MISCELLANEOUS PAPER NO. 4-788

EVALUATION OF AM2 LANDING MAT REPLACEMENT PANELS AND KEYLOCK ASSEMBLIES

by

W. B. Fenwick

January 1966

Sponsored by

Naval Air Engineering Center
Philadelphia, Pennsylvania

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

The investigation reported herein was authorized by the Naval Air Engineering Center, Philadelphia, Pa., in Project Order No. 4-0029, dated 31 January 1964. Responsibility for prosecution of the investigation was assigned to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The tests were conducted by WES from 4 February through 6 March 1964.

Engineers of the WES Soils Division actively engaged in the planning, testing, analysis, and report phases of the investigation were Messrs. W. J. Turnbull, A. A. Maxwell, C. D. Burns, W. L. McInnis, W. B. Fenwick, and M. J. Mathews. This report was prepared by Mr. Fenwick.

Directors of the WES during the conduct of this investigation and preparation of this report were Col. Alex G. Sutton, Jr., CE, and Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

SUMMARY

This study was conducted to evaluate replacement panels and keylock assemblies as accessories for use with AM2 landing mat in the construction of forward airfields. It was also desired to evaluate the capability of the AM2 mat to withstand traffic when laid in a longitudinal direction.

A test section with a 10-CBR subgrade and the AM2 mat laid in both longitudinal and transverse directions, with the accessories included, was constructed and subjected to accelerated traffic of a 27,000-lb single-wheel load with a 30.00-7.7 tire inflated to 400 psi.

It is concluded that:

a. The overall performance of the replacement panels is satisfactory.

b. The keylock assemblies function satisfactorily.

c. The AM2 mat functions equally well when laid either longitudinally or transversely.

EVALUATION OF AM2 LANDING MAT REPLACEMENT PANELS AND KEYLOCK ASSEMBLIES

PART I: INTRODUCTION

Background

1. For several years the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., has been engaged in a comprehensive test program* for the Naval Air Engineering Center (NAEC), Philadelphia, Pa., in connection with the construction and support of short airfields for tactical support in amphibious operations. These airfields, designated SATS, are defined as short, quickly constructed, tactical support airfields of temporary nature capable of handling modern jet aircraft of the Marine Corps employing assisted takeoffs and arrested landings. Requirements of the minimum operational installation are that it must be ready for use in the objective area within the first three to five days of an amphibious assault, and the runway must be capable of withstanding heavy wheel loads and arresting-hook impacts of the using aircraft and heat blasts from tailpipes of jet engines during takeoffs and must remain serviceable with minimum maintenance effort for 1600 aircraft cycles (round trips) during a 30-day period. At the time of this study, the weight of the heaviest proposed Marine aircraft that would utilize SATS was 60,000 lb (27,000 lb per main wheel) with a 30.00-7.7, 18-ply tire inflated to 400 psi. For landing rollouts and taxi operations of this aircraft, the actual vertical load on the mat surface is assumed to equal the static wheel load, or not exceed 27,000 lb per main-gear wheel. Present plans for assisted takeoffs require use of a catapult system that will be installed on the mat surface. For this type of operation, the planes will take off from a fixed position on the mat; consequently, for a given type of aircraft, the landing-gear wheels will run in the same track on each takeoff.

2. Replacement panels and keylock assemblies have been developed as

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* A list of reports of studies under this program is given on the inside of the front cover of this report.

accessories to AM2 landing mat, which is a SATS surfacing material. The replacement panels will be used to replace failed panels and are designed so that adjacent panels will not be disturbed in the replacement operation. The keylock assemblies will be located every 100 ft down the runway. They can be easily removed and the mat can be taken up in either direction. This will prevent excessive amounts of undamaged mat having to be taken up to replace a failed or damaged area of mat.

Objectives and Scope of Investigation

3. The primary objective of this study was to evaluate the AM2 replacement panels and keylock assemblies. It was also desired to determine the effectiveness of AM2 mat laid parallel to the direction of traffic. The objectives were accomplished by:

a. Constructing a test section of a heavy clay subgrade surfaced with AM2 mat laid in the longitudinal and transverse directions, including the accessories in the mat surfacing.

b. Performing accelerated traffic tests with a 27,000-lb single-wheel load and 400-psi tire inflation pressure.

c. Measuring CBR, density, and water content of the subgrade material prior to and at various intervals during traffic.

d. Observing the behavior of the AM2 mat, replacement panels, and keylock assemblies during traffic.

4. This report describes the replacement panels, keylock assemblies, test section, tests, and results obtained.

PART II: MAT ACCESSORIES, TEST SECTION, AND TEST LOAD CART

Mat Accessories

Replacement panels

5. The replacement panels, fabricated by Harvey Aluminum Company, Torrance, Calif., are 10 ft long, 2 ft wide, about 1-1/2 in. thick, and average about 145 lb in weight. Figs. 1 and 2 show a replacement panel

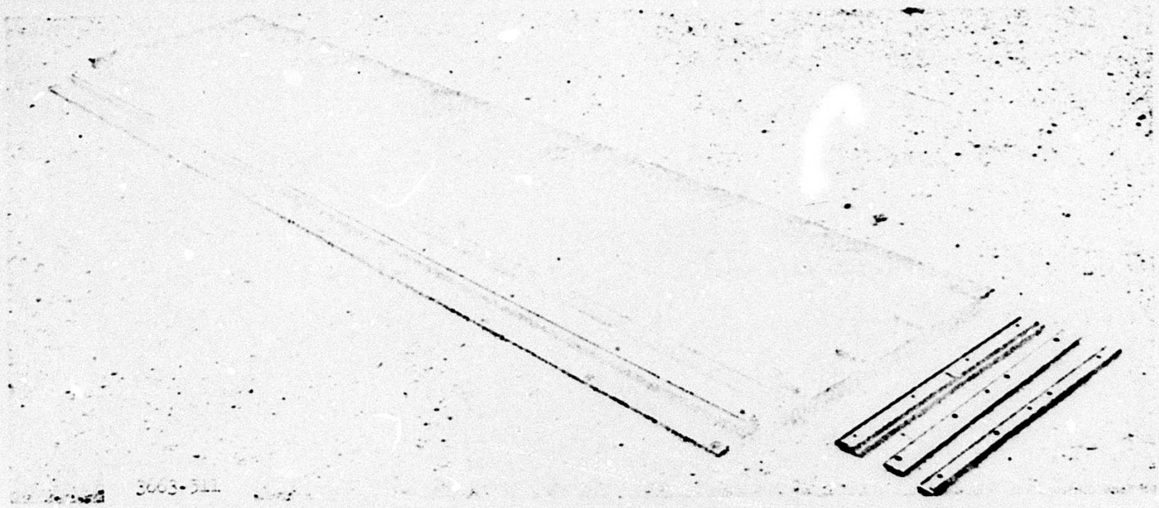


Fig. 1. Unassembled AM2 landing mat replacement panel

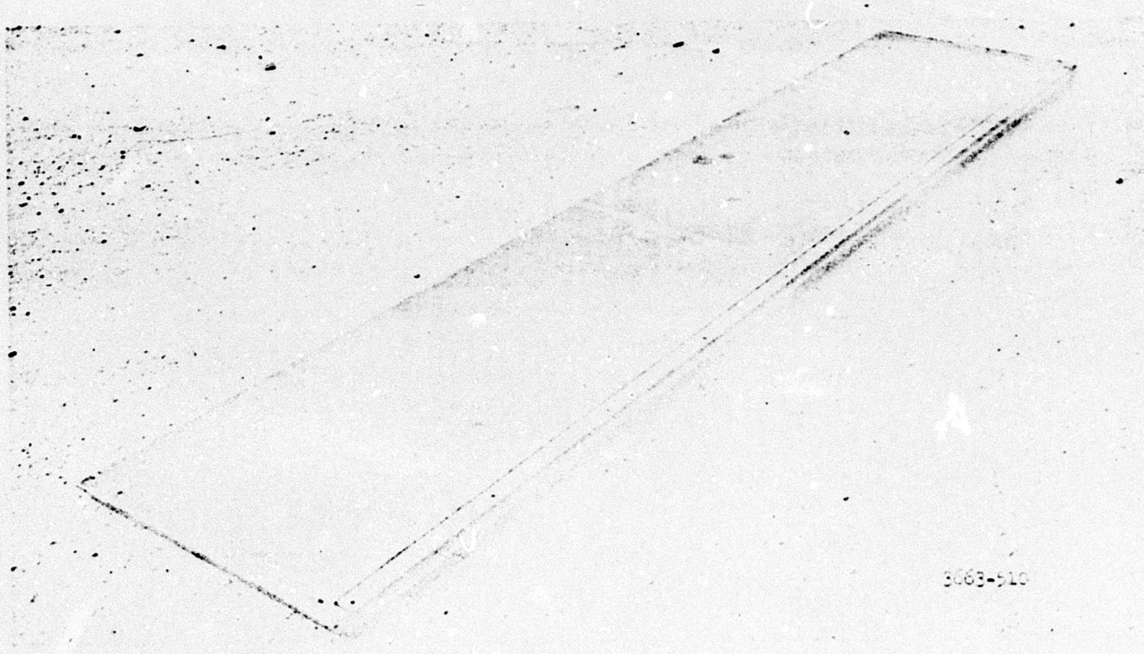


Fig. 2. Assembled AM2 landing mat replacement panel

with the side and end connectors disassembled and assembled, respectively. The side connector consists of two pieces which are held in place on the panel by ten 3/8-in. Allen screws and the end connector consists of three pieces which are held together and in place on the panel by four Allen screws. The four screws for the end connector are recessed in vertical-walled counterbores and the 10 screws for the side connector are countersunk.

