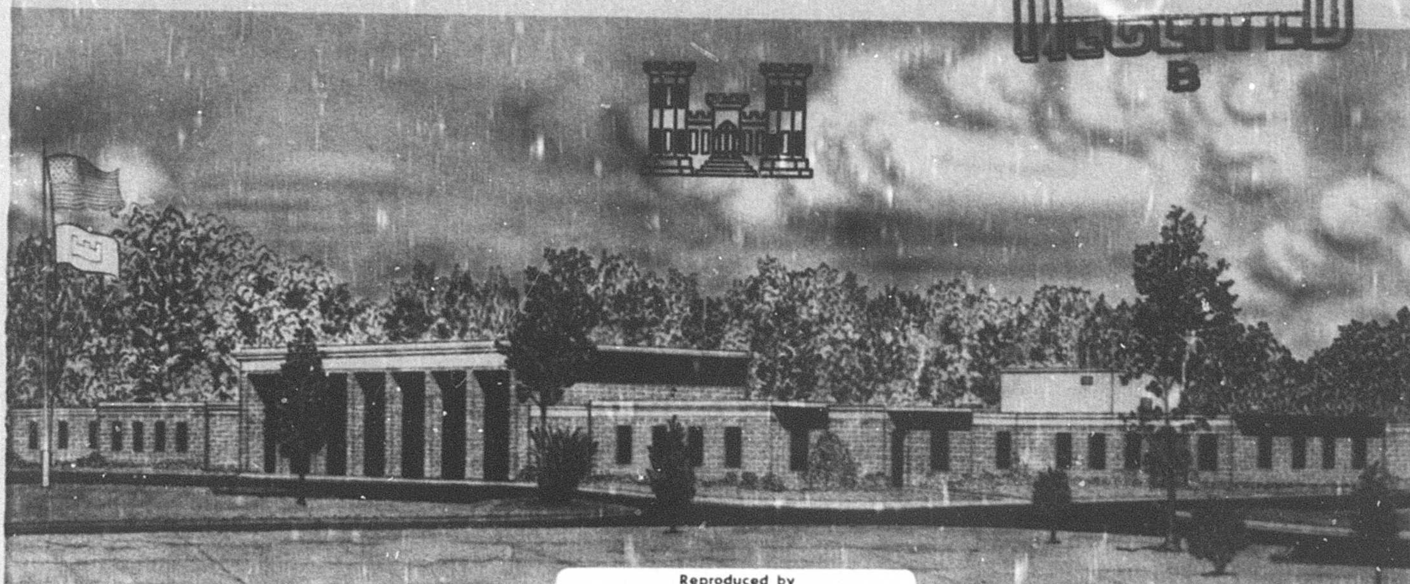
MISCELLANEOUS PAPER S-72-5

EVALUATION OF MO-MAT 158 AS LIGHT-DUTY LANDING MAT

by

C. J. Smith



February 1972

Sponsored by U. S. Army Materiel Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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13. ABSTRACT

This investigation was conducted to evaluate MO-MAT, a reinforced plastic material molded into a waffle-like configuration, for use as light-duty landing mat. Tests were conducted on four special panels of MO-MAT 158 connected by nut plates with bolts placed in predrilled holes. The traffic tests were conducted using C-130 aircraft loading on three prepared subgrades of different strengths. Results of this investigation indicated that MO-MAT 158 will sustain 96, 184, and 500 actual coverages of traffic when placed on subgrades with rated CBR's of 4.0, 6.5, and 10, respectively. Therefore, the MO-MAT 158 does not meet the Qualitative Materiel Requirement (QMR) for a light-duty mat (1000 coverages on a 4-CBR subgrade). The MO-MAT 158 panels were assembled at an average rate of 150 sq ft per man-hour, which does not meet the minimum QMR placing rate requirement of 400 sq ft per man-hour. The average coefficients of friction obtained from wet- and dry-skid tests were 0.30 and 0.45, respectively. Therefore, the coefficient of friction on a wet surface falls below the QMR coefficient of friction range of 0.4 to 0.8. Tire wear during the wet-skid tests was negligible, but small pieces of rubber were peeled from the tire during the dry-skid tests. The longitudinal and transverse joints did not provide waterproof connections; also, the longitudinal joint plastic nut plates were not strong enough to secure the bolted overlapping panels when the mat was placed on a 4-CBR subgrade. Due to hazards created when aircraft touch down short of a runway and due to possible difficulty during installation, the anchorage system used in this investigation is not considered feasible for field use. It is recommended that no further consideration be given to use of MO-MAT 158 as light-duty landing mat.

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Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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FOREWORD

This report was prepared as a part of the work authorized by the Ground Mobility Division, Directorate of Research, Development, and Engineering, U. S. Army Materiel Command, under the title "Combat Engineer Equipment," DA Project No. 1G664717DH01, Task 10 (formerly 1G664717D556, Task 01), "Landing Mat Development."

The engineer design tests pertinent to this investigation were performed at the U. S. Army Engineer Waterways Experiment Station (WES) during the period January-May 1970 under the general supervision of Mr. J. P. Sale, Chief, Soils Division. Personnel of the Expedient Surfaces Branch actively engaged in the planning, testing, analyzing, and reporting phases of this investigation were Messrs. W. L. McInnis, H. L. Green, and C. J. Smith. The Flexible Pavement Branch was responsible for constructing and trafficking the test section and also for performing the necessary soil tests under the supervision of Messrs. R. G. Ahlvin and C. D. Burns. This report was prepared by Mr. Smith.

Directors of WES during the conduct of this study and the preparation of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. F. R. Brown.

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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 inches	6.4516	square centimeters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
gallons (U. S.)	3.785412	cubic decimeters
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per square foot	4.88243	kilograms per square meter
pounds per cubic foot	16.0185	kilograms per cubic meter
kips	453.59237	kilograms
miles per hour	1.609344	kilometers per hour

SUMMARY

The investigation reported herein was conducted to evaluate MO-MAT, a reinforced plastic material molded into a waffle-like configuration, for use as light-duty landing mat. The mat was designed and fabricated by the Air Logistics Corporation, Pasadena, Calif. Standard panels of MO-MAT are normally 48-1/2 ft long and 12 ft 2 in. wide. This investigation was conducted on four special panels of MO-MAT 158 (each panel was 21 ft 9 in. long, 12 ft 2 in. wide, and 0.183 in. thick) connected by nut plates with bolts placed in predrilled holes spaced on 4-in. centers. Traffic tests were conducted in order that the MO-MAT 158 could be evaluated as a potential light-duty landing mat.

The traffic tests were conducted on a prepared subgrade, with a rolling wheel load simulating actual aircraft operations. The tests were conducted using C-130 aircraft loading, which consists of a single-wheel load of 30,000 lb with a tire inflation pressure of 100 psi, on three prepared subgrades of different strengths. Results of this investigation indicated that MO-MAT 158 will sustain 96, 184, and 500 actual coverages of traffic when placed on subgrades with rated CBR's of 4.0, 6.5, and 10, respectively. Therefore, the MO-MAT 158 does not meet the Qualitative Materiel Requirement (QMR) for a light-duty mat (1000 coverages on a 4-CBR subgrade). The mat was considered failed when a 3-in. deformation measured laterally across the traffic lane over a 10-ft distance developed. The four panels of MO-MAT 158 were assembled at an average rate of 150 sq ft per man-hour, which does not meet the minimum QMR placing rate requirement of 400 sq ft per man-hour. The average coefficients of friction obtained from wet- and dry-skid tests were 0.30 and 0.45, respectively. Therefore, the coefficient of friction on a wet surface falls below the QMR coefficient of friction range of 0.4 to 0.8. Tire wear on the wet surface was considered negligible; however, small pieces of rubber were peeled from the tire during skids on the dry surface.

The longitudinal and transverse joints did not provide waterproof connections; also, the longitudinal joint plastic nut plates did not provide enough strength to secure the bolted overlapping panels when the mat was placed on a subgrade with a CBR of 4.0. Due to hazards created when aircraft touch down short of a runway and due to possible difficulty during installation, the anchorage system used in this investigation is not considered feasible for field use.

It is recommended that no further consideration be given to the use of MO-MAT 158 as light-duty landing mat.

EVALUATION OF MO-MAT 158 AS LIGHT-DUTY LANDING MAT

PART I: INTRODUCTION

Background

1. The investigation reported herein comprises an engineer design test (EDT) in the U. S. Army Materiel Command's (AMC) RDT&E program for the development of satisfactory landing mats for use as expedient surfacing materials for forward-area airfields. As a part of this program, the U. S. Army Engineer Waterways Experiment Station (WES) has been assigned the responsibility for landing mat development, and currently is developing light-, medium-, and heavy-duty landing mats.

2. A preliminary investigation of MO-MAT 85 (0.085 in.* thick) conducted at WES[1] indicated that this item would sustain about 300 coverages of a 30,000-lb single-wheel load with a tire pressure of 75 psi when placed on a subgrade with a CBR of 6.5. Additional tests at WES[2] indicated that MO-MAT 85 would perform satisfactorily as depot surfacing on a subgrade with a CBR of about 6 (except for solid-tire forklift operations) for a period of several months. Subsequent discussions with representatives of Air Logistics Corporation, the manufacturer of MO-MAT, indicated that MO-MAT could be manufactured in thicker versions (MO-Mat 158), which might make it more successful in meeting some of the more stringent requirements for expedient surfacing materials for airfields. The test data reported herein were evaluated against the criteria for light-duty mat as established in a Qualitative Materiel Requirement (QMR) for prefabricated airfield surfacings dated 12 July 1966 and revised on 2 April 1968. The revised QMR is presented as Appendix A.

Objectives

3. The general objectives of this investigation were to evaluate

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

the performance of MO-MAT 158 as light-duty landing mat for use as an expedient surfacing material for forward-area bases. The specific objectives of the investigation were to determine:

a. The service life of the mat when placed on subgrades having CBR's of 4.0, 6.5, and 10, and trafficked with a 30,000-lb single-wheel load with tires inflated to 100 psi to produce a contact area of approximately 291 sq in.

b. The coefficients of friction of the mat with both wet and dry surfaces.

c. The average placement rate of the mat.

Scope of Report

4. This report describes and gives results of accelerated traffic tests conducted to evaluate MO-MAT 158. The desired data were obtained by the EDT as follows:

a. Traffic tests were conducted on a specially constructed test section to study subgrade behavior and to observe the performance of the mat under a rolling wheel load.

b. The force required to skid a load cart over the mat was recorded, and the coefficient of friction was determined.

c. During the assembly of the test section, mat placement time was recorded and the placing rate computed.

Definitions of Pertinent Terms

5. For information and clarity, definitions of certain terms used in this report are given below:

Test section. A prepared area on which the landing mat is placed for test purposes.

Traffic lane. Area of the test section that is subjected to the rolling wheel load of the load cart.

Subgrade. The portion of the test section constructed with soil processed under controlled conditions to provide the desired bearing capacity and upon which the landing mat is placed.

CBR (California Bearing Ratio). A measure of the bearing capacity of the soil based upon its shearing resistance. CBR is calculated by dividing the unit load required to force a piston into the soil by the unit load required to force the same piston the same depth into a standard sample of crushed stone and multiplying by 100.

Coverage. One application of the test wheel of the load cart over every point in the traffic lane.

Load cart. A specially constructed item of equipment used in WES engineering tests for simulating aircraft taxiing operations.

Test wheel. The wheel on the load cart that supports the main load.

Deflection. Temporary bending of landing mat panels under the static load from the test wheel of the load cart.

Longitudinal dishing. Permanent deformation of a panel perpendicular to the direction of traffic.

Direction of traffic. The direction in which the load cart travels on the test section. The direction of traffic is representative of actual landing directions with respect to panel joints.

PART II: DESCRIPTION OF MAT

Panels

6. MO-MAT is a reinforced plastic mat molded into a waffle-like configuration. Standard panels of MO-MAT are normally 48-1/2 ft long and 12 ft 2 in. wide. Each standard panels is composed of nine 12-ft 2-in.-wide by 5-ft 8-1/4-in.-long sections. During fabrication, these sections are bonded together along the long dimension with epoxy resin between 4-in. overlapping sections.

7. This investigation was conducted on four special panels of MO-MAT 158 connected by nut plates with bolts placed in predrilled holes spaced on 4-in. centers, which provided both longitudinal and transverse joints in the traffic lane. Each panel was composed of four 12-ft 2-in.-wide by 5-ft 8-1/4-in.-long sections bonded together along the long dimension with epoxy resin during fabrication. The effective size of each panel before joining was 21 ft 9 in. long by 12 ft 2 in. wide (plate 1a). The panels had an average material thickness of 0.183 in., and the overall thickness measured from the bottom of one node to the top of an adjacent node was approximately 3/4 in. Two panels were connected along the 12-ft 2-in. dimension to form the transverse joint, and the other two panels were also connected in a similar manner. The two 43-ft 2-in. long by 12-ft 2-in.-wide sections were then joined (fig. 1) with an

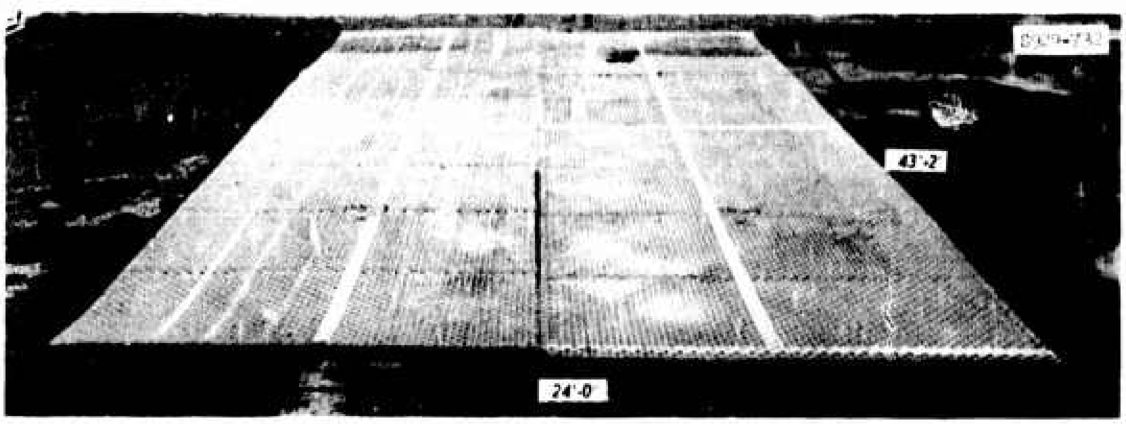

Fig. 1. Connected panels of MO-MAT 158

8-in. offset along the long dimension so that the factory bonded joints and transverse joints would not be aligned when the longitudinal joint was formed (plate 1b). When joined together, the four special panels covered an area 43 ft 2 in. long and 24 ft wide and weighed 2.00 lb per square foot of placing area.

Bundles

8. A bundle of rolled MO-MAT and accessories was secured to a wooden skid with metal bands and shipped to WES for testing (fig. 2). The bundle was 12 ft 6 in. long, 6 ft wide, and 5 ft 5 in. high. The

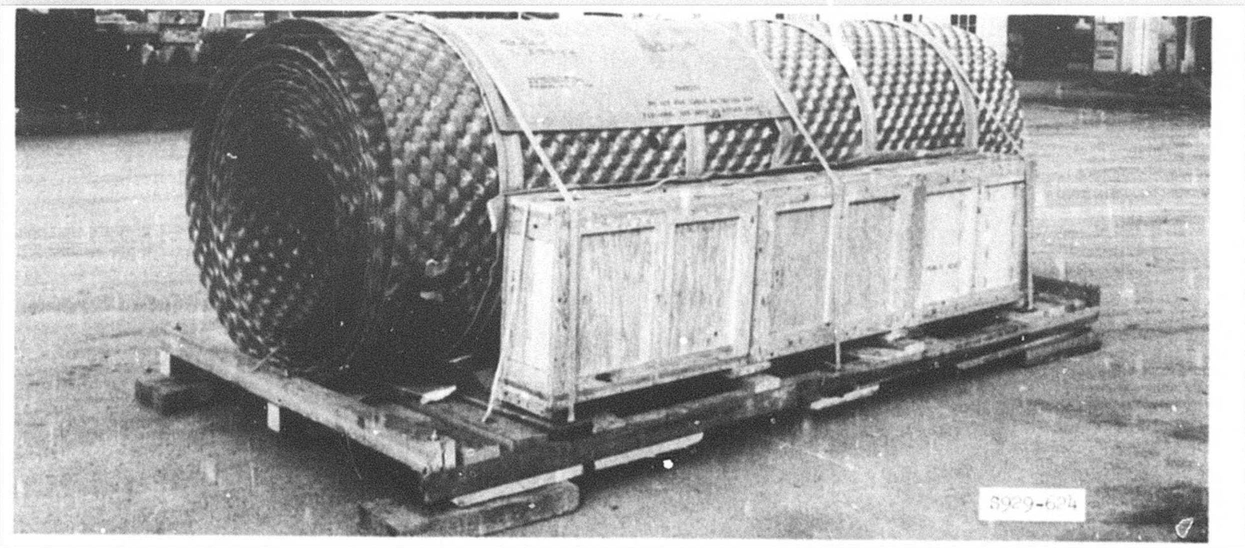

Fig 2. Bundle of MO-MAT and accessories

cubage of the bundle was 407 cu ft, and the total weight was 5095 lb. The roll had an inside diameter of 2 ft 6 in., and an outside diameter of 4 ft 11 in. Included in the bundle were the four panels of MO-MAT 158, MO-MAT 85 to be used as approach mat, and accessories, which included nut plates, bolts, sealant material, wrenches, and metal anchors.

9. Another bundle of MO-MAT with a rubber water bag inside the roll was also secured to a wooden skid with metal bands for shipment to WES (fig. 3). The roll had an inside diameter of 2 ft 11 in., and an outside diameter of 3 ft 8 in. The bundle was 12 ft 6 in. long, 3 ft 9 in. wide, and 4 ft 2 in. high, with a cubage of 195 cu ft. The total

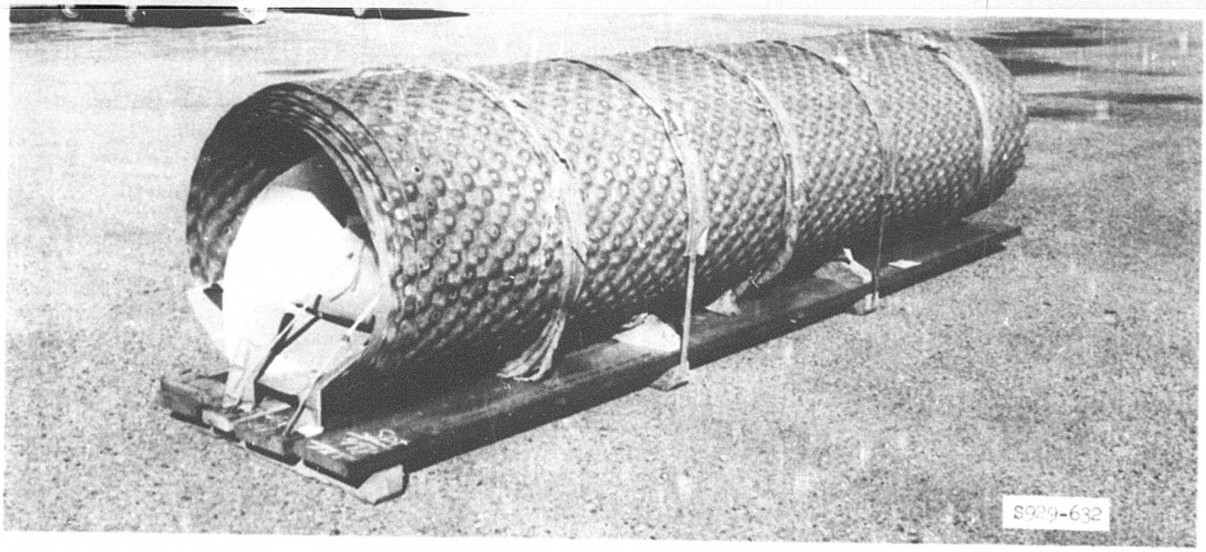

Fig. 3. Bundle of MO-MAT and water bag

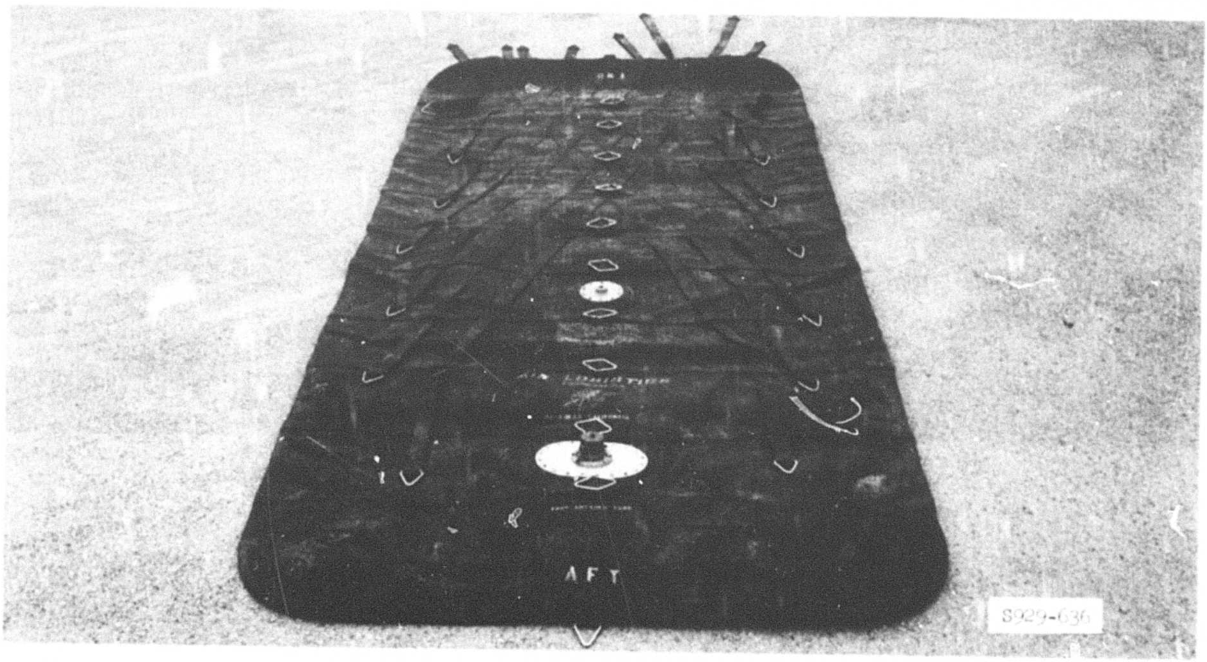

Fig. 4. Empty water bag

weight of the bundle was 1900 lb. Included in the bundle were MO-MAT 85 to be used as approach mat and a 3000-gal-capacity water bag, which weighed 625 lb empty (fig. 4). The water bag was recommended and furnished by the MO-MAT manufacturer to eliminate bow waves that had developed in previous MO-MAT tests due to the action of the rolling wheel.

PART III: TEST SECTIONS AND EQUIPMENT

Test Sections

10. The two test sections were constructed under a hangar-type structure to provide both protection from the elements and the conditions necessary for accurately controlled traffic tests. Both test sections were excavated to a depth of 24 in. below the final grade and backfilled with four 6-in.-thick compacted lifts of a heavy clay (CH)[3] having an average liquid limit of 58 and an average plasticity index of 33 (plate 2). Each lift was compacted with eight coverages of a self-propelled seven-wheel roller with 65-psi tire inflation pressure and a 50,000-lb total load. After backfilling had been completed, the test sections were graded to provide a smooth surface with no transverse grade. CBR, moisture content, and density tests were conducted during construction to ensure that the desired soil strengths had been obtained. Soil data for the test sections are shown in tables 1 and 2. Anchor ditches were dug at each end of the test section, and a catenary ditch was dug between the north anchor ditch and sta 0+00 (plate 3). These ditches were part of the anchorage system recommended by the MO-MAT manufacturer. Due to hazards created when aircraft touch down short of a runway and due to possible difficulty in digging anchor and catenary ditches, the water bag method of anchorage would create numerous problems for field use.

11. Test 1 and 2 mat sections covered an effective area 43 ft 2 in. long and 24 ft wide with 129.6-in.-wide traffic test lanes along the longitudinal centers (plates 3 and 4). An approach area was provided at each end of each test section to allow maneuver area for the load cart in the application of traffic. The mat was laid on the test sections in accordance with the manufacturer's recommendation, i.e., with a continuous joint in the longitudinal direction and staggered joints in the transverse direction. Individual sections in the test lanes were numbered for identification. The section for test 1 consisted of items 1 and 2, each item constituting one-half the length of

the test section (plate 3). The in-place CBR's of items 1 and 2 prior to traffic were 4.1 and 6.6, respectively. After all test 1 data had been taken, the subgrade was reprocessed for test 2 to an in-place CBR of 10.0 in order to evaluate the MO-MAT 158 on a firmer subgrade.

Mat Assembly and Placement

12. All components for surfacing for the first test, including MO-MAT 85 and MO-MAT 158, were assembled at one end of the test section. Transverse joints (joints perpendicular to the direction of traffic) were formed by securing metal nut plates to the underlap panel, applying sealant stripping for waterproofing purposes, and overlapping the panels 4 in. Accessories for joining the MO-MAT are shown in fig. 5.

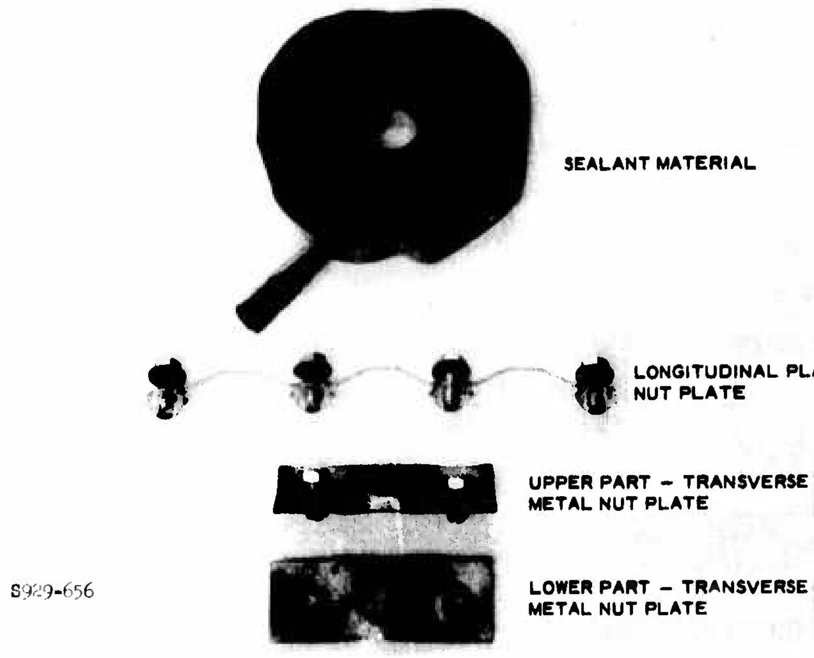

Fig. 5. Accessories for joining MO-MAT

The panels were secured by bolts located on 4-in. centers and tightened by a ratchet and speed handle (fig. 6). The lower part of the transverse metal nut plate (fig. 5) was designed to snap into position for retainment during assembly of the transverse joint; however, it was determined during assembly that these nut plates would not retain their positions. Therefore, transverse joints were assembled by:

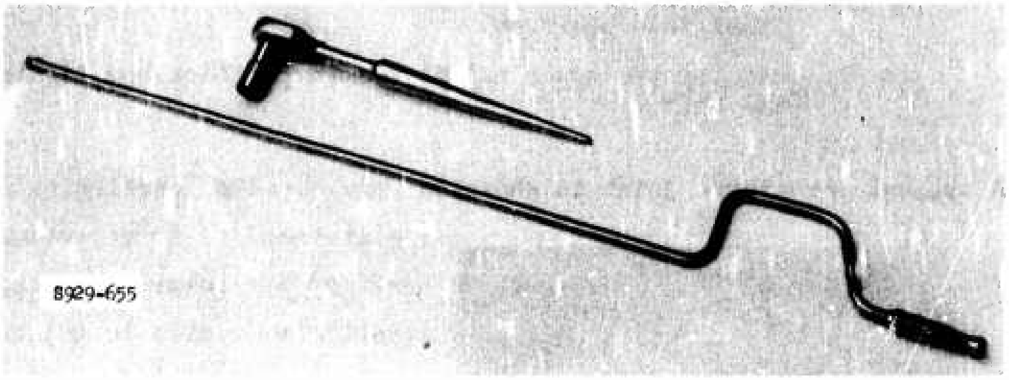

Fig. 6. Tools for assembling MO-MAT

a. Aligning the overlap and underlap holes with the tapered end of the ratchet.

b. Holding the overlap panel up while the bottom nut plates were placed on a flat surface beneath the underlap and held in position by a few turns of the bolts (fig. 7).

c. Placing the sealant strip. (Note sealant material in fig. 7.)

