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EVALUATION OF REDESIGNED XW18 MEMBRANE AND ACCESSORIES

Frank M. Palmer

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

May 1973

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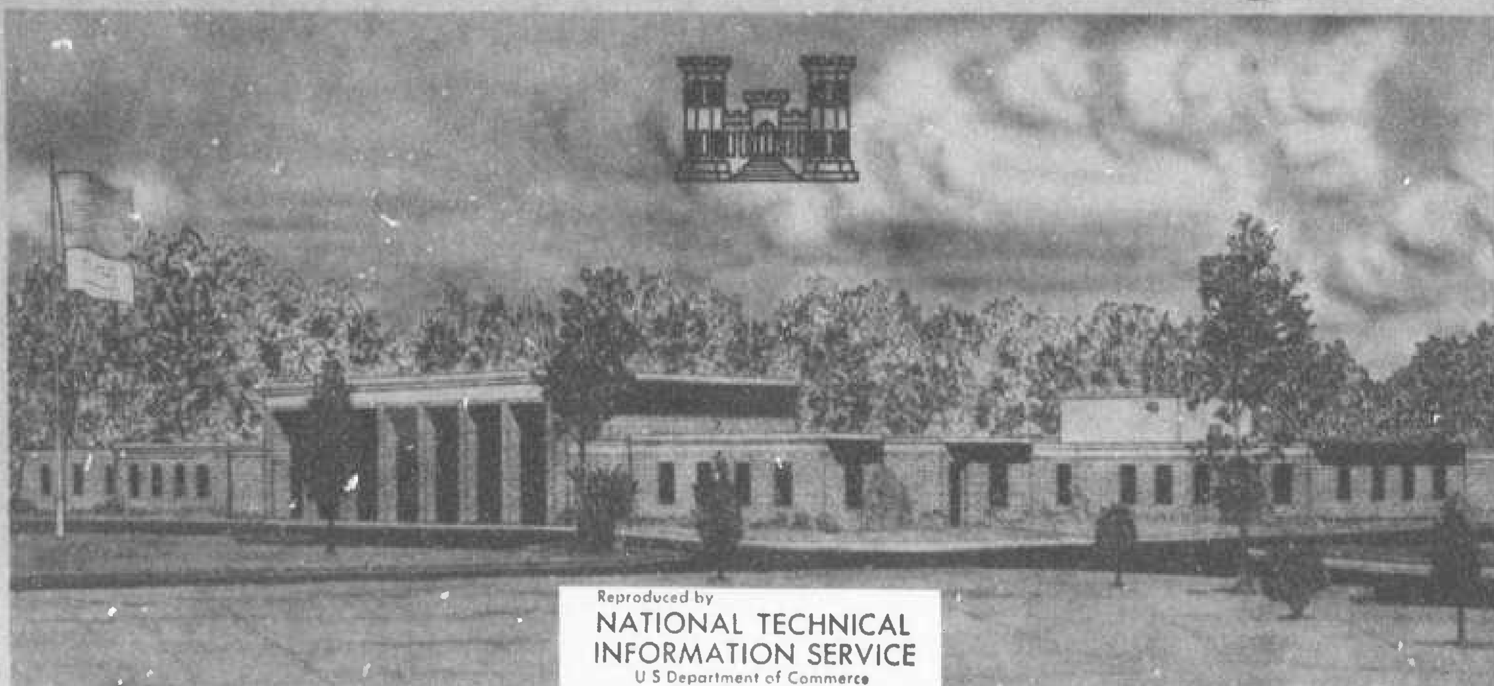
by

F. M. Palmer



May 1973

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Conducted by U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
Vicksburg, Mississippi

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13. ABSTRACT

Tests were conducted at the U. S. Army Engineer Waterways Experiment Station to determine the suitability of the redesigned XW18 membrane and accessories as expedient surfacing for waterproofing and dustproofing hastily prepared airfields for operations of C-130 aircraft. The objectives of the tests were as follows: to compare the redesigned XW18 membrane with the WX18 membrane, which was considered unsuitable as an expedient surfacing for C-130 operations as a result of integrated engineering and service tests conducted at Ft. Campbell, Kentucky, during 11 May to 15 November 1966, and to determine whether the XW18 membrane met the requirements of the Department of the Army approved Qualitative Materiel Requirement (QMR) for Prefabricated Airfield Surfacings. Laboratory tests conducted to determine the physical characteristics of the redesigned XW18 membrane indicated the surfacing was equal or superior in strength to the WX18 membrane. The tests also indicated that the surfacing met the QMR specifications with respect to weight, POL resistance, and high- and low-temperature resistance. Skid tests conducted to simulate locked-wheel braking action of C-130 aircraft in touchdown areas of assault runways indicated that the redesigned XW18 membrane possessed the strength and abrasion resistance to withstand repetitive stresses of the magnitude produced by C-130 aircraft. However, the redesigned XW18 did not have the durability of the WX18 membrane in that fewer repetitive skids were required to produce failure of the surfacing. Skid tests were also conducted to determine if the nonskid compound as applied to the surfacing would produce sufficient skid resistance for all-weather operations of C-130 aircraft (i.e., according to the QMR, possess a Runway Condition Reading of 13-25). The tests indicated that the nonskid produced the minimum required coefficients of friction but lacked the necessary adhesion to withstand the abrasion of the test wheel. Placement and traffic tests were conducted on the surfacing to determine conformance with the QMR with respect to packaging, placement rate, suitability of accessories, service life, and maintainability. Two test areas were constructed in which the membrane was placed directly on a prepared soil subgrade and subjected to rolling traffic of a C-130 wheel. Test results indicated that the surfacing met the QMR specifications for placement rate and suitability of accessories but did not possess the required service life of six months of 1200 C-130 sorties. Furthermore, the redesigned XW18 membrane required excessive maintenance. Improved designs of this membrane will be directed toward the elimination of deficiencies indicated as a result of these tests. The improvements will be incorporated in the final design of the heavy-duty membrane airfield surfacing.

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FOREWORD

This report describes an investigation that was conducted under the sponsorship of the Surface Systems Division, Research and Development Directorate (formerly the Ground Mobility Office, Directorate of Development), Headquarters, U. S. Army Materiel Command, under Project No. 1G664717D556, "Prefabricated Surfacings and Dust Control," Task 02, "Prefabricated Membrane Development." The investigation was conducted during the period March 1969 to January 1970 at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

Engineers of the Soils and Pavements Laboratory who were actively engaged in the planning, testing, analyzing, and reporting phases of this investigation were Messrs. W. J. Turnbull (retired), J. P. Sale, R. G. Ahlvin, W. L. McInnis, S. G. Tucker, R. H. Grau, A. J. Bush, and F. M. Palmer. This report was prepared by Mr. Palmer.

Directors of the WES during the conduct of this investigation and the preparation and publication of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Directors were Messrs. J. B. Tiffany and F. R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square feet	0.092903	square meters
pounds (mass)	0.45359237	kilograms
tons (2000 lb)	907.18474	kilograms
pounds (force)	4.448222	newtons
pounds (mass) per cubic foot	16.0185	kilograms per cubic meter
pounds (force) per inch	1.7512685	newtons per centimeter
pounds (force) per square inch	0.6894757	newtons per square centimeter
ounces (mass) per square yard	33.905742	grams per square meter
inch-pounds	0.11298483	meter-newtons
feet per second	0.3048	meters per second
pints (U. S. liquid)	0.4731765	cubic decimeters
gallons (U. S. liquid)	3.785412	cubic decimeters
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* 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: $K = (5/9)(F - 32) + 273.15$.

SUMMARY

Tests were conducted at the U. S. Army Engineer Waterways Experiment Station to determine the suitability of the redesigned XW18 membrane and accessories as expedient surfacing for waterproofing and dustproofing hastily prepared airfields for operations of C-130 aircraft. The objectives of the tests were as follows:

a. To compare the redesigned XW18 membrane with the WX18 membrane, which was considered unsuitable as an expedient surfacing for C-130 operations as a result of integrated engineering and service tests conducted at Ft. Campbell, Kentucky, during 11 May to 15 November 1966.

b. To determine whether the XW18 membrane met the requirements of the Department of the Army approved Qualitative Materiel Requirement (QMR) for Prefabricated Airfield Surfacings.

Laboratory tests conducted to determine the physical characteristics of the redesigned XW18 membrane indicated the surfacing was equal or superior in strength to the WX18 membrane. The tests also indicated that the surfacing met the QMR specifications with respect to weight, POL resistance, and high- and low-temperature resistance.

Skid tests conducted to simulate locked-wheel braking action of C-130 aircraft in touchdown areas of assault runways indicated that the redesigned XW18 membrane possessed the strength and abrasion resistance to withstand repetitive stresses of the magnitude produced by C-130 aircraft. However, the redesigned XW18 did not have the durability of the WX18 membrane in that fewer repetitive skids were required to produce failure of the surfacing.

Skid tests were also conducted to determine if the nonskid compound as applied to the surfacing would produce sufficient skid resistance for all-weather operations of C-130 aircraft (i.e., according to the QMR, possess a Runway Condition Reading of 13-25). The tests indicated that the nonskid produced the minimum required coefficients of friction but lacked the necessary adhesion to withstand the abrasion of the test wheel.

Placement and traffic tests were conducted on the surfacing to determine conformance with the QMR with respect to packaging, placement rate, suitability of accessories, service life, and maintainability. Two test areas were constructed in which the membrane was placed

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directly on a prepared soil subgrade and subjected to rolling traffic of a C-130 wheel. Test results indicated that the surfacing met the QMR specifications for placement rate and suitability of accessories but did not possess the required service life of six months of 1200 C-130 sorties. Furthermore, the redesigned XW18 membrane required excessive maintenance.

Improved designs of this membrane will be directed toward the elimination of deficiencies indicated as a result of these tests. The improvements will be incorporated in the final design of the heavy-duty membrane airfield surfacing.

EVALUATION OF REDESIGNED XW18 MEMBRANE AND ACCESSORIES

PART I: INTRODUCTION

Background

1. Service tests of T17 membrane (a two-ply, neoprene-coated, nylon fabric) were conducted at Ft. Campbell, Kentucky, during 21 July 1965 to 1 April 1966. The findings of these tests (reported in reference 1) indicated that the T17 membrane was not capable of withstanding C-130 aircraft landings, using maximum wheel braking, and takeoffs, using maximum engine runup. The T17 membrane was torn 33 times during 228 landings by C-130 aircraft, and, of these tears, 72 percent occurred within 300 ft* of the end of the runway. Laboratory tests indicated the breaking strength of the T17 membrane ranged below the estimated C-130 aircraft braking load of 857 lb per in.

2. To reduce maintenance requirements on the ends of membrane-surfaced runways, an improved membrane was designed for these areas. It was designated WX18 membrane, since renamed XW18 membrane (a four-ply, neoprene-coated nylon), and was service tested on the first 300 ft at each end of the runway at Ft. Campbell during May to November 1966.[2] Results of these tests indicated that the WX18 membrane could withstand C-130 landings; however, during the tests, three butt joints (prefabricated joints that were oriented perpendicular to the longitudinal direction of the runway) were peeled apart. It was difficult to remove slack from the surfacing, and the nonskid compound applied in the field required too many man-hours for application. Therefore, the WX18 membrane was considered unsuitable for expedient surfacing of assault-type runways.

3. Since the unsuccessful service test of the WX18 membrane at

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

Ft. Campbell, the surfacing has been redesigned and thus will be referred to in this report as "redesigned" XW18 membrane. The surfacing has been designed with no butt joints allowed in the center 36 ft of the surfacing, and nonskid compound has been sprayed on the surfacing in the factory in a polka-dot pattern (2-in.-diam circles on 4-in. centers) to provide adequate braking for aircraft during inclement weather.

Purpose and Scope

4. The study reported herein was conducted to provide preliminary laboratory and field test data of the redesigned XW18 membrane and to determine its suitability as expedient surfacing for waterproofing and dustproofing hastily prepared airfields for operations of C-130 aircraft. The specific objectives of this investigation were to:

- a. Compare the performance of the WX18 membrane with that of the redesigned XW18 membrane.
- b. Evaluate the flexibility and skid-resistance characteristics of the nonskid compound as applied in the factory.
- c. Investigate improved placement techniques.
- d. Determine the ability of the redesigned XW18, in conformance with the Department of the Army approved revised Qualitative Materiel Requirement (QMR) for Prefabricated Airfields Surfacing, dated 2 April 1968, to:
  - (1) Be emplaced directly on graded subgrades with the accessories provided.
  - (2) Sustain an initial operational requirement of 100 C-130 sorties without failure.*
  - (3) Possess a service life of not less than six months of 1200 C-130 sorties, with not more than 10 percent replacement of material due to failure.
  - (4) Be readily repairable in the field.
  - (5) Be designed so that individual damaged sections can be removed and replaced.

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* A failure is defined by the revised QMR as a repair necessary to restore performance of the membrane surfacing to within operational limits requiring greater than 24 man-hours of total effort by personnel from an Engineer Platoon of an Airmobile Divisional Engineer Battalion.

(6) Provide effective braking for aircraft landings and control during all ground operations.

(7) Be capable of withstanding wheel loads without destruction of waterproof properties.

(8) Be designed so that maintenance required does not exceed 150 man-hours per month (typical maintenance to restore performance of the membrane to the above requirements consists of cleaning and inspecting for damage, tightening anchors, patching, replacing damaged sections, and repairing the nonskid surface).

Definitions of Pertinent Terms

5. For clarity, the meanings of certain terms used in this report are given below.

a. Membrane

(1) Neoprene. A synthetic, rubber-like plastic formed by the polymerization of chloroprene.

(2) Base fabric. A planar structure of woven fabric produced by interlacing two or more sets of yarns, fibers, or filaments and in which the elements pass each other essentially at right angles and one set of elements is parallel to the fabric axis.

(3) Ply. A single thickness or layer of the base fabric.

(4) Yarns per inch. The number of warp or fill (see below) yarns in a 1-in.-wide specimen of the base fabric.

(5) Run. A strip equal to one width of the neoprene-coated base fabric.

(6) Warp. The direction parallel to the long axis of a run of membrane.

(7) Fill. The direction perpendicular to the long axis of a run of membrane.

b. Laboratory tests

(1) Breaking strength. The strength shown by a specimen under tension, measured in pounds (force) per inch.

(2) Elongation at break. The deformation (measured in percent of the original specimen length parallel to the direction of load) of a tensile specimen at failure.

(3) Tear strength. The force required to start or

continue a tear in a fabric specimen.

(4) Flame resistance. The relative resistance of the coated fabric to flame and glow propagation and tendency to char.

(5) Ball bursting strength. The force required to rupture a fabric by distending it with a force applied at right angles to the plane of the fabric. The force is applied to the fabric with a 1-in.-diam steel ball.

c. Test areas

(1) Test section. An area on which the membrane is placed and tested under controlled conditions.

(2) Traffic lane. Area in which the coverages by the load cart (see below) are uniformly applied to the membrane.

(3) Soil subgrade. The uniformly processed soils upon which the membrane is placed.

(4) Density. The dry weight of soil, in pounds per cubic foot, existing in the subgrade at a specified time.

(5) CBR (California Bearing Ratio). An evaluation of the ability of soil to resist shear deformation.

d. Test equipment and data

(1) Skid cart. A specially designed cart consisting of the front half of a 6x6 truck with a load frame attached. The load frame is supported on a wheel equipped with a 20.00x20 C-130 tire that can be locked. A two-wheeled, rubber-tired tractor with a Bros roller attached is used to pull the skid cart.

(2) Load cart. A cart consisting of the front half of a 2-1/2-ton 6x6 truck to which a load frame is attached to permit mounting the test wheel and application of the design load with lead weights. The truck section of the cart provides the power for maneuvering the load.

(3) Drag force. The force required to move the locked wheel of the skid cart across the surface of the membrane. The force required to initiate movement of the skid cart is referred to as the static drag force, and the force required to maintain movement of the skid cart is referred to as the dynamic drag force.

(4) Coverage. One application of the load cart over each point in the traffic lane.

PART II: MATERIALS TESTED

Membrane

Membrane surfacing, 66 by 53 ft

6. The XW18 membrane evaluated in this study was a neoprene-coated, four-ply, nylon fabric consisting of 54-in.-wide runs joined with a series of 6- to 6-1/2-in.-wide, single-lap adhesive joints. The membrane was manufactured by the Firestone Tire and Rubber Company, Coated Fabrics Division, Magnolia, Arkansas, under U. S. Army Engineer Waterways Experiment Station (WES) Contract No. DACA39-68-C-0064. Each membrane sheet was approximately 66 ft wide and 53 ft long (plate 1). Nonskid compound was applied in the factory (as described in paragraph 3) in a polka-dot pattern at a coverage rate of 22.7 percent to an area 16 ft either side of the center line of the section. For alignment purposes, center- and edge-line stripes were painted on the surfacing with white paint.

7. To eliminate butt joint failures (as described in paragraph 2), the XW18 membrane was redesigned with no transverse joints allowed in the center 36 ft of surfacing; i.e., for 18 ft on either side of the center line of the surfacing.

8. To improve the physical strength properties of the membrane, the weight of the base fabric was increased from 5.1 ± 0.2 oz per sq yd to 5.3 ± 0.2 oz per sq yd. The number of yarns per inch (minimum) in the base fabric was increased from 22 ± 1 to 23 ± 1 yarns per in. in the warp direction.

Membrane surfacing, 3 by 66 ft

9. The membrane surfacing was a neoprene-coated, four-ply, nylon fabric, the same as that described in paragraph 6. The membrane surfacing was furnished in a roll that was 3 ft long and approximately 10 in. in diameter (fig. 1). The roll of membrane surfacing was used to reinforce adhesive construction joints and to provide a layer of membrane over disk-type anchors placed in construction joints.

Fig. 1. Roll of XW18 membrane surfacing, 3 ft wide and 66 ft long

Accessories

Disk-type anchor

10. Each anchor consisted of a 3/4-in.-diam reinforcing rod, 12 in. long, that was welded to a 1/8-in.-thick concave steel plate, 8 in. in diameter (fig. 2). The steel anchors were driven through the surfacing into the soil subgrade to hold the surfacing in place.

Paint rollers and handles

11. The paint rollers, which were 9 in. wide with 48-in.-long handles, were used to apply adhesive to the construction joints used to bond sections of membrane surfacing. The roller covers were disposable and were made of lamb's wool or synthetic fabric.

Adhesive

12. Adhesive MG-180 was used during construction and for dry weather repair of the membrane. The adhesive consisted of a synthetic rubber resin dispersed in a solvent that evaporated rapidly after

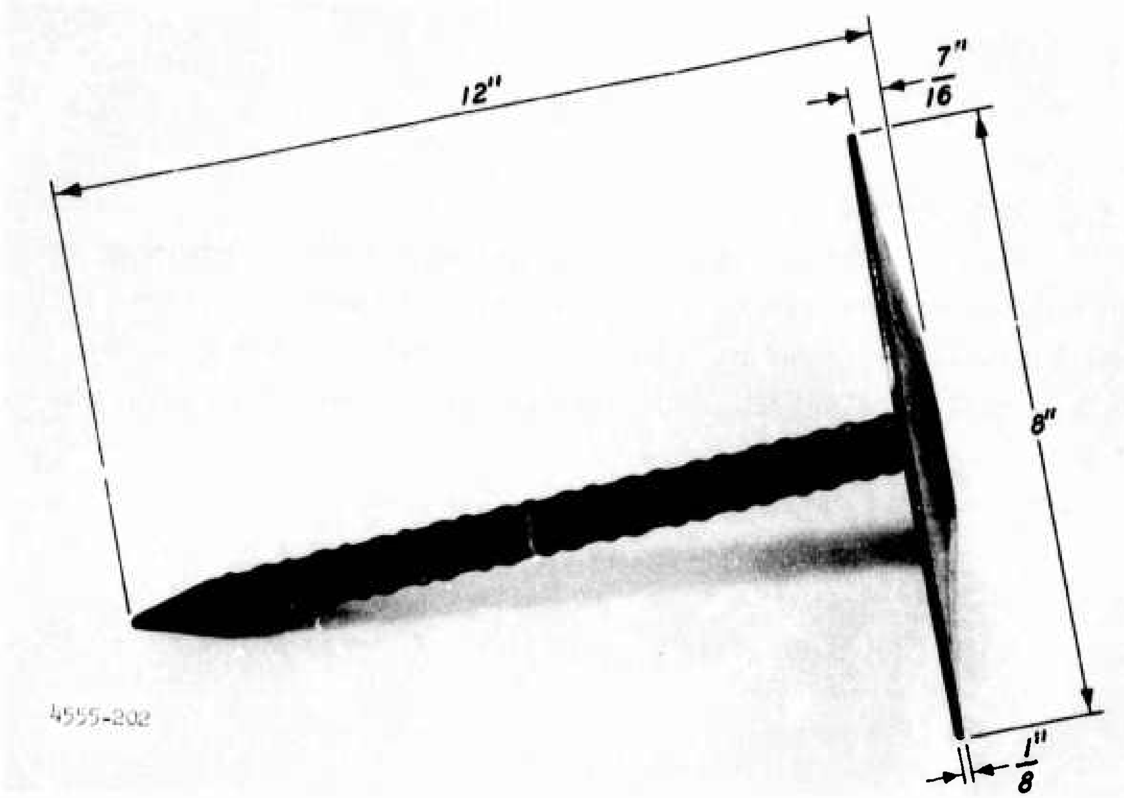

Fig. 2. Steel anchor consisting of 8-in.-diam, shaped-steel plate welded to 3/4-in.-diam reinforcing rod

exposure to air, thus developing the bond strength of the resin. The adhesive, supplied in 5-gal pails that weigh approximately 40 lb each, was applied to the membrane surfacing with the long-handled paint rollers.

Joint sealants

13. Two industrial joint sealers were evaluated to determine their effectiveness in preventing water infiltration through the adhesive field joints. These sealers were:

a. 3M Sealer EC801, Class A. A heavy liquid synthetic rubber compound, which, upon the addition of an accelerator, chemically cured to a rubbery solid. The sealer was supplied in a 1-gal can, and the accelerator was supplied in a 1-pt can.

b. 3M Sealer Weatherban 101. A one-part gun grade sealant that chemically cured when exposed to moisture to form a rubbery waterproof seal. The sealant was applied to seams and joints with a 1/10-gal caulking gun and a 1-1/4-in.-wide putty knife.

PART III: LABORATORY TESTS AND RESULTS

Tests

Coated fabric requirements

14. Laboratory tests were conducted at the WES to determine the physical characteristics of the redesigned XW18 membrane. These tests were conducted in accordance with applicable methods of Federal Test Method Standard (FTMS) No. 191, "Textile Test Methods,"[3] and American Society for Testing and Materials (ASTM) standards and other methods, and were based on the following requirements:

- a. Weight, oz per sq yd - FTMS No. 191, Method 5041.
- b. Thickness, in. - FTMS No. 191, Method 5030.
- c. Breaking strength and elongation at break - ASTM standard D1682[4] (modified grab, Section 20).
- d. Tear strength, lb - ASTM standard D2263-68[5] (trapezoid tearing load, Sections 34-46).
- e. Low-temperature resistance (4 hr at -40 F) - FTMS No. 191, Method 5874.
- f. High-temperature resistance (4 hr at 125 F) - FTMS No. 191, Method 5972.
- g. Water resistance - FTMS No. 191, Method 5516.
- h. Flame resistance - FTMS No. 191, Method 5903.
- i. Ball bursting strength, lb - FTMS No. 191, Method 5120.
- j. Stiffness, in.-lb - FTMS No. 191, Method 5202.
- k. Tensile and elongation loss after 24-hr immersion in JP-4 jet fuel - ASTM standard D1682 (modified grab, Section 20).

Lap-joint tests

15. Laboratory tests were conducted on the adhesive, single-lap joints, used to connect the runs of material in the factory, to determine if the shear strength of the joint was equal to or greater than that of the material joined. Tests were also conducted on the fabricated joints to determine the peel-strength characteristics of the factory adhesive. The test joints were cut from a typical factory fabricated joint. Tests used to evaluate the joints were modifications of

ASTM standard D1002-64[6] (joint shear strength) and ASTM standard D903-49[7] (joint peel strength), which are described as follows:

a. Shear strength (ASTM standard D1002-64) and peel strength (ASTM standard D903-49) of a factory fabricated single-lap joint; dry test: Test specimens were conditioned for 24 hr at a relative humidity of 50 ± 5 percent and a temperature of 70 ± 2 F and were tested under these same conditions.

b. Shear strength (ASTM standard D1002-64) and peel strength (ASTM standard D903-49) of a factory fabricated single-lap joint; wet test: Test specimens were conditioned as outlined in paragraph 15a above. After conditioning, the specimens were immersed in distilled water for 48 hr at a temperature of 77 ± 2 F. The tests were performed immediately upon removal of the specimens from the water.

c. Shear strength (ASTM standard D1002-64) and peel strength (ASTM standard D903-49) of a factory fabricated single-lap joint; JP-4 puddling test: Test specimens were conditioned as outlined in paragraph 15a above. After conditioning, JP-4 jet fuel was puddled on the joint for 24 hr at a temperature of 77 ± 2 F. The tests were performed on specimens cut from the joint immediately upon removal of the JP-4. When necessary, the specimens were blotted dry to prevent slippage in the jaws of the testing machine.

Nonskid evaluation

16. The nonskid material, applied as described in paragraph 3, was evaluated as follows:

a. Weight, oz per sq yd - FTMS No. 191, Method 5041. Five specimens, 8 by 8 in. each, were used to determine the increase in weight of the surfacing due to the application of the nonskid.

b. Thickness, in. - FTMS No. 191, Method 5030. Five nonskid-coated membrane specimens, each 12 by 12 in., were used to determine the average thickness of the applied nonskid. A gage of the deadweight type, equipped with a dial graduated to read directly to 0.001 in. and a pressure foot with a diameter of 0.375 in., was used.

c. Adhesion of nonskid compound, high-temperature effect. Five nonskid-coated membrane specimens, each 12 by 12 in., were cut so that one of the 2-in.-diam circles of nonskid was in the center of the specimen. The specimen was then folded back-to-back and then face-to-face (the untreated side being the back and the nonskid-treated side being the face), making a 6- by 6-in. square. The folded specimen was then placed between two glass plates 6-1/2 in. square, and a 20-lb weight was placed on the top glass so as to exert even pressure on the specimen. The prepared specimen was placed in an environmental chamber for 4 hr at 125 F. It was then removed from the environmental chamber and carefully unfolded. Any cracking, peeling, or flaking of the nonskid was noted. Hairline cracking of the nonskid was acceptable, but a minimum of 90 percent retention of the nonskid pattern was required.

d. Adhesion of nonskid compound, low-temperature effect. The nonskid-treated membrane specimens were prepared as described in paragraph 16c and placed in an environmental chamber for 4 hr at -40 F. They were then removed from the chamber and carefully examined for cracking, peeling, or flaking of the nonskid. A minimum of 90 percent retention of the nonskid in the 2-in.-diam circles was required.

Test Results

17. The results of the laboratory tests on the XW18 membrane are shown in table 1. Five determinations on each test specimen were conducted, and the averages of these determinations are listed in table 1. The average strengths determined for the WX18 membrane are included in the table for comparison purposes. The laboratory tests indicated that the average strengths of the redesigned XW18 membrane were approximately equal to or greater than the strengths of the WX18 membrane.

PART IV: SKID TESTS

Test Equipment

18. A specially designed skid cart (fig. 3), consisting of the

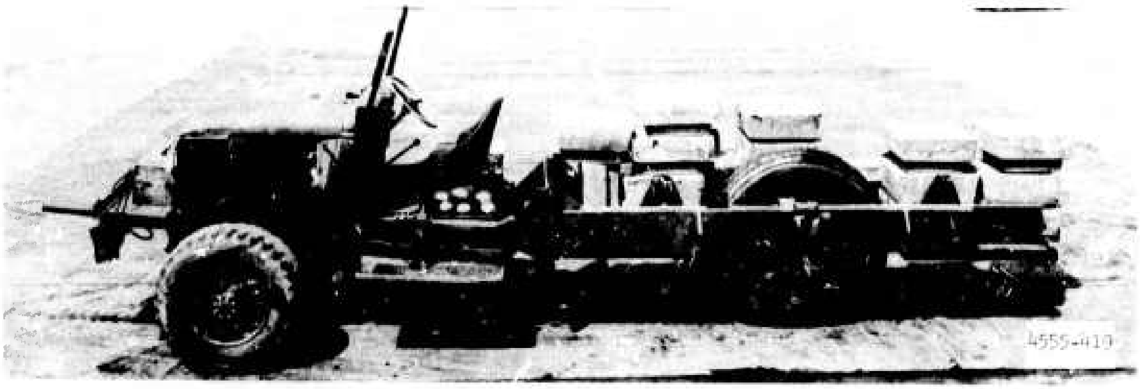

Fig. 3. Skid cart equipped with 20.00x20 C-130 aircraft tire

front half of a 6x6 truck with a load frame attached, was used in the skid tests to simulate locked-wheel braking actions of a C-130 aircraft. The load frame was supported on a wheel equipped with a 20.00x20 C-130 tire that could be locked. The truck section was used only for steering purposes; a Caterpillar Model 619 puller with Bros roller attached was used to pull the skid cart (fig. 4).

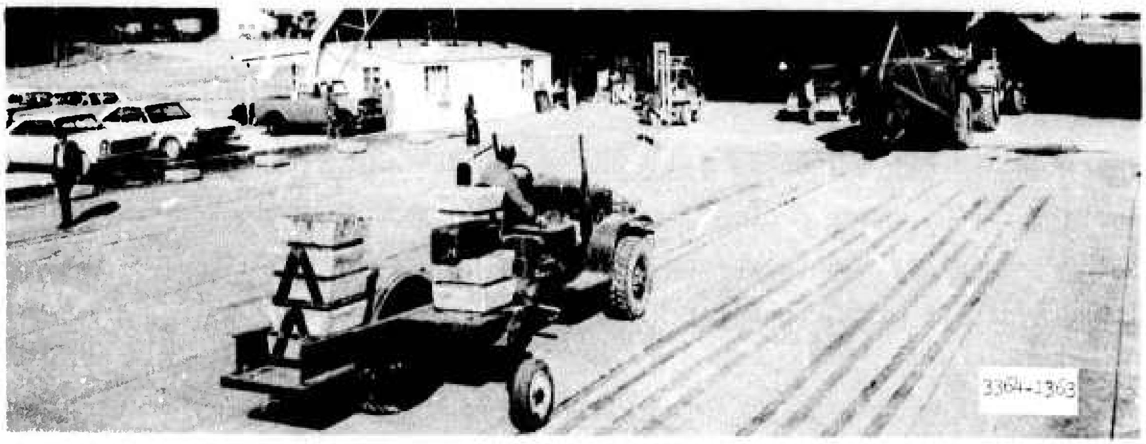

Fig. 4. Skid cart equipped with 20.00x20 C-130 aircraft tire being pulled by Caterpillar Model 619 puller and motor grader

19. A 50,000-lb-capacity dynamometer connected between the two vehicles was used to measure the magnitude of the force required to drag the test wheel. A Model 7100A strip chart recorder with a d-c bridge balance was connected to the dynamometer to record the force.

Test Section

20. The skid tests were conducted on a soil subgrade constructed with an 8 to 10 CBR for a depth of 18 in. The 8 to 10 CBR and the depth of 18 in. were selected to conform with the design curve shown in plate 2. The test area was excavated to a depth of 18 in. below final grade and then backfilled with three 6-in. lifts of a fat clay (CH). A gradation curve for this soil is shown in plate 3. Tests for CBR, water content, and density of the subgrade were conducted during construction to ensure that the design soil strength was obtained. The test area was located under a hangar to provide the conditions necessary for accurately controlled soil strength.

21. Three 40- by 40-ft prefabricated membrane sections were placed on the controlled soil subgrade. Prior to placement of each membrane section, the subgrade was graded smooth, and sharp pebbles and gravel were removed from the surface. The membrane sections were unfolded from pallets, placed on the subgrade, and then anchored in place. All membrane sections were stretched as wrinkle-free as possible and anchored with 2000-lb lead weights to secure the surfacing during the skid tests. Plate 4 shows a layout of a test section and anchor system. Tests for CBR, water content, and density of the subgrade were conducted before and after each membrane was tested. A summary of the results of these tests is given in table 2.

Test Procedures

Application of nonskid coating

22. Previous tests of T17 membrane conducted at the WES[8] showed that a membrane must be coated with a nonskid compound in order to

provide adequate skid resistance during inclement weather. However, the method of application of nonskid to the T17 membrane with paint rollers proved to be time consuming, and the weight of the membrane was increased considerably. Subsequent tests at the WES[9] revealed that a membrane sprayed with nonskid at a 22.7 percent coverage rate would provide adequate skid resistance for C-130 aircraft operations (i.e., according to the QMR, provide minimum coefficients of friction of 0.50 and 0.30 on dry and wet surfaces, respectively). Therefore, for tests of the redesigned XW18 membrane, the 22.7 percent coverage rate was achieved by spraying nonskid on the membrane in a polka-dot pattern using a template that had 2-in.-diam holes spaced on 4-in. centers. Application of the nonskid material in this manner prevented excessive cracking and flaking of the coating when the membrane was folded and permitted a substantial reduction in membrane weight.

Evaluation of skid resistance

23. Skid tests were conducted on the three XW18 membrane test sections to determine the ability of the factory applied nonskid coating to produce minimum coefficients of friction of 0.50 and 0.30 on dry and wet surfaces, respectively. The skid cart was loaded to produce a single-wheel load of 30,000 lb, and the 20.00x20 tire was inflated to 74 psi (i.e., to a load and tire pressure equivalent to those of a C-130 aircraft with a gross weight of 130,000 lb). The skid cart was positioned on the dry membrane surface in approximately the center of a run; the test wheel was locked, the instrumentation was zeroed, and the cart was pulled across the surface at a uniform rate (approximately 1 ft per sec) until a representative reading was obtained on the recorder (for a distance of approximately 15 ft). The test wheel was then unlocked, and the skid cart was positioned on another run of the test section. A total of four dry skids were made on each of the three XW18 membrane test sections. After completion of the dry skids, wet skids were made on the test sections after water had been puddled on the surfaces for 24 hr. The same procedure used for the dry skids was used for the wet skids. A summary of the data obtained during the dry and wet skid tests is given in table 3. Cross sections made at 6-ft intervals and profiles of the

center line of a typical rut caused by skidding are shown in plates 5-7.

<u>Tests for comparison of performance of XW18 and WX18 membranes</u>

24. After the evaluation of the factory applied nonskid compound, further skid tests were conducted to compare the performance of the redesigned XW18 membrane with that of the WX18 membrane under simulated C-130 braking action. Continuous dry skids were made over a minimum of two runs of each XW18 test section until at least two complete membrane failures occurred.

25. Results of field tests conducted by the Lockheed-Georgia Company* showed that 10 percent of the horizontal drag forces incurred by the landing gear of a C-130 aircraft during off-runway landings would exceed 21,500 lb. Therefore, the skid cart used for the tests reported herein and in previous tests of the WX18 membrane[9] was calibrated during a series of preliminary skids to produce drag forces of the desired magnitude. It was determined that, to produce a 21,500-lb drag force, a single-wheel load of 32,750 lb, a tire pressure of 76 psi, and a skid velocity of 1 ft per sec were required.

26. The CBR, water content, and density of the subgrade were determined before and after each test section was tested, and, when necessary, the subgrade was reworked to maintain the desired CBR. The data from these determinations are shown in table 2.

27. Prior to the skid tests for the purpose of comparing the XW18 and WX18 membranes, the skid cart was positioned on a run of the test section that had not been skidded on previously. The 20.00x20 tire was locked, and the cart was pulled across the surfacing for the entire length of the run (approximately 25 ft). Then the test wheel was unlocked, and the skid cart was repositioned at the beginning of the same run of membrane. The test wheel was locked again, and the cart was pulled across the same area of membrane. This procedure was repeated until the membrane failed completely. A summary of the static and

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* These results have not been published; they were obtained informally from the Lockheed-Georgia Company.

dynamic drag forces and the coefficients of friction for each run tested is presented in table 4. Plates 8-11 show cross sections made at 6-ft intervals and profiles of the center line of a typical rut caused by skidding.

Test Results

Evaluation of XW18 membrane skid resistance

28. Test section 1. Photo 1 shows the membrane prior to the skid tests. An inspection of the surface revealed that the general condition of the nonskid coating was excellent (photo 2). Since only a small percentage of the nonskid coating was removed in the center of the test section (photo 3) when the surfacing was unfolded, it was determined that the polka-dot pattern of nonskid was effective in preventing loss of the nonskid due to folding.

29. Photo 4 shows XW18 membrane test section 1 after four dry skids, and photo 5 shows the section after four wet skids. The average rated braking conditions* for the dry and wet skids were 0.68 and 0.44, respectively (table 3). These values correspond to dynamic coefficients of friction of 0.60 and 0.38, respectively; thus, the skid resistance of the surface exceeded the required minimum coefficients of 0.50 and 0.30 for dry and wet surfaces, respectively.

30. An examination of the surface after the skid tests revealed that approximately 97 percent of the nonskid compound was removed after the dry skids (photo 6) and approximately 59 percent was removed after the wet skids (photo 7). Cross sections of the surface made at 6-ft intervals and a center-line profile of a rut caused by a typical skid are shown in plate 5.

31. Test section 2. Photo 8 shows the general condition of the membrane surface prior to the skid tests. Partial cracking and flaking of the nonskid coating occurred in isolated areas (photo 9).

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* The rated braking condition is determined by averaging the static and dynamic coefficients of friction. It is used because of the antiskid device employed on all C-130 aircraft to prevent locking of the brakes.

32. Photo 10 shows XW18 membrane test section 2 after four dry skids, and photo 11 shows the section after four wet skids. The average rated braking conditions for the dry and wet skids were 0.74 and 0.50, respectively (table 3), corresponding to dynamic coefficients of friction of 0.59 and 0.45, respectively.

33. An examination of the surface after the skid tests revealed that approximately 36 percent of the nonskid compound was removed after the dry skids (photo 12) and approximately 23 percent was removed after the wet skids (photo 13). Cross sections of the surface made at 6-ft intervals and a center-line profile of a rut caused by a typical skid are shown in plate 6.

34. Test section 3. The general condition of the membrane surface prior to the skid tests was excellent; cracking and flaking of the nonskid coating occurred only in isolated areas.

35. The condition of XW18 membrane test section 3 after four dry and four wet skids (photo 14) was similar to that described for test sections 1 and 2. The average rated braking conditions for the dry and wet skids were 0.72 and 0.50, respectively (table 3), corresponding to dynamic coefficients of friction of 0.63 and 0.41, respectively.

36. An examination of the surface after the skid tests revealed that approximately 97 percent of the nonskid compound was removed after the dry skids and approximately 57 percent was removed after the wet skids. Cross sections of the surface made at 6-ft intervals and a center-line profile of a rut caused by a typical skid are shown in plate 7.

Tests for comparison of performance of XW18 and WX18 membranes

37. Test section 1.

a. Run 1. After the second repetitive skid on the same area of run 1, the top ply of nylon fabric failed in nine places (photo 15). This fabric failure was not considered to constitute a complete failure of the membrane, since three plies of fabric remained to waterproof the subgrade. The severity of top-ply failures increased during subsequent skids. Photo 16 shows the membrane after six repetitive skids had been completed. However, only top-ply failures had occurred. Complete failure of the membrane occurred when an attempt was made to skid the test wheel over the same area of run 1 for the tenth time. The membrane failure was in a U-shaped 12- by 13-ft area (photo 17). Cross sections of the surface taken at 6-ft intervals and a center-line profile of the rut caused by the tire skidding are shown in plate 8. These cross sections and the profile show typical rutting incurred by the subgrade during the three failure point determinations made on XW18 test section 1.

b. Run 2. After the second repetitive skid across the same area of run 2, only small amounts of neoprene had been stripped from the surface (photo 18). No top-ply failures occurred at this time as they had on run 1. No change in the condition of the membrane was evident following the third repetitive skid. However, during the fourth skid, the membrane failed after the tire had skidded a distance of approximately 2 ft. The failure extended completely across the run (approximately 4 ft) and was 12 ft long (photo 19). As is evident in photo 19, rutting of the subgrade was negligible.

c. Run 3. Top-ply fabric failures occurred at two places in run 3 after the second repetitive skid. These types of failures increased in number during subsequent skids. During the fifth repetitive skid, complete failure of the membrane occurred after a skid of approximately 2 ft. The failed area was 16 ft wide and 6 ft long (photo 20).

38. Test section 2.

a. Run 1. Top-ply failures occurred after two repetitive skids and increased in number and severity during subsequent skids. Complete failure of the membrane occurred approximately 2 ft after the initiation of the eighth skid in an area 4 ft wide and 9 ft long (photo 21). As is shown in photo 21, rutting of the subgrade was somewhat more severe than during previous tests. Cross sections of the surface taken at 6-ft intervals and a center-line profile of the rut caused by the skidding are shown in plate 9.

b. Run 2. Three repetitive skids over the same area of run 2 were required to completely fail the membrane. The area of failure extended across two runs of the membrane (approximately 7-1/2 ft) and was 8 ft long (photo 22). The failure developed before the test wheel began to skid, and it occurred in an area where no top-ply failures had been observed previously.

c. Run 3. Top-ply failures occurred after three repetitive skids, but the membrane did not completely fail in an area that had been weakened by such failures. After six repetitive skids, the membrane failed completely in a 7-1/2-ft-wide by 8-1/2-ft-long area (photo 23).

39. Test section 3.

a. Run 1. Top-ply failures occurred during the third skid and increased in number during subsequent skids (photo 24). In an area where the membrane had been weakened by these failures, complete failure of the membrane occurred 3 ft after the beginning of the seventh skid. The area failed was 4 ft wide and 8 ft long (photo 25). Cross sections of the surface taken at 6-ft intervals and a center-line profile of the rut caused by the skidding are shown in plate 10.

b. Run 2. Top-ply failures occurred after three repetitive skids. During the eighth skid, several second-ply failures occurred (photo 26), leaving the membrane with only half of its original strength. Complete failure of the membrane occurred during the tenth skid. The area failed was 4 ft wide and 8 ft long (photo 27). As is shown in plate 11, rutting of the subgrade was quite severe.

Summary of Test Results

Evaluation of skid resistance

40. The average rated braking conditions and percent of nonskid compound removed during the skid tests are summarized in the following tabulation:

XW18 Membrane Test Section No.	Rated Braking Condition		Percent of Nonskid Removed	
	Wet	Dry	Wet	Dry
1	0.44	0.68	59	97
2	0.50	0.74	23	36
3	0.50	0.72	57	97

These results show that the skid resistance of the three XW18 test sections exceeded the minimum required coefficients of friction of 0.50 and 0.30 for dry and wet surfaces, respectively. Therefore, the braking conditions required for safe operation of C-130 aircraft during inclement weather were provided by the redesigned XW18 membrane. However, the amount of nonskid removed during the skid tests was considered to be excessive. These results indicate that the polka-dot pattern was effective in preventing flaking and cracking of the nonskid when folded and that adequate coefficients of friction were provided. However, increased adhesion of the nonskid to the membrane is needed.

Test for comparison of XW18 and WX18 membranes

41. Results from the repetitive skid tests on the XW18 membrane test sections are compared with results from previous tests on WX18 membrane in the following tabulation:

Type Membrane	Test Section No.	Run No.	Average Drag Force, 10^3 lb Static	Dynamic	No. of Skids to Failure
WX18	--	1	24.5	17.9	15
		2	24.9	17.7	18
XW18	1	1	28.9	18.8	10
		2	29.0	18.8	4
		3	28.2	19.3	5
XW18	2	1	29.0	20.4	8
		2	28.7	20.2	3
		3	28.5	18.1	6
XW18	3	1	29.0	19.5	7
		2	32.1	21.3	10

The values tabulated above indicate that the XW18 membrane was capable of sustaining repeated stresses of the magnitude of those applied by the main landing gear of a C-130 aircraft during braking actions. An average of 6.6 dry skids over the same area of a given run were required to completely fail the membrane. By contrast, an average of approximately 16.5 skids were required to completely fail the WX18 membrane. This difference in the number of skids required to produce failure in these membranes can be attributed to the following:

a. The XW18 membrane was subjected to greater drag forces during the skids than was the WX18 membrane during previous tests. Although the other test variables were comparable, the average drag forces on the XW18 membrane test sections were higher than those on the WX18 membrane by 4475 and 1750 lb for the static and dynamic forces, respectively. These increased drag forces caused early failure of the XW18 membranes even though they developed strengths greater than the WX18 when tested in the laboratory.

b. The XW18 membrane was coated with nonskid compound in a polka-dot pattern at a 22.7 percent coverage rate, while the WX18 membrane was solid coated with nonskid. The solid coating of nonskid on the WX18 protected the neoprene coating and prevented failure of the top ply of fabric during the initial skids, whereas more of the neoprene coating on the XW18 membrane was exposed to the direct scuffing and abrasion of the skidding tire.

PART V: TRAFFIC TESTS

Construction of Test Sections

General

42. A 60-ft-wide by 150-ft-long open area exposed to prevailing weather conditions was used for traffic tests. A 20-ft-wide lane located in the center of this area was selected for use as the control subgrade and was processed to provide an in-place CBR that conformed to the design curve for 2,400 coverages of a C-130 aircraft with a gross weight of 130,000 lb and a tire inflation pressure of 74 psi (plate 12). The subgrade area was excavated to a depth of 30 in. below the final grade and then backfilled with five 6-in. lifts of a lean clay (CL). The classification and gradation data for the control subgrade are shown in plate 13. Tests for CBR, water content, and density of the subgrade were conducted during and after construction to ensure that the desired soil bearing strength was obtained. After compaction of the controlled subgrade was completed, the test area was graded to a crown with a transverse slope of 2 percent. Ditches were constructed along the sides to provide adequate drainage.

43. Two traffic test sections were surfaced with the redesigned XW18 membrane. The first test section (plate 14) consisted of three 53- by 66-ft sheets of membrane placed directly on the control subgrade. The sheets were joined at the 66-ft-long ends by 2-ft-wide, single-lap adhesive construction joints. After the traffic tests on section 1 were completed, the membrane was removed, and the test area was bladed smooth before the second membrane test section was placed (plate 15). Two 53- by 66-ft sheets of membrane were used in section 2 to reduce the amount of time necessary to apply the required traffic. A 25-ft-long approach area of landing mat was provided at each end of section 1, and a 50-ft-long approach was provided at each end of section 2.

Traffic test section 1

44. After the subgrade was graded, 2-ft-deep, L-shaped anchor

ditches were constructed along one end and two sides of the 60- by 150-ft test area with a motor grader (photo 28). One end of the test area was not ditched so that vehicles could be moved onto the test area during construction and so that an exact location for the final anchor ditch could be determined. The spoil removed from the ditches during construction was windrowed outside the area to be surfaced with membrane.

45. The membrane sheets and accessories were packaged in wooden crates. During the construction of the anchor ditches, the tops and sides of the crates were removed to facilitate rapid placement procedures. The accessories were first removed from the pallets, then the pallets were loaded onto a truck and positioned so that the membrane could be unfolded lengthwise as the truck was driven down the length of the test area.

46. Placement of the first sheet of membrane was initiated by positioning the truck at the ditched end of the test area. After the truck was positioned on the center line, the placing crew unfolded the membrane so that it extended for approximately 3 ft into the anchor ditch (photo 29). As the truck was driven slowly down the center line of the test area, the placing crew ensured that the membrane was unfolded in a straight line and that all slack was removed. After the first sheet had been unfolded from the pallet, the crew was stationed at equal intervals along the 53-ft length of the surfacing to unfold the sheet to one side of the test lane and place the edge of the surfacing into the side anchor ditch (photo 30). The other half of the sheet was unfolded to the opposite anchor ditch using the same procedure. The sheet was then stretched to obtain proper alignment of the center-line and edge stripes with the layout of the test area and to remove as much slack as possible. At this point, the protective paper wrapping was removed from both ends of the sheet (photo 31).

47. Steel anchors (paragraph 10) were driven into the end of the sheet placed in the end anchor ditch through alternate single-lap adhesive joints (photo 32). White guidelines had been painted 1 ft from the edges of the sheets to ensure proper alignment of the anchors. With one end of the sheet thus anchored, the placing crew again stretched

the sheet to remove additional slack, and, as the slack was removed, the surfacing was secured with anchors that were driven through alternate single-lap adhesive joints of the free edge (photo 33). The edges placed in the side ditches were also secured with anchors driven at intervals of 25 ft. Fig. 5 shows the profile of a typical anchoring location.

