AD-758 444

EVALUATION OF GOODYEAR MEDIUM-DUTY ALUMINUM HONEYCOMB LANDING MAT

Gordon L. Carr

Army Engineering Waterways Experiment Station

Prepared for:

Army Materiel Command

March 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

AD 758444

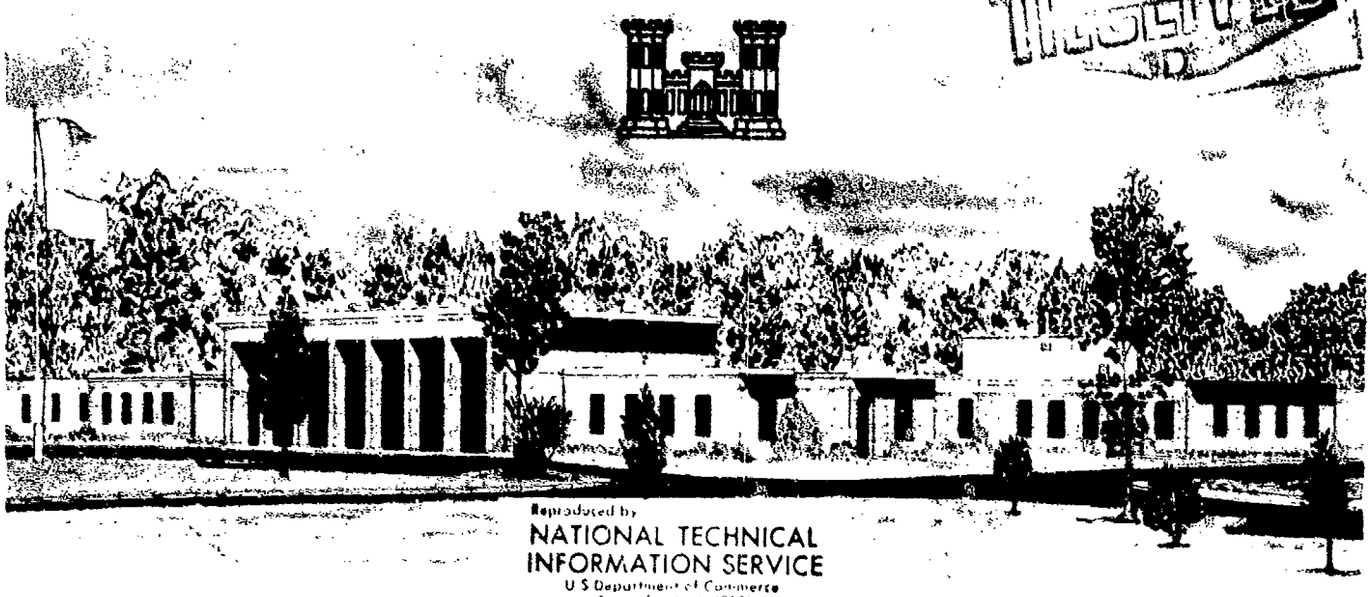
MISCELLANEOUS PAPER S-73-8

EVALUATION OF GOODYEAR MEDIUM-DUTY ALUMINUM HONEYCOMB LANDING MAT

by

G. L. Carr

D D C
1973



Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

March 1973

Sponsored by U. S. Army Materiel Command

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

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

47
R

ACCESSION for
NTIS White Section ☑
DDC Buff Section ☐
UNANNOUNCED ☐
JUSTIFICATION
BY
DISTRIBUTION/AVAILABILITY CODES
Dist. AVAIL. and/or SPECIAL
A

Destroy this report when no longer needed. Do not return it to the originator.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U. S. Army Engineer Waterways Experiment Station Vicksburg, Miss.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

EVALUATION OF GOODYEAR MEDIUM-DUTY ALUMINUM HONEYCOMB LANDING MAT

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final Report

5. AUTHOR(S) *(First name, middle initial, last name)*

Gordon L. Carr

6. REPORT DATE March 1973	7a. TOTAL NO. OF PAGES 41	7b. NO. OF REFS 9

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 1G664717DH01-10 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Miscellaneous Paper S-73-8 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Materiel Command Washington, D. C.

13. ABSTRACT

This report describes an investigation to evaluate a medium-duty aluminum honeycomb-core landing mat designed and fabricated by Goodyear Aerospace Corporation, Akron, Ohio, as a result of the Government request for proposal dated 6 May 1968. The medium-duty mat was a sandwich-type structure with a honeycomb core bonded by an epoxy film adhesive to aluminum top and bottom skins. Extruded aluminum edge connectors were also bonded with a similar adhesive to the top and bottom skins and to the core. Individual panels were joined along two edges with a hinge-type connection and along the adjacent two edges by overlap-/underlap-type connections that were locked together by insertion of a connector bar. The panel dimensions, weight, and placing rate were 4 ft by 4 ft by 1.5 in., 67.5 lb, and 478 square feet per man-hour, respectively. The weight per square foot of placing area was 4.1 lb. Traffic and skid tests were conducted to obtain information for evaluating the service life and performance of the medium-duty mat as specified by project requirements. Laboratory tests were performed to determine the mechanical properties of the mat panels and their component parts, and results indicated that the materials in the mat met the specified requirements. The traffic tests were conducted with a rolling wheel load, simulating aircraft operations on mat placed on a prepared subgrade. The tests were conducted using a single-wheel load of 25,000 lb with a tire-inflation pressure of 250 psi on a mat-surfaced subgrade with a rated CBR of 3.8. The Goodyear medium-duty mat sustained 622 coverages of traffic under the above-stated conditions, which is equivalent to 890 coverages on a 4.0-CBR subgrade; thus, the mat failed to meet current requirements of 1000 coverages on a 4.0-CBR subgrade. The medium-duty mat sustained almost twice as many coverages as a previously tested Goodyear all-bonded mat. Failure of individual panels resulted from a gradual depression of the surface of the panels caused by failure of the adhesive between the core and skins and by overstressing of the adhesive between the edge connectors and skins. The coefficients of friction obtained from dry and wet skid tests were 0.57 and 0.45, respectively.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Aluminum landing mats						
Goodyear aluminum mats						
Honeycomb landing mats						
Landing mats						

Unclassified
Security Classification

MISCELLANEOUS PAPER S-73-8

EVALUATION OF GOODYEAR MEDIUM-DUTY ALUMINUM HONEYCOMB LANDING MAT

by

G. L. Carr

DDC
RECEIVED

Details of illustrations in
this document may be better
studied on microfiche

March 1973

Sponsored by U. S. Army Materiel Command
Project No. 1G664717DH01-10
(Formerly 1G664717D556-01)

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

ARMY-MRC VICKSBURG, MISS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

FOREWORD

The investigation reported herein was conducted as part of the landing mat development program, Project No. 1G664717DH01-10 (formerly 1G664717D556-01), under the sponsorship of the Ground Mobility Office, Director of Development, U. S. Army Materiel Command.

The tests pertinent to this investigation were performed at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., during the period September-October 1969 under the general supervision of Mr. J. P. Sale, Chief, Soils and Pavements Laboratory. Personnel of the Expedient Surfaces Branch who were actively engaged in the planning, testing, analyzing, and reporting phases of this investigation, under the supervision of Mr. W. L. McInnis, were Messrs. H. L. Green, G. L. Carr, D. W. White, Jr., and D. A. Ellison. The General Engineering Support Branch was responsible for constructing and trafficking the test section and for performing the necessary soils tests under the supervision of Messrs. R. G. Ahlvin and C. D. Burns. This report was prepared by Mr. Carr.

The Directors of the WES during the investigation 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.

Preceding page blank

CONTENTS

	Page
FOREWORD	v
CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT	ix
SUMMARY	xi
PART I: INTRODUCTION	1
Background	1
Objectives and Scope of Investigation	2
Definitions of Pertinent Terms	3
PART II: DESCRIPTION OF MAT	4
Fabrication Features	4
Physical Dimensions	6
PART III: TEST SECTION, EQUIPMENT, AND PROCEDURES	8
Test Section	8
Mat Placement	9
Traffic Test Equipment	9
Application of Traffic	10
Skid Test Equipment	10
PART IV: CRITERIA FOR MAT FAILURE AND TYPES OF DATA RECORDED	11
Failure Criteria	11
Types of Data Recorded	12
PART V: TRAFFIC AND SKID TEST RESULTS AND ANALYSIS	13
Test Results	13
Analysis of Results	16
PART VI: LABORATORY TESTS	18
Test Equipment	18
Tests and Results	18
PART VII: SUMMARY OF RESULTS AND CONCLUSIONS	21
Results	21
Conclusions	21
LITERATURE CITED	22

Preceding page blank

CONTENTS

Page

TABLES 1-3

PHOTOS 1-10

PLATES 1-6

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	25.4	millimeters
square inches	6.4516	square centimeters
feet	0.3048	meters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
pounds (mass)	0.45359237	kilograms
pounds (force)	4.448222	newtons
pounds per square inch	0.6894757	newtons per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter
kips	453.59237	kilograms
tons (2000 lb)	907.1847	kilograms
miles per hour	1.609334	kilometers per hour

SUMMARY

This report describes an investigation to evaluate a medium-duty aluminum honeycomb-core landing mat designed and fabricated by Goodyear Aerospace Corporation, Akron, Ohio, as a result of the Government request for proposal dated 6 May 1968. The medium-duty mat was a sandwich-type structure with a honeycomb core bonded by an epoxy film adhesive to aluminum top and bottom skins. Extruded aluminum edge connectors were also bonded with a similar adhesive to the top and bottom skins and to the core. Individual panels were joined along two edges with a hinge-type connection and along the adjacent two edges by overlap-/underlap-type connections that were locked together by insertion of a connector bar. The panel dimensions, weight, and placing rate were 4 ft by 4 ft by 1.5 in., 67.5 lb, and 478 square feet per man-hour, respectively. The weight per square foot of placing area was 4.1 lb.

Traffic and skid tests were conducted to obtain information for evaluating the service life and performance of the medium-duty mat as specified by project requirements. Laboratory tests were performed to determine the mechanical properties of the mat panels and their component parts, and results indicated that the materials in the mat met the specified requirements.

The traffic tests were conducted with a rolling wheel load, simulating aircraft operations on mat placed on a prepared subgrade. The tests were conducted using a single-wheel load of 25,000 lb with a tire-inflation pressure of 250 psi on a mat-surfaced subgrade with a rated CBR of 3.8. The Goodyear medium-duty mat sustained 622 coverages of traffic under the above-stated conditions, which is equivalent to 890 coverages on a 4.0-CBR subgrade; thus, the mat failed to meet current requirements of 1000 coverages on a 4.0-CBR subgrade. The medium-duty mat sustained almost twice as many coverages as a previously tested Goodyear all-bonded mat. Failure of individual panels resulted from a gradual depression of the surface of the panels caused by failure of the adhesive between the core and skins and by overstressing of the adhesive between the edge connectors and skins. The coefficients of friction obtained from dry and wet skid tests were 0.57 and 0.45, respectively.

Preceding page blank

EVALUATION OF GOODYEAR MEDIUM-DUTY ALUMINUM HONEYCOMB LANDING MAT

PART I: INTRODUCTION

Background

1. The investigation reported herein comprised an engineer design test in the U. S. Army Materiel Command's continuous program for the development of satisfactory landing mats for use as expedient surfacing materials for forward-area airfields. As part of this program, the U. S. Army Engineer Waterways Experiment Station (WES) is responsible for the development of metallic and nonmetallic landing mats.

2. In 1965, the WES tested a Kaiser medium-duty aluminum honeycomb-core landing mat,[1] which was subsequently designated XM19 and was type classified for limited production in 1967 (see reference 2 for Federal stock number and mat nomenclature). A production contract was awarded for 9,000,000 sq ft* of the XM19 mat for use in Southeast Asia. The WES tests of the production XM19 mat are reported in reference 3.

