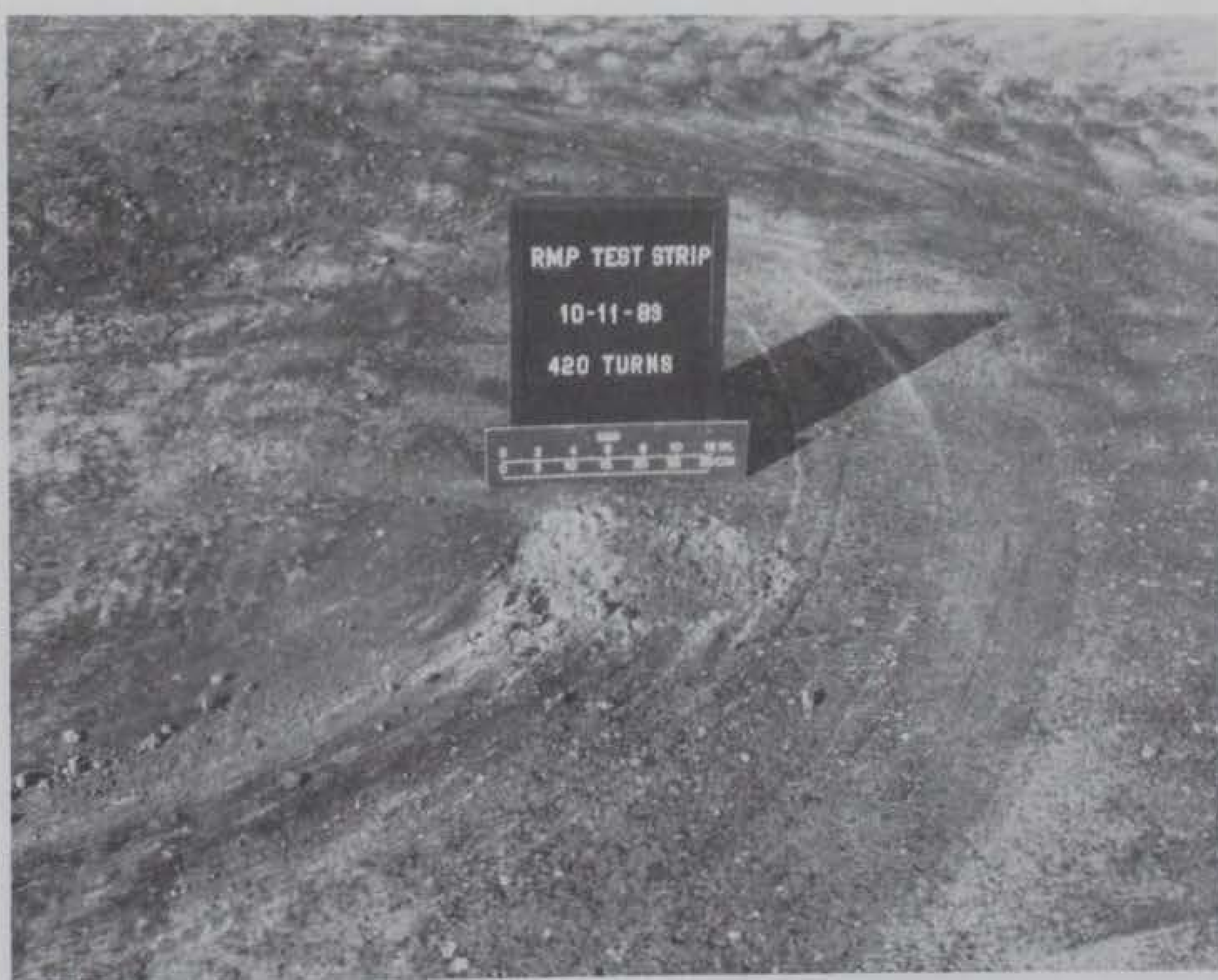

Figure 15. RMP after 420 pivot steer turns

46. At 600 pivot steer turns, the turning traffic was stopped because the abrasive action had produced a raveled area 1 in. deep covering 35 sq ft (Figure 16). It was thought that a large number of concentrated pivot turns of this nature are not commonly applied to one location in the field, making this traffic test much more severe than normal applications. As an example, it would require the tanks of two armored divisions performing 180 deg pivot steer turns at the same exact point to equate to this traffic test.

47. The 5,000 straight passes with the tank traffic only caused slight surface wearing of the grout, which exposed the surface of the coarse aggregate. The condition of the RMP surface at various intervals is shown in Figures 17 to 20. The tracked vehicle moving forward and in reverse caused no significant damage to the RMP. At the conclusion of the tracked vehicle trafficking, it was determined that the RMP had effectively demonstrated a resistance to severe traffic abrasion and could be used as a pavement surface for tracked vehicles.