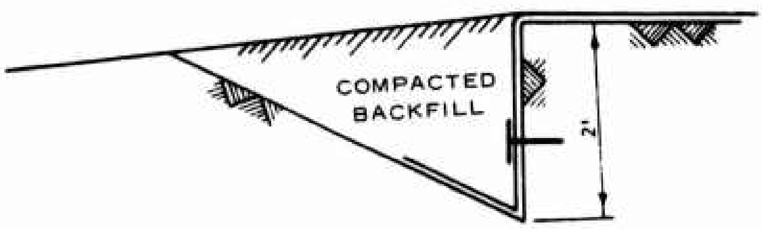

Fig. 5. Profile of anchor location for traffic test section 1. Anchors placed on 25-ft centers

After the first sheet was in place, the second sheet was unfolded along the center line and allowed to overlap the first sheet by approximately 24 in. While this second sheet was being placed, the end anchor ditch was backfilled (photo 34) and compacted, and the side ditches were backfilled to within approximately 6 ft of the free end of sheet 1. The second sheet was unfolded to both sides of the test area using the same procedure as for the first sheet. The edge and center-line stripes of the two sheets were aligned, and steel anchors were driven approximately 6 in. into the subgrade through the overlapping ends of the sheets (photo 35). The anchors were driven only half way into the subgrade so that the construction of the adhesive joint between the sheets could be accomplished concurrently with the removal of excessive slack in sheet 2. As the second sheet was stretched from its free end, steel anchors were driven through the single-lap adhesive joints of this end using the same procedure described for sheet 1.

48. To construct the joint between sheets 1 and 2, the 2-ft-wide overlapping end of sheet 2 was lifted with 48-in.-long paint roller handles while the adhesive (see paragraph 12) was poured onto the lower surface and spread with another paint roller (photo 36). The upper surface was held off of the lower until the adhesive became tacky. Then

the upper surface was lowered, and the anchors were driven flush with the surface. After the joint had set for 10 to 15 min, it was rolled with a panel truck to remove air pockets and excess adhesive. The joint was then reinforced with a 36-in.-wide strip of membrane that was bonded to the membrane with adhesive (photo 37). The reinforcing strip was also rolled with the truck after it had set for 10 to 15 min.

49. The third sheet of membrane was placed using the procedures described for the second sheet; however, special 6-in.-diam anchor gaskets of XW18 material (photo 38) were used on the anchors at the adhesive construction joint between sheets 2 and 3. The gaskets formed a double thickness of membrane to provide additional protection to the puncture in the surfacing made by the reinforcing rod. The diameter of the gasket extended to the periphery of the concave portion of the anchors. Thus, when the anchor was driven flush with the surfacing, the outer edge of the gasket butted the flat portion of the anchor head to form a seal. When the slack had been removed from the sheet, adhesive was applied to the joint in 9-ft increments. Adhesive was also applied to both sides of each gasket. The anchors were driven flush with the surfacing after each adhesive increment was completed. The reinforcing strip was not placed over this joint so that the ability of the adhesive and the gasket seals to effectively waterproof the joint could be determined.

50. While the second adhesive joint was being constructed, the anchor ditch for the remaining end of the test section was constructed. The free end of the third sheet of membrane was first folded back approximately 3 ft to determine the location for the final ditch and then was pulled back enough to permit construction of the ditch with a motor grader (photo 39). After construction of the ditch, the membrane was folded into the ditch, and the edge was anchored (photo 40). All anchor ditches were then backfilled and compacted. Photo 41 shows the completed test section composed of three XW18 membrane sheets.

Traffic test section 2

51. The two sheets of XW18 membrane used in test section 2 were placed directly on the subgrade and anchored in 2-ft-deep ditches

constructed around the perimeter. The procedures for constructing test section 2 were the same as those for section 1, except for the placement of the anchors. The anchors in section 2 were driven through the membrane on the outside slope of the L-shaped anchor ditch (photo 42). Fig. 6 shows a profile of a typical anchor location. The

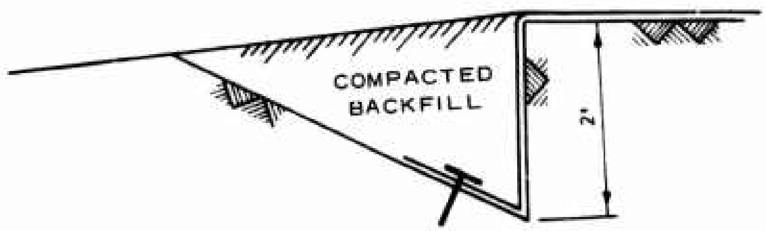

Fig. 6. Profile of anchor location for traffic test section 2. Anchors placed on 17-ft centers

anchors along the sides of the test section were driven at 17-ft intervals rather than at the 25-ft intervals used in section 1. When the anchors were driven in the outside slope of the ditches, the membrane spanning the ditches was stretched to leave approximately 6 in. between the sheet and the bottom of the ditch. Thus, when the ditches were backfilled and compacted, additional slack would be removed by the sheets being forced to the bottom of the ditches by the weight of the compacted soil. A 1 percent slope to the edge of the test section was used when constructing the two 50-ft-long approach areas so that the load cart could accelerate while on the landing mat and thus minimize wear caused by the drive wheels on the ends of the test section. Photo 43 shows the completed test section composed of two XW18 membrane sheets.

Placement times

52. Approximately 3-1/2 hr were required to unfold, anchor, and join the three membrane sheets and backfill the anchor ditches of test section 1. This time period does not account for constructing the second end anchor ditch, anchoring the third sheet in this ditch, and backfilling. These three operations were not counted for the construction time period since, in an actual runway, which would contain approximately 70 sheets of membrane, these operations would not represent

as significant a period of time as they did during these tests. The personnel and equipment requirements for section 1 were as follows:

Crew Responsibilities	No. of Personnel	Equipment
Operating equipment	Three (1 motor grader operator, 1 forklift operator, and 1 truck driver)	One motor grader One forklift One 2-1/2-ton truck
Unfolding, stretching, anchoring, joining	Ten (6 men to unfold sheets and align, 4 to drive anchors and construct joints)*	Two 12-lb sledgehammers

* The full crew of ten was required to unfold the membrane to the side ditches.

The total effort required to construct test section 1 amounted to 45.5 man-hours for the 13-man crew. Thus, since the three sheets of membrane in the section had a total area of 10,494 sq ft, the membrane was placed at a rate of 230 sq ft per man-hour. This placement rate exceeded the QMR requirement of a minimum rate of 200 sq ft per man-hour. It should be noted that the placement procedures were somewhat slowed by the photography required for documenting the tests. Approximately 15 min was required to place the reinforcing strip across the joint between sheets 1 and 2 of the first test section. Eliminating this operation in construction of the joint between the second and third sheets resulted in a reduction in effort of 3-1/4 man-hours.

Test Equipment

53. A specially designed load cart (fig. 7) was used to apply simulated coverages of C-130 aircraft to the test sections. The load cart consisted of the front half of a 2-1/2-ton 6x6 truck to which a load frame was attached to permit mounting the test wheel and application of the design load with lead weights. A 20.00x20 all-weather C-130 aircraft tire was mounted on the load cart for traffic tests. The load cart was loaded to 30,000 lb, and the tire was inflated to a pressure of 74 psi.

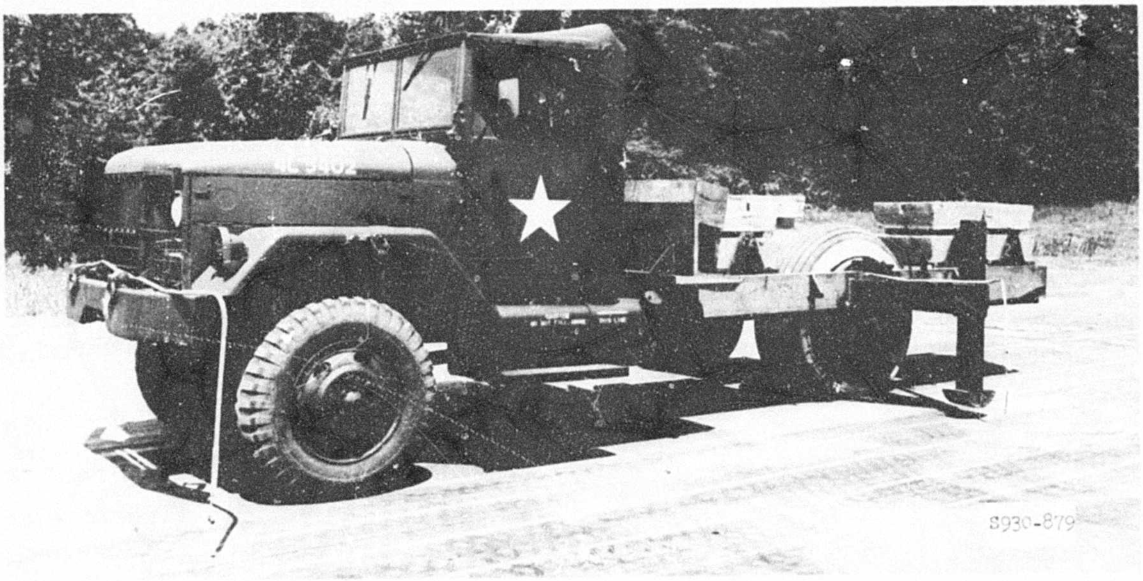

Fig. 7. Traffic load cart equipped with 20.00x20 C-130 aircraft tire

54. When it was necessary to simulate rainfall on the test sections in order to determine the effectiveness of the membrane in waterproofing the subgrade, a water truck with a spray bar attached (fig. 8)

Fig. 8. Water truck with spray bar attachment used to simulate rainfall on traffic test section

was used on the test section before traffic and after each 200 coverages.

Test Procedures

55. Tests to determine the CBR, water content, and density of the subgrade were conducted before, during, and after traffic testing. A summary of the data obtained from these tests is shown in tables 5 and 6 for test sections 1 and 2, respectively.

56. Before traffic was initiated, water was applied to the 16-ft-wide traffic lane using the water truck. During a period of 1 hr, approximately 1500 gal of water were sprayed on the traffic lane to simulate a 1-in. rainfall during the same time period.

57. Traffic was initiated on the test section by positioning the load cart at one side of the traffic lane. The coverages were achieved by applying a sufficient number of passes of the test wheel (11) in adjacent parallel wheel paths to completely cover the 16-ft-wide traffic lane. The load cart was driven forward and then backward in the same path for the length of the traffic lane. The path of the cart was shifted laterally 17.5 in. (the width of a tire print) on each successive forward trip. Thus, two coverages of the traffic lane were accomplished when the load cart had maneuvered from one side of the lane to the other. This method of traffic application was continued throughout the tests. A total of 1200 coverages was applied to the traffic lane of test section 1 during the period 25 April to 28 July. A daily record of coverages applied, temperature extremes, and amount of rainfall is shown in plate 16. During the period 17 September to 4 December, a total of 1200 coverages was applied to test section 2. A daily record of coverages, temperatures, and rainfall for this section is also shown in plate 16.

Test Results

Traffic test section 1

58. Photo 41 shows test section 1 prior to traffic. At two

coverages, a small amount of soil was found to have pumped through the field construction joint at station (sta) 1+00,* 4 ft west of the center line of the traffic lane, indicating that the water sprayed on the membrane prior to traffic was working its way through the joint to the subgrade. The water was seeping through the gap in the adhesive joint at the 6-in.-wide overlap of the factory fabrication joints (see photo 44). Because of the thickness of the membrane at these junctures, it was impossible to completely seal the joint in all cases where these overlaps occurred. The pumping of the subgrade was minor, and did not affect the serviceability of the membrane. The remainder of the test section showed no signs of leakage.

59. Traffic was continued to 100 coverages with no major occurrences. Photo 45 shows the general condition of sheet 3, which was typical of the condition of the test section. An inspection of the nonskid pattern showed little removal of the abrasive compound by the test wheel (plate 17). The general condition of the neoprene coating on the surfacing was excellent, but the scuffing action of the tire had exposed the first ply of fabric at locations where the surface was wrinkled (photo 46). This localized removal of neoprene coating did not destroy the waterproofing capabilities of the membrane, since four plies of nylon and four layers of neoprene remained to protect the subgrade. The two 2-ft-overlap adhesive construction joints remained in good condition, with only minor repairs required in limited areas, such as that shown in photo 47.

60. At 150 coverages, slight rutting of the subgrade was observed at sta 1+00, 4 ft west of the center line of the traffic section, and at sta 0+75, 6 ft east of the center line. The subgrade had rutted approximately 2 in. in both locations (photo 48). This rutting, however, did not affect the serviceability of the surfacing, since the maximum permissible rutting for safe operation of C-130 aircraft is 6 in.[10]

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* Sta 1+00 and all other locations so cited herein are in feet from the north ends of the respective test sections (see plates 14 and 15).

61. At 200 coverages, no failures of the XW18 membrane or subgrade had occurred. The general condition of the surfacing was good (photo 49). The water puddled along the outside edges of the traffic lane shows the consolidation of the subgrade under traffic at this coverage level.

62. To help seal the 2-ft-wide adhesive construction joints, the 3M Company EC801, Class A "trowel-on" grade sealant (described in paragraph 13a) was applied to the edges of the joints. The sealant was applied with a Semco Model air gun connected to a compressor with an air pressure of 35 psi (photo 50). The sealant was applied in a 1/4-in.-wide bead to both edges of the reinforcing strip on the joint between sheets 1 and 2 and to the overlapped edge of the joint between sheets 2 and 3. An inspection of the condition of the sealant was made daily during the remainder of the traffic testing, and any repairs necessary to keep the joints waterproof were made.

63. At 400 coverages, the rutting at sta 0+75, 6 ft east of the center line, had increased to 3-1/2 in. (photo 51). The rutting of the subgrade at sta 1+00, 4 ft west of the center line, was unchanged from the 2-in. depression observed at 200 coverages. Photo 52 shows the general condition of the test section after water had been applied with the water distributor at 400 coverages.

64. At 522 coverages, one anchor in the joint without the reinforcing strip failed. The anchor was in the rutted area at sta 1+00, 4 ft west of the center line. In this area the subgrade was soft, and the anchor head had been bent back and forth with each pass of the test wheel until the 8-in.-diam steel plate anchor head separated from the 12-in.-long reinforcing rod (photo 53). The failed anchor represented a potential tire hazard which necessitated immediate repair. The reinforcing rod was pulled from the subgrade, and a 16-in.-diam patch of membrane was placed over the position of the failed anchor. Then a new anchor was driven through the surfacing into the subgrade in a location approximately 4 in. from the position of the failed anchor (photo 54).

65. At 538 coverages, traffic was suspended because of excessive

rutting of the subgrade. Cross sections of the traffic lane showing the severity of the rutting are shown in plate 18. At sta 1+05, the subgrade had rutted to approximately 2-1/2 in. (photo 55). On the east edge of the traffic lane at sta 0+75, the rutting had increased to 6 in. (photo 56). This rutting caused excessive wear on membrane sheet 3 due to the abrasion of the drive wheels of the test vehicle as it traveled through the ruts. Sheet 3 lost approximately 93 percent of its factory applied nonskid material due to this excessive wear (plate 17). Therefore, it was decided that a major repair of the subgrade was required to prevent further undue wear on the membrane surfacing by the drive wheels of the test vehicle.

66. Since nearly all of the factory applied nonskid had been removed by the test wheel, sheet 3 of test section 1 was replaced. Replacement of the worn sheet provided the opportunity to determine the capability of the membrane to be replaced rapidly in accordance with the requirements of the QMR (see paragraph 4d). Placement of the new section also permitted the collection of additional data on the nonskid compound and neoprene coating exposed to the abrasion of the test wheel. The replacement was also used to determine the cause of excessive wear on the replaced sheet of surfacing. Traffic was continued on the two sheets that remained in place to determine if a watertight joint could be maintained throughout the period of traffic.

67. CBR readings were taken before the removal of sheet 3 at the two locations where rutting had taken place, sta 0+75 and 1+07. For comparison purposes, at sta 0+75, a pit was run in the rutted area as well as outside the traffic lane. In the rutted area, the surface reading of the subgrade had decreased from 12 CBR to 6 CBR. Outside the traffic lane at sta 0+75, 15 ft west of the center line, the surface reading had increased to 31 CBR. Two readings were also taken in the approximate location of the rutted area at sta 1+07. These readings showed that the surface soil strengths had decreased to 4 CBR and 7 CBR at locations 4 ft west of the center line and 4 ft east of the center line, respectively. The pit run at sta 1+30, 4 ft east of the center line, indicated that the CBR had increased considerably at the surface and

to a depth of 18 in. in the traffic lane (table 5).

68. To replace sheet 3, the sheet was cut around its perimeter immediately adjacent to the anchor ditches. Then the surfacing was folded up and removed to allow a motor grader to remove the remaining membrane buried in the ditches (photo 57). Sheet 2 was cut along a line approximately 4 ft from the anchor ditches parallel to the traffic lane for a distance of 30 ft and folded back to expose the rutted area at sta 0+75 (photo 58). Photo 59 shows the rutted area at sta 1+05 near the joint between sheets 2 and 3 after removal of the surfacing. The freshly disturbed soil to the left and right in the photo are areas where CBR pits were run prior to the removal of the membrane.

69. The subgrade where the rutting had occurred was aerated by means of a Buffalo Springfield, 8-ft-wide, self-propelled Pulvi-Mixer. Dry lean clay was also mixed with the wet soil to speed up the drying process. The reworked soil was then compacted with a 50,000-lb towed roller and graded to a 2 percent crown with a motor grader. Surface readings taken after repair of the subgrade showed an average CBR of 21 had been obtained.

70. Upon completion of the subgrade repair, sheet 2 was folded back into position, and a 3-ft-wide strip of membrane was placed over the cut made for the soil repair (photo 60). Then the new sheet, designated sheet 3A, was overlapped on sheet 2, unfolded, and anchored in the ditches as described previously for the first three sheets. A 3-ft-wide reinforcing strip was placed over the joint between sheets 2 and 3A in the manner described in paragraph 48. It was determined that the unreinforced joint had not provided sufficient waterproofing capabilities as was evidenced by the rutting that occurred near the joint. In addition, the anchor failure that occurred at 522 coverages constituted a tire hazard. If a reinforcing strip had been used on this joint, the tire hazard would have been eliminated, since the strip would have covered the failed head and reinforcing bar. The repair of the subgrade and replacement of the worn sheet required 104 man-hours of effort. Photo 61 is a general view of the traffic test section after repair of the subgrade and replacement of the third sheet.

71. The 3M Sealer EC801 was again applied to one edge of the reinforcing strips, as described in paragraph 62. However, for the purpose of comparison, the 3M Company Weatherban Sealant 101 described in paragraph 13b was applied to the other side of the reinforcing strip. The sealant was furnished in sealed cartridges and applied with a 1/10-gal, half-barrel caulking gun (photo 62). The sealant was then beveled with a putty knife, as shown in photo 63, so that the sealant was flush with the upper edge of the reinforcing strip. This procedure of beveling the sealant with a putty knife was used to minimize peeling of the sealant by the test wheel during trafficking.

72. With the repair of the subgrade and replacement of sheet 3 completed, trafficking was resumed. At 738 coverages, no rutting of the subgrade was noted. The general condition of sheets 1, 2, and 3 at this time is shown in photos 64-66. The neoprene coating on one run of sheet 1 had worn down to the fabric. Photo 67 is a close-up of this condition showing the top ply of the fabric exposed in most areas except where the nonskid pattern remained. After 738 coverages, an inspection of the nonskid pattern on sheets 1 and 2 revealed that an average of 64 and 86 percent, respectively, of the nonskid remained. After 200 coverages, 84 percent of the nonskid pattern remained on sheet 3A (plate 17). The general condition of both sealants used along the edges of the reinforcing strips was good (photo 68). Both sealants exhibited adequate resistance to the wear of the test wheel, adhered well to the membrane, and provided watertight seals.

73. After 910 coverages, considerable wear had occurred on sheets 1 and 2, as shown in photos 69 and 70. The light areas in the traffic lane shown in the photos are areas where the neoprene coating was removed by the abrasion of the test wheel and the top ply of nylon fabric was exposed. The 6-in.-wide factory fabrication joints, however, were still in good condition. No repairs were necessary, and the membrane remained weatherproof. Sheet 3A also exhibited signs of wear, but to a lesser degree than sheets 1 and 2 (photo 71). However, a total of only 372 coverages of the test wheel had been applied to sheet 3A since it had been placed when the subgrade was repaired after

538 coverages. No appreciable rutting of the subgrade had taken place since the reworking of the subgrade at 538 coverages. The two sealants still showed good adhesion and required only minor repairs.

74. At 1200 coverages, the condition of the surfacing was generally unchanged. Photos 72-74 are general views of sheets 1, 2, and 3A, respectively. The patches shown on the membrane surfaces in the photos are areas where the membrane had been cut for CBR determinations. Severe wear of the neoprene coating on sheets 1 and 2 had been caused by the abrasion of the test wheel at this coverage level. Photos 75 and 76 show a close-up of the wear on sheets 1 and 2, respectively. Severe wear of the neoprene coating of this type was present on approximately half of the area of both sheets. Sheet 3A (photo 77), which had received a total of 662 coverages since it had been placed at 538 coverages, showed no degree of wear approaching that of sheets 1 and 2.

75. CBR determinations were made at six locations at 1200 coverages. Pits were run beneath each of the three sheets; one pit was run inside the traffic lane and one outside the traffic lane for the purpose of comparing the subgrade beneath each section with the subgrade that had not been trafficked (table 5). The results indicated that the soil in the traffic lane had consolidated under the load of the test wheel and that the soil strength had increased from an average CBR of 14 on the surface to an average CBR of 33. This increase in soil strength prevailed to a depth of 12 to 18 in. in most cases inside the traffic lane. Determinations taken outside the area trafficked by the test wheel showed an increase in the average surface CBR from 14 to 21. This increase did not, however, prevail past the surface reading.

76. It was decided at this time to terminate trafficking of the membrane. Although the surfacing remained sufficiently waterproof to protect the subgrade, two of the sheets (1 and 2) were severely worn. The third sheet, which had received only 662 coverages of the test wheel since its placement at 538 coverages, was not worn as badly as the other sheets, but 56 percent of the factory applied nonskid pattern had been removed from this sheet.

Traffic test section 2

77. A general view of test section 2 prior to traffic is shown in photo 43. Prior to the initiation of traffic by the test vehicle, an inspection of the nonskid pattern on the two sheets of the section revealed that some of the nonskid pattern had been lost due to the folding of the sheets in the factory and subsequent unfolding during placement of the membrane. However, less than 1 percent of the total nonskid pattern was lost due to this folding. The general condition of the field construction joint with the 3-ft-wide reinforcing strip is shown in photo 78. (Note the use of 3M Weatherban sealant along the edges of the reinforcing strip to further protect the joint from water infiltration.) The 3M Weatherban sealant was used exclusively in this traffic test section. The Weatherban sealant and the EC801 sealant had both demonstrated good resistance to wear of the test wheel in test section 1, but the EC801 sealant required special equipment for its use (paragraph 62). Therefore, the Weatherban sealant was selected for use on test section 2. The sealant was applied to the edges of the joint using the procedure described in paragraph 71 for the first test section.

78. Photo 79 shows the general condition of the test section after 200 coverages. At this coverage level, there were no major occurrences, and the membrane showed little wear. Photo 80 shows the condition of the 3-ft-wide reinforcing strip on the joint between the two sheets. The sealant shown along the edges of the strip was wearing well and required no repair at this point. However, several of the 6-in.-wide factory fabrication joints that connected the runs of membrane were beginning to peel loose (photo 81). When the test wheel passed over a joint where a wrinkle resulting from slack in the surfacing was present, the wheel folded the wrinkle over, stressing the adhesive bond between the double layer of surfacing and causing the surfacing to peel loose. The peeled areas extended approximately 1 in. into the 6-in.-wide factory joints and were repaired by use of the MG-180 adhesive. Approximately 12 percent of the nonskid compound on sheet 1 and 5 percent of the nonskid material on sheet 2 had been removed by trafficking of the test vehicle at this coverage level (plate 19).

79. Traffic was continued on the test section to 400 coverages. Since no normal rainfall occurred during the period, water was applied with the distributor at 200 and 400 coverages of the test section to simulate a 1-in. rainfall. This periodic wetting of the membrane surfacing indicated that the surfacing still retained its waterproof seal, since there was no evidence of soil pumping or surface deformation during trafficking.

80. Further peeling of the 6-in.-wide factory fabrication joints required that steps be taken to prevent water infiltration through the joints to the subgrade. It was found that the dry-weather adhesive did not have adequate peel strength to effectively seal the wrinkles in the joints. However, a watertight seal was effected by use of the Weatherban sealant. The sealant was applied by inserting the plastic spout of the sealant cartridge into the peeled area of the joint and completely filling the void with sealant. Then pressure was exerted on the face of the membrane to fill the void left by the spout and provide a seal on the outside of the joint. Photo 82 shows a joint sealed using this procedure.

81. An inspection of the nonskid pattern remaining after 600 coverages revealed that sheet 1 had lost approximately 38 percent of its nonskid pattern and sheet 2 had lost approximately 27 percent (plate 19). On one of the 54-in.-wide runs of material on sheet 2, the nonskid compound had been removed completely by the test vehicle. On this run, the nonskid had not bonded to the surfacing properly during factory application. This lack of bond was probably due to contamination of the surface of the run of material prior to application of the nonskid or due to improper curing of the neoprene coating. The run of material was recoated with nonskid to determine if the nonskid would adhere to the surfacing well enough to withstand trafficking. The run was cleaned thoroughly with solvent, and then nonskid compound was applied to the run in a solid coating with long-handled paint rollers. A general view of the run of material after reapplication of nonskid is shown in photo 83.

82. The 3-ft-wide cover strip on the joint between the two sheets was in good condition (photo 84). Only minor repair had been required

at this joint and was limited to the repair of the Weatherban sealant along the edges of the cover strip. The repair was accomplished by removing the defective sealant, if needed, and applying new sealant to the affected area of the joint. This procedure, however, was required only in isolated areas of the joint.

83. The general conditions of sheets 1 and 2 after 800 coverages of the load wheel are shown in photos 85 and 86, respectively. No appreciable deterioration of the membrane surfacing or subgrade was evident at this coverage level. However, the percentage of nonskid compound remaining on the two membrane sheets had been reduced to 36 percent for sheet 1 and to 52 percent for sheet 2. The nonskid compound applied with paint rollers (as described in paragraph 81) to an area of sheet 2 was holding up well. Approximately 80 percent of the solid-coated nonskid compound remained after 200 coverages of the test wheel (photo 87).

84. Rainfall occurred on five days during the 200-coverage interval (plate 16) and totaled 2.93 in. However, there was no evidence of any infiltration of this rainfall through the surfacing to the subgrade.

85. A total of 69 percent of the nonskid compound had been worn off by the test wheel on sheet 1, and approximately 66 percent of the nonskid had been lost on sheet 2 after 1000 coverages. The general condition of sheets 1 and 2 after 1000 coverages is shown in photos 88 and 89, respectively.

86. An overall view of the test section taken following a heavy rain at 1200 coverages is shown in photo 90. As can be seen by the good drainage of the section, only slight rutting of the subgrade had occurred during trafficking, indicating that the membrane had retained its waterproof seal. (A total of 2.08 in. of rainfall had occurred since the 1000-coverage level.) The good condition of the subgrade was confirmed by cross sections taken at 1200 coverages that indicated only consolidation of the subgrade under the test wheel with no appreciable rutting (plate 20). CBR readings taken at this coverage level indicated a slight increase in soil strength in the area of the traffic lane (table 6).

87. An inspection of the nonskid pattern remaining after

1200 coverages revealed that only 27 and 30 percent of the nonskid remained on sheets 1 and 2, respectively. However, wear of the neoprene coating on the surface of the membrane was not as severe as that experienced for the first traffic test section. However, it was decided at this time to terminate trafficking of the section. It was evident from the data thus far collected that the nonskid coating would not withstand the wear produced by the test wheel for more than 700 to 800 coverages before the percentage of nonskid remaining would be below that required for safe operation of C-130 aircraft.

Membrane Evaluation

88. The following summary of test results indicates those requirements of the QMR pertaining to the performance and the physical and maintenance characteristics of membrane surfacing that were met by the XW18 membrane:

a. The membrane surfacing was capable of sustaining an initial operational requirement of 100 C-130 sorties (200 coverages of the test wheel) without failure. The subgrade failure and severe removal of neoprene from the surfacing experienced in traffic test section 1 were eliminated by new placement and testing procedures in traffic test section 2.

b. The membrane surfacing was readily repairable in the field, with all repairs necessitated by traffic wear of the surfacing accomplished expediently by use of the adhesive or joint sealant.

c. The membrane surfacing was designed so that individual damaged sections could be removed and replaced. During testing of traffic test section 1, a sheet of membrane was removed and replaced with a new sheet following repair of the subgrade (paragraphs 68-71).

d. The membrane surfacing was capable of withstanding wheel loads without destruction of waterproofing properties. Following replacement of the failed sheet in traffic test section 1, reinforcement of all field adhesive construction joints with a 3-ft-wide strip of membrane, and application of the 3M Weatherban sealant to the edges of the joints, the surfacing showed no evidence of appreciable water infiltration to the subgrade.

89. The following summary of test results indicates those requirements of the QMR pertaining to the performance and the physical and maintenance characteristics of membrane that were not met by the XW18 membrane:

a. The membrane surfacing did not possess a service life of not less than six months of 1200 C-130 sorties (2400 coverages). The performance of the neoprene coating on traffic test section 1 and of the 6-in.-wide factory joints on traffic test section 2 was considered inadequate.

b. The membrane surfacing did not possess a surface which provided a Runway Condition Reading of 13-25. Rapid deterioration of the nonskid pattern was experienced on both traffic test sections, and the percentage of nonskid retained was below the minimum required before 700 coverages had been applied (plate 21).

c. The surfacing was not designed so that maintenance performed would not exceed 150 man-hours per month. Although it is difficult to relate maintenance required on a small test section to that required on a full-scale assault runway, it can be assumed that the reapplication of nonskid compound to the entire runway would cause the maintenance required to exceed the maximum permissible amount. Assuming that a crew of seven men could recoat one sheet of surfacing with nonskid material in 1 hr, it would take approximately 500 man-hours for a 3500-ft runway to be recoated. This amount of effort would leave only 400 man-hours (of the maximum permissible of 900 man-hours for the six-month-long service life) for patching, replacing of damaged sections, and repairing anchors.

PART VI: CONCLUSIONS

90. Based on the results of this investigation, the following conclusions are believed warranted:

a. As determined in the laboratory tests, the average strengths of the redesigned XW18 membrane are approximately equal to or greater than those of the WX18 membrane.

b. The redesigned XW18 membrane exhibited less durability than the WX18 membrane when exposed to repetitive skids equal in magnitude to those produced by C-130 aircraft.

c. The nonskid compound as applied to the redesigned XW18 provided adequate coefficients of friction when wet or dry but showed inadequate resistance to abrasion during skid and traffic testing.

d. Placement tests showed that the redesigned XW18 membrane could be placed directly on graded subgrades with the accessories provided at a rate faster than the minimum required placement rate.

e. Traffic tests showed that the redesigned XW18 membrane did not possess the durability to withstand 1200 sorties (2400 coverages) of a C-130 aircraft, due to severe wear of the neoprene coating and excessive maintenance necessitated by joint peeling and nonskid wear.

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Table 1

Results of Laboratory Tests on Membrane

Type Membrane Specimen	Weight oz/yd^2	Breaking Strength lb		Percent Elongation at Break		Tear Strength lb		Thick-ness in.	Stiffness in.-lb		Low-Temperature Resistance (4 hr at -40 F)	High-Temperature Resistance (4 hr at 125 F)	Water Resistance	Flame Resistance			
														Time, sec*		Char Length, in.	
		Warp	Fill	Warp	Fill	Warp	Fill		Warp	Fill				Warp	Fill	Warp	Fill
WX18	64.8	641	560	15	19	207	175	0.067	2.06	1.54	Pass	Pass	No leakage	1.3	2.0	0.0	0.0
Redesigned XW18	73.9	636	546	15	20	197	163	0.074	1.72	1.62	↓	↓	↓	3.7	4.7	0.0	0.0
	80.0	664	525	15	17	191	168	0.080	2.03	1.54	↓	↓	↓	0.0	0.0	0.1	0.0
	74.9	746	690	19	21	240	230	0.069	2.03	1.96	↓	↓	↓	1.0	1.0	0.1	0.2
	70.9	616	524	16	17	201	176	0.070	2.16	1.51	↓	↓	↓	4.6	2.3	0.5	0.3
	70.4	709	623	17	19	196	161	0.078	2.73	2.01	↓	↓	↓	0.0	1.8	0.0	0.0
	71.4	716	606	19	21	202	178	0.074	1.98	1.71	↓	↓	↓	1.4	0.6	0.1	0.1
	75.2	649	550	17	19	190	165	0.075	2.07	1.70	↓	↓	↓	0.0	0.0	0.1	0.1
	74.2	654	572	16	18	203	180	0.074	2.04	1.89	↓	↓	↓	3.1	2.0	0.3	0.1
	76.1	625	541	16	17	205	176	0.075	2.00	1.91	↓	↓	↓	0.5	0.5	0.0	0.0

Type Membrane Specimen	JP-4 Fuel Resistance				Ball Bursting Strength lb	Fabricated Joint Tests						Nonskid Tests			
	Breaking Strength lb		Percent Elongation at Break			Breaking Strength** lb	Peel Strength lb	Water Resistance		JP-4 Fuel Resistance		Cold Fold	Hot Fold	Thick-ness in.	Weight oz/yd^2
								Breaking Strength** lb	Peel Strength lb	Breaking Strength** lb	Peel Strength lb				
	Warp	Fill	Warp	Fill											
WX18	364	331	6	9	2152	--	--	--	--	--	--	--	--	--	--
Redesigned XW18	692	620	21	27	1821	683	12.0	670	12.0	706	13.0	No cracking or flaking	No cracking or flaking	0.035	1.8
	700	605	18	23	1768	852	11.0	787	10.7	825	11.0	↓	↓	0.037	1.7
	740	648	18	21	2021	904	11.0	867	10.1	875	12.1	↓	↓	0.027	1.2
	682	536	18	19	1910	714	10.5	710	10.4	722	10.1	↓	↓	0.028	1.3
	717	664	20	23	1818	798	11.7	770	11.5	805	11.0	↓	↓	0.032	1.7
	725	691	19	22	1990	802	12.0	782	12.1	810	12.0	↓	↓	0.030	1.5
	693	555	15	20	1815	803	12.3	762	11.8	800	9.9	↓	↓	0.029	1.4
	671	543	18	21	2000	825	10.2	805	10.4	814	10.[illegible]	↓	↓	0.025	1.2
	659	582	19	23	1925	784	12.7	775	11.7	792	12.9	↓	↓	0.026	1.3

* Time was considered as the amount of time that the membrane burned after the flame was taken away.
** The material joined failed, not the joint.

Table 2

Summary of CBR, Density, and Water Content Determinations for Skid Tests

	Before Skids						After Skids					
XW18 Section No.	Distance Right of Base Line, ft	Station	Distance from Surface, in.	Water Content % Dry Weight	Dry Density pcf	CBR	Distance Right of Base Line, ft	Station	Distance from Surface, in.	Water Content % Dry Weight	Dry Density pcf	CBR
1	28	0+30	0	26.5	94.0	10	28	0+15	0	26.3	93.2	14
			6	28.2	92.1	7			6	26.6	92.4	11
			12	26.1	94.6	9			12	29.6	88.5	7
			18	26.5	94.4	9			18	26.5	92.7	9
			Avg	26.8	93.8	9			Avg	27.3	91.7	10
	40	0+15	0	26.3	94.3	9	40	0+30	0	25.0	95.0	12
			6	28.1	93.2	8			6	24.9	94.2	11
			12	28.3	91.7	7			12	27.6	91.5	9
			18	25.7	96.1	10			18	26.6	94.9	9
			Avg	27.1	93.8	9			Avg	26.0	93.9	10
2	28	0+30	0	26.0	95.1	9	28	0+10	0	25.6	95.6	13
			6	26.5	93.5	8			6	27.4	92.3	11
			12	29.6	88.5	7			12	26.2	94.0	11
			18	26.5	92.7	9			18	25.2	95.9	13
			Avg	27.2	92.5	8			Avg	26.1	94.5	12
	40	0+15	0	27.4	93.2	8	40	0+20	0	26.7	93.0	10
			6	27.3	92.9	10			6	27.6	92.6	10
			12	27.6	91.5	9			12	26.6	93.9	10
			18	26.6	94.9	9			18	27.0	93.5	12
			Avg	27.2	93.1	9			Avg	27.0	93.3	11
3	20	0+15	0	25.6	94.3	10	25	0+18	0	26.3	92.8	9
			6	26.4	93.8	9			6	25.5	93.6	11
			12	26.2	93.7	11			12	25.5	94.4	9
			18	26.9	93.3	10			18	25.8	94.3	9
			Avg	26.3	93.8	10			Avg	25.8	93.8	10
	44	0+25	0	26.7	93.1	8	42	0+18	0	26.1	93.3	10
			6	26.2	93.2	8			6	25.8	93.8	12
			12	27.9	91.3	8			12	26.5	93.4	10
			18	26.4	93.2	10			18	24.3	93.8	12
			Avg	25.8	92.7	9			Avg	25.7	93.6	11

Table 3

Summary of Data Obtained on Wet and Dry Nonskid-Coated Surfacing During Evaluation of Skid Resistance

XW18 Test Section No.	Skid No.	Condition of Surfacing	Drag Force, lb: Static A	Drag Force, lb: Dynamic B	Coefficient of Friction: Static C (A/30,000 lb)	Coefficient of Friction: Dynamic D (B/30,000 lb)	Rated Braking Condition* [(C + D)/2]	Percent of Compound Removed from Surfacing
1	1	Dry	23,000	18,000	0.77	0.60	0.69	98
	2	Dry	23,700	18,000	0.79	0.60	0.70	95
	3	Dry	21,200	17,800	0.71	0.59	0.65	99
	4	Dry	21,600	18,500	0.72	0.62	0.67	96
		Avg	22,375	18,075	0.75	0.60	0.68	97
	1	Wet	16,100	13,000	0.54	0.44	0.49	81
	2	Wet	15,000	12,000	0.50	0.40	0.45	86
	3	Wet	14,200	10,200	0.47	0.34	0.41	29
	4	Wet	12,700	10,500	0.42	0.35	0.39	40
		Avg	14,500	11,425	0.48	0.38	0.44	59
2	1	Dry	25,000	18,000	0.83	0.60	0.72	68
	2	Dry	30,000	17,500	1.00	0.58	0.79	25
	3	Dry	24,300	17,000	0.81	0.57	0.69	17
	4	Dry	25,400	18,500	0.85	0.62	0.74	32
		Avg	26,175	17,750	0.87	0.59	0.74	36
	1	Wet	20,000	13,000	0.67	0.44	0.51	26
	2	Wet	15,600	14,300	0.52	0.48	0.50	25
	3	Wet	15,900	14,000	0.53	0.47	0.50	33
	4	Wet	16,400	12,400	0.55	0.41	0.48	8
		Avg	16,975	13,425	0.57	0.45	0.50	23
3	1	Dry	23,300	19,300	0.78	0.64	0.71	95
	2	Dry	25,600	18,200	0.85	0.61	0.72	97
	3	Dry	23,600	19,000	0.79	0.63	0.71	98
	4	Dry	23,800	19,200	0.79	0.64	0.72	96
		Avg	24,075	18,925	0.80	0.63	0.72	97
	1	Wet	15,300	10,500	0.51	0.35	0.43	72
	2	Wet	19,000	14,000	0.63	0.47	0.55	57
	3	Wet	14,600	12,000	0.49	0.40	0.45	57
	4	Wet	20,800	12,100	0.69	0.40	0.55	42
		Avg	17,425	12,150	0.58	0.41	0.50	57

* The rated braking condition is determined by averaging the static and dynamic coefficients of friction and is used because of the antiskid device employed on all C-130 aircraft to prevent locking of the brakes.

Table 4

Summary of Static and Dynamic Drag Forces and Coefficients of Friction,
Comparison of Performance of XW18 and WX18 Membranes

Type Membrane	Run No.	No. of Skid	Drag Force 10^3 lb Static	Drag Force 10^3 lb Dynamic	Coefficient of Friction Static	Coefficient of Friction Dynamic	Length of Skid ft
WX18	1	1	22.5	20.0	0.69	0.61	15
		2	25.7	19.0	0.78	0.58	
		3	24.8	18.5	0.76	0.56	
		4	22.1	18.0	0.67	0.55	
		5	22.6	17.5	0.69	0.53	
		6	23.7	17.0	0.72	0.52	
		7	22.4	16.8	0.68	0.51	
		8	23.2	17.0	0.71	0.52	
		9	24.2	17.0	0.74	0.52	
		10	24.4	17.5	0.75	0.53	
		11	25.9	17.5	0.79	0.53	
		12	26.4	18.2	0.81	0.56	
		13	26.4	17.8	0.81	0.54	
		14	25.8	18.5	0.79	0.56	
		15	26.8*	--	0.82	--	0
		Avg	24.5	17.9	0.75	0.54	
	2	1	22.7	20.0	0.69	0.61	15
		2	26.7	18.8	0.82	0.57	
		3	24.3	18.5	0.74	0.56	
		4	24.2	18.0	0.74	0.55	
		5	23.0	16.8	0.70	0.51	
		6	23.4	17.5	0.71	0.53	
		7	24.8	16.8	0.78	0.51	
		8	25.2	16.8	0.77	0.51	
		9	25.4	16.2	0.78	0.50	
		10	26.3	17.5	0.80	0.53	
		11	25.2	16.8	0.77	0.51	
		12	25.3	17.5	0.77	0.53	
		13	24.0	17.2	0.73	0.53	
		14	23.2	17.5	0.71	0.53	
		15	23.2	18.5	0.71	0.56	
		16	22.8	18.8	0.70	0.57	
		17	30.1	18.0	0.92	0.55	
		18	28.2*	--	0.86	--	0
		Avg	24.9	17.7	0.76	0.54	
XW18 (Section 1)	1	1	24.3	15.5	0.74	0.47	15
		2	22.4	17.4	0.68	0.53	
		3	25.6	18.0	0.78	0.55	
		4	23.4	18.9	0.71	0.58	
		5	27.2	19.7	0.83	0.60	
		6	34.0	20.0	1.04	0.61	
		7	36.7	20.0	1.12	0.61	
		8	31.3	19.7	0.96	0.60	
		9	27.5	20.0	0.84	0.61	
		10	36.6*	--	1.12	--	2
		Avg	28.9	18.8	0.88	0.57	
	2	1	25.7	19.0	0.78	0.58	15
		2	27.1	19.0	0.83	0.58	15
		3	33.0	18.5	1.01	0.56	15
		4	30.0*	--	0.92	--	2
		Avg	29.0	18.8	0.89	0.57	

(Continued)

* Membrane failed.

Table 4 (Concluded)

Type Membrane	Run No.	No. of Skid	Drag Force 10^3 lb Static	Drag Force 10^3 lb Dynamic	Coefficient of Friction Static	Coefficient of Friction Dynamic	Length of Skid ft
XW18 (Section 1)	3	1	21.6	18.5	0.72	0.62	15
		2	25.0	19.8	0.76	0.60	15
		3	27.2	19.7	0.83	0.60	15
		4	26.8	19.0	0.82	0.58	15
		5	40.5*	--	1.24	--	2
		Avg	28.2	19.3	0.87	0.60	
XW18 (Section 2)	1	1	22.3	19.4	0.68	0.59	15
		2	24.2	19.0	0.74	0.58	↓
		3	27.5	19.7	0.84	0.60	↓
		4	24.7	20.5	0.75	0.63	↓
		5	27.6	21.3	0.84	0.65	↓
		6	33.8	21.7	1.03	0.66	↓
		7	33.0	21.5	1.00	0.66	↓
		8	38.6*	--	1.18	--	2
		Avg	29.0	20.4	0.88	0.62	
	2	1	27.0	20.5	0.82	0.63	15
		2	27.5	19.8	0.84	0.60	15
		3	31.6*	--	0.96	--	0
		Avg	28.7	20.2	0.87	0.62	
	3	1	20.0	13.0	0.67	0.44	15
		2	28.5	18.7	0.87	0.57	↓
		3	29.8	19.8	0.91	0.60	↓
		4	31.5	19.5	0.96	0.60	↓
		5	28.8	19.5	0.88	0.60	↓
		6	32.6*	--	0.99	--	0
		Avg	28.5	18.1	0.88	0.56	
XW18 (Section 3)	1	1	23.7	18.0	0.72	0.55	15
		2	26.2	18.7	0.80	0.57	↓
		3	29.0	20.0	0.89	0.61	↓
		4	31.6	20.4	0.96	0.62	↓
		5	26.0	20.0	0.79	0.61	↓
		6	33.4	19.7	1.02	0.60	↓
		7	33.3*	--	1.02	--	3
		Avg	29.0	19.5	0.89	0.59	
	2	1	28.5	19.0	0.87	0.58	15
		2	27.8	19.5	0.85	0.60	↓
		3	32.7	22.2	1.00	0.68	↓
		4	33.4	20.5	1.02	0.63	↓
		5	36.2	21.5	1.11	0.66	↓
		6	31.9	22.5	0.97	0.69	↓
		7	29.0	22.0	0.89	0.67	↓
		8	34.5	22.5	1.05	0.69	↓
		9	33.4	22.3	1.02	0.68	↓
		10	33.4*	--	1.02	--	6
		Avg	32.1	21.3	0.98	0.65	

* Membrane failed.