3. The WES was directed to obtain mats for testing that met the full spectrum of the performance specifications of the Qualitative Materiel Requirements (QMR), revised 2 April 1968. In response to the WES request for proposal dated 6 May 1968, Goodyear Aerospace Corporation submitted a proposal to design, develop, and fabricate a medium-duty mat. This proposal resulted in contract No. DACA39-69-C-0011, and Goodyear's efforts were directed to meet the QMR performance specifications for medium-duty mat. After extensive experimentation, Goodyear began to fabricate a medium-duty aluminum honeycomb-core mat of sandwich-type construction that was similar in some respects to an all-bonded mat previously fabricated by Goodyear and tested at the WES.[4]

---

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

4. The edges of the XM19 and both Goodyear mats interlocked, and the internal construction of each was similar. The Goodyear mats differed from the XM19 mat as follows: the core-to-edge members of the Goodyear mats were joined with a film adhesive, whereas a potting compound joined those of the XM19; the skins-to-edge members of the Goodyear mats were also joined with a film adhesive, whereas those of the XM19 were welded.

Objectives and Scope of Investigation

Objectives

5. The general objective of this investigation was to evaluate both the design and the performance of the Goodyear medium-duty aluminum honeycomb mat as an expedient surfacing material for military airfields. Specific objectives were to determine the following:

- a. The service life of the mat when placed on a 4.0-CBR subgrade and trafficked with a 25,000-lb single-wheel load with the tire inflated to 250 psi to produce a contact area of 111 sq in.
- b. The average placing rate for the mat.
- c. The skid-resistance and tire-wear characteristics of the mat.
- d. The mechanical properties of the mat.

Scope

6. This report describes laboratory, skid, and traffic tests conducted to evaluate the Goodyear medium-duty landing mat. Data for the evaluation were obtained as follows:

- a. Traffic tests were conducted on the test section to study subgrade behavior and to observe the performance of the mat under a rolling wheel load.
- b. The placement times were recorded for use in computing the placing rate.
- c. Skid tests were conducted to determine the force required to skid a loaded cart over the mat and the coefficients of friction.
- d. Laboratory tests were performed on specimens cut from panels selected at random to determine the mechanical properties of the mat.

Definitions of Pertinent Terms

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

Subgrade. That 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.

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 wheel load of the load cart.

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

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

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

Static deflection. Temporary longitudinal bending of landing mat panels under the static load from the test wheel.

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

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

CBR (California Bearing Ratio). A measure of the bearing capacity of the soil based upon its shearing resistance. The CBR value 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.

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

PART II: DESCRIPTION OF MAT

Fabrication Features

8. The 4- by 4-ft Goodyear medium-duty landing mat (fig. 1) consisted of an aluminum honeycomb core bonded into a sandwich-type structure with 0.063-in.-thick top and bottom sheets by an epoxy fiber-film adhesive. Extruded edge-connecting members were also bonded to the top and bottom sheets and to the aluminum honeycomb core with a film adhesive. The core was formed from 5056-H19* aluminum alloy foil. The foil was 0.0027 in. thick and was formed into 1/8-in. hexagonal cells. All surface pieces of the panel were formed from 6061 aluminum alloy artificially aged to the T6* condition, which resulted from a process involving solution heat treatment and oven cycling to produce a stable temper.

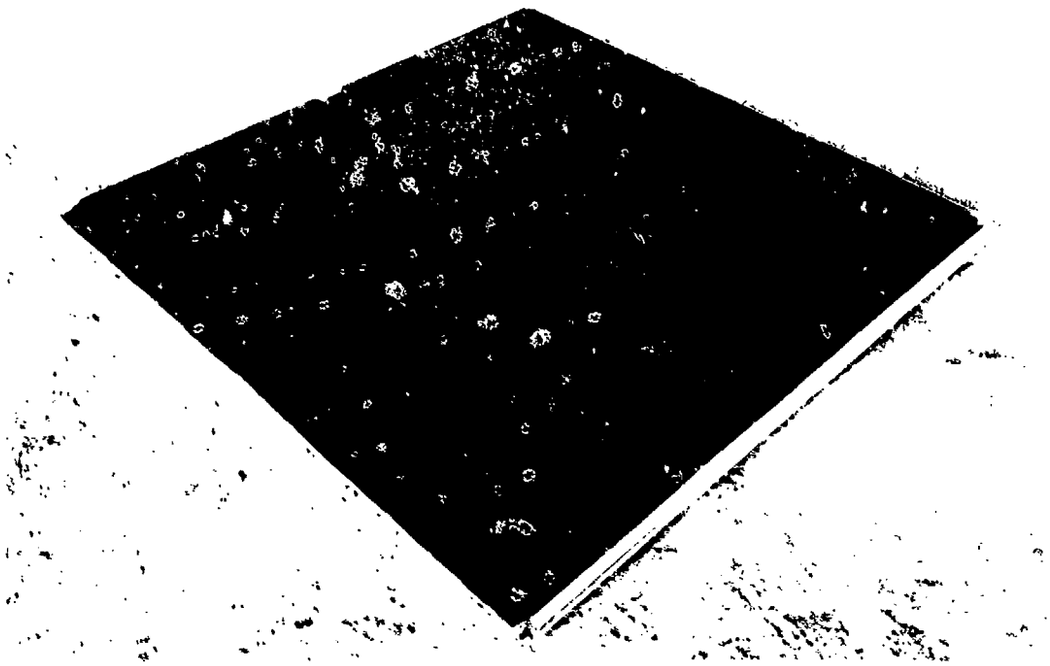


Fig. 1. Goodyear medium-duty landing mat

---

* H and T denote temper conditions to produce various strengths.

The mechanical properties specified in reference 5 for extruded 6061-T6 aluminum alloy are as follows:

	Specified Minimum
Tensile strength, psi	
Ultimate*	38,000
Yield	35,000
Elongation, percent (2-in. gage length)	10

* 42,000 psi for sheet aluminum.

9. The panels were interlocked along the two edges parallel to traffic by hinge-type connections and along the adjacent two edges by overlap/underlap connections. A locking bar secured the overlap/underlap connection after individual panels had been joined together. The top facing of each panel was coated with an antiskid compound.

10. At the manufacturer's request, two special panels (fig. 2) were included in the test. The structure of these panels was the same as that of the mat described in paragraphs 8 and 9 except that the core

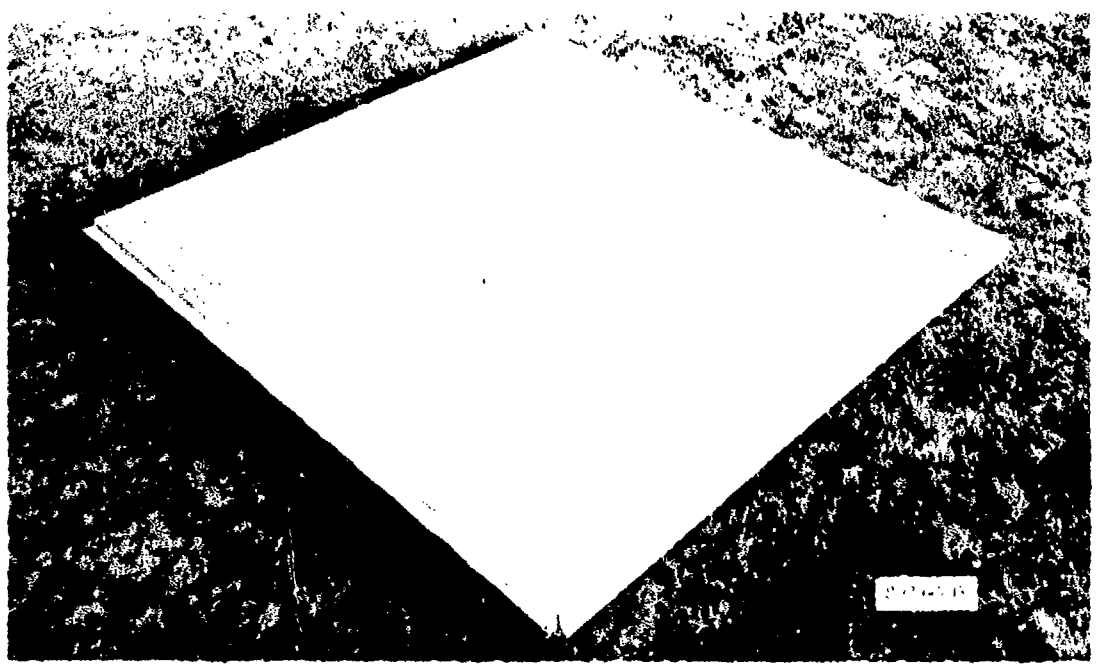


Fig. 2. Goodyear medium-duty landing mat with 5052 core

was made from 5052 aluminum alloy and the panels were not coated with an antiskid compound and painted. Use of the 5052 alloy would represent a cost savings of 20 to 25 percent of the cost per square foot of core material. The location of these two panels is indicated in plate 1.

Physical Dimensions

11. The mats were shipped in bundles (fig. 3) containing an average of 18 panels and weighing approximately 3/4 ton. The panels were approximately 4 ft square and 1.5 in. thick. No panels were damaged during shipment. The average weight of the locking bars was 0.5 lb .

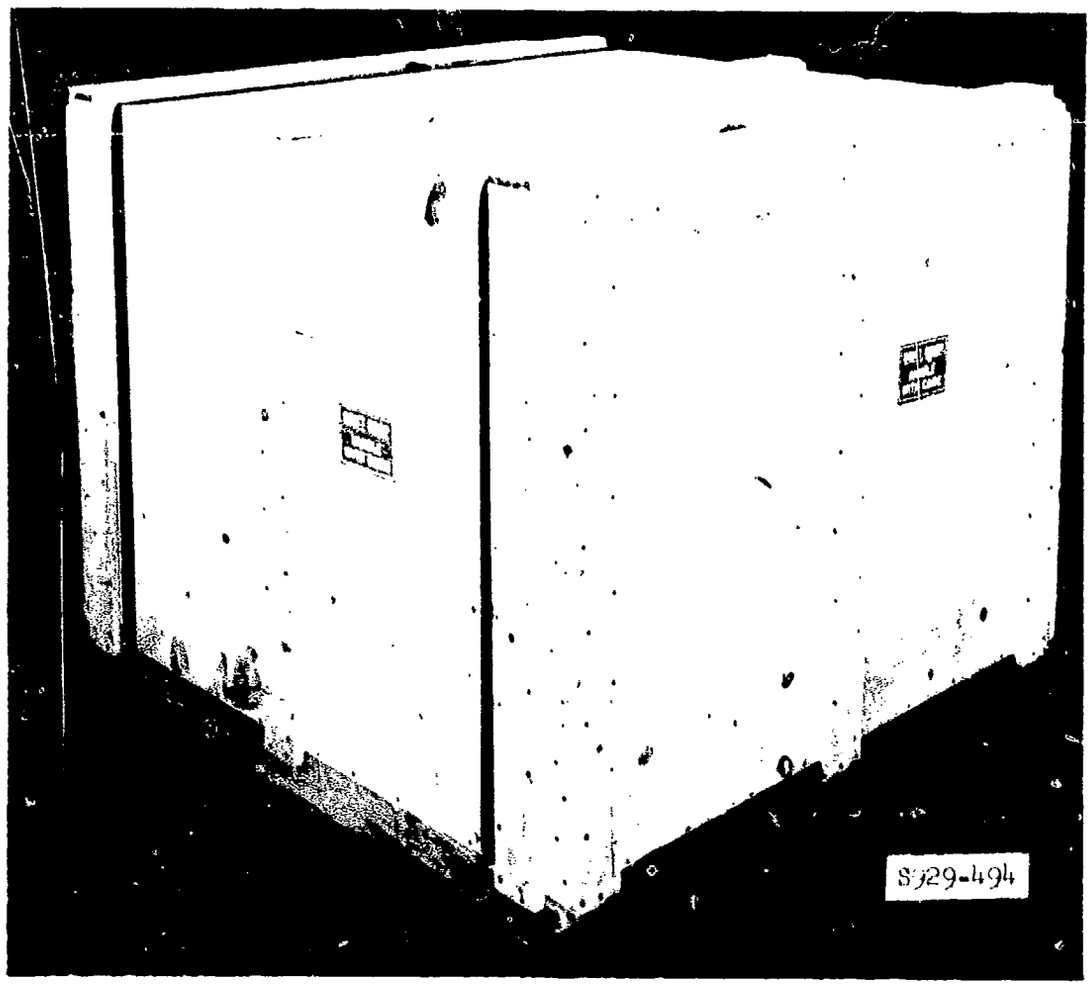


Fig. 3. Bundle of Goodyear medium-duty landing mat

Individual panels and bundles were measured and weighed, and average dimensions and weights were as follows:

Panels

Overall Dimensions in.			Placing Dimensions				
Width	Length	Depth	Width in.	Length in.	Area sq ft	Weight lb	Weight per sq ft of Placing Area, lb
49.50	50.25	1.50	49.20	49.32	16.85	67.5	4.1

Bundles

Length ft	Width ft	Height ft	Volume cu ft	Weight lb	No. of Panels	Total Placing Area sq ft	Volume per 100 sq ft of Placing Area, cu ft
4.6	4.6	3.7	78.3	1542	18	303.3	25.8

PART III: TEST SECTION, EQUIPMENT, AND PROCEDURES

Test Section

12. The test section was constructed under a hangar to provide protection from the elements and to maintain the necessary controlled conditions for obtaining the required subgrade strength. The test section was 24 ft wide and 46 ft long with a 10-ft-wide traffic lane in the longitudinal center and a 30-ft-long approach area at each end of the section (plate 1).