Fig. 7. Underlap panel prior to bolting

d. Removing the bolts and carefully lowering the overlap panel into position.

e. Placing the upper nut plates in position and tightening the bolts.

A typical transverse joint is shown in fig. 8. The longitudinal joint (joint parallel to direction of traffic) was formed by securing plastic nut plates to the underlap panel, applying sealant stripping for waterproofing purposes, and overlapping the panels 4 in. The plastic longitudinal nut plates (fig. 5) snapped into the underlap panels and remained in position during installation without any difficulty. The four special panels, shown connected in fig. 1, were assembled by an experienced crew of eight men at an average rate of 150 sq ft per man-hour.

Fig. 8. Typical transverse joint after bolting

13. After all mat had been assembled at one end of the test section, metal anchors were connected to the opposite end of the MO-MAT 85 (fig. 9), a cable was attached to the anchors, and the mat-attached anchors were pulled by a truck-powered winch across the test section and the catenary ditch (fig. 10). A support frame was built in the catenary ditch to prevent the MO-MAT from sagging during installation. The mat-attached anchors were placed in the north anchor ditch, and then the ditch was backfilled (fig. 11). Prior to anchorage on the south end, the support frame across the catenary ditch was lifted with jacks to remove all possible mat sag across the ditch (fig. 12). After the south anchor ditch had been backfilled the support frame was removed. Then the water bag was

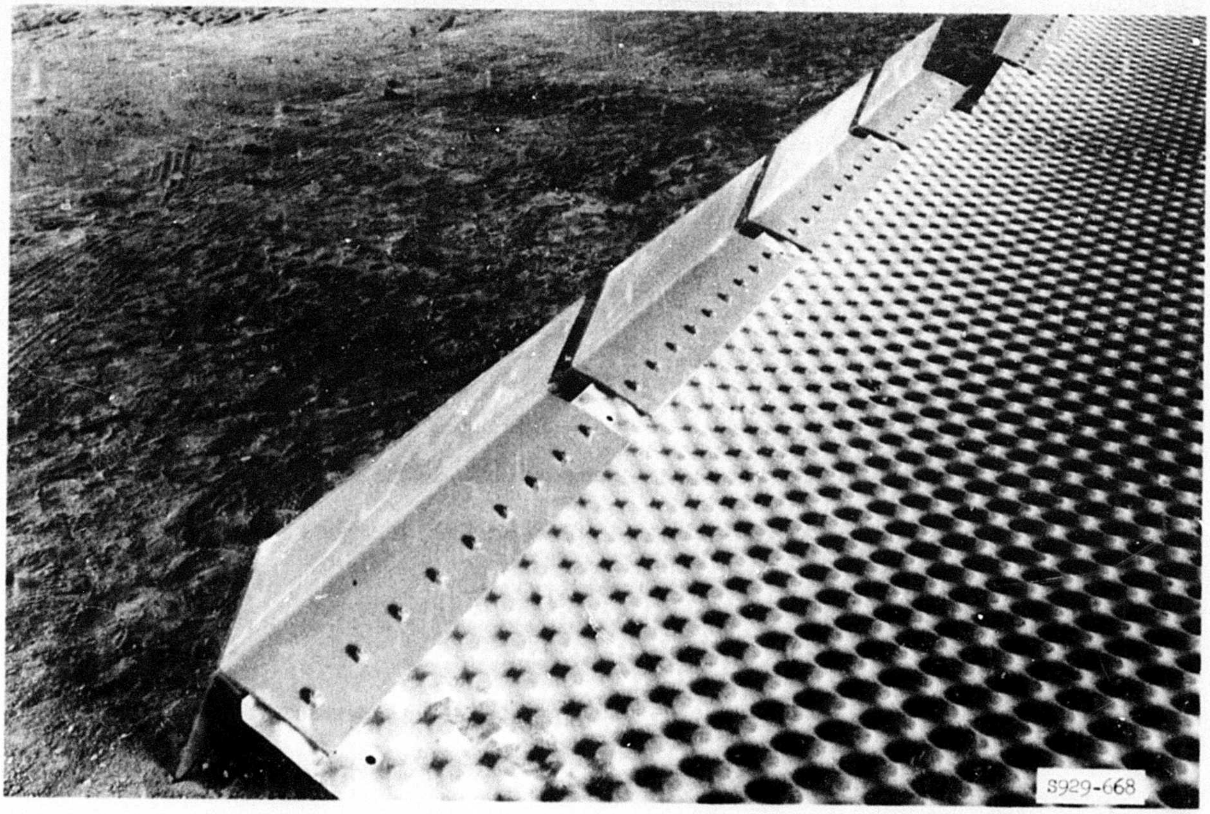

Fig. 9. Metal anchors connected to MO-MAT 85

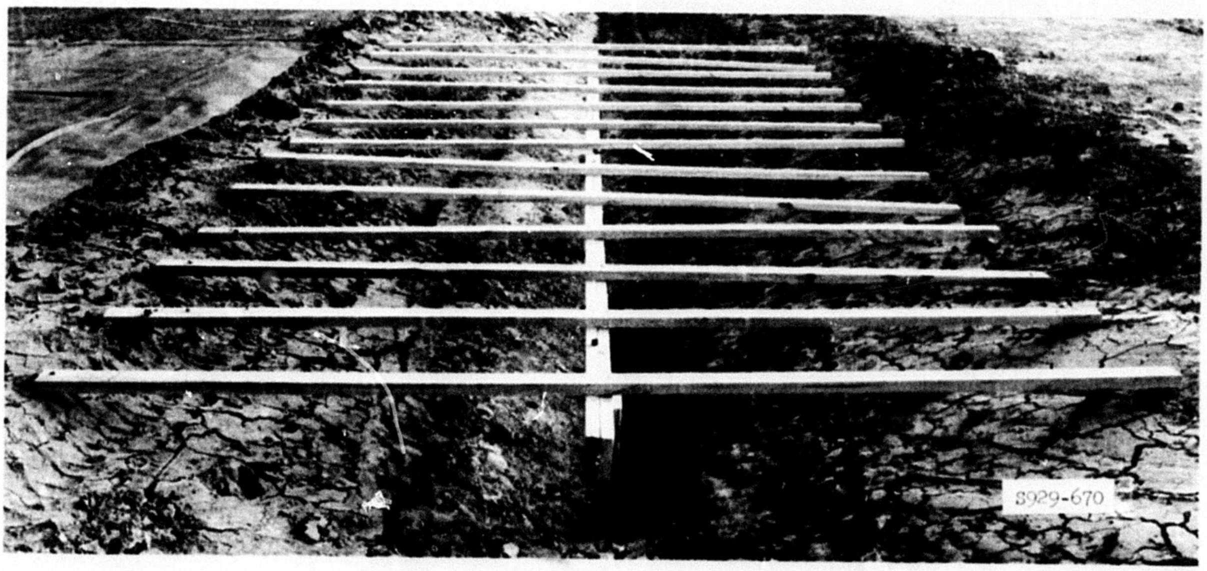

Fig. 10. View of catenary ditch and support frame

Fig. 11. Equipment used to backfill anchor ditch

Fig. 12. Frame lifted to eliminate sag in MO-MAT across catenary ditch

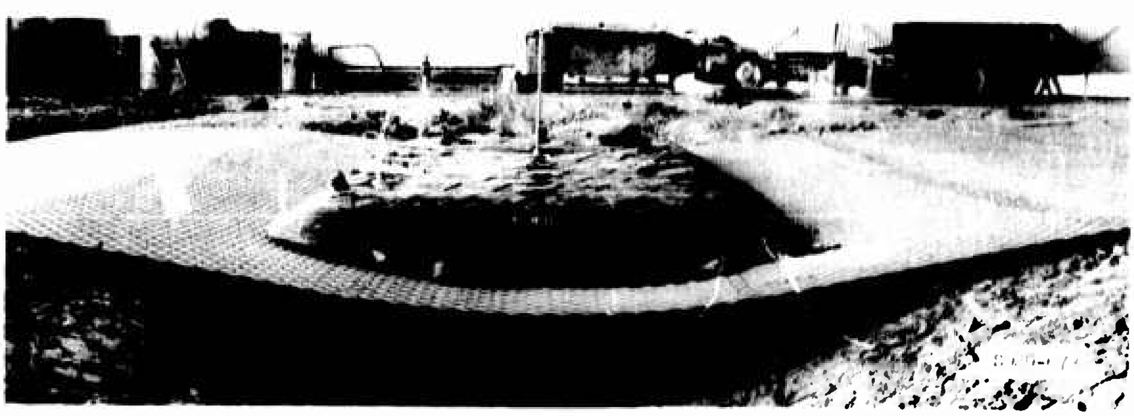

Fig. 13. Water bag on mat over catenary ditch

was positioned on the MO-MAT and was filled with 1100 gal of water to provide posttensioning to the MO-MAT to eliminate bow waves caused by a moving wheel (fig. 13). A view of the overall test section ready for traffic tests is shown in photo 1.

Test Load Cart

14. A specially designed single-wheel test cart (fig. 14) loaded to 30,000 lb was used in the traffic tests. It was fitted with an

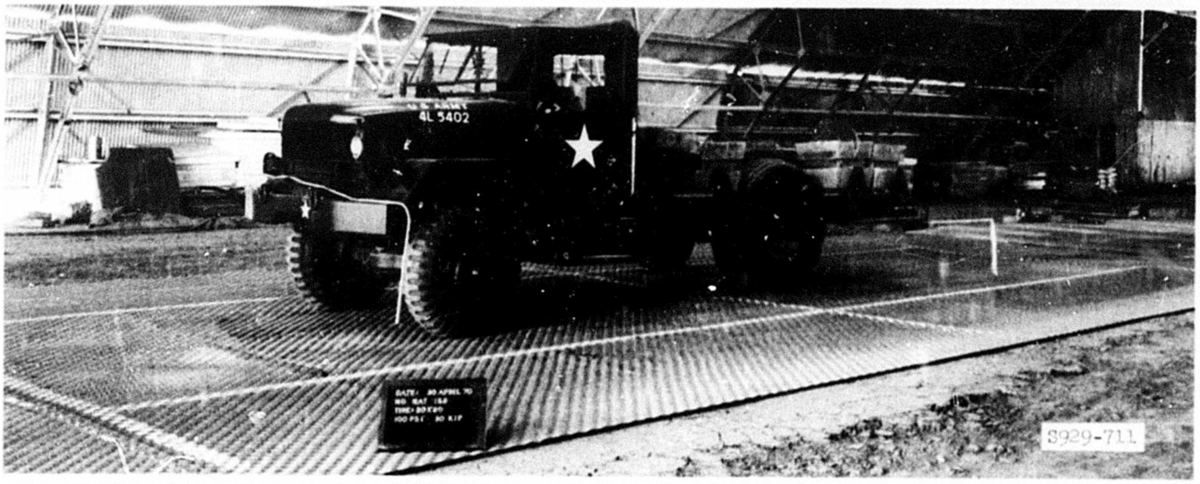

Fig. 14. C-130 load cart with 30,000-lb single-wheel load on 20.00-20 tire inflated to 100 psi

outrigger wheel (load considered insignificant) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load wheel had a 20.00-20, 22-ply tire inflated to 100 psi, which produced a contact area of 291 sq in. and an average contact pressure of 103 psi.

Application of Traffic

15. Traffic was applied to simulate the traffic distribution pattern that would be encountered in actual aircraft takeoffs and landings. This pattern approaches a statistically normal distribution curve.[4,5] Traffic was started at one side of the test lane, and 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 16.2 in. (the width of a tire print) on each successive forward trip. Thus, two coverages of the entire traffic lane were accomplished when the load cart was maneuvered from one side of the traffic lane to the other. The interior 97.2 in. of the traffic lane was then trafficked for six additional coverages. The longitudinal center 64.8 in. of the traffic test lane received two additional coverages for a total of ten coverages. The net result was that the center 64.8-in.-wide strip of the traffic lane received 100 percent of the traffic; the 16.2-in.-wide strips on each side of the center 64.8 in. received 80 percent; and the two 16.2-in.-wide edge strips received only 20 percent (plate 5). This pattern of traffic was repeated until mat failure occurred.

Skid-Resistance Equipment

16. Skid tests were performed on both dry and wet surfaces of each type of mat prior to the traffic tests. The skid vehicle used was a C-130 load cart loaded to 30,000 lb on a 20.00-20, 20-ply tire inflated to 100-psi tire pressure. The truck section of the test cart was used only for steering, and a Tournadozer was used to pull the skid cart.

17. To perform the tests, the skid cart was positioned along one side of the traffic lane, and the load wheel was locked to prevent rotation. The cart was skidded over the mat section at a uniform rate of speed for a given distance to determine the skid resistance offered by the mat surface and the tire wear resulting from the skidding.

PART IV: TYPES OF DATA RECORDED

Skid Tests

18. The force required to pull the skid cart with a locked wheel over the mat surface was measured with an electronic recording dynamometer with a capacity of 50,000 lb. Electronic recordings of the force required to pull the skid cart and of the distance of the skid were made on individual oscillograms. Comparative tire wear was estimated by visual observations supplemented by photos. Observations and photos of the mat surface were made before and after the skid tests.

Traffic Tests

19. In-place densities, water contents, and CBR's measured prior to traffic testing, during the test period, and at the conclusion of traffic are given in tables 1 and 2. These soil tests were made at the surface of the subgrade and at depths of 6 and 12 in., with a minimum of three values taken at each depth. Static deflections of the mat due to the load on the test wheel were measured at various locations, and the results are shown in plates 6 and 7. Level readings of cross sections (plates 8 and 9) and center-line profiles (plate 10) were taken prior to and at the conclusion of traffic to measure permanent deformation of the section. Cross sections of the mat and subgrade were taken at the conclusion of traffic to reveal the bridging of mat across the traffic lane (plates 11 and 12). Deformation of the traffic lane was determined during the test by measuring the variation of the traffic lane surface from a 10-ft straightedge placed in a transverse position (perpendicular to the direction of traffic). Tables 3 and 4 give a summary of the deformation data at various coverage levels. Visual observations of the mat and subgrade behavior and other relevant factors were recorded throughout the period of traffic and were supplemented by photos.

PART V: TEST RESULTS

Test 1

Item 1

20. Traffic tests. The average CBR of item 1 at the start of traffic was 4.1 (table 1), and the mat surface was generally smooth (photo 2). After 96 coverages of traffic, item 1 was considered failed due to excessive longitudinal rutting along the traffic lane (photo 3). The criterion for failure was the development of 3 in. of deformation measured laterally across the traffic lane over a 10-ft distance.[6] When a deformation of 3 in. or more occurred, a test item or section was considered failed due to roughness. Photo 4 shows a 3-7/8-in. deformation measured with a 10-ft straightedge across sections 1 and 2 of item 1. Deformation measurements, summarized in table 3, show a maximum of 3-7/8 in. after 96 coverages. The maximum change in static deflections beneath the tire from the beginning to 96 coverages of traffic was 0.3 in., which occurred at the quarter-point joint of sections 5 and 7 (plate 6). The maximum changes in both cross-section (plate 8) and profile (plate 10) measurements from the beginning to 96 coverages of traffic were 1.1 and 1.7 in., respectively.

21. Water was applied to the surface of the mat and to edges of the section in order to prevent drying of the subgrade, and all longitudinal joint bolts were tightened prior to continuance of traffic. Traffic was continued in order that the MO-MAT could be further evaluated but had to be temporarily terminated after 184 coverages because the severe rutting in item 1 tended to tip the small load cart to an unbalanced condition. Therefore, another load cart (C-130 load cart with 30,000-lb single-wheel load on 20.00-20 tire inflated to 100 psi) was used for further traffic (fig. 15).

22. Traffic was resumed using the larger load cart; however, after 316 coverages, traffic was terminated (photo 5). Deformation across sections 3 and 4 had progressed to 6-1/2 in. (photo 6), and with the load wheel positioned at the same location, the deformation

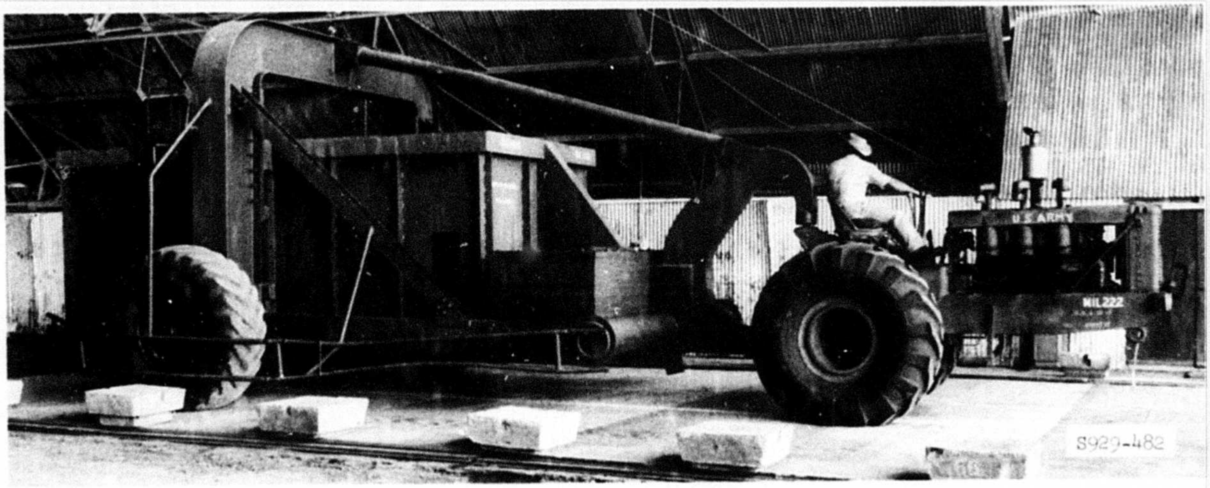

Fig. 15. C-130 load cart with 30,000-lb single-wheel load on 20.00-20 tire inflated to 100 psi

increased to 8-1/16 in. (photo 7). No mat breakage had occurred after 316 coverages.

23. Skid tests. An average force of 13,500 lb was required to skid the test cart with the 30,000-lb locked wheel a distance of 18 ft on a dry mat surface. On a wet surface, an average force of 9000 lb was required to skid the wheel a distance of 18 ft. The coefficients of friction for these data are as follows:

$$\text{Dry:} \quad \frac{13{,}500}{30{,}000} = 0.45$$

$$\text{Wet:} \quad \frac{9{,}000}{30{,}000} = 0.30$$

The presently used QMR* specifies a surface that provides effective braking with a Runway Condition Reading (RCR)** of 13 to 25 for aircraft operations on a wet or dry surface. This range of RCR corresponds approximately to a coefficient of friction range of 0.4 to 0.8. Although the test results were low, the coefficients of friction could be

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* Revised Department of Army Approved Qualitative Materiel Requirement (QMR) for Prefabricated Airfield Surfacings, April 1968.

** The RCR is an index of surface slickness measured by a special decelerometer instrument.

increased by application of antiskid particles to the mat surface during fabrication. Tire wear on the wet surface was negligible, but small pieces of rubber were peeled from the tire during skids on the dry surface (photo 8).

Item 2

24. The average CBR of the subgrade for item 2 at the start of traffic was 6.6 (table 1), and the mat surface was relatively smooth (photo 9). After 184 coverages, item 2 was considered failed due to 3-in. deformations across the traffic lane (photo 10). Because the water bag placed tension on the mat, the mat surface did not conform to the actual subgrade deformation across the traffic lane. Therefore, the load wheel was positioned on the bridging mat in order that true subgrade deformation could be measured with a 10-ft straightedge. Deformation measurements are summarized in table 3. The maximum change in static deflections beneath the tire from the beginning to 184 coverages of traffic was 0.3 in., which occurred at the quarter-point joint of sections 10 and 12 (plate 6). The maximum change in both cross-section (plate 8) and profile (plate 10) measurements from the beginning to 184 coverages of traffic was 1.7 in. Although the section was considered failed when the 3-in. deformation was reached, traffic was continued to 316 coverages in order that the mat could be further evaluated (photo 11). Bolts along the longitudinal joint were not loosened by the action caused by the rolling wheel load, and no mat breakage had occurred after 316 coverages.

Mat inspection and removal

25. Due to movement of the rolling wheel load along the longitudinal joint, 11 out of 60 bolts in item 1 had stripped threads from the longitudinal plastic nut plates and could not be retightened after 316 coverages. Photo 12 shows eight bolts stripped from the longitudinal joint between sections 5 and 6, and photo 13 shows a typical delamination spot that developed on all sections in items 1 and 2.

26. In order for the mat to be rolled from the test section to obtain subgrade data, the water bag was emptied and the mat was disconnected at the transverse joint between item 1 and the MO-MAT 85 approach

mat at sta 0+00 (plate 3). Inspection of several longitudinal nut plates removed from item 1 revealed that random threads were battered and stripped and portions of the plastic nut plates, which snap into the predrilled panel holes, were marred or broken off (photo 14). Photo 15 shows a close-up of threads stripped on a plastic nut plate that was typical of the type of damage incurred. The surface of the subgrade was moist; therefore, water that had been applied as described in paragraph 21 had seeped through the longitudinal and transverse joints. Subgrade deformations measured with a 10-ft straightedge on items 1 and 2 were 9 and 7-1/4 in., respectively (photos 16 and 17). The rated CBR's for items 1 and 2 were 4.0 and 6.5, respectively (table 1). Cross-section measurements of the mat and subgrade after traffic are presented in plate 11.

Test 2

Longitudinal joint repair

27. After all data had been taken from test 1, the test section was reprocessed to obtain a CBR of 10.0 (table 2) in order that the capabilities of the MO-MAT 158 could be further evaluated. Prior to rejoining the mat at sta 0+00 (plate 4), damaged longitudinal nut plates were replaced with new nut plates from sta 0+00 to 0+15. The manufacturer's initial recommended position of placement of sealant material to waterproof all joints is shown in photo 18. However, during test 1 this placement position allowed water to flow beneath overlap panels, seep through underlap panel bolt holes, and enter the subgrade. During repairs of the longitudinal joint from sta 0+00 to 0+15, the manufacturer recommended placement of sealant material on the opposite side of underlap panel bolt holes. The revised placement position is also shown in photo 18.

Traffic tests

28. After the mat had been rejoined and 830 gal of water added to the bag (as recommended by MO-MAT manufacturer), the test section appeared relatively smooth prior to traffic (photo 19). After 340 coverages

of traffic, a small crack was noticed that began 18 in. west of the longitudinal joint and terminated on the bonded joint between sections 2 and 4, 18 in. from the point of origin. The test section was considered failed after 500 coverages due to deformation of 3 in. across the traffic lane. A 3-1/2-in. deformation was measured on section 3, as shown in photo 20. Deformation measurements are presented in table 4. To bring the bridging mat in contact with the subgrade, the front wheels of a pickup truck were positioned transversely across the traffic lane, and deformations were measured with a 10-ft straightedge. Photo 21 shows a crack in the factory bonded joint between sections 2 and 4 as well as delaminations of material on section 4 after 500 coverages. The maximum change in static deflections beneath the tire from the beginning to 500 coverages of traffic was 0.3 in., which occurred at the center-line joint of sections 13-16 (plate 7). The maximum changes in both cross-section (plate 9) and profile (plate 10) measurements from the beginning to 500 coverages of traffic were 2.0 and 1.8 in., respectively.

29. In order that the MO-MAT could be further evaluated, traffic was continued from sta 0+16 to 0+42 (plate 4) but was terminated after 600 coverages due to deformations of 3 in. across the traffic lane (table 4). A 3-in. deformation was measured across sections 9 and 10, as shown in photo 22. After the water bag had been emptied and the mat disconnected at sta 0+00, subgrade deformations beneath sections 3 and 4 and sections 11 and 12 were 4-1/4 and 4-3/4 in., respectively (photos 23 and 24). The average CBR at the end of the test was 9.0, and the rated CBR for the test section was 10 (table 2). Cross-section measurements of the mat and subgrade at the end of traffic are shown in plate 12.

Waterproofing capability test

30. After the traffic tests, MO-MAT 158 was disconnected from MO-MAT 85 at both the north and south approaches, and tests were conducted to determine the waterproofing capability of the repaired longitudinal joint described in paragraph 27. The MO-MAT 158 that was initially placed between sta 0+00 and 0+15 was moved and positioned between two spanning pipes across the catenary ditch in order that water could be ponded on

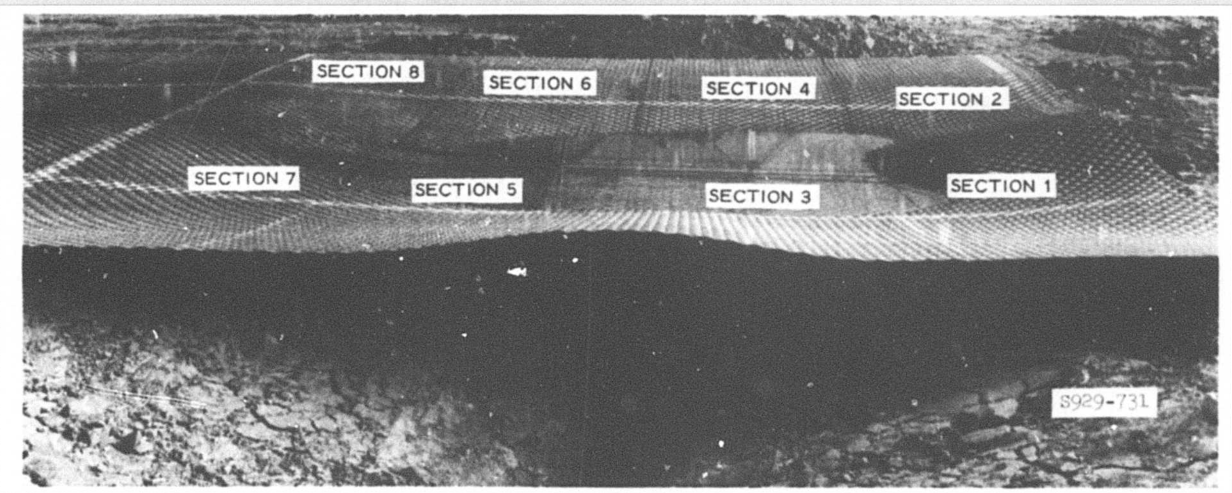

Fig. 16. Waterproofing capability test setup

the mat (fig. 16). After water had been applied to the top surface of the MO-MAT, leakage was observed at the longitudinal joint, at the cracked factory bonded joint, and at the center of a section where material had delaminated. Leakage locations are shown in plate 4.