Table 5

Summary of CBR, Density, and Water Content Determinations

Redesigned XW18 Traffic Section 1

Station	Distance Relative to ℄	Depth in.	Water Content %	Dry Density pcf	CBR
		Before Traffic			
0+00	10 ft west	Surface	17.2	97.3	18
		6	16.5	92.0	10
		12	17.1	96.1	17
		18	18.3	93.7	9
		24	18.8	100.2	12
		30	17.3	97.2	14
		Avg	17.5	96.1	13.3
0+50	10 ft east	Surface	17.8	100.7	13
		6	17.5	96.7	13
		12	18.3	99.0	16
		18	17.7	99.9	18
		24	17.3	98.7	17
		30	17.6	99.1	18
		Avg	17.7	99.0	15.8
1+00	10 ft west	Surface	17.9	100.3	12
		6	17.9	94.8	8
		12	17.9	96.3	12
		18	17.6	95.7	9
		24	17.3	97.2	14
		30	17.5	99.7	12
		Avg	17.7	97.3	11.2
		538 Coverages			
0+75	15 ft west	Surface	14.9	97.4	31
		6	17.1	94.8	12
		12	17.9	100.1	15
		18	18.5	97.8	12
		24	17.4	99.0	11
		30	21.4	99.3	7
		Avg	17.9	98.1	14.7
0+75	6 ft east	Surface	18.5	107.7	6
		6	17.6	108.0	7
		12	19.0	106.9	6
		18	19.4	103.4	17
		24	18.4	102.8	16
		30	21.5	98.2	15
		Avg	19.1	104.5	11.2
1+07	4 ft west	Surface	21.2	103.5	4
		6	17.9	107.1	9
		12	18.2	103.8	23
		18	16.5	104.1	13
		24	18.6	106.3	20
		30	21.1	98.3	12
		Avg	18.9	103.9	13.5
1+07	4 ft east	Surface	19.8	106.6	7
		6	18.0	106.8	14
		12	18.1	105.5	8
		18	19.3	103.8	10
		24	18.6	104.3	14
		30	21.2	102.2	13
		Avg	19.2	104.9	11.0
		538 Coverages (Cont'd)			
1+30	4 ft east	Surface	16.2	102.6	33
		6	17.7	102.8	28
		12	18.3	99.7	21
		18	16.6	100.0	19
		24	17.2	98.1	18
		30	18.3	104.1	17
		Avg	17.4	101.2	22.7
		1200 Coverages			
0+25	3 ft east	Surface	16.9	106.2	32
		6	17.2	105.4	29
		12	18.1	104.3	25
		18	17.8	103.0	20
		24	19.3	102.0	14
		30	18.9	105.5	22
		Avg	18.0	104.4	23.7
0+40	24 ft west	Surface	17.2	99.3	18
		6	18.3	97.2	14
		12	21.7	98.6	14
		18	23.7	90.4	8
		24	23.1	87.0	7
		30	22.4	86.6	6
		Avg	21.1	93.2	11.2
0+75	4 ft west	Surface	16.3	105.2	33
		6	17.2	104.0	31
		12	17.3	101.8	30
		18	18.9	98.3	18
		24	17.2	100.6	19
		30	18.7	94.3	12
		Avg	17.6	100.7	23.8
0+90	23 ft east	Surface	15.6	99.3	24
		6	19.0	98.7	14
		12	22.7	93.4	10
		18	22.4	89.9	9
		24	20.9	88.8	8
		30	18.2	88.8	8
		Avg	19.8	93.2	12.2
1+25	4 ft west	Surface	14.8	106.0	34
		6	16.6	101.4	24
		12	16.8	96.6	22
		18	15.8	94.2	17
		24	16.2	93.9	13
		30	18.7	102.8	23
		Avg	16.5	99.2	22.2
1+35	24 ft east	Surface	15.4	99.9	20
		6	17.6	97.6	16
		12	23.0	95.3	12
		18	23.3	94.9	9
		24	22.8	89.4	7
		30	21.9	88.4	5
		Avg	20.7	94.3	11.5

Table 6

Summary of CBR, Density, and Water Content Determinations

Redesigned XW18 Traffic Section 2

Station	Distance Relative to ℄	Depth in.	Water Content %	Dry Density pcf	CBR
		Before Traffic			
0+00	4 ft west	Surface	14.8	106.0	34
		6	16.6	101.4	24
		12	16.8	96.6	22
		18	15.8	94.2	17
		24	16.2	93.9	13
		30	18.7	102.8	23
		Avg	16.5	99.2	22.2
0+35	23 ft east	Surface	15.6	99.3	24
		6	19.0	98.7	14
		12	22.7	93.4	10
		18	22.4	89.9	9
		24	20.9	88.8	8
		30	18.2	88.8	8
		Avg	19.8	93.2	12.2
0+50	4 ft west	Surface	16.3	105.2	33
		6	17.2	104.0	31
		12	17.3	101.8	30
		18	18.9	98.3	18
		24	17.2	100.6	19
		30	18.7	94.3	12
		Avg	17.6	100.7	23.8
0+85	24 ft west	Surface	17.2	99.3	18
		6	18.3	97.2	14
		12	21.7	98.6	14
		18	23.7	90.4	8
		24	23.1	87.0	7
		30	22.4	86.6	6
		Avg	21.1	93.2	11.2

(Continued)

Table 6 (Concluded)

Station	Distance Relative to ℄	Depth in.	Water Content %	Dry Density pcf	CBR
		Before Traffic (Continued)			
1+00	3 ft east	Surface	16.9	106.2	32
		6	17.2	105.4	29
		12	18.1	104.3	25
		18	17.8	103.0	20
		24	19.3	102.0	14
		30	18.9	105.5	22
		Avg	18.0	104.4	23.7
		1200 Coverages			
0+06	℄	Surface	16.1	103.8	34
		6	18.0	103.9	34
		12	18.0	102.3	41
		18	18.8	99.9	20
		24	18.3	101.8	19
		30	20.4	100.4	18
		Avg	18.3	102.0	27.7
0+21	15 ft west	Surface	17.1	98.1	12
		6	17.2	98.0	11
		12	22.5	100.6	7
		18	19.1	101.0	16
		24	19.9	99.3	12
		30	18.0	97.1	18
		Avg	19.0	99.0	12.7
0+65	2 ft east	Surface	16.3	102.3	28
		6	17.8	105.0	29
		12	18.1	104.8	35
		18	18.2	101.3	21
		24	17.1	97.7	19
		30	20.4	102.0	13
		Avg	18.0	102.2	24.2
0+65	14 ft west	Surface	17.8	101.8	29
		6	18.9	98.9	19
		12	21.0	97.2	13
		18	20.5	96.3	11
		24	21.7	91.8	8
		30	21.9	94.7	9
		Avg	20.3	96.8	14.8

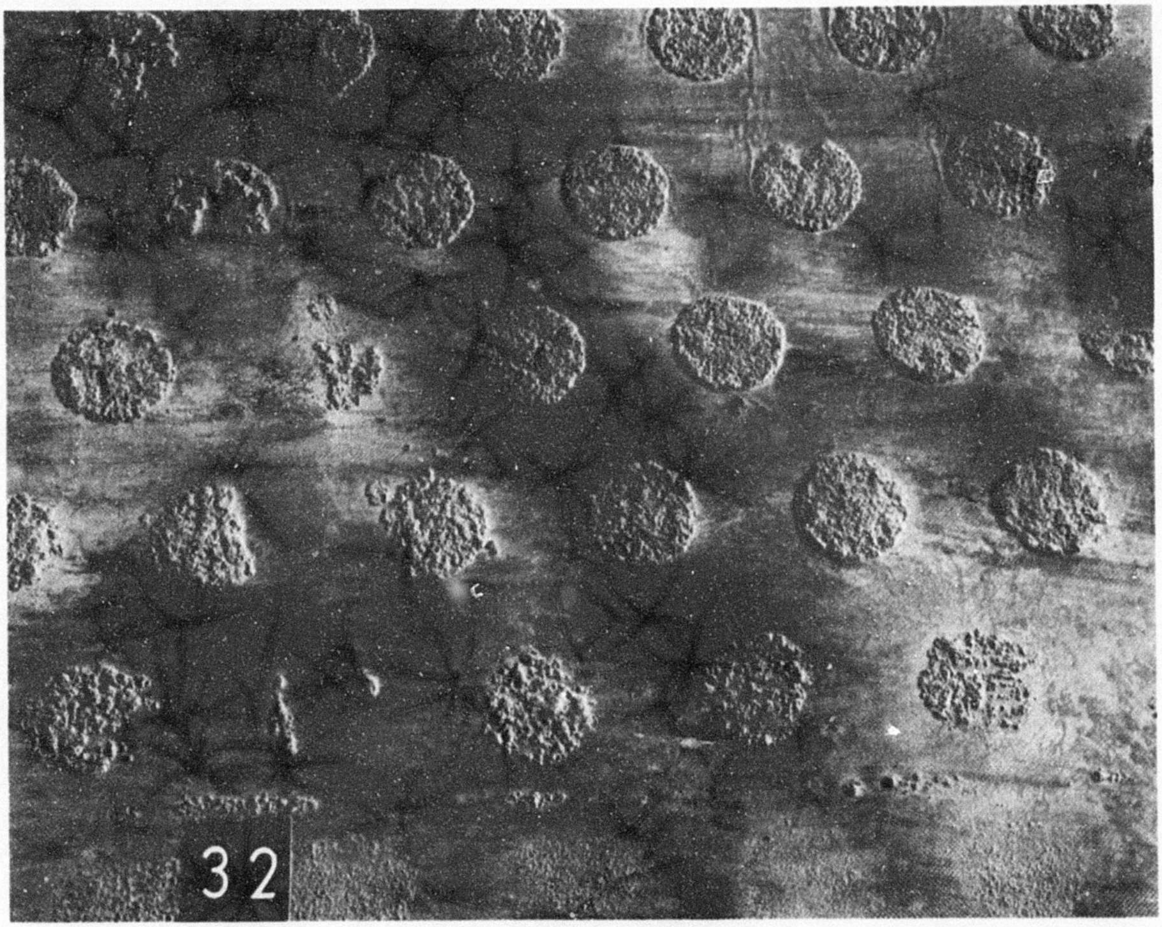


Photo 13. Nonskid removed after wet skid on XW18 membrane section 2

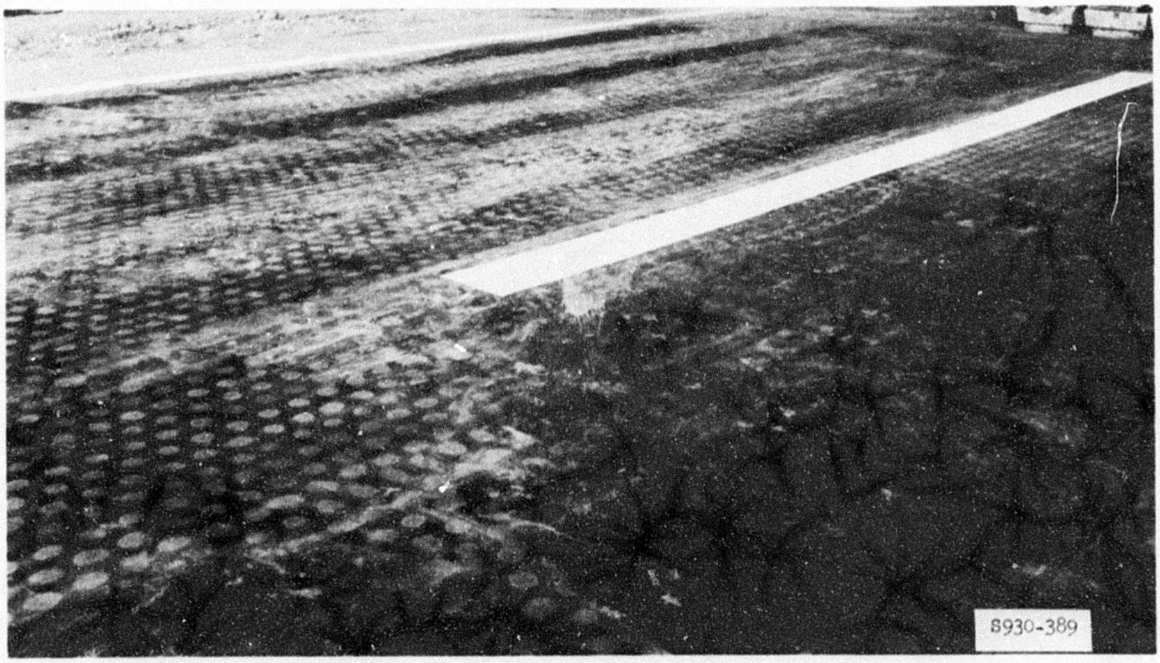


Photo 14. Condition of XW18 membrane section 3 after four wet and four dry skids

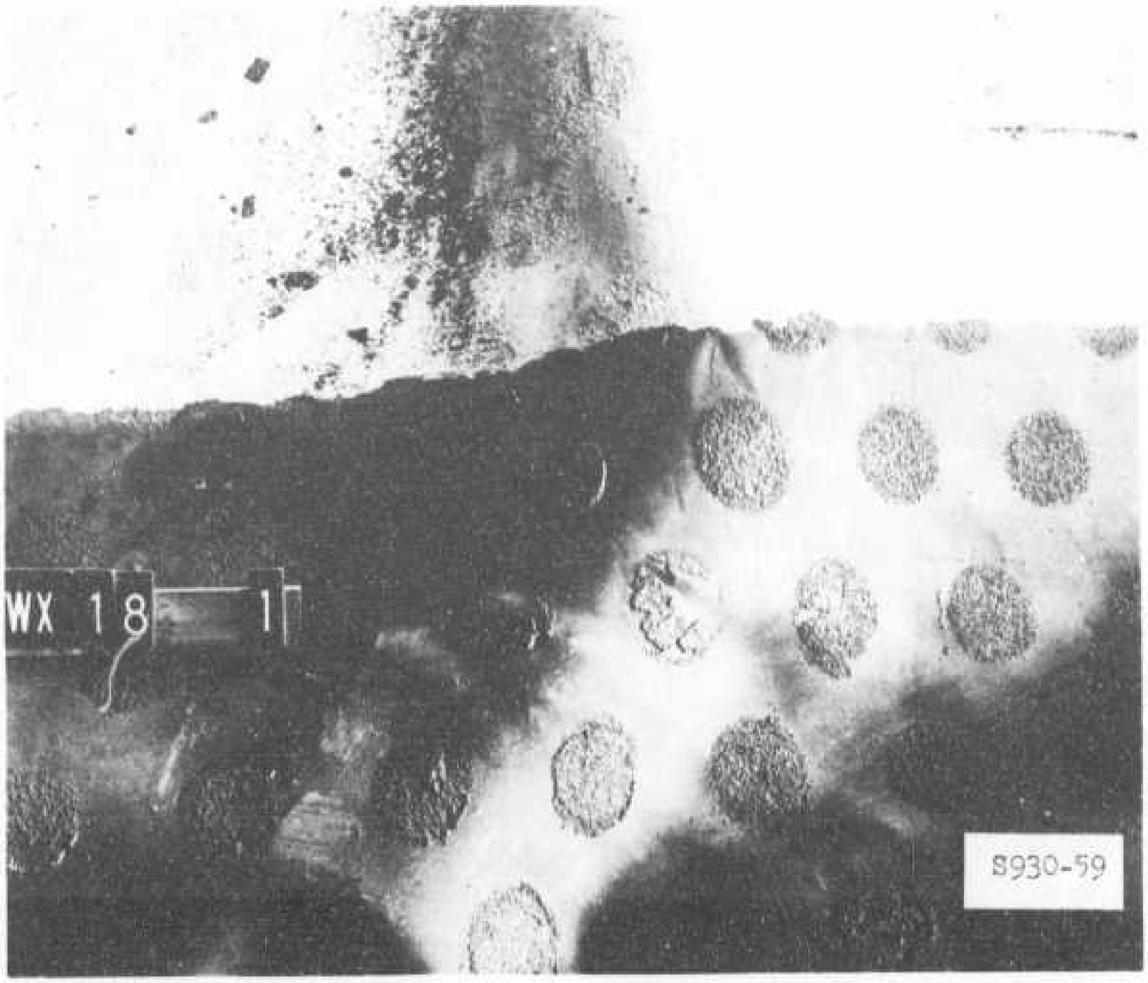


Photo 3. Small percentage of nonskid removed near center of XW18 membrane section 1 prior to C-130 skid tests

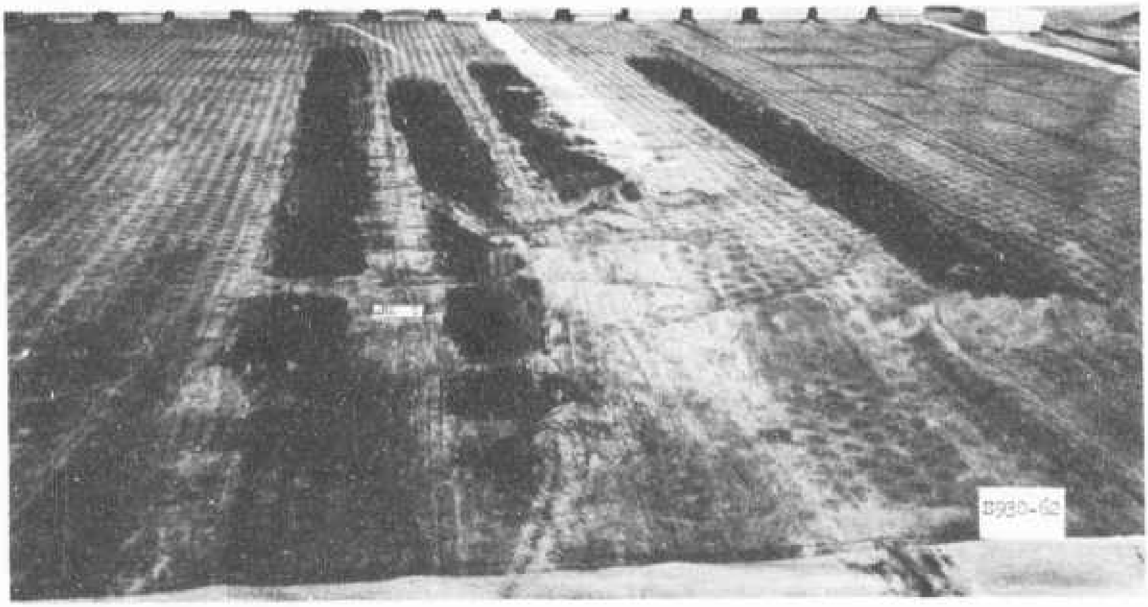


Photo 4. XW18 membrane section 1 after four dry skids

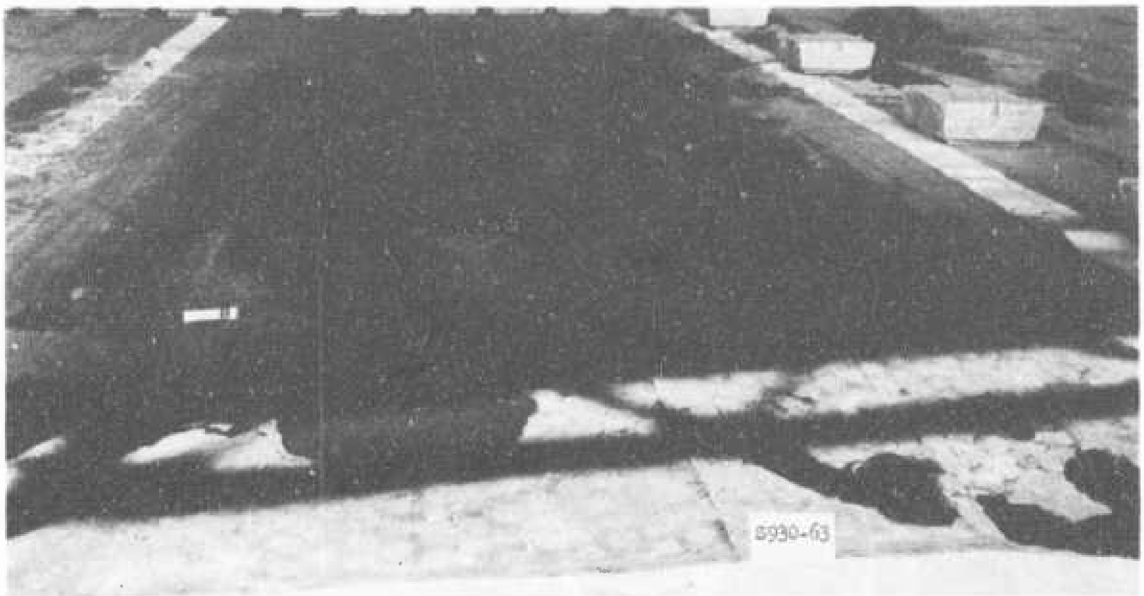


Photo 5. XW18 membrane section 1 after four wet skids

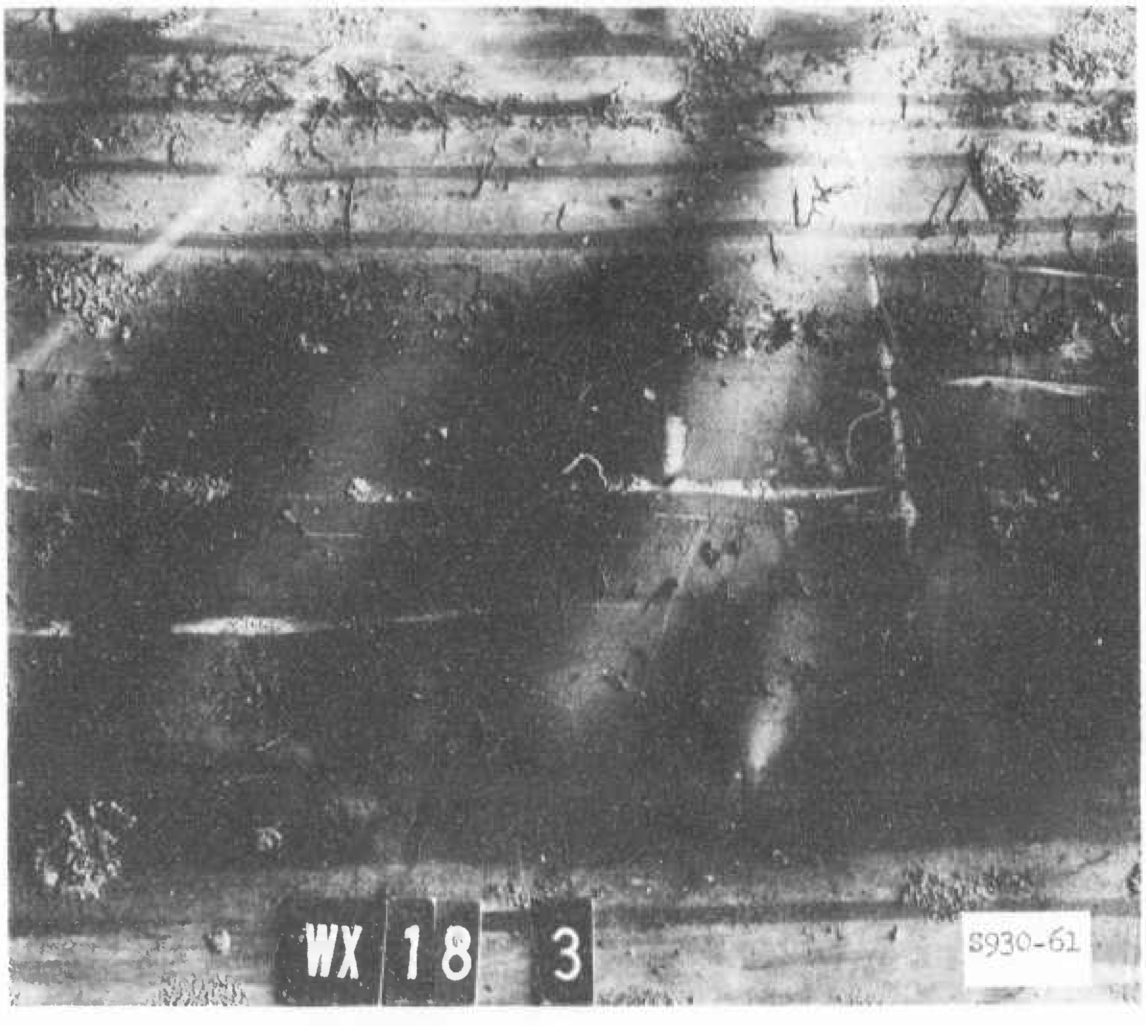


Photo 6. Removal of nonskid on XW18 membrane section 1 after one dry skid

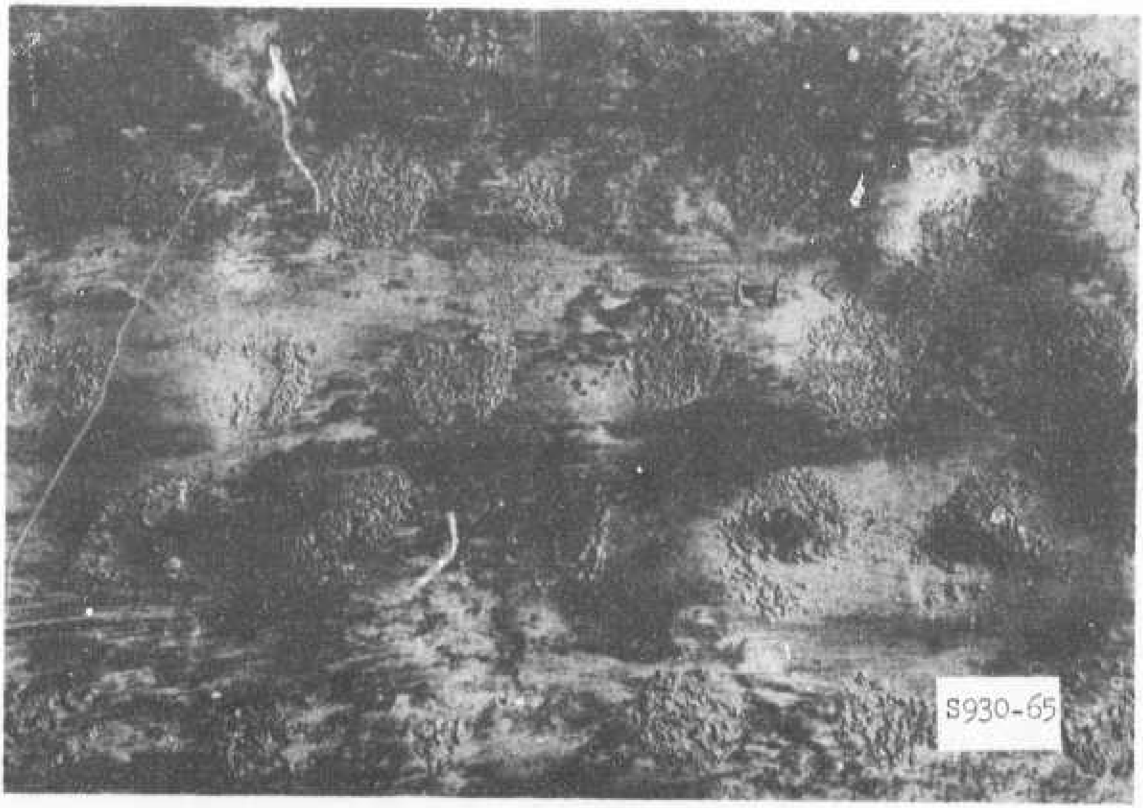


Photo 7. Removal of nonskid on XW18 membrane section 1 after one wet skid

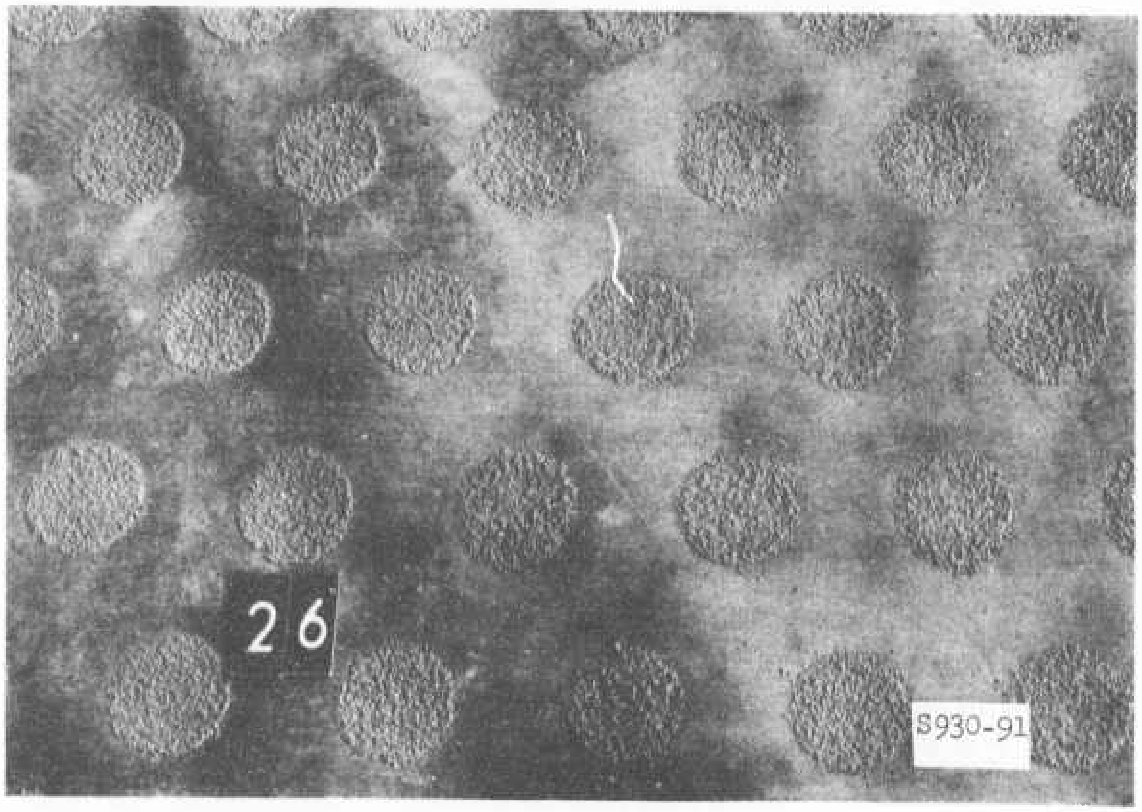


Photo 8. Condition of nonskid coating on XW18 membrane section 2 prior to skid tests

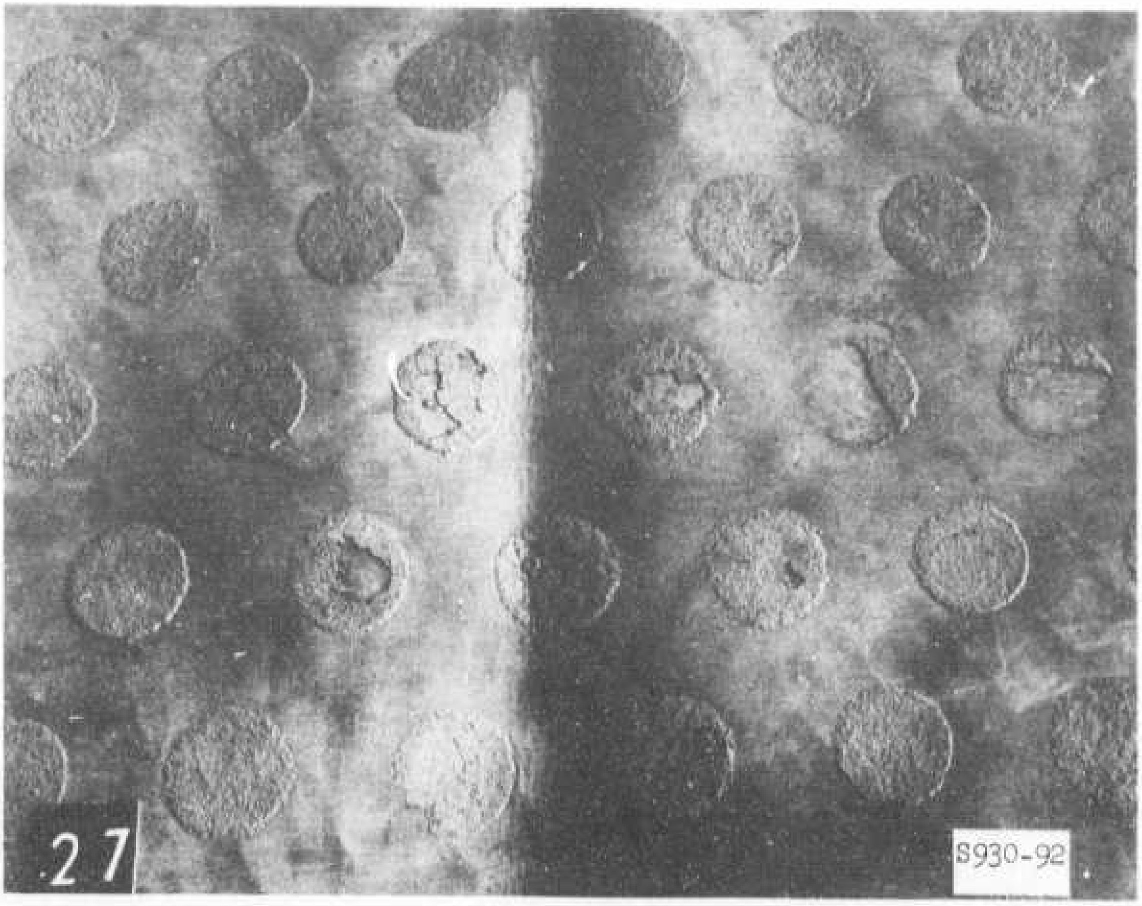


Photo 9. Cracking and flaking of nonskid coating on XW18 membrane section 2 due to effects of accordion folding

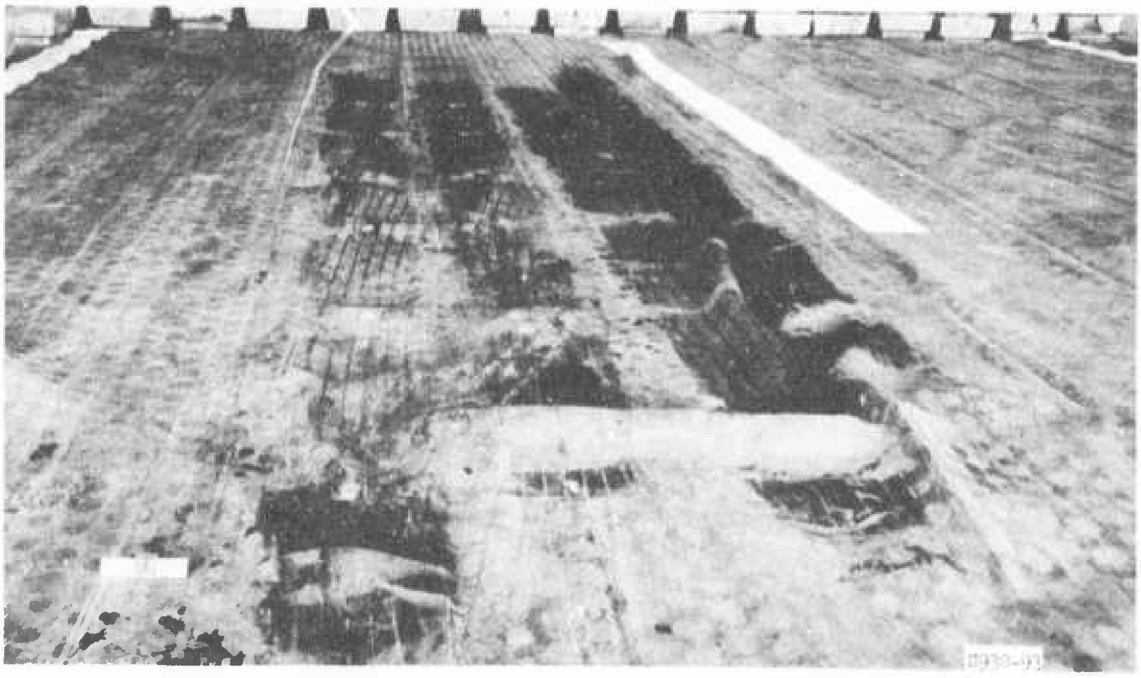


Photo 10. Condition of XW18 membrane section 2 after four dry skids

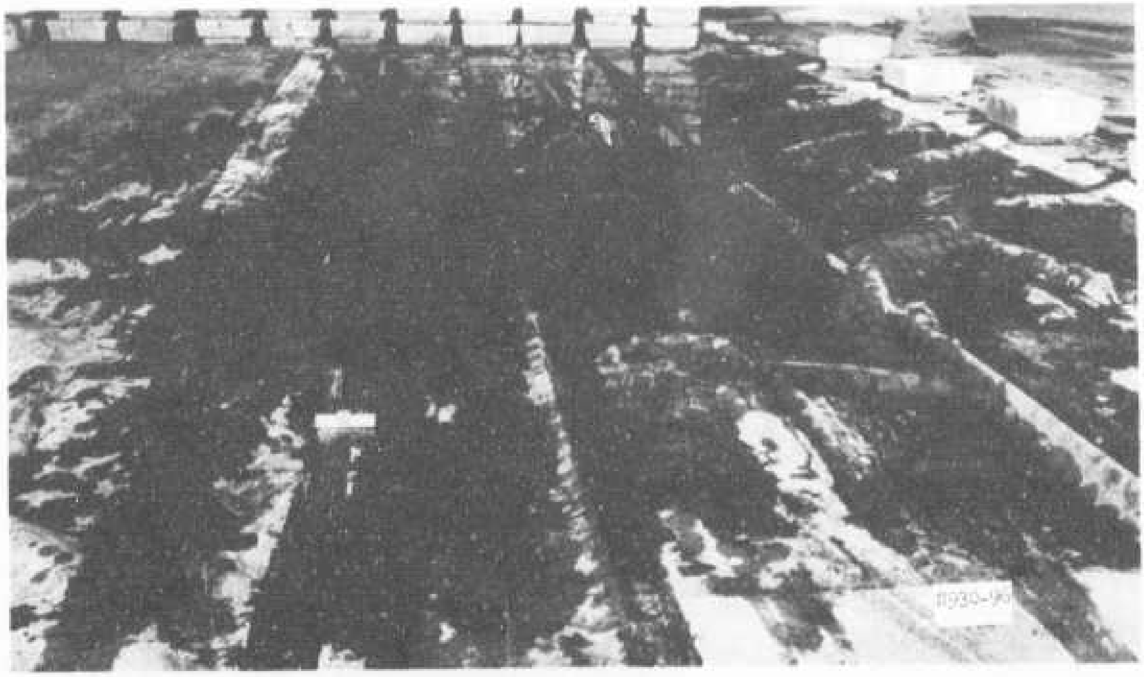


Photo 11. Condition of XW18 membrane section 2 after four wet skids

Photo 12. Nonskid removed after dry skid on XW18 membrane section 2

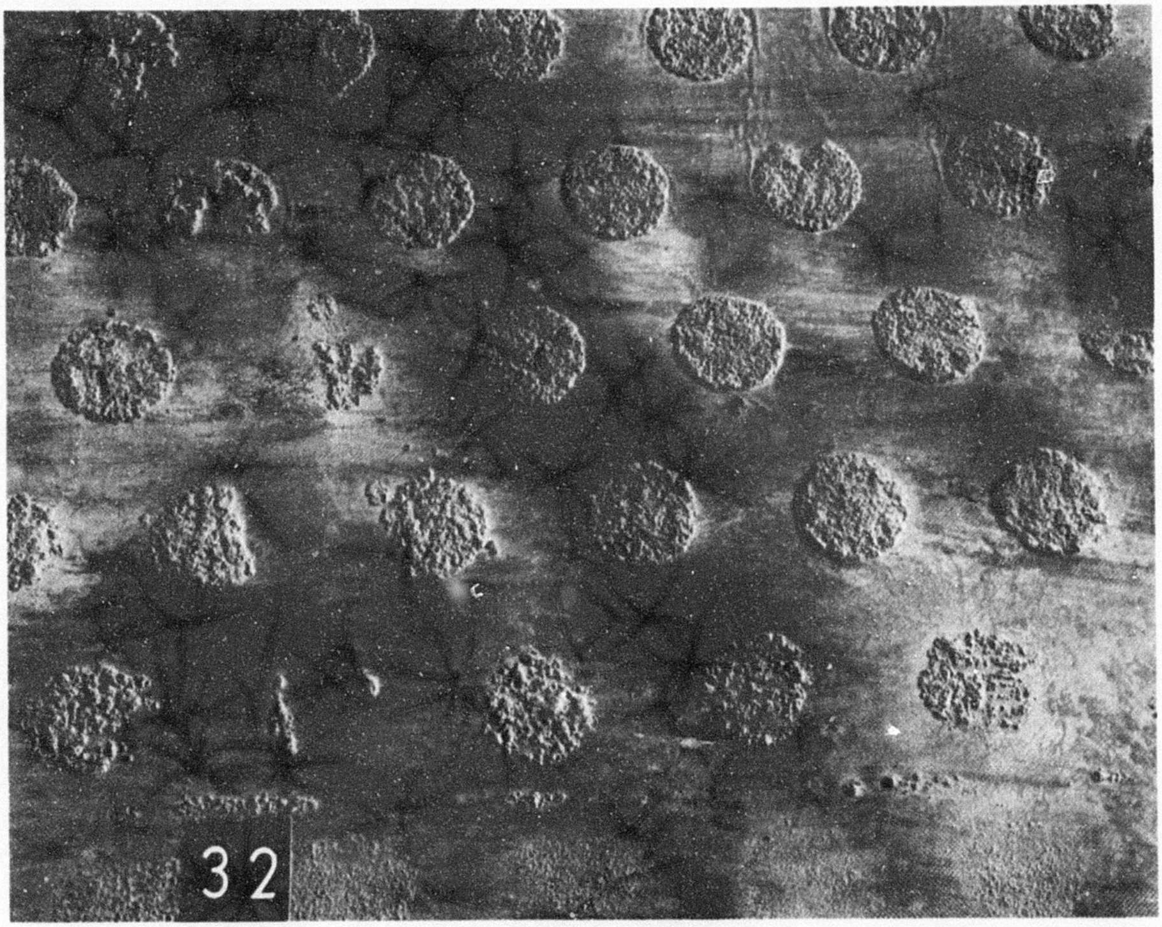


Photo 13. Nonskid removed after wet skid on XW18 membrane section 2

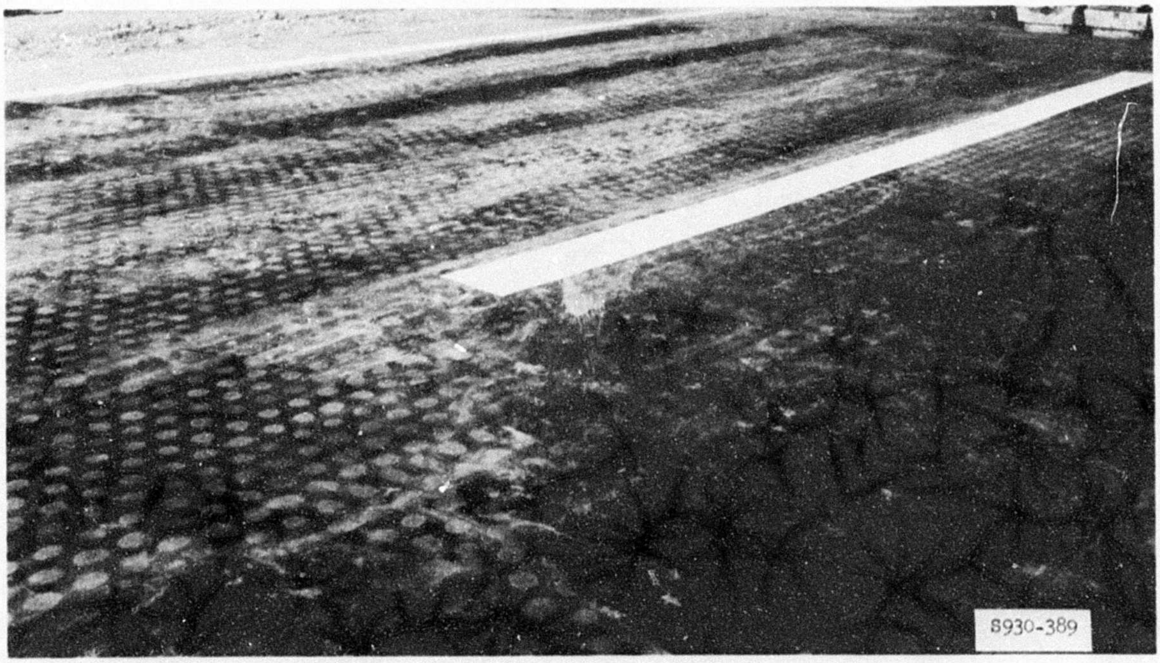


Photo 14. Condition of XW18 membrane section 3 after four wet and four dry skids

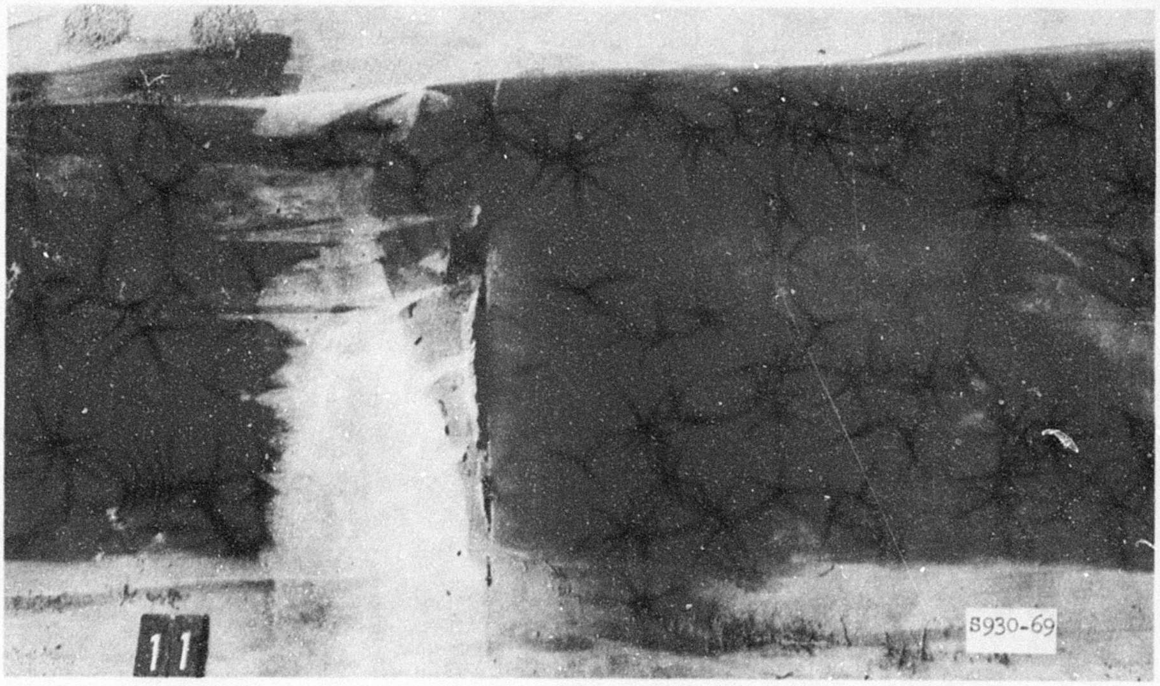


Photo 15. Failure of top ply of nylon fabric of run 1 of XW18 membrane section 1 after second repetitive skid

Photo 16. Extensive top-ply failures after sixth repetitive skid on run 1 of XW18 membrane section 1

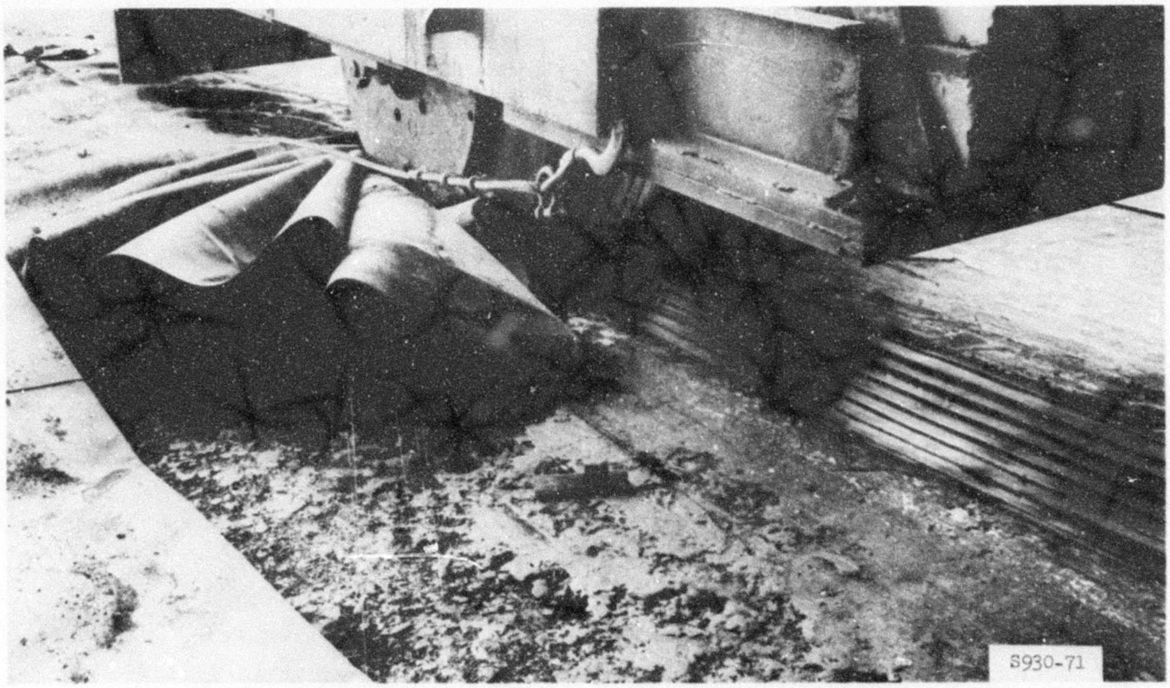


Photo 17. Failure of run 1 of XW18 membrane section 1 after ten repetitive skids

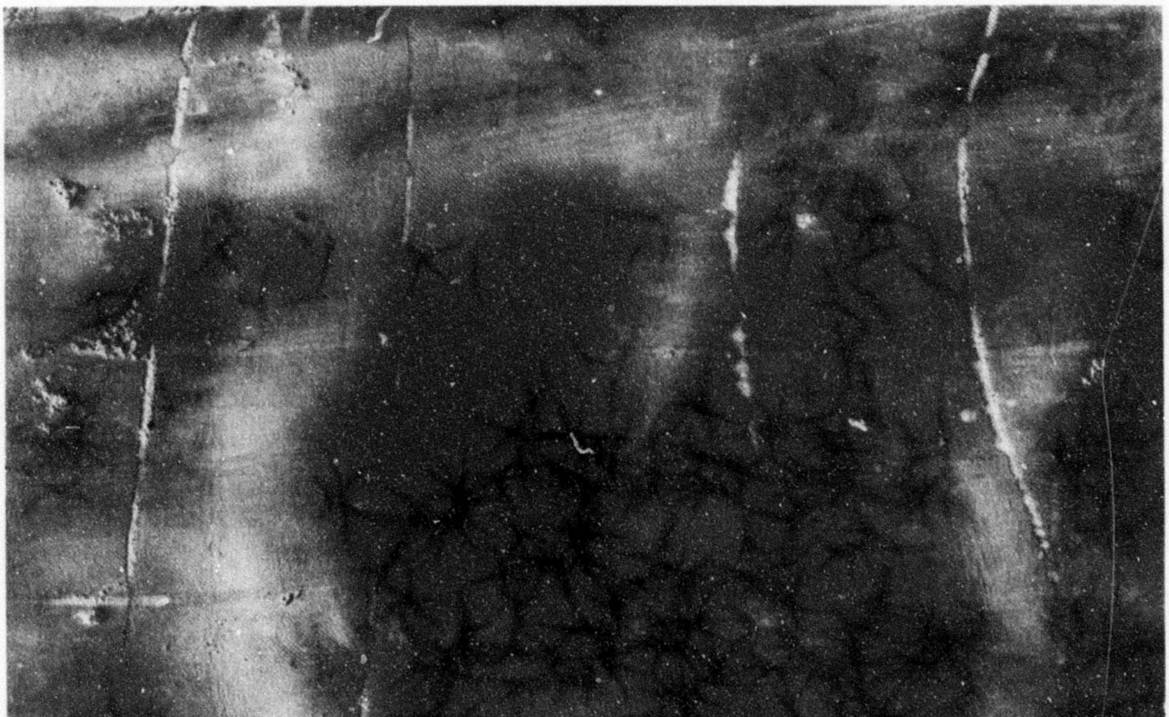


Photo 18. Condition of surfacing after second repetitive skid on run 2 of XW18 membrane section 1