13. The test section was excavated to 24 in. below final grade and backfilled with a heavy clay material (CH) with an average liquid limit of 58 and an average plasticity index of 33 (plate 2). The clay was processed to ensure uniformity, hauled to the test section, spread with a bulldozer, and compacted in 6-in. lifts. Each lift was mixed in place with a pulvimixer and then compacted by applying eight coverages of a self-propelled, seven-wheel, rubber-tired roller loaded to 50,000 lb and having a tire-inflation pressure of 65 psi. The surface of each compacted lift was scarified and sprinkled with water prior to placement of the next lift. Construction control data were obtained for each lift after compaction by means of in-place CBR, moisture content, and density tests. After backfilling had been completed, the subgrade was finished to final grade by a motor grader and then rolled with a steel-wheel tandem roller to provide a relatively smooth surface with no transverse grade.

14. Prior to mat placement, T16 neoprene-coated membrane was laid over the subgrade to retard drying that would cause a change in the subgrade strength. The mat was seated in the subgrade with the roller that had been used to compact the subgrade. Lead weights were placed along the sides of the section to anchor the panels. Results of tests conducted after completion of construction are given as zero coverage data in table 1. These data were based on measurements from two test pits in the test section. An average subgrade CBR of 3.4 was obtained in the test section before traffic.

Mat Placement

15. The mats were placed on the test section by a crew of six men under the direction of a foreman. The mats were stacked adjacent to the test section in open bundles to minimize the distance that panels had to be carried by the placing crew. A forklift was used to keep the panels as close to the placing crew as practical. The panels were placed in a brickwork pattern with the male and female connectors parallel to the direction of traffic. After the overlap/underlap connectors had been nested, they were secured with a locking bar. The average placing rate was 478 square feet per man-hour on a flat surface. The panels were stacked upside down in the bundles by the manufacturer, so the placing rate was somewhat slower than that for the XM19 mats. Nevertheless, the rate was faster than that of 446 square feet per man-hour achieved with the previously tested Goodyear mat.[4]

Traffic Test Equipment

16. A single-wheel load cart (fig.4) loaded to 25,000 lb was used

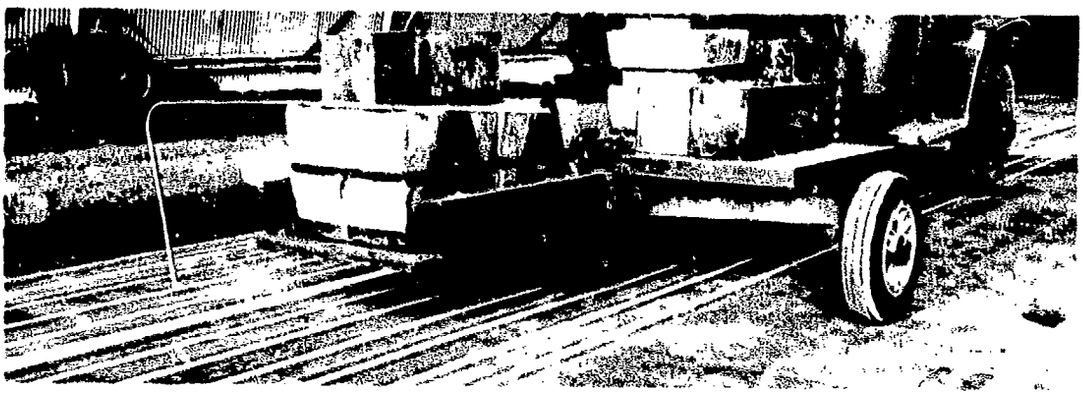


Fig. 4. Load cart used in traffic tests

in the traffic tests. It was fitted with an outrigger wheel (load considered insignificant) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load cart had a 30.00x11.5, 24-ply tire inflated to 250 psi to produce a contact area of 111 sq in.

Mat Placement

15. The mats were placed on the test section by a crew of six men under the direction of a foreman. The mats were stacked adjacent to the test section in open bundles to minimize the distance that panels had to be carried by the placing crew. A forklift was used to keep the panels as close to the placing crew as practical. The panels were placed in a brickwork pattern with the male and female connectors parallel to the direction of traffic. After the overlap/underlap connectors had been nested, they were secured with a locking bar. The average placing rate was 478 square feet per man-hour on a flat surface. The panels were stacked upside down in the bundles by the manufacturer, so the placing rate was somewhat slower than that for the XM19 mats. Nevertheless, the rate was faster than that of 446 square feet per man-hour achieved with the previously tested Goodyear mat.[4]

Traffic Test Equipment

16. A single-wheel load cart (fig.4) loaded to 25,000 lb was used

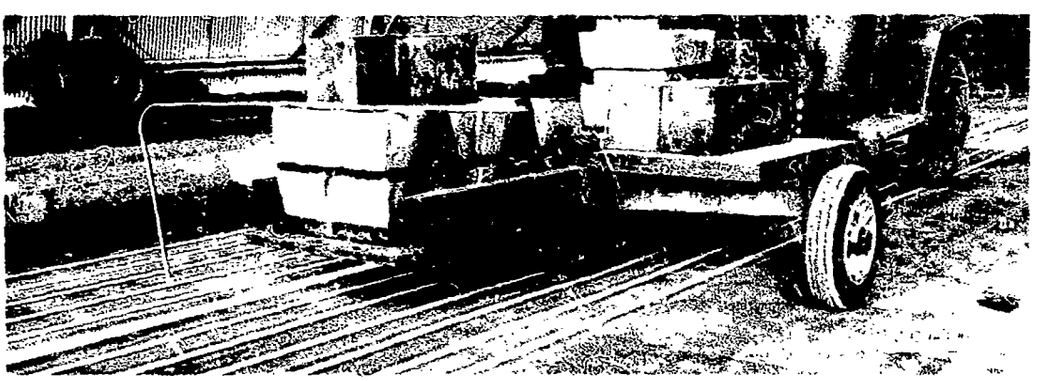


Fig. 4. Load cart used in traffic tests

in the traffic tests. It was fitted with an outrigger wheel (load considered insignificant) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load cart had a 30.00x11.5, 24-ply tire inflated to 250 psi to produce a contact area of 111 sq in.

Mat Placement

15. The mats were placed on the test section by a crew of six men under the direction of a foreman. The mats were stacked adjacent to the test section in open bundles to minimize the distance that panels had to be carried by the placing crew. A forklift was used to keep the panels as close to the placing crew as practical. The panels were placed in a brickwork pattern with the male and female connectors parallel to the direction of traffic. After the overlap/underlap connectors had been nested, they were secured with a locking bar. The average placing rate was 478 square feet per man-hour on a flat surface. The panels were stacked upside down in the bundles by the manufacturer, so the placing rate was somewhat slower than that for the XM19 mats. Nevertheless, the rate was faster than that of 446 square feet per man-hour achieved with the previously tested Goodyear mat.[4]

Traffic Test Equipment

16. A single-wheel load cart (fig.4) loaded to 25,000 lb was used

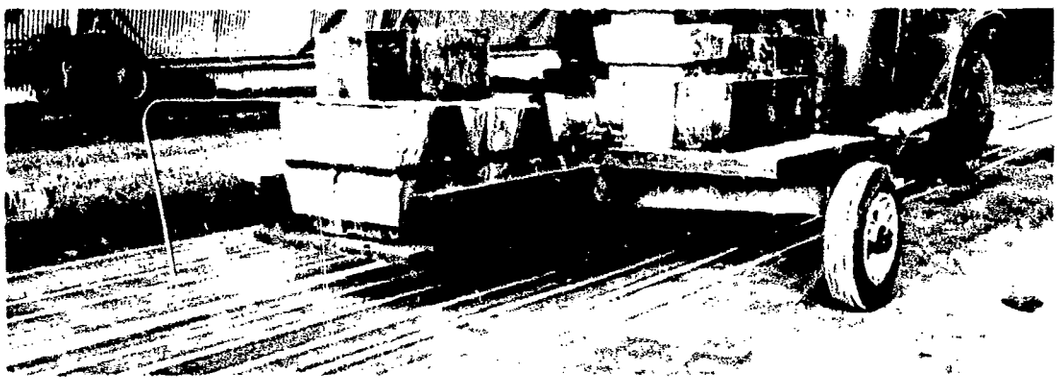


Fig. 4. Load cart used in traffic tests

in the traffic tests. It was fitted with an outrigger wheel (load considered insignificant) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load cart had a 30.00x11.5, 24-ply tire inflated to 250 psi to produce a contact area of 111 sq in.

Application of Traffic

17. The mat was subjected to traffic in a 10-ft-wide, 46-ft-long traffic lane in the longitudinal center of the test section (plate 1). Traffic was applied to simulate the traffic distribution pattern in aircraft takeoffs and landings.[6,7] Traffic was applied by starting at one side of the traffic lane, driving the load cart forward then backward in the same path for the length of the traffic lane, and then shifting the path of the cart laterally 10 in. (the width of the tire print) on each successive trip. Thus, two coverages of the entire traffic lane were produced when the load cart had maneuvered from one side of the traffic lane to the other. The interior 100 in. of the traffic lane was trafficked for six additional coverages. The longitudinal center 60 in. of the traffic lane received two additional coverages for a total of ten coverages. The net result was that this 60-in.-wide strip of the traffic lane received 100 percent of the traffic, the two 20-in.-wide strips on each side thereof received 80 percent, and the two 10-in.-wide edge strips received 20 percent (plate 3). This pattern of traffic application was repeated until mat failure occurred.

Skid Test Equipment

18. Skid tests were conducted on both dry and wet surfaces. The skid vehicle used was a C-130 load cart, loaded to 30,000 lb on a 20.00x20, 20-ply tire inflated to 100 psi. The truck section of the load cart was used only for steering, and a Tournadozer was used to pull the load cart.

19. To perform the tests, the load cart was positioned along one side of the traffic lane with the wheel locked. The cart was skidded over the mat 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. The force required to pull the load cart over the mat surface with the wheel locked was measured with a 50,000-lb-capacity dynamometer.

PART IV: CRITERIA FOR MAT FAILURE AND TYPES OF DATA RECORDED

Failure Criteria

20. The following guidelines were used to determine failure of the mat:

a. Excessive mat breakage.

(1) Weld failure: when the weld failure appreciably affected the performance of the mat or became a tire hazard.

(2) Core failure: when the core failure appreciably affected the performance of the mat or caused undue roughness.

(3) Breaks:

(a) A panel was considered failed when a break was considered to be a tire hazard.

(b) A section was considered failed when breaks exceeding 6 in. in length occurred in 50 percent of the panels or when breaks extending 40 percent of the length of a panel occurred in 20 percent of the panels.

b. Static deflection. Usually not to exceed 1 in. maximum (accompanied by indication of structural failure).

c. Roughness.

(1) Deflection not to exceed 1 in. at side joint, measured from a 4-ft-long straightedge.

(2) Dishing not to exceed 0.6 in.

(3) Instability of the load cart as determined by observations and experienced judgment when it was traveling at a uniform speed (approximately 2 to 4 mph).