Keylock assemblies

6. The keylock assemblies were also fabricated by Harvey. They are 12 ft long, 4 in. wide, and weigh about 22 lb. The standard keylock assemblies (fig. 3a) have the same side connectors as the AM2 mat. Also tested were modified keylock assemblies (fig. 3b) which had male connectors on both sides, enabling the mat to be placed on both sides. The modified keylocks were about the same size as the standard keylocks and weighed 28 lb each. All of the keylocks were 12 ft long originally, but some were sawed into other lengths to accommodate the unusual mat size combinations. An Allen screw located at the end of the keylocks was used to lock them together.

Test Section

Location

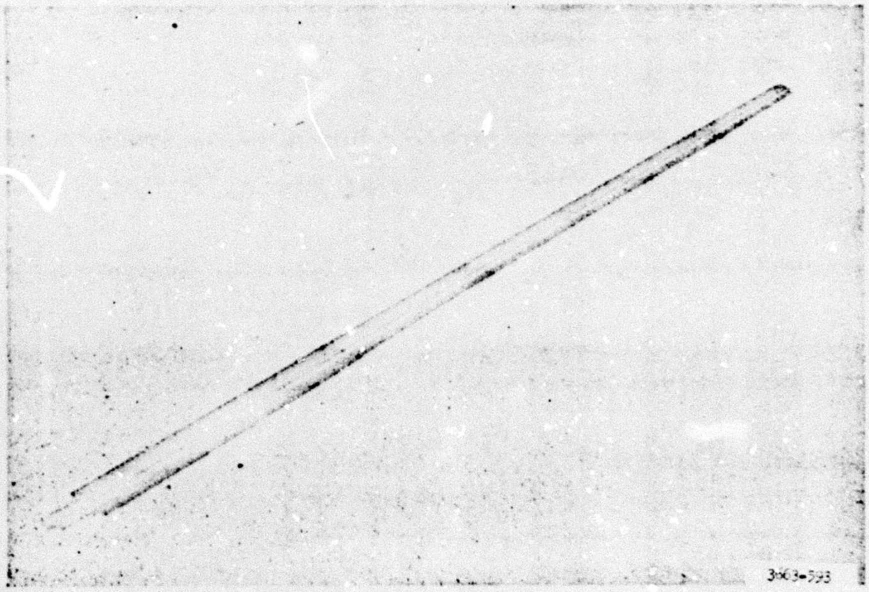
7. All tests were conducted at the WES on a special test section which was constructed and tested under shelter in order to control the subgrade water content and strength.

Description

8. The test section (plate 1) consisted of two test items, each approximately 24 ft wide. Item 1 was about 24 ft long and item 2 was about 48 ft long. Classification data for the subgrade, a heavy clay soil, are shown in plate 2. The locations of the replacement panels and keylock assemblies are shown in plate 1.

9. It was desired to construct items 1 and 2 with the heavy clay at a water content that would result in a CBR of about 10. These items were to be constructed to a total thickness of 24 in.; therefore, the existing material at the test site was excavated to a depth of 24 in. below finished grade. The soil for these items was processed to the desired water content, hauled to the test-section site, spread, and compacted in

a. Standard



b. Modified

Fig. 3. Keylock assembly

6-in. lifts. Compaction of each lift was accomplished by applying eight coverages of a four-wheel rubber-tired roller loaded to 70,000 lb with tires inflated to 90 psi. The surface of each compacted lift was scarified prior to placement of the next lift. After the fourth (final) lift was placed and compacted, the surface of the subgrade was fine-bladed to grade with a motor patrol.

Mat placement

10. The entire test section was laid with used but undamaged standard 2- by 12-ft AM2 mat, except for 2- by 10-ft panels in the runs where replacement panels were to be used. After the mat was laid, two mat panels were cut from each test item and the special replacement panels were installed, as described subsequently in paragraphs 11 and 12. All mat in item 1 was laid parallel to the direction of traffic in accordance with instructions from the Naval Air Engineering Laboratory (NAEL). The mat in item 2 was laid in the standard manner. Three runs of standard keylocks and one run of modified keylocks were placed in item 2 by the procedure described subsequently in paragraph 13. No runs of keylocks were placed in item 1 since the mat was laid longitudinally. A general view of the completed test section prior to trafficking is shown in photograph 1.

Mat replacement

11. As noted earlier, the replacement panel is to be used where it is desired to replace a damaged panel without disturbing the surrounding panels. Removal of a panel was accomplished by sawing the panel and removing it in sections. An 8-1/4-in., 13-amp, 115-volt power saw (fig. 4) was used for the sawing operations. The first cut was made along the underlapping end joint with the saw blade at a 30-deg angle from vertical to enable the blade to reach the end-connecting bar cavity. Fig. 4 shows the saw in position for this cut. Next, vertical cuts were made diagonally from the corners, followed by a longitudinal cut down the center of the panel (fig. 5). Sawing across the diagonal cuts permitted removal of the triangular plugs (fig. 6). Following this, the panel ends and sides were removed (figs. 7 and 8, respectively). Several types of saw blades were tried, and a model No. 9598 Skil blade having 20 carbide tips proved to be the most effective. Subsequent tests with the saw indicated that a shock-resistant, carbide-tipped blade manufactured by Rite-Kut Saw, Los Angeles, Calif. (model No. 9008S-RK No. 1), was superior to other blades used in the tests.

12. Following the removal of the panel, the replacement panel was installed. The separate pieces (described in paragraph 5) which make up one side and end connector for the replacement panel were carefully aligned with the proper side and end of the panels adjacent to the removed panel.

