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MISCELLANEOUS PAPER NO. 4-817

DEVELOPMENT OF CBR DESIGN CURVES FOR RUNWAYS TO BE SURFACED WITH M8A1 (FORMERLY T10) STEEL LANDING MAT

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ARMY-MRC VICKSBURG, MISS.

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FOREWORD

The investigation reported herein was authorized by the Office, Chief of Engineers, in a letter to the U. S. Army Engineer Waterways Experiment Station (WES) dated 24 January 1951, subject "Criteria for Designing Runways Surfaced with Landing Mat and Membrane-Type Materials - Project No. 8-69-04-064" (currently DA Project 1-V-0-21701-A-046, "Trafficability and Mobility Research," under staff direction of the U. S. Army Materiel Command).

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

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

SUMMARY

Accelerated traffic tests, which simulated aircraft taxiing operations, were conducted on test sections constructed on subgrades of various strengths and surfaced with M8A1 (formerly T10) steel landing mat. The purpose of the tests was to obtain data on the service life of the M8A1 mat under various conditions of wheel load, tire pressure, and subgrade strength. From these data, CBR design curves for runways surfaced with M8A1 mat, similar to CBR design curves for bituminous pavements, have been developed.

Operations of military aircraft with single-wheel loads ranging from 25,000 to 50,000 lb and tire pressures ranging from 60 to 300 psi and aircraft with twin-wheel assembly loads of 50,000 lb were simulated by means of a test load cart. CBR, water content, and density of the subgrade were measured before and during the traffic tests, and the condition of the test sections was recorded. Traffic was applied until the test sections failed or until it was evident that 700 coverages could be completed by the test load cart.

The design curves, which were developed by correlating the M8A1 test data with flexible pavement design relations, are considered adequate for use in designing landing strips to be surfaced with M8A1 steel landing mat.

DEVELOPMENT OF CBR DESIGN CURVES FOR RUNWAYS TO BE SURFACED WITH M8A1 (FORMERLY T10) STEEL LANDING MAT

PART I: INTRODUCTION

Background

1. For a number of years the U. S. Army Engineer Waterways Experiment Station (WES) has been engaged in a comprehensive investigation for the development of criteria for designing runways to be surfaced with landing mats or membrane-type material.

2. A series of traffic tests was conducted on various strength subgrades surfaced with M6 and M8 steel and M9 aluminum mats during calendar years 1951 through 1953. From these tests, CBR design curves were developed for the mats tested, and the design curves were published in WES Technical Report No. 3-539, entitled Criteria for Designing Runways to be Surfaced with Landing Mat and Membrane-Type Materials, dated April 1960. Since the completion of these tests, several improved mats have been developed and subjected to engineering tests. One of the new mats developed is a modification of the standard M8 mat and is designated as M8A1 steel mat.* This mat is similar to the M8 mat, but it is a stronger, more rigid panel without lightening holes and has an improved end joint.

3. The engineering tests of the M8A1 steel mat indicated that the performance of this mat under wheel loads was considerably better than that of the M8 steel mat. Therefore, during fiscal years 1962 and 1963 a series of traffic tests was performed on the M8A1 mat to obtain necessary data for the development of CBR design curves for the M8A1 mat; these tests are reported herein.

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* This mat was formerly designated T10; during the preparation of this report, the mat was type-classified as a Standard A item of issue and redesignated as M8A1.

The Problem

4. Present indications are that landing mats will be used extensively in forward areas to support air operations. The effort and cost required to produce and deliver landing mats make it imperative that the mats be placed to attain their highest degree of efficiency. To achieve this, the engineering officer designing a forward-area airfield must know the minimum California Bearing Ratio (CBR) that is required in a subgrade so that when the subgrade is covered with landing mat, it will support the anticipated aircraft loadings. If the CBR of the subgrade does not equal or exceed this minimum value, the officer must know the thickness and quality of base course or stabilized subgrade needed beneath the mat to strengthen the subgrade sufficiently to meet the CBR criterion.

Objective and Scope of Study

5. The objective of this study was to develop a family of CBR design curves for the M8A1 steel landing mat that would indicate service life in terms of subgrade strength, wheel load, and tire pressure. It was desired that the design curves be developed for full, minimum, and emergency operational categories.

6. The objective of the study was accomplished by:

a. Constructing test sections representing subgrades of various strengths and surfacing them with M8A1 steel landing mat.

b. Performing accelerated traffic tests on the specially prepared sections using single-wheel loads of 25,000 and 50,000 lb with 60-, 100-, 200-, and 300-psi tire pressures, and a twin-wheel load of 50,000 lb with 200-psi tire pressure.

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

d. Developing design curves from the data obtained during the accelerated traffic tests.

PART II: MAT, TEST SECTIONS, AND TEST LOAD CART

Mat

7. Various features of the M8A1 steel landing mat used in the tests are shown in fig. 1 and are detailed in Corps of Engineers drawing E 10000-1, except that the mat thickness was 0.125 in. instead of 0.140 in. as shown in the drawing. Fig. 2 shows the side and end connector details for the M8A1 mat. Ten M8A1 panels were weighed and measured to determine the average weight, placing dimensions, and overall dimensions. The results are presented in the following tabulation.