21. It was assumed that a certain amount of maintenance will be performed in the field during usage of the mat. It was considered feasible to replace up to 10 percent of the panels in the center portion of the traffic lane (i.e., that portion receiving 100 percent of the coverages) with new panels during a test. When an additional panel required replacement or was considered to be a tire hazard, the section was considered failed.

Types of Data Recorded

Traffic tests

22. Subgrade densities, water contents, and in-place CBR's measured before, during, and after traffic are presented in table 1. The soil tests were made at the surface of the subgrade and usually at depths of 6 and 12 in., with a minimum of three values per depth. Static deflections of the mat were measured with the load wheel at the joint of three panels, at the joint of two panels, and at the center of a panel. Level readings were taken before, during, and after traffic to measure transverse and longitudinal deformation of the test section and to reveal the degree of roughness. Observations of the mat, subgrade behavior, and other relevant factors were recorded throughout the period of traffic and were supplemented by photographs. Pertinent data will be discussed later in the report.

Skid tests

23. An electric strip chart recorded the force required to pull the load cart and the distance of the skid on individual oscillograms. Observations and photographs of the antiskid coating on the mat were made before and after the skid tests.

PART V: TRAFFIC AND SKID TEST RESULTS AND ANALYSIS

Test Results

Skid tests

24. Skid tests were conducted on the panels prior to traffic tests. The load cart described in paragraph 18 was skidded on both a dry and a wet surface. A summary of the test results is tabulated below.

	Dry Surface	Wet Surface
Total length of skid, ft	16	14
Maximum pull force, lb	29,500	15,000
Average pull force, lb	17,000	13,500
Coefficient of friction	0.57	0.45

The data above indicate that the coefficient of friction on the dry mat surface increased approximately 25 percent over that on the wet surface. (The QMR, 2 April 1968, specifies a coefficient of friction range of 0.4 to 0.8 on both dry and wet surfaces.)

25. No antiskid coating was removed from the mat under either dry or wet conditions, and the tire wear was considered slight. Skid marks and tire wear after the dry skid test are shown in photos 1 and 2.

Traffic tests

26. The test section proir to traffic (photo 3) was generally smooth, and the average CBR of the subgrade was 3.4 (table 1).

27. Traffic was applied using the load cart described in paragraph 16. After 180 coverages, panel 15 was considered failed due to a depression of approximately 43 by 7-1/2 in. parallel and adjacent to the male connector (photo 4). When the panel was removed from the test section, the surface subgrade strength under the panel was 3.8 CBR (table 1). The core had depressed 0.37 in. (maximum) along the male connector. In addition to the depression, a break 1-1/2 in. long had occurred at the corner of the male and underlap connectors. The bottom skin had broken at the male connector along the entire length of the panel. Photo 5 shows

adhesive failure at the top and bottom skins and shear failure of the core of panel 15 after 180 coverages.

28. At 500 coverages, the subgrade strength was checked, and an average CBR of 3.8 (see table 1) was measured. Traffic was continued to 596 coverages. At this coverage level, panel 2 showed evidence of separations at the underlap and male corners. After 600 coverages, the separation along the underlap connector was 4 in. in length, and a 3-in. break had developed along the male connector. The lengthening of these breaks was slight during the remaining 22 coverages of the test, so panel 2 was not considered failed.

29. At 622 coverages, the test section was considered failed due to failure of panels 3, 15, 18, and 39, which represented more than 10 percent of the mats in the 100 percent traffic area; therefore, traffic was discontinued. Panel 3 was considered failed due to a depression of 0.38 in. (maximum) along the entire length of the female connector. Also, there were 1-in.-long breaks at right angles in the corner of the overlap and female connectors and 1-1/2-in.-long breaks at the underlap and female connectors. The bottom skin had broken along the female connector for the length of the panel, along the overlap connector for a distance of 3 in., and along the underlap connector for 7 in. A section of panel 3 with the top skin removed for inspection is shown in photo 6. Note the strip that was void of film adhesive (approximately 0.5 in. wide).

30. Panel 18 was considered failed due to a depression of 0.375 in. (maximum) along the male connector, beginning at the underlap corner. The adhesive bond between the top skin and the connectors had broken for 31 in. along the male connector and for 17 in. along the underlap connector. The bottom skin had separated along the male connector for the full length of the panel. Bottom-skin separation also extended along the underlap connector for 32 in. and along the overlap connector for 2 in. The top skin at the male/underlap corner had curled upward (photo 7). The panel was removed, and the top skin was peeled from the male/underlap corner area for examination (photo 8). In some areas, there were indications that the film adhesive had wrinkled during

fabrication, thus preventing the top sheet from being completely bonded to the core. The interior corner of the underlap connection had broken only on this panel.

31. Panel 39 was considered failed due to a depression of 0.5 in. (maximum) along the female connector. The top-skin adhesive bond had broken for 34 in. along the female connector and for 2 in. along the underlap connector. A 48-in. separation had occurred between the bottom skin and the female connector, extending for 13 in. along the overlap connector and for 15 in. along the underlap connector. Photo 9 shows top-skin separation on panel 39 with the load wheel on the panel at 622 coverages. The panel had internal failures similar to those of panels 3 and 18 described in paragraphs 29 and 30, respectively (see photos 6 and 8).

32. Except for the failed panels, the test section was in good condition at the conclusion of traffic (photo 10). CBR data were recorded at two locations (plate 1), and the rated CBR for the test section was 3.8 (table 1). Cross sections and longitudinal profiles at 0 and 622 coverages are shown in plates 4 and 5, respectively. Representative static deflection measurements at 0 and 622 coverages are shown in plate 6. Permanent longitudinal deformation along the center line of the traffic lane reached a maximum of approximately 1.1 in. and averaged 0.6 to 0.7 in. The maximum static deflection measured at 0 coverages was 0.8 in. at the joint of panels 30, 31, and 34; at 622 coverages, the maximum static deflection was 0.9 at the same location. The greatest increase in static deflection, 0.2 in., occurred at the joint of panels 27 and 31 (see plate 6).

33. The two special panels, 42 and 43 (see paragraph 10), withstood the full 622 coverages of traffic. There was no evidence of cracks, core failure, or adhesive failure in either. At 622 coverages, panels 42 and 43 had maximum permanent sets of 0.115 and 0.201 in., respectively, measured at the center of the top surface of the mats, as compared to respective maximums of 0.122 and 0.225 in. on typical panels 19 and 15 of the regular test panels.

Analysis of Results

34. The coefficients of friction of 0.57 and 0.45 on a dry and wet surface, respectively, were within the range of 0.4 to 0.8 specified by the QMR.

35. All panel failures were similar in the manner in which they initiated. The film adhesive was ordered by the fabricator in 48-in.-wide rolls and was cut to the length of the skins so that all required areas could be covered for bonding. However, the width of the adhesive as delivered was undersize by approximately 0.5 in., and a splice in the adhesive was required to assure 100 percent coverage. In some of the panels tested, it appeared that the adhesive had not been spliced (see the 0.5-in.-wide void area across the center of panel 3 in photo 6). Panel 18 was void of adhesive along the overlap connector (see photo 8), and a similar condition existed on panel 39 along the female connector. Failure of panels 3, 18, and 39 was attributed to the lack of splicing in the undersize fiber-film adhesive. None of the panels failed suddenly, however; and, after being excessively stressed or weakened, each survived several additional coverages before failure.

36. The rated CBR, total single-wheel load, tire pressure, and number of coverages at failure were substituted in the equation*

$$\frac{t}{0.23 \log_{10}(C) + 0.15} = \sqrt{P\left(\frac{1}{8.1\ CBR} - \frac{1}{p\pi}\right)}$$

where

t = design thickness of pavement structure, in.

C = coverages at failure (622)

P = total single-wheel load, lb (25,000)

CBR = rated California Bearing Ratio (3.8)

p = tire pressure, psi (250)

---

* This is a combination of equation 2, page 2, and the equation for the slope of the curve in plate 3 from reference 8.

PART VI: LABORATORY TESTS

Test Equipment

37. All laboratory tests were performed on a 60,000-lb-capacity universal-type testing machine.

Tests and Results

Test specimens

38. Laboratory tests were performed on specimens of the Goodyear medium-duty mat to determine its mechanical properties and compare them with properties of the previously tested Goodyear all-bonded mat[4] and with those of XM19 mat.[1] The tests were performed on specimens cut from panels selected at random.

Test procedures

39. The specimens were tested by procedure a below, with the exception of the edge specimens, which were tested by procedure b. The procedures were as follows:

a. Compressive, shear, and flexural strength tests were conducted in accordance with reference 9. The core shear strength was determined by the sandwich-flexure method given in reference 9. Simple beam tests with loading at the quarter points were used to determine the shear and flexural strengths of the specimens. A test of this type was designed to produce failure in one of two ways:

(1) By shear of the core and/or of the core-to-facing adhesive bond.

(2) By direct compression or tension failure of the facing.

Spans of mat of 8 by 20 in. were used to determine the flexural properties, and 3- by 8-in. spans were used to determine the shear properties.

b. Specimens were subjected to static edge member tests. In these tests, the connector was left along one of the narrower edges of the specimen, and this edge was used as a support along with one other support area (fig. 5). The specimen size was 9.5 by 10.5 by 1.5 in. These tests were used to determine if the adhesive joining the core

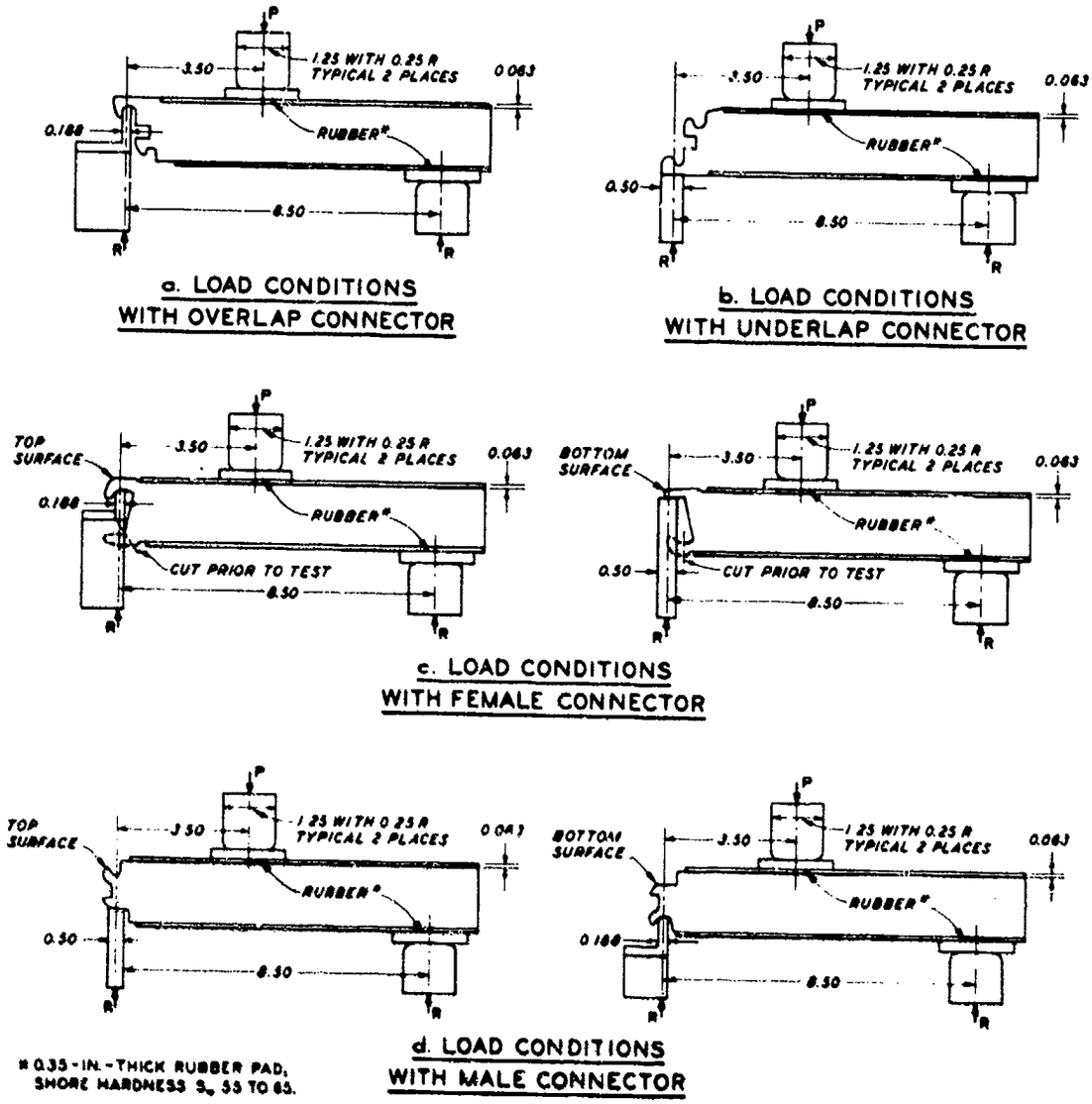


Fig. 5. Static edge member tests

to the edge connectors was as strong in shear strength as the honeycomb core, rather than to determine the strength of the edge connectors. (For structural balance, the shear strength of the adhesive bond should equal or exceed the shear strength of the panel core.) The shear strength was calculated using the equation:

$$F = \frac{5P}{8.5W(t - 0.063)}$$

where

F = shear strength, psi

P = load applied at failure, lb

W = specimen width, in. (9.5 in.)

t = specimen thickness, in. (1.5 in.)