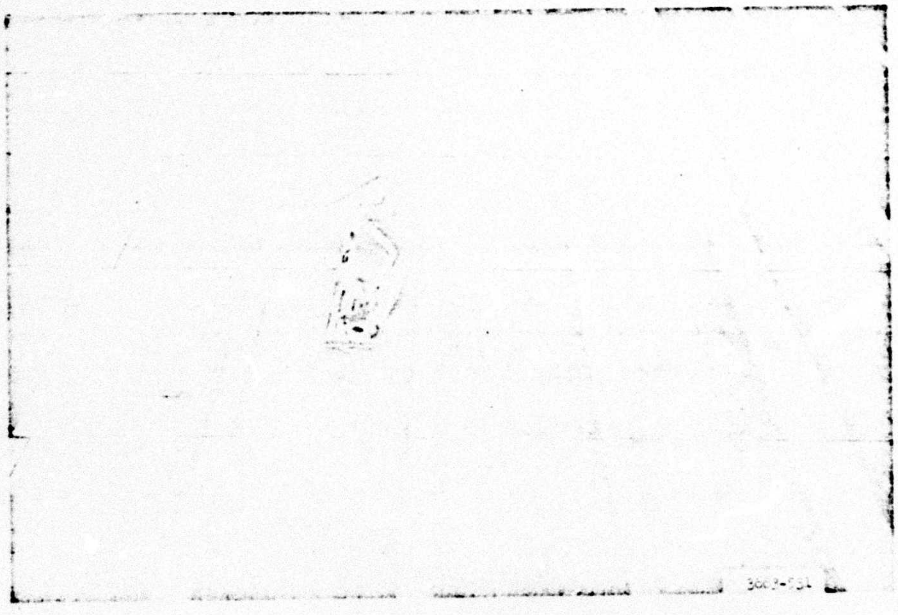


Fig. 4. Setup for sawing end joint of damaged AM2 panel

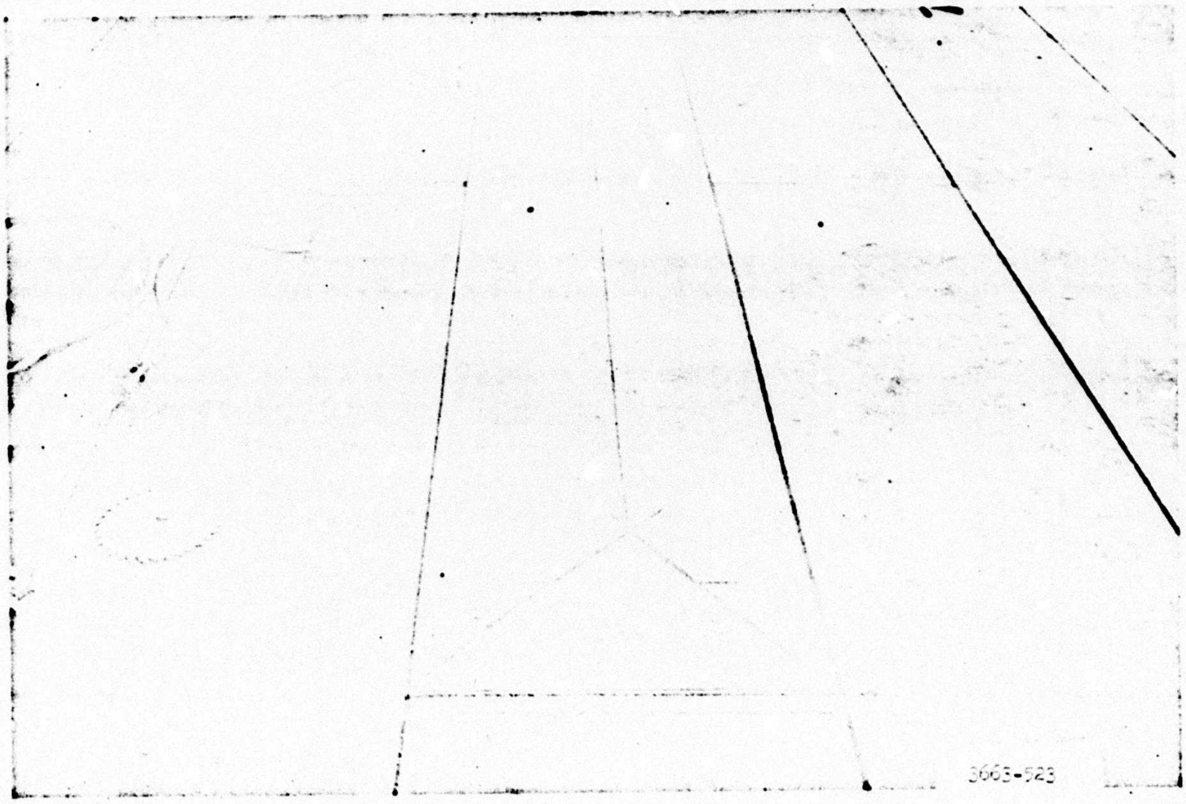


Fig. 5. View of saw cuts necessary for removal of damaged panel

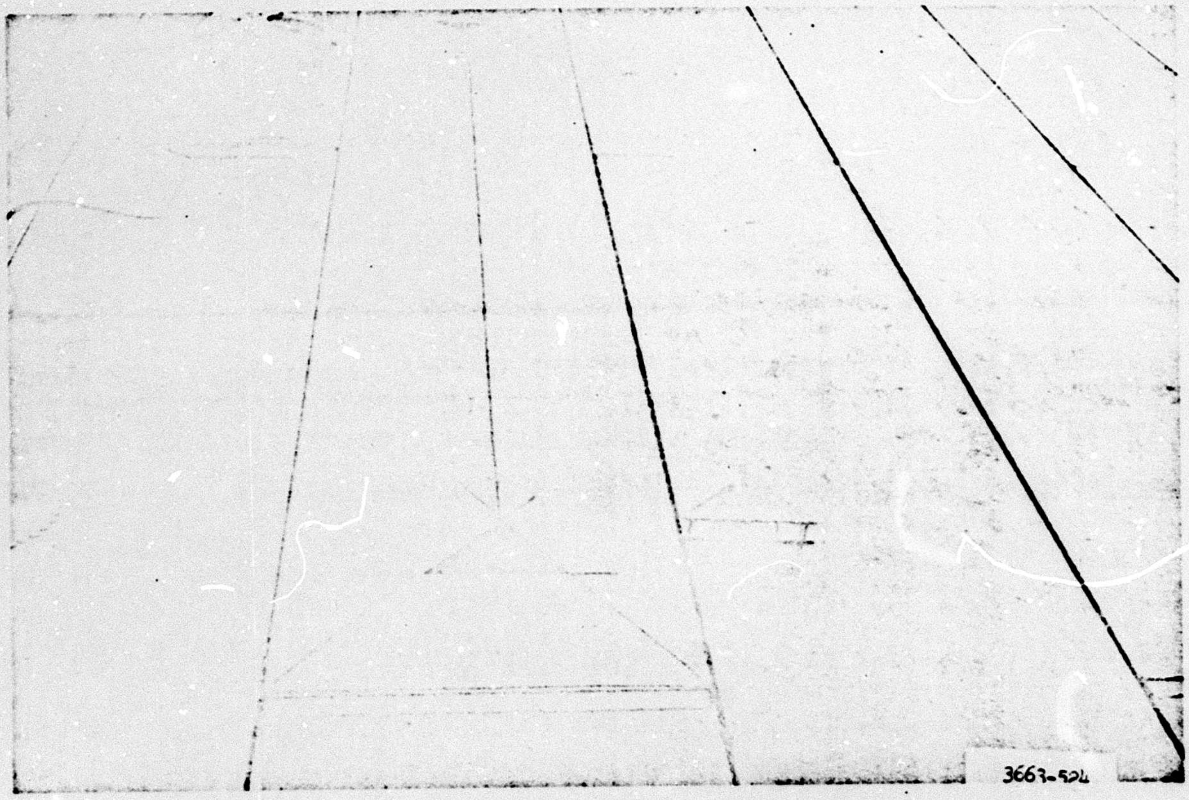


Fig. 6. Small triangles removed from damaged panel.

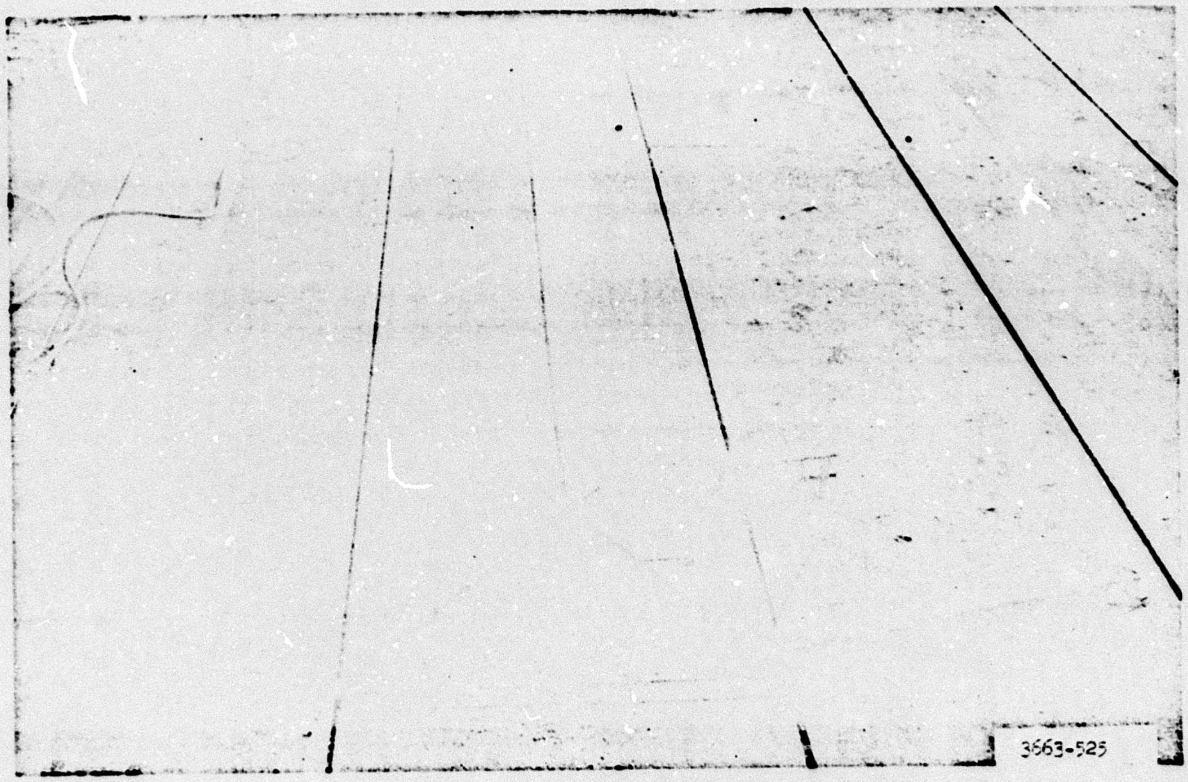


Fig. 7. Ends removed from damaged panel

Fig. 8. Entire damaged panel removed

The replacement panel was then laid in place and the screws were tightened to lock the panel in place. Approximately 35 min was required to remove and replace a panel, with the majority of this time being consumed by the sawing operation. Photograph 2 shows a replacement panel with installation complete.

Keylock placement

13. As stated in paragraph 2, the keylock assemblies will be placed at intervals down a runway so that damaged areas of mat can be easily removed. The keylocks are laid exactly like AM2 panels. When the modified keylocks are used, the mat can be laid in opposite directions. These would ordinarily be used at the midpoint of a runway so that more laying crews could be utilized, and the standard keylocks would be spaced at desired intervals along the runway. Photographs 3 and 4 show a standard and a modified keylock, respectively, after installation.

Test Load Cart

14. A specially designed single-wheel-load test cart (fig. 9) loaded to 27,000 lb was used in the traffic tests. It was fitted with an outrigger wheel (not visible in fig. 9) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load-cart wheel was equipped with a 30.00-7.7, 18-ply tire inflated to 400 psi. The tire contact area was about 82 sq in., and the average contact pressure was 330 psi.

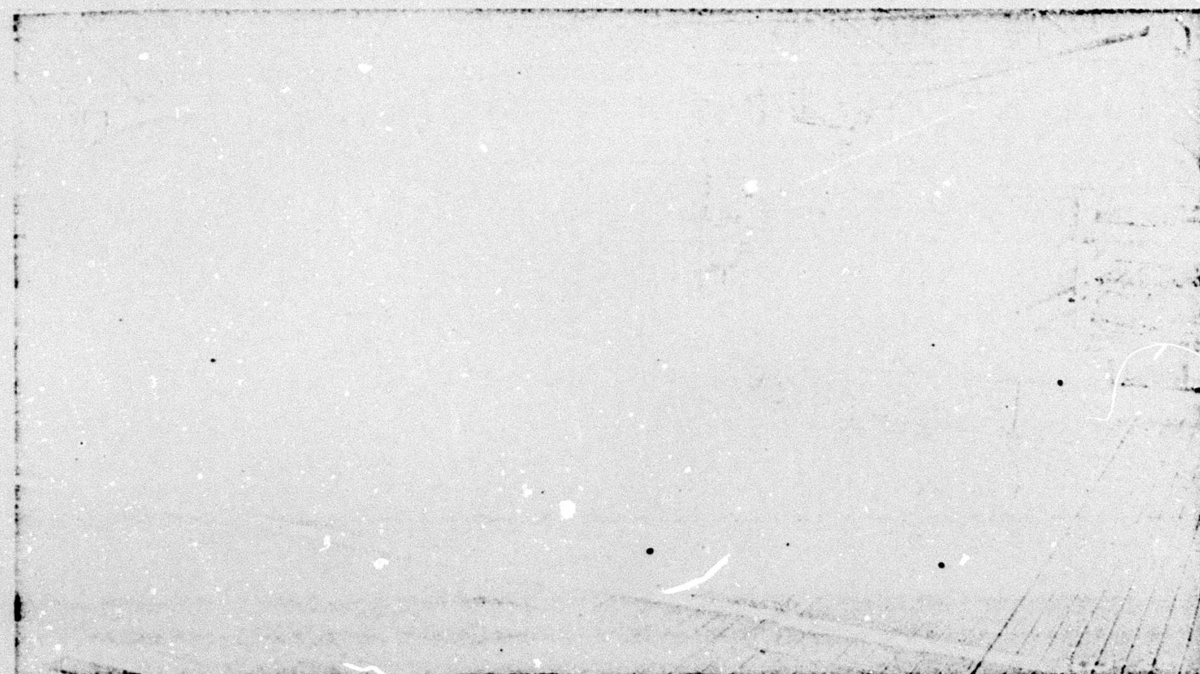


Fig. 9. Test cart with 27,000-lb single-wheel load and tire inflated to 400 psi

PART III: TESTS AND RESULTS

Traffic Tests

Uniform-coverage traffic

15. To simulate normal landing, takeoff, and taxi operations on a runway, uniform-coverage traffic was applied over a 10-ft-wide traffic lane down the center of the test section (plate 1). Traffic was applied by driving the load cart first forward and then backward the length of the test section. The path of the cart was shifted laterally about 7.3 in. (one tire-print width) on each successive forward pass. This procedure resulted in two complete coverages each time the load cart was maneuvered from one side of the traffic lane to the other. Traffic was continued to 188 coverages, which has been established as being equivalent to 1600 cycles of operations of an aircraft having a 27,000-lb single-wheel load and 400-psi tire inflation pressure (see WES MP 4-615*).