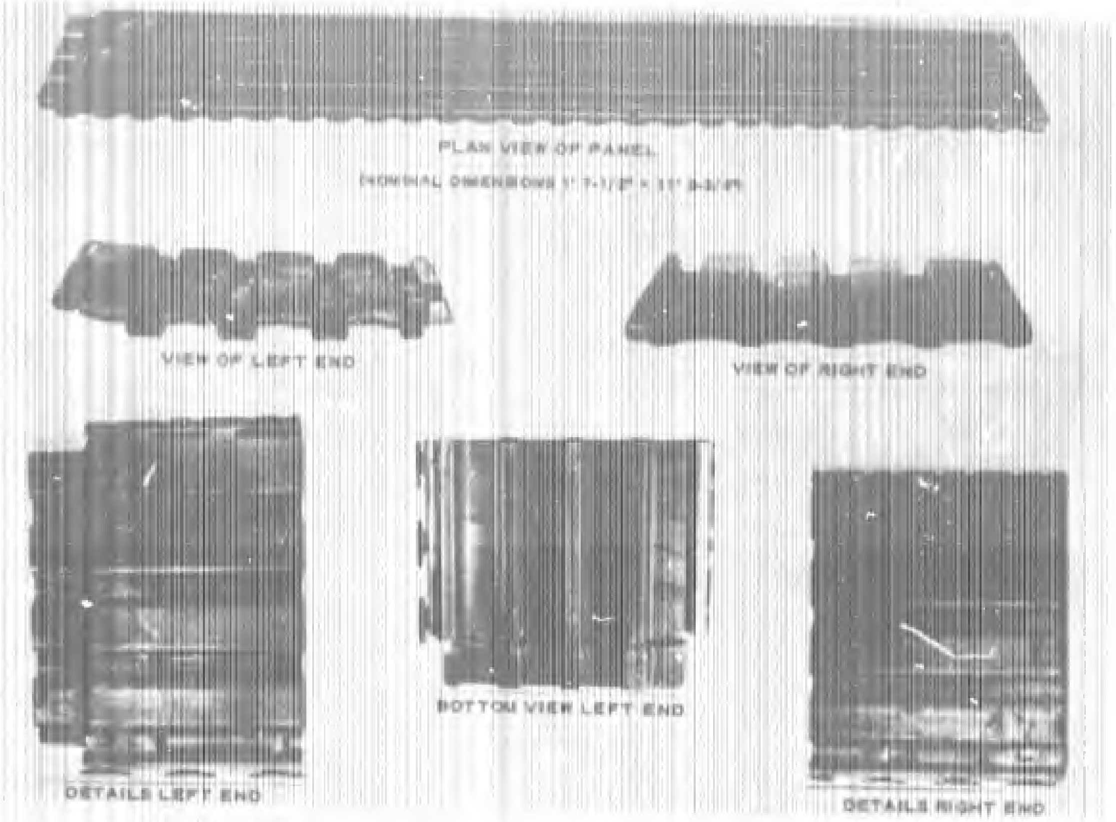

Fig. 1. Details of various features of M8A1 landing mat

Overall		Placing			
Width in.	Length ft, in.	Width in.	Length ft, in.	Area sq ft	Weight lb
20-1/2	11, 11-1/4	19-1/4	11, 9-3/4	18.95	144.00