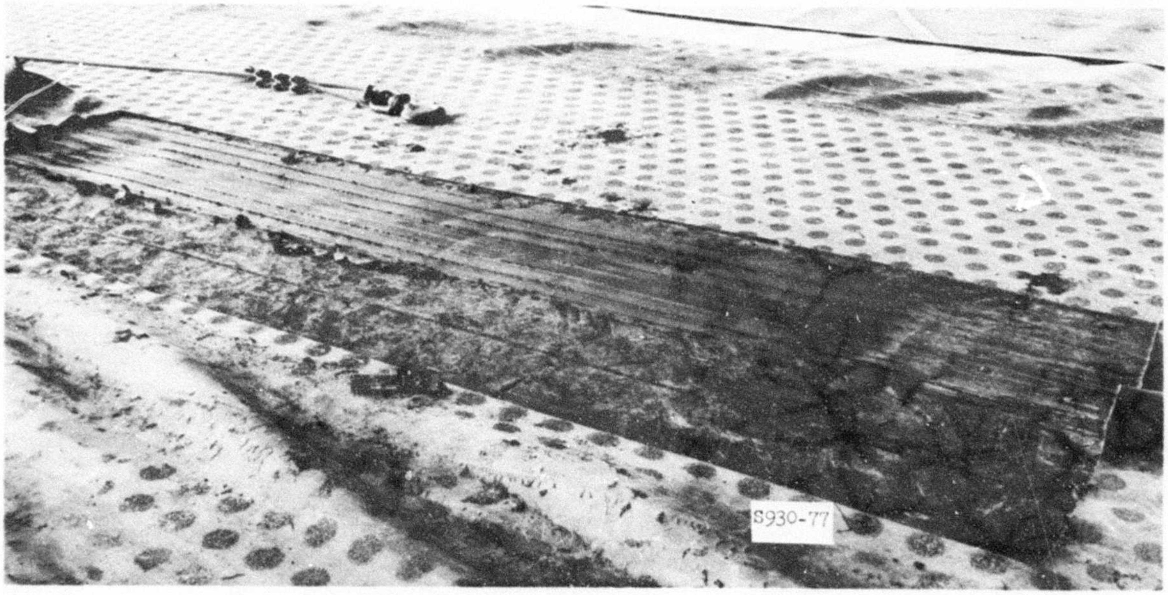


Photo 19. Failure of run 2 of XW18 membrane section 1

Photo 20. Failure of run 3 of XW18 membrane section 1

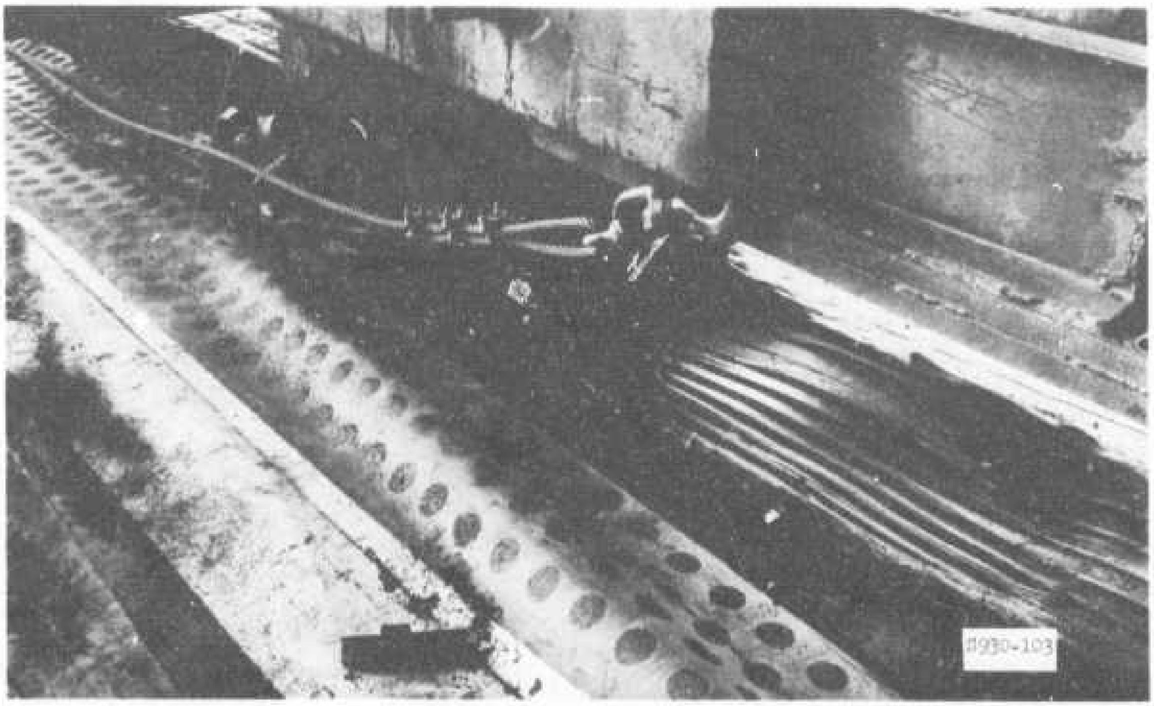


Photo 21. Failure of run 1 of XW18 membrane section 2 after eight repetitive skids

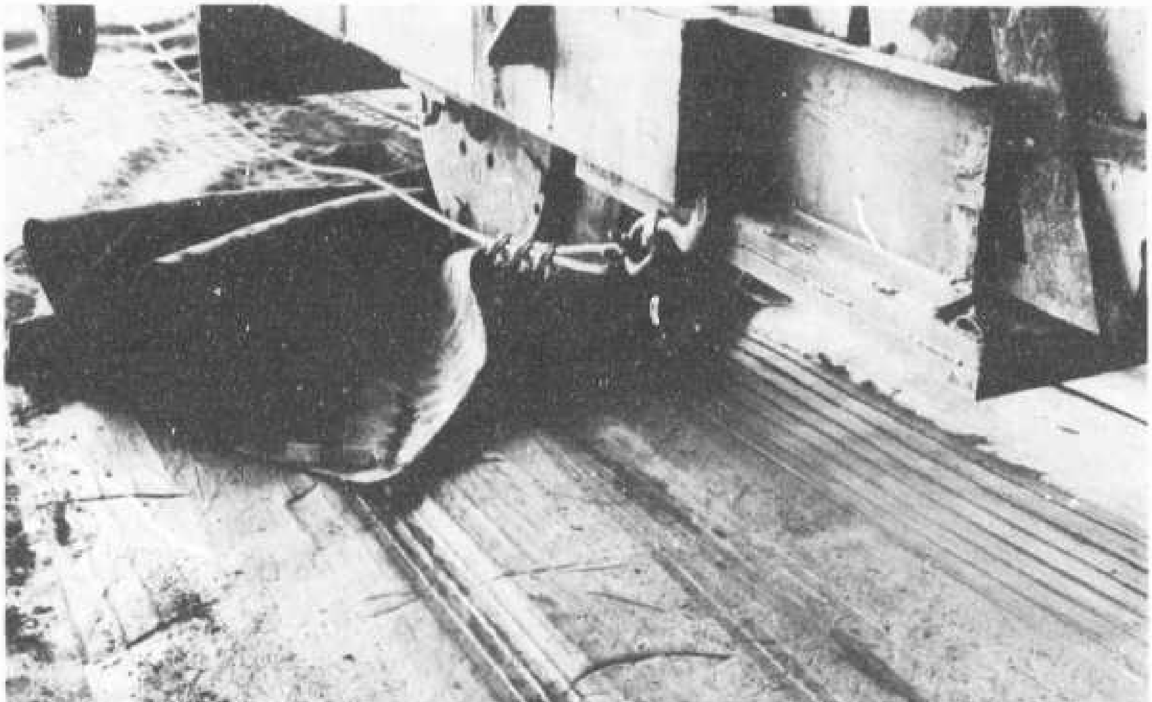


Photo 22. Failure of run 2 of XW18 membrane section 2 after three repetitive skids

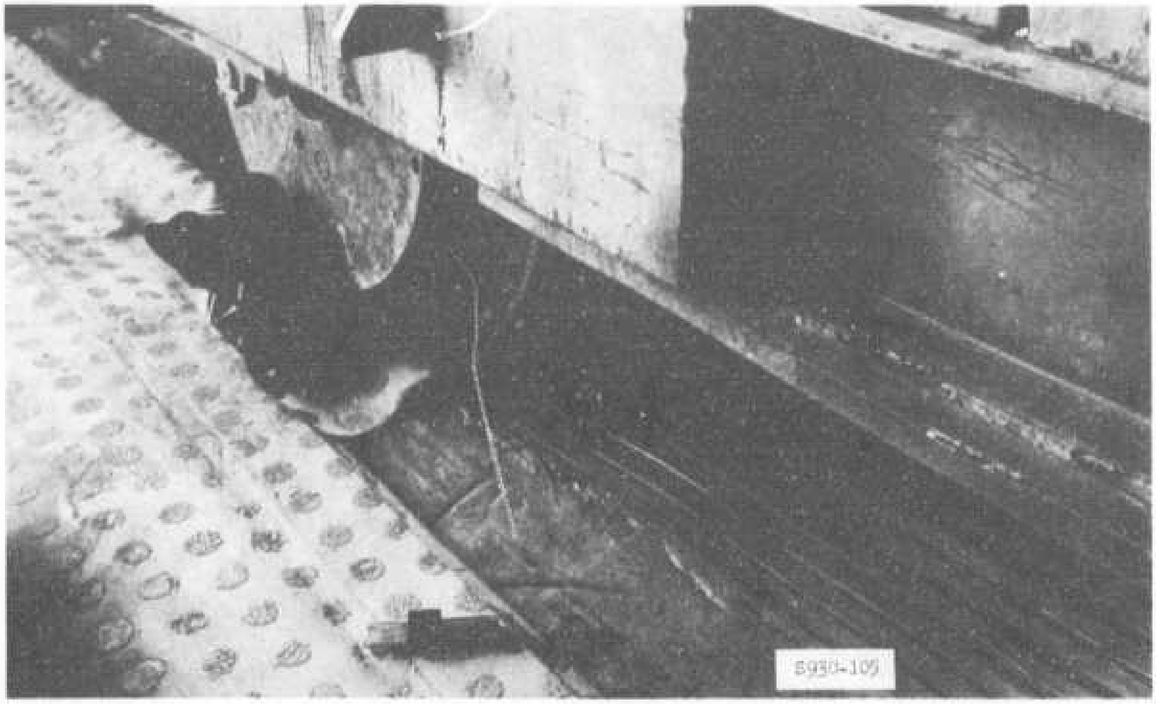


Photo 23. Failure of run 3 of XW18 membrane section 2 after sixth repetitive skid

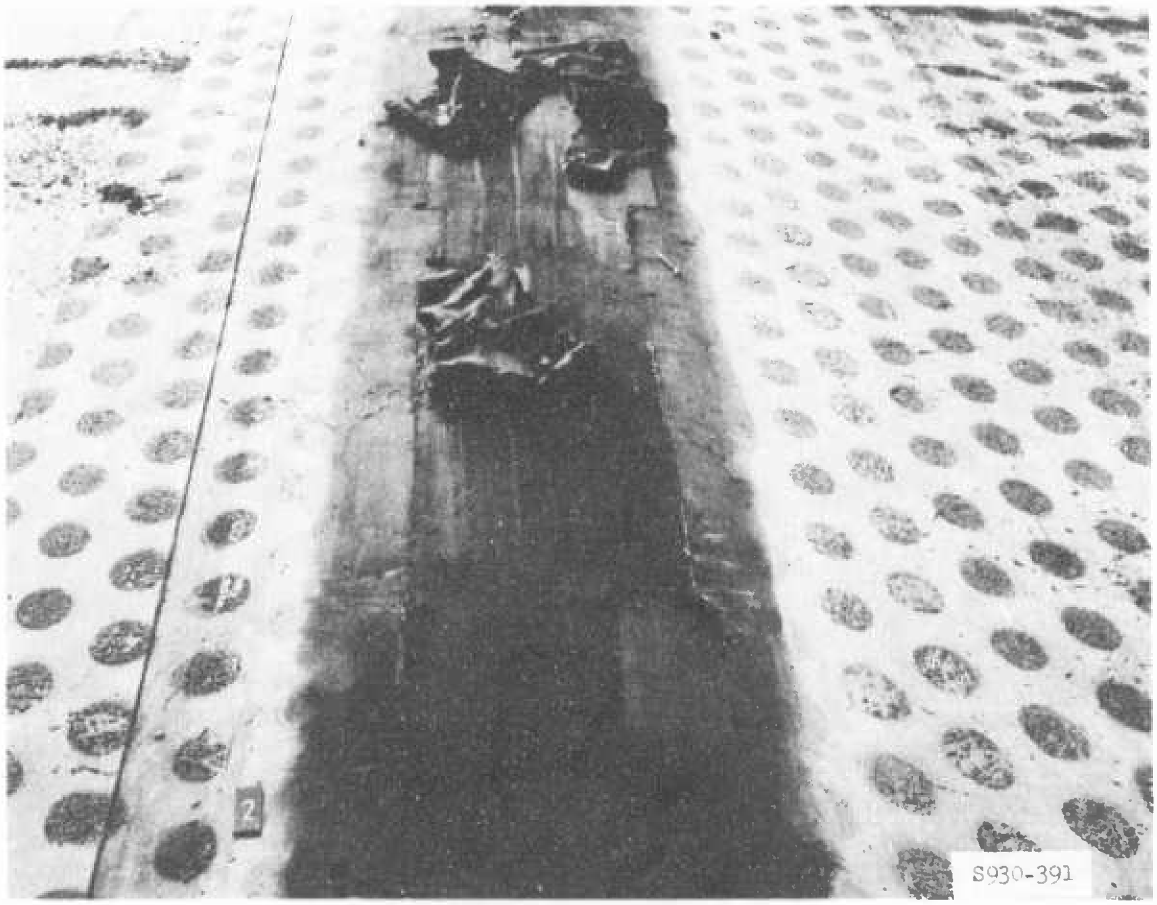


Photo 24. Condition of run 1 of XW18 membrane section 3 after six repetitive skids

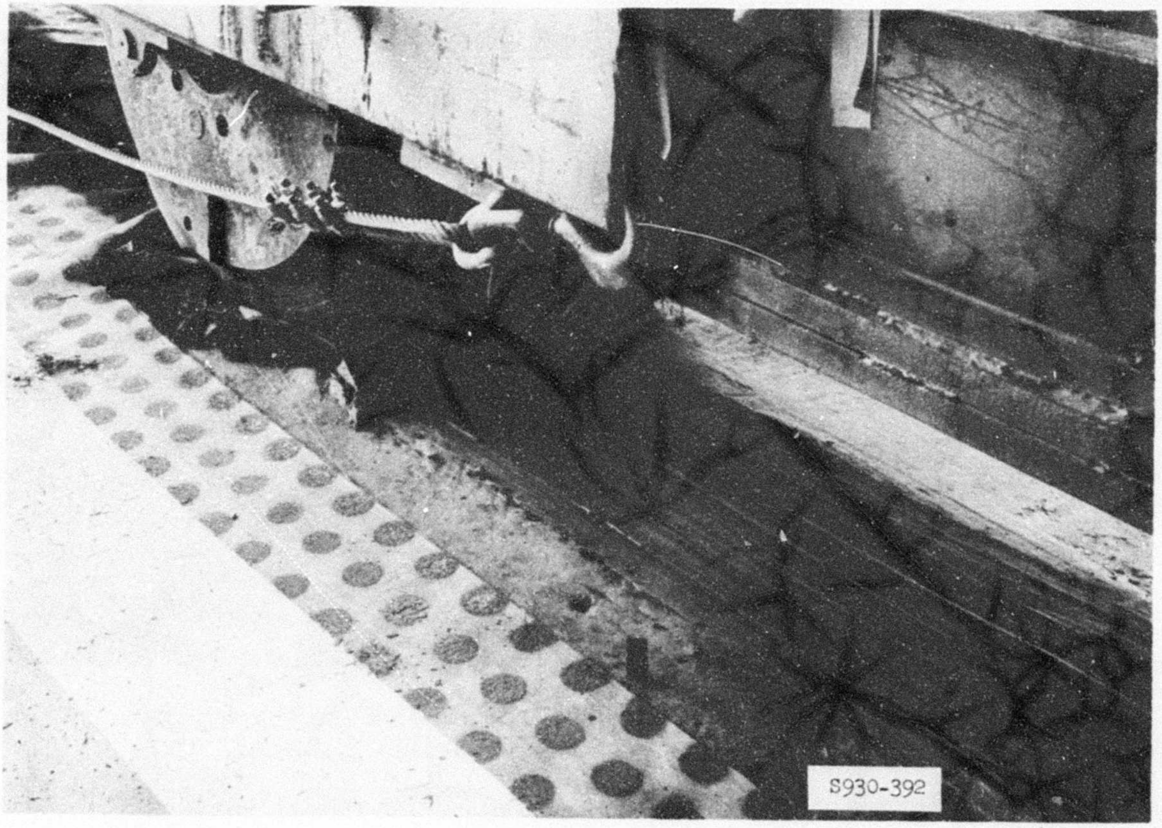


Photo 25. Failure of run 1 of XW18 membrane section 3 after seven repetitive skids

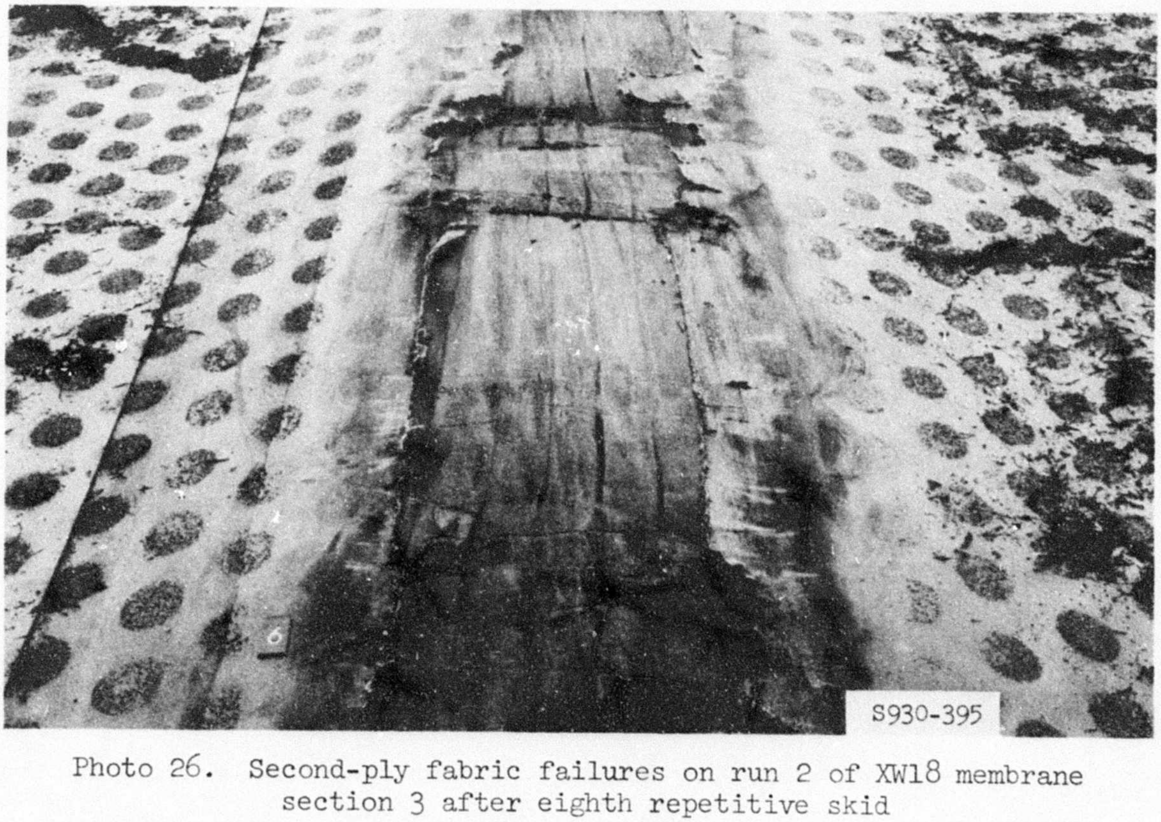


Photo 26. Second-ply fabric failures on run 2 of XW18 membrane section 3 after eighth repetitive skid

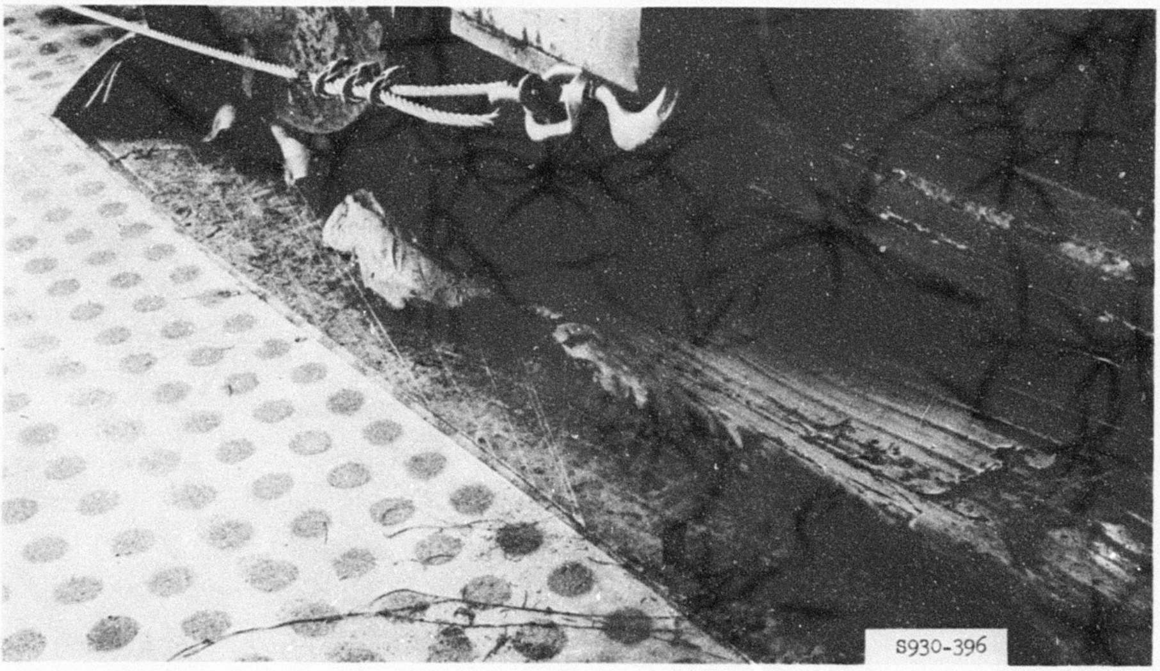


Photo 27. Failure of run 2 of XW18 membrane section 3 during tenth repetitive skid

Photo 28. Motor grader constructing 2-ft-deep anchor ditch prior to placement of membrane sheets

Photo 29. Placing membrane end in anchor ditch

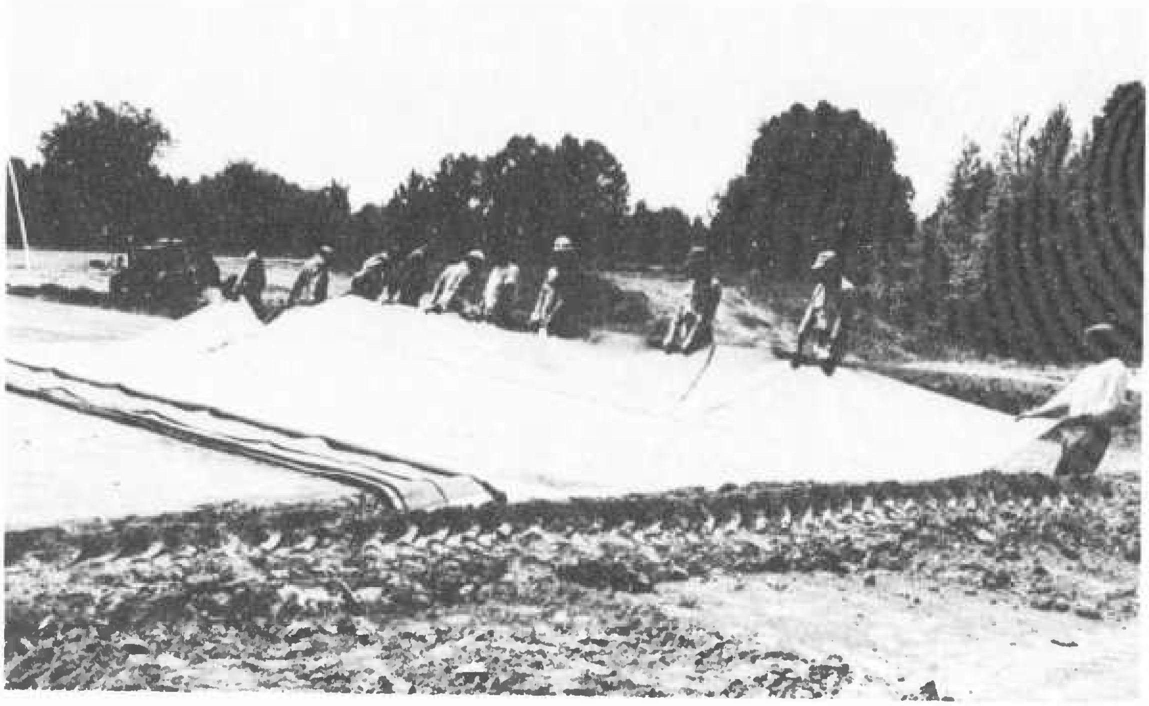


Photo 30. Unfolding first sheet of membrane to one side of test area

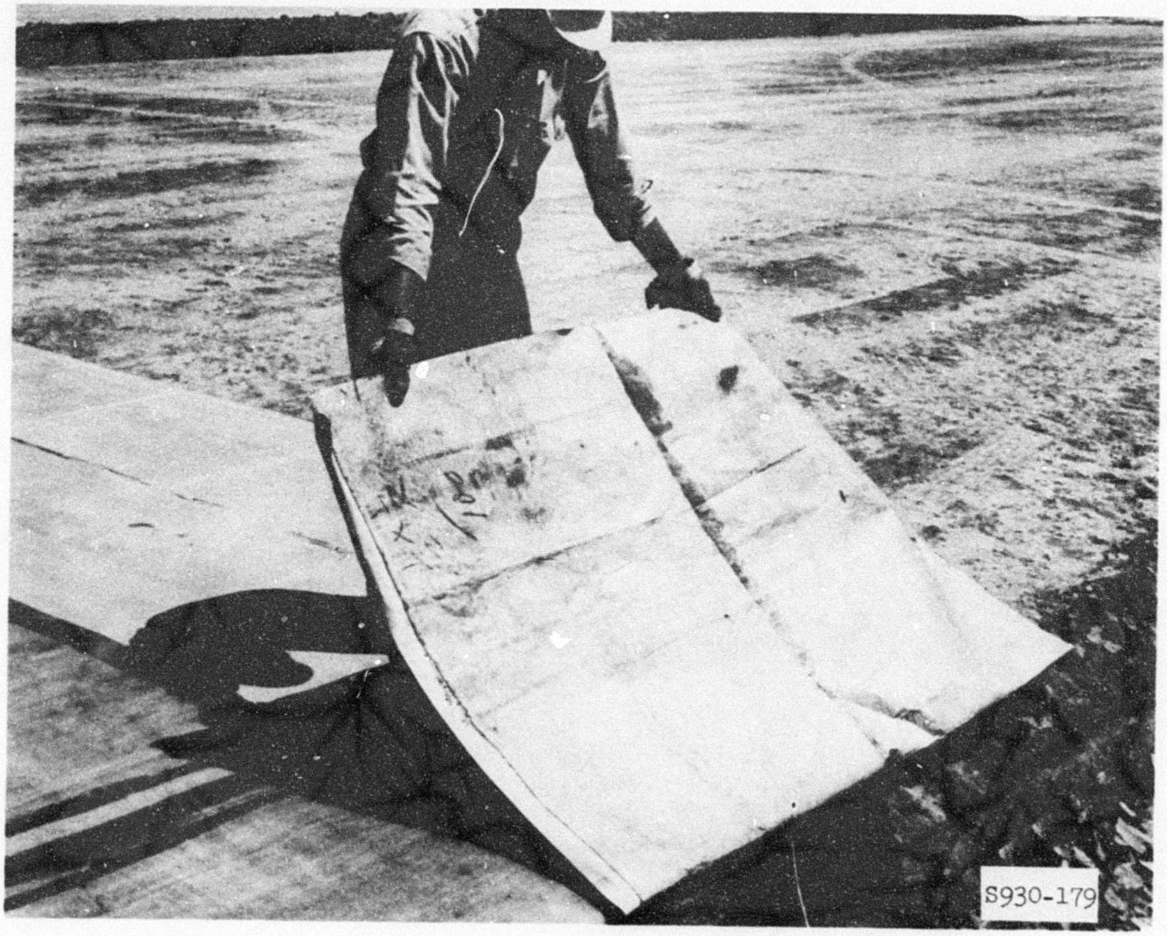


Photo 31. Removing protective paper wrapping from end of first sheet of membrane

Photo 32. Driving steel anchor through membrane placed in anchor ditch

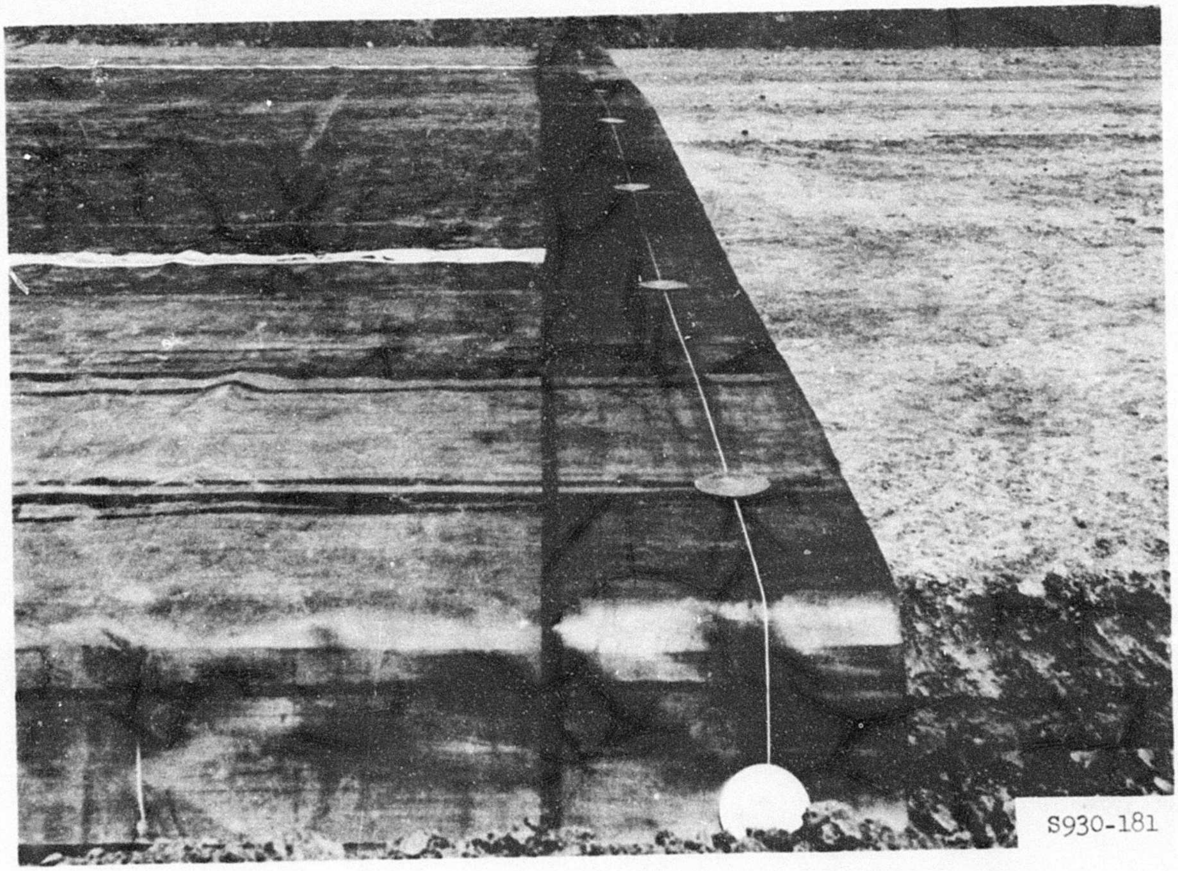


Photo 33. Steel anchors driven through alternate single-lap adhesive joints in free end of first sheet of surfacing

Photo 34. Motor grader backfilling anchor ditch

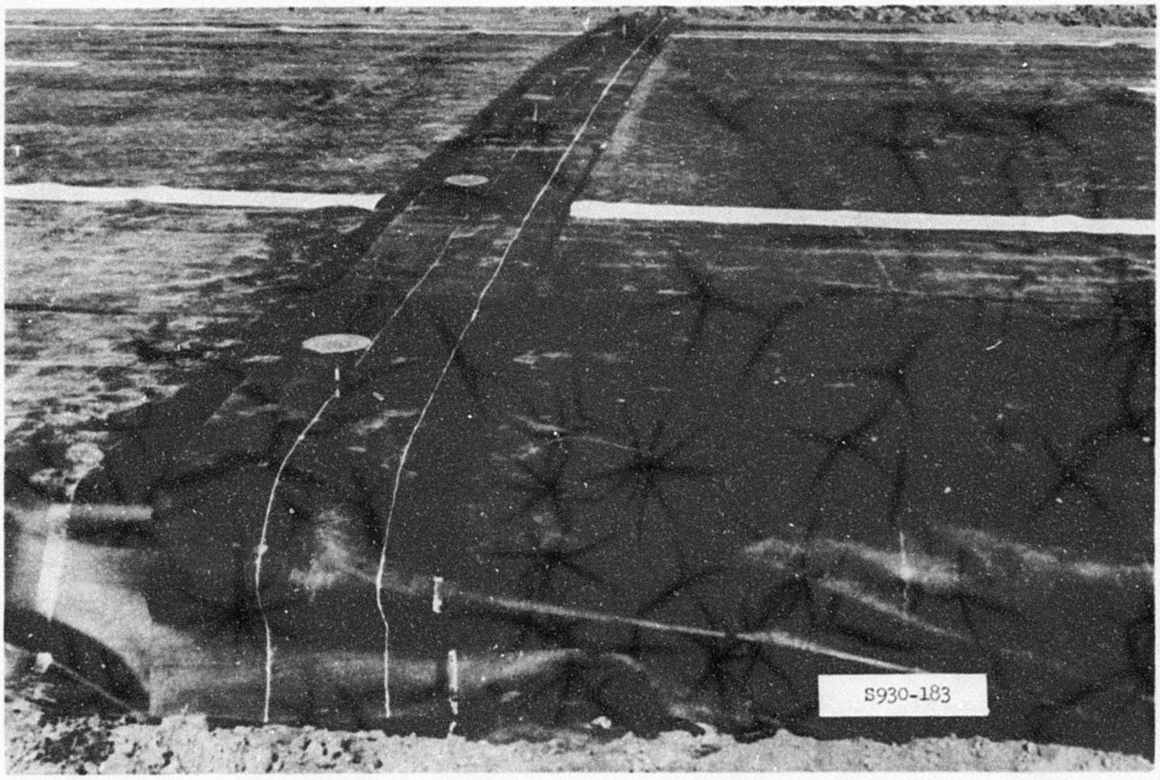


Photo 35. Anchors driven through overlapping ends of first two sheets to depth of approximately 6 in.

Photo 36. Overlapped end of second sheet raised with 48-in.-long paint roller handles while applying adhesive to joint

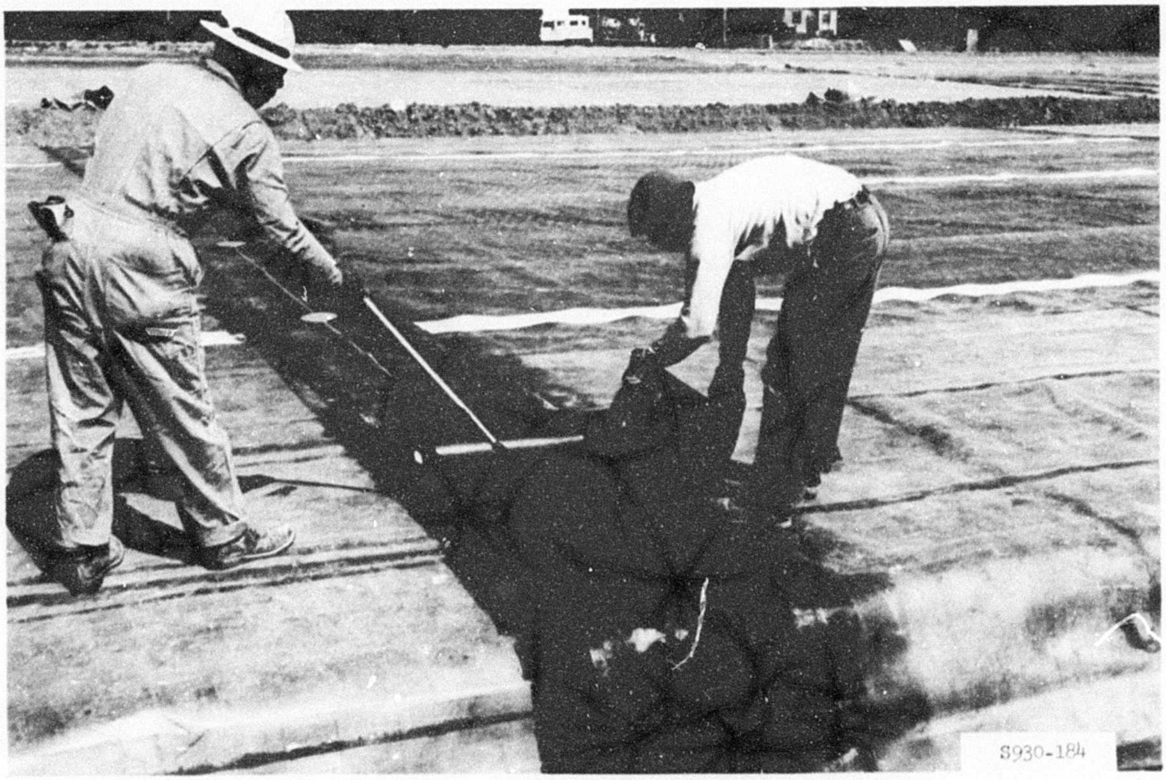


Photo 37. Reinforcing adhesive construction joint between first two sheets with 36-in.-wide strip of membrane

Photo 38. Applying adhesive to gasket of anchor at joint between second and third sheets

Photo 39. Construction of end anchor ditch for third sheet of membrane

Photo 40. Anchors driven through alternate single-lap adhesive joints in end anchor ditch

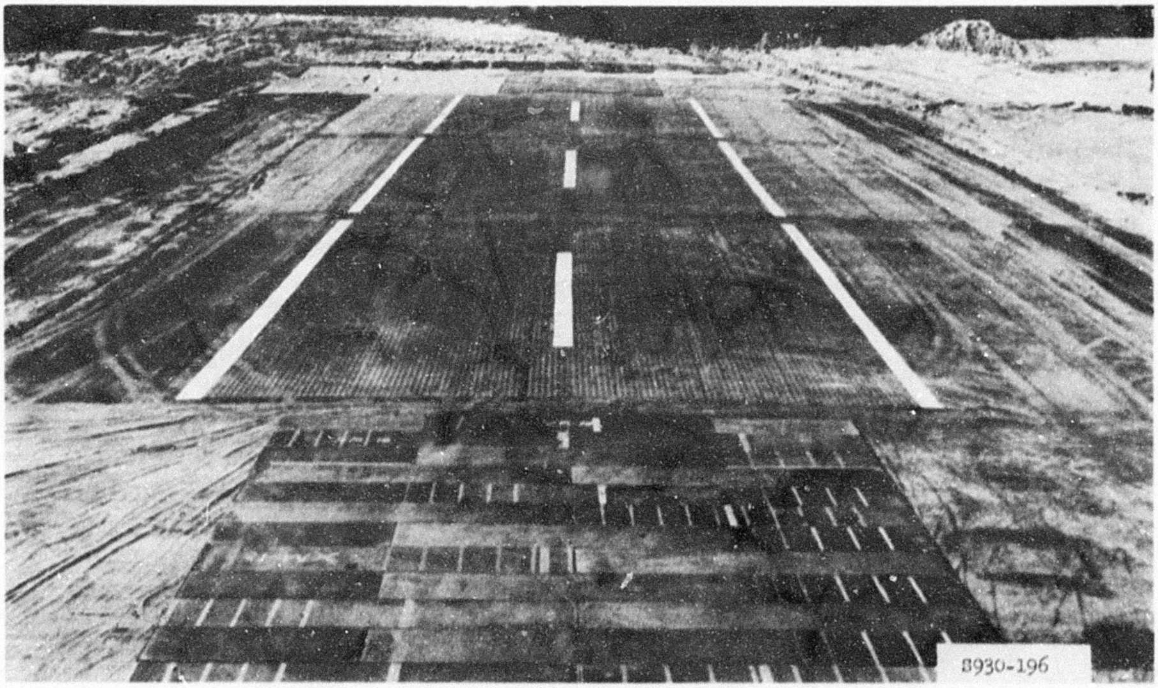


Photo 41. General view of test area after placement of three XW18 membrane sheets

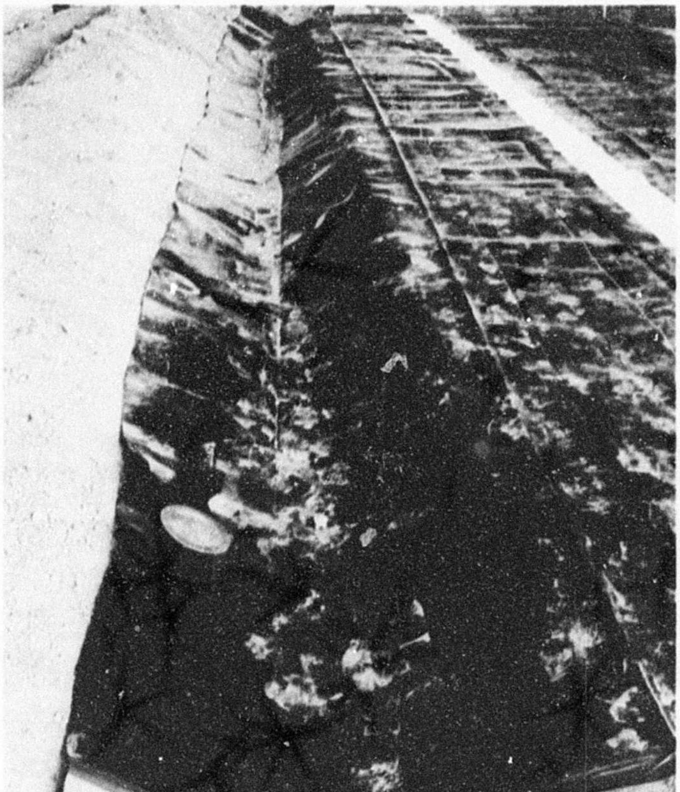


Photo 42. Steel anchors driven through surfacing on outside slope of ditch

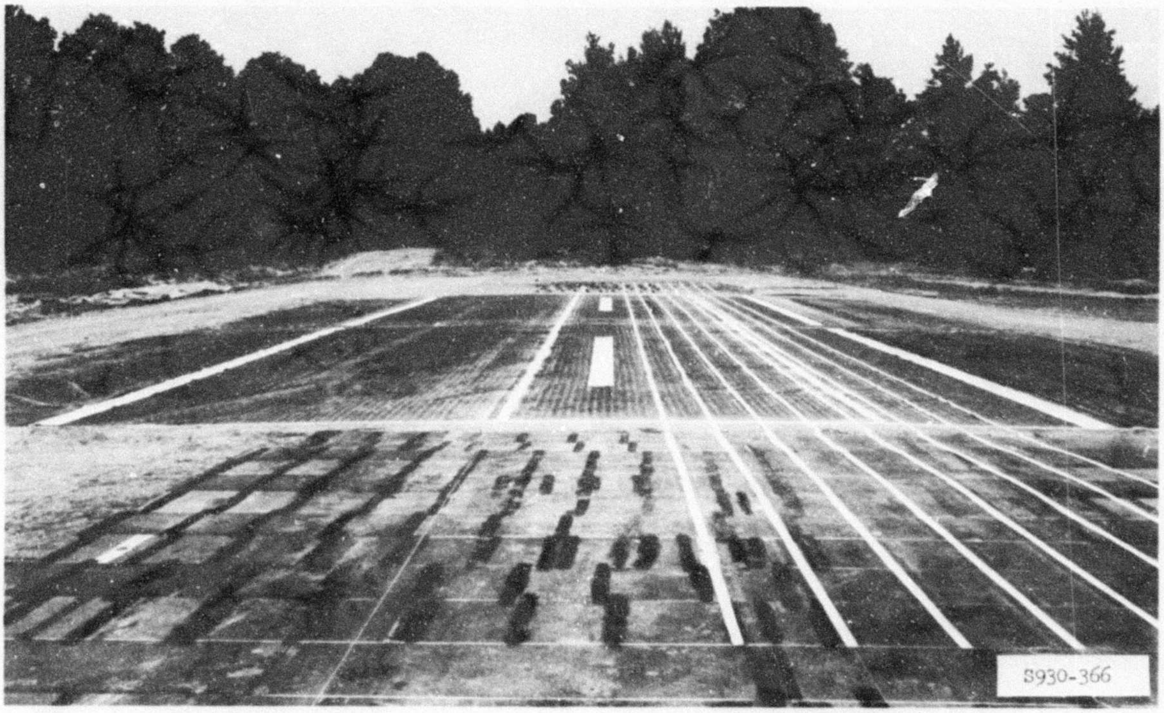


Photo 43. General view of traffic section 2 prior to trafficking

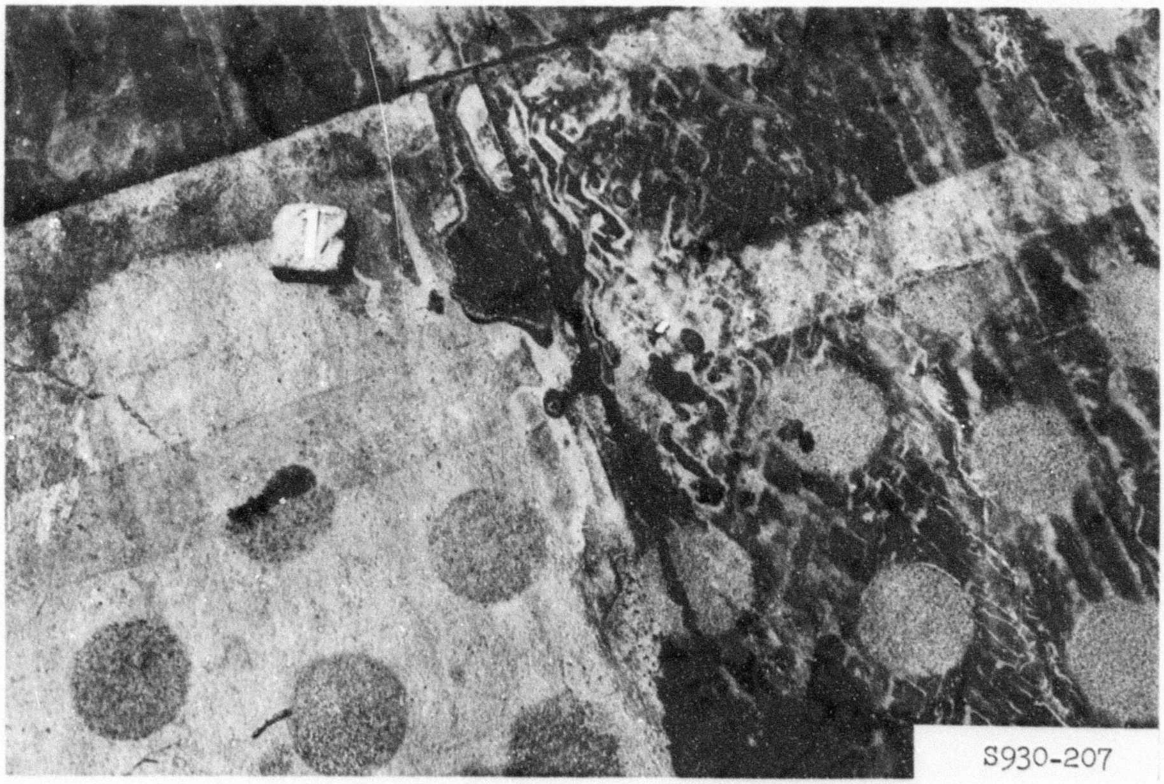


Photo 44. Soil pumping through 2-ft-wide adhesive construction joint at overlap of factory fabricated joint after 2 coverages of test wheel on test section 1