Single-track traffic

16. As explained in paragraph 1, if a catapult system is used for launching an aircraft on the mat-surfaced runway, the main-gear wheels of a given type of aircraft will run in the same path during each takeoff. For 1600 cycles of aircraft operations, 1600 launchings would be required. Therefore, to simulate these operations, the load cart was driven forward and backward in the same track for 1600 passes. The center line of the traffic path was located 2 ft outside the uniform-coverage traffic lane and 5 ft from the outside edge of the section, as shown in plate 1.

Soils Tests and Miscellaneous Observations

17. Water content, density, and in-place CBR were determined at depths of 0, 6, 12, and 18 in. in each test item before and after

* U. S. Army Engineer Waterways Experiment Station, CE, Development of CBR Design Curves for Harvey Aluminum Landing Mat, by C. D. Burns and W. B. Fenwick. Miscellaneous Paper No. 4-615, Vicksburg, Miss., January 1964.

uniform-coverage and single-track traffic. These data are summarized in table 1. At least three tests were made at each depth, and the values listed in table 1 are the averages of the values measured at each depth.

18. Visual observations of the behavior of the test items and other pertinent factors were recorded throughout the traffic testing period. These observations were supplemented by photographs. Level readings were taken prior to and at intervals during traffic to show the development of roughness, permanent mat deformation, and mat deflection under the wheel load.

Behavior of Replacement Panels, Keylock Assemblies, and AM2 Mat Under Traffic

Replacement panels

19. Item 1. In item 1, with mat laid parallel to the direction of traffic, one replacement panel was placed near the center of the uniform-coverage traffic lane and one was placed at the center of the single-track traffic path (plate 1); therefore, neither panel received both the uniform-coverage and the single-track traffic.

20. The full 188 coverages of uniform-coverage traffic were applied to the traffic lane, and no breakage was noted in the replacement panel. The 3/8-in. Allen screws at the end and side connectors were tightened one-fourth to one-half turn after 12 coverages and again after 50 coverages. At the conclusion of the uniform-coverage traffic, it was noted that the four end-connector screws could no longer be tightened, and close examination of the holes showed that the bottom of the counterbore had sheared off and the screw was loose in the hole. Photograph 5 is a close-up of the end connector on a replacement panel. The small shoulder (or bottom of the counterbore) which sheared during traffic is visible in the bottom of the holes through the end of the replacement panel. It is not known exactly when this occurred, but it did not appear to affect the performance of the replacement panel.

21. Photograph 6 shows the replacement panel in the single-track traffic path prior to trafficking. After 1600 passes of the load cart, the only apparent damage to the replacement panel was the shearing of the

counterbore on the two center screws of the end connector. These shears occurred during the last 100 passes, because the screws were observed to be tight after 1500 passes. The overall performance of the replacement panel was satisfactory.

22. Item 2. The mat in this item was laid in the standard manner, and one of the replacement panels was laid across the entire 10-ft traffic lane and the other was laid at the edge of the test section so that 3 ft of it received uniform-coverage traffic. All of the side- and end-connector screws that were exposed to traffic were tightened one-fourth to one-half turn after 50 coverages. At 150 coverages, four of the end-connector screws were loose, due to the bottom of the counterbore holes being sheared. No additional mat damage occurred to 188 coverages.

23. The single-track traffic was applied down the transverse center line of one replacement panel. Photograph 7 shows this panel prior to trafficking. The four cap screws (left end of the replacement panel in photograph 7) were used to replace the screws sheared out by the uniform-coverage traffic. The cap screws were 5 ft from the traffic path and were considered to have no effect on the test results. The replacement panel sustained 1600 passes of the single-wheel load with no damage.

Keylock assemblies

24. Both the standard and the modified keylocks withstood the uniform-coverage and single-track traffic with no damage. They functioned satisfactorily and were easily removed at the conclusion of traffic. The keylocks were found to be very useful for the expedient removal of damaged panels.

AM2 mat

25. Uniform-coverage traffic. Both the longitudinally and transversely laid mat performed satisfactorily under the uniform-coverage traffic. At an early stage during traffic, numerous small hairline cracks developed in both items in the overlapping and underlapping end connectors. A total of 29 such cracks were noted in the test section after 100 coverages of traffic but none exceeded 1 in. in length. By 188 coverages, seven of these cracks had extended entirely across the end connector. Although these end connectors were sheared completely off, no differential

deformation or tendency to part was apparent. Panels in this condition which were adjacent to keylocks or replacement panels were replaced to prevent the possibility of interference with proper evaluation.

26. The performance of longitudinally laid mat versus transversely laid mat was about equal. The differences in mat breakage in item 1 and item 2 were insignificant. Between 100 and 188 coverages of traffic, it was noted that the riding surface in item 1 appeared to be slightly smoother than in item 2, but both items provided very even riding surfaces.

27. Single-track traffic. The entire 1600 passes of the load wheel produced no mat breakage or any other deficiency under the single-track traffic. No significant difference was apparent in the surface smoothness of item 1 or item 2, although there was slightly less bounce of the load cart in item 1.

28. Permanent deformation. Level readings taken to show permanent deformation of the mat during traffic are shown in plates 3 and 4. The data in plate 3 show average cross sections after the uniform-coverage traffic for the AM2 mat (laid longitudinally and transversely) and for the keylock assemblies in item 2. These data indicate that a relatively uniform deformation of about 1/4 in. occurred over the entire test section under the uniform-coverage traffic. Plate 4 shows a profile of the single-track traffic path after 1600 passes of the load wheel. These data show that the maximum permanent deformation was about the same in item 1 and item 2. However, more variation in the surface elevation developed in item 2 than in item 1.

29. Mat deflection. Level readings taken to show the mat deflection in item 1 are shown in plate 5. These data indicate the elastic deflection, or rebound, of the mat as the load wheel moved over the surface. Plate 6 shows data from item 2 on the AM2 mat and for standard and modified keylocks in item 2 at an end joint and at a center point of a panel. These data show that deflections of about 1/4 to 3/4 in. occurred throughout the test period.

Summary of Test Results

Replacement panels

30. The overall performance of the replacement panels was satisfactory except for the shearing of the four end-connector screw-bearing shoulders during uniform-coverage traffic. The first evidence of the sheared shoulders was noted when the screws could no longer be tightened. This minor mat damage did not appear to affect the load-carrying capabilities of the mat.

Keylock assemblies

31. Both the standard and the modified keylocks functioned satisfactorily. They were easily placed and easily removed.

AM2 mat

32. There appeared to be no significant advantages in placing the mat either longitudinally or transversely. Mat performance under traffic was similar regardless of direction of laying.

PART IV: CONCLUSIONS

33. The following conclusions are based on the data presented in this report:

- a. Replacement panels perform satisfactorily except for the shearing of the end-connector screw-bearing shoulders. The shearing can probably be avoided by increasing the thickness of the shoulder with a resultant decrease in the height of the screwhead.
- b. The sawing operation in removing a damaged panel requires considerable time. Since about 20 lin ft of cutting is required to remove a panel, a special saw blade should be developed or a heavier-duty saw used to facilitate this operation.
- c. Both the standard and modified keylocks function satisfactorily. Their use will result in a considerable saving in time and effort in replacing damaged runway mat.
- d. The performance of the AM2 mat is similar whether the mat is laid transversely or longitudinally.