PART VI: APPLICATION OF TEST RESULTS

31. After traffic tests on the MO-MAT 158, the failure points of 96, 184, and 500 coverages on subgrades of 4.0, 6.5, and 10 CBR, respectively, were plotted in order to extrapolate helicopter operational capabilities on MO-MAT 158. The four parameters (CBR, tire pressure, load, and coverages) were separated in order that a two-dimensional plot could be made from the failure points. Therefore, to develop the desired data, CBR × 100/tire pressure was plotted versus coverages/load (kips). The curve developed was then extrapolated to a family of curves for various equivalent single-wheel loads (ESWL). The spacings between these curves, shown in plate 13, were obtained by assuming that the ratios of the spacings between similar curves developed for unsurfaced soils would apply to MO-MAT 158. The following example demonstrates use of the family of curves for MO-MAT 158 by estimating its service life when placed on an 8-CBR subgrade and trafficked with a C-130 aircraft.

<u>Typical Example</u>

Aircraft Characteristics: 30,000-lb ESWL and 100-psi tire pressure

Solution:

<u>a</u>. Calculate CBR × 100/tire pressure: CBR × 100/tire pressure = 8 × 100/100 = 8.0

<u>b</u>. From the 30.0-kip ESWL curve in plate 13, read coverages/load of 9.4.

<u>c</u>. Calculate coverages: coverages = 9.4 × 30.0 kips = 280

Based on the example calculation shown above, the expected coverage levels on MO-MAT 158 placed on an 8-CBR subgrade for a CH-47C helicopter with an ESWL of 17,300 lb and a tire inflation pressure of 88 psi and for a CH-54 helicopter with an ESWL of 16,900 lb and a tire inflation pressure of 181 psi are 610 and 90, respectively.

PART VII: SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATION

Results

32. Results of this investigation are as follows:

a. The four special panels of MO-MAT 158 were placed at a rate of 150 sq ft per man-hour.

b. The average coefficients of friction on dry and wet surfaces were 0.45 and 0.30, respectively.

c. Traffic capability results of the MO-MAT 158 indicate that the material will sustain 96, 184, and 500 coverages of a 30,000-lb single-wheel load with a tire inflation pressure of 100 psi when placed on subgrades with CBR's of 4.0, 6.5, and 10, respectively.

Conclusions

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

a. The MO-MAT 158 does not meet the light-duty mat requirement of sustaining 1000 coverages of a 30,000-lb single-wheel load with a tire inflation pressure of 100 psi when placed on a 4.0-CBR subgrade.

b. MO-MAT 158 does not meet the minimum QMR placing rate requirement of 400 sq ft per man-hour.

c. The coefficient of friction on a wet surface (0.30) falls below the QMR required minimum (0.4); however, the coefficient of friction could be increased by application of antiskid particles to the mat surface during fabrication.

d. The longitudinal plastic nut plates do not provide enough strength to secure the bolted overlapping panels when the mat is placed on a 4.0-CBR subgrade.

e. The longitudinal and transverse joints do not provide a waterproof connection.

f. Excessive deflection of the MO-MAT 158 occurs because of lack of rigidity.

g. Due to the installation problems and to the potential hazards to aircraft that it would create, the anchorage system used in this test is not feasible for field use.

Recommendation

34. It is recommended that no further consideration be given to the use of MO-MAT 158 as light-duty landing mat.

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Table 1

Summary of Test 1 Water Content, Density, and CBR Data

Item	Station	Coverages	Depth in.	Water Content %	Dry Density pcf	CBR	Rated CBR
1	0+07	0	0	30.3	89.7	3.4	4.0
			6	28.3	89.8	4.3	
			12	28.9	88.7	3.7	
			Avg	29.2	89.4	3.8	
	0+15	0	0	28.1	89.0	3.4	
			6	28.3	91.6	4.4	
			12	27.3	93.6	5.0	
			Avg	27.9	91.4	4.3	
	0+10	316*	0	28.5	89.6	3.6	
			6	29.0	90.0	2.4	
			12	29.3	89.6	2.4	
			Avg	28.9	89.7	2.8	
	0+15	316*	0	27.2	92.9	4.1	
			6	27.6	90.3	3.7	
			12	28.7	90.8	4.0	
			Avg	27.8	91.3	3.9	
	0+15	316*	0	27.8	91.7	5.0	
			6	28.3	89.9	3.9	
			12	27.8	91.4	5.3	
			Avg	28.0	91.0	4.7	
2	0+30	0	0	26.7	93.7	5.8	6.5
			6	26.3	92.0	5.7	
			12	26.5	93.3	7.0	
			Avg	26.5	93.0	6.2	
	0+35	0	0	26.8	92.5	5.9	
			6	25.7	93.5	7.5	
			12	24.8	96.1	7.2	
			Avg	25.8	94.0	6.9	
	0+30	316**	0	26.9	93.5	6.0	
			6	26.4	94.3	6.0	
			12	27.1	96.0	6.0	
			Avg	26.8	94.6	6.0	
	0+35	316**	0	27.4	92.3	6.0	
			6	26.5	93.2	7.0	
			12	25.7	95.0	8.0	
			Avg	26.5	93.5	7.0	

* Item 1 subgrade failed at 96 coverages, but traffic was continued to 316 coverages.

** Item 2 subgrade failed at 184 coverages, but traffic was continued to 316 coverages.

Table 2

Summary of Test 2 Water Content, Density, and CBR Data

Station	Coverages	Depth in.	Water Content %	Density pcf	CBR	Rated CBR
0+15	0	0	25.6	94.1	8.0	10
		6	24.3	96.5	11.0	
		12	24.4	95.6	12.0	
		Avg	24.8	95.4	10.0	
0+30	0	0	25.5	93.9	9.0	
		6	23.4	90.4	10.0	
		12	24.3	94.9	11.0	
		Avg	24.4	93.1	10.0	
0+12	500	0	26.3	94.1	8.0	
		6	24.2	98.3	10.0	
		12	24.6	98.1	10.0	
		Avg	25.0	96.8	9.0	
0+27	600*	0	25.4	94.6	8.0	
		6	24.2	96.5	10.0	
		12	25.9	96.6	8.0	
		Avg	25.2	95.9	9.0	↓

* Section failed at 500 coverages, but traffic was continued to 600 coverages.

Table 3

Test 1 Deformation Measurements

Coverages	Item 1				Item 2			
	Sections 1 and 2	Sections 3 and 4	Sections 5 and 6	Sections 7 and 8	Sections 9 and 10	Sections 11 and 12	Sections 13 and 14	Sections 15 and 16
96	3-7/8	--	--	1-3/8	--	--	--	1-1/8
150	3-1/4	3-3/4	2-3/4	2-1/2	--	2	--	1-1/2
184	3-3/8	4-3/8	3-3/4 (5-1/2)	3-1/2	-- (4-1/4)	2-3/4	2-3/8 (3-1/8)	1-7/8
300	--	5-7/8	5-5/8	5-3/8	4-7/8	--	4-1/8	3-3/8
316	--	6-1/2 (8-1/16)	6-3/8	6-1/8	5-7/8	5-1/2	5	4-5/8

(hatched box) Deformation Failure

Note: Deformation values are in inches. Values in parentheses are values obtained with the load wheel still on the point of deformation; all other values were obtained after the load cart had been removed.

Table 4

Test 2 Deformation Measurements

Coverages	Sections							
	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	13 and 14	15 and 16
100	3/4	--	3/4	--	3/4	--	--	--
130	1-1/4	--	--	1/2	--	--	1/2	1/2
200	1-1/4	1-3/8	1	--	1-3/16	--	--	--
300	2-3/8 (2-1/2)	-- (2-1/4)	1-1/2 (1-1/2)	--	1-3/4	--	3/4 (1)	--
370	(2-3/4)	(2-5/8)	(2)	--	(2)	--	(7/8)	(1)
400	3	3	2-1/2	--	2	--	--	--
450	3-1/4	3-1/4	2-1/2	--	2-1/2	--	--	--
480	3-1/2	3-1/2	2-1/2	2-1/2	2-1/2	2	1-3/4	1
500	3-1/2	3-1/2	2-1/2 (2-5/8)	2-1/2 (2-5/8)	2-1/2 (3-1/8)	2-1/8 (2-3/8)	1-3/4	1
530	--	--	2-3/4	2-3/4	3	2-1/8	1-3/4	1
560	--	--	3-1/8 (3-3/8)	3 (3-1/2)	3-1/8 (3-3/4)	2-3/4 (3)	2 (1-7/8)	1
600	--	--	3 (3-1/2)	3	3 (3-7/8)	3 (3)	2-1/4	2-1/4

(hatched box) Deformation Failure

Note: Deformation values are in inches. Values in parentheses were obtained with the front wheels of a pickup truck positioned on the point of deformation; all other values were obtained with neither the load cart nor the pickup truck on the test section.

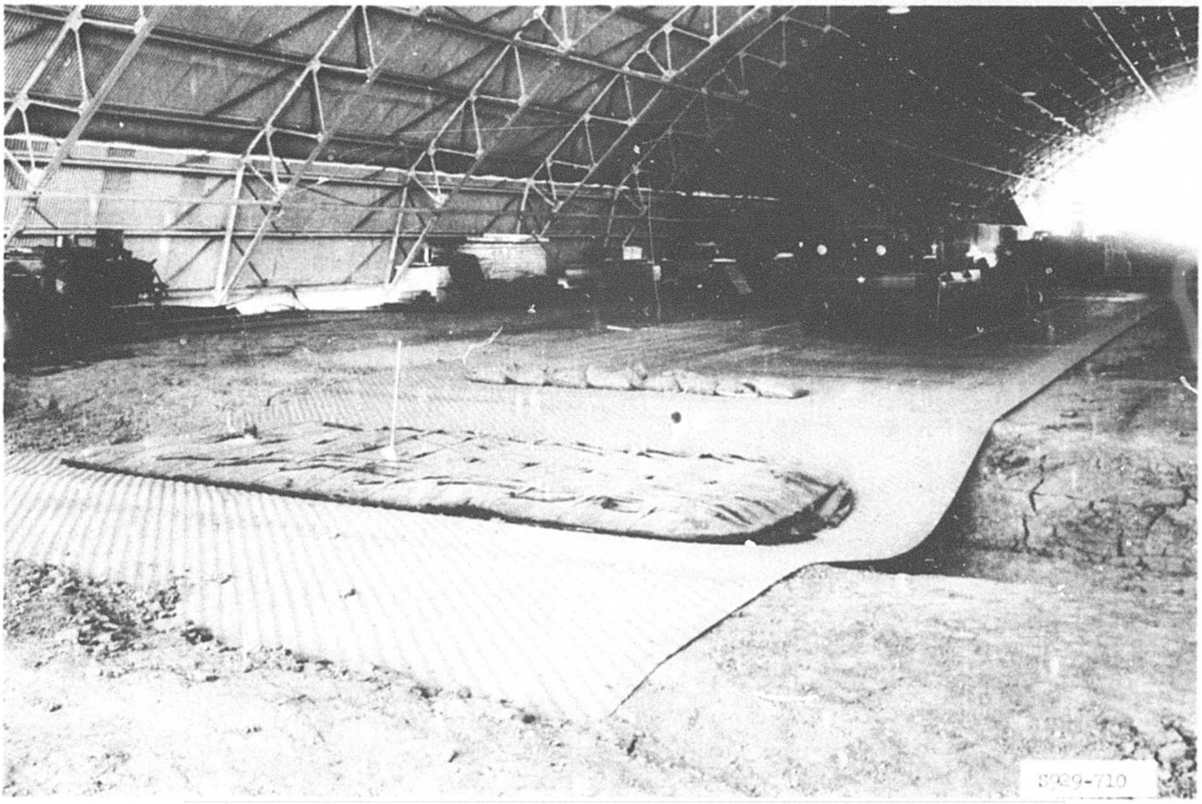


Photo 1. Overall view of test section

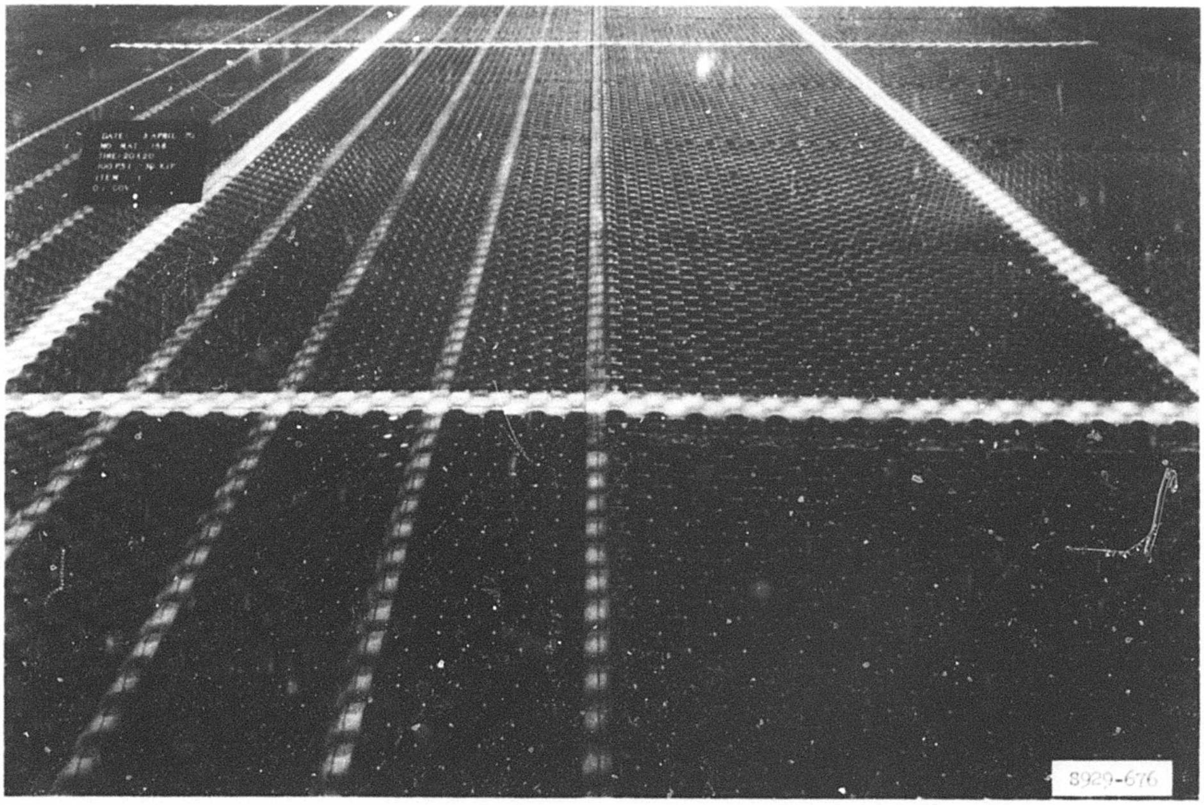


Photo 2. Item 1 prior to traffic, test 1

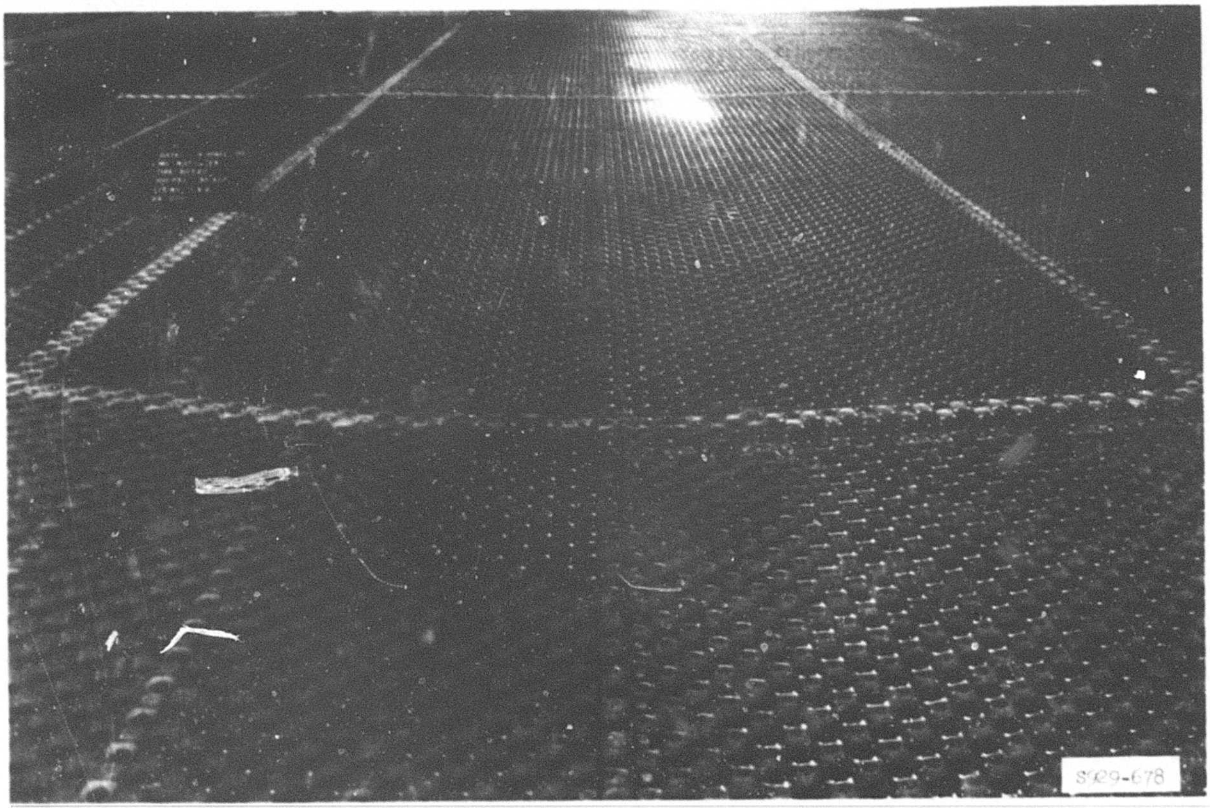


Photo 3. General view of test section after 96 coverages, test 1

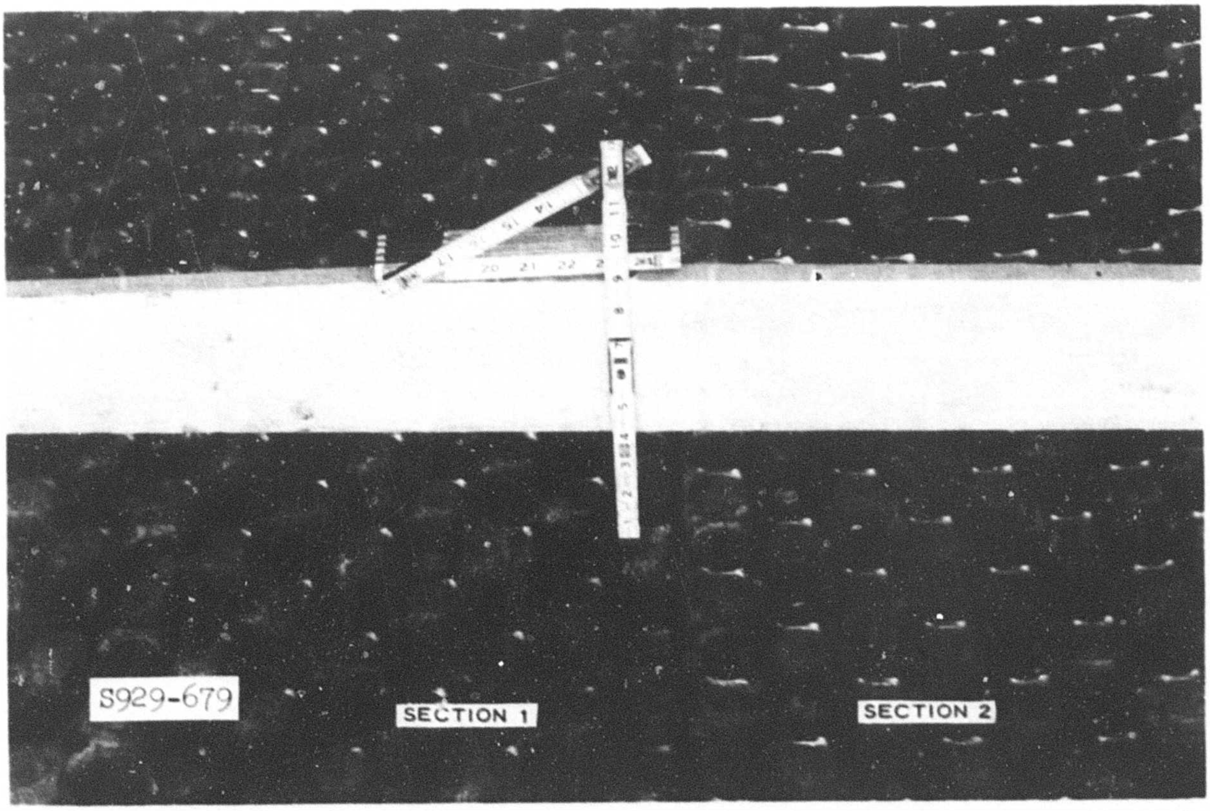


Photo 4. Close-up of 3-7/8-in. deformation across sections 1 and 2 of item 1 after 96 coverages, test 1

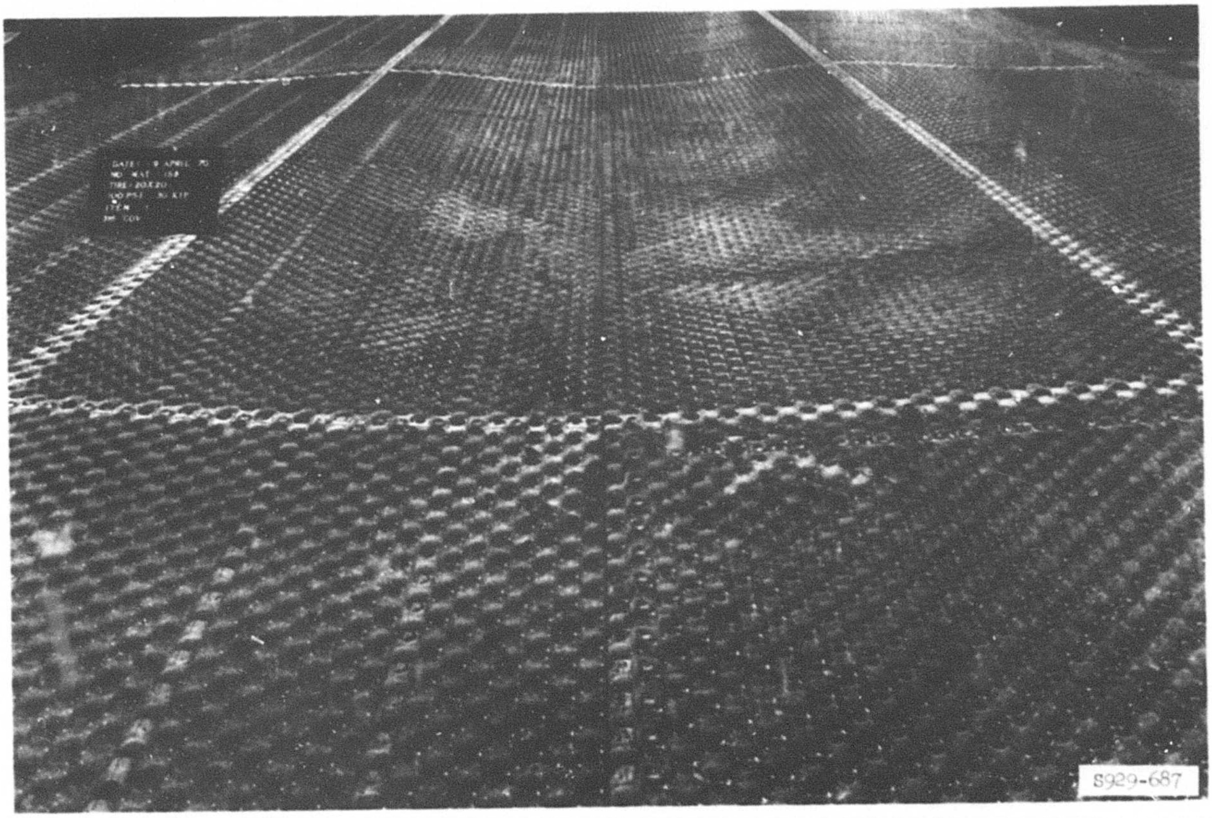


Photo 5. Item 1 after 316 coverages, test 1

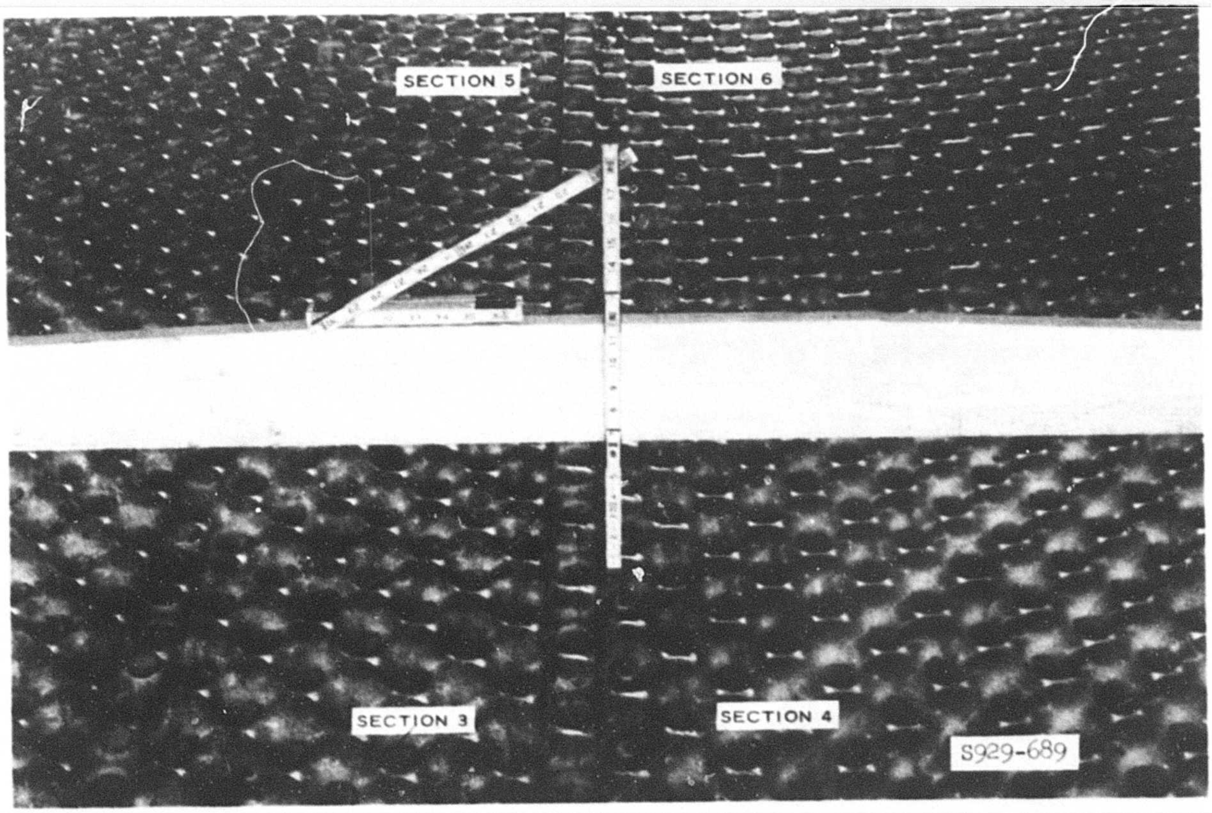


Photo 6. Deformation of 6-1/2 in. across sections 3 and 4 after 316 coverages, test 1