Figure 16. RMP after 600 pivot steer turns

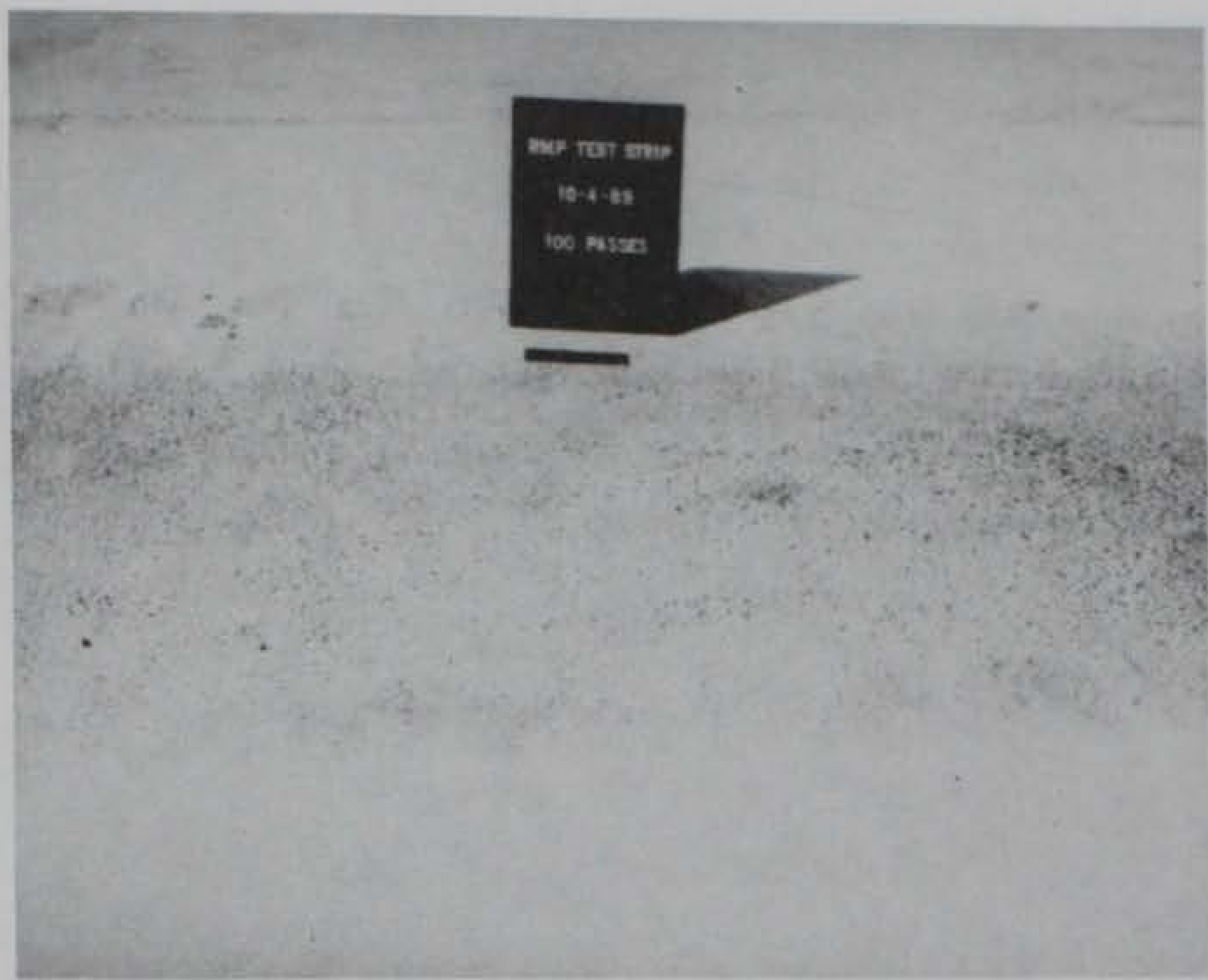

Figure 17. RMP after 100 straight passes

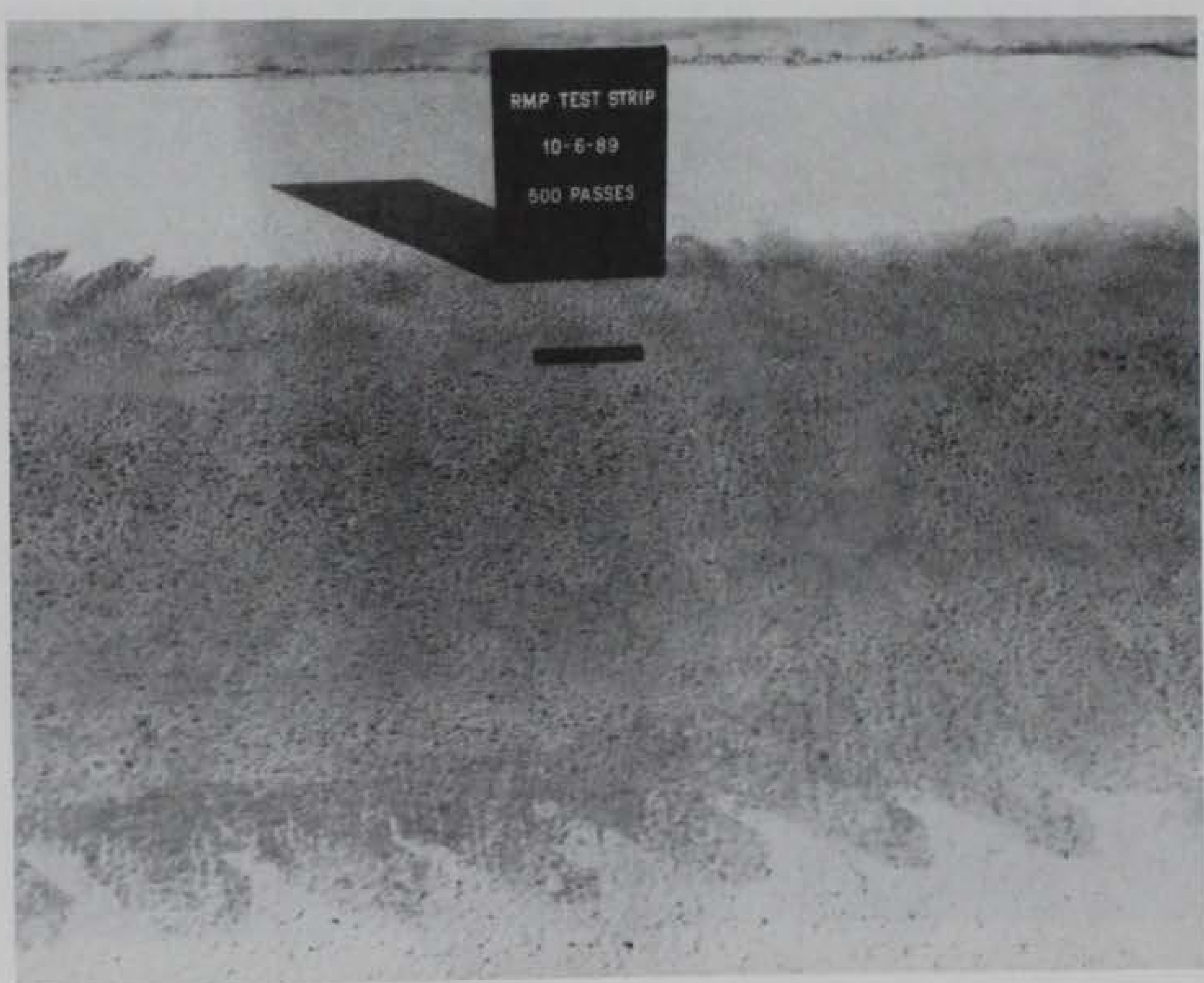

Figure 18. RMP after 500 straight passes

Figure 19. RMP after 2,500 straight passes

Figure 20. RMP after 5,000 straight passes

Fuel and Oil Spillage

48. Five different fuels and oils were used to evaluate the effectiveness of the RMP in resisting deterioration caused by fuel and oil spillage. Jet aviation fuel, gasoline, diesel, synthetic oil, and hydraulic oil were spilled on the RMP. Thirty cycles consisting of 1 qt of each material were spilled on the RMP surface. Each spilled area was 8 by 10 ft. The materials were spilled from a height of 30 in. The rate of spillage was set so that each material took 20 to 30 min to drip 1 qt. The apparatus used to spill the fuel and oil is shown in Figure 21. The fuels and oils were allowed to set on the RMP for an additional 30 days after the 30 cycles of spillage were completed. Figure 22 shows the condition of the fuel and oil spillage areas after this 30-day period.

49. Visual observations indicated that the RMP was resisting deterioration from fuel and oil spillage. However, field cores taken from the spillage areas indicated that the fuels and oils had penetrated the RMP causing varying degrees of low level deterioration. The gasoline and jet aviation fuels had a fast rate of evaporation which prevented these materials from significantly penetrating the RMP. The diesel fuel penetrated the RMP the fastest and caused the most damage. Once again, this test is thought to be an acceleration of typical fuel spillage problems in the field as most spills are normally cleaned and not allowed to soak into the pavement for several months.

50. After the fuel and oil penetration had been discovered, the stability of the RMP was questioned. The maximum penetration was approximately 1 in. in the diesel area. The remaining fuels and oils penetrated less than 1/2 in. A 1-ton van was used to traffic the fuel spillage areas. Fifty passes and fixed position, power steering turns were applied to the contaminated areas by the van. Only slight scuffing was noticed after the van had trafficked the RMP with no appreciable damage.

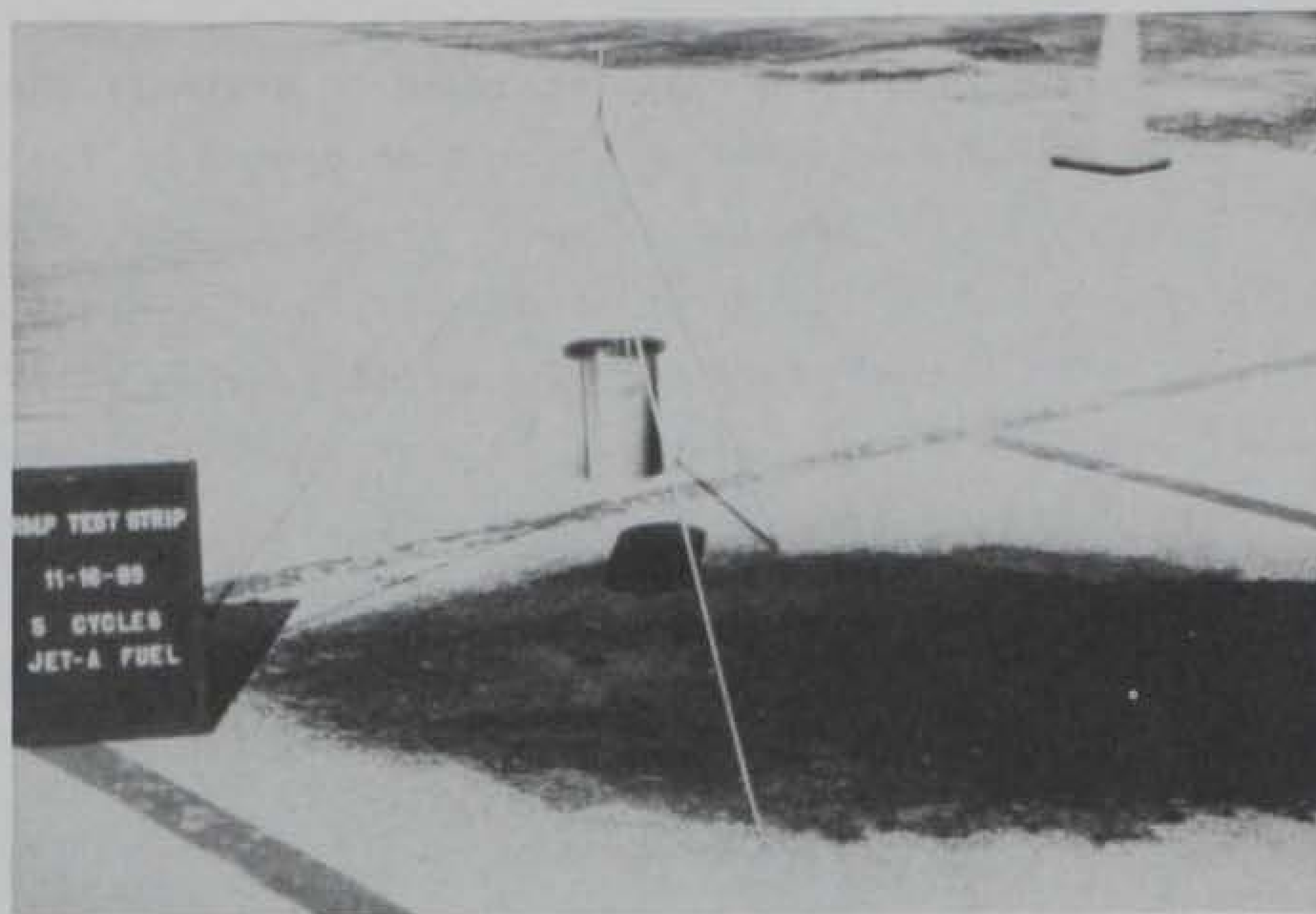

Figure 21. Fuel and oil spillage apparatus

Figure 22. Fuel and oil spillage areas

Accelerated Loading Facility (ALF)

51. The Federal Highway Administration's ALF was also used to traffic the RMP test strip (Figure 23). ALF simulated truck traffic by applying a load of 19,000 lb to a dual wheel assembly with tire pressures of 140 psi. ALF applied 80,000 passes to a 48-in.-wide strip of the RMP. No appreciable deterioration or deformation occurred in the wheel path. Only slight wearing of the excess grout on the RMP surface was observed. The ALF evaluation indicated that vehicular traffic had little effect on the RMP and that the RMP should have good field performance when trafficked by rubber-tired vehicles.

Figure 23. The ALF trafficking the RMP test strip

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

52. Based on the background analysis and the construction, trafficking, and evaluation of the RMP test strip, the following conclusions were made:

a. The RMP can be constructed with standard paving equipment without major changes in standard paving procedures and techniques.

b. The RMP does resist significant abrasion damage due to tracked vehicle maneuvers including both straight passes and 180 deg pivot steer turns.

c. The RMP does resist significant damage due to fuel and oil spillage.

d. Heavy loads and high tire pressures of vehicular traffic have little or no adverse effect on the RMP.

53. The RMP provides a tough and durable surfacing material for military pavements. The current data and evaluations indicate that the RMP process has potential for several pavements use. The variable costs of materials (aggregates, asphalt cement, portland cement) as well as construction costs throughout the United States make cost estimates for the RMP very site specific. However, the additional cost of the resin additive can be isolated to range from \$4 to \$6 per sq yd, depending on the void content of the open-graded support layer and the dosage rate of additive in the slurry grout. Therefore, it is estimated that the initial cost of the RMP in 1990 will be between \$10 and \$15 per sq yd as compared to \$15 to \$25 per sq yd for portland cement concrete with equally similar vehicle abrasion resistance. At this price, the RMP is a cost-competitive method to construct or rehabilitate many of the Army's abrasion and fuel-resistant pavements.

Recommendations

54. Based on the conclusions derived from the findings and results of the evaluation on the RMP test strip, the following recommendations were made:

a. The RMP construction process can be used to construct new pavements or rehabilitate existing pavements that are subjected to heavy, abrasive loads and fuel spillage.

b. The RMP can be used to surface areas trafficked by tracked vehicles such as tank trails and crossings, hardstands, staging areas, and wash facilities.

c. The RMP can be used to surface areas that are subjected to fuel and oil spillage such as motor pools, refueling pads, and aircraft parking aprons.

55. The RMP provides an alternative surfacing material in areas where conventional pavement materials have excessive maintenance problems. The RMP can be used in place of asphalt concrete and portland cement concrete in these specialized areas. Further recommendations concerning the RMP process are listed below:

a. Monitoring RMP test strip and other in-place RMP's should be conducted to determine long-term pavement performance under various traffic conditions.

b. Further research is needed to develop laboratory tests and procedures to evaluate RMP materials and proper mix design procedures.

c. Field test sections need to be constructed in order to modify and improve RMP construction techniques so that the RMP process can be customized to US standards.

d. Design failure criteria need to be determined so that proper design thickness procedures can be implemented.

e. Construction specifications, mix design procedures, thickness design criteria, and application guidance should be established and documented in existing standard practice manuals and Corps of Engineers guide specifications.