Table 1

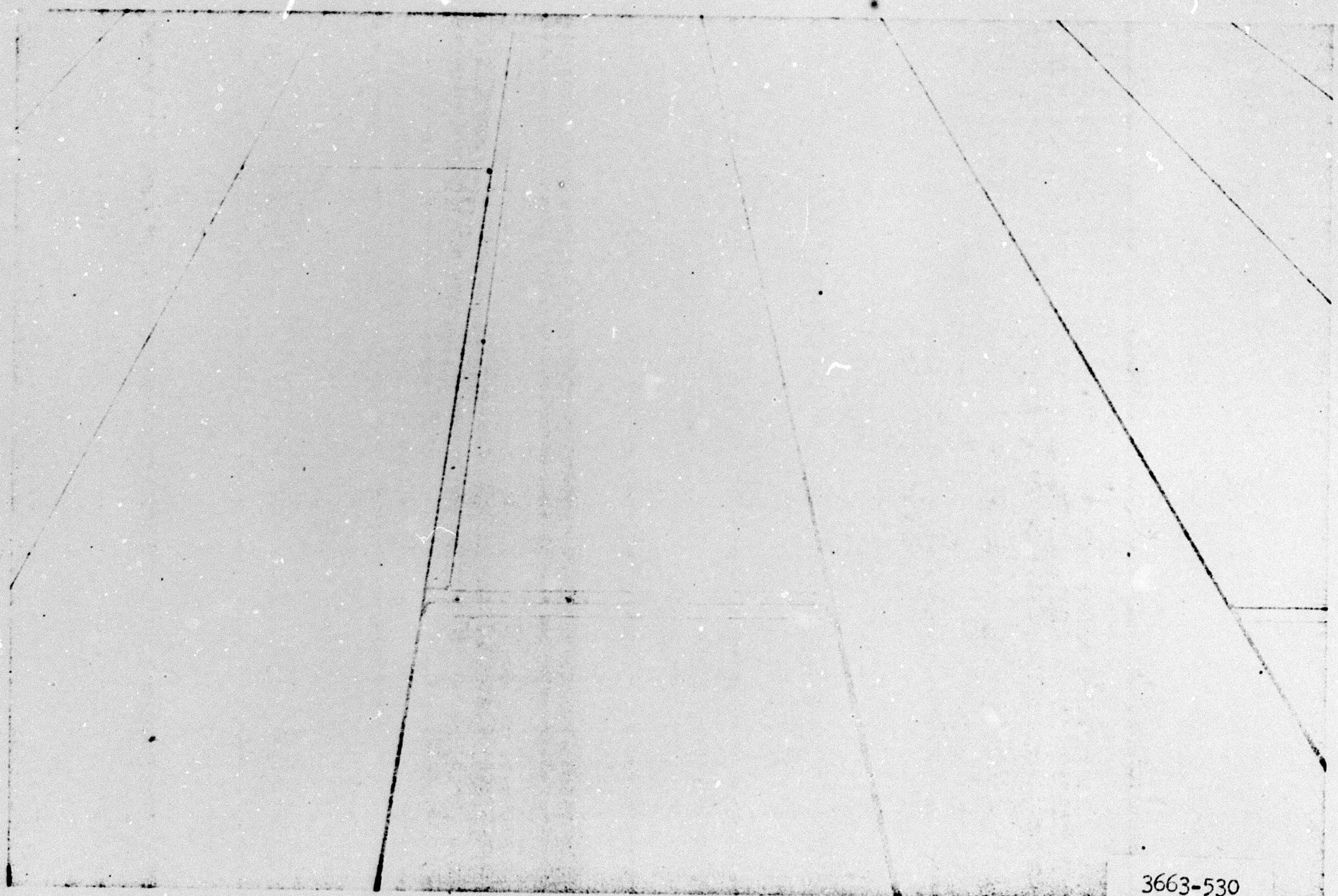
Summary of CBR, Water Content, and Density Data

Test Item	Subgrade material	0 Coverages Depth in.	CBR	Water Content %	Dry Density lb/cu ft	188 Coverages Depth in.	CBR	Water Content %	Dry Density lb/cu ft
				Uniform-Coverage Traffic					
1	Clay	0	8	22.3	100.0	0	14	21.5	104.6
		6	15	20.1	102.5	6	19	20.2	104.0
		12	16	18.6	102.9	12	13	18.8	101.9
						18	7	22.0	97.9
2	Clay	0	12	18.8	102.5	0	11	22.3	--
		6	8	24.3	99.1	6	11	21.3	103.9
		12	8	23.8	97.9	12	10	19.5	101.6
						18	5	24.7	96.4

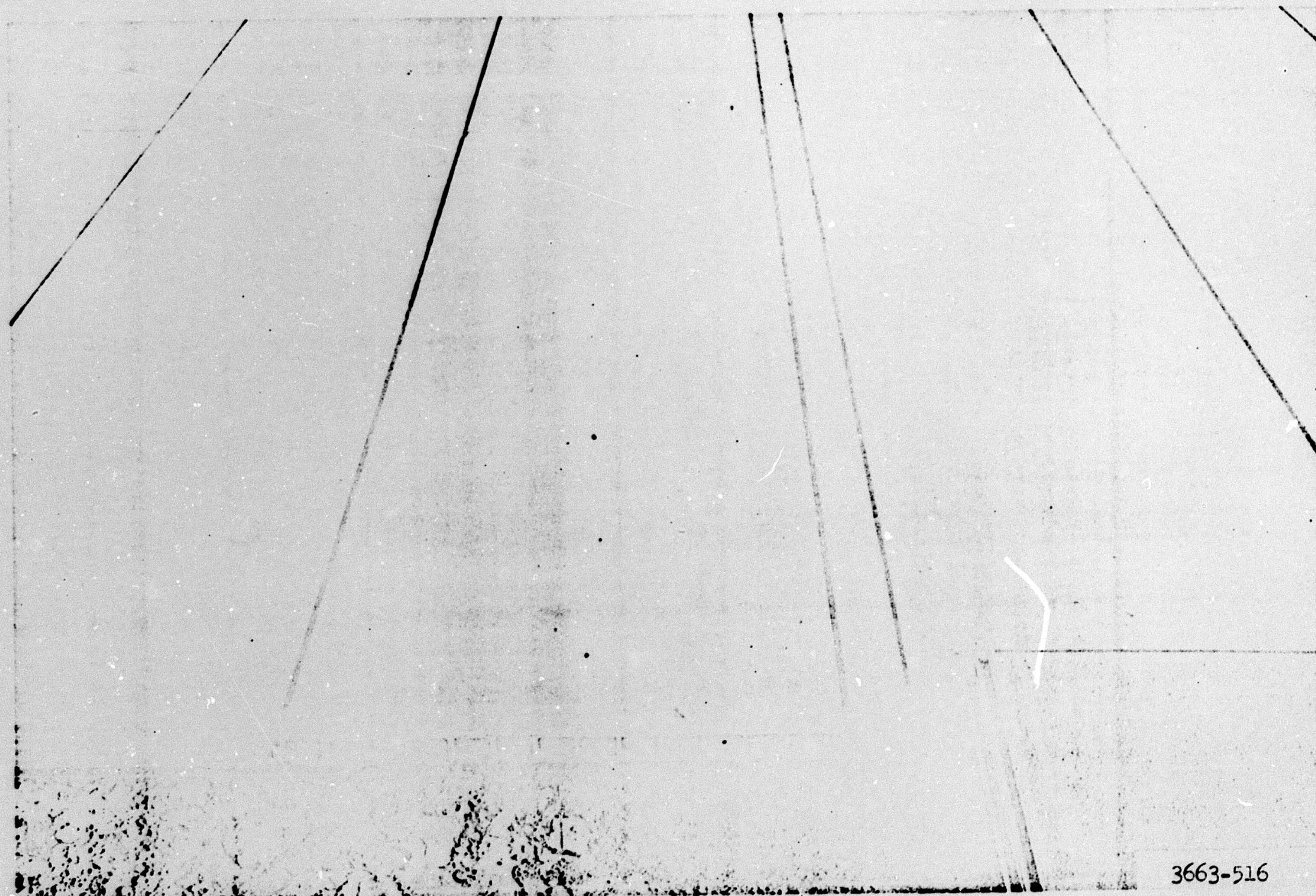
Test Item	Subgrade material	0 Passes Depth in.	CBR	Water Content %	Dry Density lb/cu ft	1600 Passes Depth in.	CBR	Water Content %	Dry Density lb/cu ft
				Single-Track Traffic					
1	Clay	0	17	21.4	101.4	0	9	22.8	103.7
		6	18	21.2	102.8	6	16	20.6	103.5
		12	14	18.9	99.4	12	14	18.0	99.1
		18	10	20.5	96.8	18	5	24.4	97.6
2	Clay	0	12	21.5	103.1	0	18	20.0	102.1
		6	16	20.1	104.2	6	14	18.9	99.2
		12	6	23.2	98.6	12	16	25.0	93.5
		18	5	26.0	95.6	18	7	24.4	95.6

Note: Traffic was applied using 27,000-lb single-wheel load and 400-psi tire pressure.

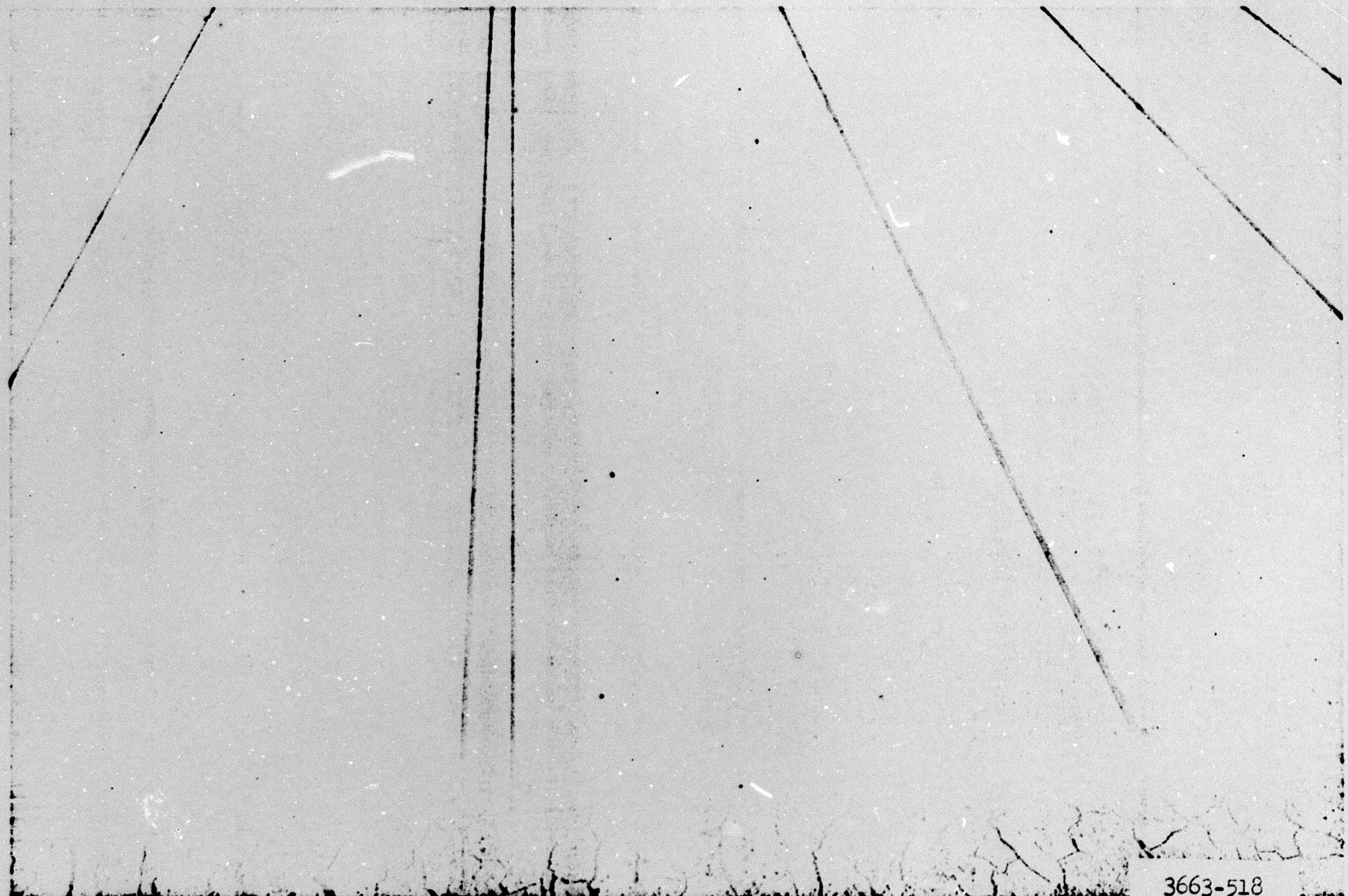
Photograph 1. Completed test section prior to traffic