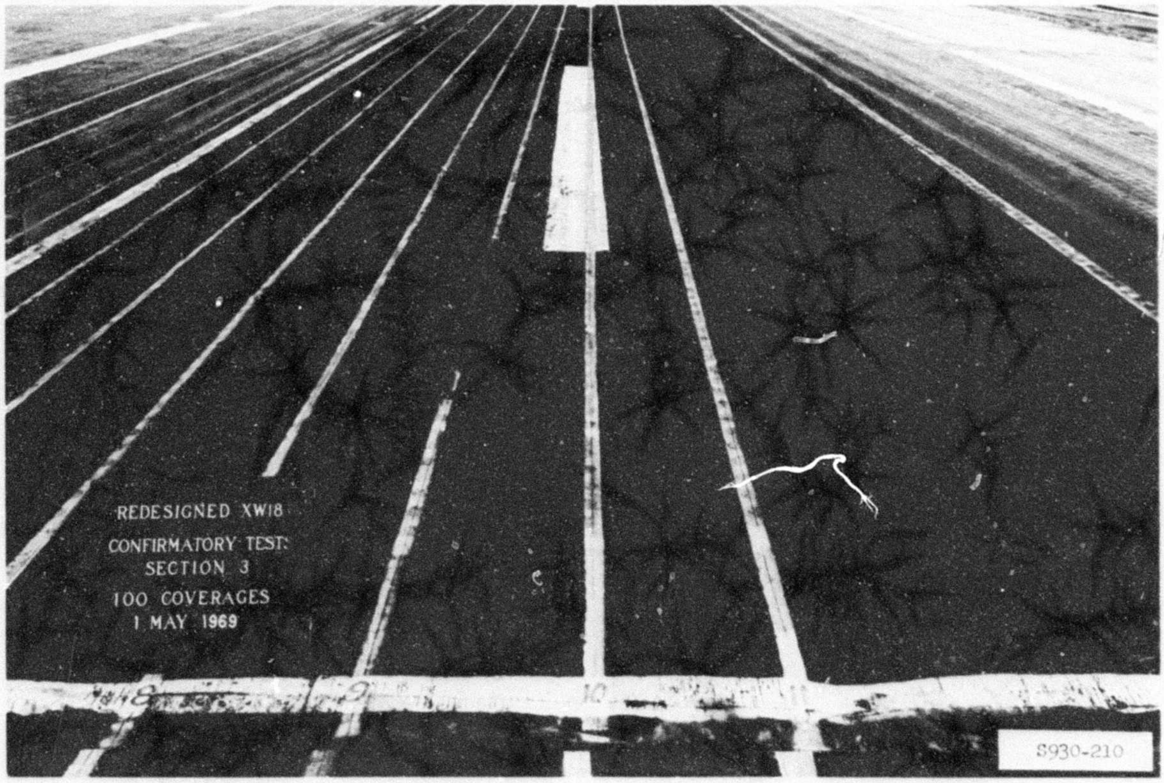


Photo 45. General condition of sheet 3 of test section 1 after 100 coverages

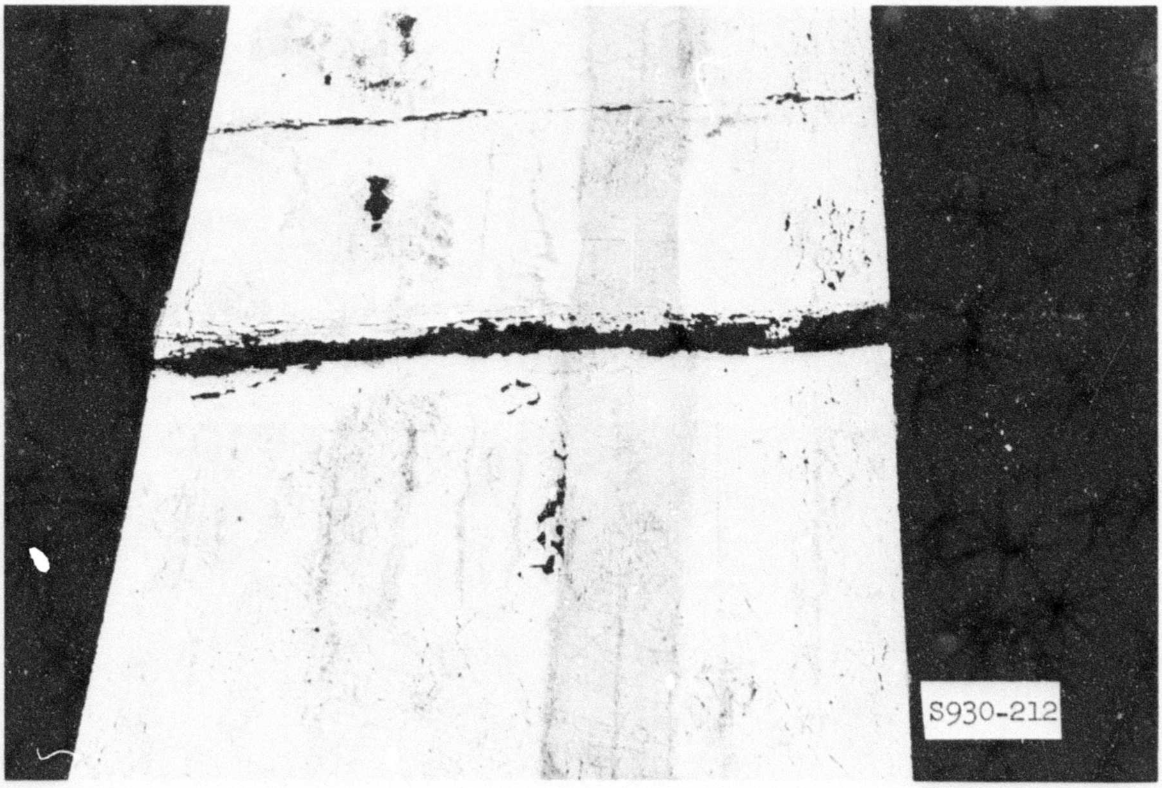


Photo 46. Heavy wear on edges of folds in surfacing caused by test wheel (100 coverages on test section 1)

Photo 47. Edge of 3-ft-wide reinforcing strip on adhesive construction joint worked loose by test wheel (100 coverages on test section 1)

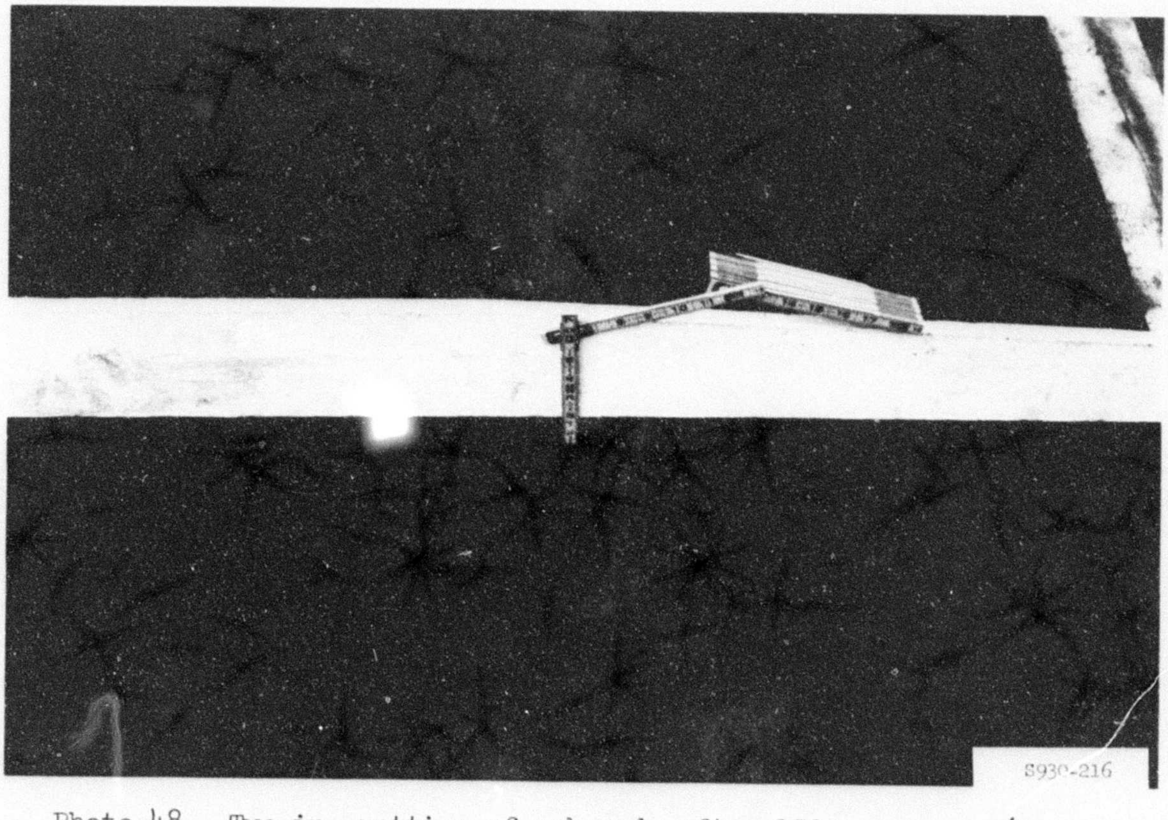


Photo 48. Two-in. rutting of subgrade after 150 coverages (test section 1, sta 0+75)

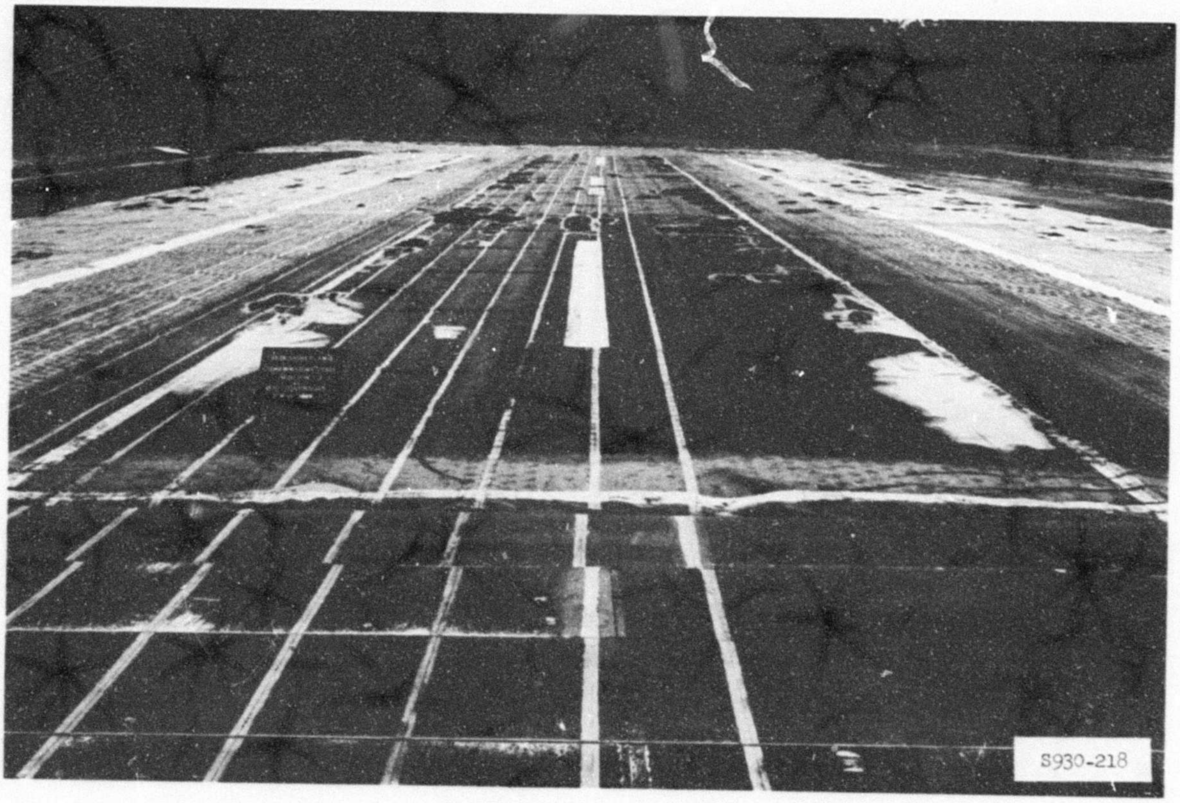


Photo 49. General condition of test section 1 after 200 coverages

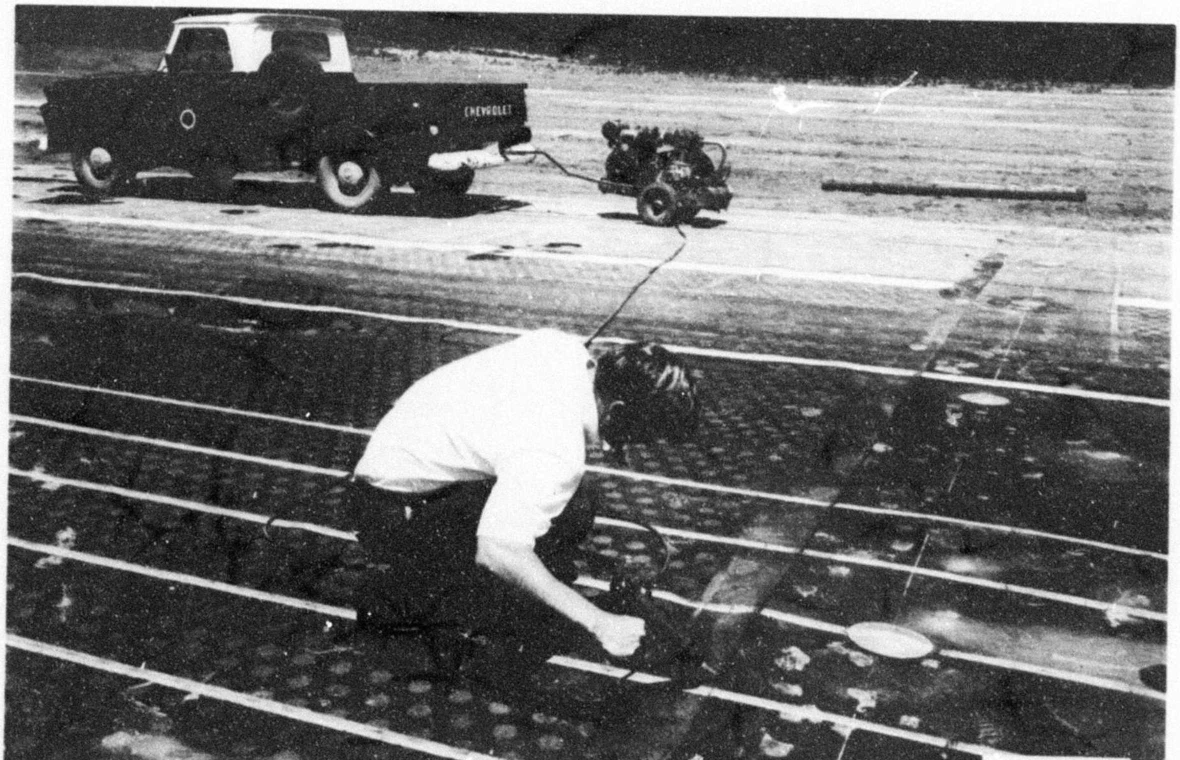


Photo 50. Applying EC801 sealant to edge of 2-ft-wide construction joint of test section 1 with air gun

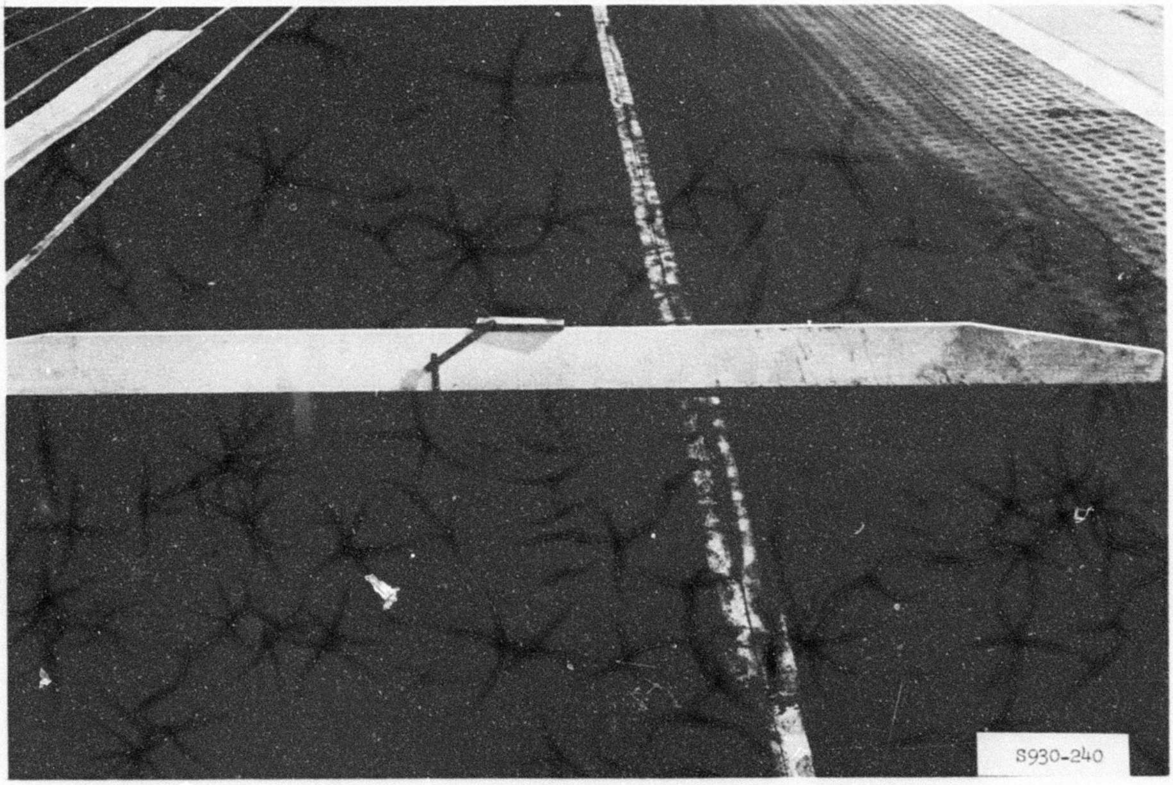


Photo 51. Rutting of subgrade of test section 1, sta 0+75, after 400 coverages

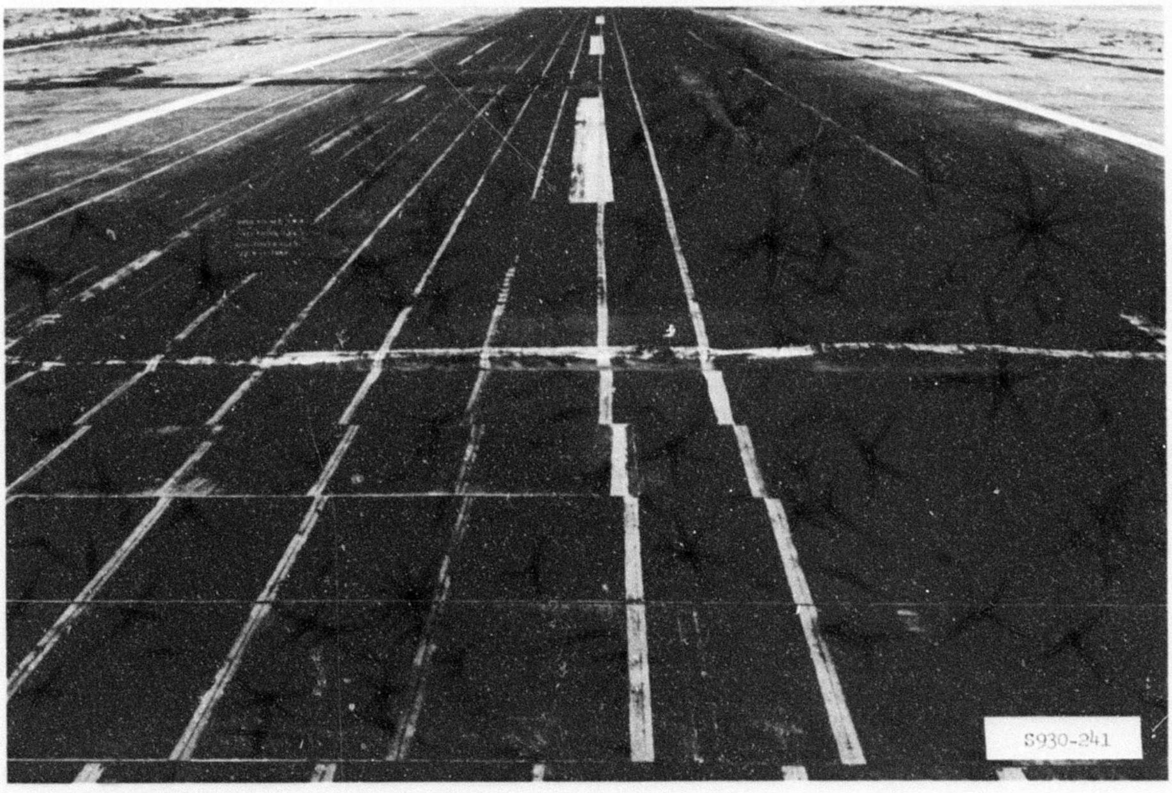


Photo 52. General condition of test section 1 after 400 coverages

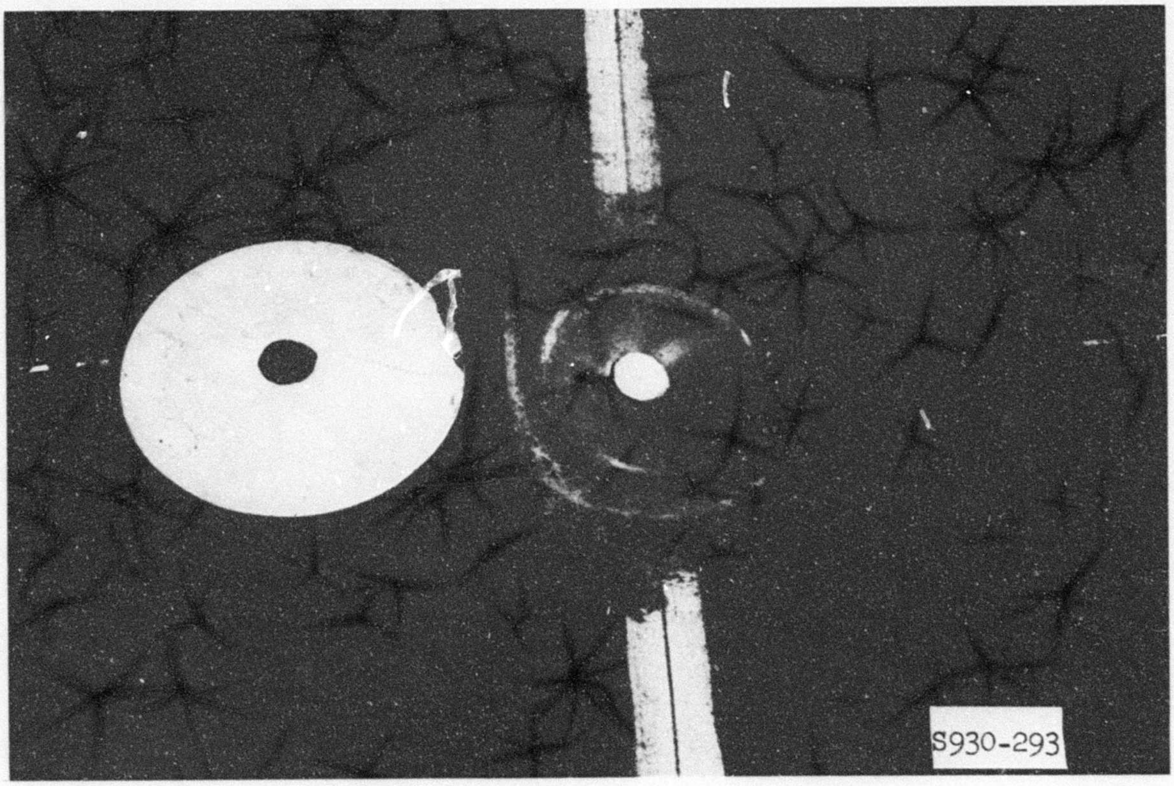


Photo 53. Failure of steel anchor at joint between sheets 2 and 3 of section 1 after 522 coverages

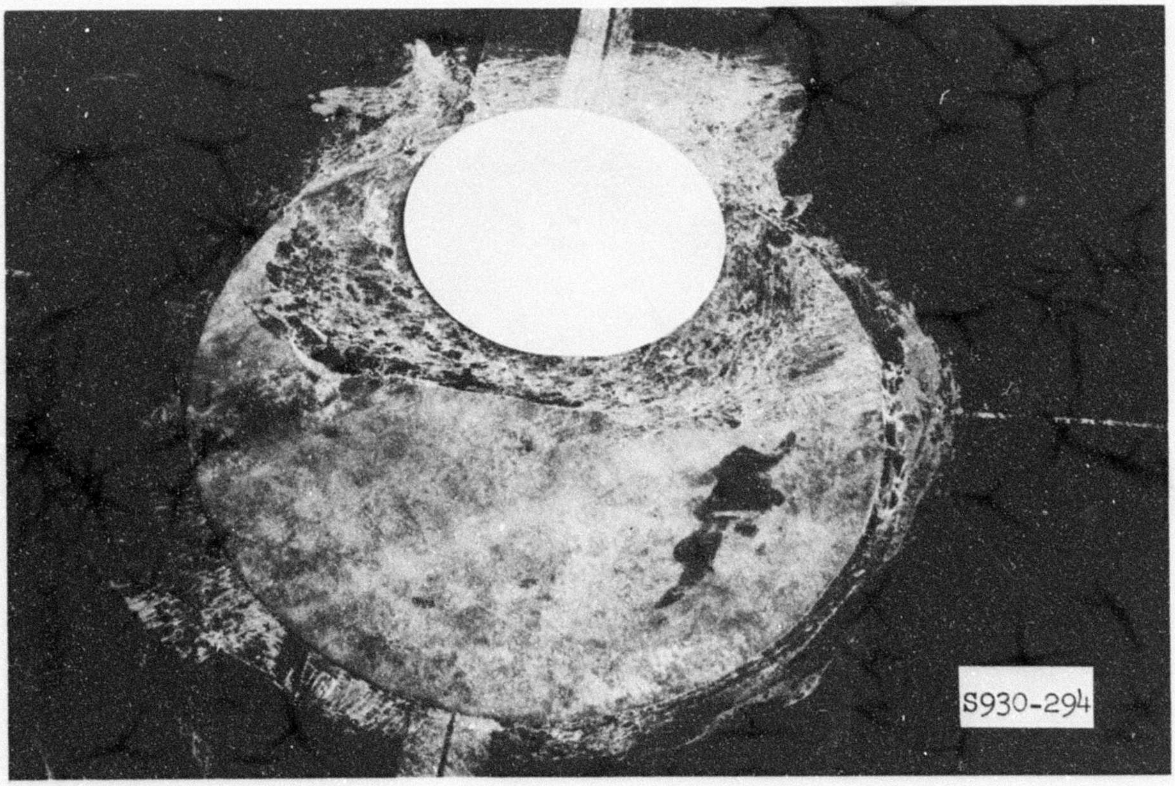


Photo 54. Replacement of failed anchor at joint between sheets 2 and 3 of test section 1

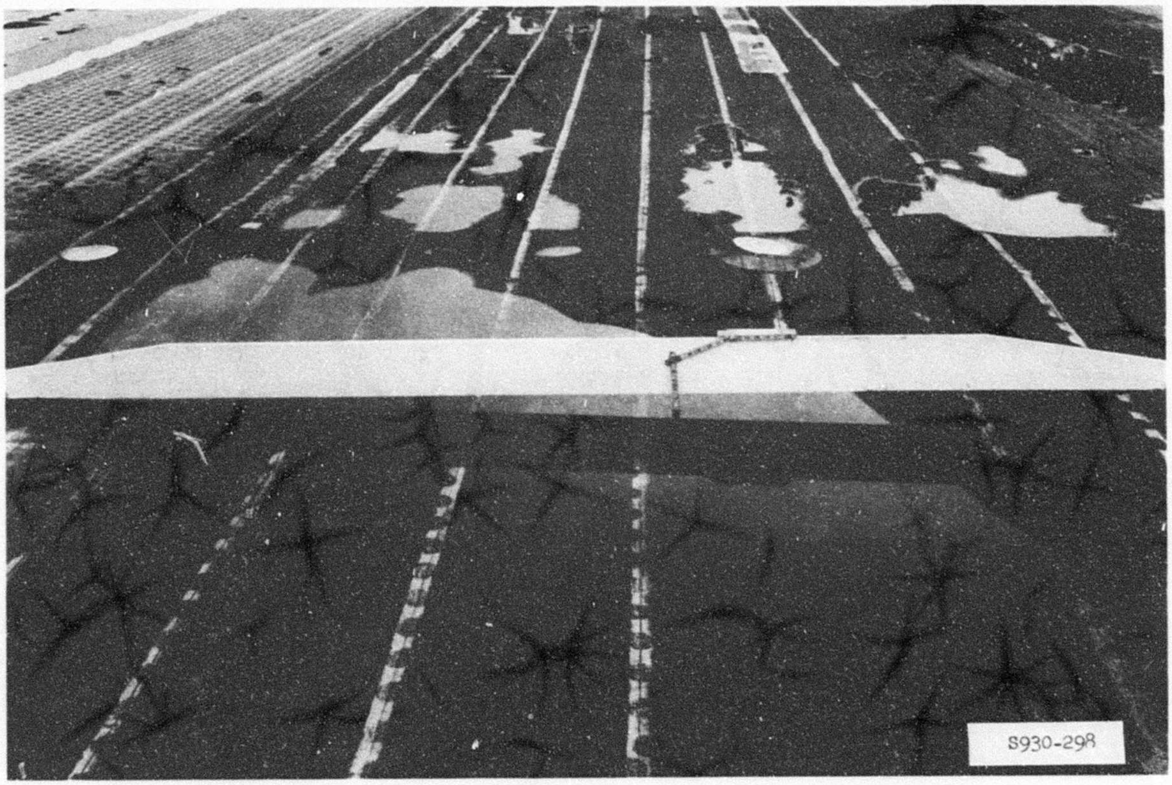


Photo 55. Rutting of subgrade of test section 1, sta 1+05, after 538 coverages

Photo 56. Rutting of east edge of subgrade of test section 1, sta 0+75, after 538 coverages

Photo 57. Motor grader removing remainder of sheet 3, test section 1, that was buried in anchor ditches

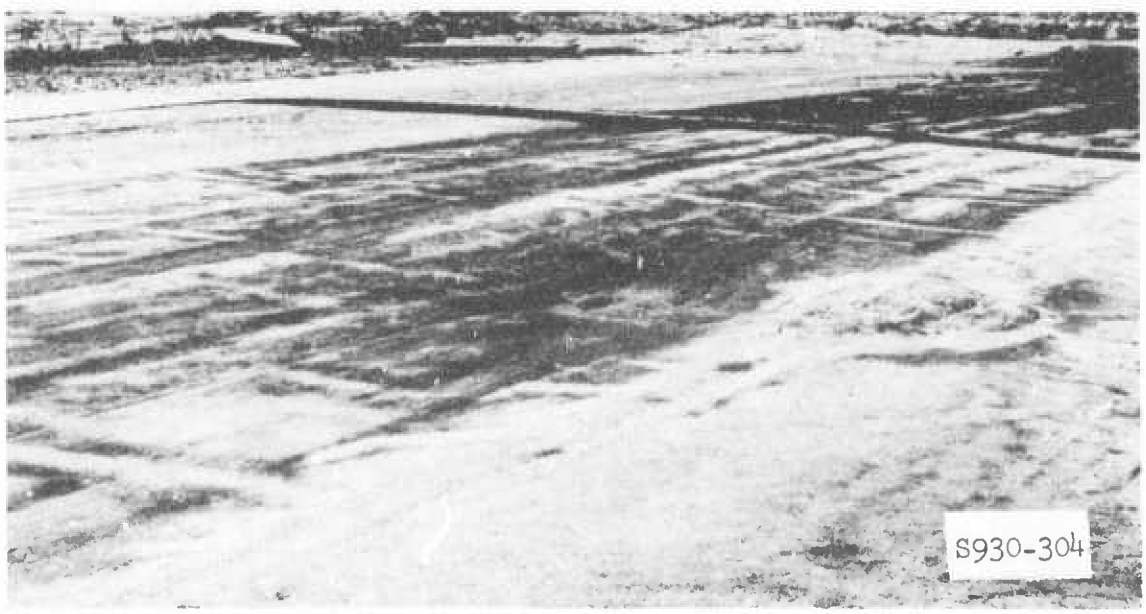


Photo 58. Sheet 2 of test section 1 cut along sides and folded back for repair of subgrade (538 coverages); note depressed area at center

Photo 59. Condition of lean clay subgrade of test section 1, sta 1+05, after 538 coverages

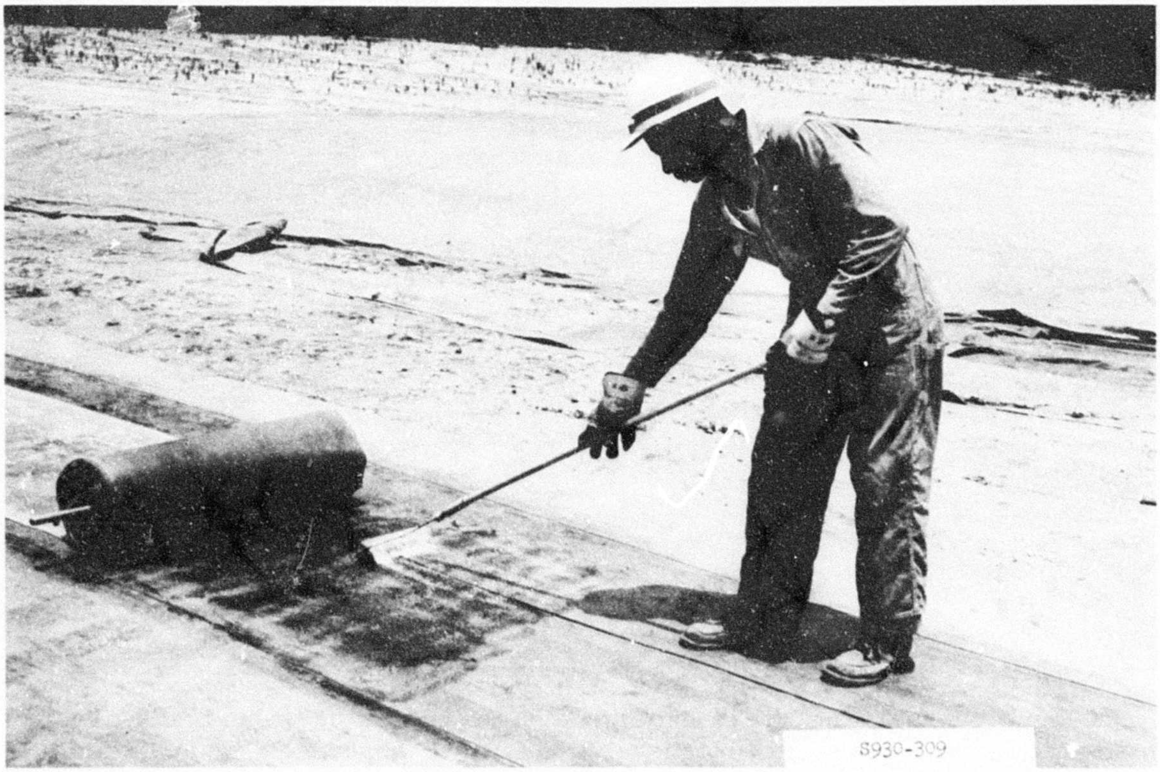


Photo 60. Applying 3-ft-wide strip of membrane to cut made on sheet 2 of test section 1 for subgrade repair

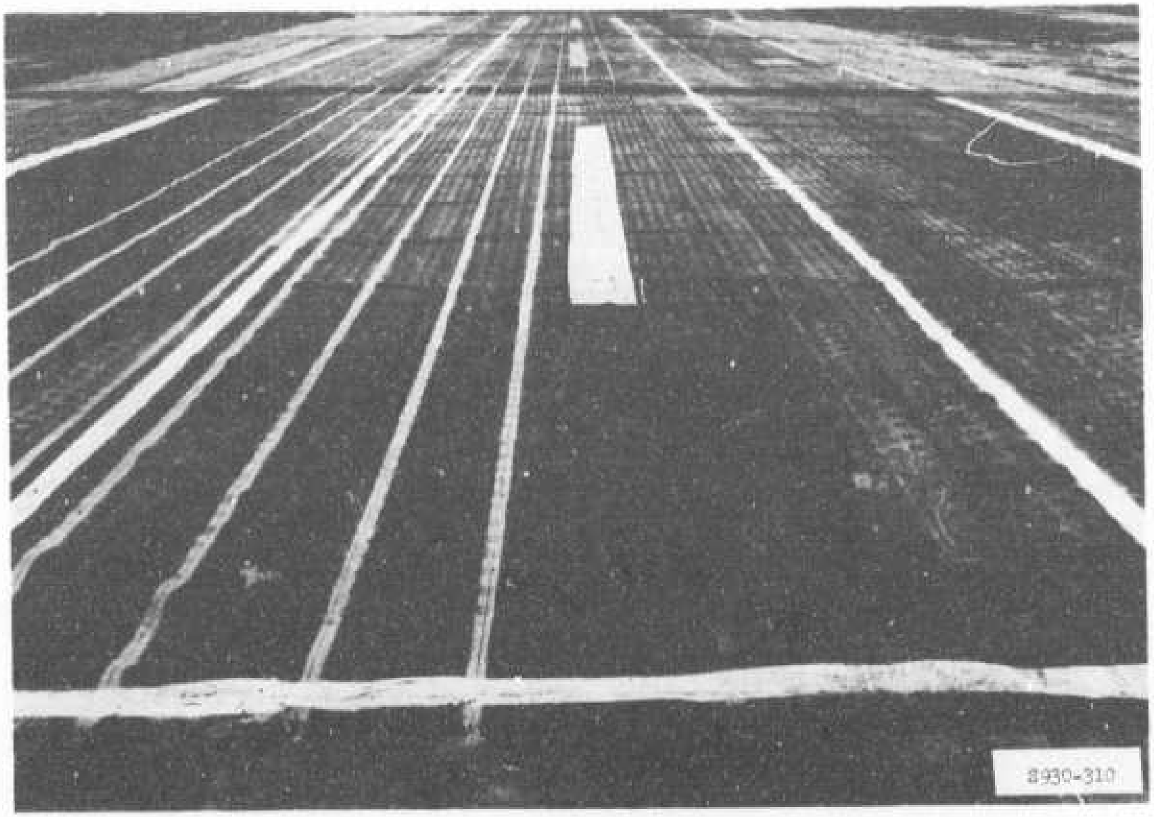


Photo 61. General view of traffic test section 1 after repair of subgrade (538 coverages)

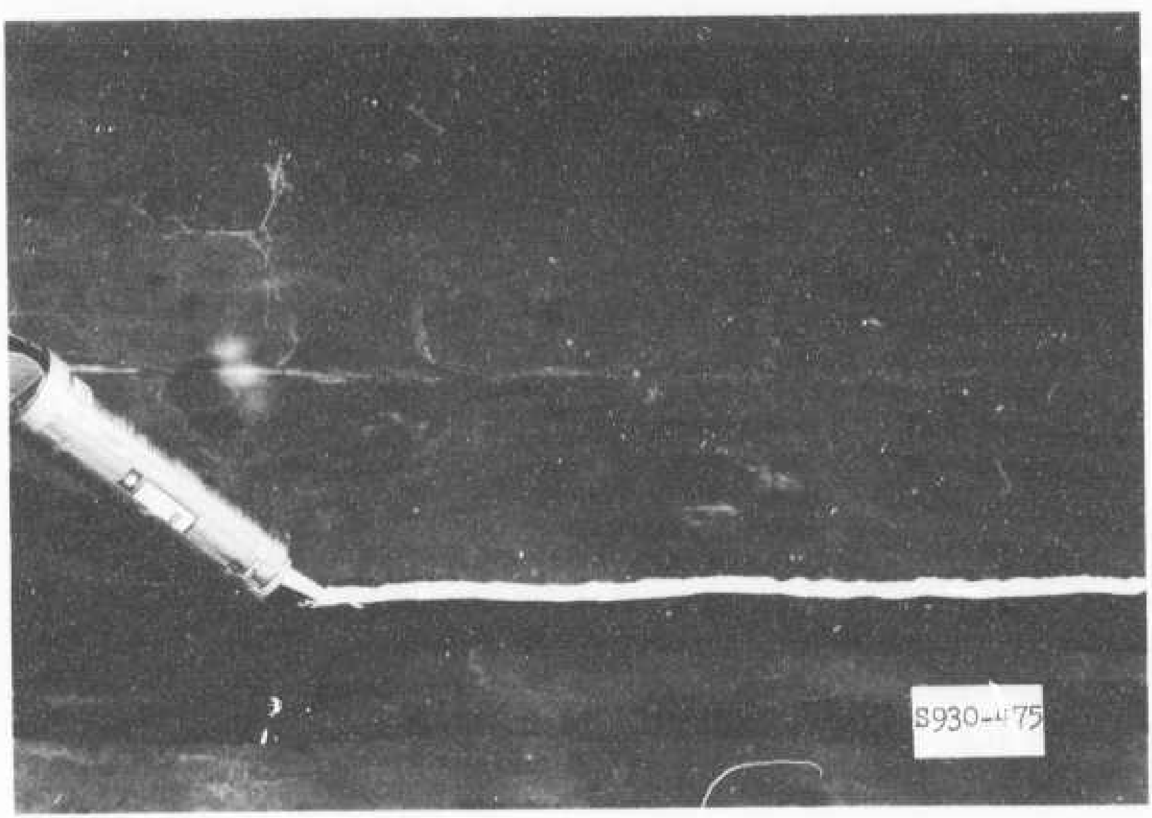


Photo 62. Application of Weatherban 101 sealant to edge of joint with caulking gun

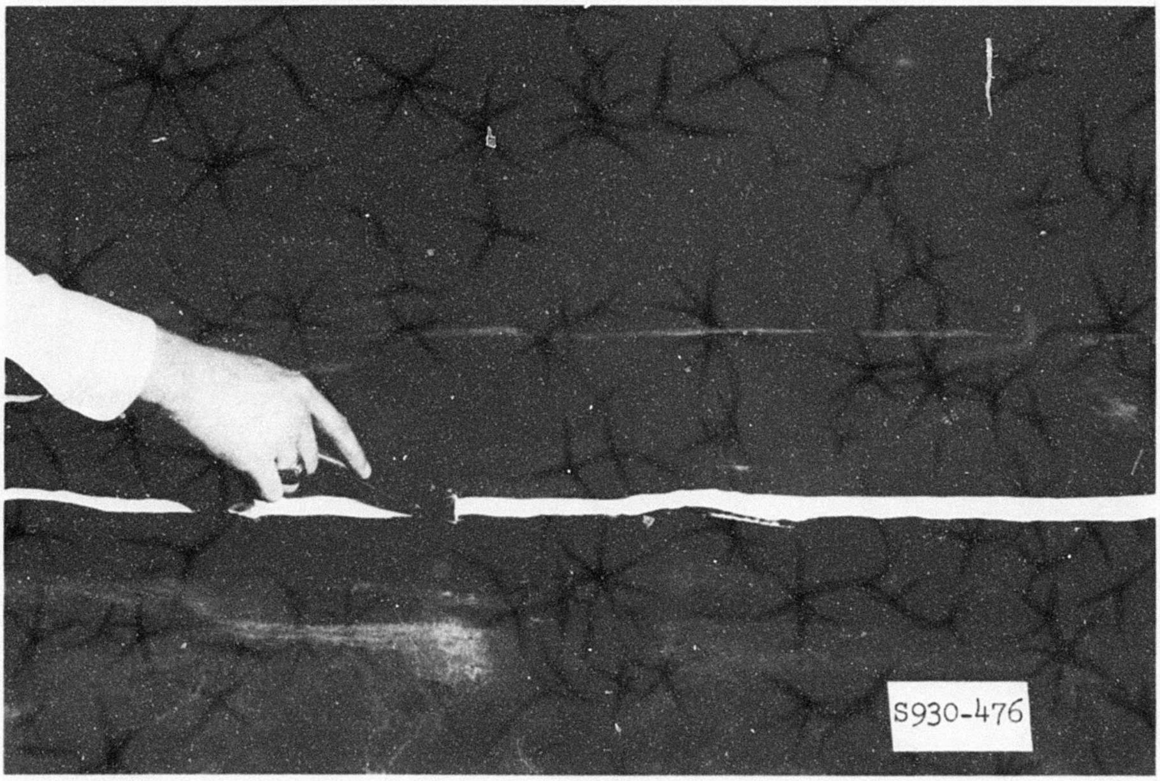


Photo 63. Beveling bead of Weatherban 101 sealant with putty knife

Photo 64. Sheet 1 of test section 1 after 738 coverages

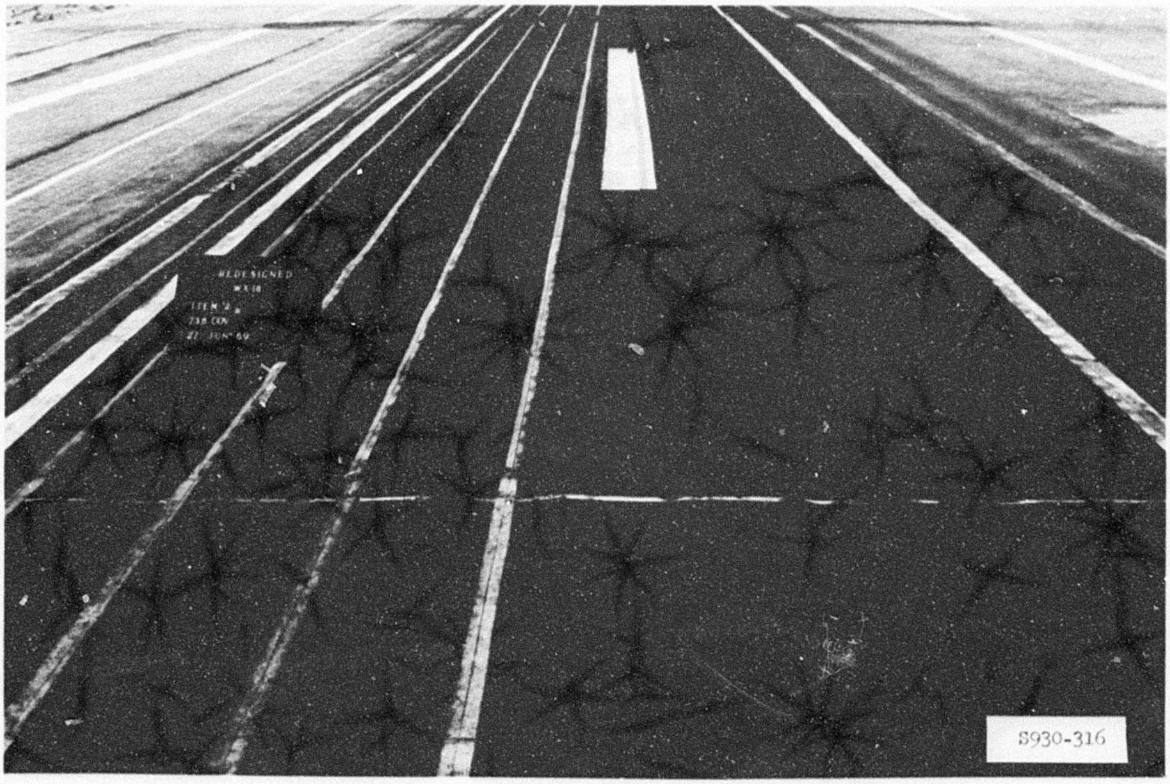


Photo 65. Sheet 2 of test section 1 after 738 coverages

Photo 66. Sheet 3A of test section 1 after 200 coverages (total of 738 coverages on test section)