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APPENDIX A: FIELD INSPECTION AND EVALUATION OF SALVIACIM PAVEMENT TEST SITES

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P.O. BOX 631
VICKSBURG, MISSISSIPPI 39180-0631

REPLY TO
ATTENTION OF

CEWES-GP-IM

1 June 1988

MEMORANDUM FOR RECORD

SUBJECT: Inspection and Evaluation of Field Test Sites of Salviacim Pavement Process

1. Mr. Gary Anderton and I visited several sites in France and England to evaluate the field performance of the Salviacim pavement process. These inspections were conducted on various types of pavement structures with different traffic conditions. The pavements inspected included a parking facility for heavy commercial trucks, a parking apron at a commercial airport, range roads for tracked vehicles, a heliport, and maintenance and staging areas for tank vehicles.

2. The Salviacim pavement is best described as either a semi-rigid or semi-flexible pavement. The Salviacim pavement process is basically an open-graded asphalt concrete mixture that contains 20-25 percent voids which are filled with a slurry grout. This grout is composed of cement, sand, mineral filler, water and Prosalvia L7 (proprietary material). The grout material is poured onto the open-graded asphalt after the asphalt has cooled, squeeged over the surface and vibrated into the voids with a small vibratory roller (3-5 tons). Depending on the type of portland cement used in the grout, the cure time may vary between 1 and 7 days.

3. Mr. Anderton and I were accompanied by Mr. Jean Claude Roffe of Jean LeFebvre Enterprise on all site visits. Jean LeFebvre is the asphalt paving company which developed the Salviacim process and holds a patent on the material in France. Mr. Roffe is the Department Manager in charge of marketing the Salviacim process throughout the world. During the inspections of the pavements in France, Mr. Tyrone Maitland of Omni Tech International took part in the evaluations. Mr. Maitland was a consultant for the Alyan Corporation which is marketing the Salviacim pavement process in the United States. Mr. Maitland is a retired Lieutenant Colonel in the U.S. Army. He served as a Corps of Engineers (CE) facility engineer at several installations in Europe.

4. Prior to inspecting the field sites, we visited the Jean LeFebvre Research Laboratory at Dourdan, France. In this facility, all research and testing for asphalt concrete and Salviacim pavements is conducted. After discussing laboratory procedures and observing the testing equipment, it was evident that many of the standard procedures used by Jean LeFebvre were different than the standard CE procedures. In order to properly evaluate the Salviacim pavement, I informed Mr. Roffe that I needed to know the step-by-step laboratory procedures involved in determining mix designs for the open graded asphalt concrete support layer and the slurry grout. I implied that certain

modifications to laboratory procedures and equipment used for evaluating the Salviacim pavement might be developed for the standard equipment used in the United States.

5. On 3 May 1988, we inspected a parking facility at a roadside truck stop in Niort, France. This pavement was approximately 300 ft (90m) wide and 500 ft (150m) long. Three lanes, approximately 75 ft (22m) wide, were surfaced with the Salviacim pavement. These areas were used for parking the commercial trucks (maximum load 80,000 lb). The reason for using the Salviacim pavement, according to Jean LeFebvre, was to withstand the heavy static loads and to prevent damage due to fuel spillage (Photo 1).

6. The pavement structure of this parking facility was the thinnest of all the pavements inspected. This pavement was classified as a light traffic area according to Jean LeFebvre. The pavement structure consisted of a soil cement stabilized base 6 in. (15cm) thick with a 1.5 in. (4cm) layer of Salviacim pavement as the surface.

7. The condition of this pavement looked satisfactory for a 5-year-old pavement that was constructed over a cement treated base. Random hairline cracks, some with a block cracking pattern, were evident on the surface. Most of these cracks were less than 1/8 in. (0.3cm) wide and would be classified as low-severity cracks (Photos 2-3). Diesel fuel and motor oil spills were observed on the pavement surface with no evidence of damage. No rutting was observed in the wheelpaths of the Salviacim pavement.

8. We also visited the Merignac Airport in Bordeaux, France, on 3 May 1988. The airfield served both commercial air traffic and the French Air Force. Our inspection of the Salviacim pavement only involved the civilian facility. I was told by the airport engineer that the Salviacim pavement had been used extensively on the military side on parking aprons and in maintenance hangars and was performing as well as the civilian side.

9. The original parking apron of the commercial airport was constructed by a U.S. Army Engineer Battalion in 1957. This pavement was an 8-in. (20cm) thick jointed PCC slab, 12.5 ft by 12.5 ft (5m by 5m). In 1976, the pavement was redesigned to carry the increased weights of new aircraft. The new overlay included 4-6 in. (12-16cm) of dense graded asphalt concrete topped with 1.5 in. (4cm) of Salviacim pavement.

10. The condition of this 12-year-old pavement was good to excellent. All joints from the existing PCC slabs had reflected through the asphalt concrete and the Salviacim pavement. All cracks in the Salviacim pavement had been sealed. Typical reflective cracks are shown in Photos 4-5. Some random cracking did occur in the slabs but was not evident in all areas. Overall, this pavement had withstood the loading and fuel spillage that had occurred during the pavement's service life very successfully.

11. In 1979, the overlay project was extended several hundred feet. The pavement thickness was the same as in 1976, but a saw cut was placed above each PCC joint. The controlling of the reflection cracks was an effective method of controlling the cracking problem of the previous section. These saw cuts were sealed similar to a PCC joint. This reduction in random cracking within slabs produced a pavement requiring much less maintenance. These joints had not been resealed in 9 years. The typical condition of a sawed joint is shown in Photo 6.

12. Some random hairline cracks had developed in the 1979 pavement. These cracks were 1/8 in. (0.3cm) or less and had been sealed with a bandaid approach (Photos 7-8). All cracks in the Salviacim pavement were surface cracks and would be classified as low-severity cracks. This pavement had also been subject to fuel spillage. Some areas had been contaminated with jet fuel while other areas had received spillage of diesel fuel and motor oils from airport equipment. Minor surface damage was evident due to excessive fuel spillage; surface fines and grout material had been worn off with no structural damage to the Salviacim pavement (Photos 9-10).

13. Two areas of the 1976 pavement were replaced in 1985 and 1986. We were told by the airport engineer that these two areas received the heaviest traffic (747 aircraft) and the most fuel spillage. He stated that after 10 years, these pavements were "worn out". The rehabilitation of these pavements involved removing the old Salviacim layer and placing a new 1.5-in. (4cm) layer of Salviacim.

14. In 1979, a small section of the parking apron was completely reconstructed using a flexible pavement design. The pavement structure consisted of 15.5 in. (40 cm) of gravel base course, 2.5 in. (6cm) of asphalt concrete, and 1.5 in. (4cm) of Salviacim. This pavement had small hairline cracks but not large enough to be sealed. This pavement was in excellent condition.

15. A direct comparison of the Salviacim pavement to asphalt concrete was seen in the parking area for the 747 aircraft. This asphalt concrete pavement adjacent to the Salviacim had to be covered with a fuel-resistant sealer, known as Promak (Photo 11). Fuel spills had caused structural problems in the asphalt concrete; the evidence was a depression caused by aircraft tires (Photo 12). No pavement failures were observed in the Salviacim area.

16. The airport engineer informed us that he had chosen the Salviacim pavement over a PCC pavement because of the comparative economics. He said that he was satisfied with the performance of Salviacim and would recommend its use in areas with heavy static loads and fuel spills if economics dictated.

17. On 4 May 1988, we inspected Salviacim pavements at the Regiment De Chasseurs Army Base in Fontevraud, France. This installation had several pavements constructed with Salviacim including an artillery range and several tank trails. The Salviacim pavements had been constructed throughout the installation between 1979 and 1984. Approximately 114,000 sq yd (95,000 sq m) of Salviacim had been placed for tracked vehicles.

18. The pavement structures for all trails were constructed on natural material that had a very high moisture content. The pavement structure was designed with drainage layers at the bottom. A filter layer of sand 4 in. (10cm) thick was placed on the subgrade, followed by a 12-in. (30cm) layer of coarse gravel. A dense graded base course 4 in. (10 cm) thick was constructed on top of the drainage layers. The remainder of the pavement included 3 in. (7cm) of asphalt concrete and a 2-in. (5cm) layer of Salviacim. All Salviacim pavements constructed on this installation used this thickness design.

19. The artillery range, which was constructed in 1984, consisted of four lanes of Salviacim pavement approximately 1,500 ft (400m) long. Each lane was approximately 15 ft (4.5m) wide. At one end of the range, a rise or hill was constructed (Photos 13-14). The Salviacim pavement had extensive longitudinal cracking on the hill portion of the ranges. I believe this cracking was due to a weak pavement structure or a lack of compaction of the base course (Photo 15). The remainder of the artillery range was in excellent condition with minimum cracking and no abrasion or wear due to the tracked vehicles (Photo 16).

20. The second area that was inspected was a tank range road that was used by tracked vehicles as they exited the ranges. This pavement was constructed in 1979. A portion of this pavement was covered with mud, but the remaining pavement was surfaced with Salviacim. While we were inspecting the pavement, four MX30 tanks performed locked wheel turns at an intersection. These tracked vehicles caused no appreciable damage to the Salviacim pavement as only rubber marks from the pads were seen (Photo 17-18). One tank was running with only 50 percent pads, and the steel plates were not harming the pavement (Photo 19-20). This Salviacim pavement was performing extremely well under these severe conditions.

21. On 10 May 1988, Messrs. Anderton, Roffe, and I visited the Royal Navy Air Station at Portland, England. We were escorted to the helicopter field by Mr. William Heather of Associated Asphalt, the contractor who constructed the airfield. The airfield had several Salviacim pavements that had been constructed as early as 1976. The main runway and isolated refueling pads were constructed during 1986-1987. An overall view of the airfield is shown in Photo 21.

22. The airfield was constructed on a landfill reclaimed from the ocean bay. The pavement was placed on a 12 in. (30cm) layer of compacted fill material. The pavement structure consisted of a 2-in. (5cm) tar intermediate course, 1 in. (2.5 cm) of a tar wearing course, and 1.5 in. (4cm) of Salviacim. The remaining portion of the airfield was a flexible pavement with Promak fuel resistant sealer on the surface.

23. All Salviacim pavements were in good to excellent condition except for an isolated fuel pad which was not constructed properly according to both the base engineer and the contractor. Small hairline cracks were observed, but were very few in number. Tire marks from helicopters were observed on the pavement but had not caused any damage to the Salviacim. Heavy fuel spillage was observed on each Salviacim pad with no appreciable deterioration (Photos 22-23).