Photograph 2. Replacement panel installed

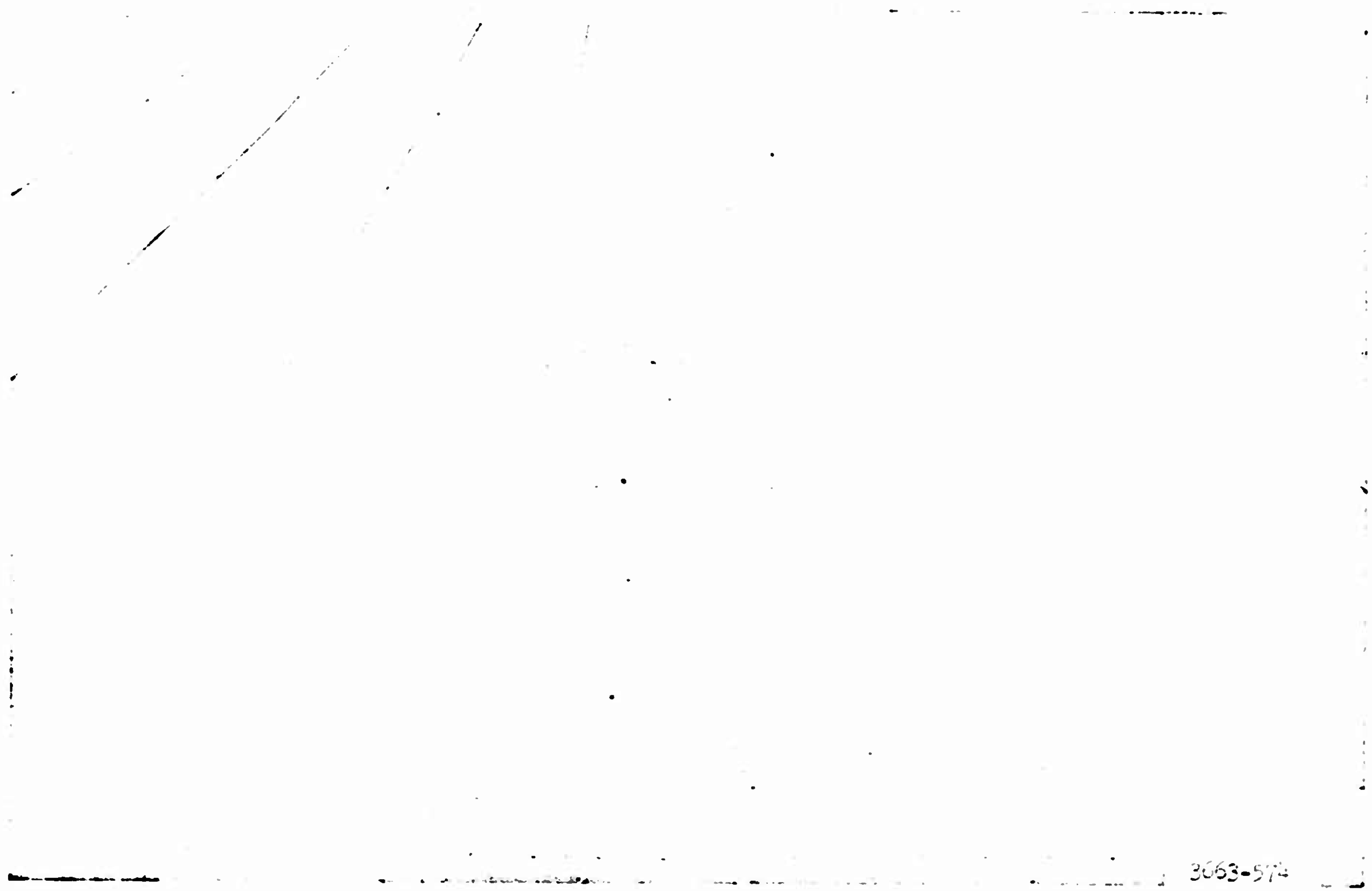


Photograph 3. Standard keylock installed



Photograph 4. Modified keylock installed

Photograph 5. Replacement panel end connector



Photograph 6. Replacement panel in single-track traffic path prior to trafficking

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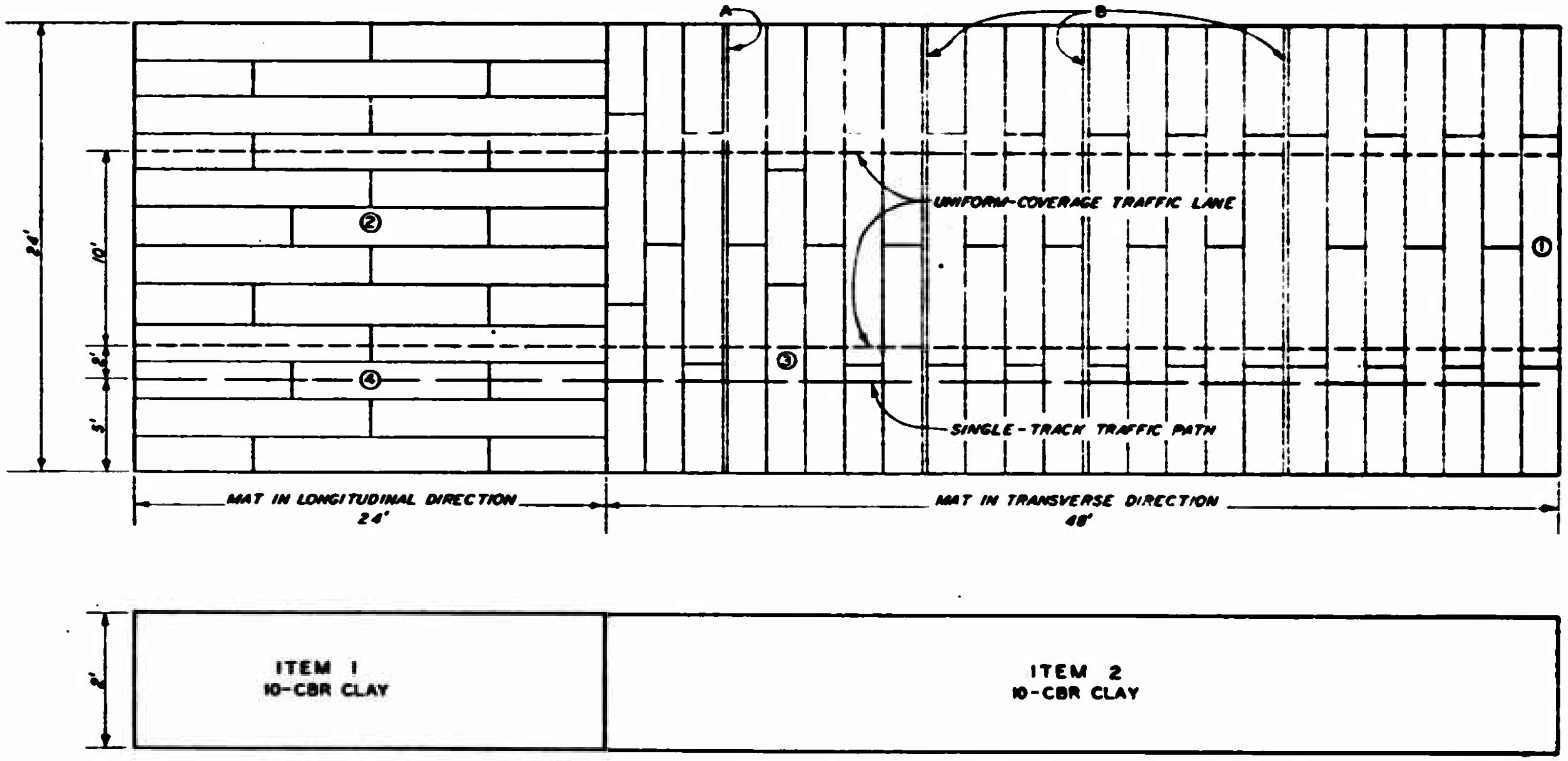
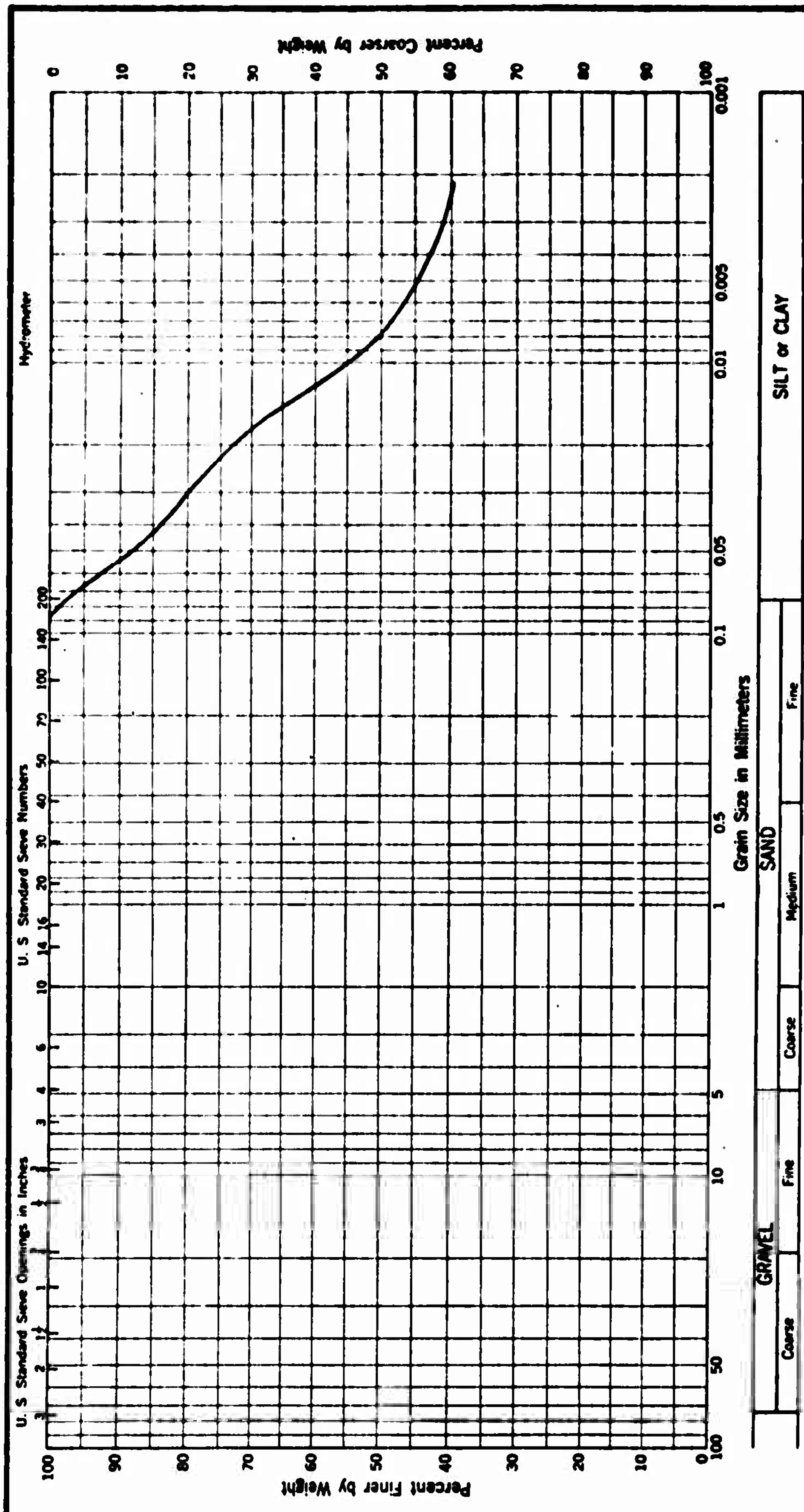
Photograph 6. Replacement panel in single-track traffic path prior to trafficking