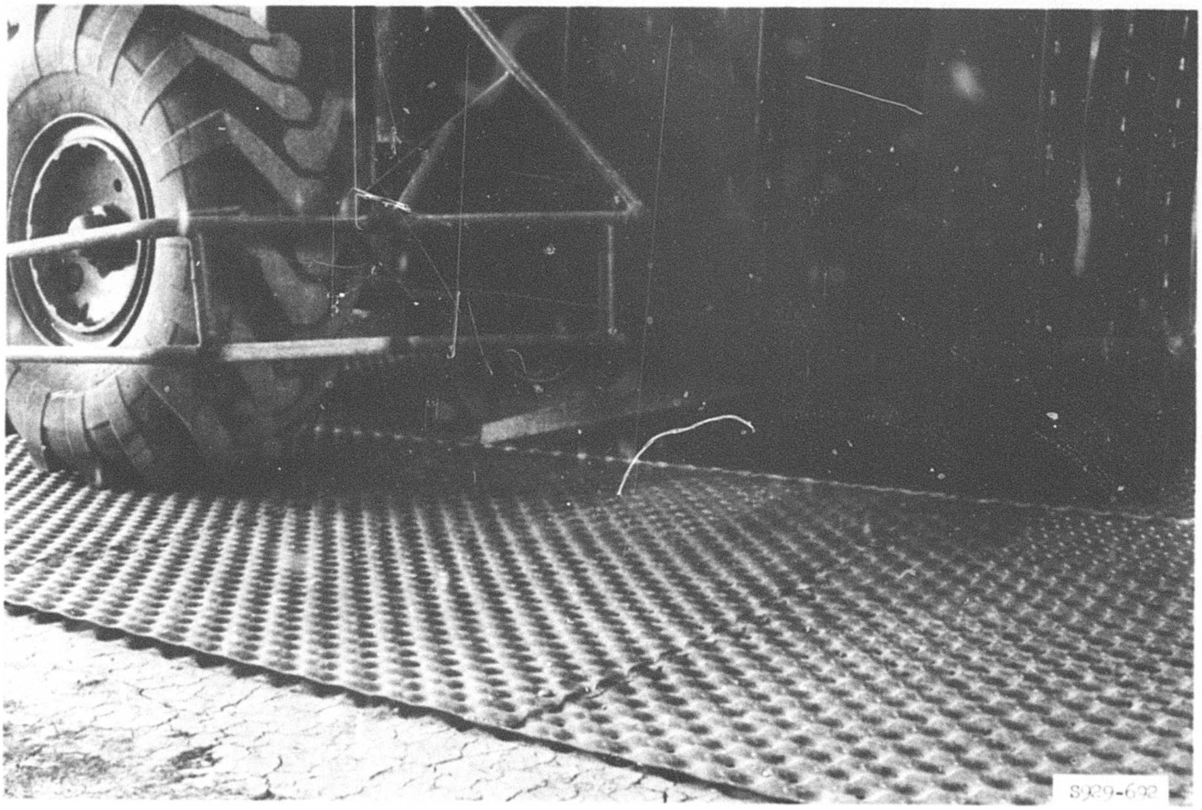


Photo 7. Load wheel deforming mat and subgrade 8-1/16 in. across sections 3 and 4 after 316 coverages, test 1

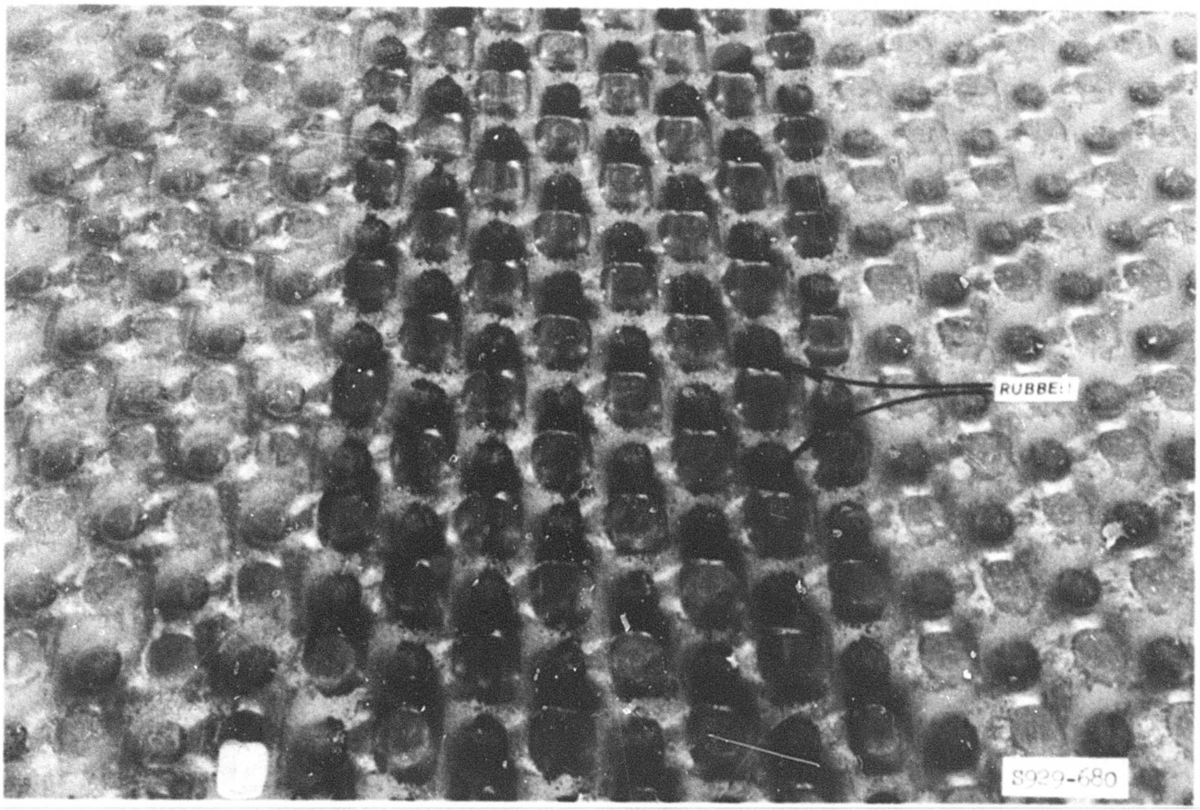


Photo 8. Evidence of tire wear on dry surface

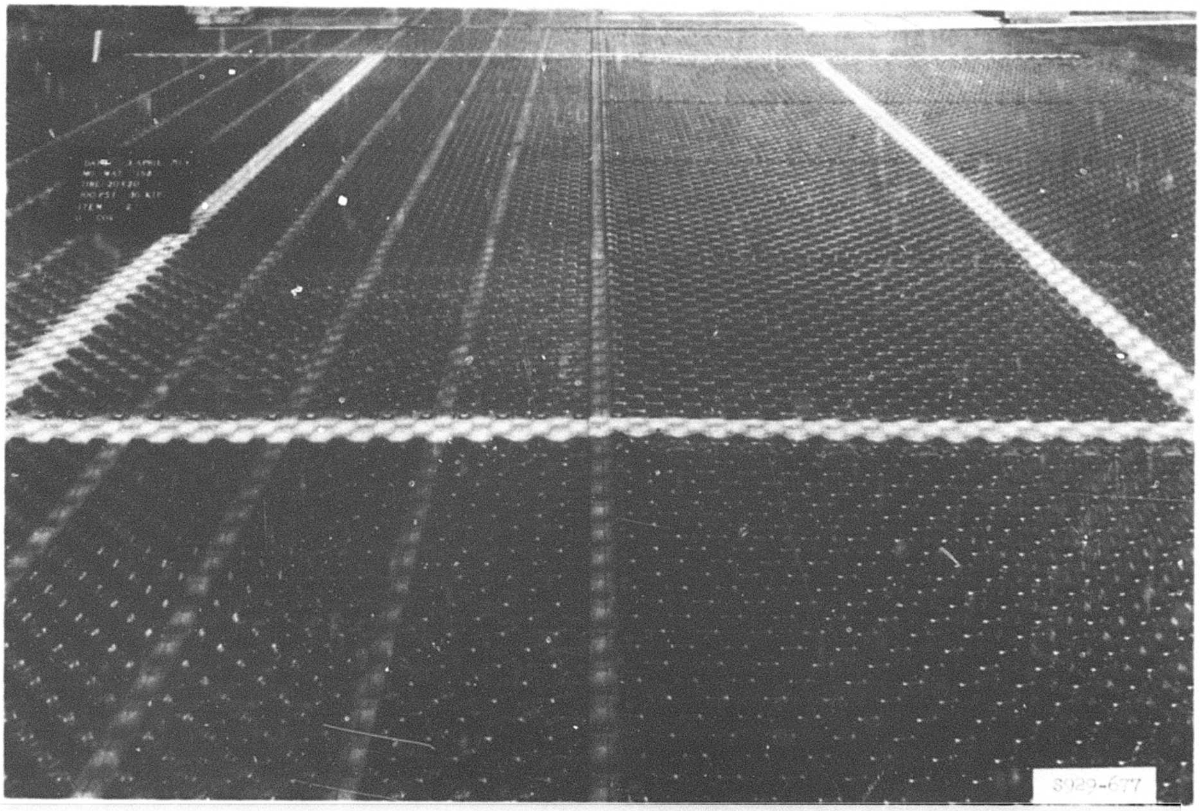


Photo 9. Item 2 prior to traffic, test 1

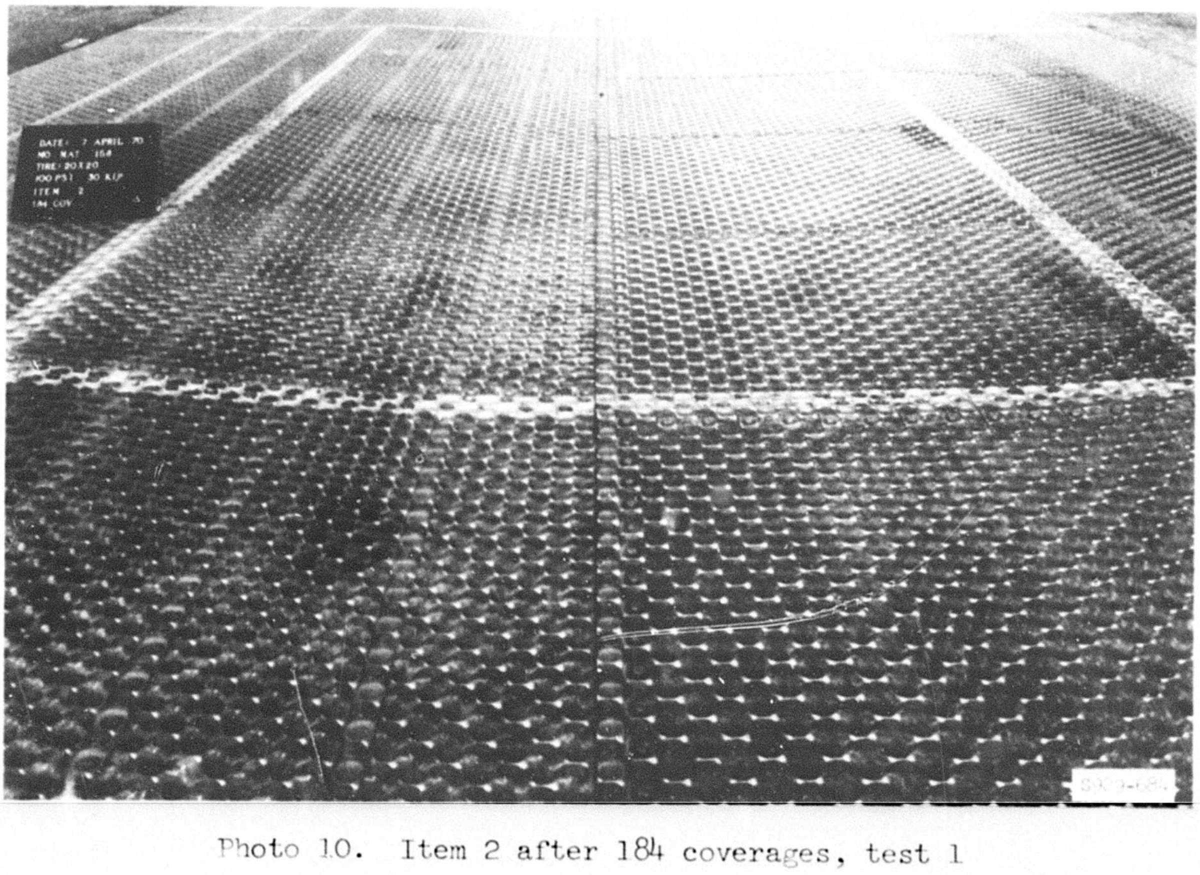


Photo 10. Item 2 after 184 coverages, test 1

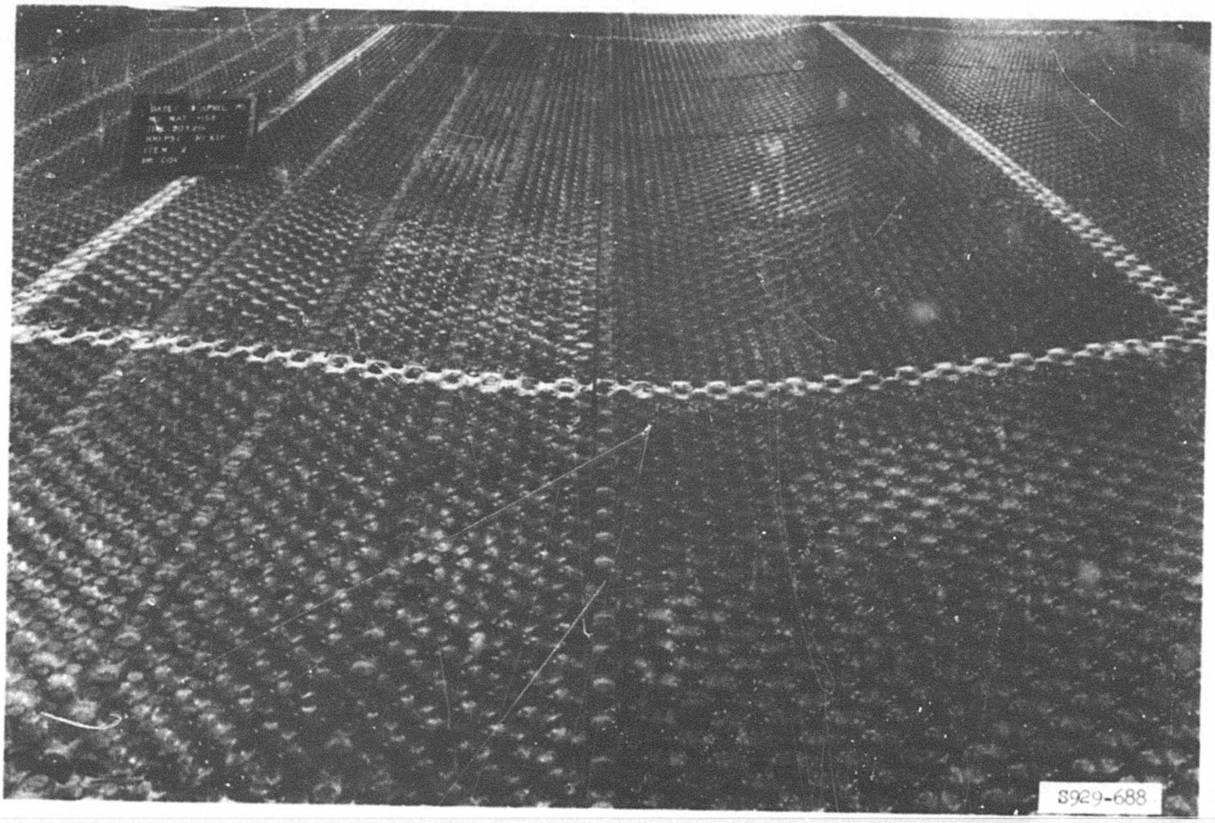


Photo 11. Item 2 after 316 coverages, test 1

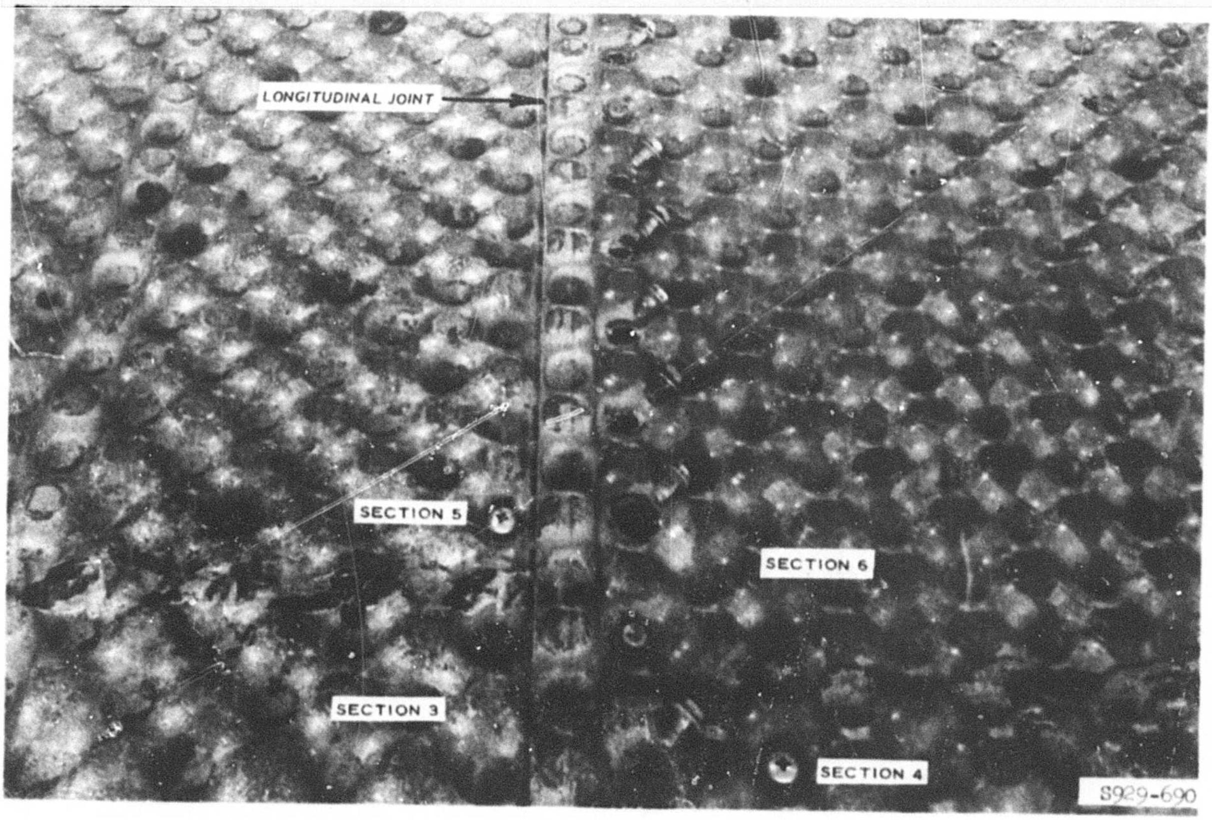


Photo 12. Close-up of bolts stripped from longitudinal joint between sections 5 and 6, test 1