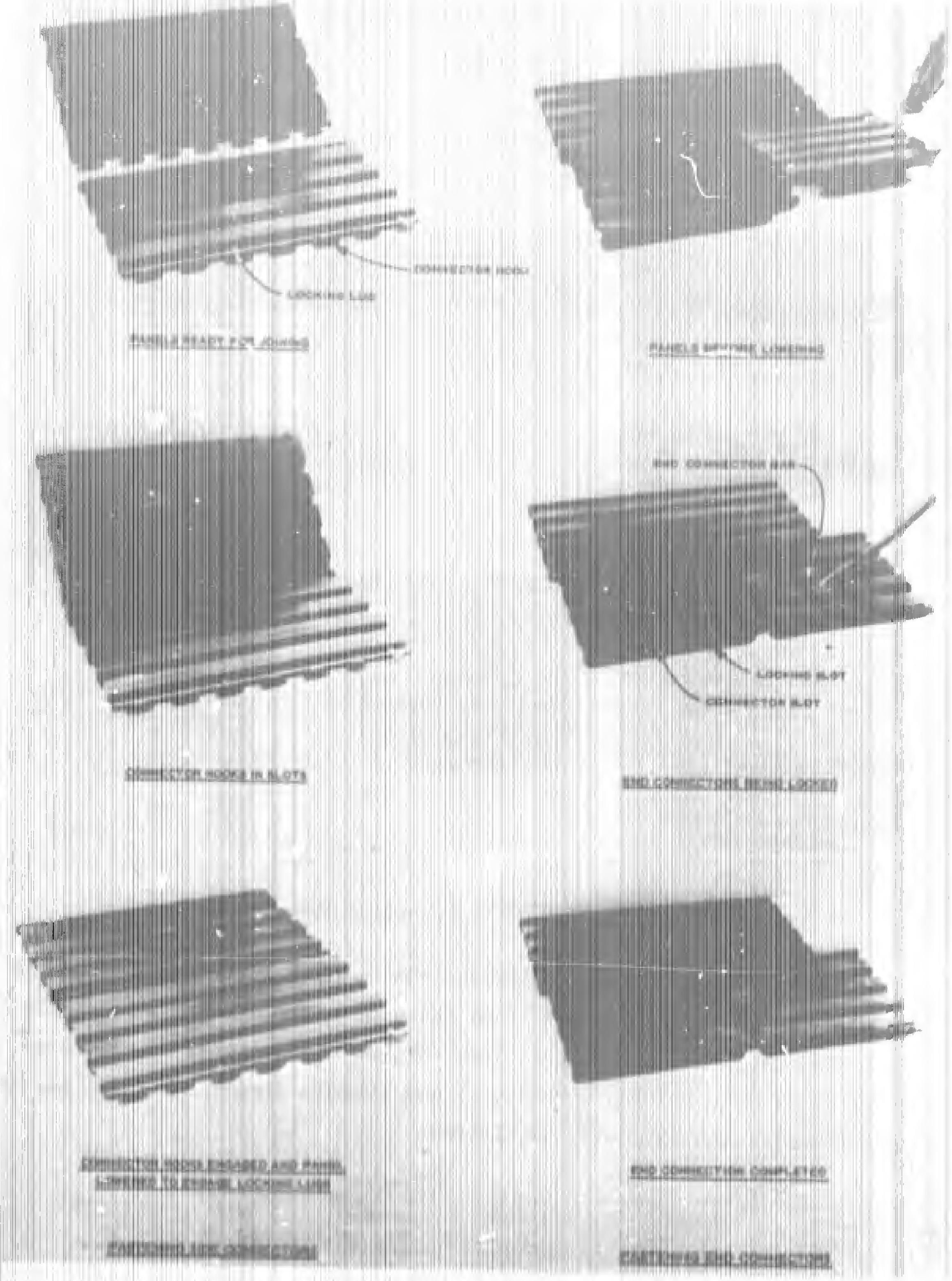

Fig. 2. Details of side and end connectors of M8A1 landing mat

A detailed description of the mat is given in WES Technical Report No. 3-507, Engineering Tests of T10 Steel Airplane Landing Mat (Modified M8), Dust-Alleviation Type, dated June 1959.

Test Sections

Location

8. All traffic tests were conducted at the WES on special test sections which were constructed and tested under shelter in order to control the subgrade water content and strength.

Description

9. Three test sections were prepared especially for these tests. Each test section was approximately 54 ft wide and 90 ft long and consisted of two traffic lanes with three test items, each 30 ft in length. The subgrade soil in each test item within a test lane was placed and compacted at a different predetermined water content so as to develop a range of subgrade strengths. A layout of a typical test section is shown in plate 1. As indicated in plate 1, the only variable within a test lane was subgrade strength. Thus, whenever the load cart (described in paragraph 12) traversed the entire length of the test lane with a given wheel load and tire pressure, data were obtained for several different values of subgrade strength.

10. The subgrade soil for all tests consisted of a heavy clay which was placed in the test sections at controlled strengths to a depth of 24 in. Gradation and classification data for the heavy clay soil are shown in plate 2. The soil had a liquid limit of 56 and a plasticity index of 33 and classified as CH according to MIL-STD-619. Laboratory compaction and CBR data for the heavy clay are shown in plate 3.

Construction

11. In constructing the subgrades, the existing material was excavated to a depth of 24 in. below finished grade. The soil for each item was processed to the desired water content, hauled to the test section site by truck, spread, and compacted in four 6-in.-thick lifts. Compaction of each lift was accomplished by applying eight coverages with a four-wheel

pneumatic-tired roller loaded to 50,000 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 and final lift was placed and compacted, the surface of the subgrade was fine-bladed to grade with a motor patrol. In-place CBR tests were conducted on each lift immediately after placement to ensure that proper subgrade strengths were being obtained. The entire subgrade was then surfaced with the M8A1 mat (see fig. 3).

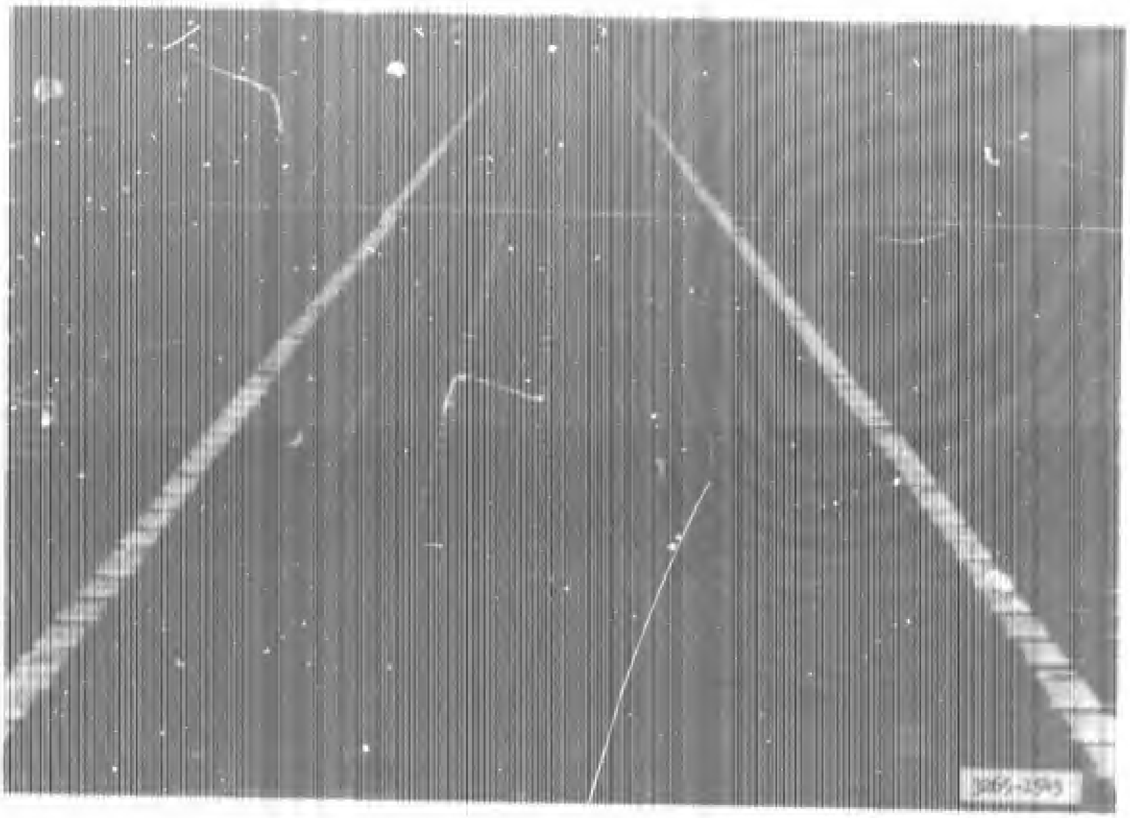

Fig. 3. Typical test section after placement of M8A1 landing mat

Test Load Cart

12. Traffic was applied to the M8A1 mat with a special test load cart (fig. 4). The load cart consisted of a frame with two outrigger wheels and a load box mounted inside the frame and was towed by a Super C Tournapull. A 56.00-16, 32-ply rating, nylon cord tire was used in the