Results

40. The results of the laboratory tests conducted on the Goodyear medium-duty mat (tables 2 and 3) compared favorably with those determined for previously tested Goodyear all bonded mat[4] and with those for the XM19 mats.[1] The vertical shear values obtained in tests of the Goodyear medium-duty mat exceeded the 550-psi minimum specified for the XM19 mat. Tests of the static edge members produced shear failures in the honeycomb core but no shear failures in the core-to-edge-connector adhesive; therefore, the core-to-edge-connector adhesive appeared adequate to resist a greater shear load than that required to fail the honeycomb core.

PART VII: SUMMARY OF RESULTS AND CONCLUSIONS

Results

41. The following results were obtained from the investigation:

    a. The placement rate of the medium-duty Goodyear landing mat was 478 square feet per man-hour on a flat surface.

    b. The mat supported 622 coverages of a 25,000-lb single-wheel load on a subgrade with a rated CBR of 3.8.

    c. Tire wear during skid tests was slight, and the performance of the antiskid compound was considered adequate. The coefficients of friction on dry and wet surfaces were 0.57 and 0.45, respectively.

    d. Core shear, compression, and flexural strength values were comparable to those of the previously tested Goodyear all-bonded mat and the XM19 mat; thus, the mat met the mechanical specifications for the materials.

    e. The film adhesive did not cover all necessary and intended areas.

Conclusions

42. The placing rate and the coefficients of friction of the medium-duty mat met the QMR performance specifications. However, the mat will not meet the performance specification of supporting a 25,000-lb single-wheel load with tire-inflation pressure of 250 psi on a 4.0-CBR subgrade for 1000 coverages.

LITERATURE CITED

1. Turner, R. and Carr, G. L., "Evaluation of Kaiser Aluminum Honeycomb Landing Mat," Miscellaneous Paper No. 4-897, Aug 1967, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

2. Headquarters, Department of the Army, "Sets, Kits, and Outfits Components List, Mat Set, Landing: Federal Stock No. S680-089-5920," Supply Catalog SC 5680-97-CL-E03, Jan 1968, Washington, D. C.

3. McCormick, C. T., "Evaluation of Kaiser Production Aluminum Honeycomb Landing Mat," Miscellaneous Paper S-71-7, Mar 1971, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

4. McCormick, C. T. and Carr, G. L., "Evaluation of Goodyear All-Bonded Aluminum Honeycomb Landing Mat," Miscellaneous Paper S-69-49, Dec 1969, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. American Society for Testing and Materials, "Standard Specification for Aluminum-Alloy Extruded Bars, Rods, Shapes, and Tubes," Designation: B 221-69, 1970 Book of ASTM Standards, Part 6, 1970, Philadelphia, Pa., pp 160-170.

6. Vedros, P. J., "Study of Lateral Distribution of Aircraft Traffic on Runways," Miscellaneous Paper No. 4-369, Jan 1960, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

7. U. S. Army Engineer Waterways Experiment Station, CE, "Study of Channelized Traffic," Technical Memorandum No. 3-426, Feb 1956, Vicksburg, Miss.

8. Ahlvin, R. G., "Developing a Set of CBR Design Curves," Instruction Report No. 4, Nov 1959, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

9. U. S. Department of Defense, "Sandwich Constructions and Core Materials; General Test Methods," MIL-STD-401B, 26 Sep 1967, U. S. Government Printing Office, Washington, D. C.

Table 1

Summary of CBR, Water Content, and Density Data

Coverages	Test Pit Location	Depth in.	CBR	Water Content % Dry Weight	Dry Density pcf	Rated CBR
0	Panel 13	0	3.3	29.5	87.2	
		6	3.6	29.7	89.1	
		12	3.5	30.1	86.8	
		Avg	3.5	29.8	87.7	
	Panel 32	0	3.8	28.8	89.9	
		6	3.3	30.9	87.2	
		12	3.1	30.7	87.4	
		Avg	3.4	30.1	88.2	
180	Panel 15	0	3.8	30.2	89.9	
500	Joints of panels 7 and 11	0	3.7	28.7	89.7	
		6	3.5	29.9	88.8	
		12	3.9	30.0	88.7	
		Avg	3.7	29.5	89.1	3.8
	Joints of panels 31 and 35	0	4.0	29.9	91.7	
		6	3.5	29.4	90.2	
		12	3.9	29.8	88.3	
		Avg	3.8	29.7	90.1	
622	Joints of panels 18 and 19	0	5.0	29.2	89.5	
		6	4.5	29.6	89.9	
		12	4.5	30.1	88.8	
		Avg	4.7	29.6	89.4	
	Joints of panels 34 and 30	0	4.2	30.7	88.9	
		6	4.1	29.8	90.1	
		12	3.9	30.2	88.0	
		Avg	4.1	30.2	89.0	

Table 2

Comparison of Compression, Shear, and Flexural Strength Values

Type of Test	Sample Size, in.	Load Orientation on Core*	Stress, psi** XM19†	Stress, psi** Previously Tested Goodyear All-Bonded Mat††	Stress, psi** Goodyear Medium-Duty Mat
Compressive	3 by 3	Not applicable	1790	1500	1690
Shear	3 by 12 (1/4-point loading, 8-in. span)	Weak	600	730	580
		Strong	1070	1060	950
Flexure	9.5 by 24 (1/4-point loading, 20-in. span)	Weak	46,280	53,920	--
		Strong	--	--	--
Flexure	8 by 24 (1/4-point loading, 20-in. span)	Weak	48,570‡	--	45,870
		Strong	65,120‡	--	56,240

* Weak: sample oriented so load was applied parallel to ribbon of core. Strong: sample oriented so load was applied perpendicular to ribbon of core.
** All samples failed in the core.
† Reference 1 of text.
†† Reference 4 of text.
‡ Data from tests conducted on a 1968 production quantity of XM19 mat (reference 3 of text).

Table 3

Comparison of Vertical Shear Strength Values (Static Edge Member Method)

Connector Tested	Sample Size, in.	Load Orientation on Core*	Vertical Shear Stresses, psi XM19†	Vertical Shear Stresses, psi Previously Tested Goodyear All-Bonded Mat††	Vertical Shear Stresses, psi Goodyear Medium-Duty Mat	Load at Failure, lb per in. of Width** XM19†	Load at Failure, lb per in. of Width** Previously Tested Goodyear All Bonded Mat††	Load at Failure, lb per in. of Width** Goodyear Medium-Duty Mat
Overlap	9.5 by 10.5	Weak	590	680	570	1440	1670	1390
Underlap	9.5 by 10.5	Weak	590	650	590	1460	1600	1430
Female	9.5 by 10.5	Strong (top load)	890	860	--	2180	2100	--
		Strong (bottom load)	810	780	630	1990	1900	1550
Male	9.5 by 10.5	Strong (top load)	850	840	660	2080	2050	1620
		Strong (bottom load)	760	790	620	1860	1920	1530

* Weak: sample oriented so load was applied parallel to ribbon of core. Strong: sample oriented so load was applied perpendicular to ribbon of core.
** All samples failed in the core.
† Reference 1 of text.
†† Reference 4 of text.