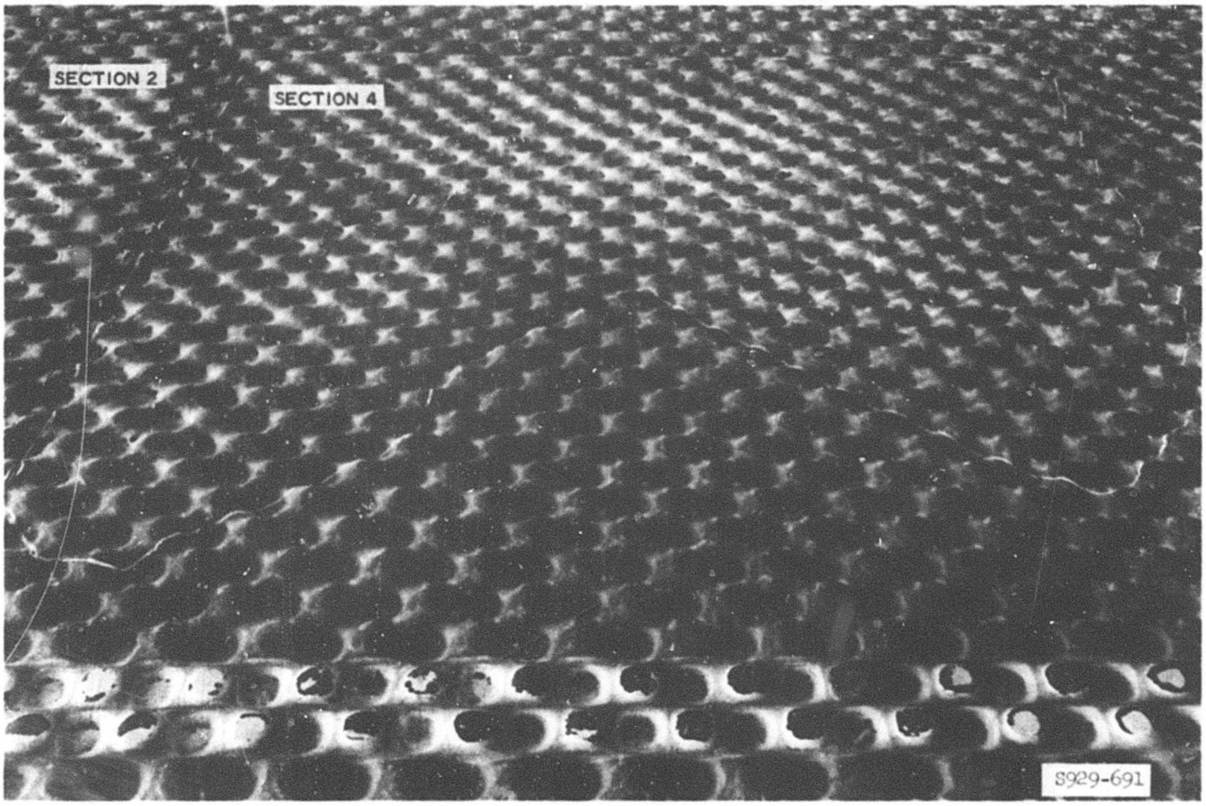


Photo 13. Typical delamination spot, test 1

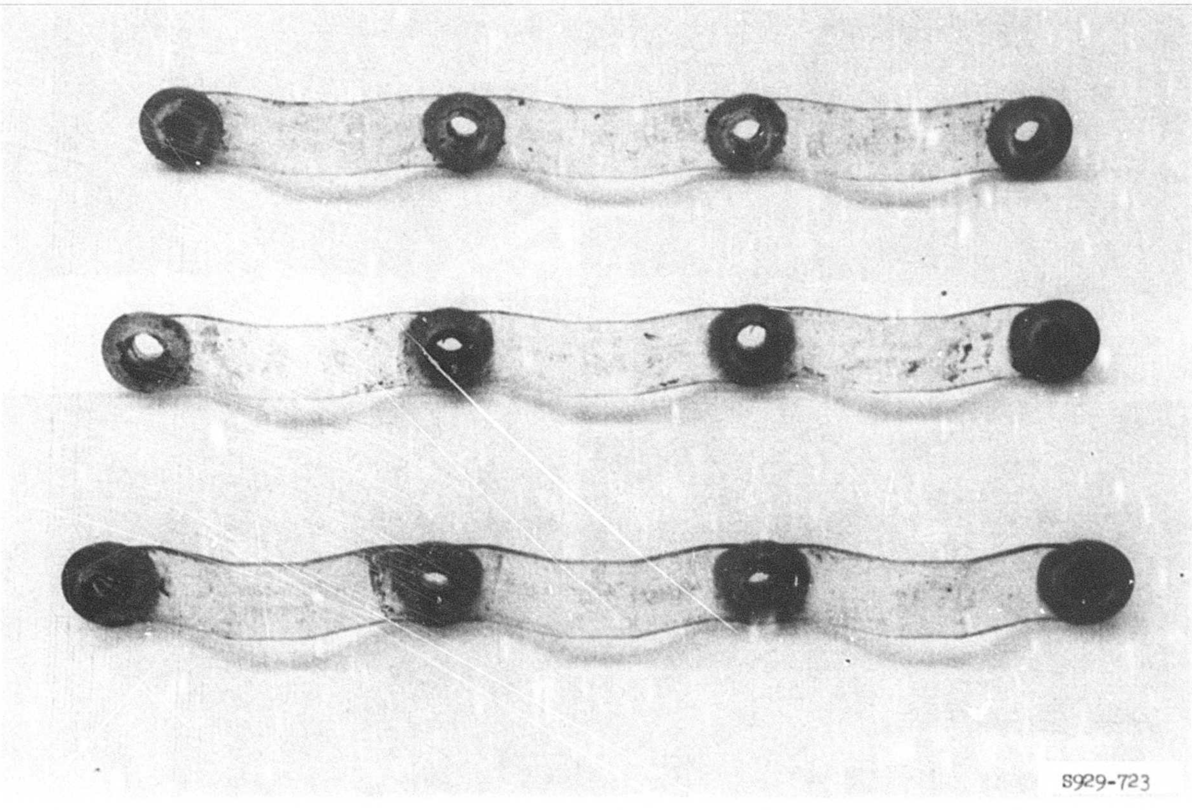


Photo 14. Typical damaged plastic nut plates, test 1

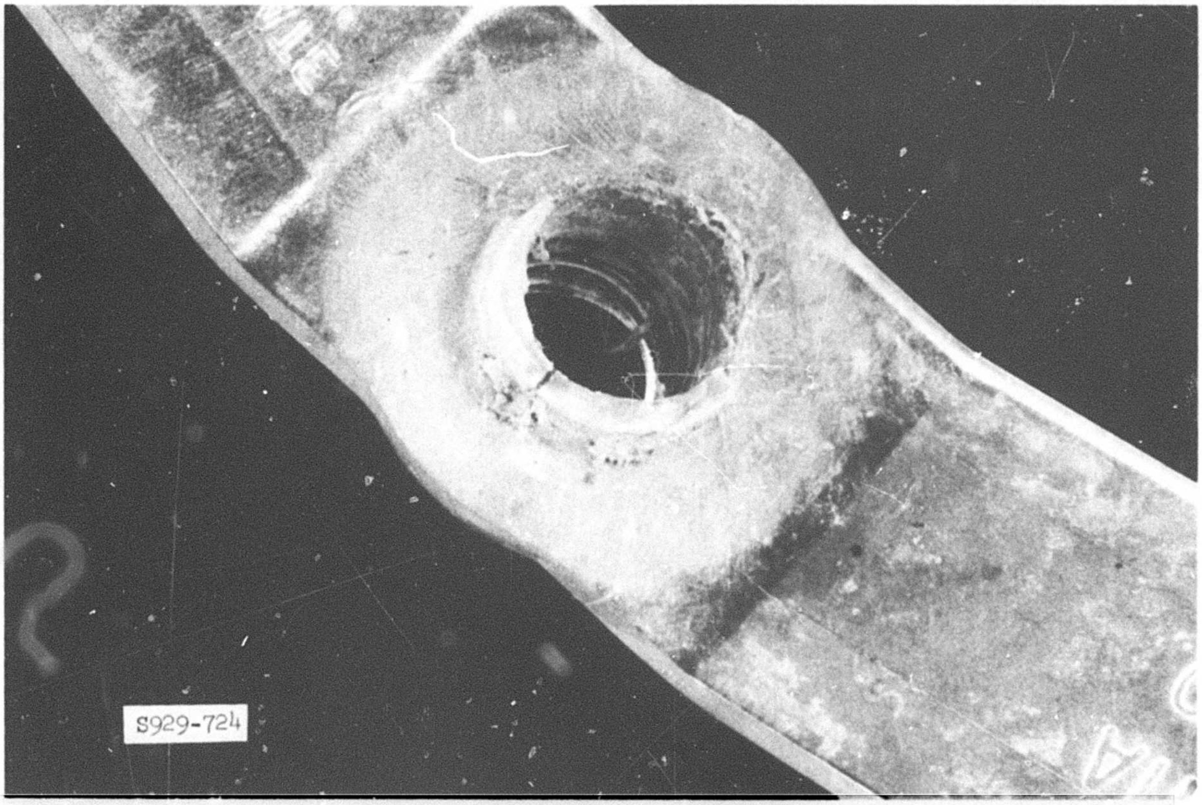


Photo 15. Close-up of stripped threads on plastic nut plate, test 1

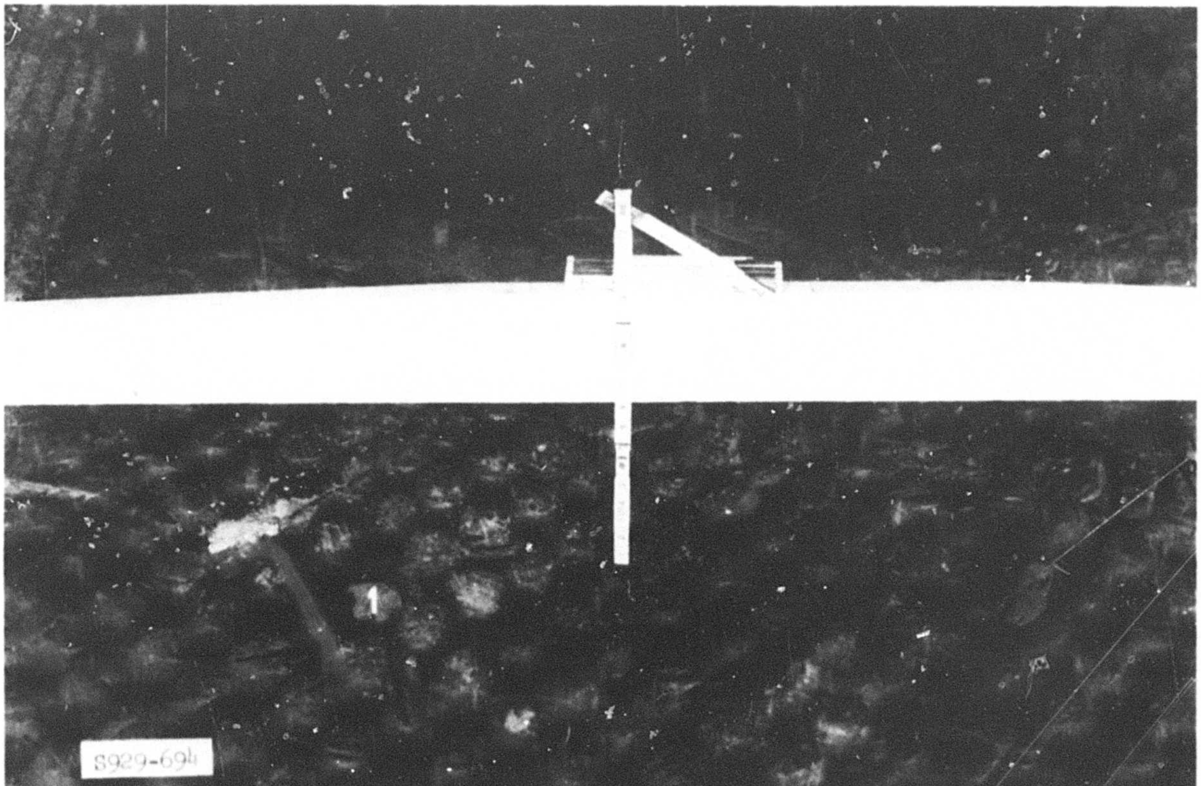


Photo 16. Measurement of 9-in. subgrade deformation on item 1 after completion of test 1

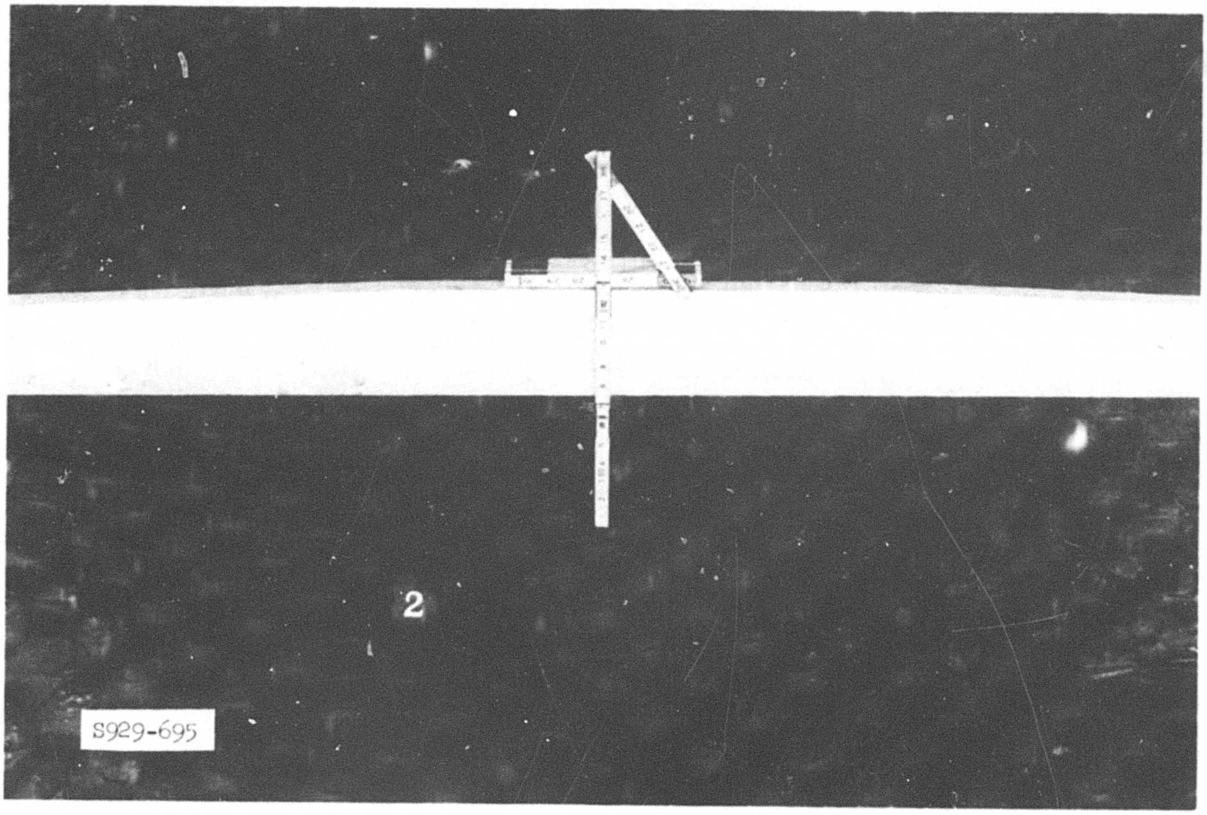


Photo 17. Measurement of 7-1/4-in. subgrade deformation on item 2 after completion of test 1

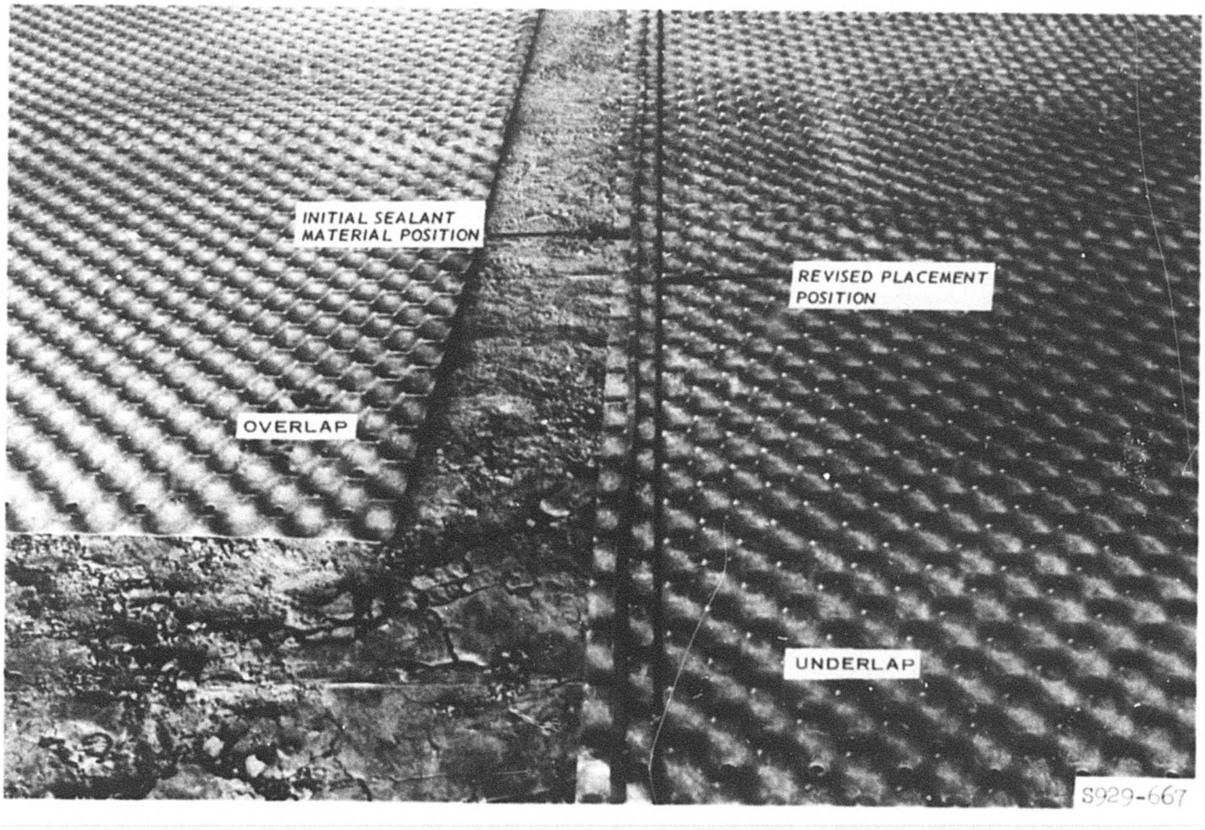


Photo 18. Placement of sealant material at joints

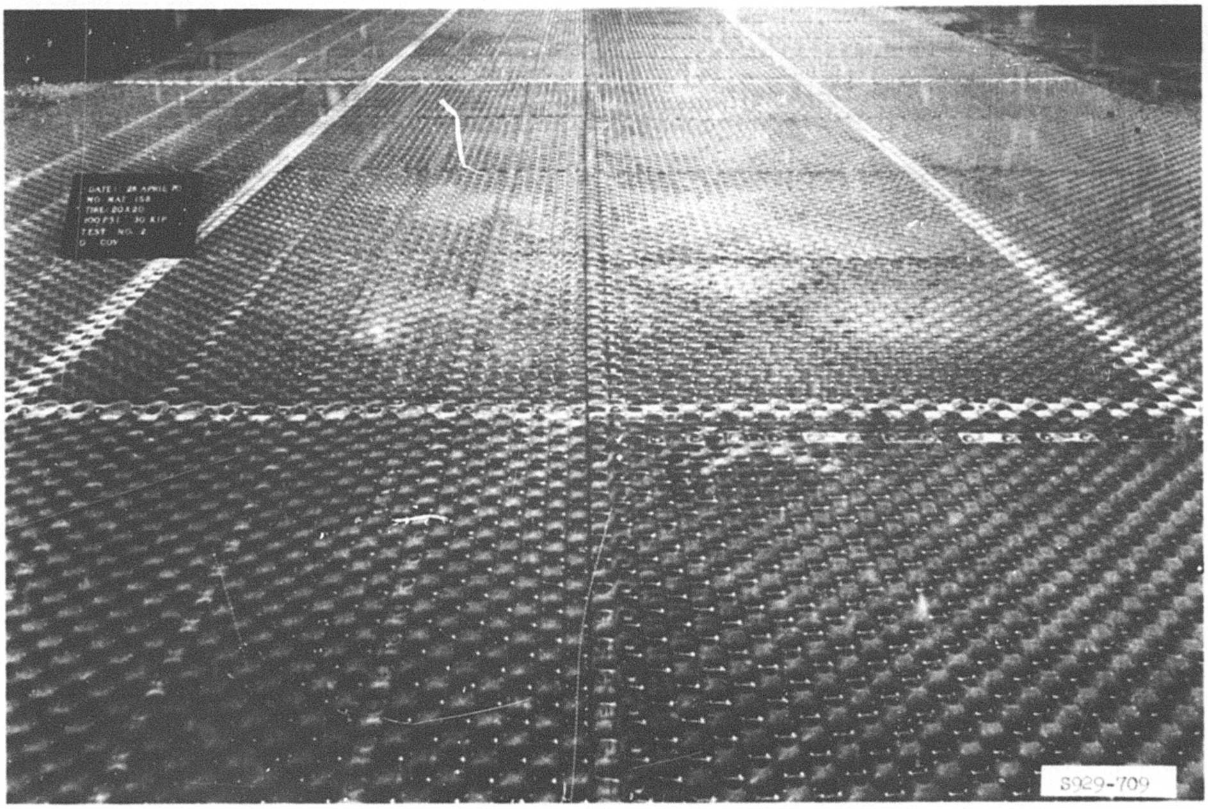


Photo 19. Test section prior to test 2 traffic

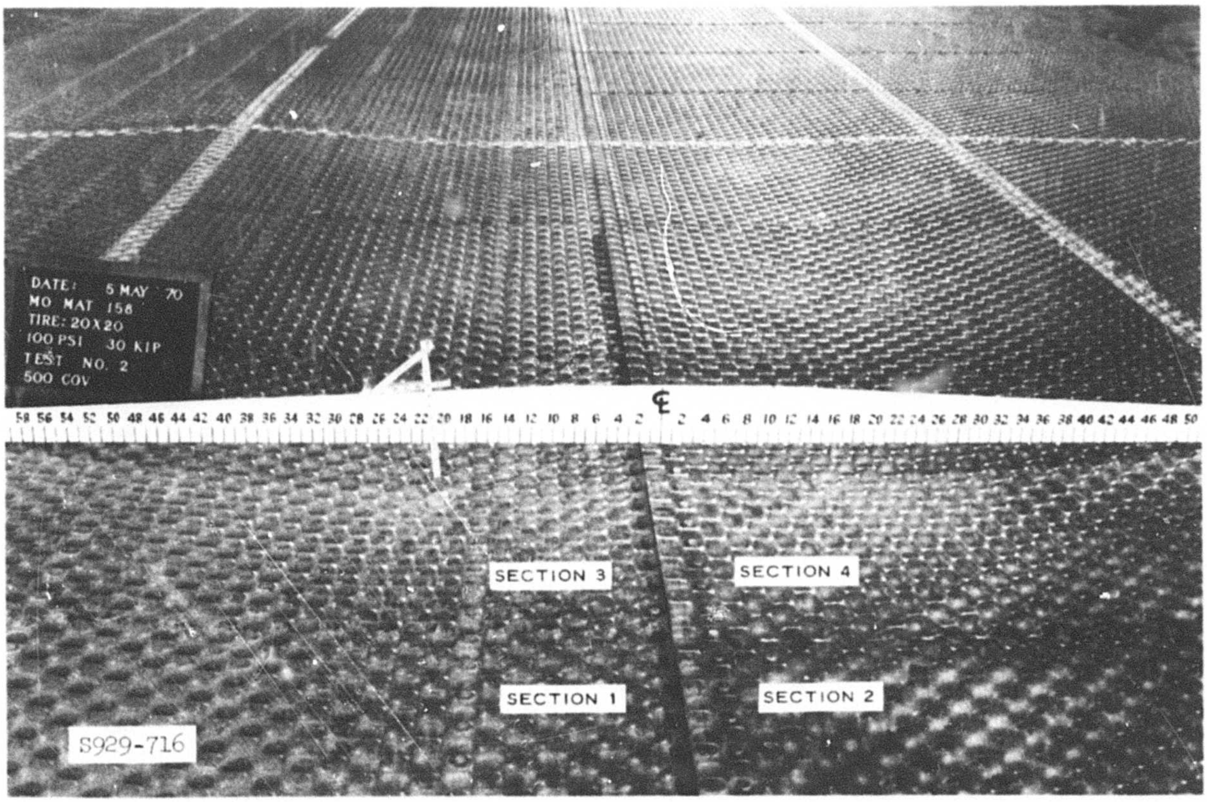


Photo 20. View of 3-1/2-in. deformation across sections 3 and 4 after 500 coverages, test 2

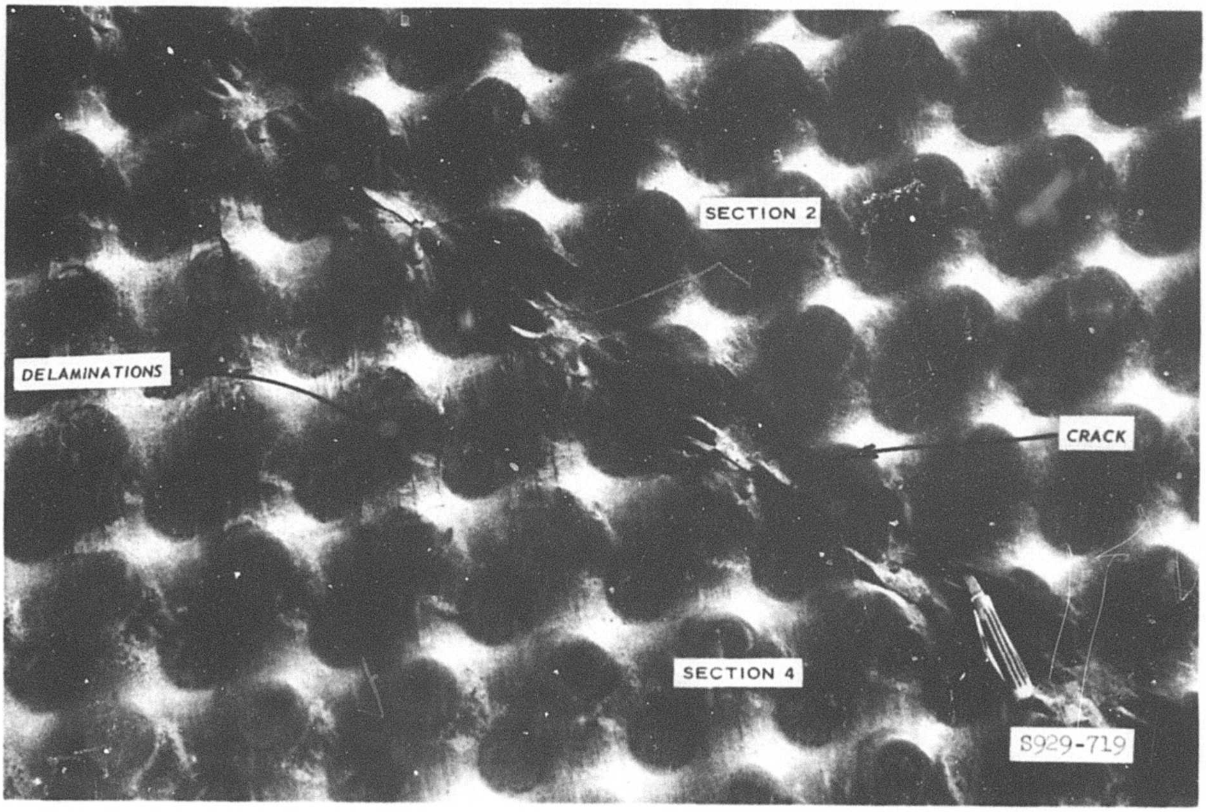


Photo 21. Crack in factory bonded joint between sections 2 and 4 and material delaminations after 500 coverages, test 2

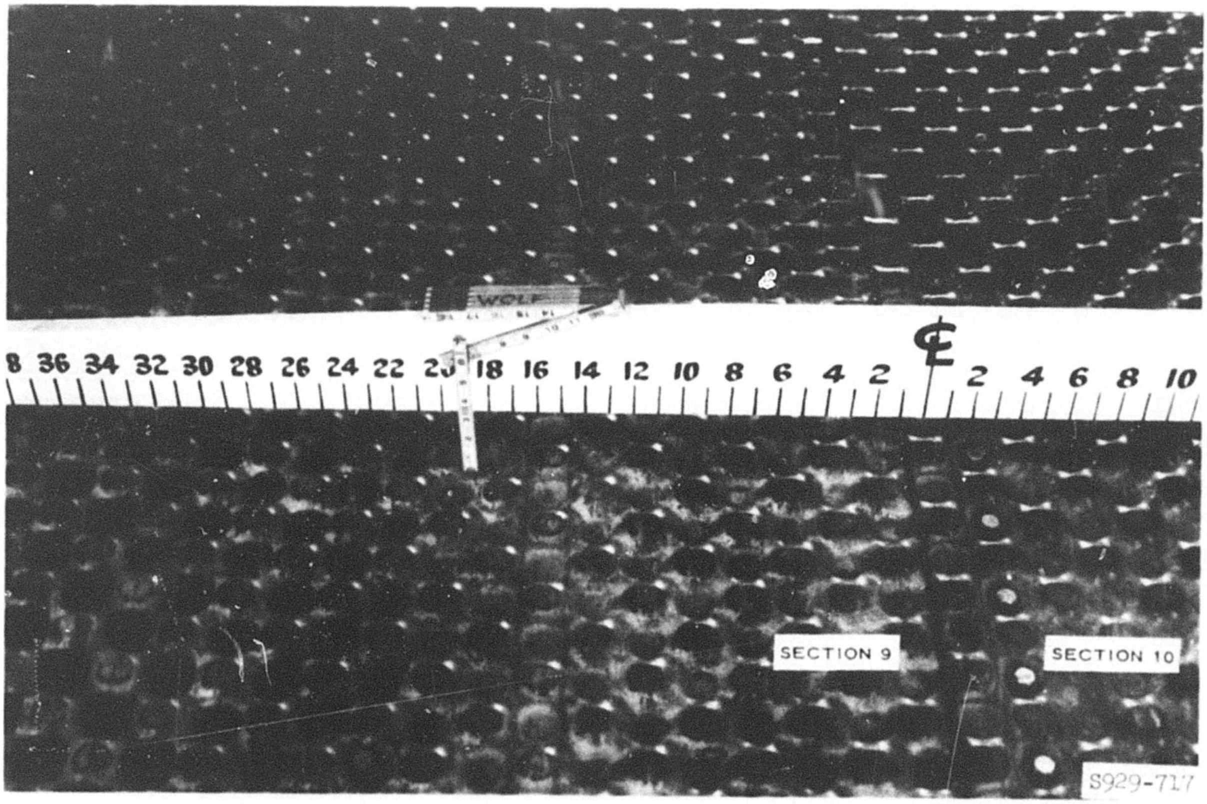


Photo 22. Measurement of 3-in. deformation across sections 9 and 10 after 600 coverages, test 2

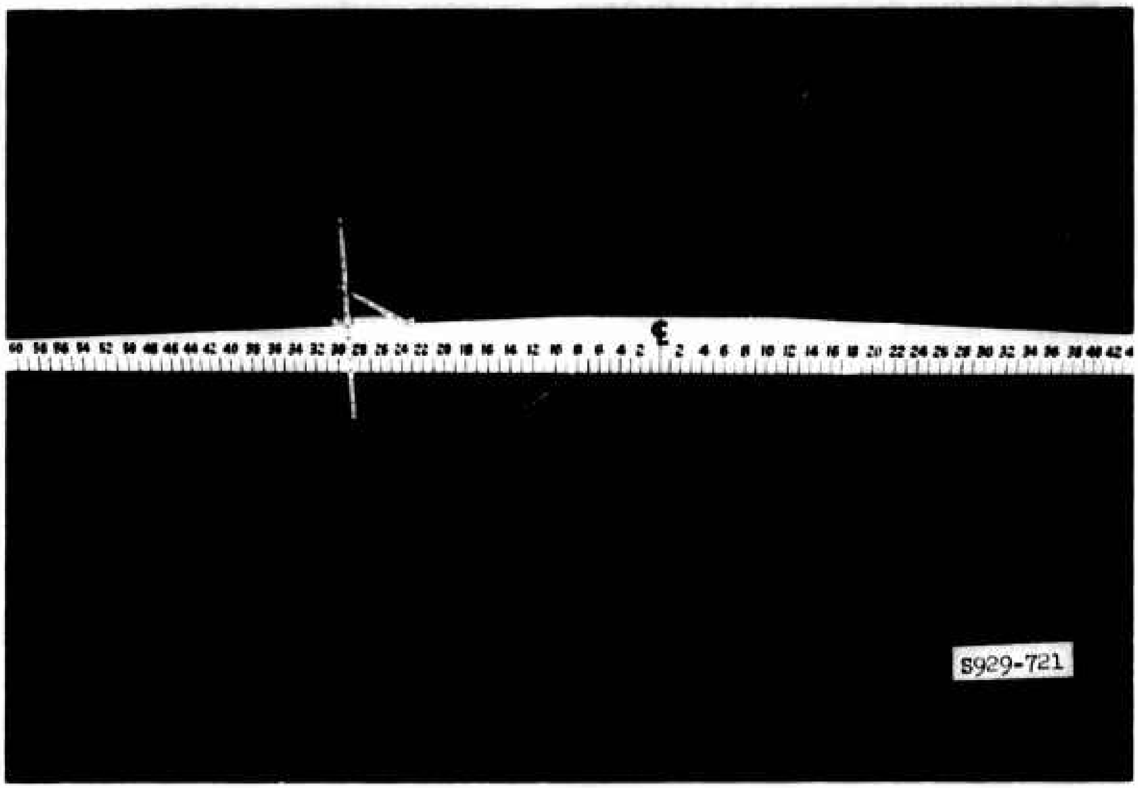


Photo 23. Subgrade deformation of 4-1/4 in. beneath sections 3 and 4 after 500 coverages, test 2