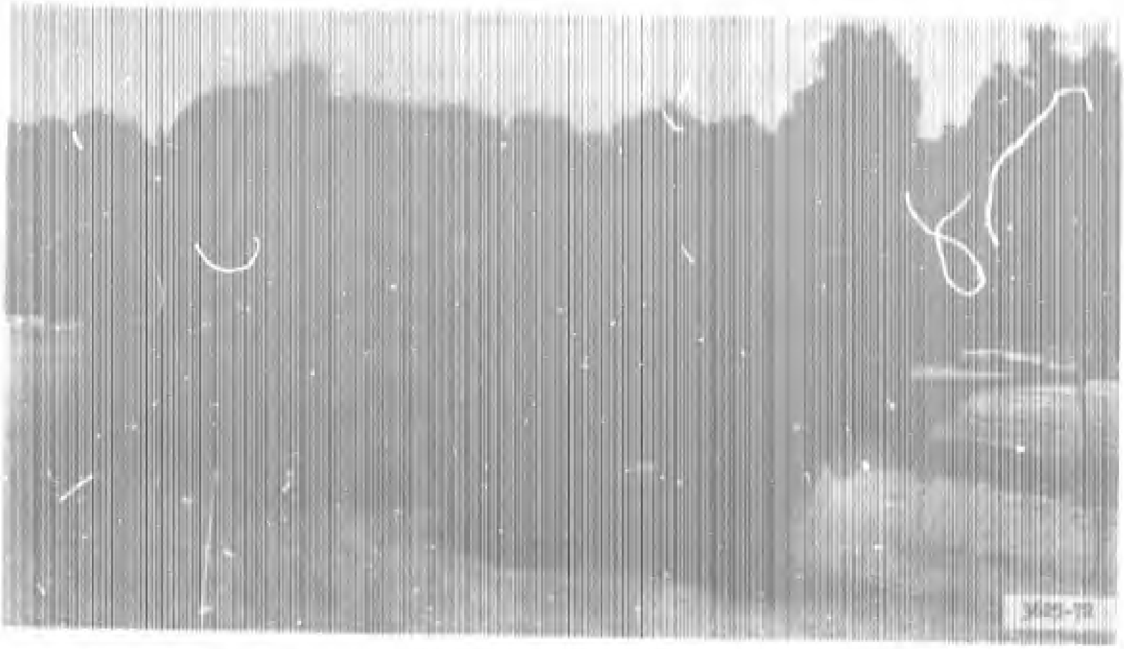

Fig. 4. Test load cart with single wheel mounted under load box

100-, 200-, and 300-psi tire pressure traffic tests, and a 25.00-28, 32-ply rating tire was used in the 60-psi tire pressure traffic test. The following tabulation shows the relations between load, tire pressure, and contact area:

Load lb	Tire Inflation Pressure psi	Tire Contact Area sq in.	Average Contact Pressure psi
25,000	100	232	108
25,000	200	145	173
25,000	300	112	223
50,000	60	804	62
50,000	100	372	134
50,000	200	270	185
50,000	300	187	267

PART III: TESTS AND RESULTS

Traffic Tests

13. A total of 18 tests were conducted in this investigation. The conditions of subgrade, wheel load, and tire pressure under which the traffic tests were conducted are shown in table 1. Traffic was applied by operating the test load cart forward and then backward in the same track throughout the entire length of the test lanes. On each forward pass, the load cart with single-wheel assemblies was shifted laterally the width of the load tire so that two complete coverages were applied as the test cart progressed from one side of the lane to the other. For the twin assemblies (5.4-radii spacing), a similar pattern was followed, except that after every third forward pass the cart was shifted the width of a complete assembly. All traffic was applied across the mat transverse to the long axis of the panels and was continued until failure developed or until it was evident that the mat would withstand at least 700 coverages.

Soil Tests and Miscellaneous Observations

14. Water content, density, and in-place CBR tests were made prior to and at various intervals during traffic at depths of 0, 6, and 12 in. Data obtained 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 particular depth.

15. Visual observations of the behavior of the test sections 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 determine the development of roughness, settlement, and mat deformation and deflection under the wheel load. The term "deformation" as used herein refers to the change in surface elevation of the mat at any given interval of traffic from the original elevation prior to traffic. The term "deflection" denotes the elastic vertical movement or rebound of the mat surface following the passing of the wheel load.

Behavior of Subgrades and Mat Under Traffic

16. In addition to other data, table 2 summarizes the results of traffic tests and the behavior of the various test sections under traffic. The general behavior of the subgrade and mat is discussed in the following paragraphs.