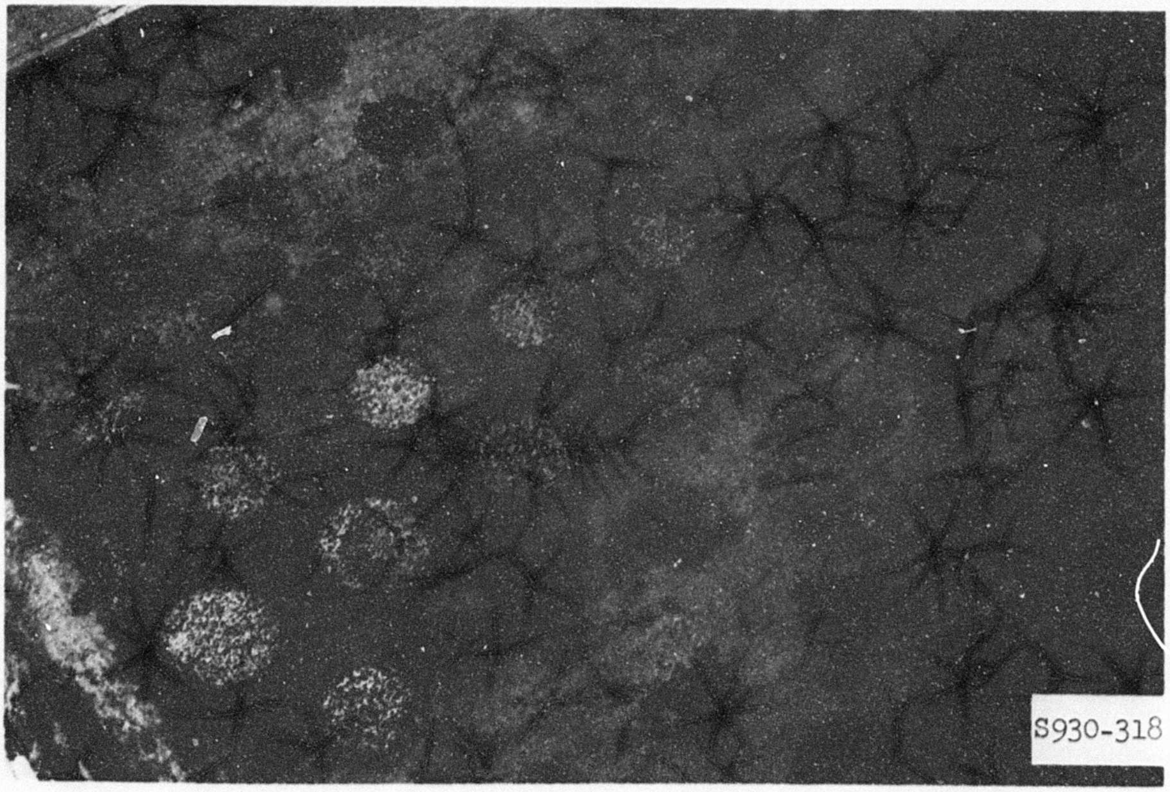


Photo 67. Closeup view of wear on sheet 1 of test section 1 (738 coverages)

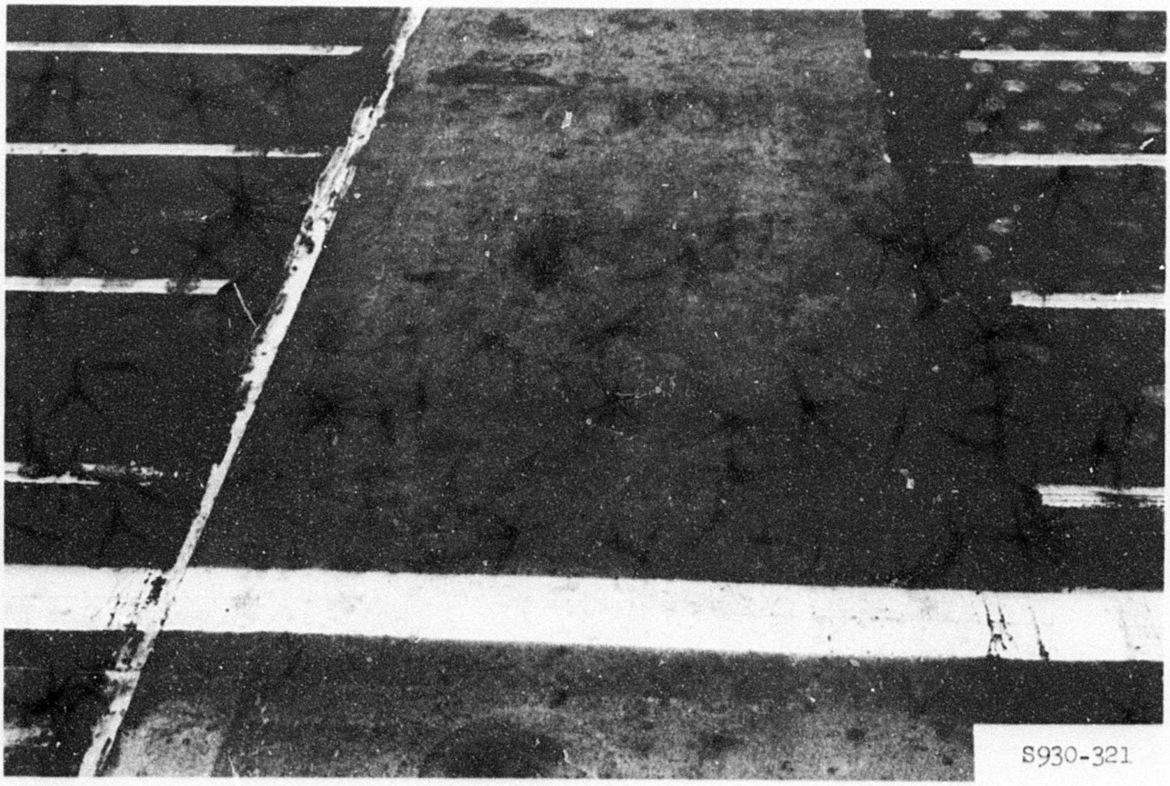


Photo 68. General condition of Weatherban 101 sealant (left edge of joint) and EC801 sealant (right edge of joint) after 200 coverages on sheet 3A of test section 1

Photo 69. Condition of membrane sheet 1 of test section 1 after 910 coverages

Photo 70. Condition of membrane sheet 2 of test section 1 after 910 coverages

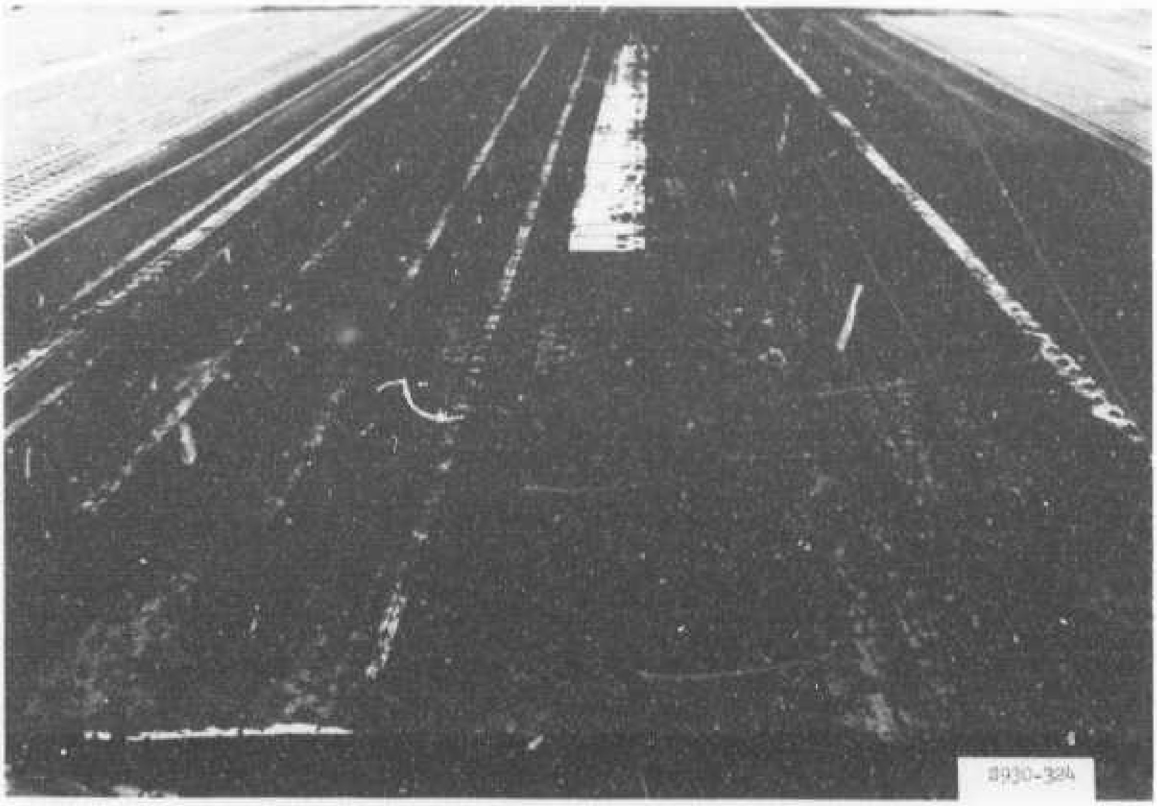


Photo 71. Condition of membrane sheet 3A of test section 1 after 372 coverages (total of 910 coverages on test section)

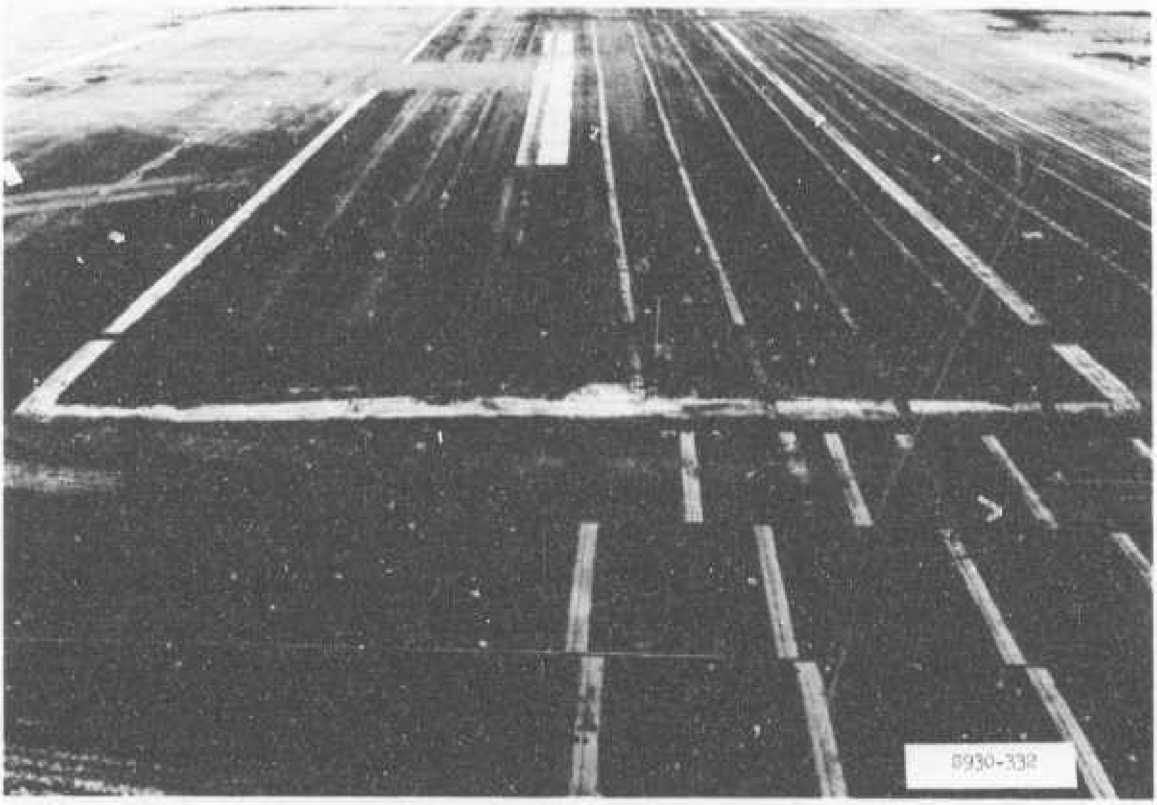


Photo 72. Condition of sheet 1 of test section 1 after 1200 coverages

Photo 73. Condition of sheet 2 of test section 1 after 1200 coverages

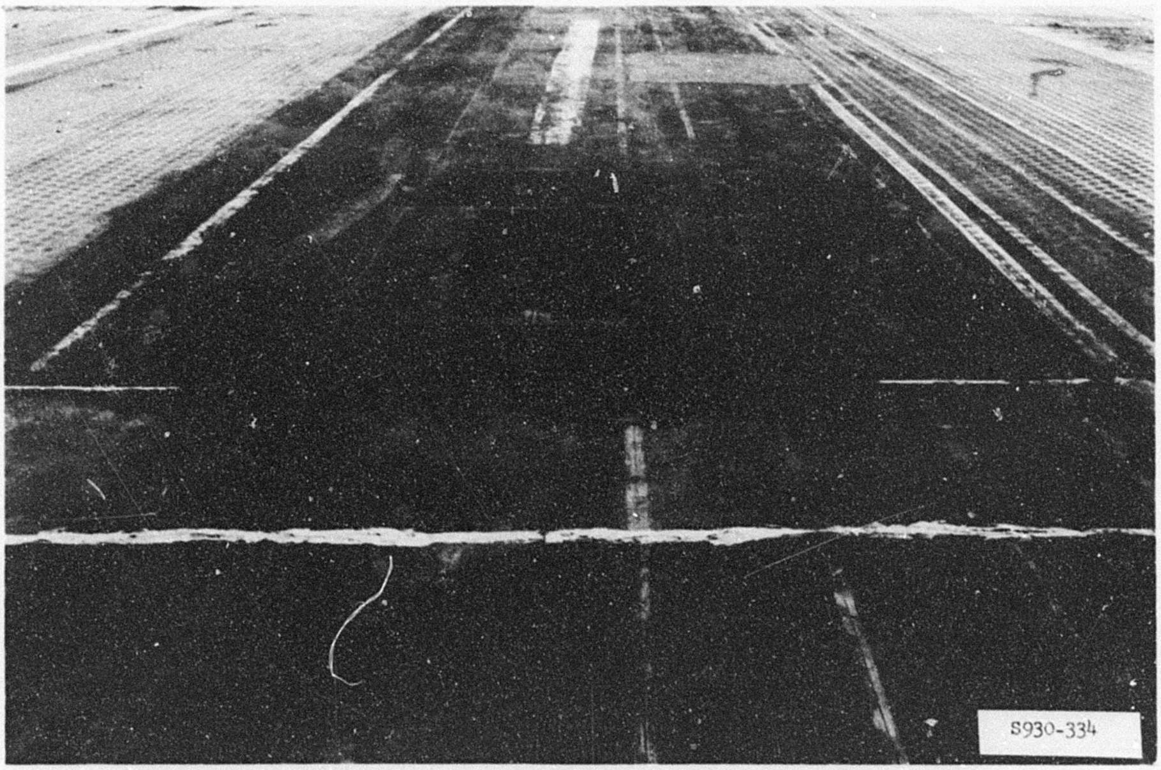


Photo 74. Condition of sheet 3A of test section 1 after 662 coverages (total of 1200 coverages on test section)

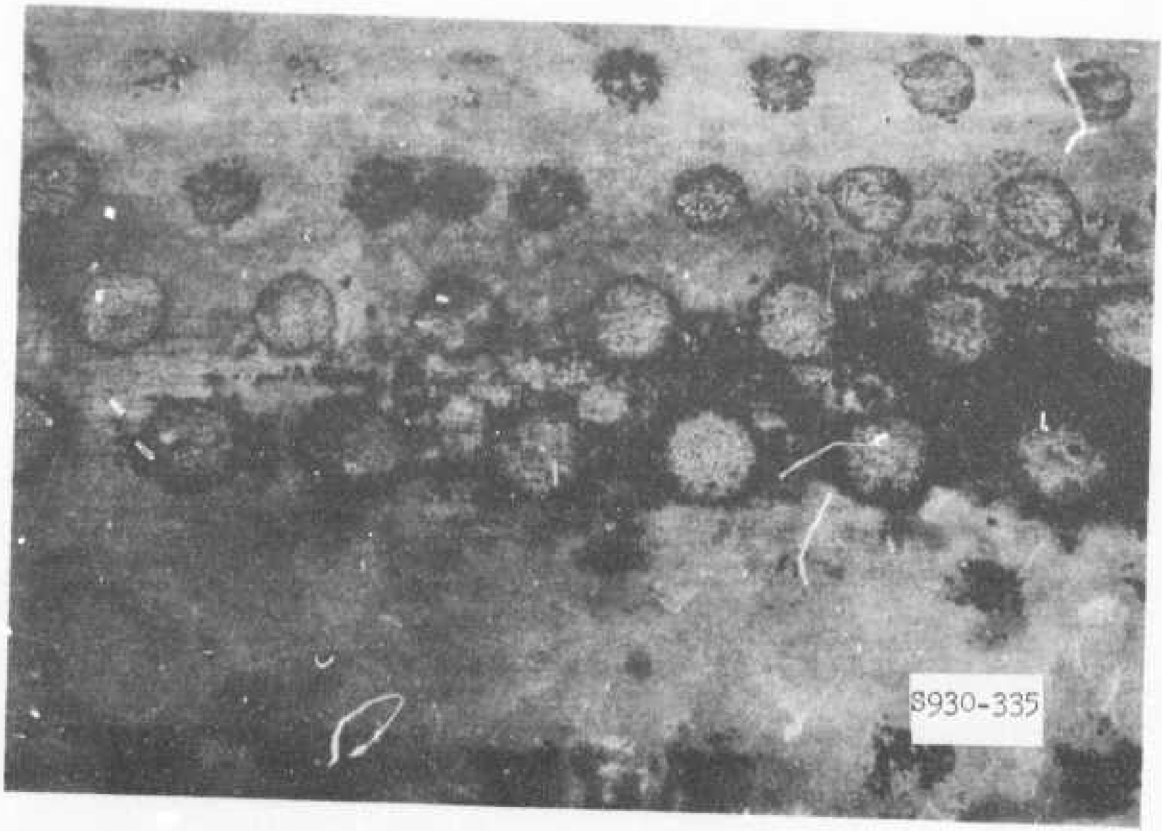


Photo 75. Severe wear of neoprene coating on sheet 1 of test section 1 (1200 coverages)

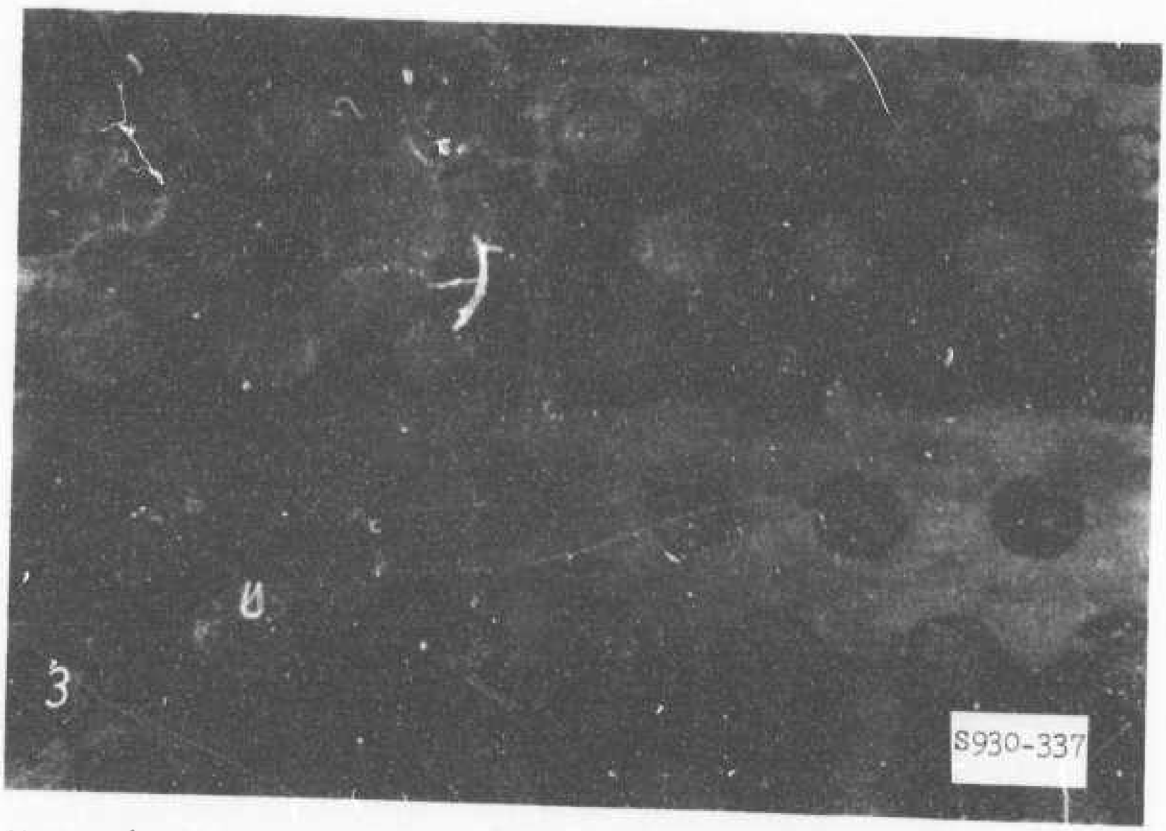


Photo 76. Severe wear of neoprene coating on sheet 2 of test section 1 (1200 coverages)

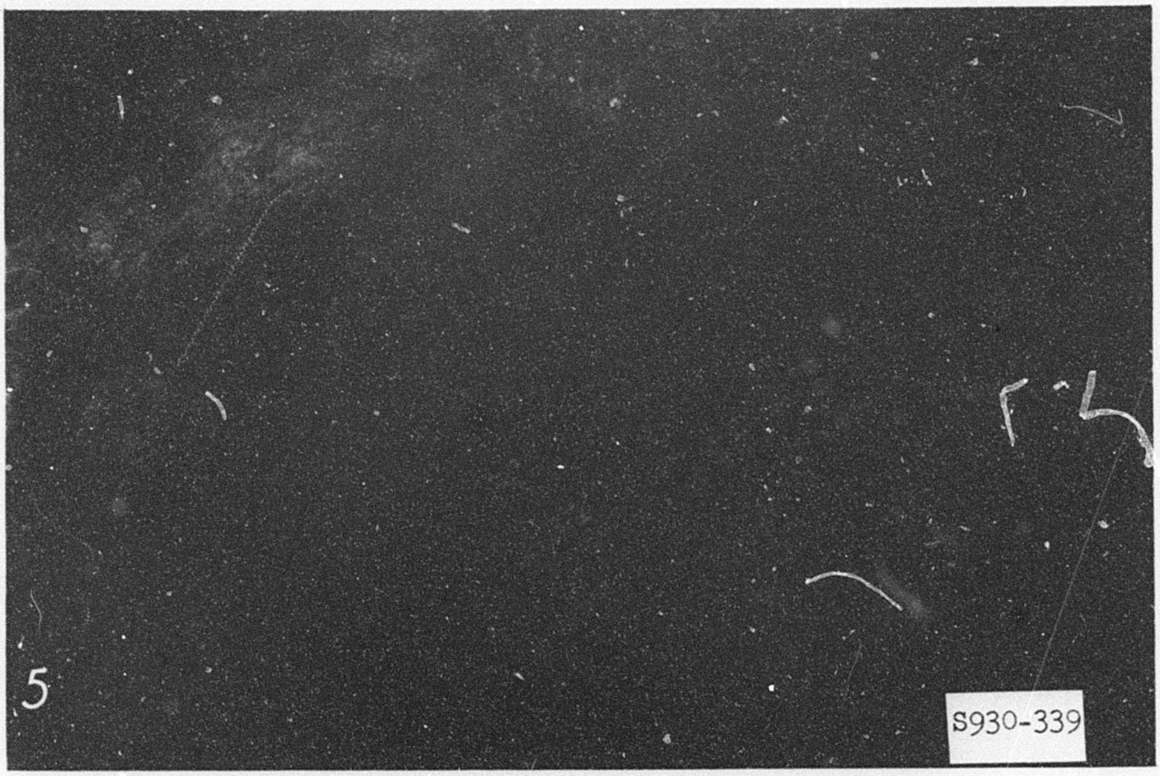


Photo 77. Typical wear on membrane sheet 3A of test section 1 after 662 coverages (1200 total coverages on test section)

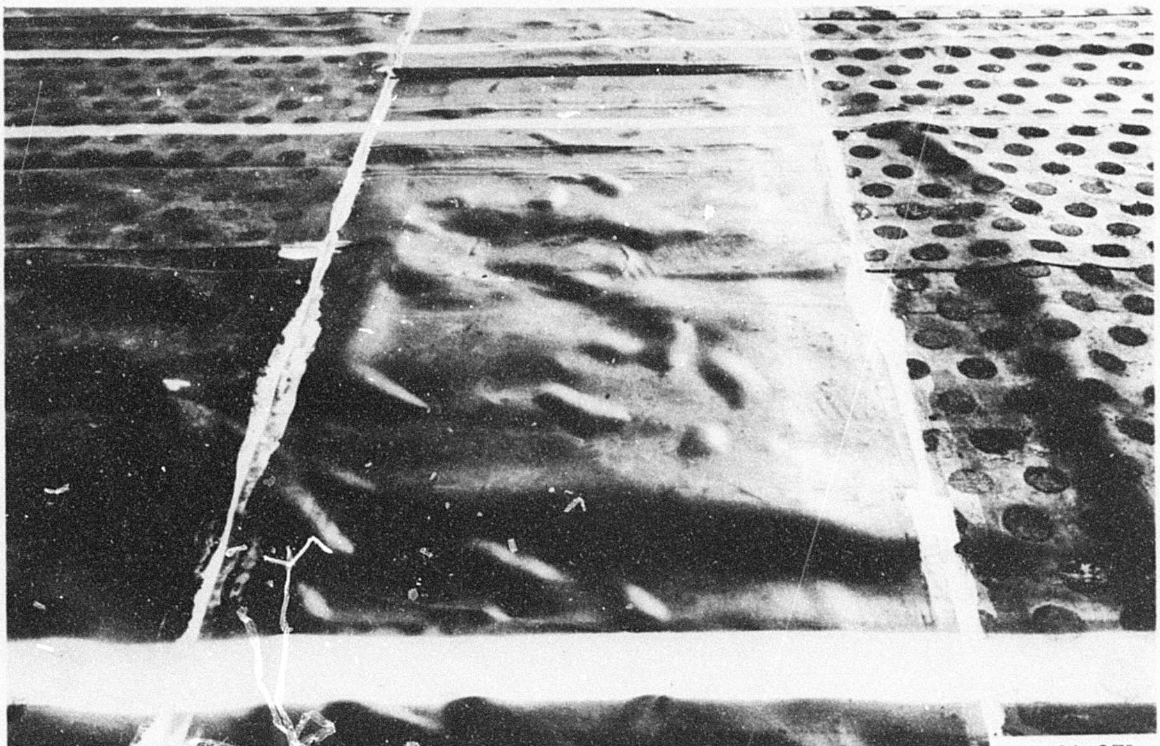


Photo 78. Condition of reinforcing strip and joint sealant prior to traffic on test section 2

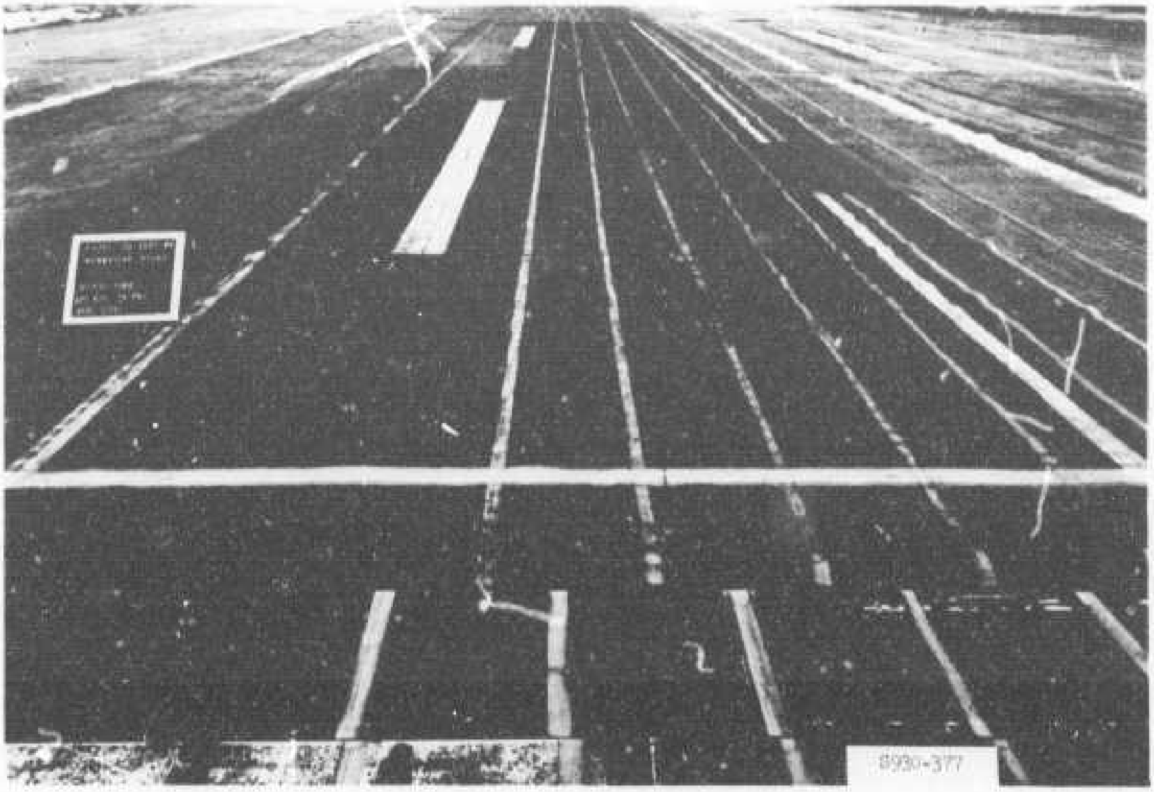


Photo 79. General condition of traffic test section 2 after 200 coverages

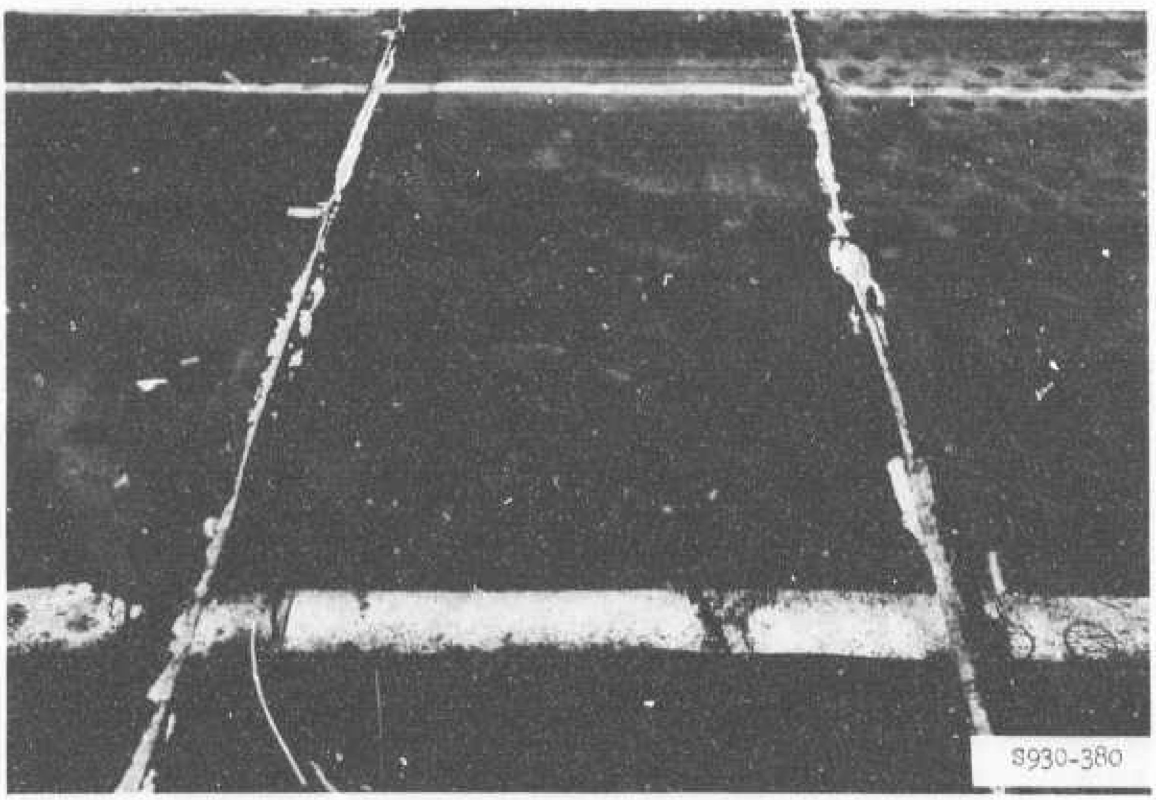


Photo 80. General condition of reinforcing strip and joint sealant of traffic test section 2 after 200 coverages

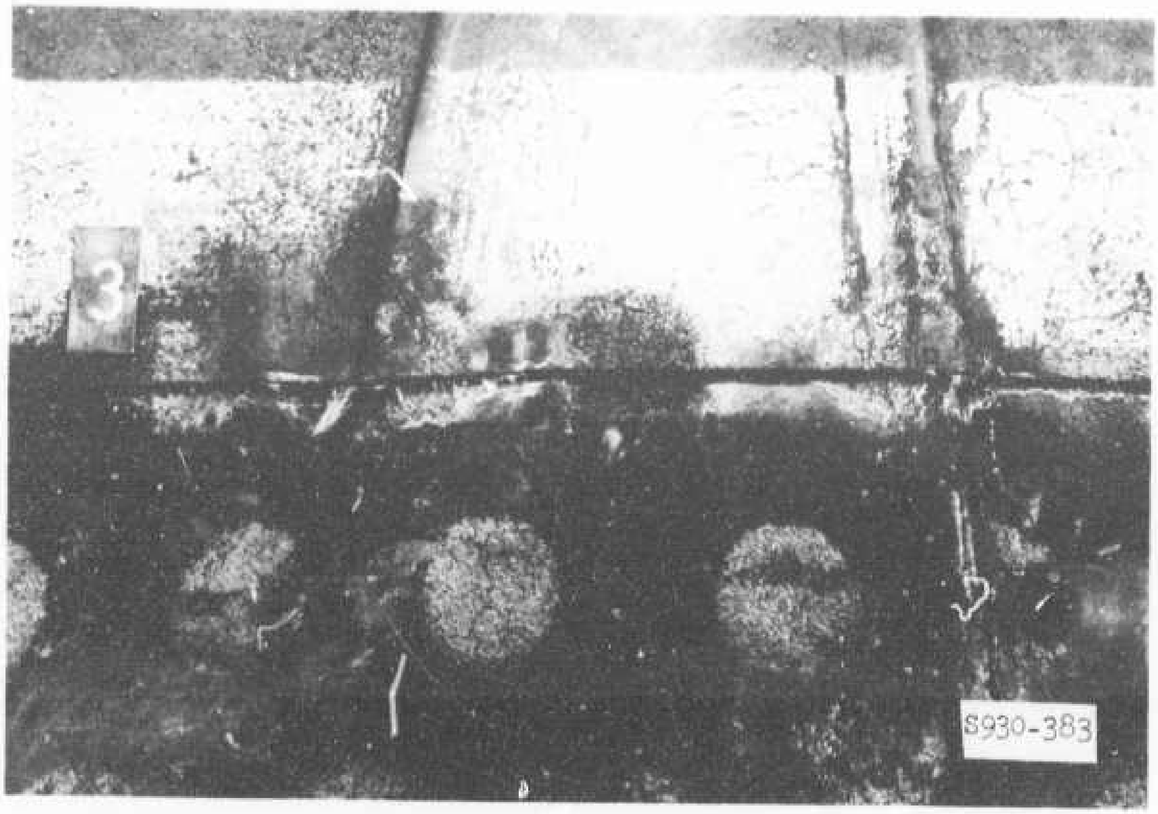


Photo 81. Peeling of 6-in.-wide factory fabrication joints on test section 2 at 200 coverages

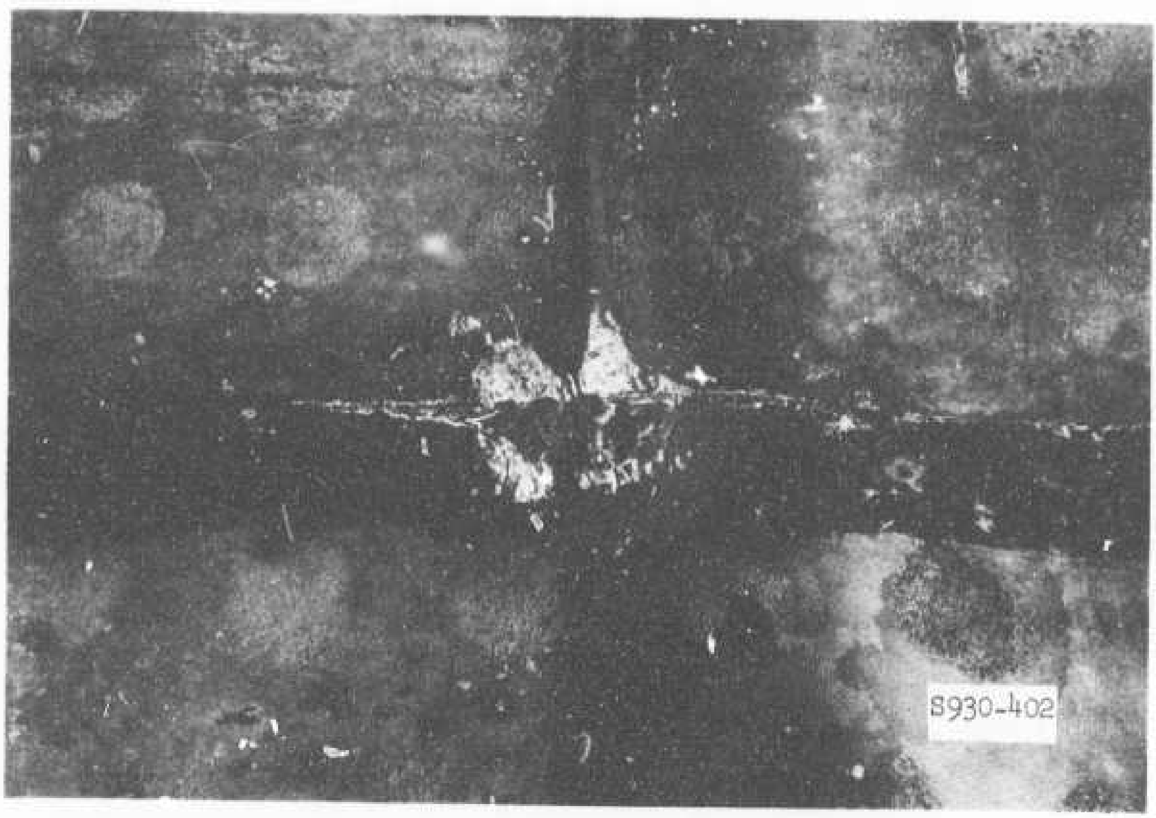


Photo 82. Use of 3M Weatherban sealant on peeling 6-in.-wide factory fabrication joint of test section 2

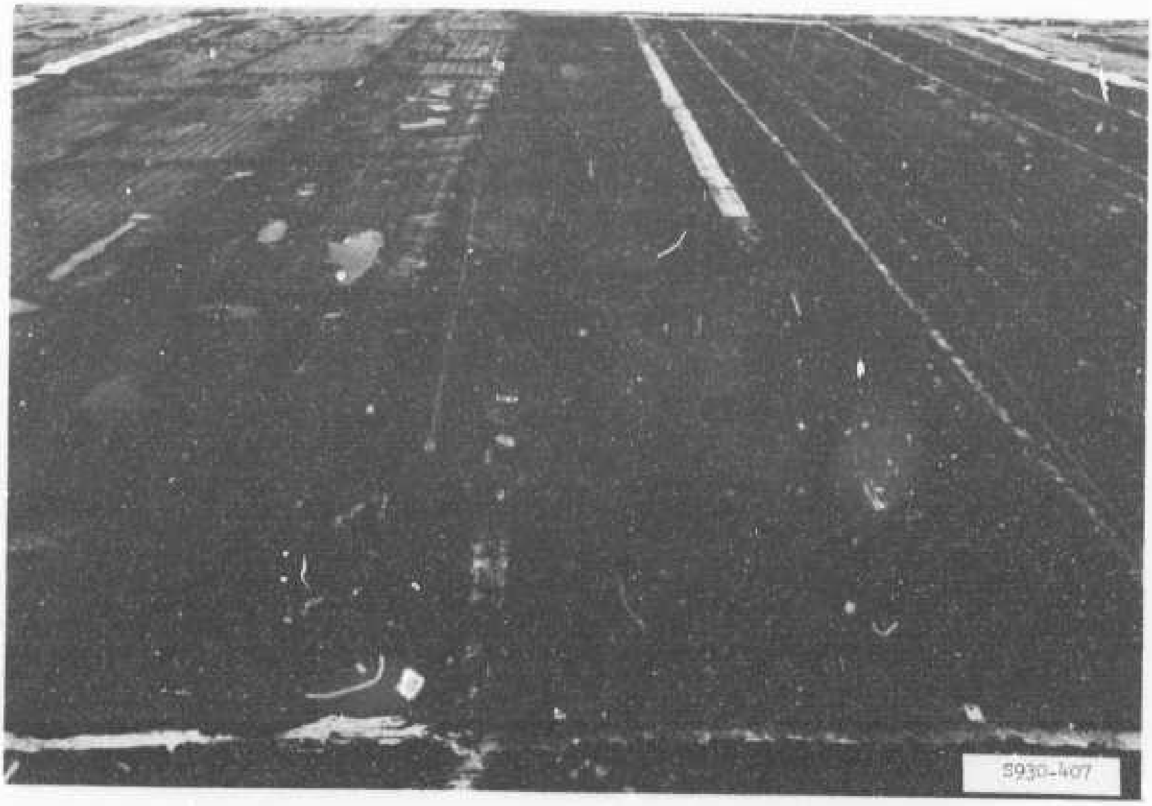


Photo 83. 54-in.-wide run of material of sheet 2 of test section 2 recoated with nonskid compound

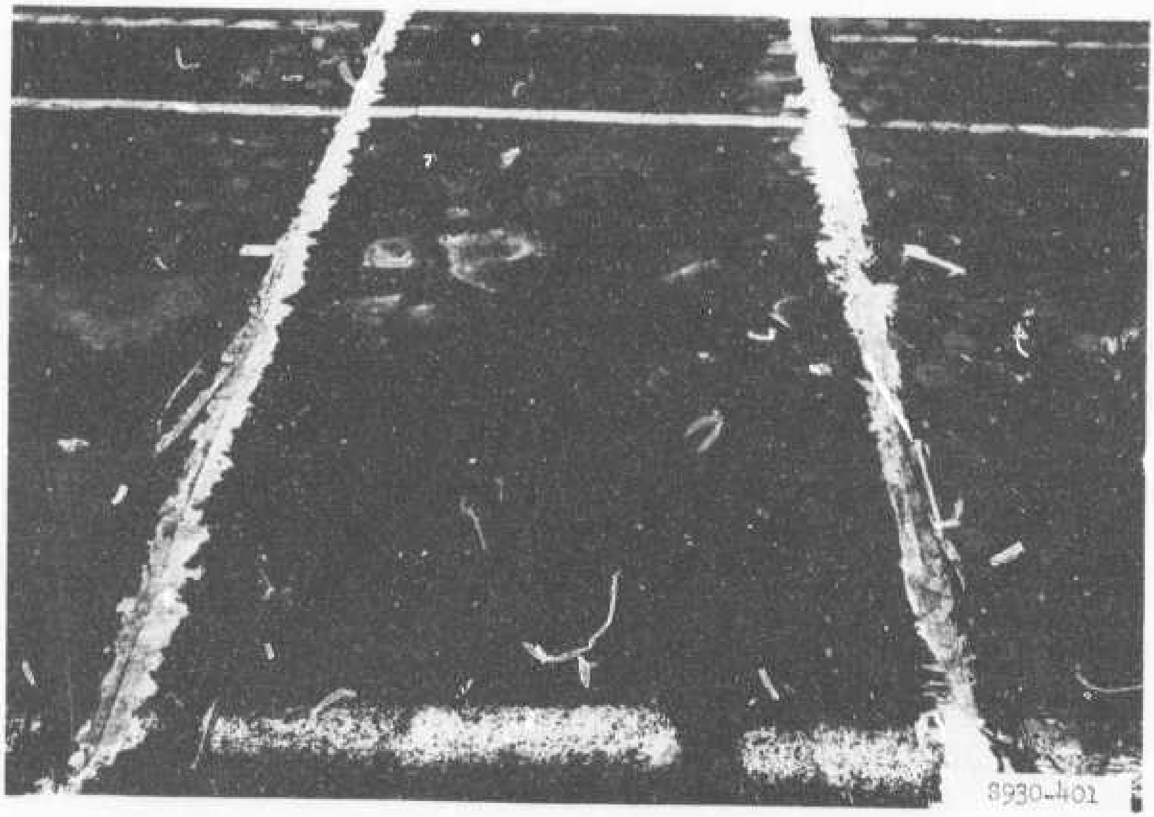


Photo 84. General condition of 3-ft-wide reinforcing strip after 600 coverages on test section 2