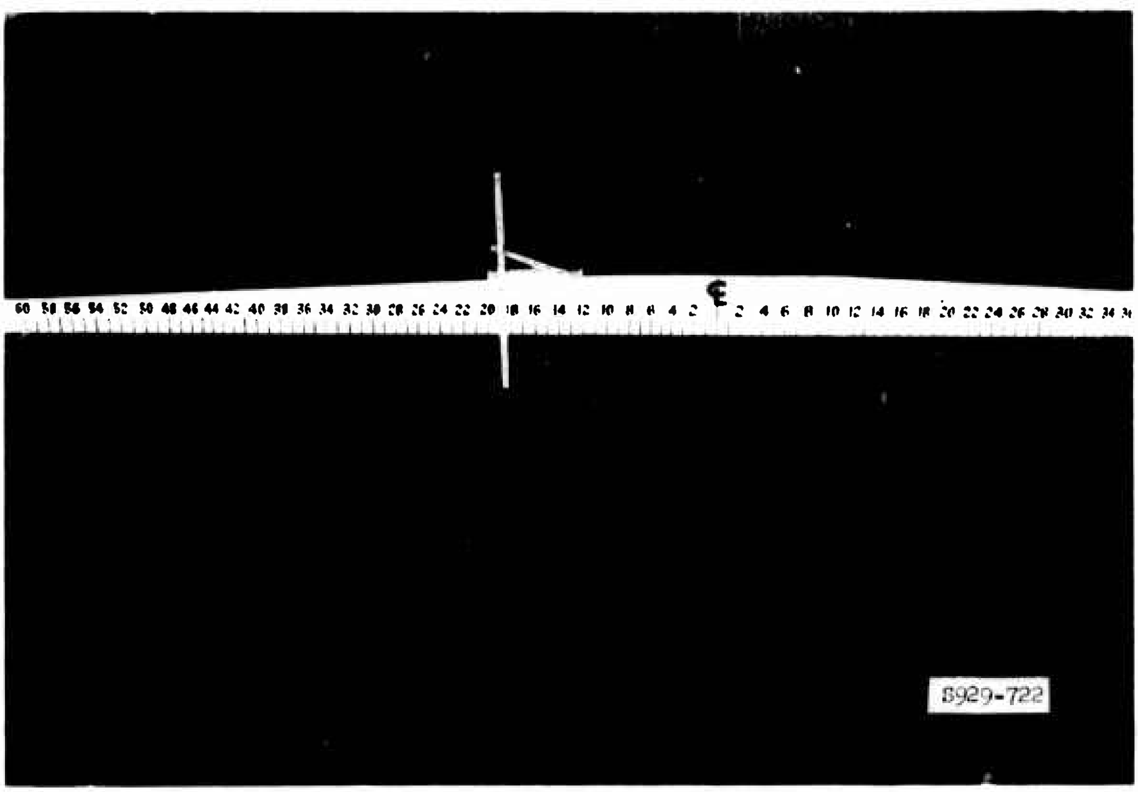
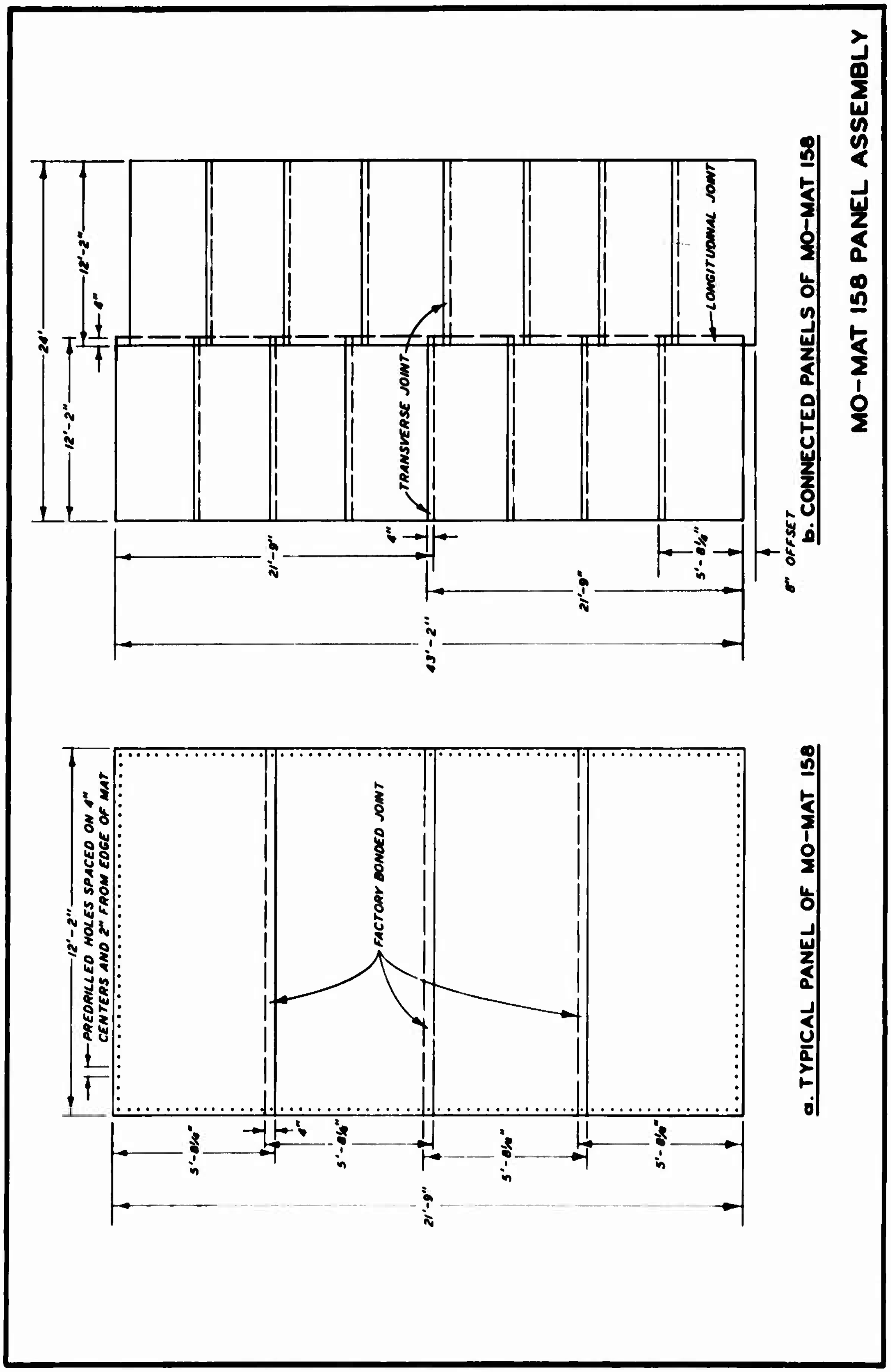


Photo 24. Subgrade deformation of 4-3/4 in. beneath sections 11 and 12 after 600 coverages, test 2



b. CONNECTED PANELS OF MO-MAT 158

a. TYPICAL PANEL OF MO-MAT 158

MO-MAT 158 PANEL ASSEMBLY

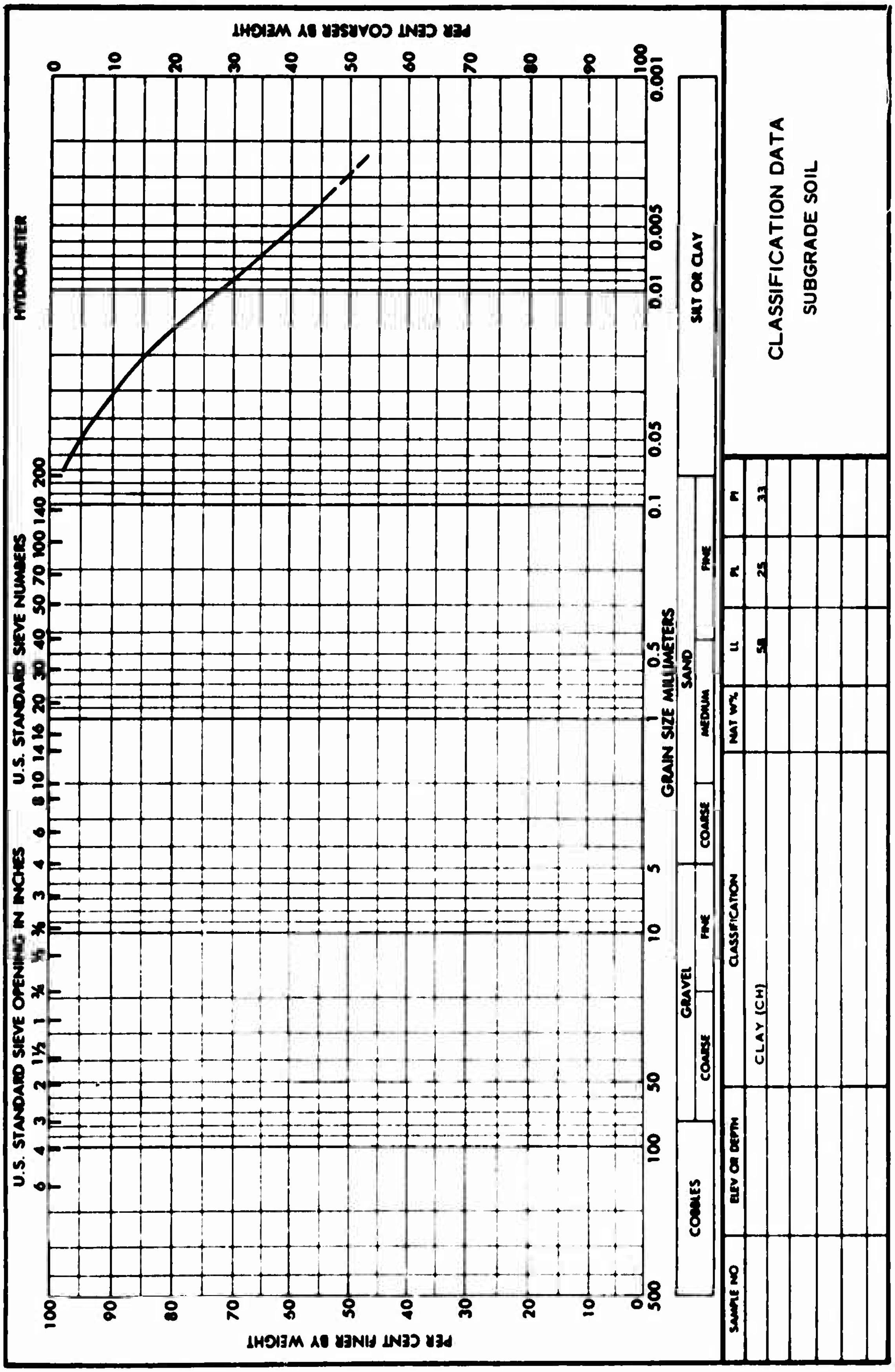
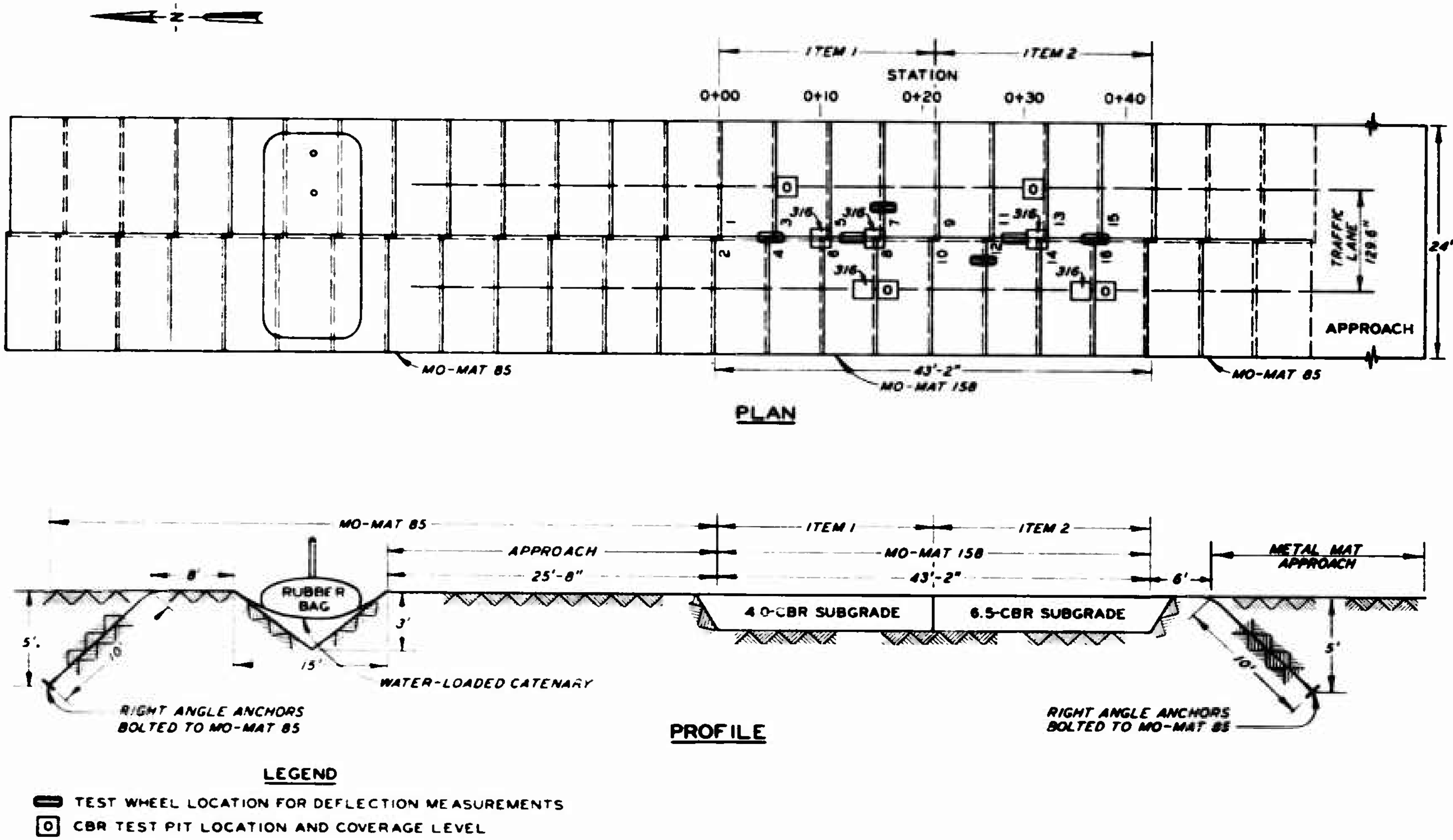
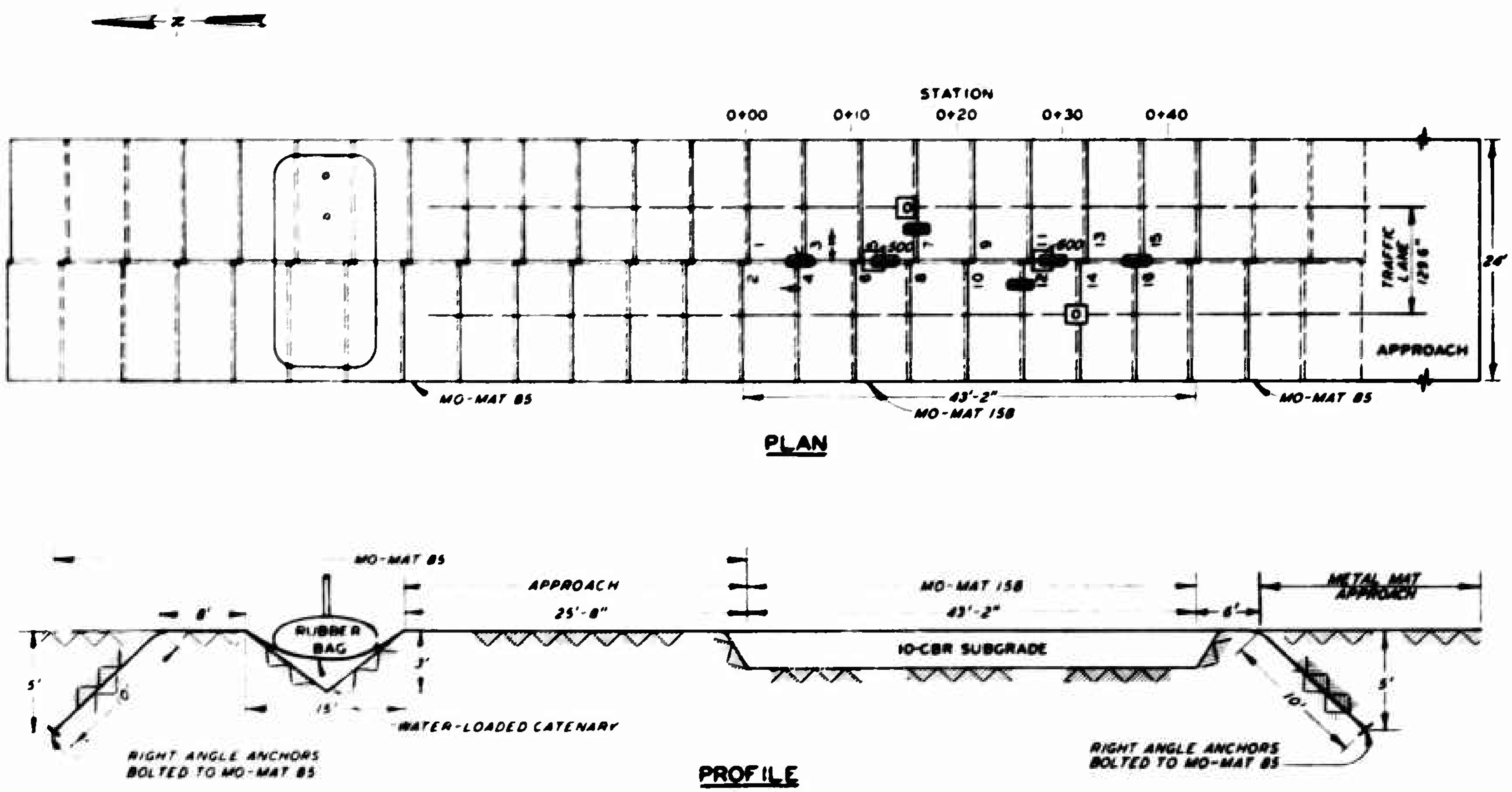

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PER CENT COARSER BY WEIGHT
PER CENT FINER BY WEIGHT
GRAIN SIZE MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
SAMPLE NO
ELEV OR DEPTH
CLASSIFICATION
NAT W%
LL
PL
PI
CLAY (CH)
58
25
33
CLASSIFICATION DATA
SUBGRADE SOIL

PLATE 2



TEST SECTION LAYOUT
TEST 1

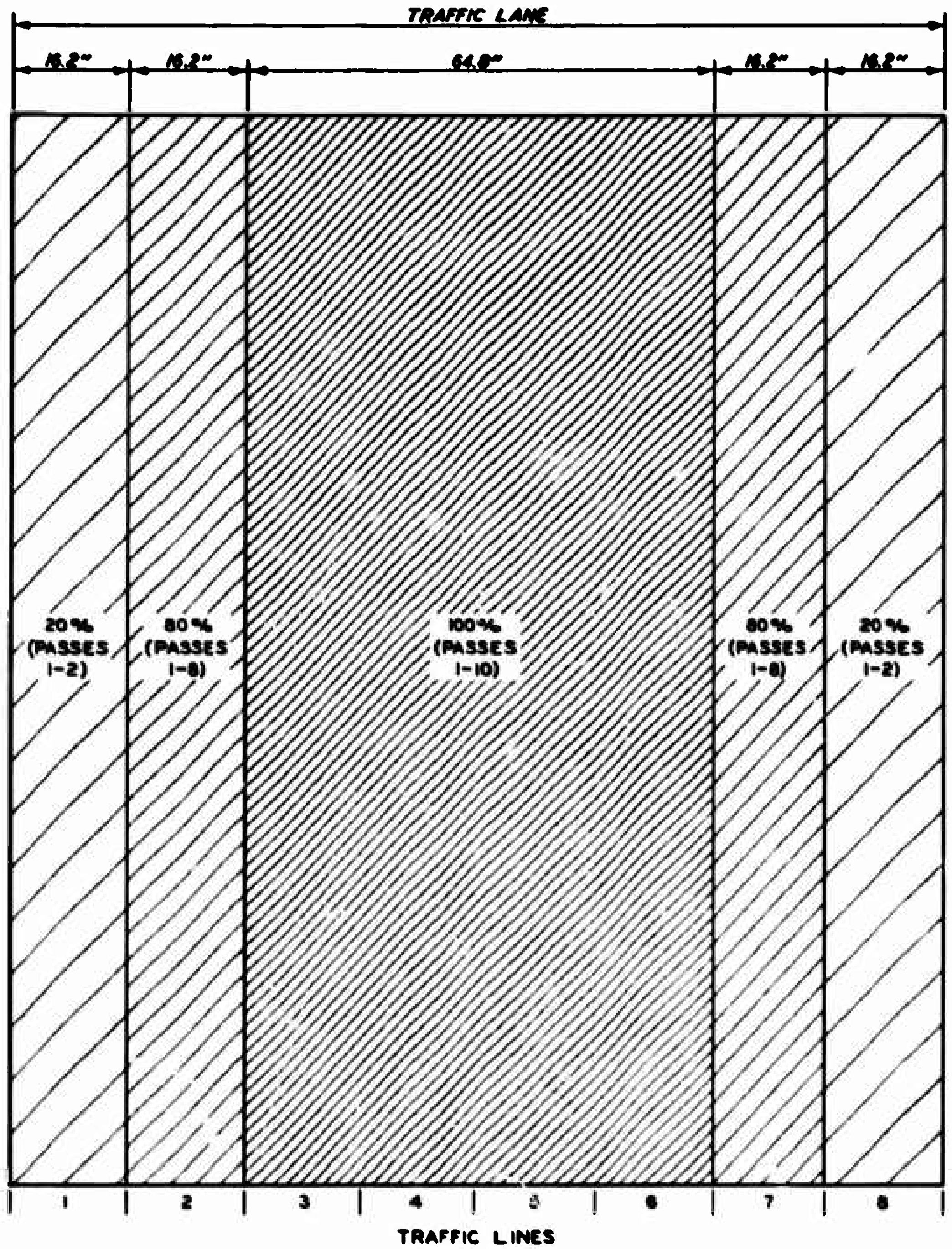


LEGEND

- TEST WHEEL LOCATION FOR DEFLECTION MEASUREMENTS
- [0] CBR TEST PIT LOCATION AND COVERAGE LEVEL
- LEAKAGE LOCATION

TEST SECTION LAYOUT
TEST 2

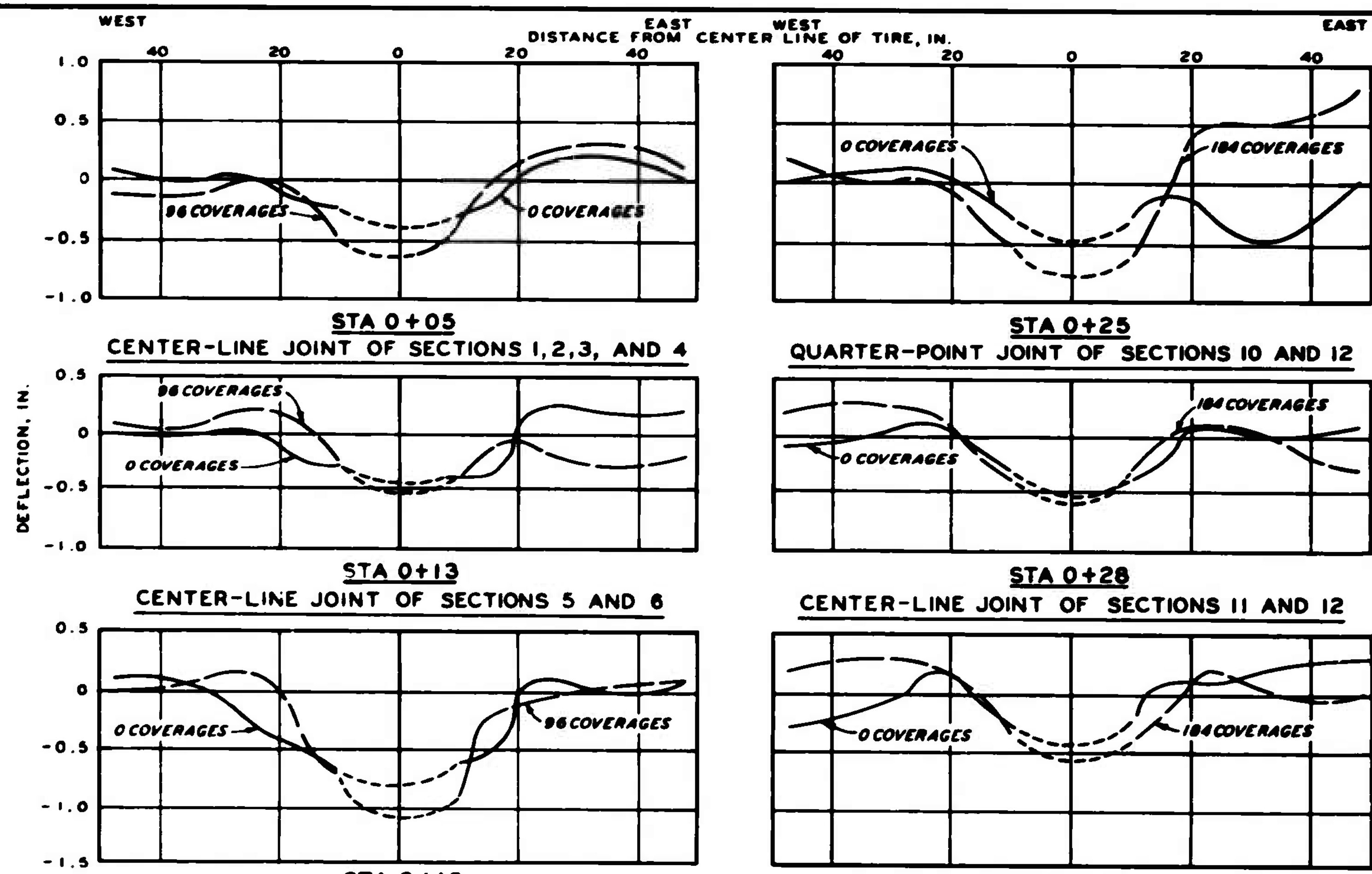
PLATE 4



NOTE: EACH PASS IS EQUAL TO A COVERAGE BY THE 16.2-IN.-WIDE WHEEL OVER EACH TRAFFIC LINE.