LEGEND
A MODIFIED KEYLOCK
B STANDARD KEYLOCK
①-④ REPLACEMENT PANELS

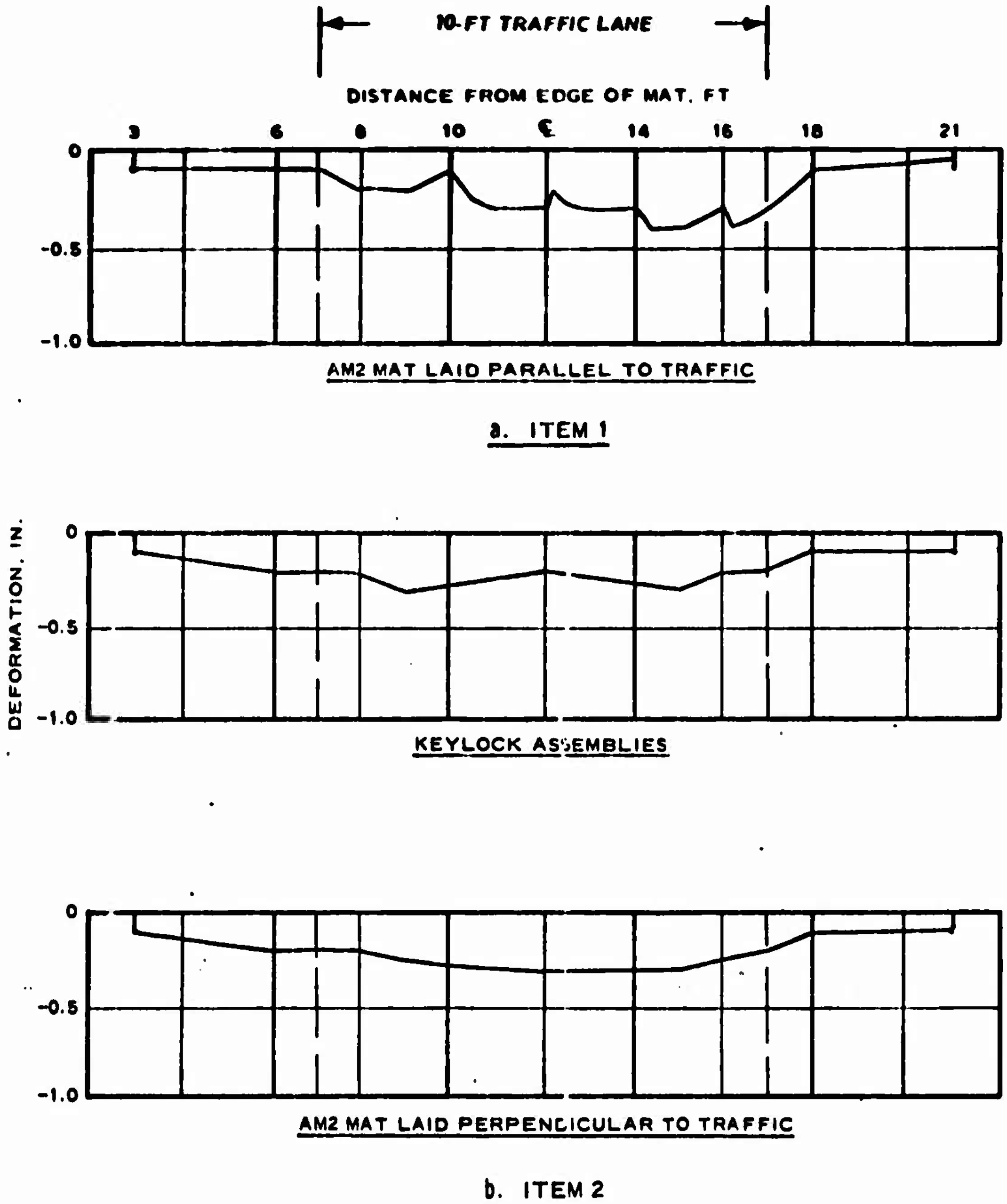
TEST SECTION LAYOUT



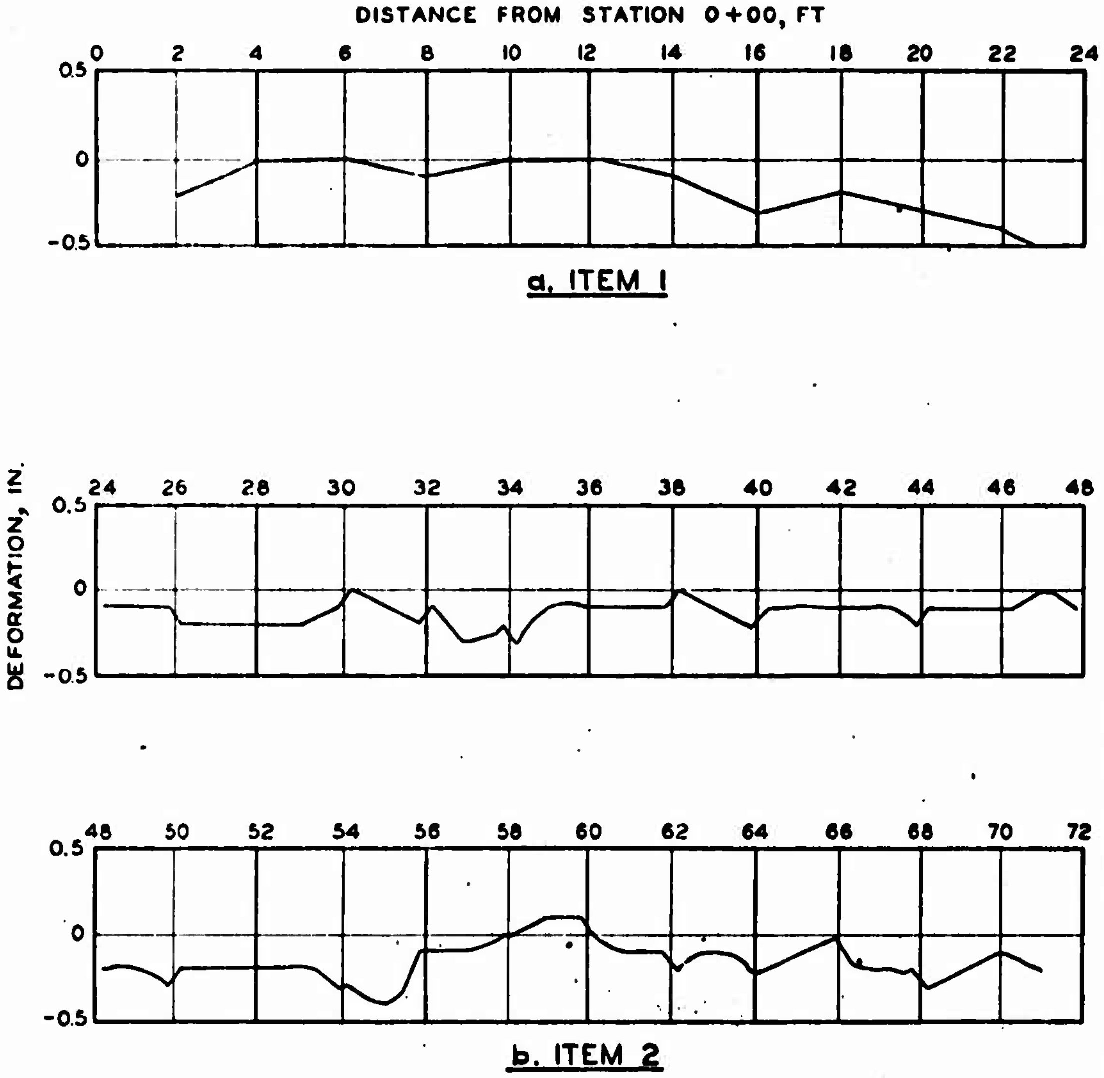
CLASSIFICATION DATA

Number	Depth	Natural Moisture	L L	P L	P I	Classification
			58	27	31	HEAVY CLAY (BUCKSHOT), CH

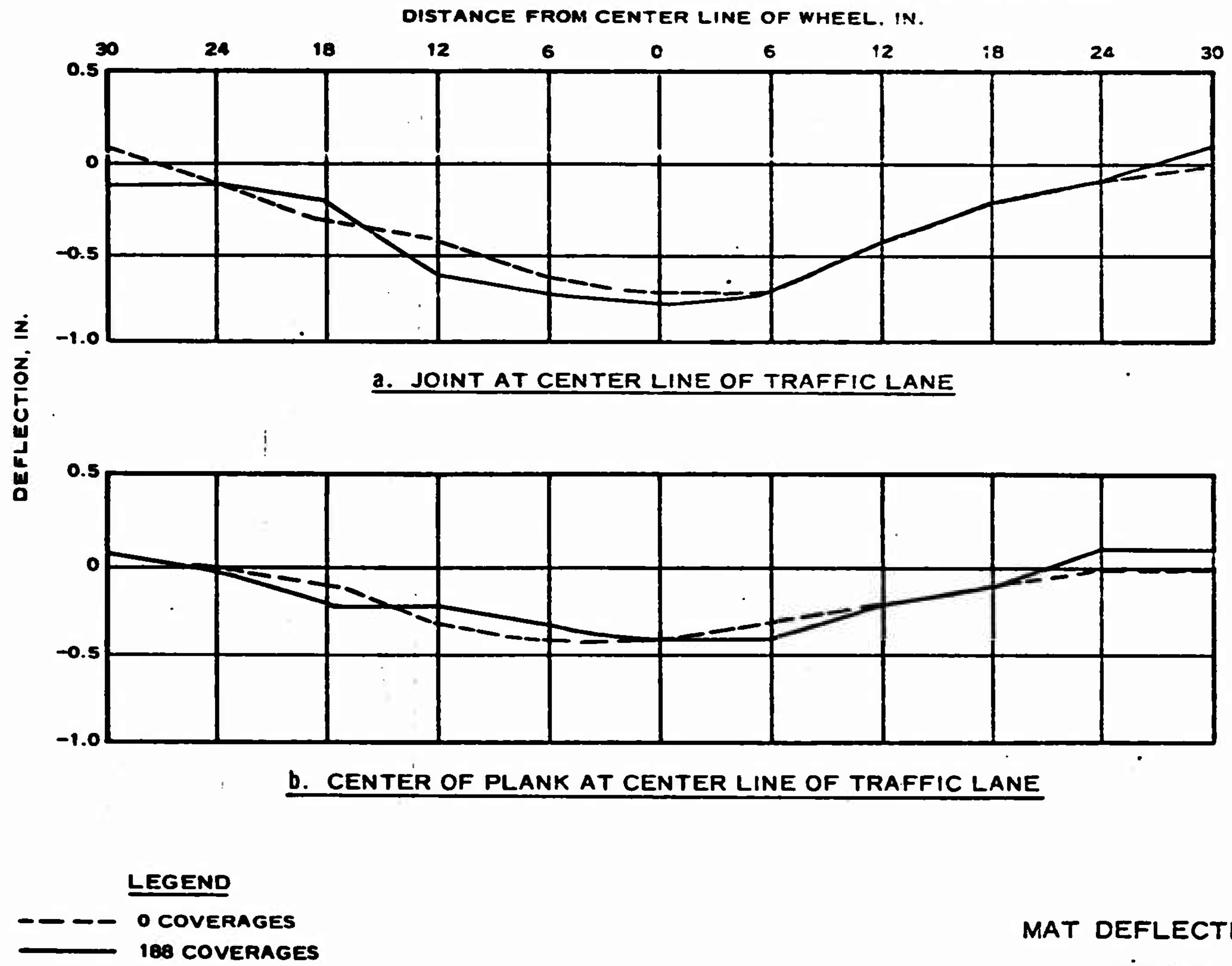
PLATE 2



PERMANENT MAT DEFORMATION