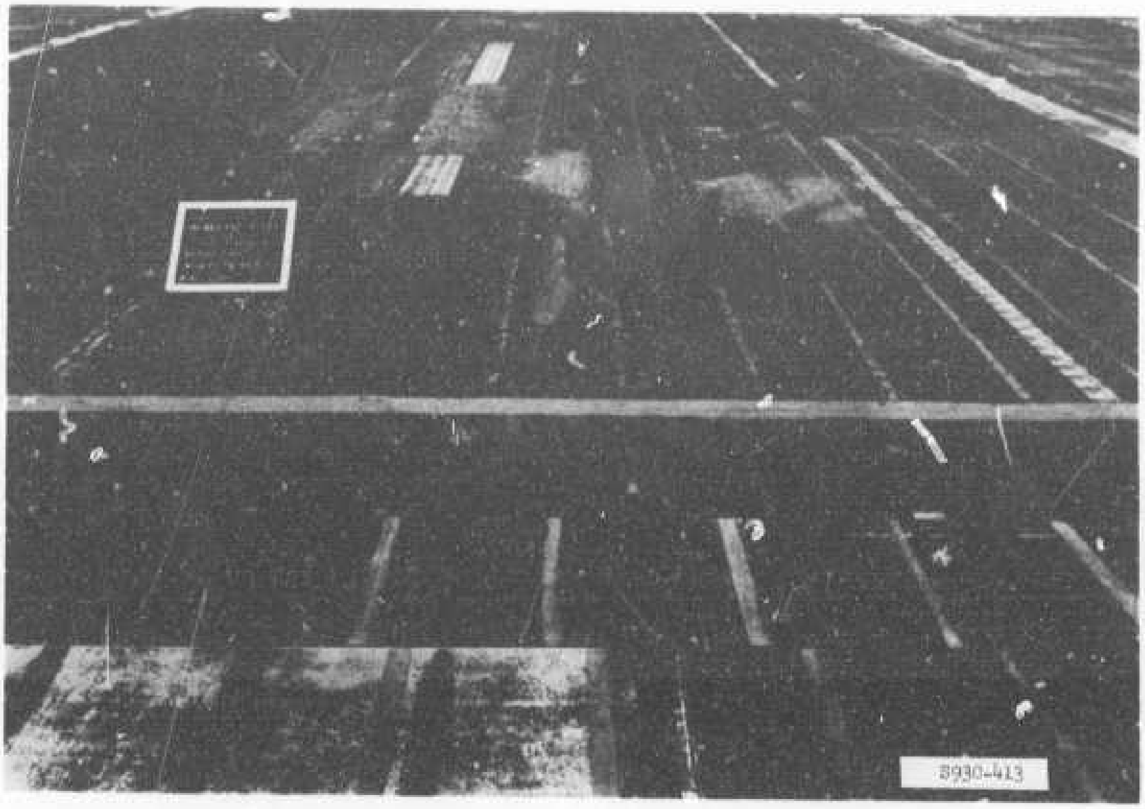


Photo 85. General condition of sheet 1 of test section 2 after 800 coverages

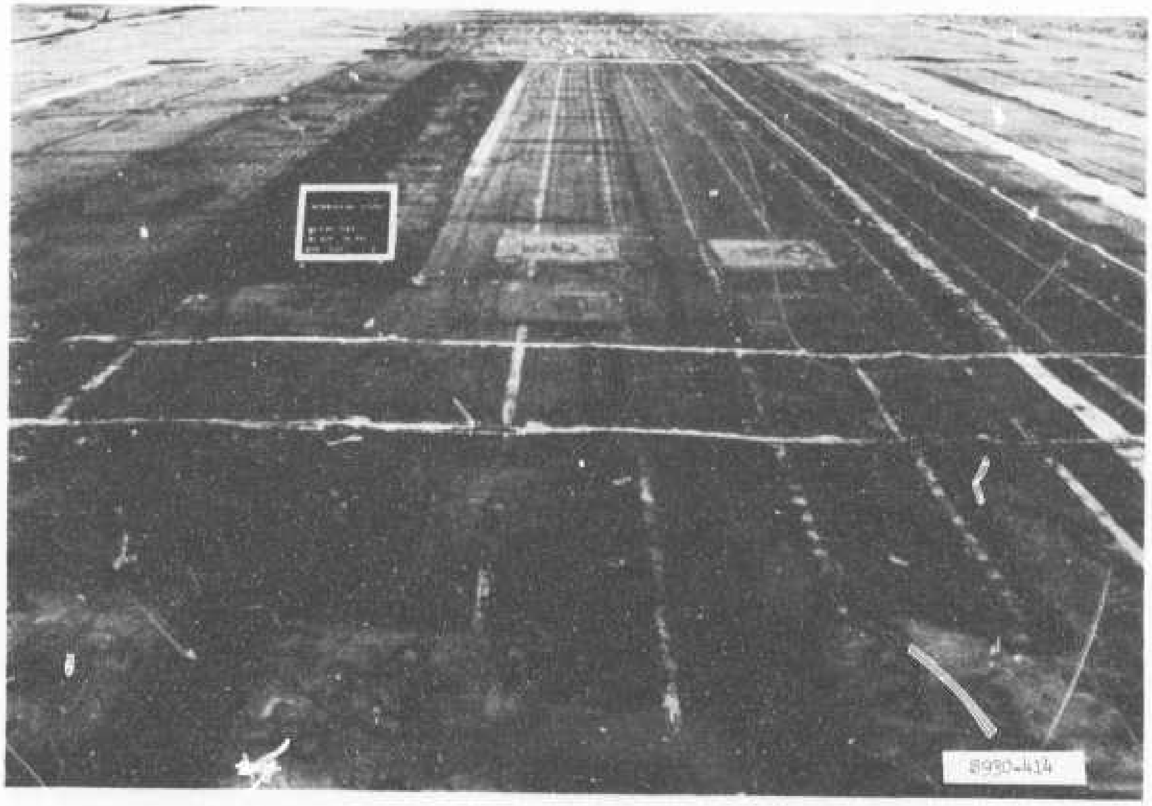


Photo 86. General condition of sheet 2 of test section 2 after 800 coverages

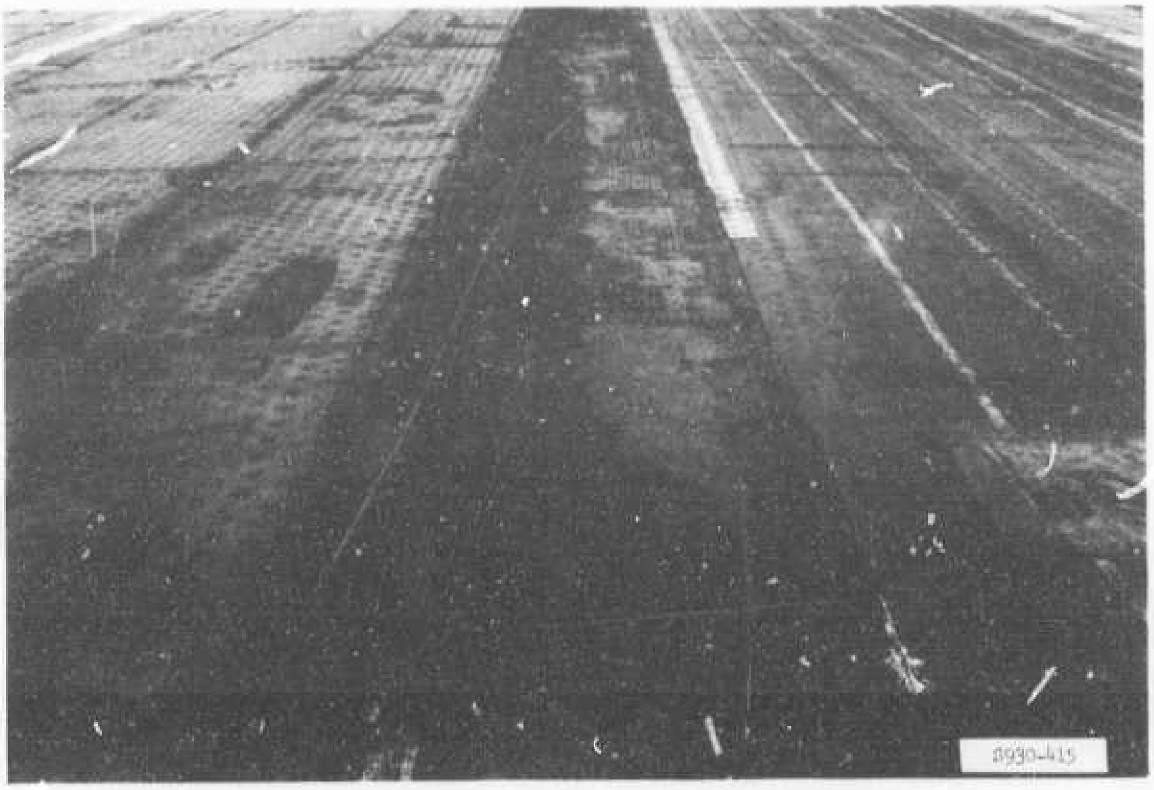


Photo 87. General condition of 54-in.-wide run of material that was recoated with nonskid after 200 coverages on test section 2

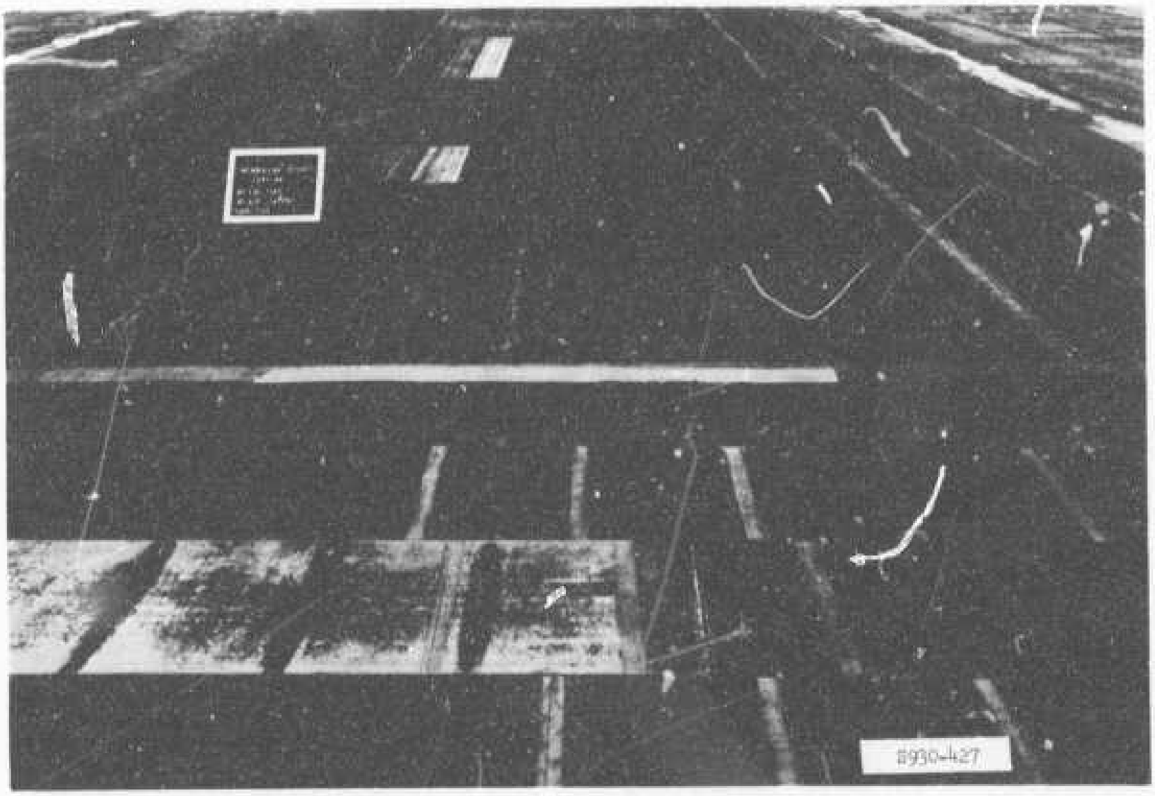


Photo 88. General condition of sheet 1 of test section 2 after 1000 coverages

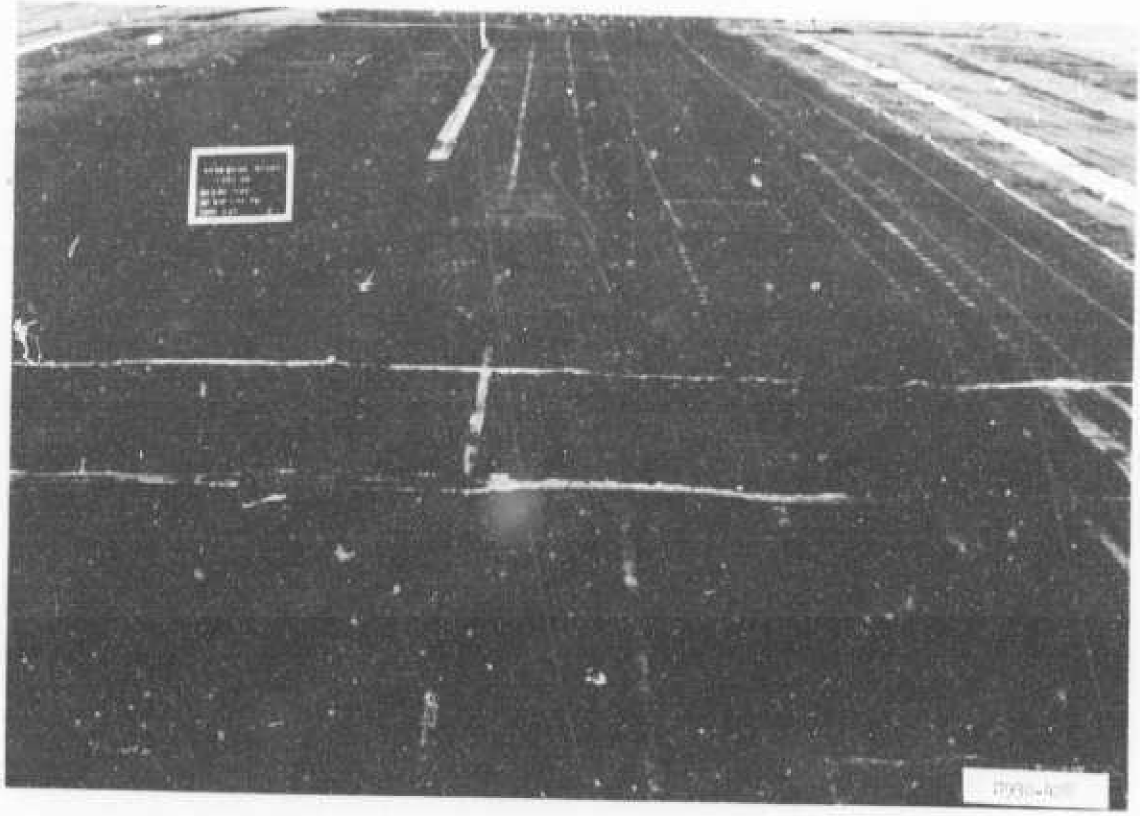


Photo 89. General condition of sheet 2 of test section 2 after 1000 coverages

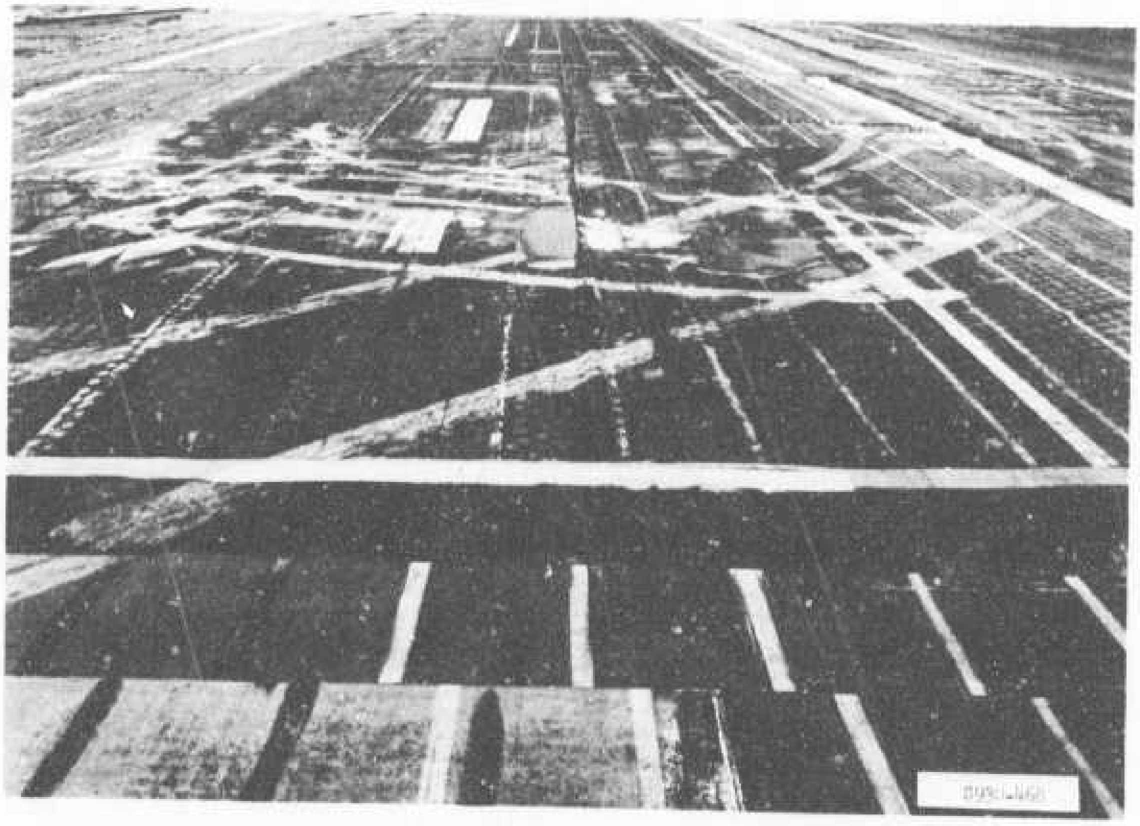


Photo 90. General condition of test section 2 after 1200 coverages

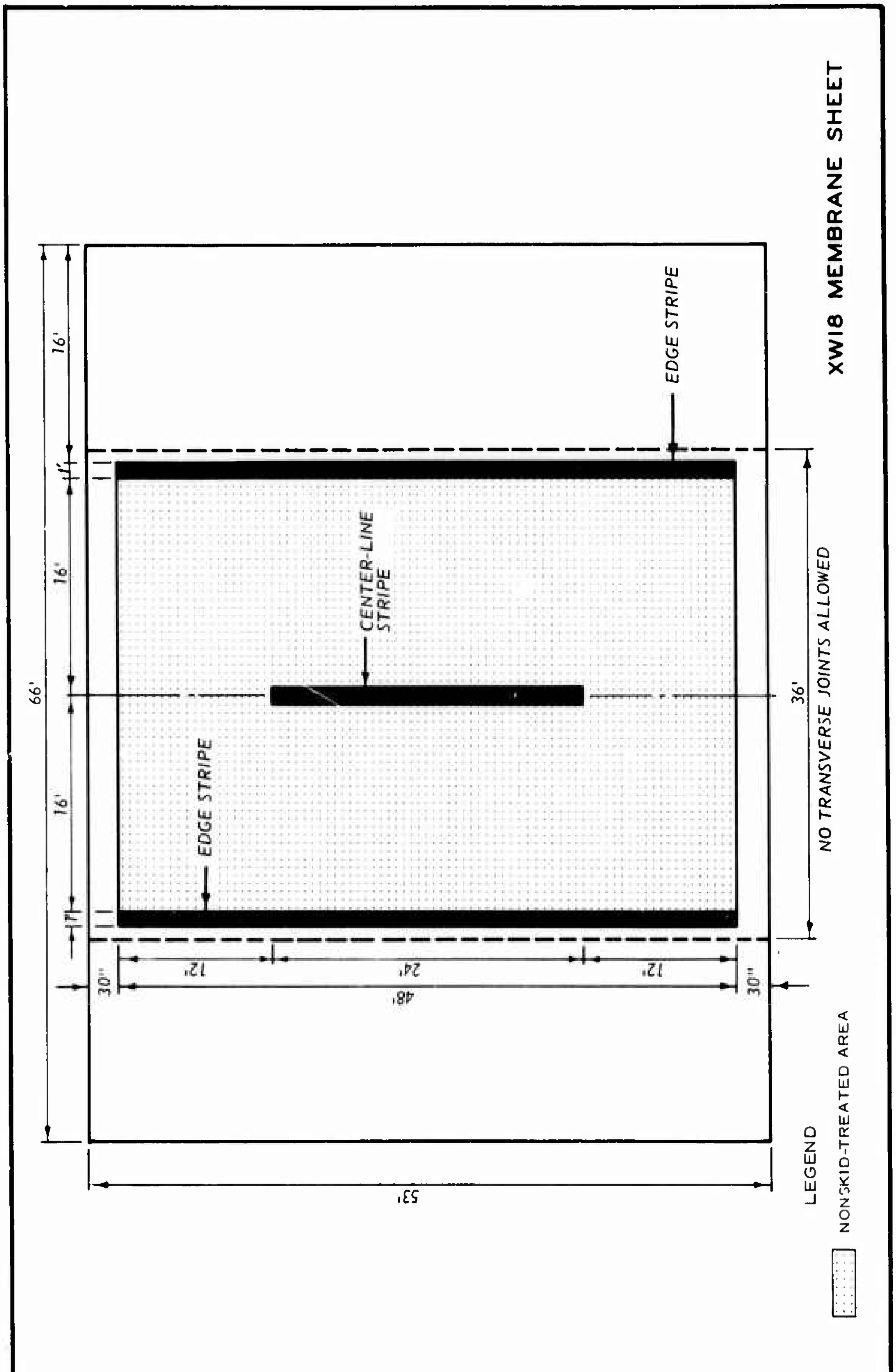
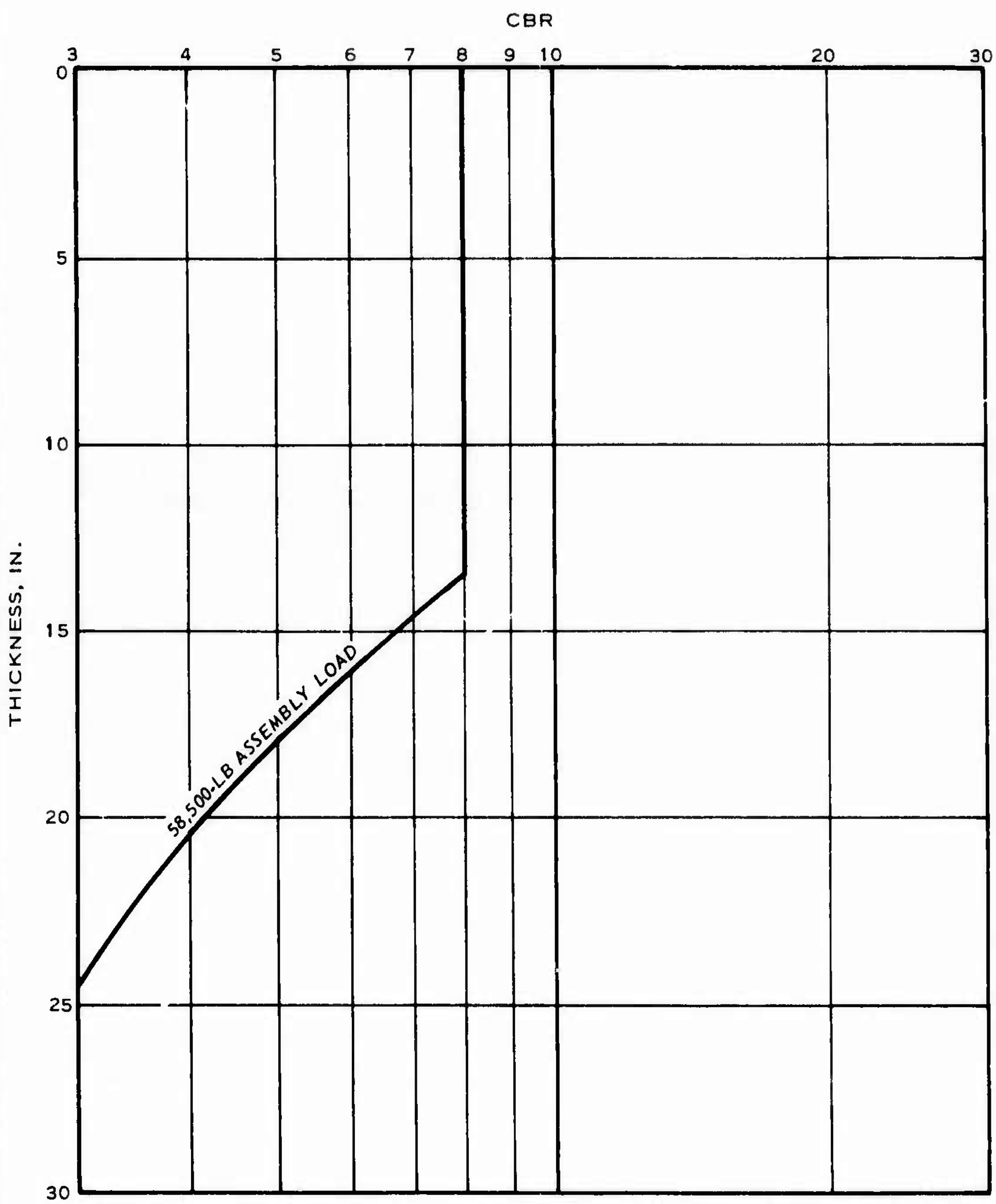
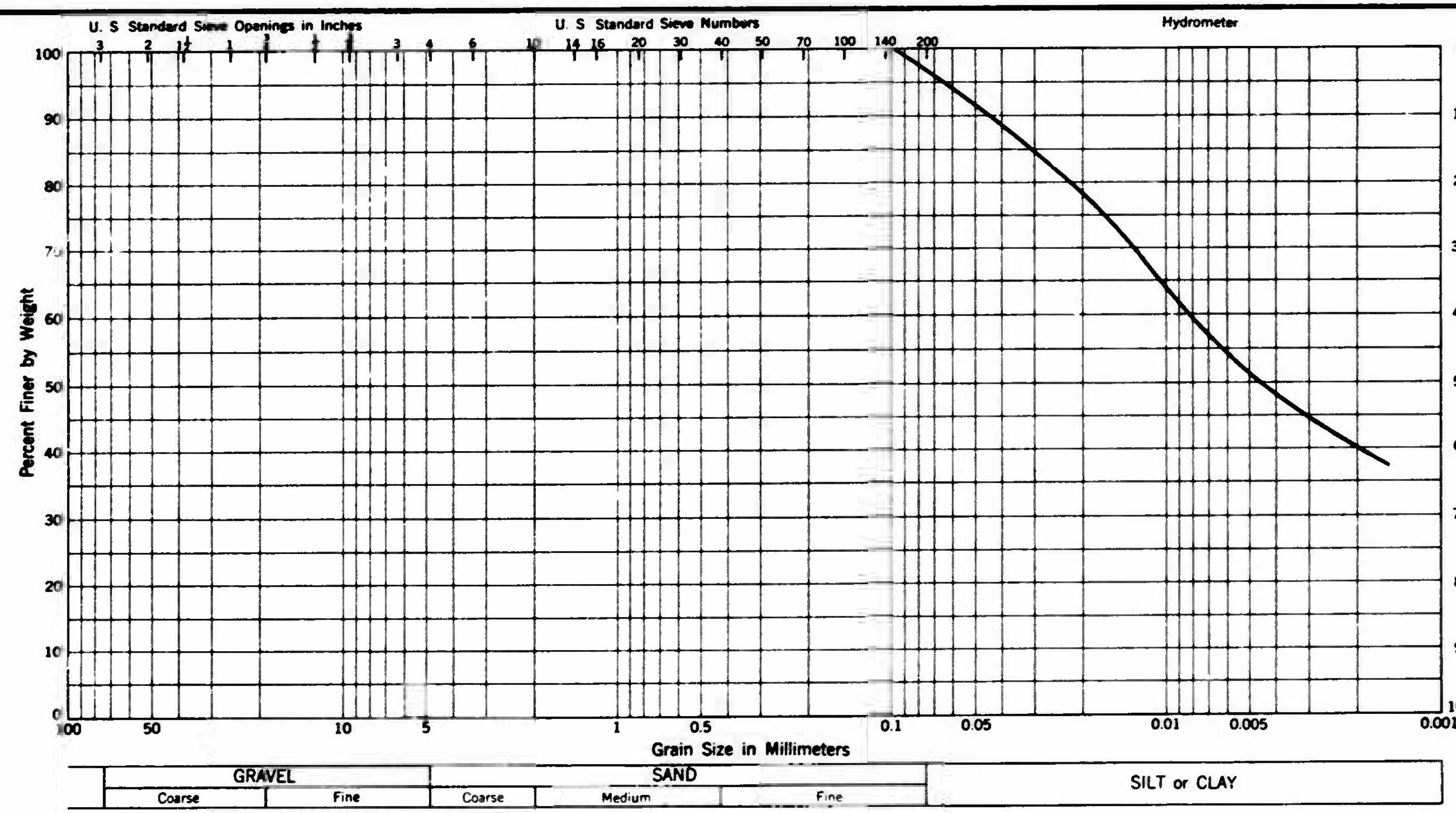

XW18 MEMBRANE SHEET
EDGE STRIPE
CENTER-LINE STRIPE
EDGE STRIPE
NO TRANSVERSE JOINTS ALLOWED
16'
1'
16'
16'
1'
66'
36'
12'
24'
12'
48'
30"
30"
53'
LEGEND
NONSKID-TREATED AREA

PLATE 1



CBR DESIGN CURVE FOR
MEMBRANE-SURFACED SOIL

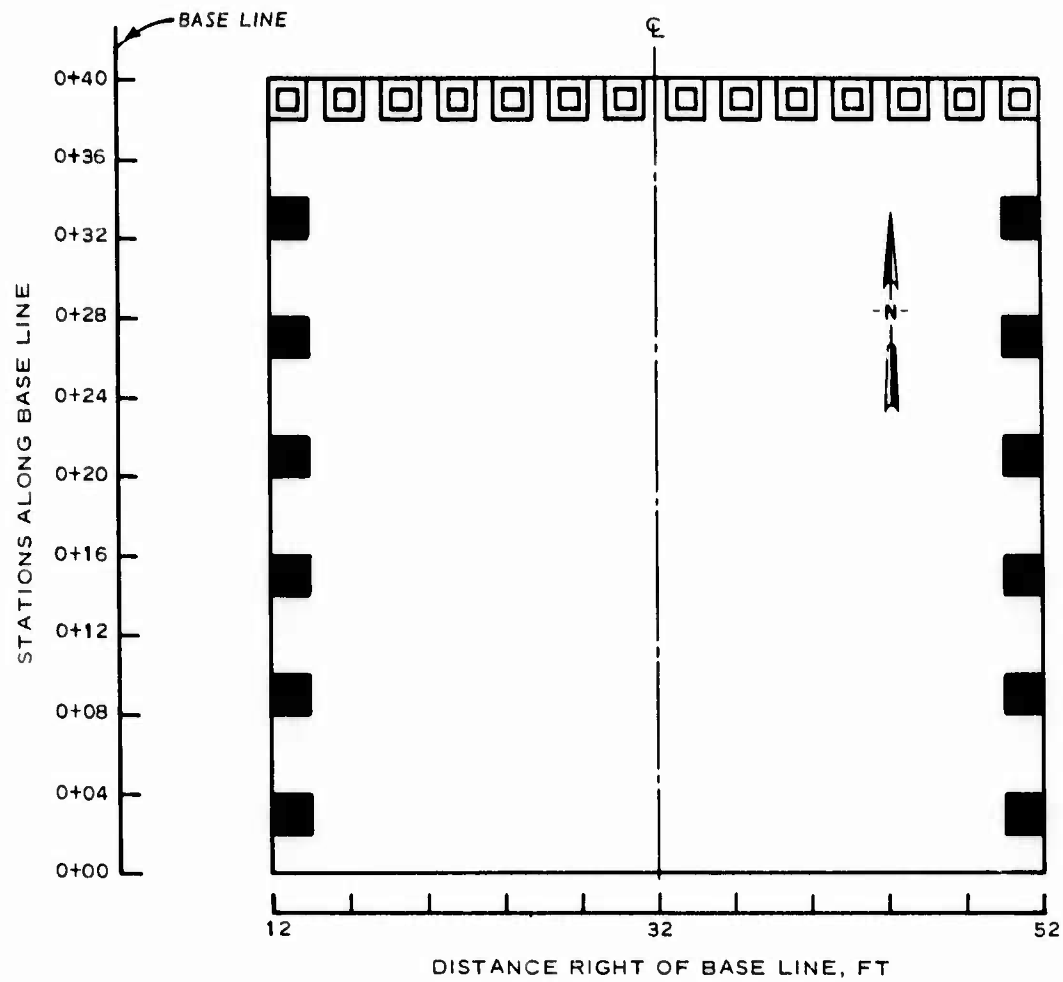
C-130 AIRCRAFT, 130,000-LB GROSS LOAD
400-SQ-IN. CONTACT AREA
200 COVERAGES



Number	Depth	Natural Moisture	L L	P. L	P. I.	Classification
	0-18"		54	21	33	CLAY (CH)

CLASSIFICATION DATA AND GRADATION CURVE

CLAY USED IN TEST SECTIONS FOR C-130 SKID TESTS

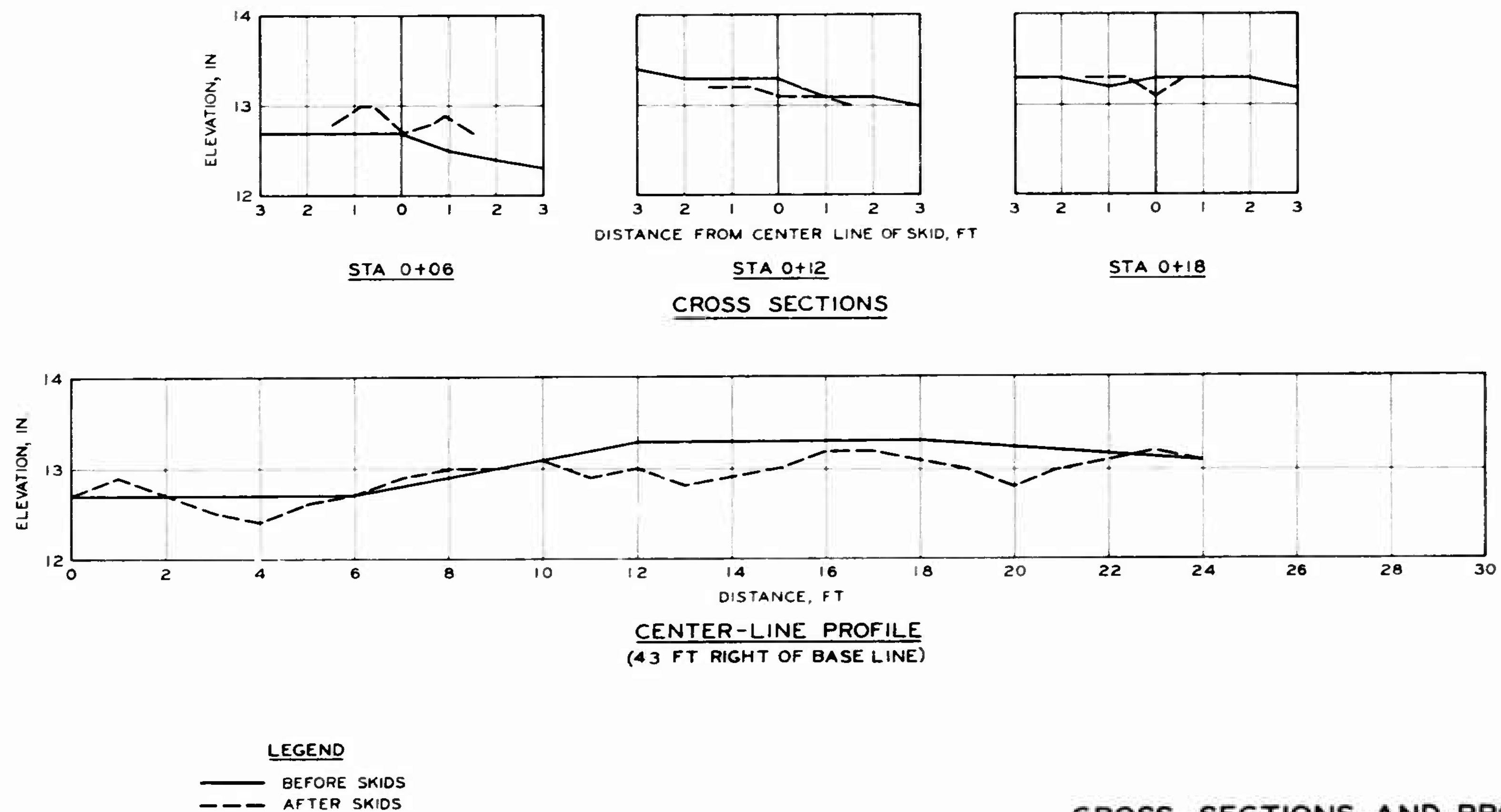


LEGEND

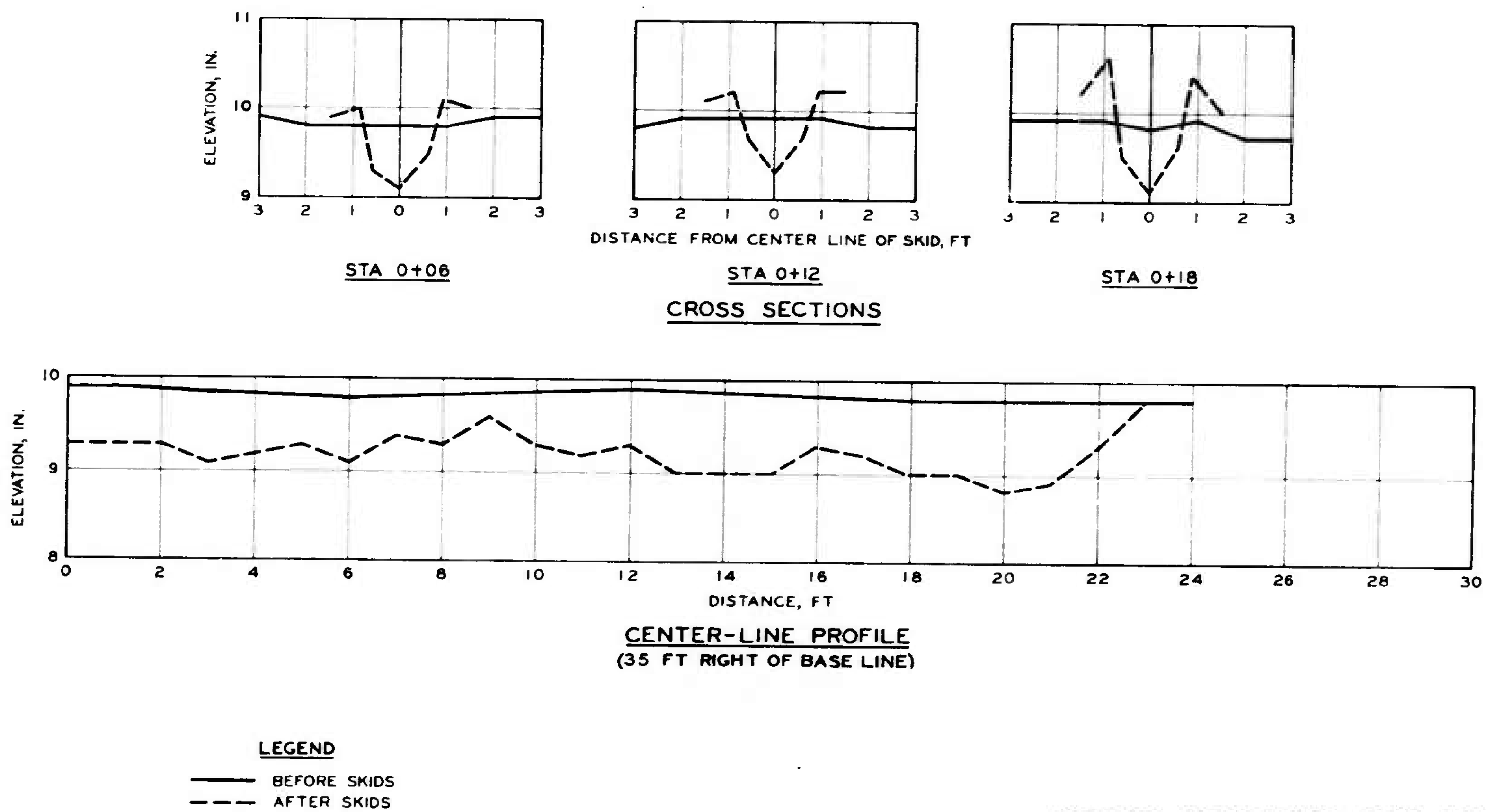
- STACK OF FOUR 1-TON LEAD WEIGHTS
- SINGLE 1-TON LEAD WEIGHT

TYPICAL LAYOUT
OF SOIL TEST SECTION
AND ANCHOR SYSTEM FOR
SKID TESTS

PLATE 4



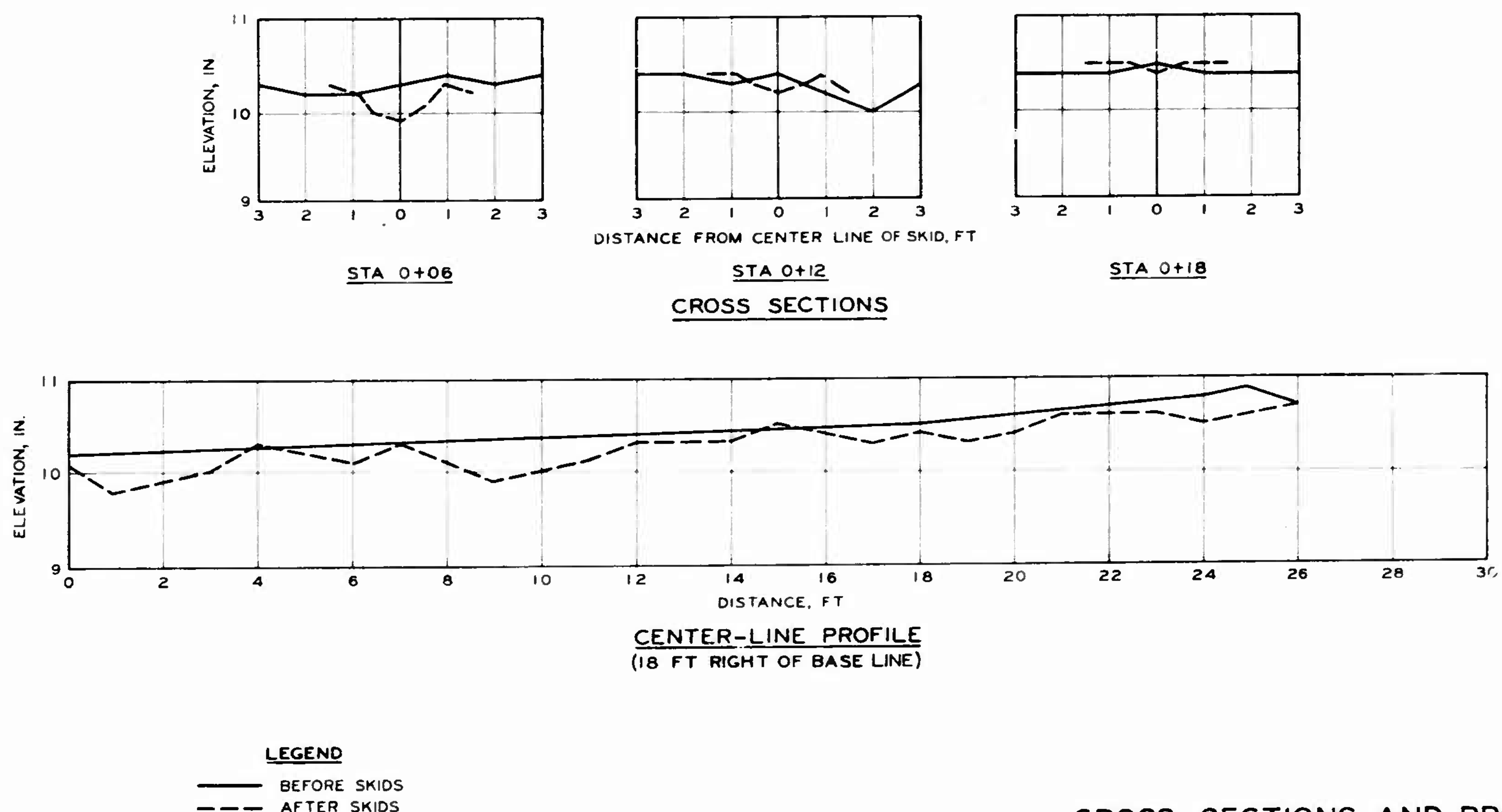
CROSS SECTIONS AND PROFILE
XW18 MEMBRANE
SECTION 1
DETERMINATION OF
COEFFICIENT OF FRICTION



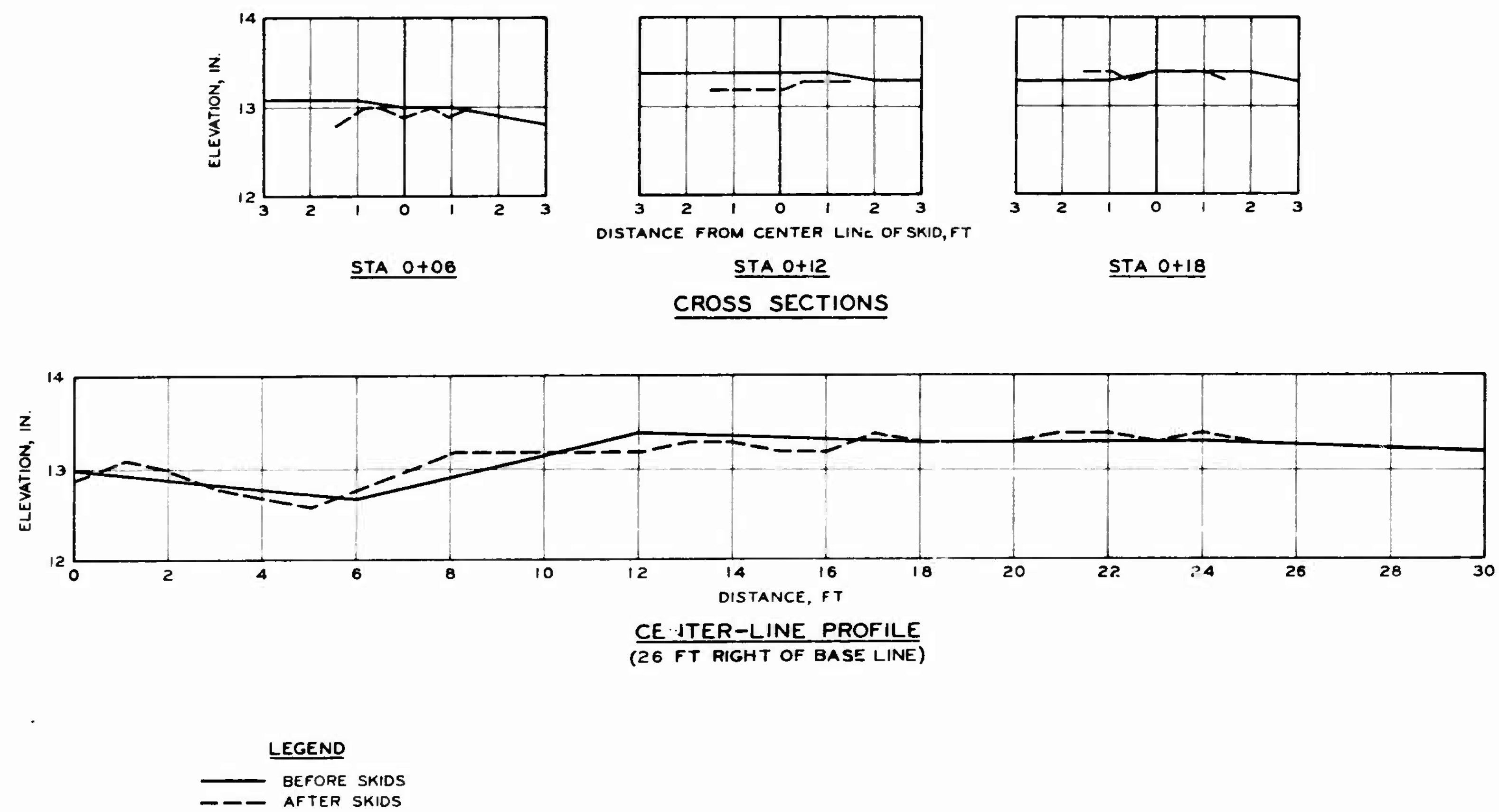
CROSS SECTIONS AND PROFILE
XW18 MEMBRANE

SECTION 2
DETERMINATION OF
COEFFICIENT OF FRICTION

PLATE 6

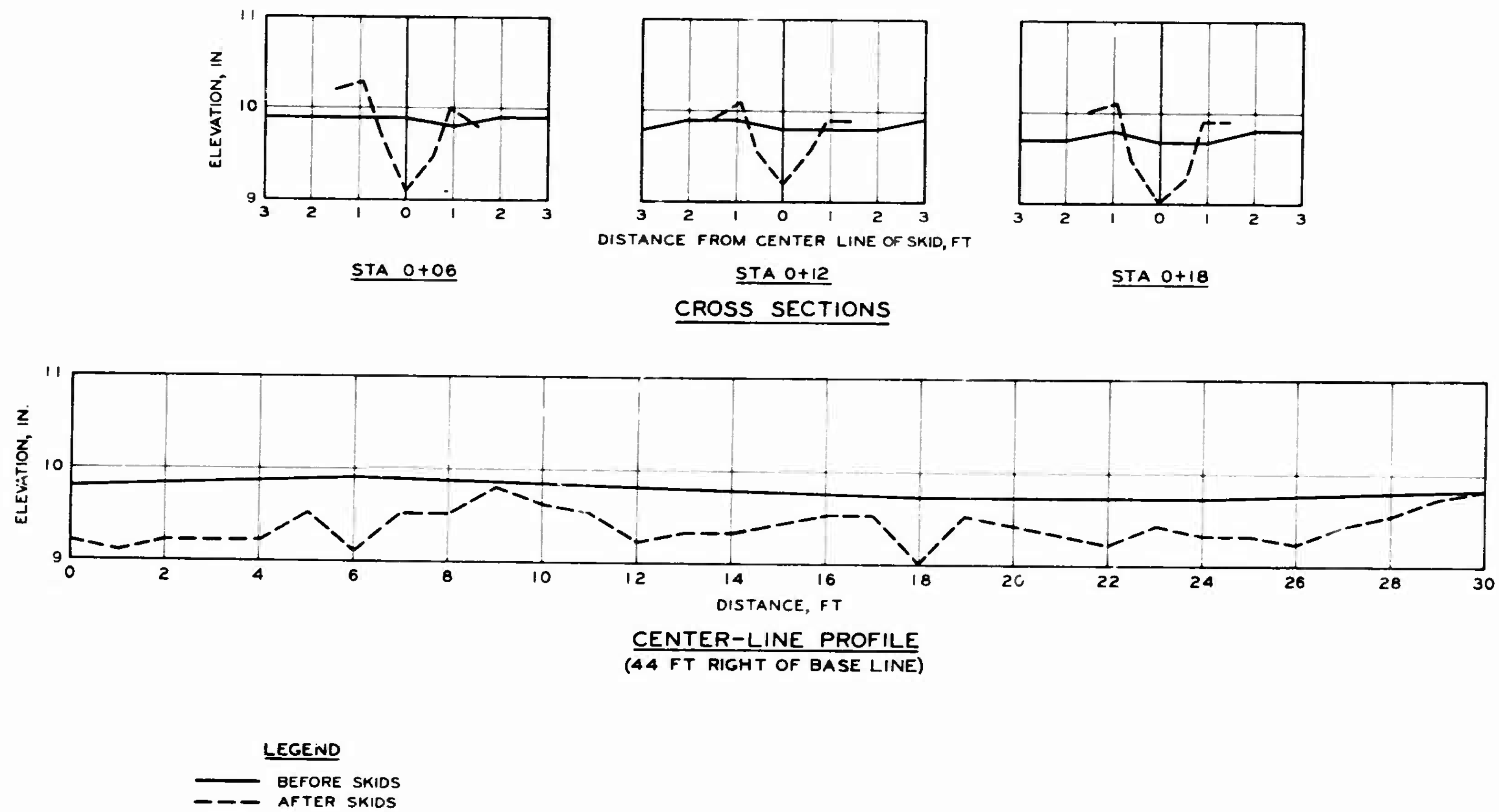


CROSS SECTIONS AND PROFILE
XW18 MEMBRANE
SECTION 3
DETERMINATION OF
COEFFICIENT OF FRICTION



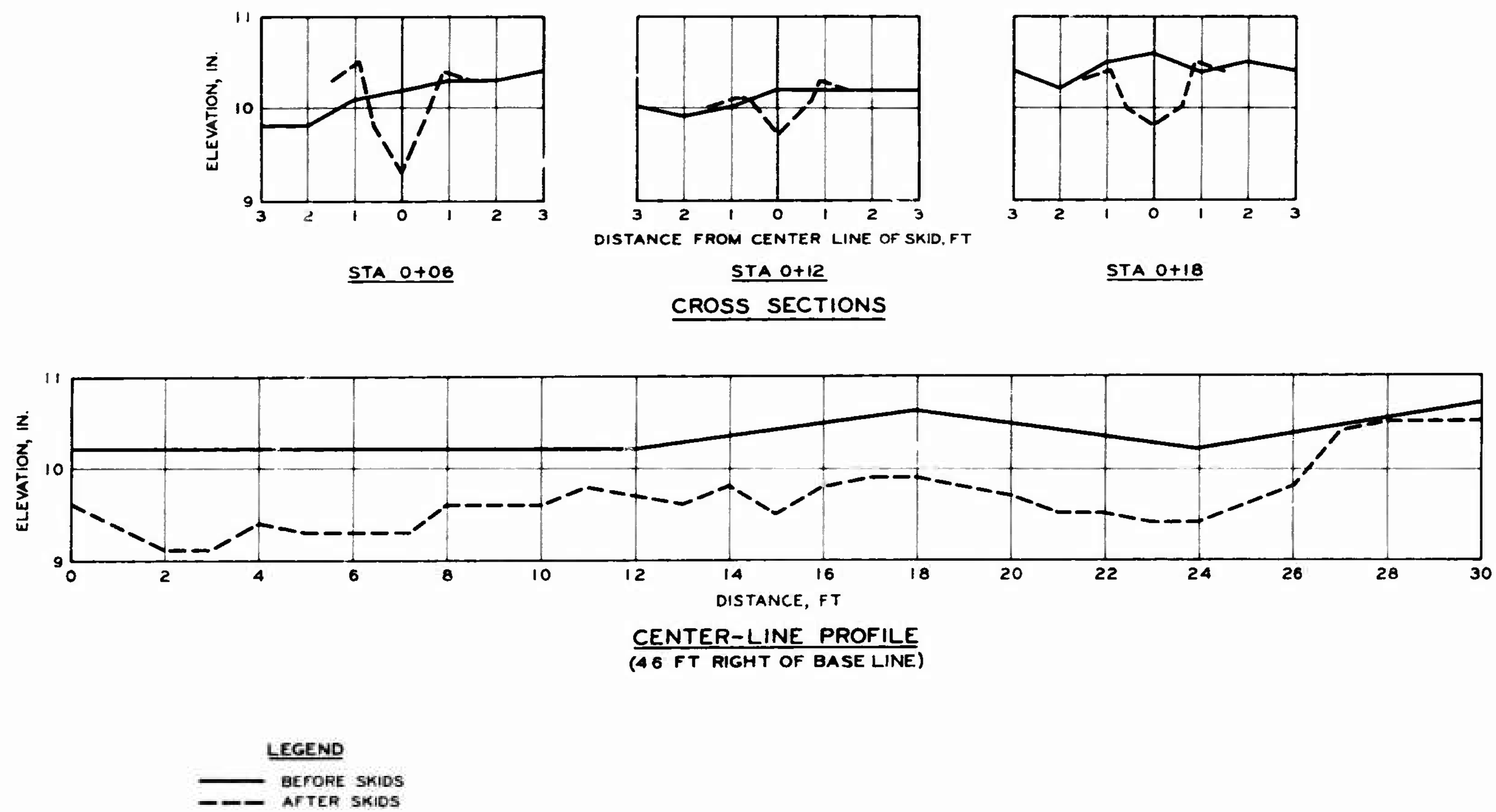
CROSS SECTIONS AND PROFILE
XW18 MEMBRANE
SECTION 1, RUN 1
FAILURE POINT DETERMINATION