TRAFFIC DISTRIBUTION FOR C-130 LOADING

30,000-LB LOAD
100-PSI TIRE PRESSURE



STA 0+05
CENTER-LINE JOINT OF SECTIONS 1,2,3, AND 4

STA 0+13
CENTER-LINE JOINT OF SECTIONS 5 AND 6

STA 0+16
QUARTER-POINT JOINT OF SECTIONS 5 AND 7

ITEM 1

STA 0+25
QUARTER-POINT JOINT OF SECTIONS 10 AND 12

STA 0+28
CENTER-LINE JOINT OF SECTIONS 11 AND 12

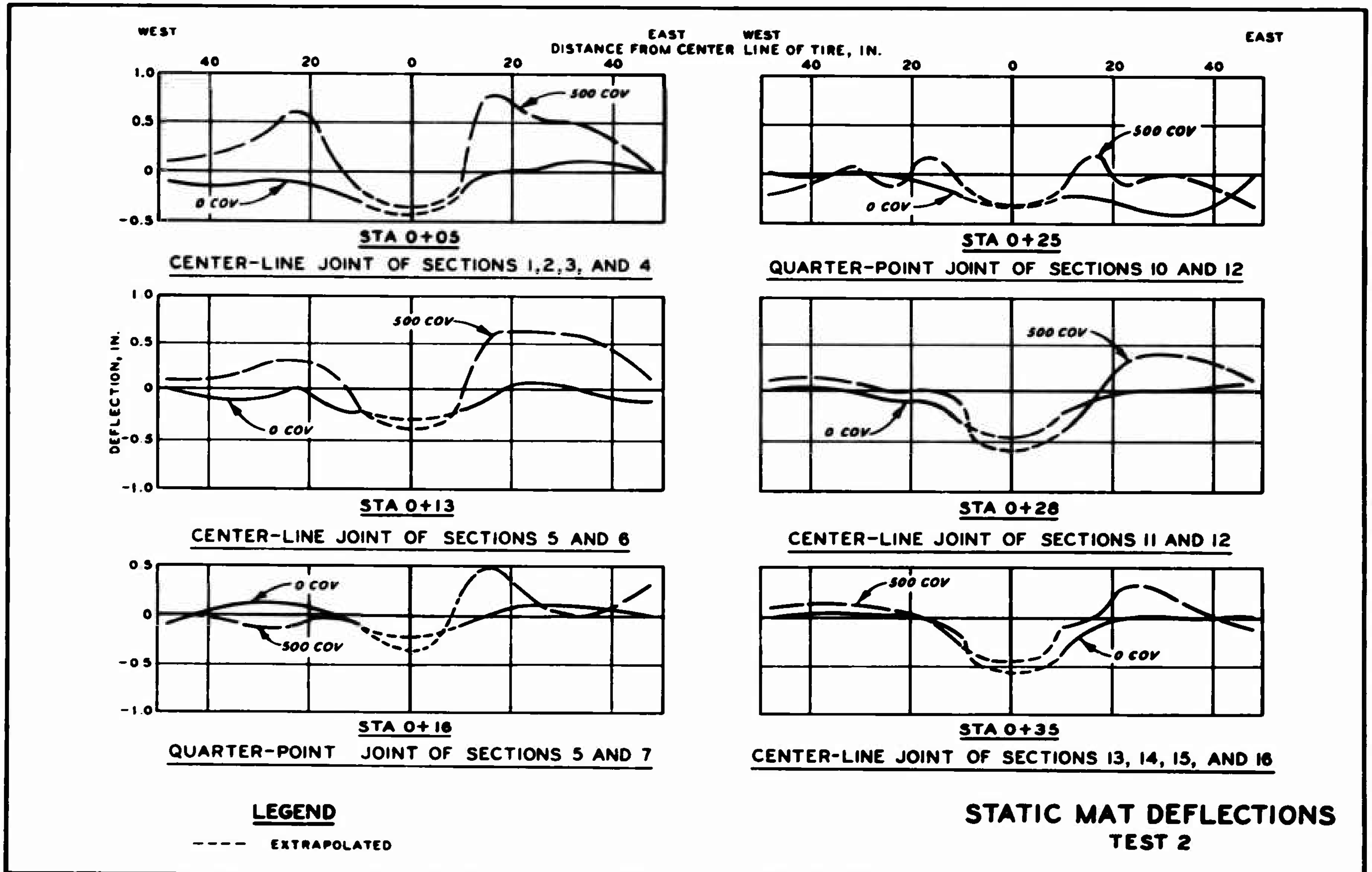
STA 0+35
CENTER-LINE JOINT OF SECTIONS 13, 14, 15, AND 16

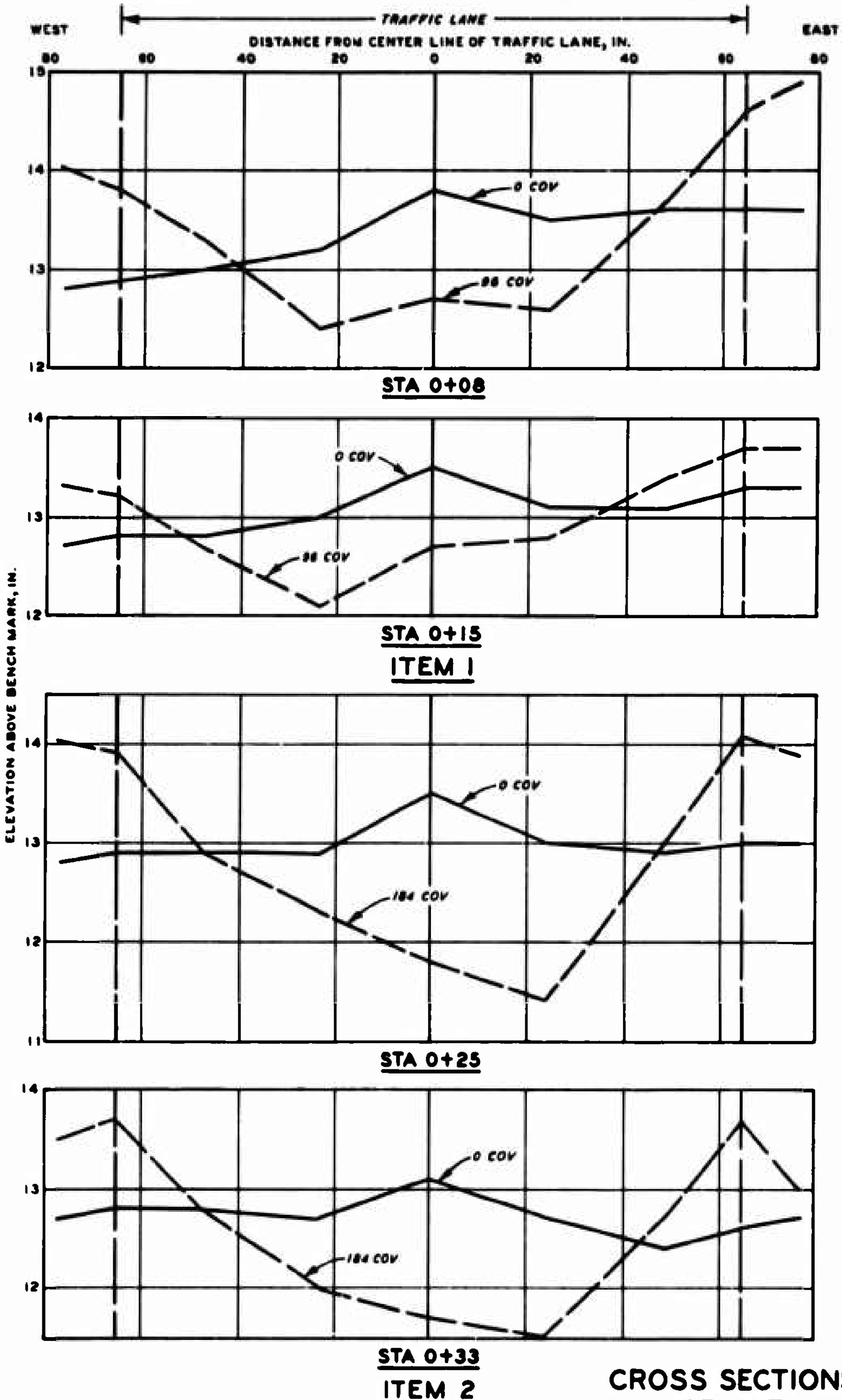
ITEM 2

LEGEND
---- EXTRAPOLATED

STATIC MAT DEFLECTIONS
TEST 1

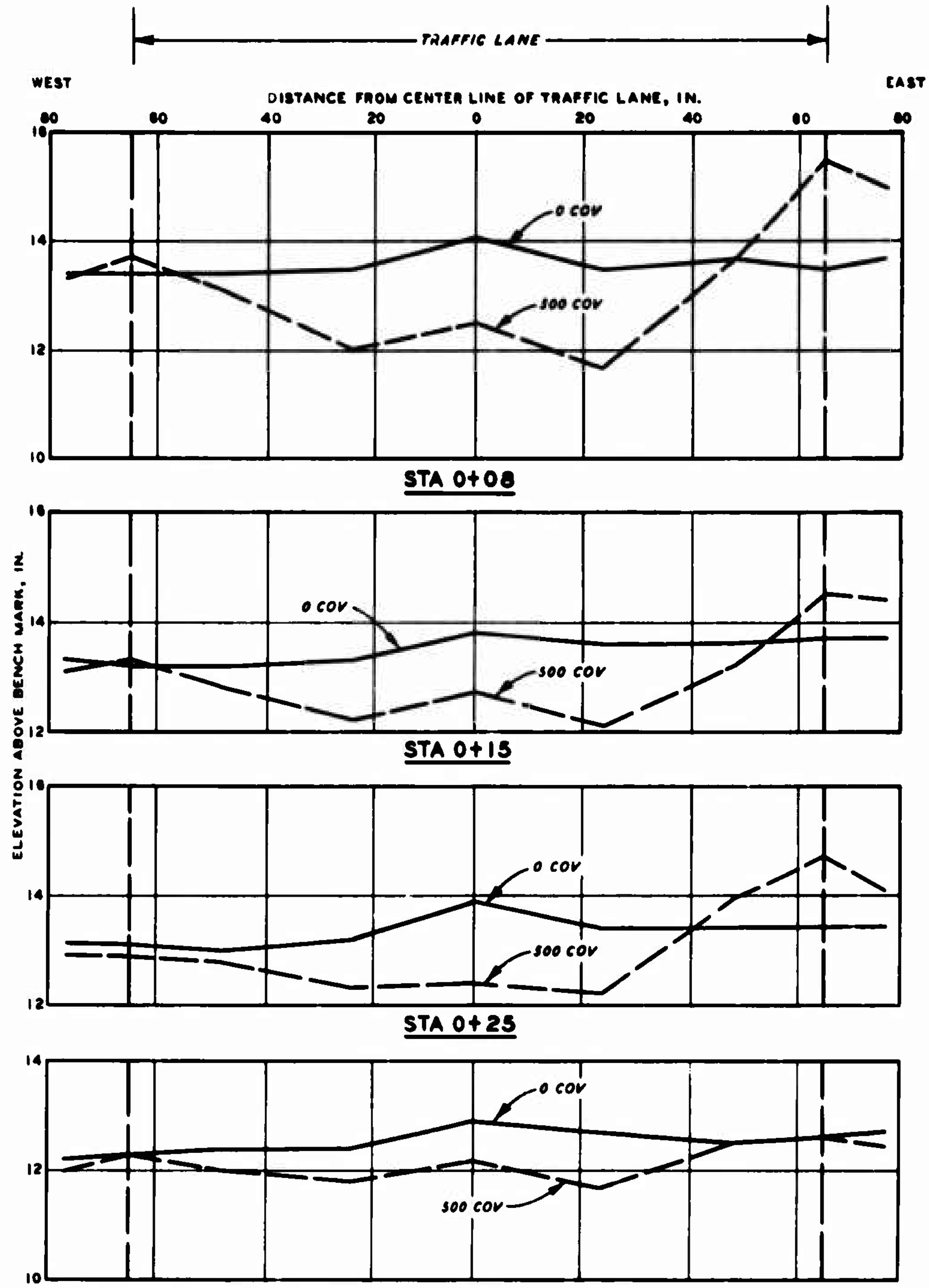
PLATE 6


WEST
EAST
WEST
EAST
DISTANCE FROM CENTER LINE OF TIRE, IN.
40
20
0
20
40
DEFLECTION, IN.
1.0
0.5
0
-0.5
-1.0
500 COV
0 COV
STA 0+05
CENTER-LINE JOINT OF SECTIONS 1,2,3, AND 4
STA 0+25
QUARTER-POINT JOINT OF SECTIONS 10 AND 12
STA 0+13
CENTER-LINE JOINT OF SECTIONS 5 AND 6
STA 0+28
CENTER-LINE JOINT OF SECTIONS 11 AND 12
STA 0+16
QUARTER-POINT JOINT OF SECTIONS 5 AND 7
STA 0+35
CENTER-LINE JOINT OF SECTIONS 13, 14, 15, AND 16
LEGEND
---- EXTRAPOLATED
STATIC MAT DEFLECTIONS
TEST 2

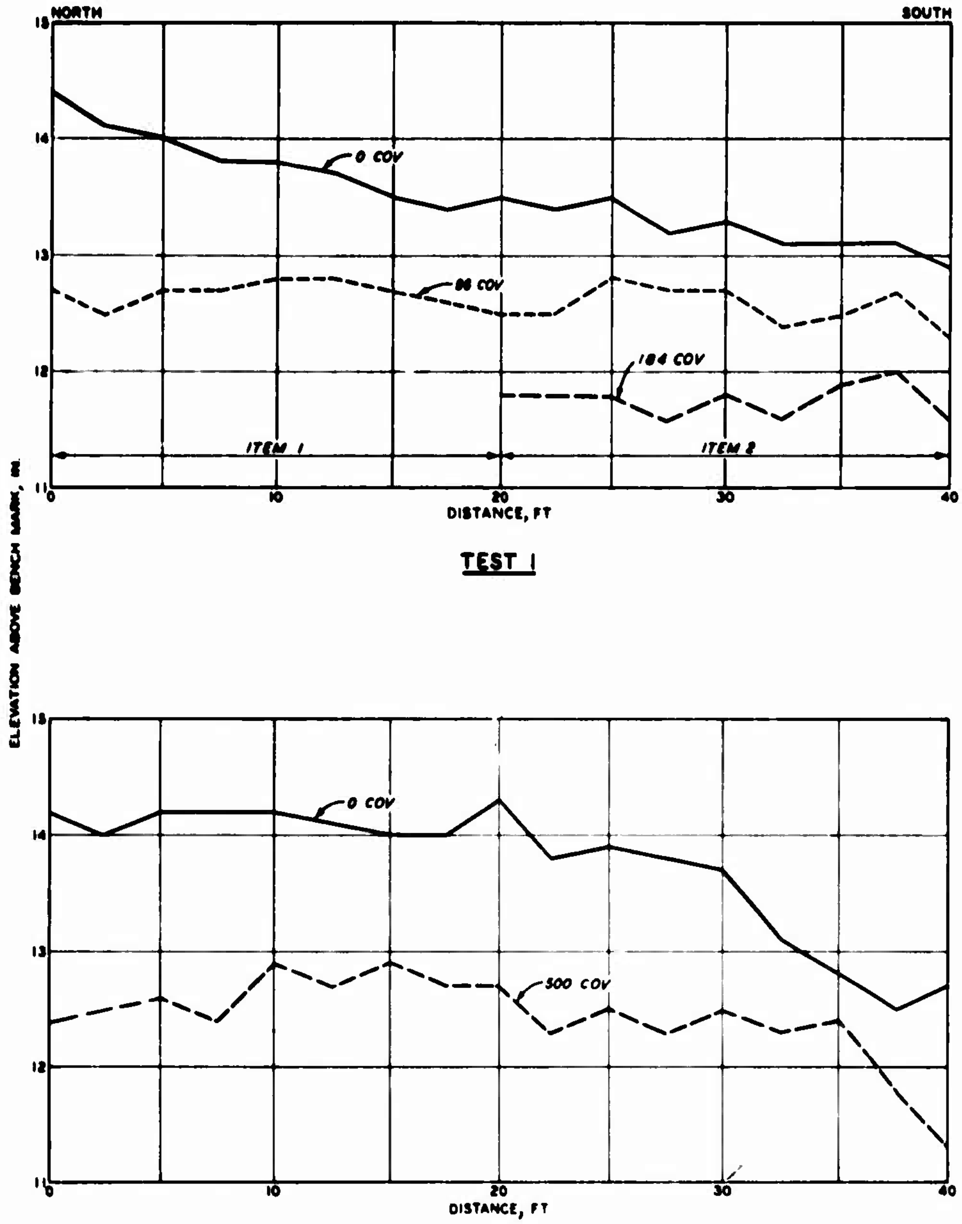


CROSS SECTIONS
OF MAT
TEST I

PLATE 8



CROSS SECTIONS OF MAT
TEST 2

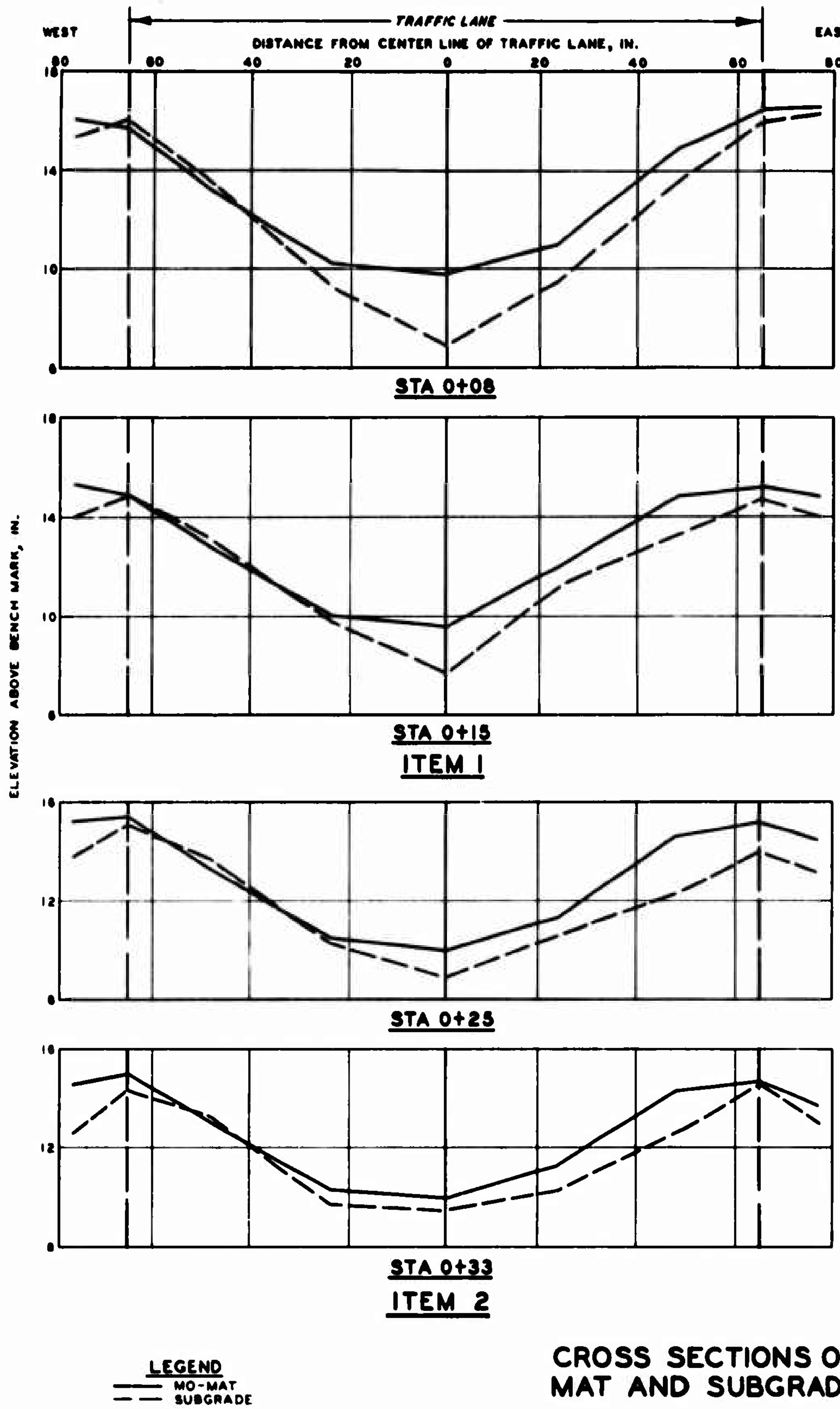


TEST 1

TEST 2

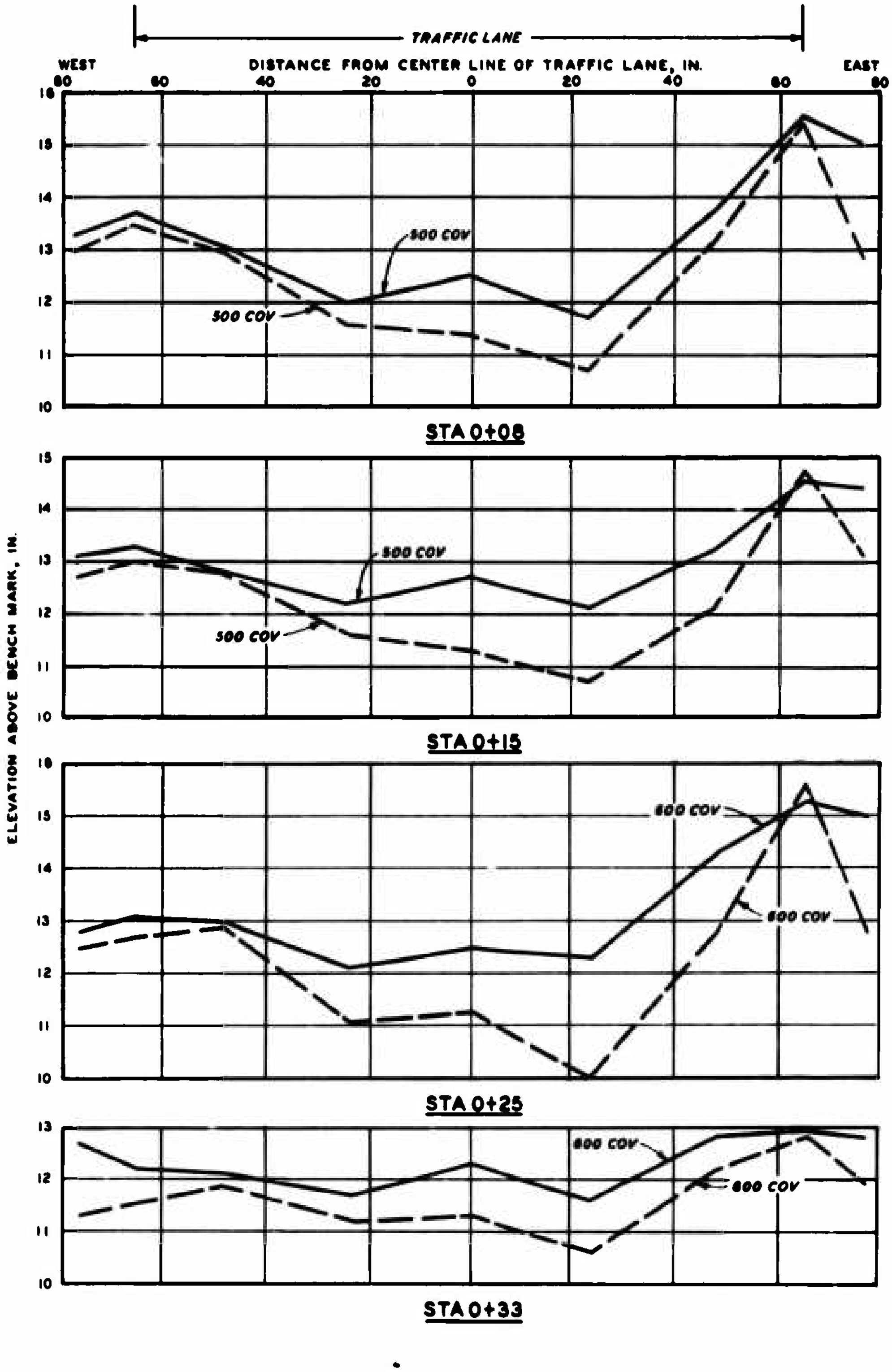
CENTER-LINE PROFILES

PLATE 10



CROSS SECTIONS OF
MAT AND SUBGRADE
TEST I AFTER TRAFFIC

PLATE II



CROSS SECTIONS OF MAT AND SUBGRADE
TEST 2 AFTER TRAFFIC

PLATE 12

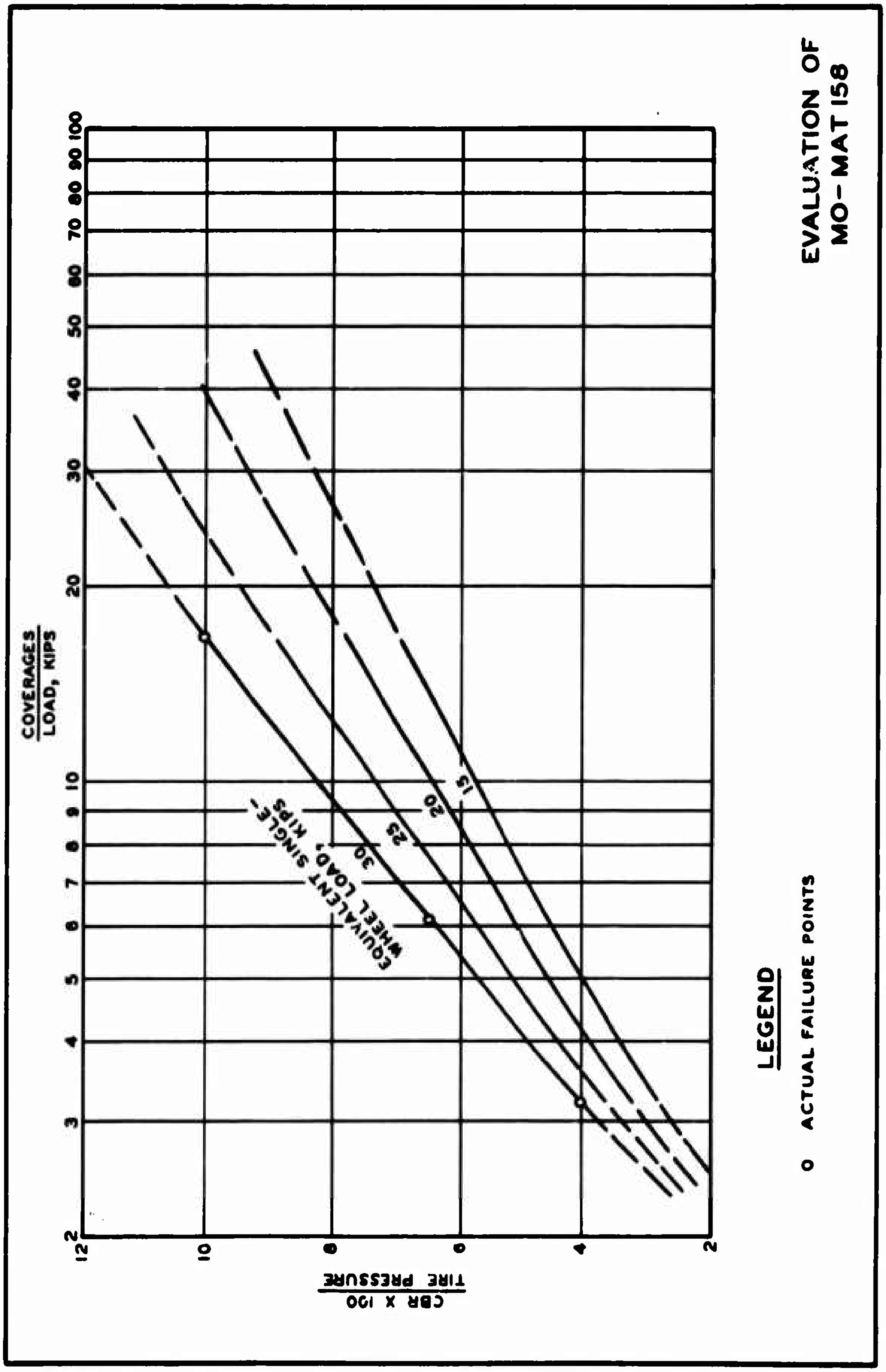

EVALUATION OF
MO-MAT 158
COVERAGES
LOAD, KIPS
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
CBR X 100
TIRE PRESSURE
12
10
8
6
4
2
EQUIVALENT SINGLE-
WHEEL LOAD,
KIPS
15
20
25
30
LEGEND
o ACTUAL FAILURE POINTS