Subgrade

17. As stated previously, a heavy clay material was used in constructing the test sections. For the low-strength sections, the clay was compacted at water contents of 26 to 28 percent, which is well on the wet side of MIL-STD-621 CE-55 optimum, to dry densities of about 95 lb per cu ft. This resulted in CBR values of about 4 to 6. For the medium-strength sections, the clay was compacted at water contents of 23 to 25 percent, which is also on the wet side of MIL-STD-621 CE-55 optimum, to dry densities of about 98 lb per cu ft. This resulted in CBR values of about 9 to 12. For the high-strength sections, the clay was compacted at water contents of 21 to 22 percent, which is also on the wet side of MIL-STD-621 CE-55 optimum, to dry densities of about 100 lb per cu ft. This resulted in a CBR value of about 16. At water contents of 22 percent and higher, the CBR of this material shows only slight changes with small changes in water content and density, as can be noted from the plots in plate 3. For example, from the middle plot of plate 3, it can be seen that for a water content of 22 percent and density ranging from 98 to 104 lb per cu ft, the CBR varies from a low value of 12 to a high of 18. At higher water contents, the variation in CBR with changes in density is even less pronounced. In general, the water content, density, and CBR of the subgrades remained about constant throughout the traffic period. However, occasional sprinkling of the surface was necessary to prevent the formation of a surface crust.

18. The behavior of the three different strength subgrades under traffic was similar. Higher deformation and deflection values were noted in the lower-strength subgrades. These values increased in magnitude as traffic continued.

Landing mat

19. Effect of wheel load. Single-wheel loads of 25,000 and

50,000 lb were used in the tests. Tests 5 and 15 have been selected to illustrate the significance of the additional stress on the mat and subgrade caused by an increase in load from 25,000 to 50,000 lb. It can be seen from table 1 that test 5 involved a 300-psi tire loaded to 25,000 lb on a 5-CBR subgrade and that test 15 involved a 300-psi tire loaded to 50,000 lb on a 10-CBR subgrade. Photograph 1 shows the mat in test 5 after 76 coverages, and photograph 2 shows the mat in test 15 after 66 coverages. These photographs show that the 50,000-lb load caused considerably more mat and subgrade damage than the 25,000-lb load, in spite of the fact that the subgrade under the 50,000-lb load was twice as strong as that under the 25,000-lb load.

20. The M8A1 mat performed satisfactorily on sections where the load intensities were not severe enough to cause excessive deflections or rutting in the subgrade. The mat embedded rapidly in the lower-strength subgrades and bent under traffic to conform to the contour of the subgrade. Where the load intensities caused distress in the subgrades, the soil usually tended to move laterally from under the point of load and build up under the end connection joints and along the outside edges of the traffic lanes. As the load wheel passed directly over the end joints, the joints were deflected downward. This intermittent bending up and down caused numerous breaks to occur in the vicinity of an end joint. Photograph 3 shows typical breaks in the center of an overlapping edge adjacent to an end joint. Photograph 4 shows a typical break at the side locking lug. A break which originated in the locking lug slot and extended into the overlapping panel is shown in photograph 5.

21. Effect of tire pressure. Tire inflation pressures of 60, 100, 200, and 300 psi were used in these tests, and tests 12, 13, and 15 have been selected to illustrate the significance of tire pressure variations. These three tests were made with a 50,000-lb single-wheel load with tire pressures of 100, 200, and 300 psi, respectively. They were performed on subgrades having comparable rated subgrade CBR's of 12, 12, and 11 respectively (table 2). Thus, the only significant variable in these three tests was tire pressure. Table 1 shows that in test 12 (100 psi) the mat withstood 500 coverages and would have withstood the full 700 coverages, in

test 13 (200 psi) the mat failed at 400 coverages, and in test 15 (300 psi) it failed at 66 coverages. It is apparent from these data and from similar comparisons of data in table 1 that an increase in tire pressure will substantially reduce the number of traffic coverages that can be applied before failure occurs.

Failure Criteria

22. Failures of test sections were judged on the basis of excessive mat breakage and development of roughness in the mat to the point of endangering aircraft operations. In general, these two conditions occurred at about the same time in the traffic tests; that is, when the subgrade experienced sufficient movement to produce detrimental deformation in the surface, the mat started breaking at a rapid rate. Photographs 6, 7, and 8 are typical views of test sections both prior to and after failure, together with plots of deformation and deflection of the mats before and after failure. The deflection curves in photographs 6-8 were obtained with the load wheel over an end joint near the center of the traffic lane. In general, when significant deformation occurred, a ridge developed under the end joints as can be observed in the photograph and in the deformation plot in photograph 6. The mat would deflect downward under the load and then rebound to about the position indicated by the deformation plots as the load wheel moved forward (note that the vertical scale in the deformation plots is severely exaggerated).

PART IV: DEVELOPMENT OF DESIGN CURVES

Approach

23. The method used to prepare design curves for runways surfaced with M8A1 landing mat was similar to that used previously for other types of mat. The basic CBR design curves for flexible pavements were used as a behavior pattern; and from the data obtained in the tests just described, a determination was made as to the equivalent thickness of pavement that was replaced by the landing mat. CBR design curves for runways surfaced with M8A1 mat were then prepared by reducing the total thickness requirements of the basic flexible pavement design curves by the equivalent thickness provided by the mat.

Airfield Operational Categories

24. The Air Force has defined four categories of theater-of-operations airfield construction based on anticipated usage of the field. Definitions of the operational categories are given below.

- a. Capacity operational category. Maximum allowable loadings for unlimited aircraft operations for a period of more than 10 yr.
- b. Full operational category. Maximum allowable loadings for normal aircraft operations for a period of 1 to 2 yr.
- c. Minimum operational category. Maximum allowable loadings for normal aircraft operations for a period of 4 to 6 months.
- d. Emergency operational category. Maximum allowable loadings for normal aircraft operations for a period of 2 to 3 weeks.

25. Use of landing mat is anticipated only for the full, minimum, and emergency operational categories. The amount of traffic for which such fields are designed is represented by 1000, 200, and 40 coverages, respectively. These are the coverage levels for which CBR design curves for runways surfaced with M8A1 steel landing mat were to be developed.