PLATE 8



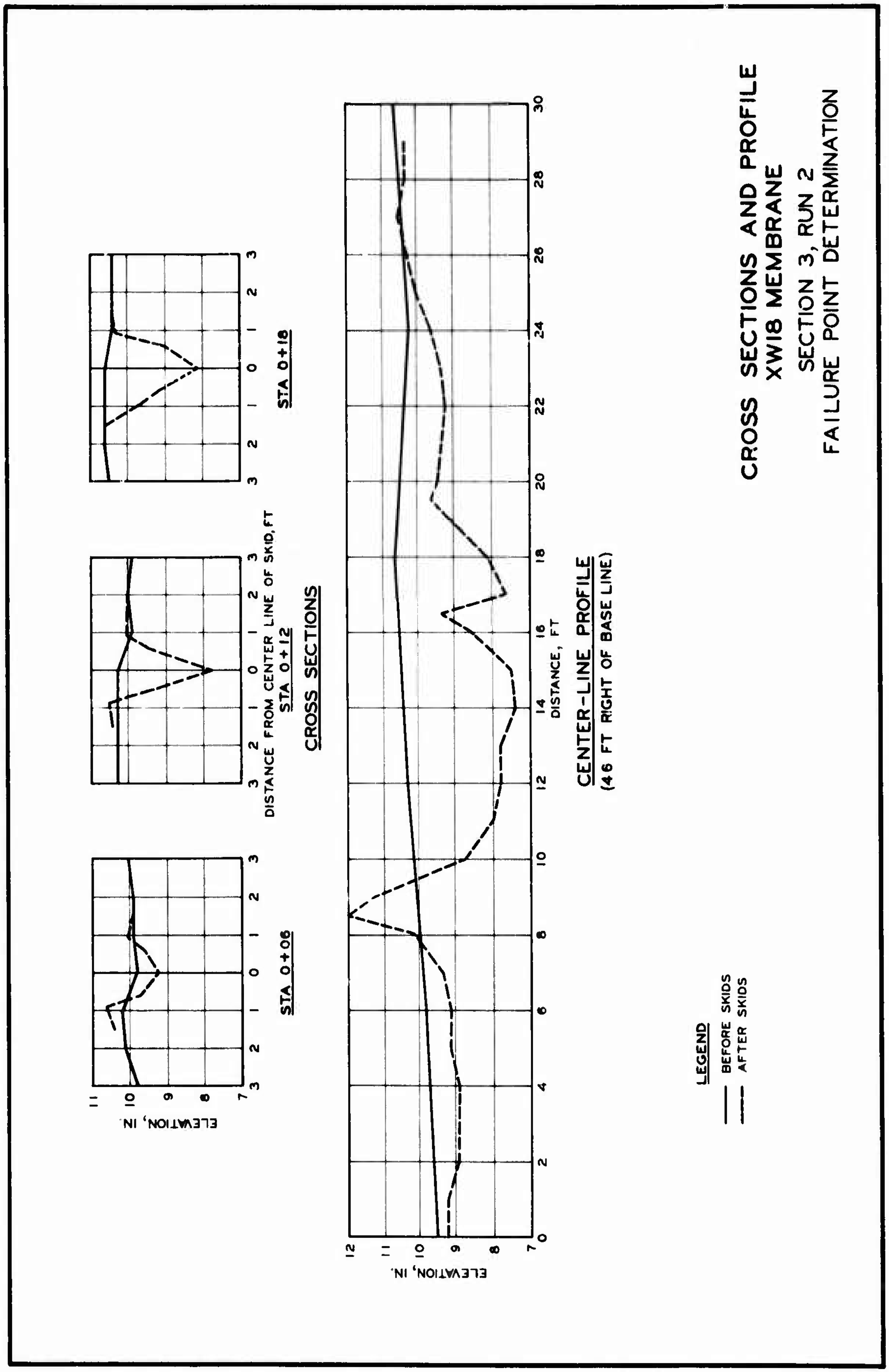
CROSS SECTIONS AND PROFILE
XW18 MEMBRANE

SECTION 2, RUN 1
FAILURE POINT DETERMINATION

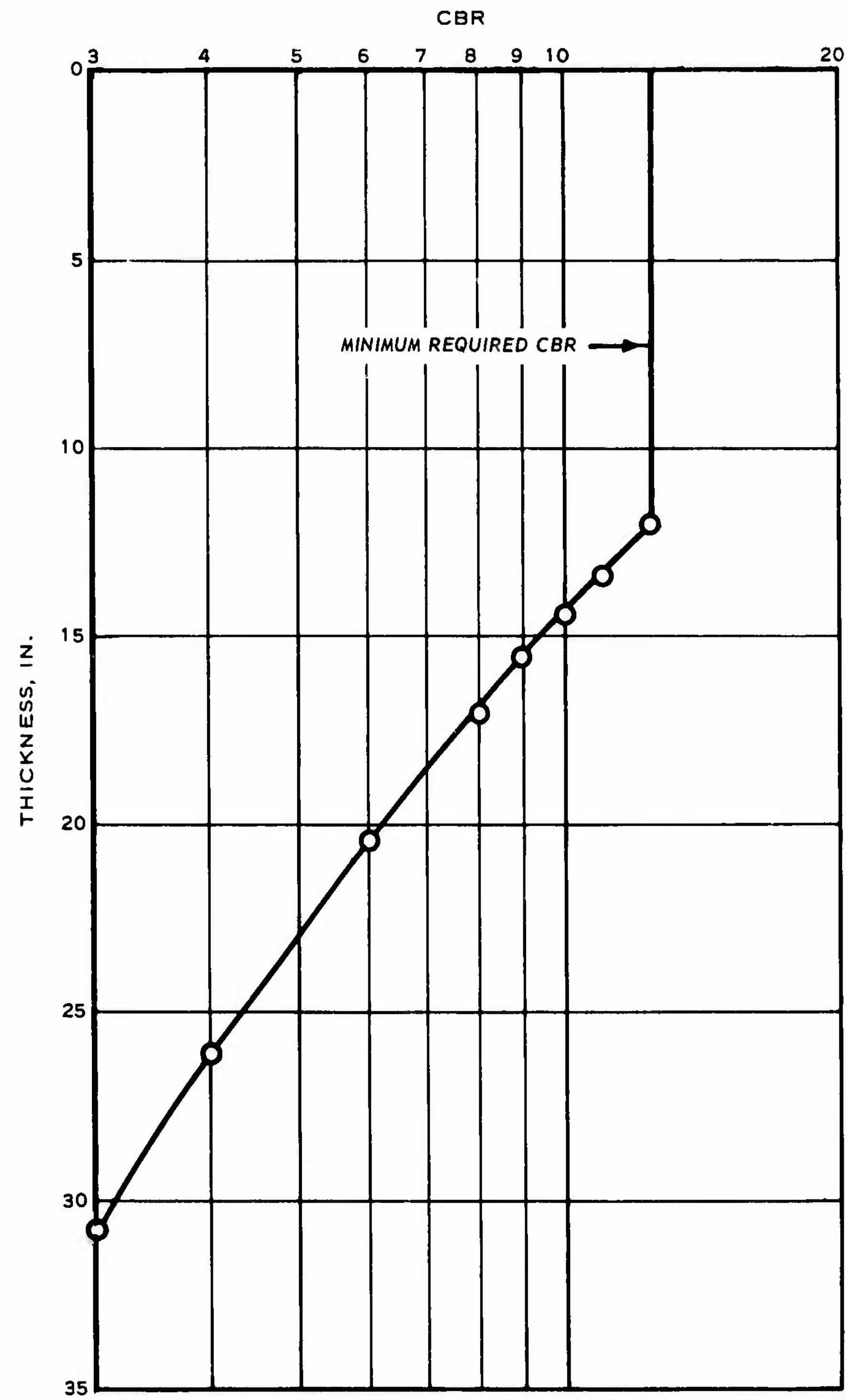


CROSS SECTIONS AND PROFILE
XW18 MEMBRANE
SECTION 3, RUN 1
FAILURE POINT DETERMINATION

PLATE 10



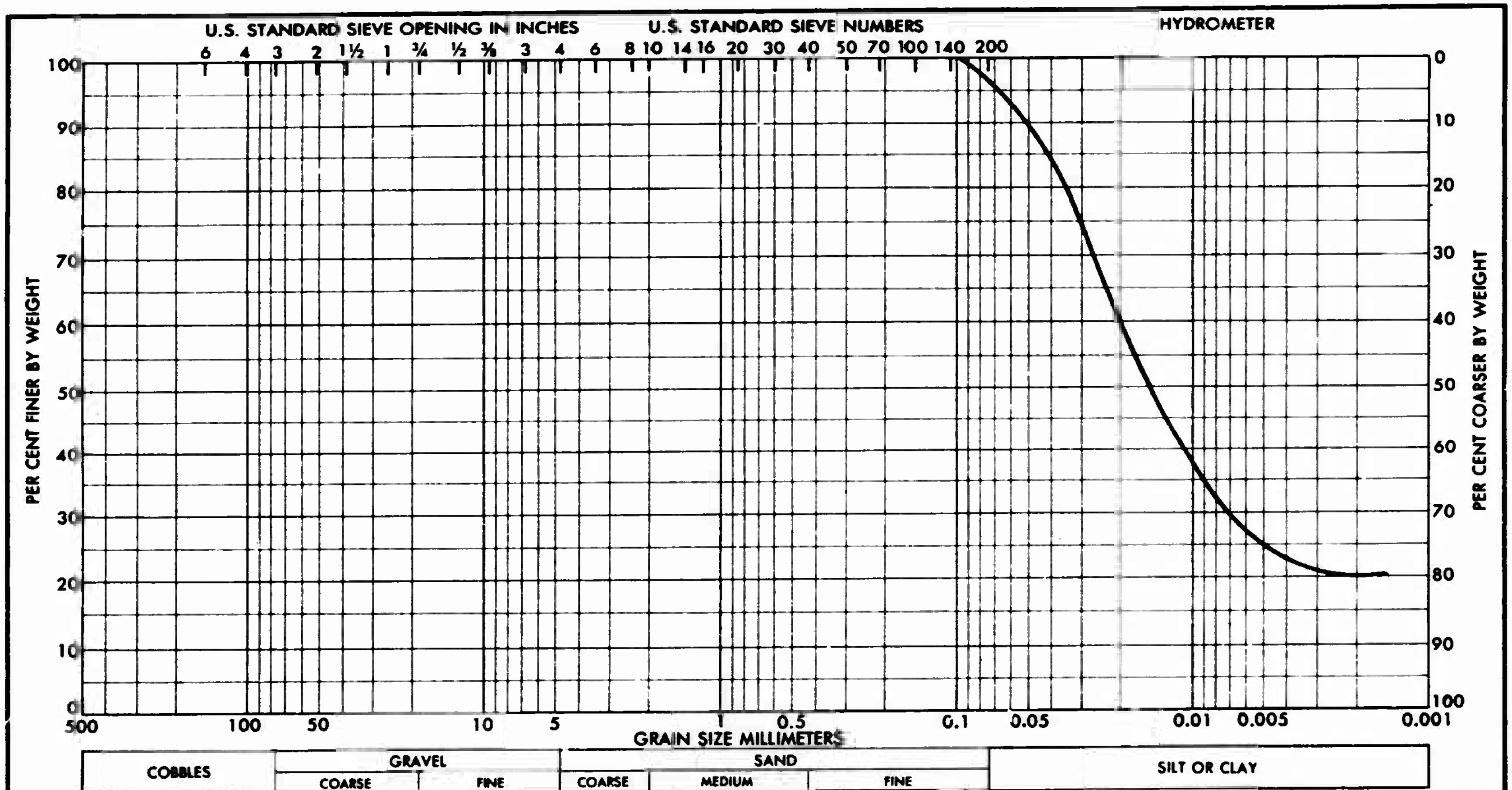
CROSS SECTIONS AND PROFILE
XW18 MEMBRANE
SECTION 3, RUN 2
FAILURE POINT DETERMINATION



CBR DESIGN CURVE FOR
C-130 AIRCRAFT

GROSS LOAD 130,000 LB
TIRE CONTACT AREA 400 SQ IN.
2,400 COVERAGES

PLATE 12



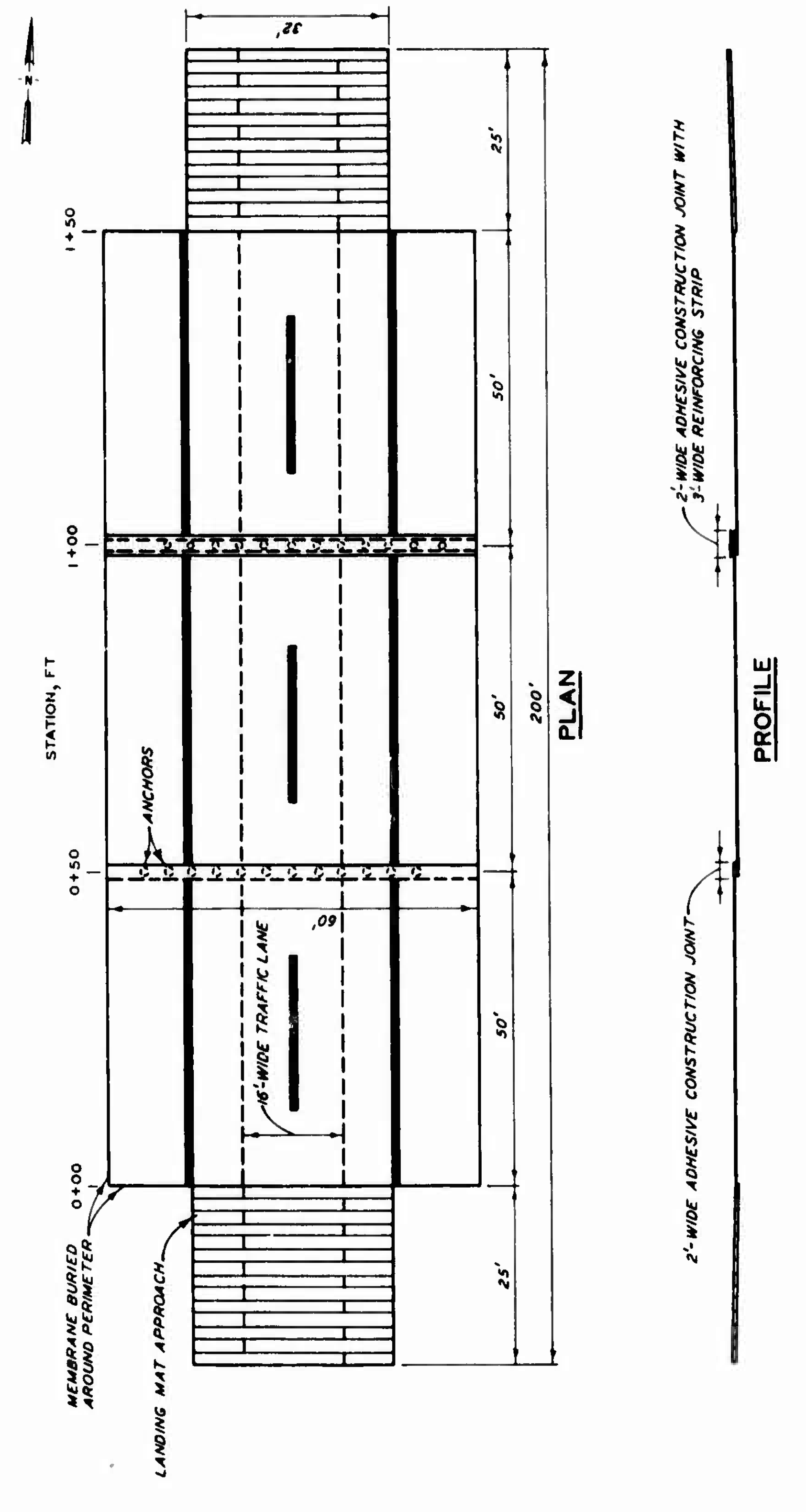
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
	0-30"	CLAY (CL)		36	21	15

GRADATION CURVES

CLASSIFICATION DATA AND GRADATION CURVE OF CLAY TEST SECTION (LEAN CLAY) USED FOR TRAFFIC TESTS

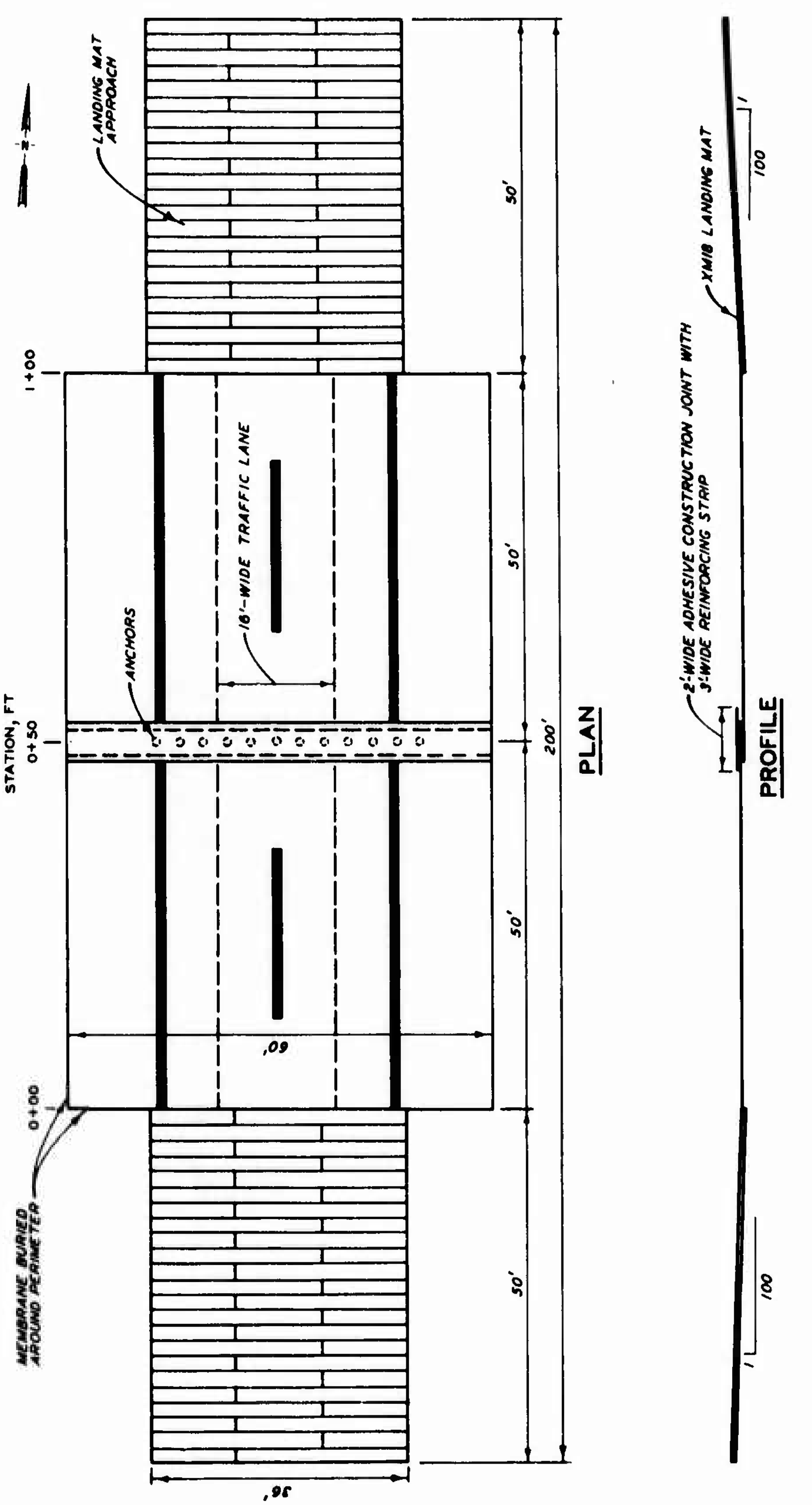
ENG FORM 2087
1 MAY 63
REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*

U.S. GOVERNMENT PRINTING OFFICE 1963 OF—709-126

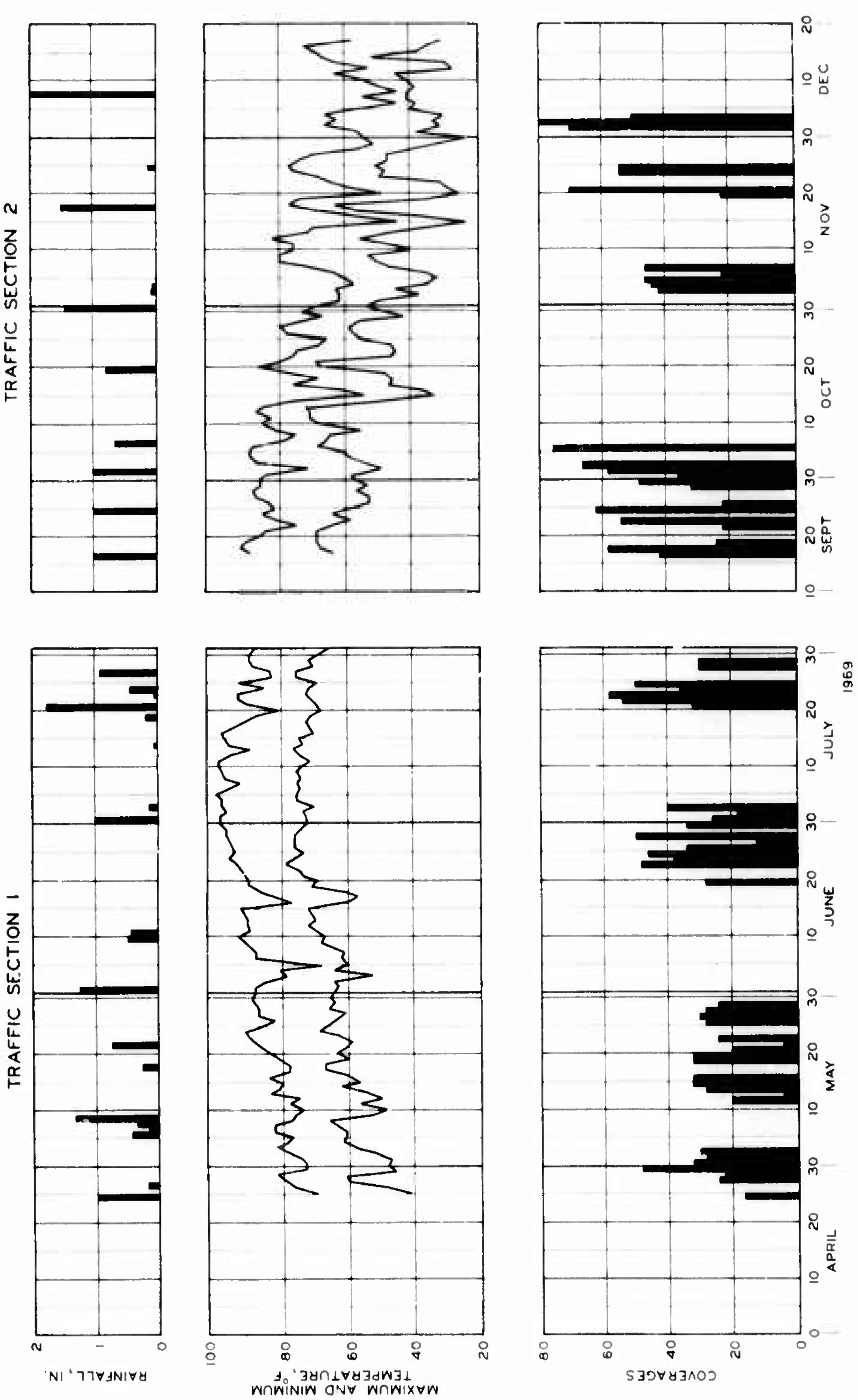


LAYOUT OF TRAFFIC TEST SECTION I

PLATE 14

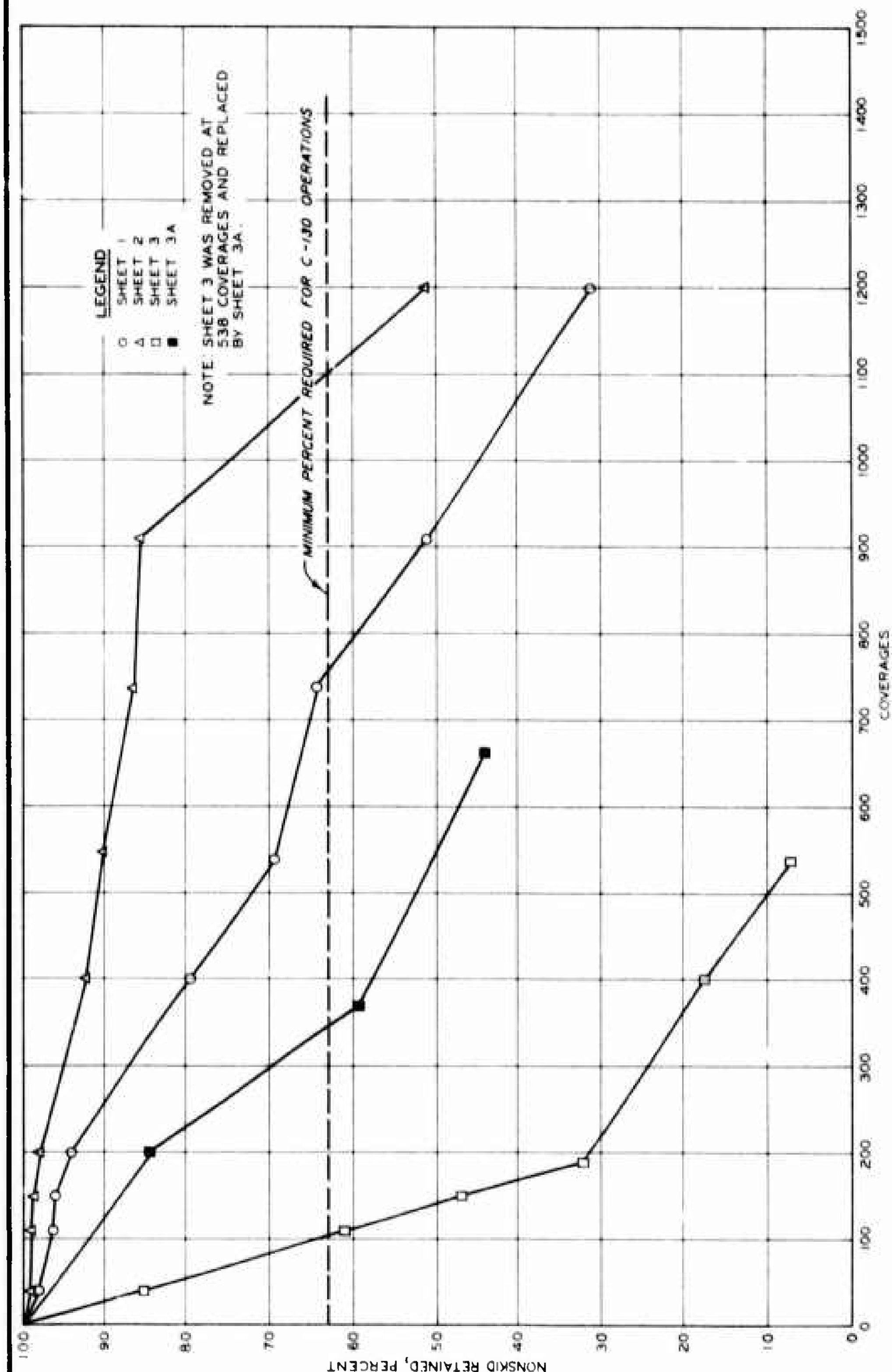


LAYOUT OF TRAFFIC TEST SECTION 2



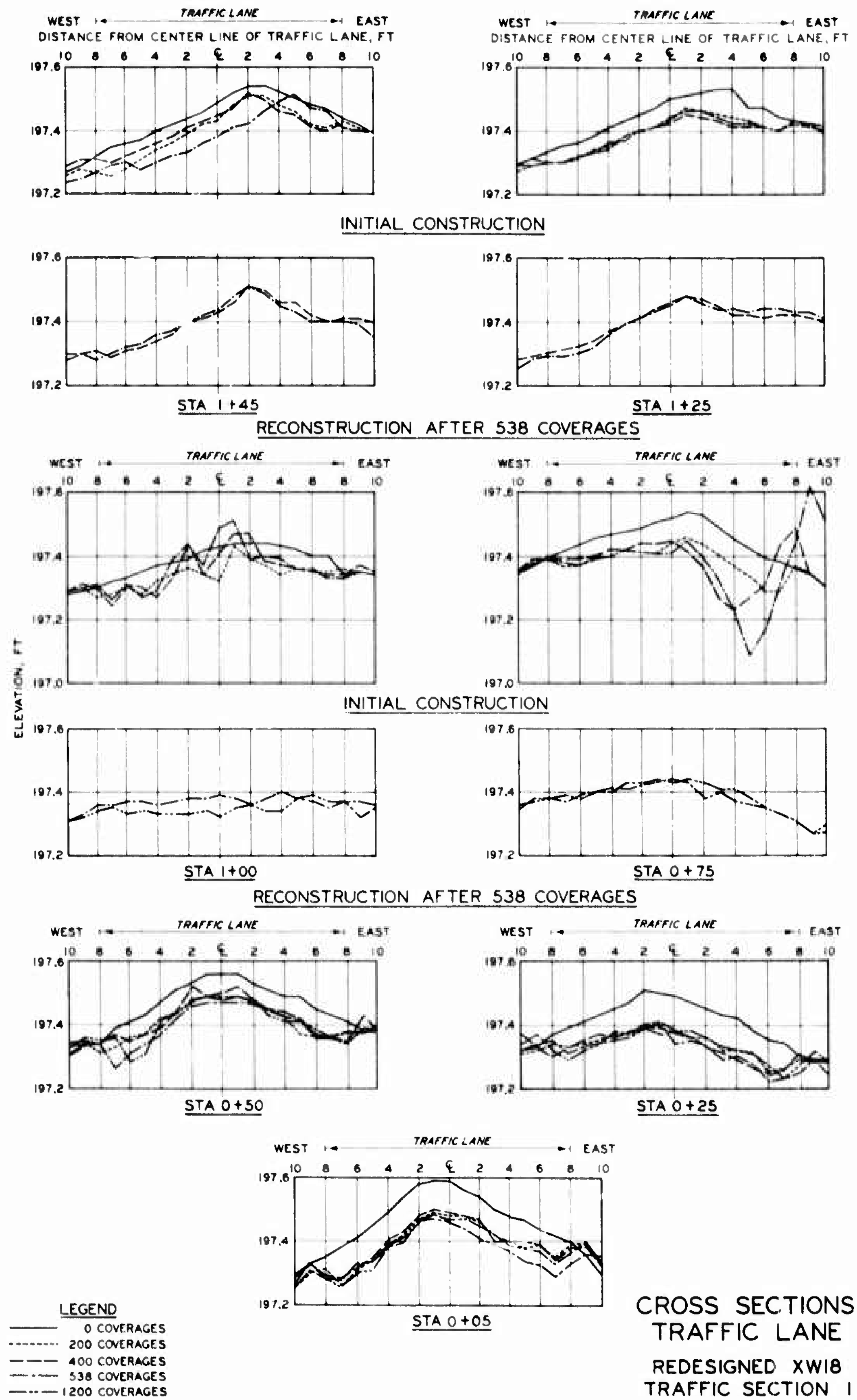
RAINFALL, TEMPERATURE, AND TRAFFIC DATA
REDESIGNED XW18 MEMBRANE TESTS

PLATE 16



NONSKID RETAINED VS COVERAGES

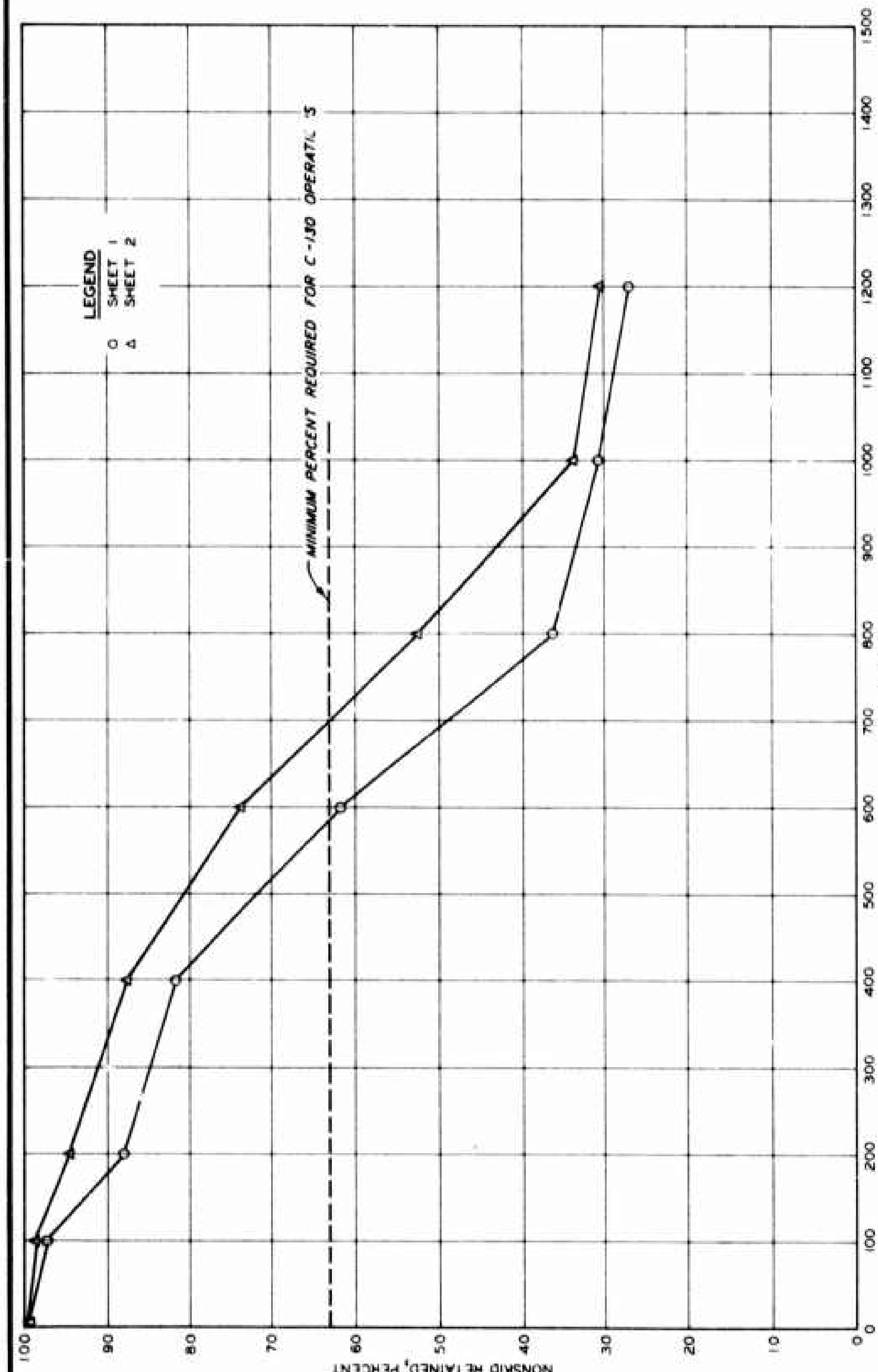
XW18 TRAFFIC TEST SECTION 1



CROSS SECTIONS
TRAFFIC LANE

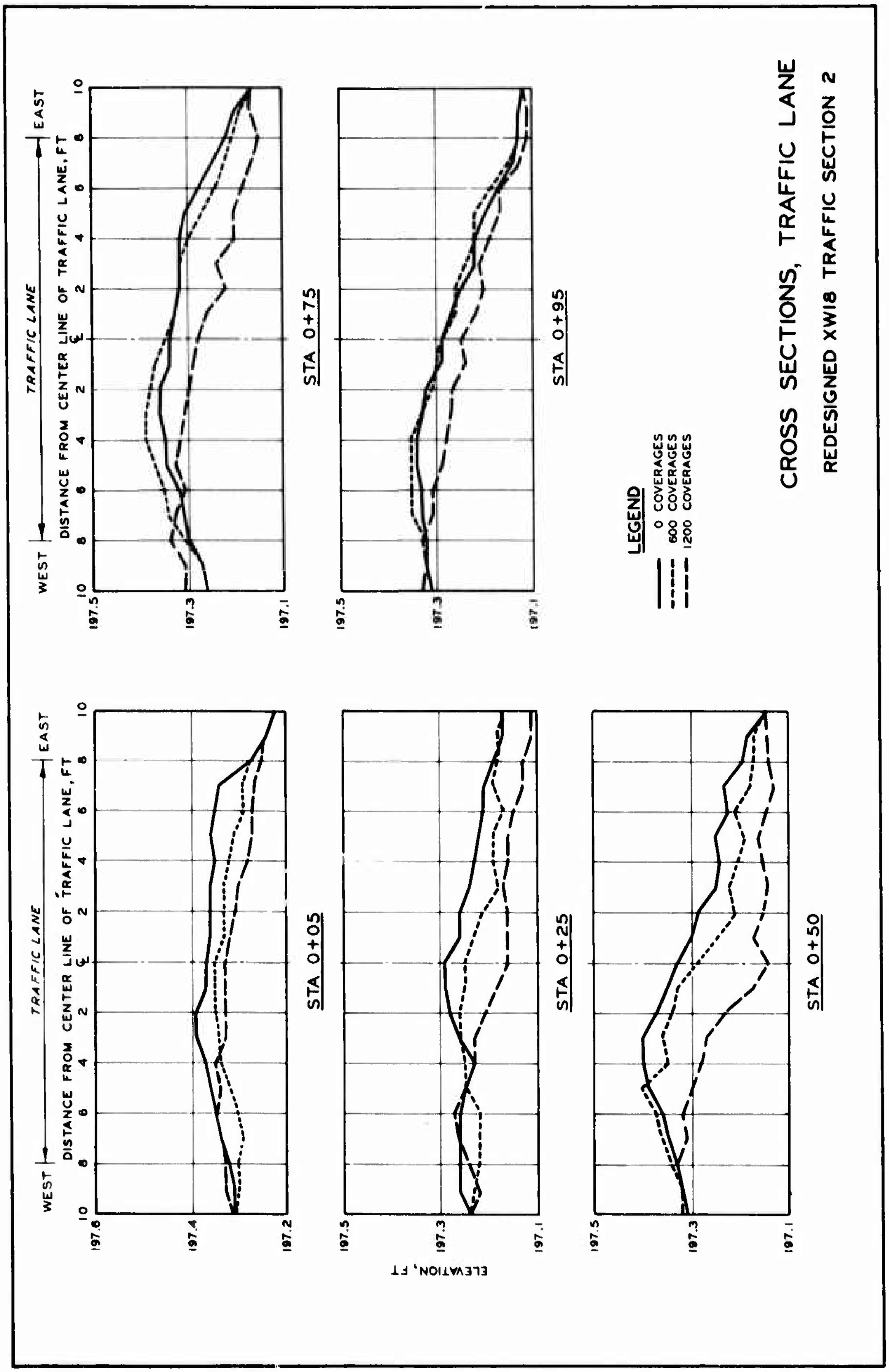
REDESIGNED XW18
TRAFFIC SECTION 1

PLATE 18



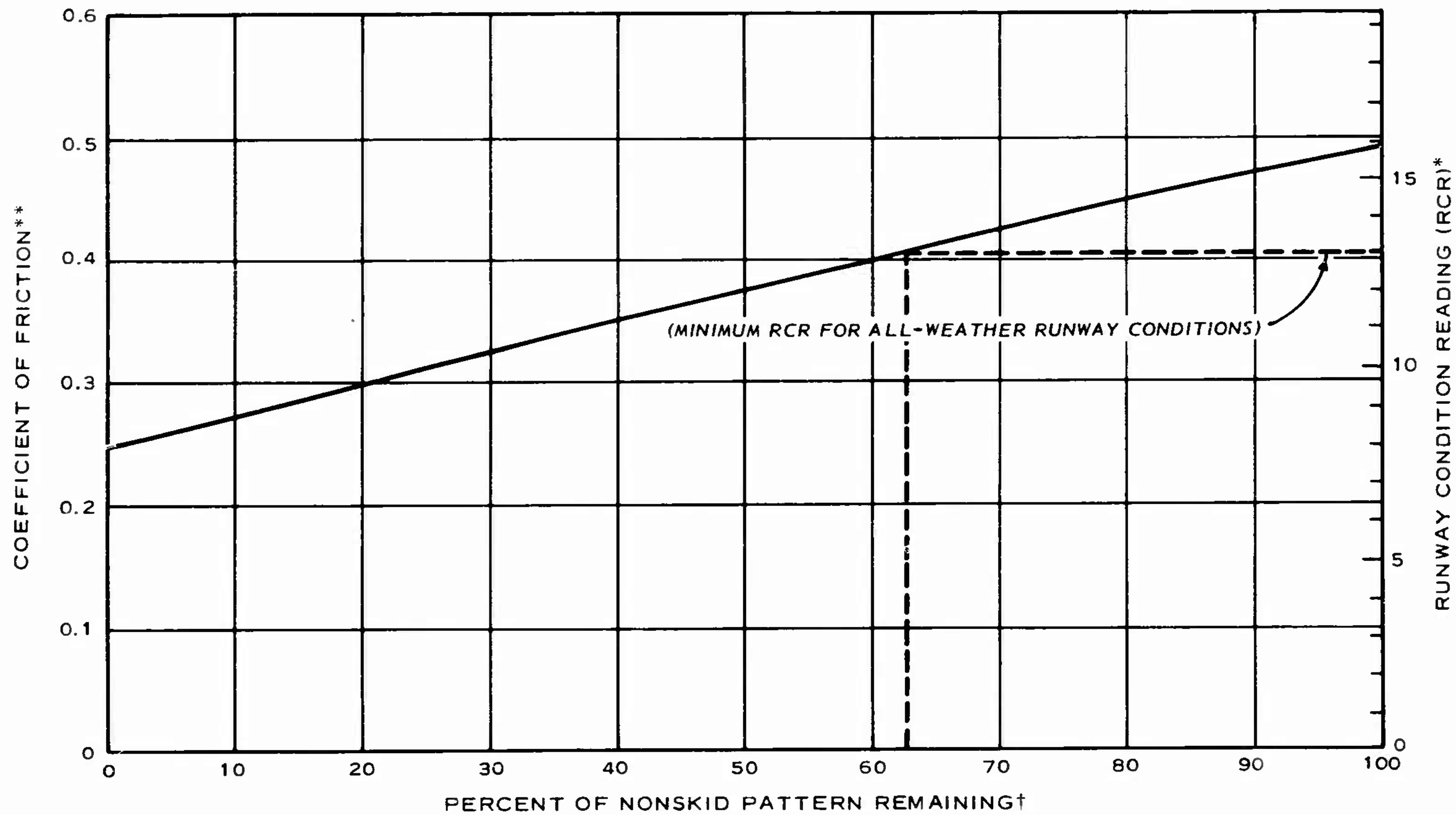
NONSKID RETAINED VS COVERAGES

XW18 TRAFFIC TEST SECTION 2



CROSS SECTIONS, TRAFFIC LANE

REDESIGNED XW18 TRAFFIC SECTION 2



* DETERMINATIONS MADE WITH JAMES BRAKE DECELEROMETER ON WET NONSKID COATED MEMBRANE

** RUNWAY CONDITION READING DIVIDED BY 32.2

† PERCENT OF ORIGINAL NONSKID PATTERN REMAINING AFTER TRAFFIC

PERCENT OF NONSKID PATTERN REMAINING VS RUNWAY CONDITION READING