PLATE 13

APPENDIX A

REVISED DEPARTMENT OF THE ARMY APPROVED QUALITATIVE MATERIEL REQUIREMENT FOR PREFABRICATED AIRFIELD SURFACINGS

Section I - Statement of Requirement

1. Statement of Requirement

Prefabricated or expedient airfield surfacings are required to provide the Army with improved capability to produce the required aircraft landing facilities, in theaters of operations, which are essential for support of air mobility concepts. Economy in logistics and costs and flexibility in design of landing facilities can best be provided by development of mats and membranes. The landing mats will provide a bearing surface capable of supporting specified aircraft loadings on low strength soils. Use of the matting will greatly reduce the time and engineer effort required to construct airfields by substantially reducing the need for subgrade preparation and by providing a surface which can be rapidly emplaced. The membranes will provide a rapid means of waterproofing and dustproofing runways and taxiways in areas where soil strength is adequate and of waterproofing subgrades beneath landing mats. Use of the membranes will enable in-situ soil strength to be maintained, reducing airfield construction and maintenance effort required, and provide dust control, reducing safety hazards to aircraft operation and airfield detection. It is desirable that these membrane requirements be met by a single membrane. All surfacings will be lightweight, consistent with meeting operational requirements, reusable without rehabilitation if undamaged, and packaged for ease of handling. The landing mats and membranes will be of such superiority to warrant replacement of current standard items. Army engineer units or groups of indigenous personnel under Army engineer supervision will use the surfacings to improve existing airfields or to construct new airfields in all areas of the world where operations require airfield support. (TF: 70) (CDOG para 639b (2)) (Approved 14 Apr 66)

Section II - Operational, Organizational and Logistical Concepts

2. Operational Concepts

a. Requirements. The proposed airfield surfacings will provide rapid means for preparing and/or improving airfields and landing areas capable of accommodating all types of aircraft in support of military operations including strategic and tactical lift (inter-theater and intra-theater), and tactical air support. The surfaces must provide all-weather operational capability and be capable of installation during all times except when the proper subgrade conditions cannot be obtained or maintained. The landing mat must be capable of providing operational surfacing for two weeks or

500 sorties (sortie - one takeoff and one landing) without failure. A typical daily 24-hour mission for an airfield is 36 sorties. The membrane must be capable of providing operational surfacing for two weeks or 100 sorties without failure. A typical daily 24-hour mission for a membrane surfaced airfield is seven sorties. The method of construction and materials used will provide for the suppression of dust to the extent that visual detection and adverse effects on aircraft maintenance will be reduced.

b. Operational Information.

(1) Planned deployment. The proposed materiel is essential to the successful conduct of air operation within any theater of operations. The airfield surfacings may be utilized to support air operations in any land area of the world; however, primary use is expected to be in the underdeveloped areas where airfields are either nonexistent or inadequate. The surfacing will also be used to repair damage of existing airfields with like surfacings. Adoption of this materiel will provide significant reductions in logistical tonnages and manhours of installation and maintenance effort required. The proposed surfacings will be installed primarily by Army engineer combat and construction battalions or trained indigenous personnel, under supervision of Army engineers.

(2) Turnaround time. Predicted turnaround time is unknown. Turnaround time is the time needed to remove, inspect for reuse, reprovision, and install at another site.

(3) Reaction time. Reaction time is the time needed to inspect the airfield surface to determine if an aircraft can take off or land without damage. The reaction time will not exceed ten minutes per landing or takeoff. Normally, the suitability of the airfield to perform a typical 24-hour mission will be determined during a daily (1 hour essential) (30 minutes desired) visual inspection of the runway surface. The daily visual inspection will be performed from a moving ground vehicle driving up one side and down the other side of the runway with intermediate stops as necessary.

(4) Service life. The surfacing will have a service life of not less than six months or equivalent sorties with not more than a 10 percent replacement of materiel due to failures.

(5) Availability. It is desired that operational availability be at least 93 percent, with 15 percent replacement parts (AR 700-19).

(6) Reliability. The materiel shall demonstrate a Mean Time Between Failures (MTBF) of not less than two weeks or equivalent sorties. A failure is defined for the purposes of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion.

(7) Durability. Surfacing materiel shall without failure complete the following initial operations requirement of 500 sorties for mat and 100 sorties for membrane.

3. Organizational and Logistical Concepts

a. The size and numbers of the installing crews will be consistent with construction requirements and the time factors dictated by operational requirements.

b. The proposed surfacings will be Class IV supply items.

c. Specific quantities required will be determined after completion of the current US Army Combat Developments Command Study, Airfield Construction Requirements, Theater of Operations 1967-1970.

Section III - Justification, Feasibility and Priority

4. Reason for the Requirement

The requirements for air support to ground combat operations have increased significantly and are continuing to grow. Present planning in both general and limited war situations, and for sustained ground, airborne and airmobile operations, call for an unprecedented volume of Air Force and Army aircraft for such air missions as inter-theater strategic lift, close tactical support, air assault operations, intra-theater airlift in an air line of communications (ALOC), and intra-division airlift to front line units. Additionally, the concept of total air mobility as developed by the Army Tactical Mobility Requirements Board will create many new aircraft missions within the front line division area. Current Army construction capabilities in support of these concepts are not compatible with requirements in terms of time and geographical areas of employment. Concepts dictate that airfields be readied in the early stages of troop deployment in airmobile operations and that airfields be located in proximity to the supported forces thereby ensuring that the mobility of the Army force is consistent with strategic and tactical objectives. Current airfield surfacing methods require either the selection of a site where the California Bearing Ratio (CBR) of the soil will sustain aircraft loadings or the extensive preparation of the subgrade to achieve necessary soil strengths. In many areas of the world where deployment of US airmobile forces is foreseen, required airfields do not exist, are too few in number, or cannot sustain the loadings of supporting aircraft. Also, construction materials for preparation of airfield subgrades and surface are not available or necessitate disproportionate demands for time and effort to locate, process, transport, emplace and compact granular materials for airfield base construction. Current military systems (PSP, M6, M8, and M9 mats) due to weight and load bearing characteristics and conventional methods of constructing airfields do not permit the development of air landing facilities for airborne and airmobile forces throughout the world on a selective basis within envisioned time parameters. Without the construction capability to support airborne and airmobile forces their employment is seriously jeopardized if not totally prevented. This proposed system will facilitate the construction envisaged.

a. The time phasing of this requirement is immediate in relationship to present material and capabilities. The requirement satisfies immediate and long-range objectives.

b. The requirement for this type materiel is supported in CDOG paragraph 639b(2).

c. References which support this requirement are:

(1) US Army Tactical Mobility Requirements Board Final Report, August 1962.

(2) Final Report of Joint Exercise SWIFT STRIKE III, 20 November 1963.

(3) Army Air Mobile Evaluation, Headquarters, US Army Combat Developments Command, 15 February 1965.

5. Technical Feasibility

It is technically feasible, as stated Appendix I, to develop the airfield surfacings which will satisfy the requirements of this QMR.

6. Priority

This QMR is assigned Priority I, functional group 4 Tactical Movement, Appendix C, CDOG.

Section IV - Characteristics

7. Performance Characteristics

a. It is essential that the landing mats for the various classifications:

(1) Be capable of being directly installed upon graded subgrades.

(2) Be capable of withstanding the aircraft loading conditions shown on Incls 1 and 2.

(3) Be capable of withstanding coverages and loads shown on Incls 1 and 2, with a maximum of 10 percent replacement.

(4) Be capable of:

(a) Heavy duty mats will withstand aircraft operations to include maximum takeoffs using afterburner. These mats shall withstand blast effects of 700°F for 10 seconds.

(b) Medium duty mats will withstand aircraft operations to include maximum takeoffs using afterburner. These mats shall withstand blast effects of 300°F for 5 seconds.

(c) Light duty mats shall withstand C-130 aircraft assault landings utilizing maximum wheel braking and reverse thrust procedures.

(d) Surfacing at locations of arresting cables and arresting hook impacts are subject to unusual loadings and impact effects and are considered critical areas. Special surfacing will be provided when heavy and medium duty mats do not meet the requirements listed below for critical areas of runways surfaced with heavy or medium duty mats.

1. Surfacing for critical areas of heavy duty mat surfaced runways will withstand five F4 tailhook impacts of 80 knots at equivalent 18 feet per second (FPS) sink speed at the same location without structural failure due to rupture of the top surface of the mat.

2. Surfacing for critical areas of heavy duty mat surfaced runways will withstand 20 roll-over loadings on a one inch diameter arresting cable with a 50,000-lb wheel load, having a nominal tire contact area of 200 sq in. and a tire-inflation pressure of 250 psi, without structural failure due to rupture of the top surface of the mat.

3. Surfacing for critical areas of medium duty mat surfaced runways will withstand two F4 tailhook impacts of 80 knots at equivalent 18 FPS sink speed at the same location without structural failure due to rupture of the top surface of the mat.

4. Surfacing for critical areas of medium duty mat surfaced runways will withstand 20 roll-over loadings on a one inch diameter arresting cable with a 25,000-lb wheel load, having a nominal tire-contact area of 100 sq in. and tire-inflation pressure of 250 psi without structural failure due to rupture of the top surface of the mat.

(5) Be so designed so as to not cause damage to waterproofing or dustproofing treatment applied to the subgrade, or desirably, inherently provide waterproofing and dustproofing of the underlying soil surface.

(6) Be capable of withstanding ambient temperature variations in accordance with paragraph 7c of AR 705-15, change 1, without deformation of such magnitude as to interfere with assembly and operations.

(7) Possess a surface which provides effective braking with a Runway Condition Reading (RCR) of 13-25 for aircraft landings and control during all ground operations, under conditions specified in AFR 60-13 and in paragraph 7a, b, and c of AR 705-15, change 1.

(8) Resist adverse effects, when installed operationally, resulting from exposure to POL spillage, downwash from helicopters, and wheel vehicle traffic.

(9) Be capable of storage and air transit under conditions stated in paragraph 7.1a, b, and d of AR 705-15, change 1: for closed storage, ten years; for open storage, five years without adverse effects upon the system components.

(10) Possess a service life of not less than six months or 6000 sortie with not more than a 10 percent replacement of material due to failures.

(11) Possess an operational availability of at least 93 percent, with 15 percent replacement parts (AR 700-19).

(12) Possess reliability that the Mean Time Between Failures (MTBF) shall be not less than two weeks or 500 sorties. A failure is defined for the purpose of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion.

(13) Possess a durability which will enable the mats to sustain 500 sorties of initial operations without failure.

b. It is essential that the membranes:

(1) Be capable of being directly installed upon graded subgrades.

(2) Possess a surface which provides effective braking with a Runway Condition Reading (RCR) of 13-25 for aircraft landings and control during all ground operations, under conditions specified in AFR 60-13 and paragraph 7a, b, and c of AR 705-15, change 1.

(3) Be capable of withstanding wheel loads without destruction of waterproof properties when laid on soils capable of supporting these wheel loads, or when placed underneath landing mat, see Incl 3.

(4) Resist adverse effects, when installed operationally, resulting from exposure to POL spillage, helicopter downwash, and wheel vehicle traffic.

(5) Be capable of storage and air transit under conditions stated in paragraph 7.1a, b, and d of AR 705-15, change 1: for closed storage, five years; for open storage, three years without adverse effects upon the system components.

(6) Be capable of withstanding ambient temperature variations in accordance with paragraph 7c of AR 705-15, change 1, without elongation or contraction of such magnitude as to interfere with assembly and operations.

(7) Be readily repairable in the field under conditions as specified in paragraph 7a and b of AR 705-15, change 1.

(8) Possess a service life of not less than six months or 1200 sorties with not more than 10 percent replacement of material due to failure.

(9) Possess an operational availability of at least 93 percent assuming adequate logistical support.

(10) Possess reliability that the MTBF shall be not less than two weeks or 100 sorties. A failure is defined for the purposes of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from a Engineer Platoon of an Airmobile Divisional Engineer Battalion.

(11) Possess a durability which will enable the membrane to sustain initial operations of 100 sorties without failure.

8. Physical Characteristics

a. It is essential that the landing mats:

(1) Be as lightweight as possible consistent with other requirements, and weigh as shown on Incls 1 and 2.

(2) Be capable of installation by trained personnel at the rates shown on Incl 1, Table 3.

(3) Permit replacement of an individual mat panel within two hours essential, one hour desirable.

(4) Be capable of placement with a minimum number of accessories and special tools.

(5) Be provided with a simple method of transition and laying from runway to taxiway and parking aprons.

(6) Be provided with an adequate system of anchoring runways and taxiways to prevent movement, lift, and not cause damage to aircraft tires.

(7) Be capable of being installed directly on graded subgrades with maximum crowns of 3 percent, longitudinal grades of 5 percent, and a maximum longitudinal grade change of 2 percent in 100 ft.

(8) Individual mats be of such size, shape, and weight to be handled by two men (desirable maximum weight - 100 lb, essential maximum weight - 120 lb).

(9) Be packaged so as to compliment ground transportation and installation and for ease of aircraft transportation in accordance with para 5a of AR 705-35.

(10) Be provided with a capability which will allow rapid replacement of buckled (forced together) and forced apart panels in the center of the runway from bomb or other damage.

(11) Be provided with components which will permit joining light duty panels to medium duty panels, and medium duty panels to heavy duty panels.

(12) (Desirable) Be provided with 45-deg transition connector panel which will allow construction of high speed taxiways.

b. It is essential that the membranes:

(1) Be as lightweight as possible as shown on Incl 1, Table 4.

(2) Be capable of being installed by trained personnel at the rates shown on Incl 1, Table 5.

(3) Withstand locked-wheel braking action and maximum wheel braking procedures of critical aircraft.

(4) Be packaged to facilitate hand laying so as to compliment ground transportation and installation and for ease of aircraft transportation in accordance with para 5a of AR 705-35.

(5) Be provided with suitable anchoring devices which will not damage the membrane or tires.

(6) Be capable of being installed directly on graded subgrades with maximum crowns of 3 percent, longitudinal grades of 5 percent, and a maximum longitudinal grade change of 2 percent in 100 ft.

9. Maintenance Characteristics

a. The mats and membranes shall be designed to minimize maintenance. It is essential that maintenance be as follows:

(1) Be designed to facilitate maintenance accessibility in the field environment at all categories so that required maintenance will be performed in the minimum practicable time with a minimum degree of skill, variety of tools, test equipment, and other supplies.

(2) Be designed towards minimization of maintenance by utilization of the most reliable components; modular construction; built-in, simple, failure indicators; and other technological advances in components and/or methods.

(3) Be designed so that individual and/or damaged sections of materials may be removed and replaced.

b. Typical maintenance to restore performance specified herein will consist of but not necessarily be restricted to the following: cleaning, inspecting for repairs, alignment, tightening of anchors, patching, replacement of damaged mat panels, and repair of nonskid surface. Maintenance performed shall not exceed 150 manhours per month by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion for the service life of the materials. (Subgrade failures are not included in this paragraph.)

10. Human Engineering Characteristics

Human factors engineering characteristics of the system will include consideration of the intellectual, physical and psychomotor capabilities of the intended user.

11. Priority of Characteristics

a. Performance

b. Weight

c. Reliability and Durability

d. Transportability

e. Maintainability

Section V - Personnel and Training Considerations

12. Quantitative and Qualitative Personnel Considerations

a. The system will be installed primarily by Army engineer units. However, its simplicity of emplacement will require a minimum of training whereby any Army unit, or indigenous personnel, could install and maintain the system.

b. No new MOS will be required.

c. Although a savings in personnel strengths normally associated with airfield construction may not be effected, with this system the troop effort required to prepare base courses can be diverted to other tasks, and the overall airfield construction time reduced.

13. Training Considerations

Training for actual installation and maintenance of this system will be negligible. Preparation of the ground for installation of this system will normally be by Army engineer units which already have this capability. Training literature on the repair and reuse of prefabricated airfield surfacing materials is required. This literature should cover the factors to be considered in evaluation of surfacing for reuse, evaluation methods and procedures, repair techniques and methods, repackaging information, and a basis of classification of prefabricated airfield surfacing materials for future use.

Section VI - Associated Considerations

14. Training Devices

None required. Components of the system will be utilized for training.

15. Related Materiel

No change in present items of supply is anticipated. Similar items of supply already in the Army supply system may still be required to support Army aircraft operations. It is not intended that this system be capable of inter-mix usage with current standard, similar items of supply, although this would be desirable if it could be done with no compromise of capability in the proposed system. Ancillary equipment and special tools to emplace, use, and maintain prefabricated airfield surfacings must be developed as required.

16. Concealment and Deception

Normal camouflage considerations apply; reduction in light reflectivity is required. No disguise or simulation devices are required.

17. Interest

This system will probably be of interest to British, Canadian, and Australian Armies.

18. Current Inventory Items

There are no existing items, and no items are under development by other services or allied armies which can fulfill this requirement.

19. Communication Security

None.

20. Additional Comments

a. If, during the development phase, it appears to the developing agency that the characteristics listed herein require the incorporation of certain impracticable features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods or processes, critical materials or restrictive specifications which will prove excessively expensive or serve as a detriment to the military value of the unit, such matters shall be brought to the immediate attention of the Chief of Research and Development of the Army, and Headquarters, US Army Combat

Developments Command for consideration before incorporation into a final design.

b. This materiel requirement is identified by USACDC Action Control Number 7494 and supports the following:

(1)	Army CD Program	Army 75 (70-75)
(2)	Study "Engineer 75"; USACDC Action Control No.	6493
(3)	Army Tasks	1: High Intensity Conflict 2: Mid Intensity Conflict 3: Low Intensity Conflict, Type I 4: Low Intensity Conflict, Type II 6: Military Aid to US Civil Authorities 7: Complementing of Allied Land Power
(4)	Phase	Materiel
(5)	Function	Service Support

3 Incl
Tables

Table 1

Mat Classification	Single-Wheel Load, lb	Tire Pressure psi	Nominal Contact Area sq in.	Coverage Level	CBR
Heavy duty	50,000	250	200	1000	4
Medium duty	25,000	250	100	1000	4
Light duty	30,000	100	300	1000	4

Table 2

Mat Classification	Desirable weight lb per sq ft	Essential Weight lb per sq ft
Heavy duty	5.0	6.5
Medium duty	4.0	4.5
Light duty	2.5	3.0

Table 3

Mat Classification	Desirable Placing Rate sq ft per man-hour	Essential Placing Rate sq ft per man-hour
Heavy duty	400	150
Medium duty	400	250
Light duty	600	400

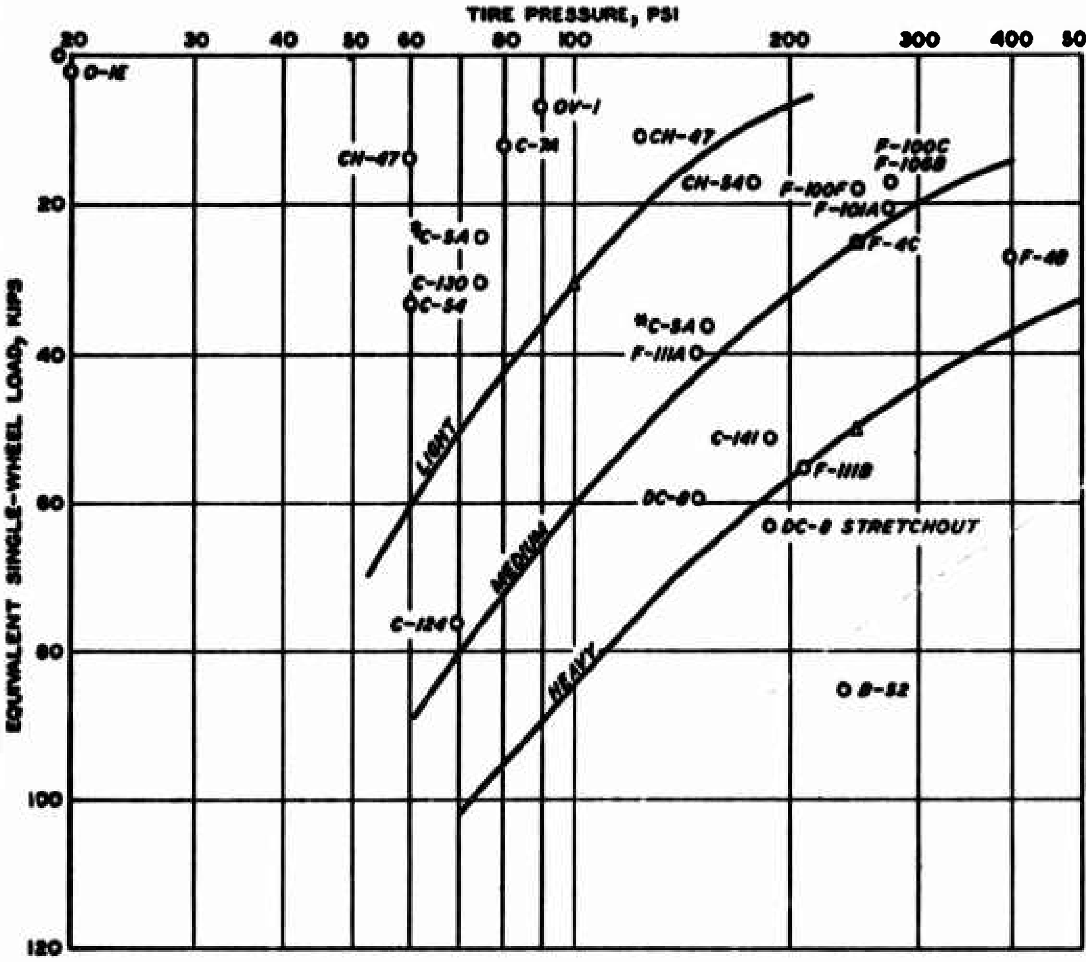
Table 4

Membrane Classification	Desirable Weight lb per sq yd	Essential Weight lb per sq yd
Heavy duty	5.0	6.0
Medium duty	3.0	4.0
Light duty	1.0	2.0

Table 5

Membrane Classification	Desirable Placing Rate sq ft per man-hour	Essential Placing Rate sq ft per man-hour
Heavy duty	300	200
Medium duty	400	300
Light duty	600	400

Incl 1 to QMR



LEGEND

- ▲ MAT CATEGORY DEFINITION
- O AIRCRAFT REQUIREMENT
- ✱ MAXIMUM TAKEOFF WEIGHT
- ✝ THEATER OF OPERATIONS WEIGHT

NOTE: THESE CURVES DO NOT INDICATE MAT CAPABILITY FOR ARRESTING GEAR LANDINGS WITH TAILHOOKS.

THE PURPOSE OF THIS FAMILY OF CURVES IS TO ILLUSTRATE THE APPROXIMATE LOAD-CARRYING CAPABILITY OF A PROPOSED FAMILY OF MATS WITH RESPECT TO LOADINGS OF SOME CURRENT AIRCRAFT. THE CURVES HAVE ONLY BEEN PARTIALLY VALIDATED AND SHOULD NOT BE USED FOR DESIGN PURPOSES.

EACH MAT WILL SUPPORT ALL AIRCRAFT PLOTTED IN A POSITION ABOVE THE CURVE REPRESENTING THAT MAT CATEGORY.

PROJECTED RELATIVE LANDING MAT CAPABILITY

1000 COVERAGES 4 CBR

(SUBJECT TO REVISION)

Incl 2 to QMR

PROJECTED PERFORMANCE OF MEMBRANES FOR PERIOD OF SIX MONTHS (1200 SORTIES*)

(This is a preliminary table subject to revision)

Aircraft	Operation: Landing	Max Engine Run-Up for Takeoff	Locked-Wheel Turns	Taxiing	Locked-Wheel Braking	Auxiliary Use: Waterproofing Beneath Landing Mats
Heavy-Duty Membrane (5-6 lb per sq yd)						
F-111A	4	4	4	4	4	4
F-111B	4	4	4	4	4	4
F-4B	4	4	4	4	4	1
C-141	4	4	4	4	4	1
C-5	4	4	4	4	4	4
C-130E	1	1	1	1	1	1
C-7A	1	1	1	1	1	1
CH-54	1	1	1	1	1	1
CH-47	1	1	1	1	1	1
UH-1	1	1	NA	1	NA	1
OV-1	1	1	1	1	1	1
O1-E	1	1	1	1	1	1
Medium-Duty Membrane (3-4 lb per sq yd)						
F-111A	4	4	4	4	4	4
F-111B	4	4	4	4	4	4
F-4B	3	3	1	4	4	1
C-141	4	4	4	4	4	4
C-5	4	4	4	4	4	4
C-130E	2	[illegible]	1	1	1	1
C-7A	1	1	1	1	1	1
CH-54	1	1	1	1	1	1
CH-47	1	1	1	1	1	1
UH-1	1	1	NA	1	NA	1
OV-1	1	1	1	1	1	1
O1-E	1	1	1	1	1	1
Light-Duty Membrane (1-2 lb per sq yd)						
F-111A	4	4	4	4	4	4
F-111B	4	4	4	4	4	4
F-4B	4	4	3	1	3	1
C-141	4	4	4	4	4	4
C-5	4	4	4	4	4	4
C-130E	3	3	2	1	2	1
C-7A	3	3	2	1	2	1
CH-54	1	1	1	1	1	1
CH-47	1	1	1	1	1	1
UH-1	3	[illegible]	NA	[illegible]	NA	1
OV-1	3	3	3	1	[illegible]	[illegible]
O1-E	1	1	1	1	1	1

Remarks:

Performance rating scale for membranes:

1 Satisfactory
2 Borderline
3 Unsatisfactory
4 No test data available

* Sortie - one landing and one takeoff

NOTE: The purpose of this projected performance of a family of membranes is to indicate their relative capabilities for selected current aircraft and helicopters.

Incl 3 to MR