Photo 1. Skid marks after skid tests on dry surface

Photo 2. Tire wear after test on dry surface

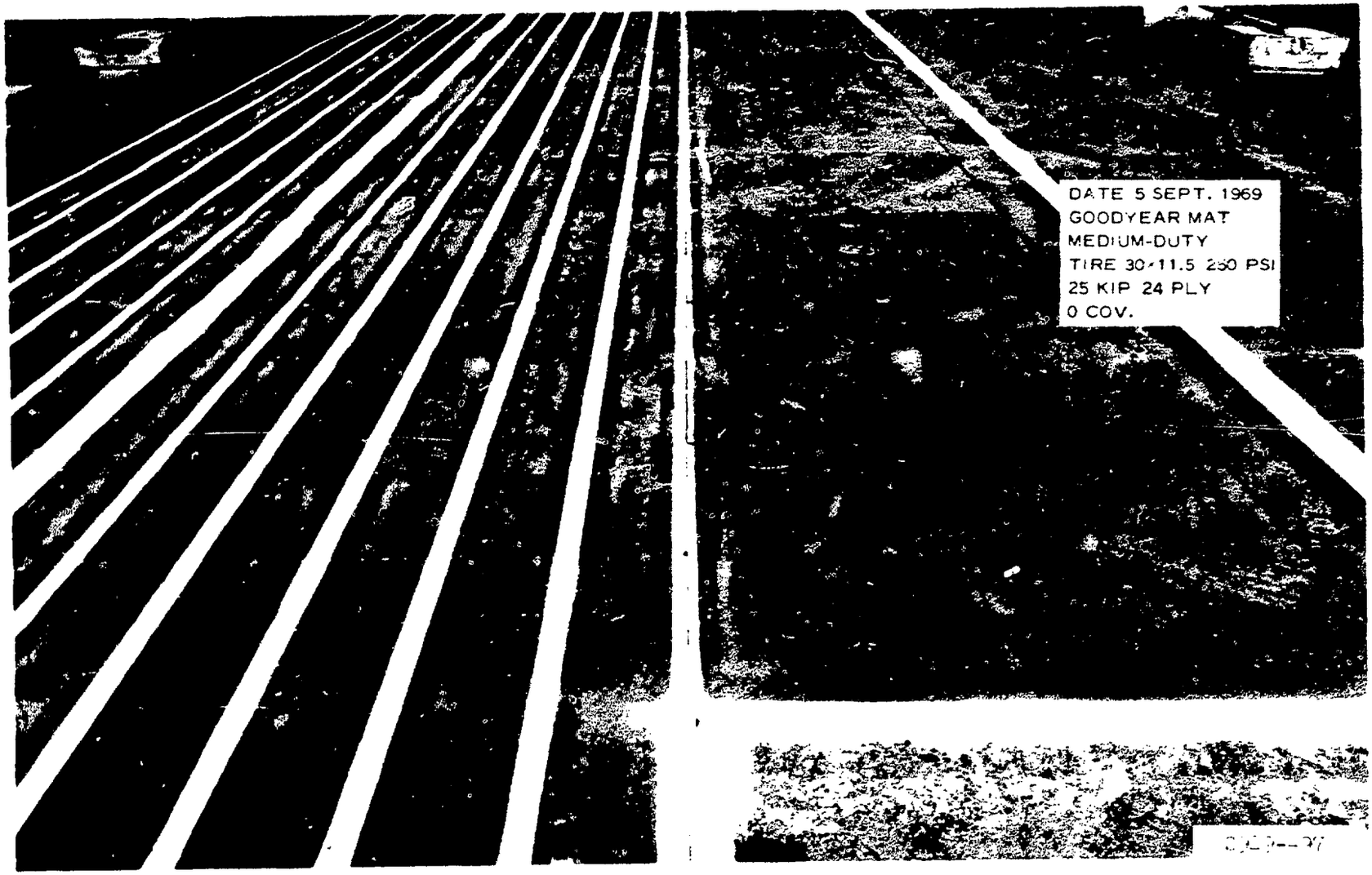


Photo 9. Test section prior to trafficking

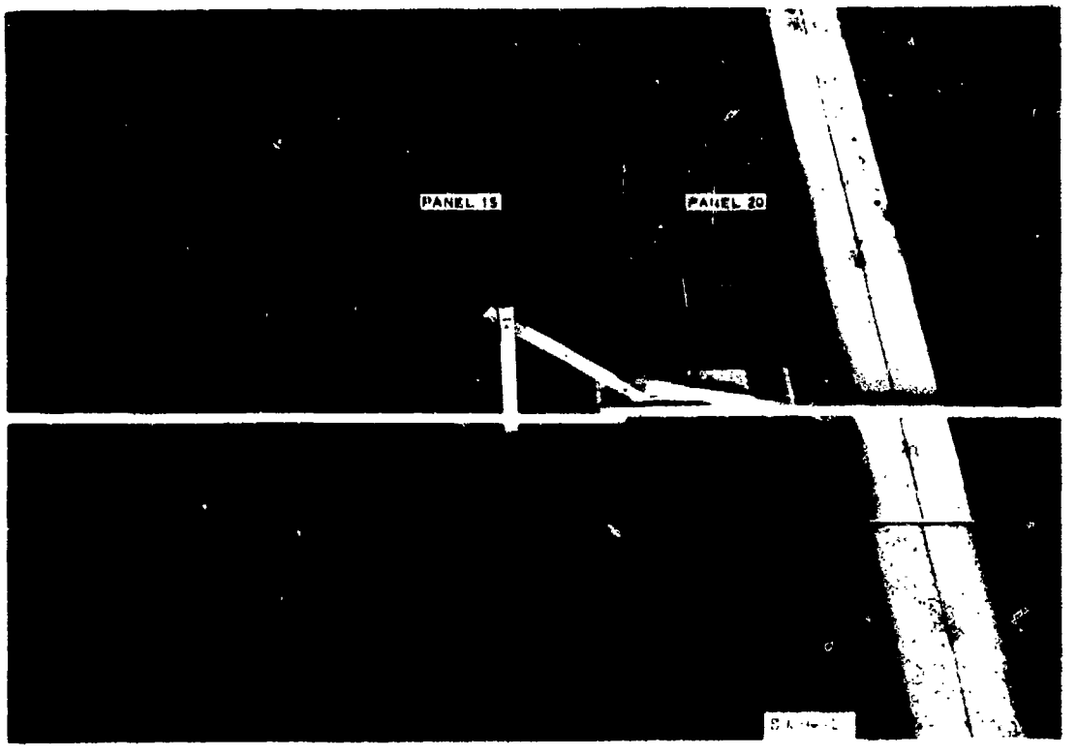
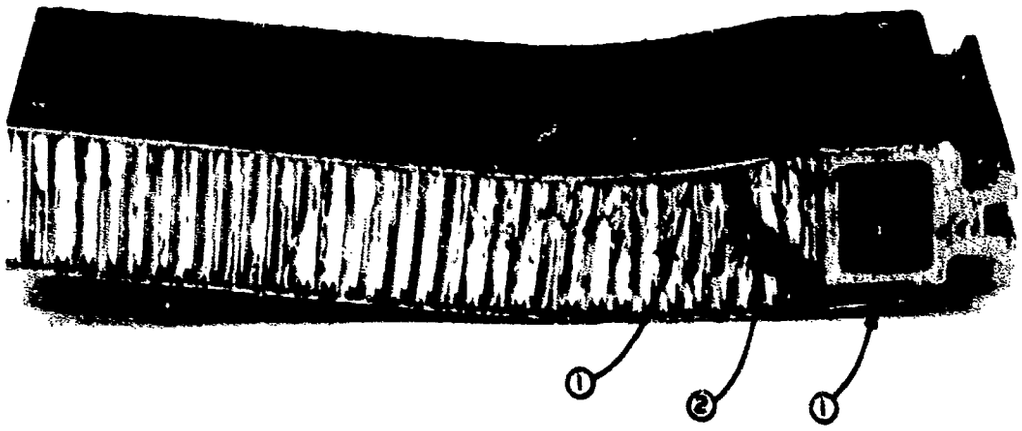


Photo 4. Failed panel 15 showing depressed area after 180 coverages



S969-516

Photo 5. Adhesive failure 1 and core shear failure 2 of panel 15 after 180 coverages

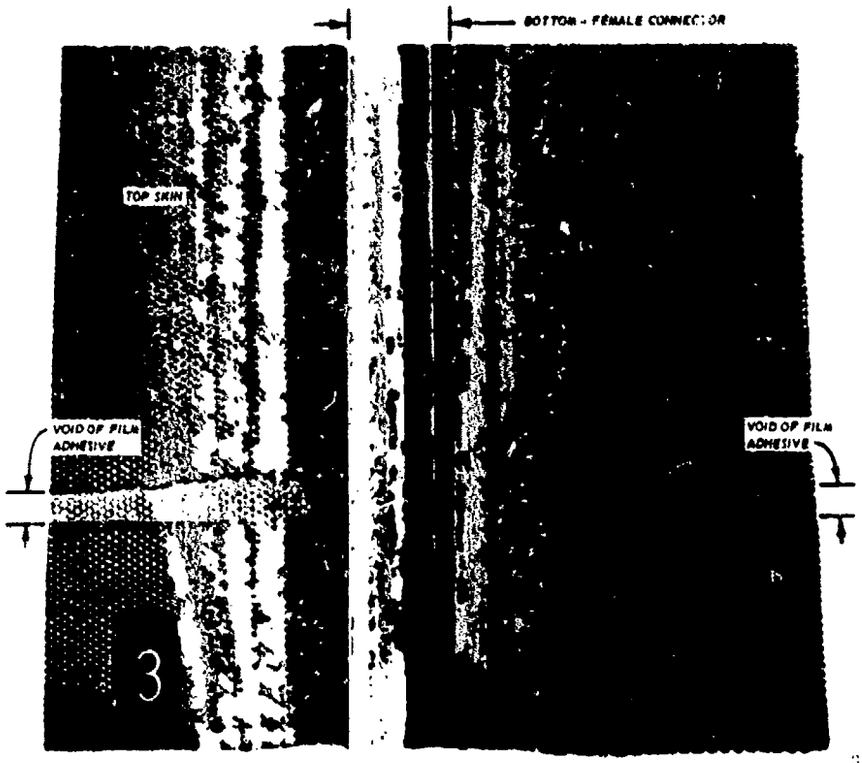


Photo 6. Section of panel 3 after 622 coverages with top skin peeled back to show internal parts

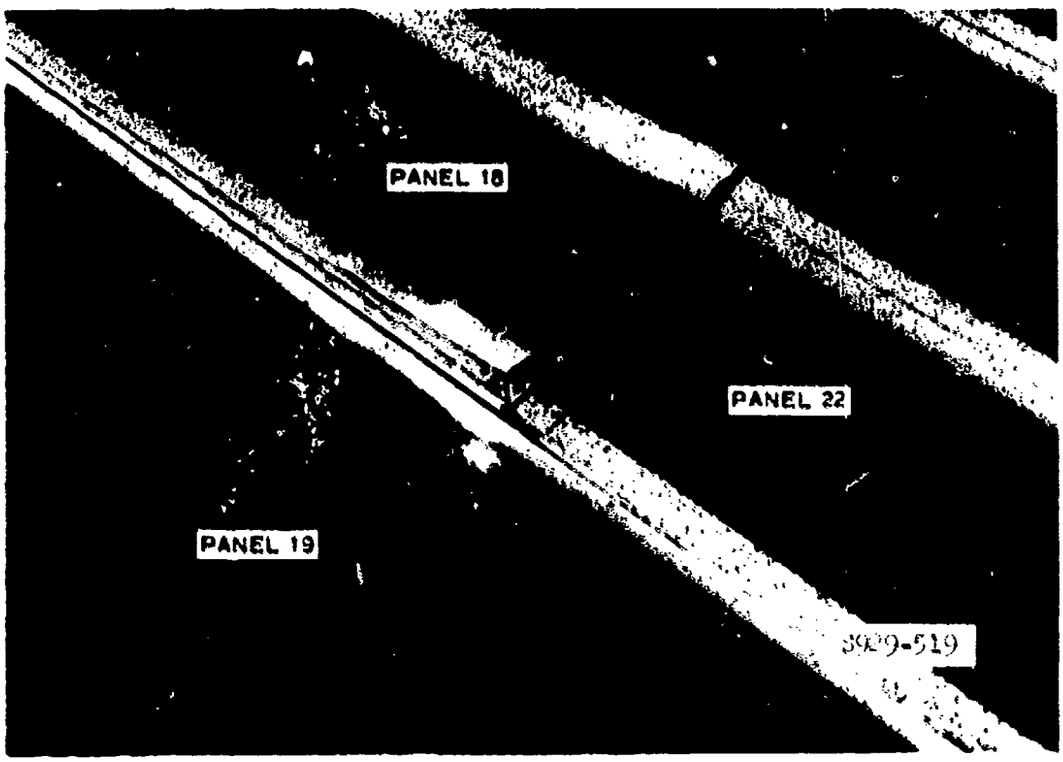


Photo 7. Failure of panel 18 showing top-skin separation at underlap/male corner at 622 coverages