24. The group met with Mr. John Broddle of the Public Services Agency who was responsible for airfield design and maintenance. Mr. Broddle said that Salviacim was a good product if 100 percent penetration of the grout material was obtained. Mr. Broddle showed us field cores that had been taken in bad areas (Photo 24). He informed us that field cores were taken during construction to ensure full penetration. When this was not achieved, the material was removed and replaced (Photo 25).

25. On 11 May 1988, Messrs. Anderton, Roffe, and I visited the Royal Armoured Corps Centre at Lulworth, England. We were escorted to the gunnery school by representatives from the Tarmac Company, Mr. Harry Rickward and Mr. Peter Williamson. We inspected two tank facilities that were constructed with Salviacim pavements.

26. A maintenance and staging area for the Cheiftan (50 tons) and Challenger (60 tons) tanks was constructed with Salviacim in 1986 (Photo 26). The pavement structure consisted of a cement treated base with 2.5 in. (6cm) of asphalt concrete and a 1.5-in. (4cm) layer of Salviacim. This pavement had daily traffic and was suspect to fuel spillage. Neither the turning action of tracked vehicles nor the fuel spillage had caused any damage to the pavement. Only minor abrasions were observed on the Salviacim surface (Photos 27-28). This pavement was in excellent condition.

27. A second tank facility that was constructed in 1979 was also inspected. No records of the pavement structure were available at the time of this site visit. This pavement was a staging area for a tank platoon. Daily usage for 9 years had not caused any appreciable damage to the Salviacim pavement. This pavement was in good condition (Photo 29).

28. These site visits to France and England allowed Mr. Anderton and myself to evaluate the field performance of the Salviacim pavement process under

various types of traffic conditions and loadings. From observations made during these inspections, the Salviacim pavement can withstand abrasive action from tracked vehicles, heavy point loads, and prevent deterioration due to fuel spillage. Based on the visual inspections, the Salviacim pavement process has the potential to become a surfacing material that can be widely used in military pavements.

29. Although the field performance of this material looked favorable, many questions about the Salviacim pavement process are unanswered. Material requirements and specifications and pavement thickness designs are two areas of uncertainty. Construction procedures, laboratory tests for mix designs and quality control methods need to be standardized for use in the United States. Information concerning these areas has been requested from Jean LeFebvre, but not until laboratory tests and field test sections are completed will the answers to these questions be known.

30. Due to the recent emergence of the Salviacim pavement process in the United States, the actual costs of this process have not been well defined. According to Jean LeFebvre, the typical cost of the Salviacim pavement in France is 10 percent more than an asphalt concrete pavement and 10 percent less than a portland cement concrete pavement. I have been informed that the Alyan Corporation is currently preparing information on the cost breakdown of Salviacim for the United States market.