Analysis of Traffic Test Data

26. For purposes of analysis, the basic test data shown in table 1 are summarized in table 2. The rated CBR values shown in table 2 represent the average of the CBR determinations made at the 0-, 6-, and 12-in. depths. The next to the last column of table 2 indicates the reduction in thickness (of subbase, base, and pavement) that can be applied to the pertinent flexible pavement design curves in establishing design curves for runways surfaced with landing mat. The flexible pavement design curves for emergency, minimum, and full operational categories are shown in plates 4, 5, and 6, respectively.

27. Plate 7 is a plot of indicated thickness reduction versus tire contact pressure. Different symbols are used for different loads, but as can be seen, the data indicate a constant thickness reduction for all load conditions and vary only according to tire pressure. Open symbols are used where no failures occurred and closed symbols where failures occurred. The test number is indicated beside each plotted point. It can be seen that the 50,000-lb dual-wheel load (tests 17 and 18) did not appear to be any more severe than the 25,000-lb single-wheel load. Although this is true for the 5.4-radii spacing used here, it is likely that closer spacing of the dual wheels would result in an increase in the severity of the load. The thickness reduction values shown in table 2 and plotted in plate 7 were computed by use of the CBR equation which was written in the general form*

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

where

t = total thickness, in.
C = number of coverages
P = single-wheel load, lb
CBR = measure of subgrade strength
p = tire pressure, psi

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* This is a combination of equation 2, page 2, and the equation for slope of curve, plate 6, in WES Instruction Report No. 4, Developing a Set of CBR Design Curves, dated November 1959.

The t value obtained from the above equation indicates the total thickness of base course and pavement construction that would be required to support the load for a given number of coverages on a subgrade of given strength. In the case of the landing mat, the t value indicates the thickness of base course and flexible pavement construction replaced by the mat. The following tabulation shows the indicated thickness reductions for the respective tire pressures as taken from plate 7.

Tire Pressure psi	Indicated Reduction in.
60	27.7
100	20.0
200	14.0
300	12.2

These data show that as the tire pressure increases, the permissible thickness reduction decreases.

CBR Design Curves

28. The M8A1 landing mat design curves were developed using the thickness reductions in the tabulation in paragraph 28 and the flexible pavement design curves in plates 4-6. The curves for emergency, minimum, and full operational categories are shown in plates 8, 9, and 10, respectively. Although the thickness reduction does not vary with load, the required thickness does depend on load, as can be seen in the design curves in plates 8-10.

Relative Service Life of M8A1 and M8 Mats

29. As pointed out earlier, the M8A1 steel mat is a modification of the M8 mat and is a stronger, more rigid mat. For identical conditions of subgrade strength and loading, the service life of the M8A1 mat is about two to three times that of the M8 mat.

PART V: CONCLUSIONS

30. Based on the results of the study described herein, the following conclusions are believed warranted:

a. The CBR design curves for runways surfaced with M8A1 landing mat (plates 8-10) are adequate for use in designing forward-area airfields.

b. A 50,000-lb dual-wheel load with a center-to-center spacing of 5.4 radii is no more severe than a 25,000-lb single-wheel load.