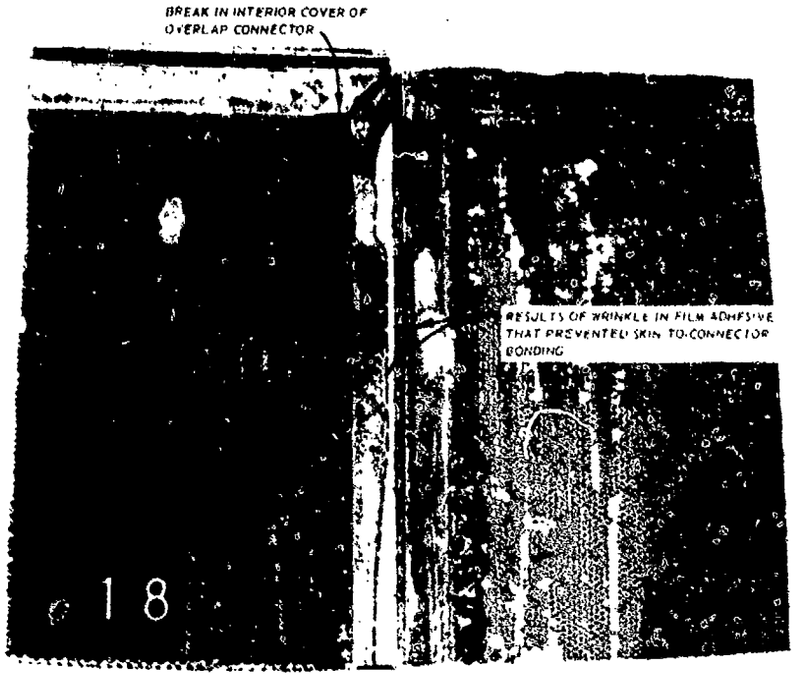


Photo 8. Section of panel 18 with top skin peeled back after 622 coverages

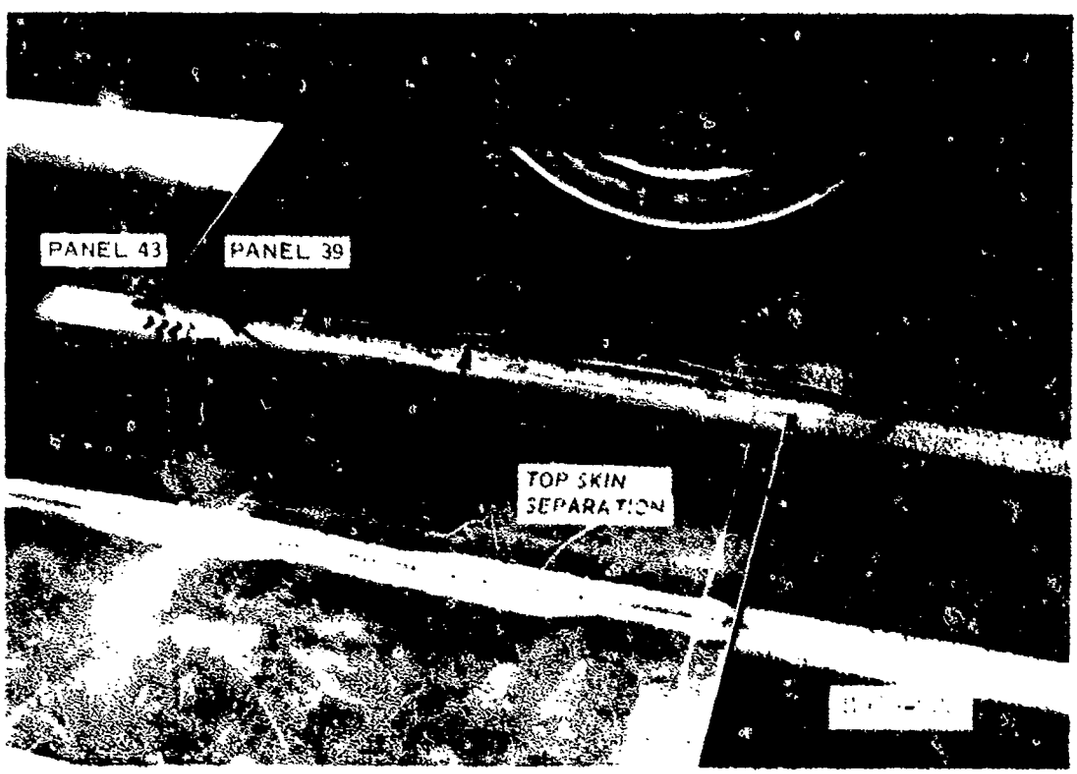
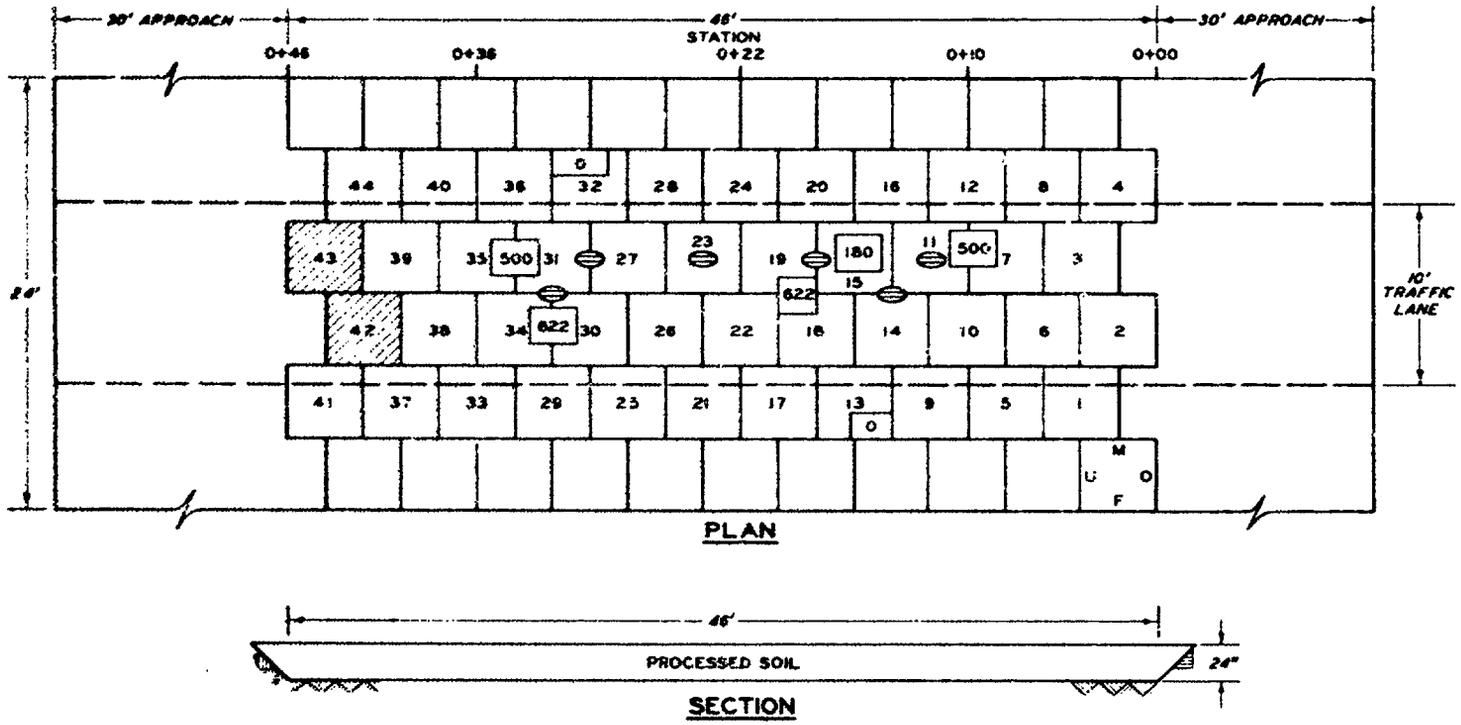


Photo 9. Panel 39 under load wheel at 622 coverages

Figure 10. [illegible] section after 22 [illegible]



LEGEND

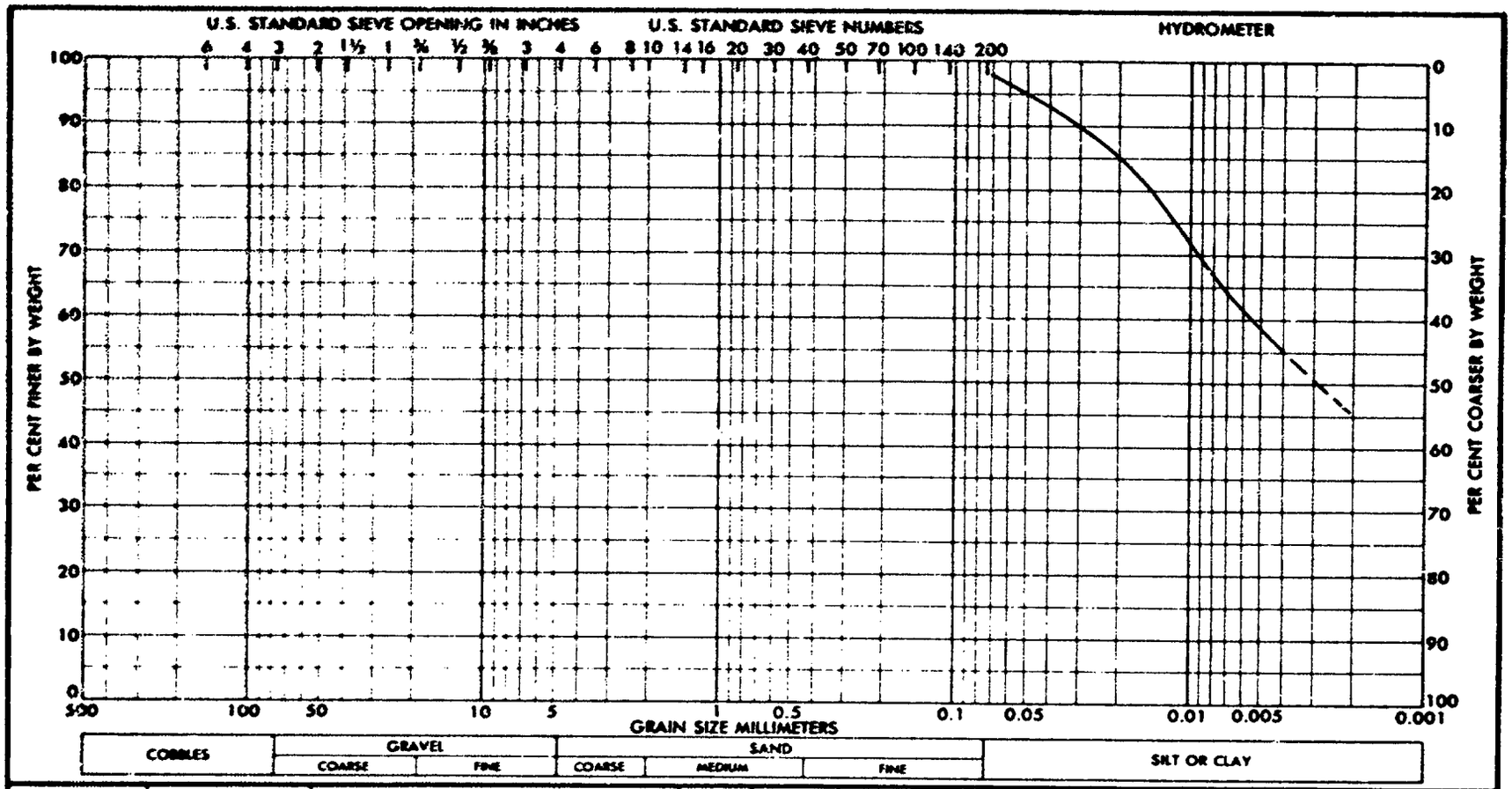
- TEST WHEEL LOCATION FOR STATIC DEFLECTION MEASUREMENTS
- SPECIAL PANELS
- TEST PIT LOCATION AND COVERAGE LEVEL

NOTE : M, F, U, O DENOTE EDGE CONNECTOR PLACEMENTS.