Randy Ahlrich
R. C. AHLRICH
Pavement Systems Division

Photo 1. Commercial parking facility - Niort, France

Photo 2. Typical crack pattern

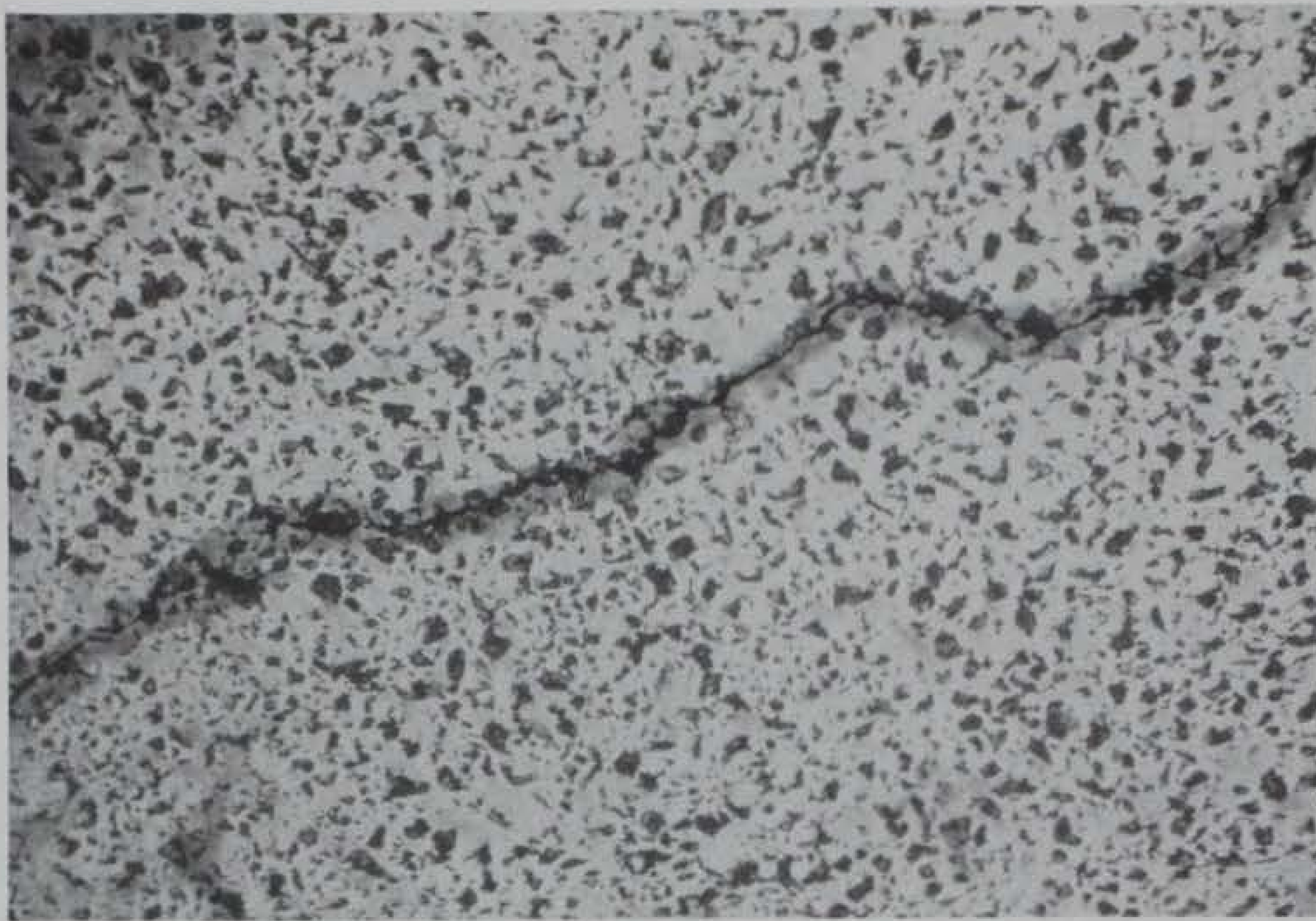

Photo 3. Close-up of hairline crack

Photo 4. Random reflective cracks in 1976 Salviacim pavement

Photo 5. Reflective joints in 1976 Salviacim pavement

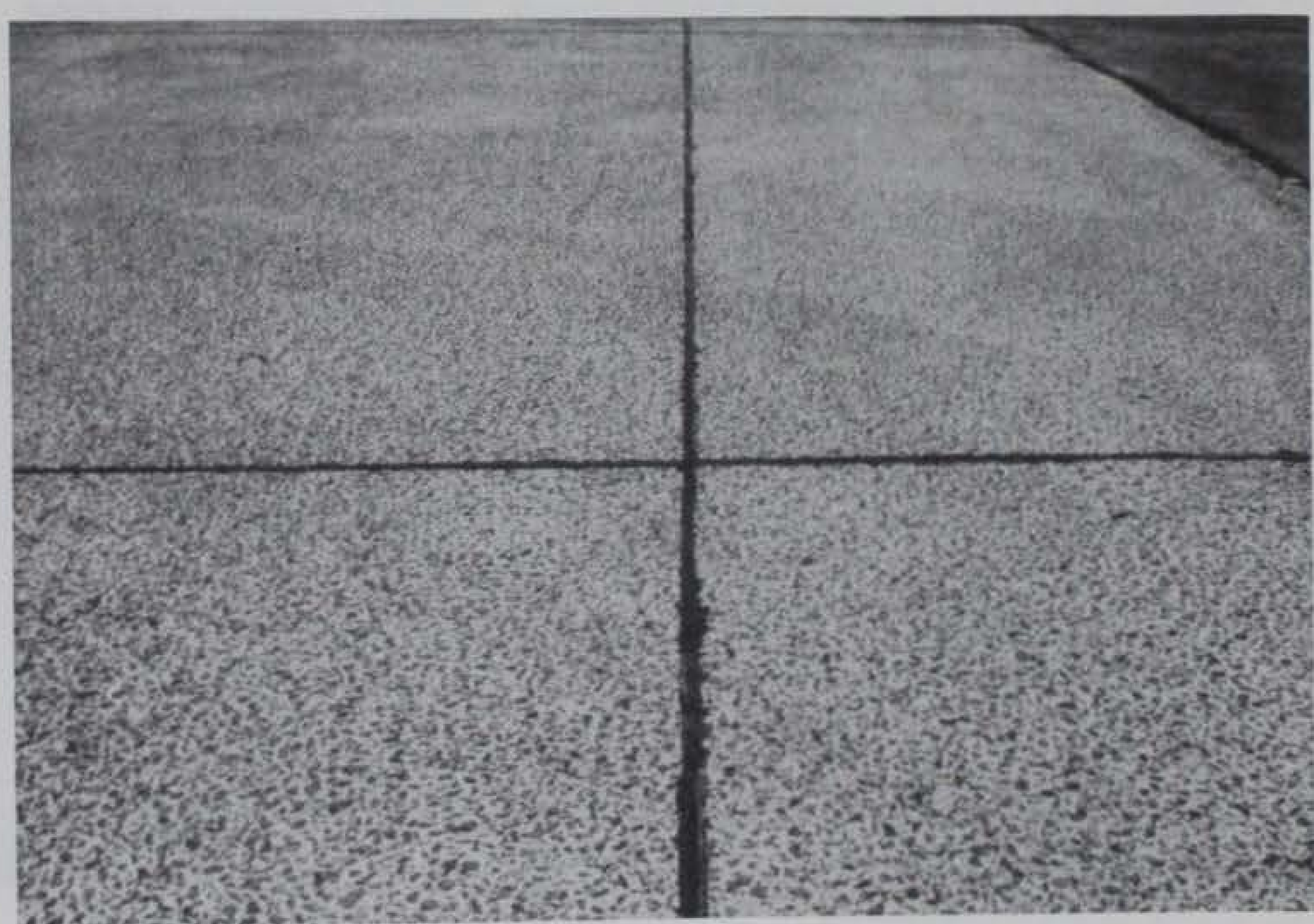

Photo 6. Typical condition of sawed joint in 1979 Salviacim pavement

Photo 7. Minor random cracking in 1979 Salviacim pavement

Photo 8. Typical bandaid seal of small crack

Photo 9. Jet fuel spillage on parking apron

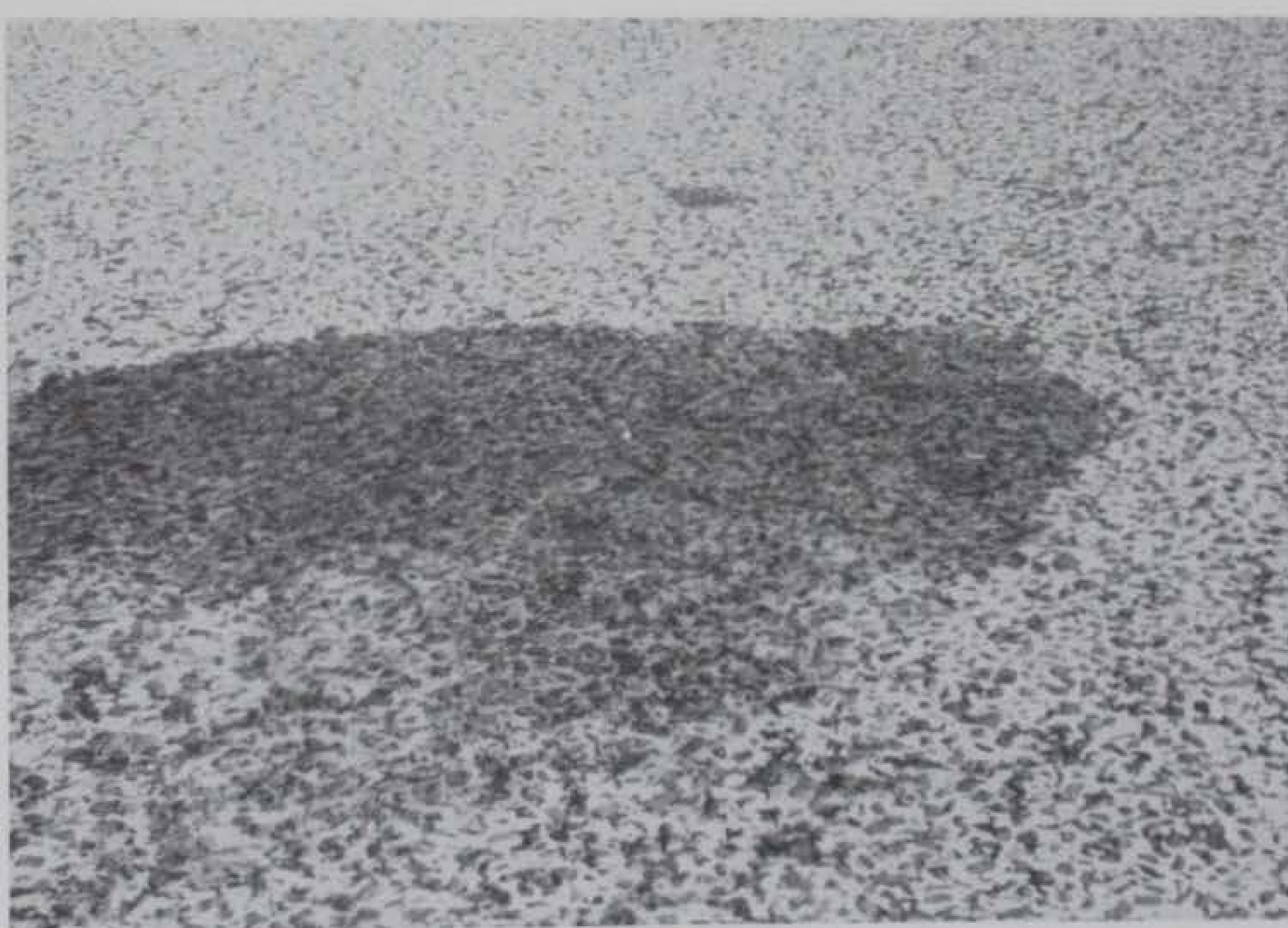

Photo 10. Discoloration and loss of surface fines due to fuel spillage

Photo 11. Asphalt concrete pavement that was sealed with Promak

Photo 12. Depression in asphalt concrete caused by fuel spillage and heavy aircraft loads