Table 1

Summary of Water Content, Density, and CBR Data for M8A1 Steel Landing Mat Tests

	Assembly				0 Coverages			40 Coverages			200 Coverages			400 Coverages			Failure or End of Test				
Test No.	Load lb	Wheel	Tire Pressure psi	Depth in.	Water Content %	Dry Density lb/cu ft	CBR	Water Content %	Dry Density lb/cu ft	CBR	Water Content %	Dry Density lb/cu ft	CBR	Water Content %	Dry Density lb/cu ft	CBR	No. Coverages	Water Content %	Dry Density lb/cu ft	CBR	Remarks
1	25,000	Single	100	0	28.0	94.5	3.3	25.2	98.1	6.5	--	--	--	--	--	--	100	--	--	--	Traffic stopped at 100 coverages. No damage so load was increased to 50 kips
				6	25.8	96.9	4.6	26.7	96.3	4.5	--	--	--	--	--	--		--	--	--	
				12	28.0	93.5	3.8	26.8	96.1	6.6	--	--	--	--	--	--		--	--	--	
				Avg	27.3	95.0	3.9	26.2	96.8	5.2	--	--	--	--	--	--		--	--	--	
2	25,000	Single	200	0	28.3	94.0	3.1	26.8	95.7	6.3	25.7	98.3	7.8	--	--	--	275	26.7	97.3	6.2	Failure at 275 coverages.
				6	27.3	95.8	3.6	29.4	96.4	4.3	25.9	95.1	4.3	--	--	--		26.0	97.0	3.8	
				12	28.9	94.1	5.7	26.0	93.0	3.9	25.5	99.1	8.9	--	--	--		25.3	96.3	5.0	
				Avg	28.1	94.6	3.6	28.1	93.8	4.9	25.7	96.8	7.0	--	--	--		26.0	96.9	5.0	
3	25,000	Single	200	0	26.8	96.7	8.6	24.2	99.9	15	24.7	100.3	13	--	--	--	200	--	--	--	Traffic stopped at 200 coverages. No damage so load was increased to 50 kips and 100 psi
				6	25.6	98.6	11.5	25.0	98.9	19	24.2	98.9	13	--	--	--		--	--	--	
				12	24.2	97.2	11.2	25.3	97.3	10	24.2	98.8	13	--	--	--		--	--	--	
				Avg	25.5	97.5	10.4	24.9	98.6	13	24.4	99.3	13	--	--	--		--	--	--	
4	25,000	Single	200	0	21.7	99.4	16	21.0	99.6	20	21.8	100.9	19	--	--	--	200	--	--	--	Traffic stopped at 200 coverages. No damage so load was increased to 50 kips and 100 psi
				6	21.6	98.3	14	21.9	98.8	15	21.8	100.0	14	--	--	--		--	--	--	
				12	22.6	97.0	18	21.7	98.4	14	22.7	98.2	18	--	--	--		--	--	--	
				Avg	22.0	98.2	16	21.5	98.6	16	22.4	99.7	17	--	--	--		--	--	--	
5	25,000	Single	300	0	28.8	94.0	5.1	30.1	90.9	5.1	--	--	--	--	--	--	75	27.1	97.6	5.1	Failure at 75 coverages
				6	29.1	95.0	5.6	29.4	93.1	5.7	--	--	--	--	--	--		28.7	96.0	5.6	
				12	28.9	96.1	5.7	29.3	92.7	4.2	--	--	--	--	--	--		28.9	95.0	5.8	
				Avg	29.1	94.6	5.5	29.6	92.9	5.0	--	--	--	--	--	--		28.6	96.2	5.5	
6	25,000	Single	300	0	26.8	96.7	8.6	24.7	98.3	10.3	24.1	101.2	18	23.7	101.9	20	600	--	--	--	Assembly satisfactory for 600 coverages
				6	25.5	96.6	11.5	25.7	98.3	10.9	26.3	98.0	12	23.6	101.4	19		--	--	--	
				12	24.2	97.1	11.9	24.9	100.5	12.0	24.6	99.8	11	23.0	100.8	14		--	--	--	
				Avg	25.5	97.5	10.6	25.1	99.4	11.9	25.0	99.7	14	23.4	101.4	14		--	--	--	
7	25,000	Single	300	0	21.7	99.4	16	22.8	101.1	20	22.0	102.1	21	22.3	102.8	21	600	--	--	--	Assembly satisfactory for 600 coverages
				6	21.6	98.3	14	22.3	98.9	19	22.1	98.4	21	21.9	102.0	21		--	--	--	
				12	22.6	97.0	18	22.8	99.2	18	22.7	100.3	19	22.1	98.9	19		--	--	--	
				Avg	22.0	98.2	16	22.6	100.0	17	22.3	101.0	21	21.9	101.1	20		--	--	--	
8	50,000	Single	60	0	25.7	95.3	3.7	--	--	--	23.5	98.3	4.3	--	--	--	300	26.6	95.8	4.3	Failure at 300 coverages
				6	28.3	97.2	3.9	--	--	--	27.3	96.4	3.8	--	--	--		25.5	96.2	3.5	
				12	26.8	93.1	3.7	--	--	--	27.7	95.0	3.2	--	--	--		27.9	95.8	3.8	
				Avg	26.8	95.3	3.4	--	--	--	26.8	96.6	3.5	--	--	--		27.1	96.0	3.9	
9	50,000	Single	100	0	25.2	95.1	6.3	--	--	--	--	--	--	--	--	--	50	26.7	96.0	4.3	Failure at 50 coverages
				6	26.7	96.3	5.5	--	--	--	--	--	--	--	--	--		26.6	96.5	3.8	
				12	26.8	96.1	6.6	--	--	--	--	--	--	--	--	--		27.5	93.9	4.9	
				Avg	26.2	96.2	6.2	--	--	--	--	--	--	--	--	--		27.1	95.5	4.3	

(Continued)

Table 1 (Continued)

Test No.	Assembly Load lb	Assembly Wheel	Tire Pressure psi	Depth in.	0 Coverages Water Content %	0 Coverages Dry Density lb/cu ft	0 Coverages CBR	[illegible] Coverages Water Content %	[illegible] Coverages Dry Density lb/cu ft	[illegible] Coverages CBR	[illegible] Coverages Water Content %	[illegible] Coverages Dry Density lb/cu ft	[illegible] Coverages CBR	[illegible] Coverages Water Content %	[illegible] Coverages Dry Density lb/cu ft	[illegible] Coverages CBR	Failure or End of Test No. Coverages	Failure or End of Test Water Content %	Failure or End of Test Dry Density lb/cu ft	Failure or End of Test CBR	Remarks
10	50,000	Single	100	0	25.2	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Failure at [illegible] coverages
				6	26.7	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	26.0	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	26.2	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
11	50,000	Single	100	0	23.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Failure at [illegible] coverages
				6	24.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--		[illegible]	[illegible]	[illegible]	
				12	24.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	23.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--		[illegible]	[illegible]	[illegible]	
12	50,000	Single	100	0	23.0	--	[illegible]	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Assumed satisfactory for [illegible] coverages
				6	24.4	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	24.1	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	23.8	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
13*	50,000	Single	200	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Failure at [illegible] coverages
				6	21.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	21.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	20.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
14*	50,000	Single	200	0	20.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Satisfactory at [illegible] coverages
				6	21.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	21.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
15	50,000	Single	300	0	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Failure at [illegible] coverages
				6	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
16	50,000	Single	300	0	21.8	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Assumed satisfactory for [illegible] coverages
				6	21.8	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	23.2	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	22.4	[illegible]	[illegible]	--	--	--	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
17	50,000	Twin	200	0	28.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--	[illegible]	[illegible]	[illegible]	[illegible]	Failure at [illegible] coverages
				6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	28.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	27.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
18	50,000	Twin	200	0	24.2	[illegible]	[illegible]	[illegible]	--	[illegible]	--	--	--	--	--	--	[illegible]	[illegible]	--	[illegible]	Satisfactory at [illegible] coverages
				6	23.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				12	25.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	
				Avg	24.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--	--	--		[illegible]	[illegible]	[illegible]	

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* Data from Engineering Tests of T10 Steel Airplane Landing Mat (Modified M8), Dust-Alleviation Item, U. S. Army Engineer Waterways Experiment Station Technical Report 3-507, June 1959.