LAYOUT OF TEST SECTION

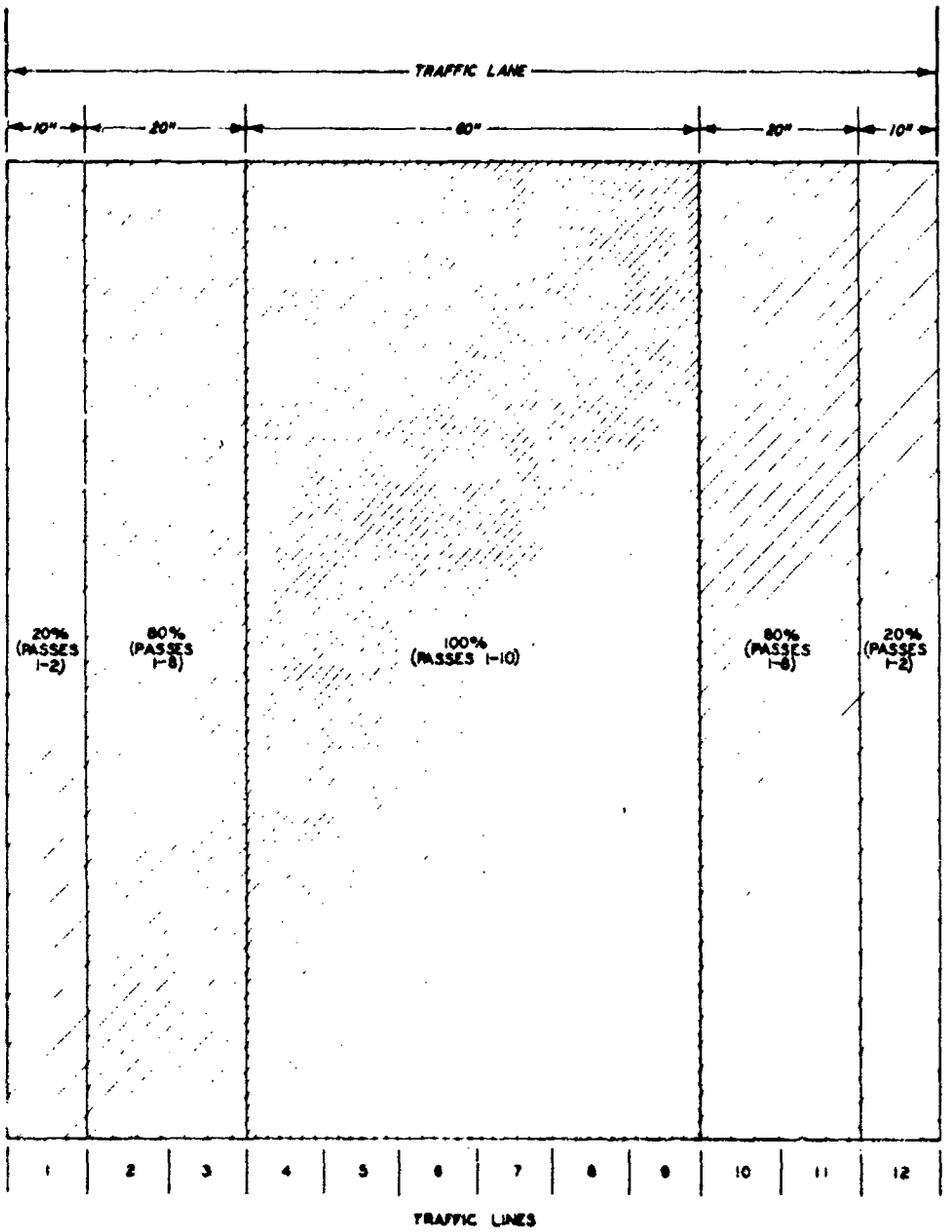
PLATE 1

PLATE 2



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
		CLAY (CH)		58	25	33

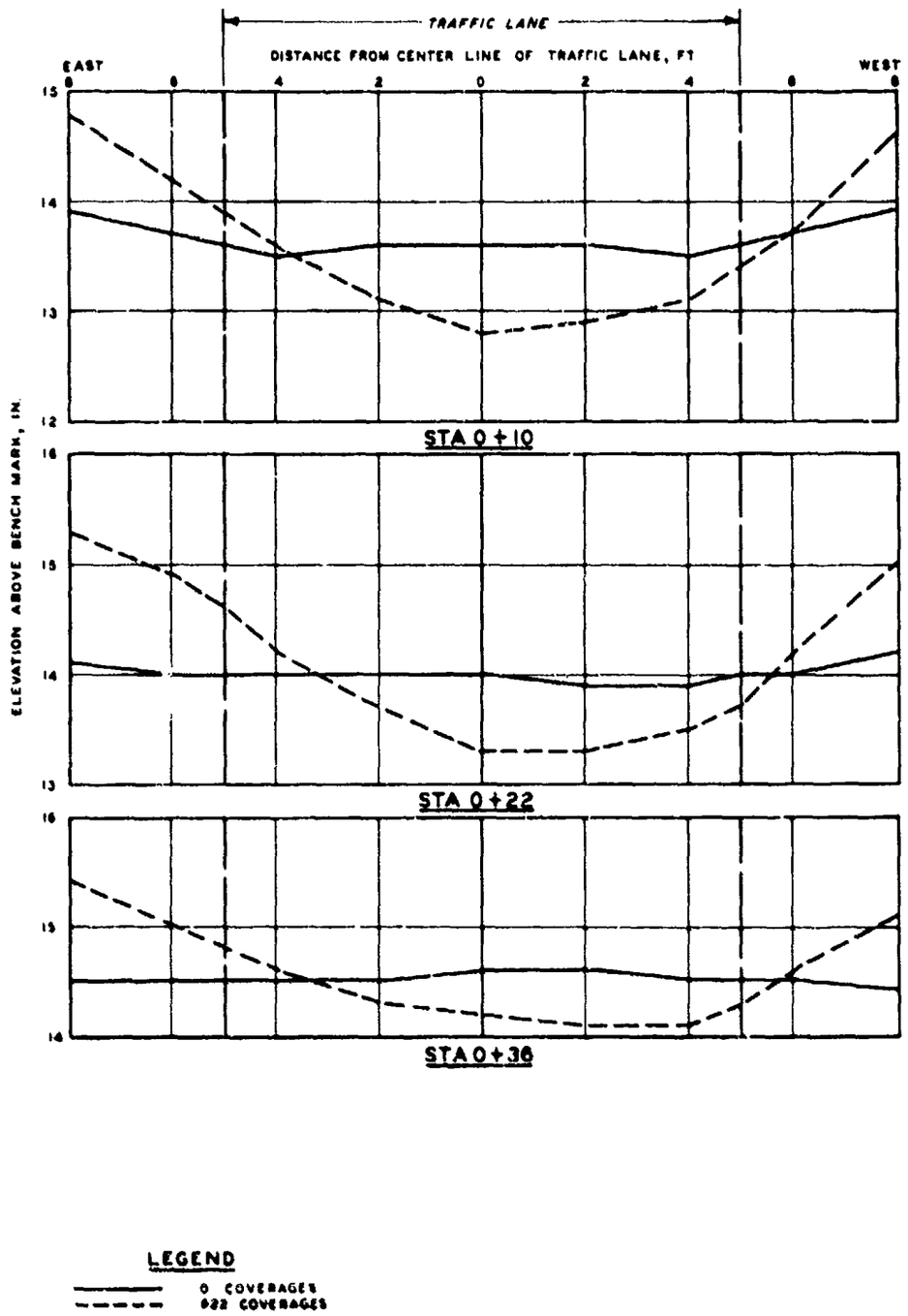
CLASSIFICATION DATA
CLAY SUBGRADE



NOTE: EACH PASS IS EQUAL TO A COVERAGE BY A 10-IN.-WIDE LOAD WHEEL OVER EACH TRAFFIC LINE

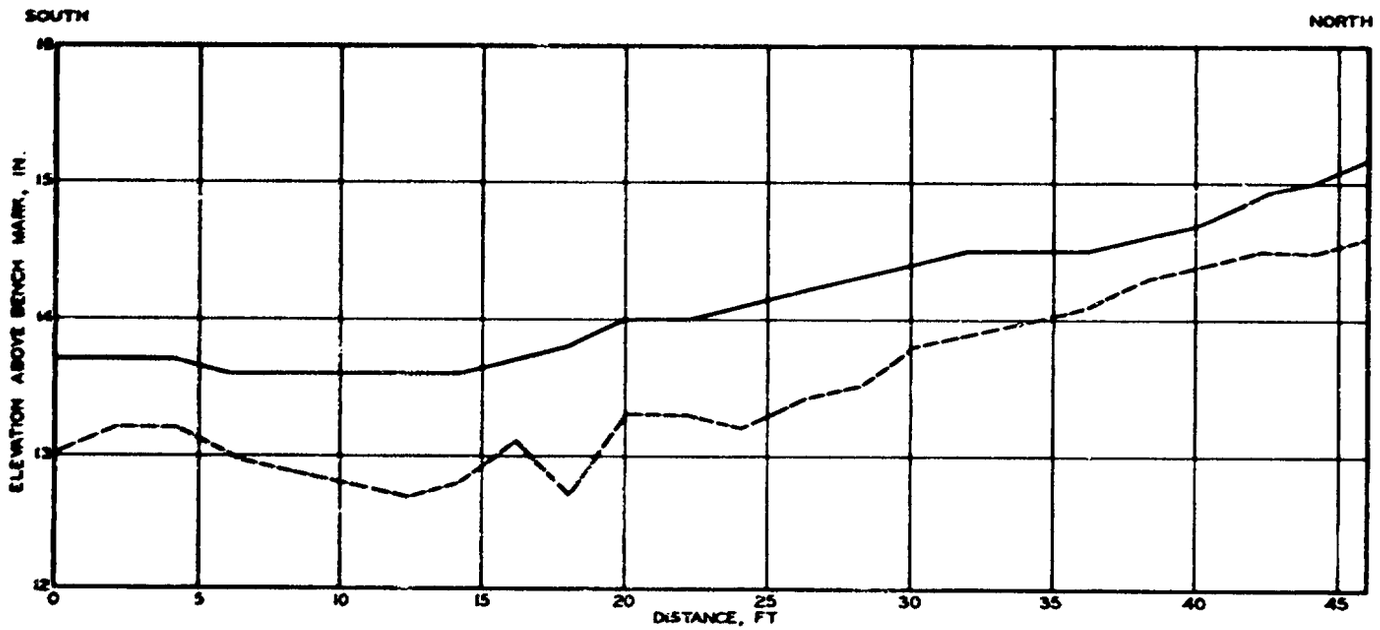
TRAFFIC DISTRIBUTION FOR F-4C LOADING

PLATE 3



CROSS SECTIONS
OF TRAFFIC LANE

PLATE 4



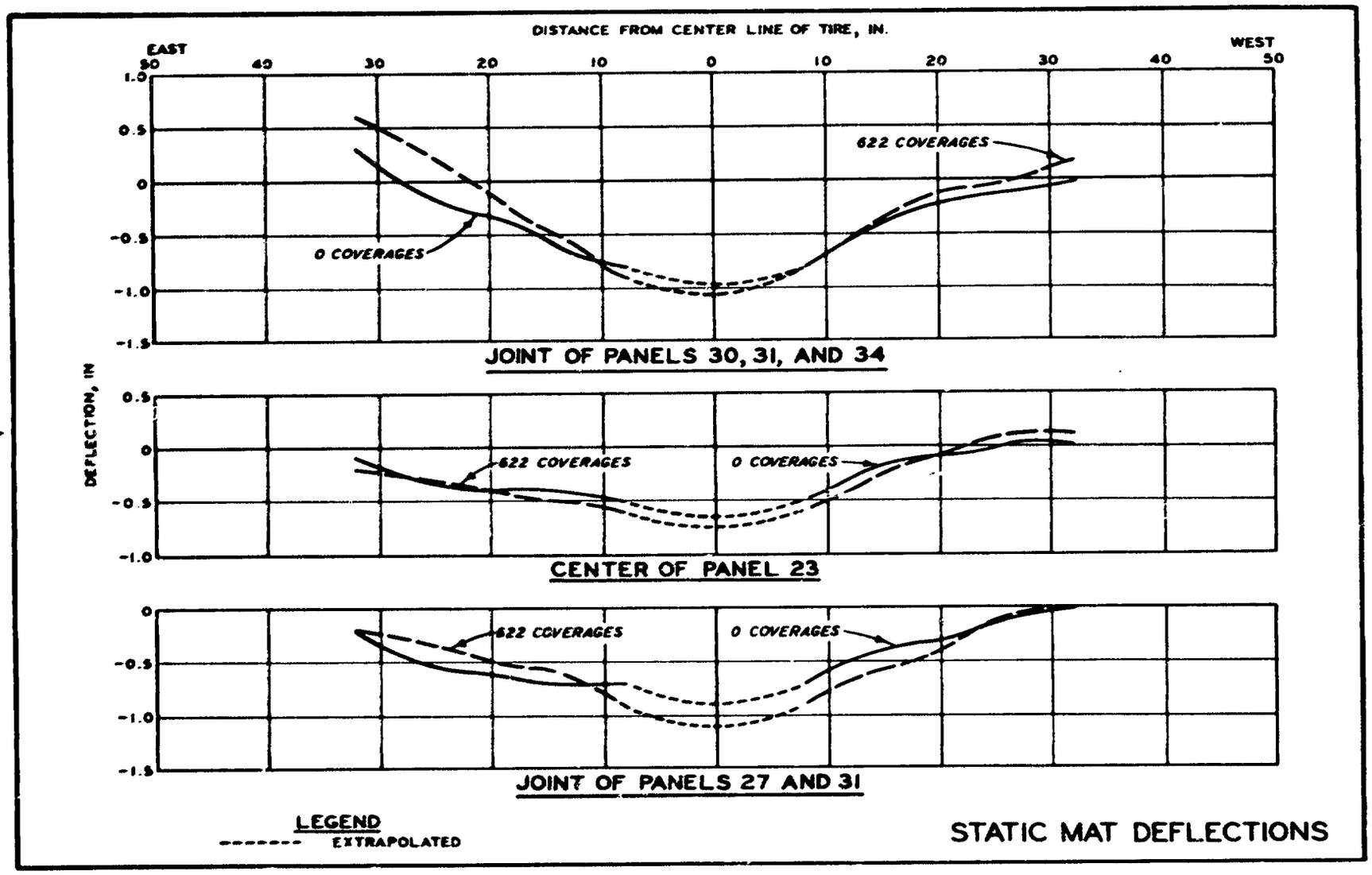
LEGEND

—— 0 COVERAGES
- - - - 822 COVERAGES

PERMANENT DEFORMATION PROFILES

CENTER LINE OF TRAFFIC LANE

PLATE 5



STATIC MAT DEFLECTIONS

PLATE 6