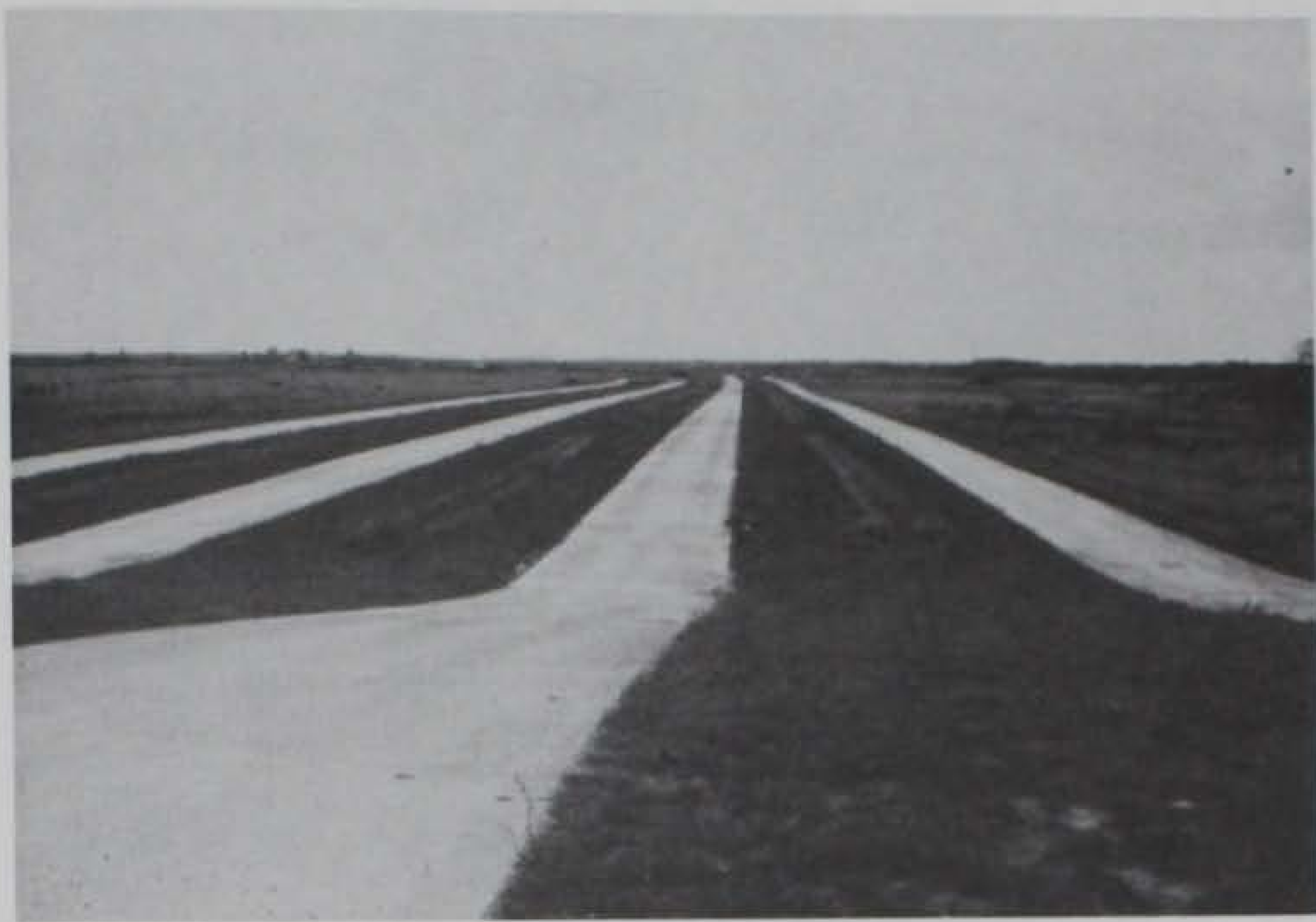

Photo 13. Artillery range, Fontevraud, France

Photo 14. Hill portion of artillery range

Photo 15. Extensive longitudinal cracking in hill portion

Photo 16. Excellent condition of Salviacim surface

Photo 17. French MX30 tank performing locked wheel turn on Salviacim pavement

Photo 18. Intersection where numerous locked wheel turns were performed

Photo 19. No appreciable damage to Salviacim surface

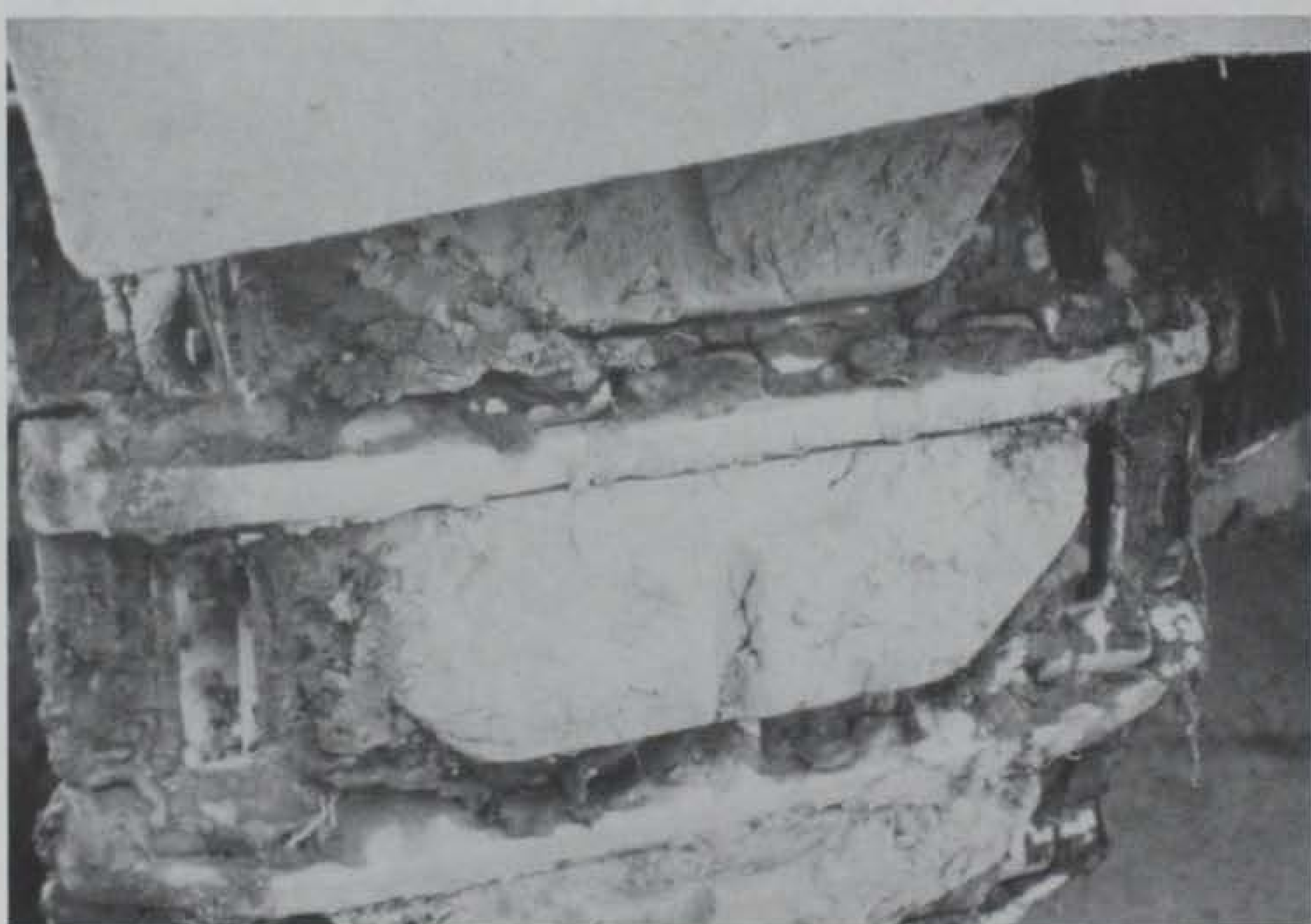

Photo 20. Poor condition of rubber pads on MX-30 tank

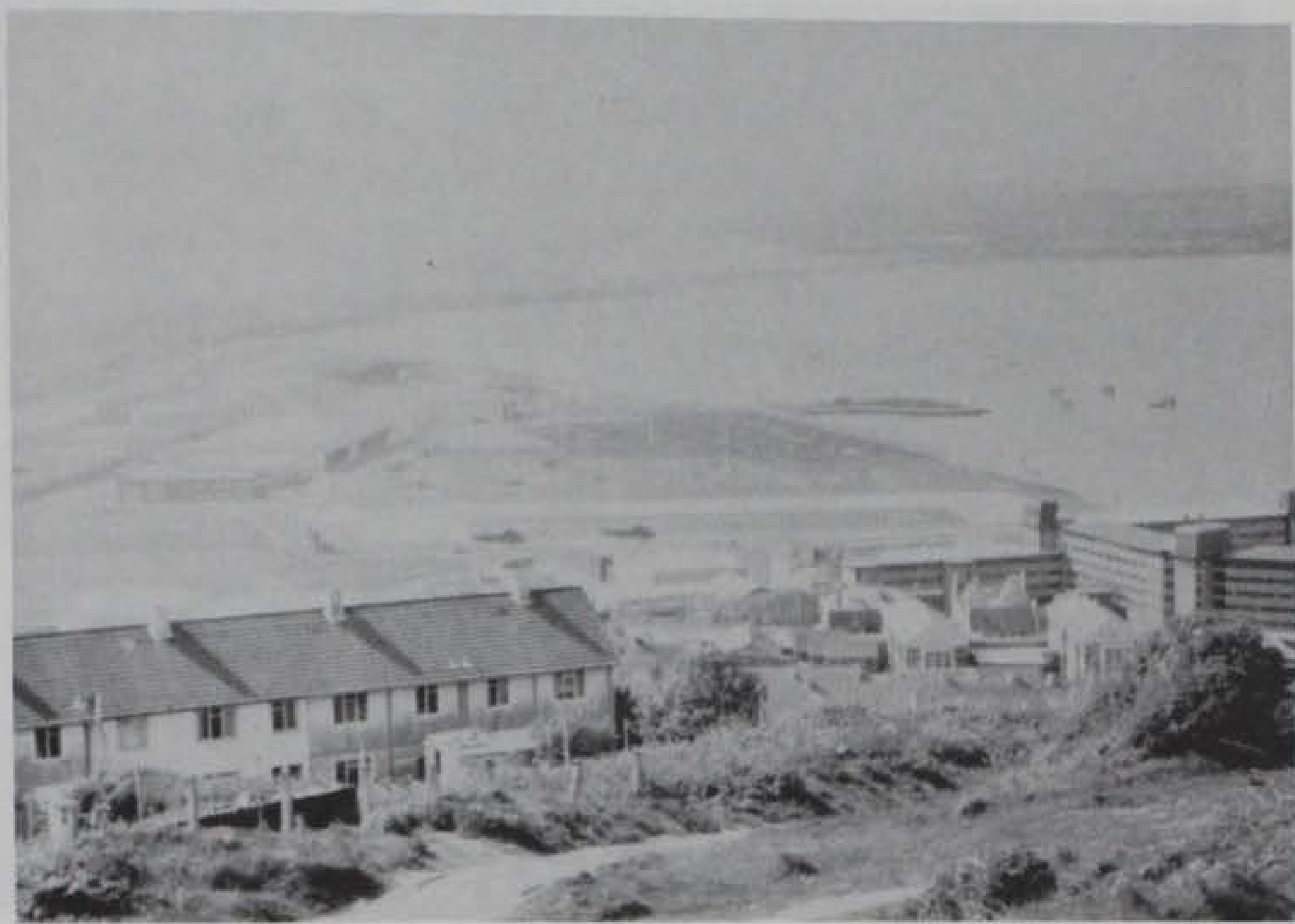

Photo 21. Royal Naval Air Station, Portland, England

Photo 22. Typical condition of Salviacim pavement

Photo 23. Typical spillage on refueling pads

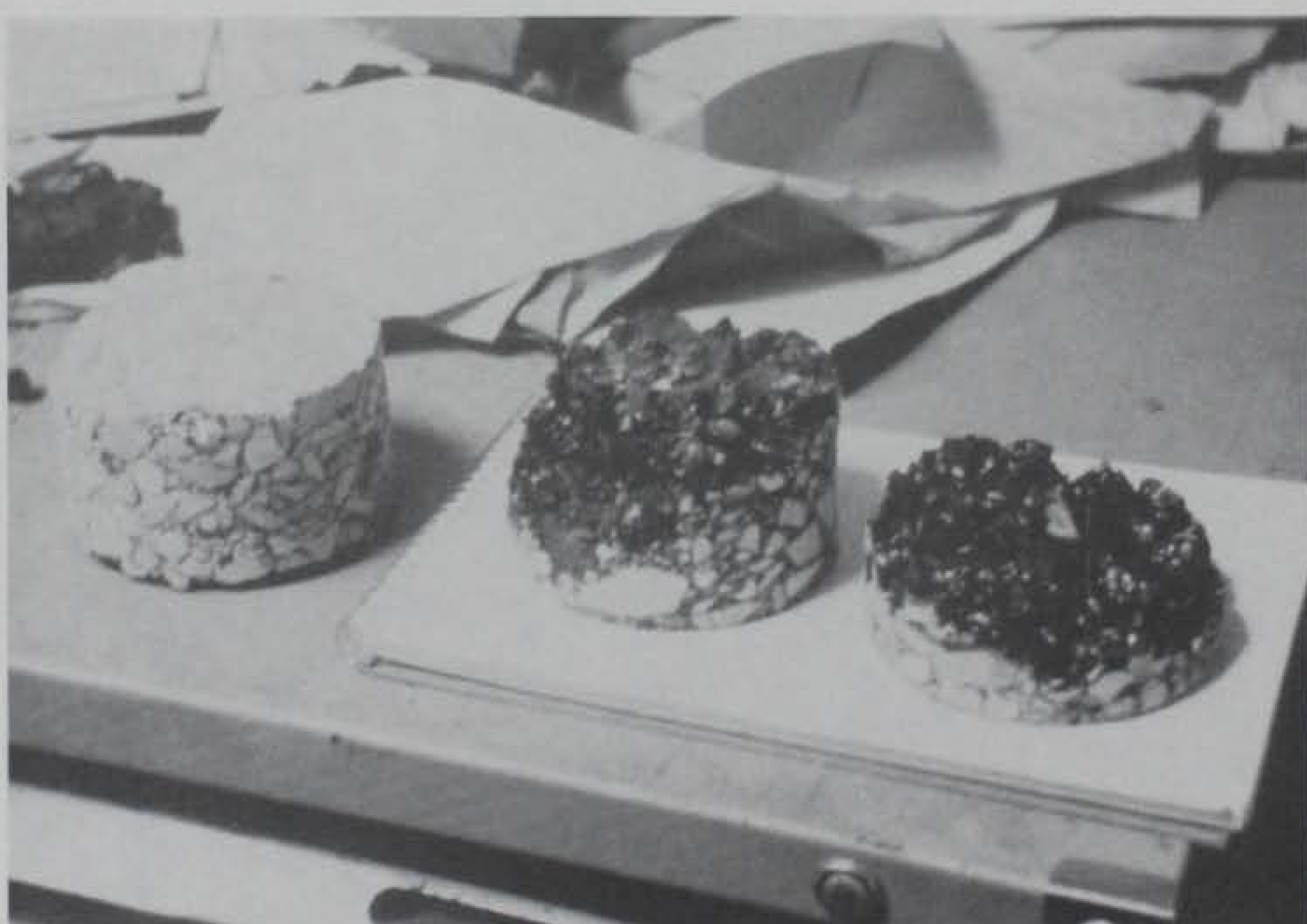

Photo 24. Field cores with less than 100 percent penetration

Photo 25. Patched area of Salviacim pavement

Photo 26. Tank maintenance and staging area, Lulworth, England

Photo 27. Tank fuel spillage on Salviacim pavement

Photo 28. Abrasions caused by locked wheel turns

Photo 29. Tank staging area constructed in 1979

APPENDIX B: RESIN MODIFIED PAVEMENT SURFACING MATERIAL SPECIFICATION

RESIN MODIFIED PAVEMENT SURFACING MATERIAL

PART 1 - GENERAL

1. APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

1.1 American Society for Testing and Materials (ASTM) Publications:

C 131-81	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 136-82	Sieve Analysis of Fine and Coarse Aggregates
C 174-82	Measuring Length of Drilled Concrete Cores
C 183	Sampling and the amount of testing of Hydraulic Cement
D 75-82	Sampling Aggregates
D 140-70	Sampling Bituminous Materials
D 242	Specification for Mineral Filler
D 423	Liquid limit
D 424	Plastic limit
D 1250-80	Petroleum Measurement Tables
D 2170-81	Kinematic Viscosity of Asphalt (Bitumens)
D 2216-80	Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures
D 3381	Specification for Viscosity-graded asphalt cement.