27,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE INFLATION PRESSURE
UNIFORM-COVERAGE TRAFFIC
188 COVERAGES



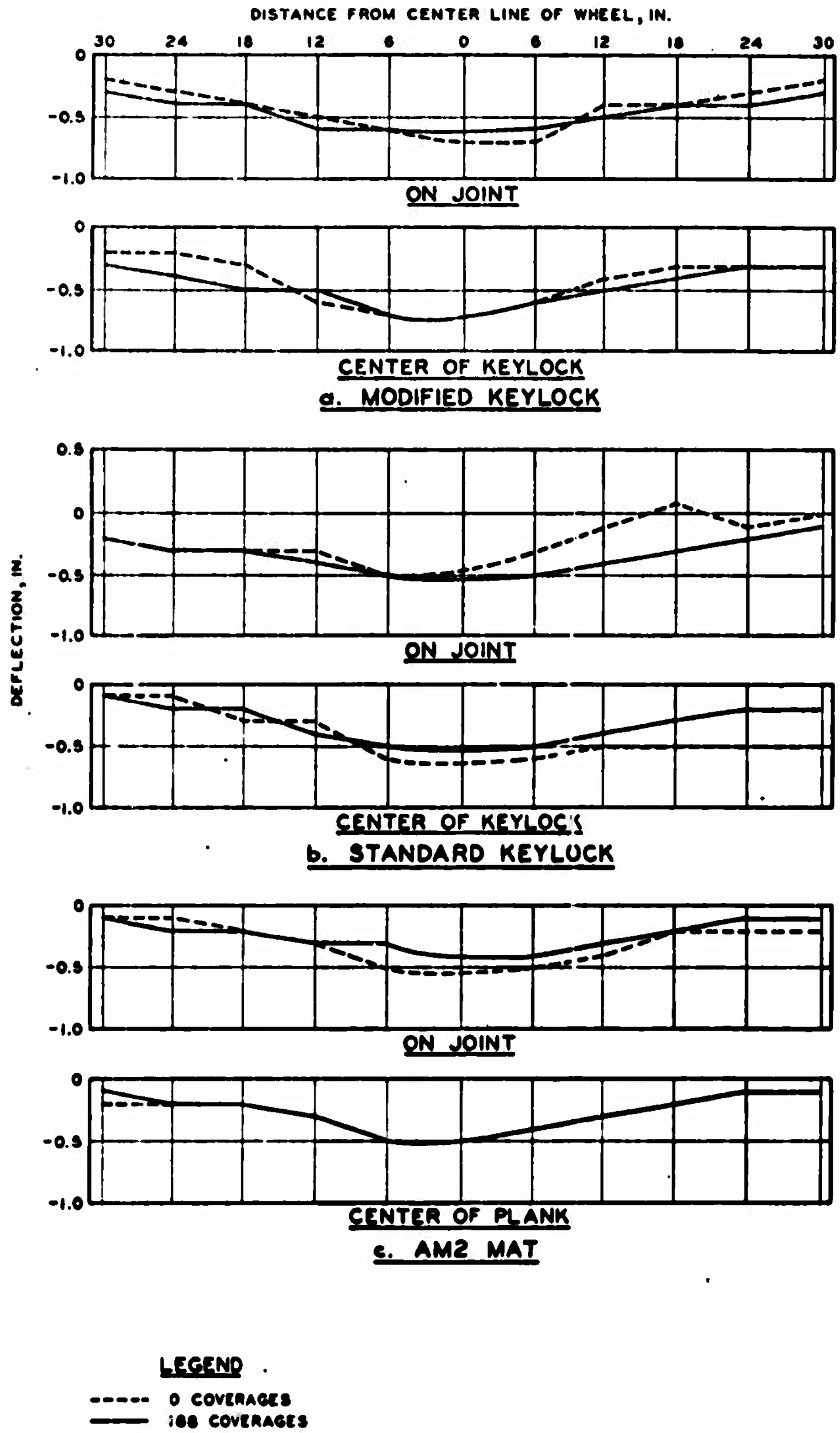
CENTER-LINE PROFILES
27,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE PRESSURE
SINGLE-TRACK TRAFFIC
1600 PASSES



MAT DEFLECTIONS

ITEM 1

27,000-LB SINGLE-WHEEL LOAD



MAT DEFLECTIONS
ITEM 2
27,000-LB SINGLE-WHEEL LOAD