1.2. Department of the Army, Corps of Engineers, Handbook for Concrete and Cement:

CRD-C 119	Flat and Elongated Particles in Coarse Aggregate
CRD-C 300	Membrane-Forming Compounds for Curing Concrete

2. **PLANT, EQUIPMENT, MACHINES, AND TOOLS: Shall be as specified in the Section Bituminous Intermediate Course for Heavy Duty Pavements. With the additional requirements of a portable or transit-mixer for grout preparation and a small 6-ton tandem steel wheeled vibratory roller for compaction.**

3. **WEATHER LIMITATIONS. The bituminous mixture shall not be placed upon a wet surface, in rain, or when the surface temperature of the underlying course is less than 60 degrees F. The temperature requirements may be waived, but only at the discretion of the Contracting Officer. Once the bituminous mixture has been placed and if rain is imminent, protective materials, consisting of rolled polyethylene sheeting at least 4 mils (0.1 mm) thick of sufficient length and width to cover the mixture shall be placed. If the open-graded bituminous mixture becomes saturated the Contractor must thoroughly dry out the pavement voids prior to applying the slurry grout.**

4. **PROTECTION OF PAVEMENT: After final rolling, no vehicular traffic of any kind shall be permitted on the pavement for 28 days.**

5. THICKNESS AND SURFACE-SMOOTHNESS REQUIREMENTS: Finished surface of Resin Modified Pavement when tested as specified below shall conform to the thickness specified and to surface smoothness requirements specified in Table I.

TABLE I. SURFACE-SMOOTHNESS TOLERANCES

Direction of Testing	Resin Modified Pavement Tolerance, inch
Longitudinal	1/4
Transverse	1/4

5.1. Surface Smoothness: Finished surfaces shall not deviate from testing edge of a 12-foot straightedge more than the tolerances shown for the respective pavement category in Table I.

5.2. Thickness: The thickness of the Resin Modified Pavement shall meet the requirements shown on the contract plans. The measured thickness of the Resin Modified Pavement shall not exceed the design thickness by more than 1/2 inch, or be deficient in thickness by more than 1/8 inch.

6. SAMPLING AND TESTING:

6.1. Aggregates:

6.1.1 General: ASTM D 75 will be used in sampling coarse and fine aggregates, and ASTM C 183 will be used in sampling mineral filler. Samples shall be submitted for approval prior to the start of production. Points of sampling will be designated by the Contracting Officer. All tests necessary to determine compliance with the requirements specified herein shall be made by the Contracting Officer.

6.1.2 Sources: Sources of aggregates shall be selected well in advance of the time that the materials are required in the work. Samples shall be submitted 15 days before starting production. If a sample of material fails to meet specification requirements, the material represented by the sample shall be replaced, and the cost of testing the replaced sample will be at the expense of the Contractor. Approval of the source of the aggregate does not relieve the Contractor of the responsibility for the delivery at the job site of aggregates that meet the requirements specified herein.

6.2. Bituminous Materials: Samples of bituminous materials shall be obtained in accordance with ASTM D 140. Sources shall be selected in advance of the time materials will be required in the work, and a 5-gallon sample shall be submitted for approval not less than 15 days before such materials are required for use in the work. In addition to the initial qualification-testing of bituminous materials, samples will be obtained and tested before and during construction when shipments of bituminous materials are received, or when necessary to assure that some condition of handling or storage has not been detrimental to the bituminous material.

7. DELIVERY, STORAGE, AND HANDLING OF MATERIALS:

7.1 Mineral Aggregates: Mineral aggregates shall be delivered to the site of the bituminous mixing plant and stockpiled in such a manner as to preclude segregation or contamination with objectionable material.

7.2 Bituminous Materials: Bituminous materials shall be maintained below a temperature of 300 degrees F. during storage and shall not be heated by the application of a direct flame to the walls of storage tanks or transfer lines. Storage tanks, transfer lines, and weigh buckets shall be thoroughly cleaned before a different type or grade of bitumen is introduced into the system.

8. ACCEPTABILITY OF WORK:

8.1 General: Initial testing for acceptability of work will be performed by the Government. Additional tests required to determine acceptability of nonconforming material will be performed by the Government at the expense of the Contractor.

8.1.1 Random samples will be taken from the open graded bituminous mixture before and after application of the slurry grout. These samples will be tested for density, voids total mix (20 to 25 percent) and grout penetration (90 percent of full depth). Samples of open graded bituminous mixture for determining asphalt content, aggregate gradation and laboratory density will be taken from loaded trucks. Field core samples (4 or 6 inch diameter) will be taken from finished surface to evaluate slurry grout penetration.

8.1.2 When a section of pavement fails to meet the specification requirements, that section shall be totally removed and replaced.

8.1.3 The Contracting Officer reserves the right to sample and test any area which appears to deviate from the specification requirements.

9. ACCESS TO PLANT AND EQUIPMENT: The Contracting Officer shall have access at all times to all parts of the paving plant for checking adequacy of any equipment in use; inspecting operation of the plant; verifying weights, proportions, and character of materials; and checking temperatures maintained in preparation of the mixtures.

PART 2 MATERIALS OR PRODUCTS

10. AGGREGATE: Aggregates shall consist of crushed stone, or crushed gravel without sand or other inert finely divided mineral aggregate. The portion of materials retained on the No. 4 sieve shall be known as coarse aggregate, the portion passing the No. 4 sieve and retained on the No. 200 sieve as fine aggregate. Aggregate material for bituminous pavements shall conform to all specifications as indicated herein.

10.1 Coarse Aggregate. Coarse aggregate shall consist of sound, tough, durable particles, free from adherent films of matter that would prevent thorough coating with the bituminous material. The percentage of wear shall not be greater than 40 percent for surface courses when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed 9 percent, after five cycles, when tested in accordance with ASTM C 88. Aggregate shall contain at least 70 percent by weight of crushed pieces having two or more fractures faces and 85 percent having at least one fractured face. The area of each face shall be equal to at least 75 percent of the smallest mid-sectional area of the piece. When two fractured faces are contiguous, the angle between the planes of fractures shall be at least 30 degrees to count as two fractured faces. Fractured faces shall be obtained by artificial crushing.

11. Particle shape of crushed aggregates shall be essentially cubical. Quantity of flat and elongated particles in any sieve size shall not exceed 8 percent by weight, when determined in accordance with CRD-C 119.

11.1 Open graded mix aggregate: The gradations in Table II represent the limits which shall determine the suitability of open graded mix aggregate for use from the sources of supply. The aggregate, as finally selected, shall have a gradation within the limits designated in Table II and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa, but shall be uniformly graded from coarse to fine.

TABLE II OPEN GRADED MIX AGGREGATE - BITUMINOUS PAVEMENTS

Sieve Size	Percent Passing - %
3/4 in.	100
1/2 in.	65-75
3/8 in.	50-60
No. 4	23-33
No. 8	9-17
No. 30	5-10
No. 200	1-3

The open graded mix aggregate gradations shown are based on aggregates of uniform specific gravity, and the percentages passing the various sieves will be subject to appropriate correction when aggregates of varying specific gravities are used.

11.2 Slurry Grout Sand: Slurry grout sand shall consist of clean, sound, durable, angular particles of silica sand that meets the requirements for wear and soundness specified for coarse aggregate. The aggregate particles shall be free from coatings of clay, silt, or other objectionable matter and shall contain no clay balls. The slurry grout sand shall have a plasticity index of not more than 3 when tested in accordance with ASTM D 424, and a liquid limit of not more than 25 when tested in accordance with ASTM D 423. The gradations is Table III represent the limits which shall determine the suitability of silica sand for use from the sources of supply.

TABLE III FINE SAND FOR SLURRY GROUT

Sieve Size	Percentage by Weight Passing Sieves Fine Sand
No. 30 (0.60 mm)	100
No. 200 (0.075 mm)	0

The sand gradations shown are based on sand of uniform specific gravity, and the percentages passing the various sieves will be subject to appropriate correction when aggregates of varying specific gravities are used.

11.3 Filler: If filler, in addition to that naturally present in the aggregate, is necessary, it shall meet the requirements of ASTM D 242 with 95 percent passing No. 200 sieve. Filler may be fly ash, limestone dust, or rock flour.

11.4 Bituminous Material. Bituminous material shall conform to the requirements of ASTM D 3381 and should be of the viscosity grade AC-30, with a penetration of 60-70.

11.5 Cement: The cement used in the slurry grout shall be portland cement Type I. The contractor shall furnish samples of the portland cement to the Contracting Officer 15 days before the start of production.

11.6 Cross Polymer Resin: A cross polymer resin of styrene and butadene, Prosalvia L7 or equivalent, shall be utilized as a plasticizing and strength producing agent. This shall be supplied by the Government. After mixing the resin into the slurry grout, the mixture shall have a viscosity which would allow it to flow from a Marsh cone in accordance with Table IV:

TABLE IV. SLURRY GROUT VISCOSITY

Time elapsed after mixing	Viscosity
after 0 minutes	7 to 9 seconds
after 15 minutes	8 to 10 seconds
after 30 minutes	9 to 11 seconds

A Marsh cone has dimensions of 155 mm base inside diameter, tapering 315 mm to a tip inside diameter of 10 mm. The 10 mm diameter neck shall have a length of 60 mm.

12. JOB MIX FORMULA AND COMPOSITION OF SLURRY GROUT:

12.1 Job Mix Formula: The JMF for the open graded bituminous mixture shall be furnished by the Contracting Officer. The Contractor shall furnish samples of materials for the mix design. Sufficient quantities of each aggregate shall be submitted to provide a minimum of 200 pounds of blended aggregate in the same approximate proportions as will be used in the project. Blending of the aggregates will be accomplished by the Government. A minimum of five gallons of the asphalt cement to be used in the project shall be submitted. All samples shall be submitted 15 days before starting production. A mixing temperature to provide an asphalt viscosity of 275 plus or minus 25 centistokes shall be determined in accordance with ASTM D 2170. No payment will be made for mixtures produced prior to the approval of the JMF. The JMF will indicate the percentage of each stockpile, the percentage passing each sieve size, the percentage of bitumen, and the temperature of the completed mixture when discharged from the mixer. Tolerances are given in Table V for bitumen content, and temperature, for tests conducted on the mix, as discharged from the mixing plant.

TABLE V. JOB-MIX TOLERANCES

Material	Tolerance, Plus or Minus
Aggregate passing No. 4 or larger sieves	4 percent
Aggregate passing Nos. 8 and 30 sieves	3 percent
Aggregate passing No. 200 sieve	1 percent
Bitumen	0.20 percent
Temperature of mixing	20 degrees F.

12.2 Composition of Slurry Grout: The slurry grout shall consist of mixture having a ratio as given in Table VI.

TABLE VI. SLURRY GROUT MIXTURE

	Weight	% Batch
Silica Sand	110 pounds	18.4
Filler	110 pounds	18.4
Water	144 pounds	23.8
Type I Cement	220 pounds	36.7
Cross Polymer Resin	15.4 pounds	2.7

Approximately 46.5 pounds to 53 pounds of mixed slurry grout will fill in one square yard (2 inch thickness) of bituminous mixture with 20 percent to 25 percent voids total mix.

12.3 Test Section: Prior to full production, and in the presence of the Contracting Officer and special paving process representatives, the Contractor shall prepare and place a quantity of surface course bituminous mixture and slurry grout according to the job mix formula. The test section shall be 40 feet long and 10 feet wide placed in one section and shall be of the same depth specified for the construction of the course which it represents. The underlying pavement structure upon which the test section is to be constructed shall be the test section of Intermediate course. The equipment used in construction of the test section shall be the same type and weight to be used on the remainder of the course represented by the test section. If the test section should prove to be unsatisfactory, the necessary adjustments to the mix design, plant operation, and/or rolling procedures shall be made. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications.

PART 3 - EXECUTION

13. PREPARATION OF BITUMINOUS MIXTURES: Rates of feed of aggregates shall be regulated so that moisture content and temperature of aggregates will be within tolerances specified. Aggregates and bitumen shall be conveyed into the mixer in proportionate quantities required to meet the JMF. Mixing time shall be as required to obtain a uniform coating of the aggregate with the bituminous material. Temperature of bitumen at time of mixing shall not

exceed 275 degrees F. Temperature of aggregate in the mixer shall not exceed 300 degrees F. when bitumen is added. Overheated and carbonized mixtures or mixtures that foam shall not be used.

14. WATER CONTENT OF AGGREGATES: Drying operations shall reduce the water content of mixture to less than 0.75 percent. Water content will be determined in accordance with ASTM D 2216; weight of sample shall be at least 500 grams. The water content shall be reported as a percentage of the total mixture.

15. STORAGE OF OPEN GRADED ASPHALT MIX: The Open Graded Asphalt Mix paving mixture shall not be stored for longer than 30 minutes to 1 hour prior to hauling to the job site.

16. TRANSPORTATION OF BITUMINOUS MIXTURE: Transportation from the mixing plant to the site shall be in trucks having tight, clean, smooth beds lightly coated with an approved releasing agent to prevent adhesion of mixture to truck bodies. Excessive release agent will be drained prior to loading. Each load shall be covered with canvas or other approved material of ample size to protect mixture from the weather and to prevent loss of heat. Loads that have crusts of cold, unworkable material or have become wet will be rejected. Hauling over freshly placed material will not be permitted.

17. SURFACE PREPARATION OF UNDERLYING COURSE: Prior to placing of Open Graded Asphalt Mix the underlying course shall be cleaned of all foreign or objectionable matter.

18. TACK COATING: Contact surfaces of previously constructed pavement, shall be sprayed with a coat of bituminous material as specified in SECTION: BITUMINOUS TACK COAT.

19. PLACING: The mix shall be placed at a temperature of not less than 200 degrees F (107 degrees C). Upon arrival, the mixture shall be spread to the full width (minimum 10 feet) by an approved bituminous paver. It shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness indicated. The speed of the paver shall be regulated to eliminate pulling and tearing of the bituminous mat. Unless otherwise directed, placement of the mixture shall begin along the centerline. The mixture shall be placed in consecutive adjacent strips. On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread, raked, and luted by hand tools.

19.1 Rollers: Small (6-ton maximum) tandem steel wheel vibratory rollers shall be used. The vibratory unit shall be turned off during smoothing of the bituminous mixture. Rollers shall be in good condition, capable of operating at slow speeds to avoid displacement of the bituminous mixture. The number, type, and weight of rollers shall be sufficient to roll the mixture to the required density which has 20 to 25 percent voids total mix while it is still in a workable condition. The use of equipment which causes excessive crushing of the aggregate will not be permitted.

19.2 Smoothing of Open Graded Bituminous Mixture: Smooth the open graded bituminous mixture with one or two passes of a 6-ton roller without vibration.

19.3 Application of Slurry Grout: The slurry grout shall be mixed using portable and/or transit-mixers and consist of a ratio of cement - 220 pounds, silica sand - 110 pounds, filler - 110 pounds, water - 144 pounds, and cross polymer resin 15.4 pounds for each batch produced. The water and cement must be incorporated into the mixture just before spreading to allow the maximum time before the grout begins to set. The cross polymer resin must be added to the mixture after the water and immediately prior to placement of the slurry. The slurry grout shall be spread over the bituminous mixture using a spreader or squeegees. Temperature of the bituminous mixture shall be less than 100 degrees F before applying grout. A 6-ton vibratory roller (with vibration turned on) passes over the grout covered asphalt mixture will facilitate full penetration of the slurry grout into the void spaces. A manufacturer's representative for the cross polymer resin must be present for the slurry grout preparation and application.

19.4 Joint: The formation of all joints shall be made in such a manner as to ensure a continuous bond between old and new sections of the course. All joints shall have the same texture, density, and smoothness as other sections of the course.

19.5 Protection of Pavement: The Contractor shall protect the pavement and its appurtenances against both public traffic and traffic caused by the Contractor's employees and agents for a period of 28 days. Any damage to the pavement occurring prior to final acceptance shall be repaired or the pavement replaced at the Contractor's expense. In order that the pavement be properly protected against the effects of rain before the pavement is sufficiently hardened, the Contractor will be required to have available at all time materials for the protection of the edges and surfaces of the unhardened pavement. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils (0.1 mm) thick of sufficient length and width to cover the pavement and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the pavement surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened pavement with protective covering.

19.6 Curing: Membrane-forming curing compounds shall be white pigmented compounds conforming to CRD-C 300.

20. ACCEPTANCE SAMPLING AND TESTING OF RESIN MODIFIED PAVEMENT FOR DENSITY AND PENETRATION: Pavement density will be determined by the density of cores taken from the compacted pavement. Slurry grout shall penetrate a minimum of 90 percent of the pavement thickness. Acceptance testing will be done by and at the sole cost of the Contracting Officer.

APPENDIX C: SLURRY GROUT VISCOSITY

1. The viscosity of the RMP cement slurry grout is determined by the time of efflux of 1 liter of grout through a Marsh flow cone and is expressed in seconds. The dimensions of the Marsh flow cone are given in Figure C1.

2. To determine grout viscosity, the flow cone is set up over a 100-ml measuring cylinder, and its bottom orifice is sealed with a stopper. Approximately 1,100 to 1,200 ml of grout is poured into the flow cone immediately after mixing. As soon as the flow cone is filled, the stopper is removed and the time taken to fill the 1,000-ml cylinder is recorded. The time taken between mixing and testing of the grout should be held to a minimum (less than 15 sec) to prevent the sand in the grout from settling out of solution.

3. The grout viscosity is considered satisfactory under normal conditions if a time between 7.0 and 9.0 sec is recorded.

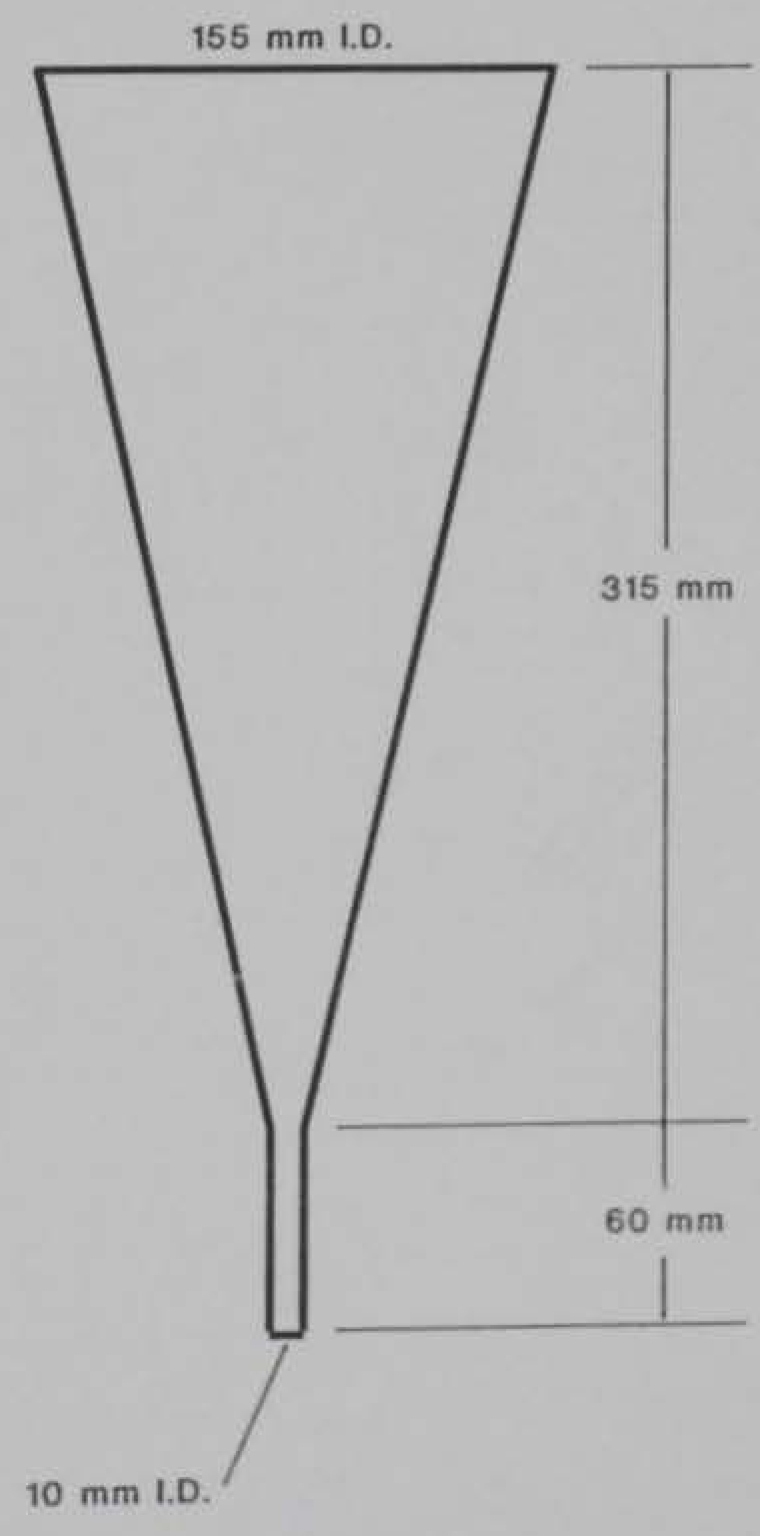

Figure C1. Marsh flow cone