(2 of 2 sheets)

Table 1

Summary of Results of Traffic Tests on M8M1 Steel Landing Mat

Test No.	Assembly Load, lb	Wheel	Tire Contact Pressure, psi	Evaluation Data Coverages	CBR	Behavior	Rated Subgrade CBR	Indicated Thickness from Flexible Pavement Design Curves, in.	Rated on the Basis of Thickness
1	15,000	Single	100	0 40 100	6.0 6.5 --	Satisfactory at 100 coverages	5.0	10.6	Satisfactory
2	15,000	Single	100	0 40 100 175	1.6 1.8 1.1 1.1	Failure at 175 coverages	1.7	23.4	Failure
3	15,000	Single	125	0 40 200	10.6 11 11	Satisfactory at 200 coverages	11	10.5	Satisfactory
4	15,000	Single	125	0 40 200	18 20 19	Satisfactory at 200 coverages	18	8.4	Satisfactory
5	15,000	Single	200	0 40 75	5.0 5.0 5.4	Failure at 75 coverages	5.5	13.3	Failure
6	15,000	Single	200	0 40 100 400	10.4 11.0 14 16	Assumed satisfactory for 700 coverages	10	10.4	Satisfactory
7	15,000	Single	200	0 40 100 400	16 17 21 20	Assumed satisfactory for 700 coverages	16	9.0	Satisfactory
8	50,000	Single	60	0 100 300	3.4 3.0 3.8	Failure at 300 coverages	3.6	27.4	Failure
9	50,000	Single	134	0 40	6.0 8.0	Failure at 40 coverages	6	17.5	Failure
10	50,000	Single	134	0 80	6.0 7.0	Failure at 80 coverages	6.7	16.6	Failure
11	50,000	Single	134	0 40 100 300	10 11 9.5 9.3	Failure at 300 coverages	10	13.8	Failure
12	50,000	Single	134	0 700	20 21	Assumed satisfactory for 700 coverages	20	10.3	Satisfactory
13*	50,000	Single	185	0 40 400	11 10 11	Failure at 400 coverages	11	13.5	Failure
14*	50,000	Single	185	0 40 700	13 16 16	Satisfactory at 700 coverages	14	13.0	Satisfactory
15*	50,000	Single	287	0 40	8.3 10	Failure at 40 coverages	10	16.8	Failure
16*	50,000	Single	287	0 450	12 25	Assumed satisfactory for 700 coverages	20	13.0	Satisfactory
17	50,000	Twin	175	0 40 700	5.0 7.0 4.0	Failure at 700 coverages	5	16.3	Failure
18	50,000	Twin	175	0 40 700	9.0 8.0 11	Satisfactory at 700 coverages	9	14.0	Satisfactory

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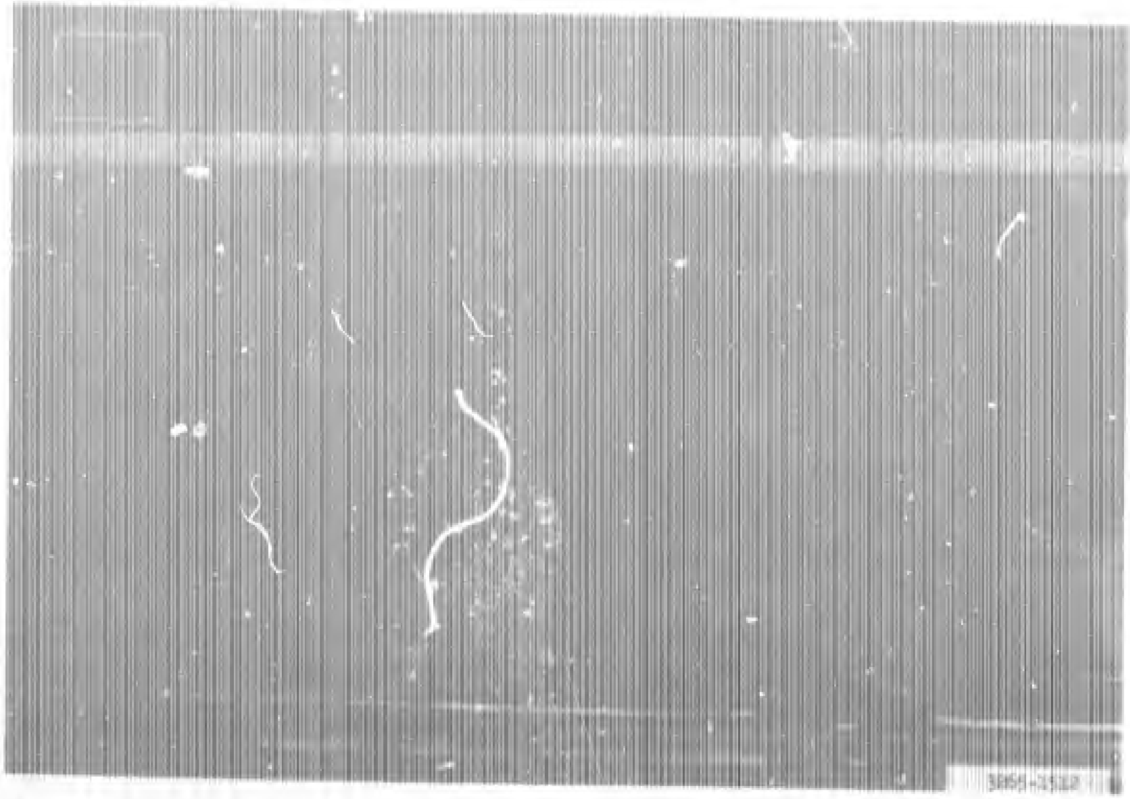
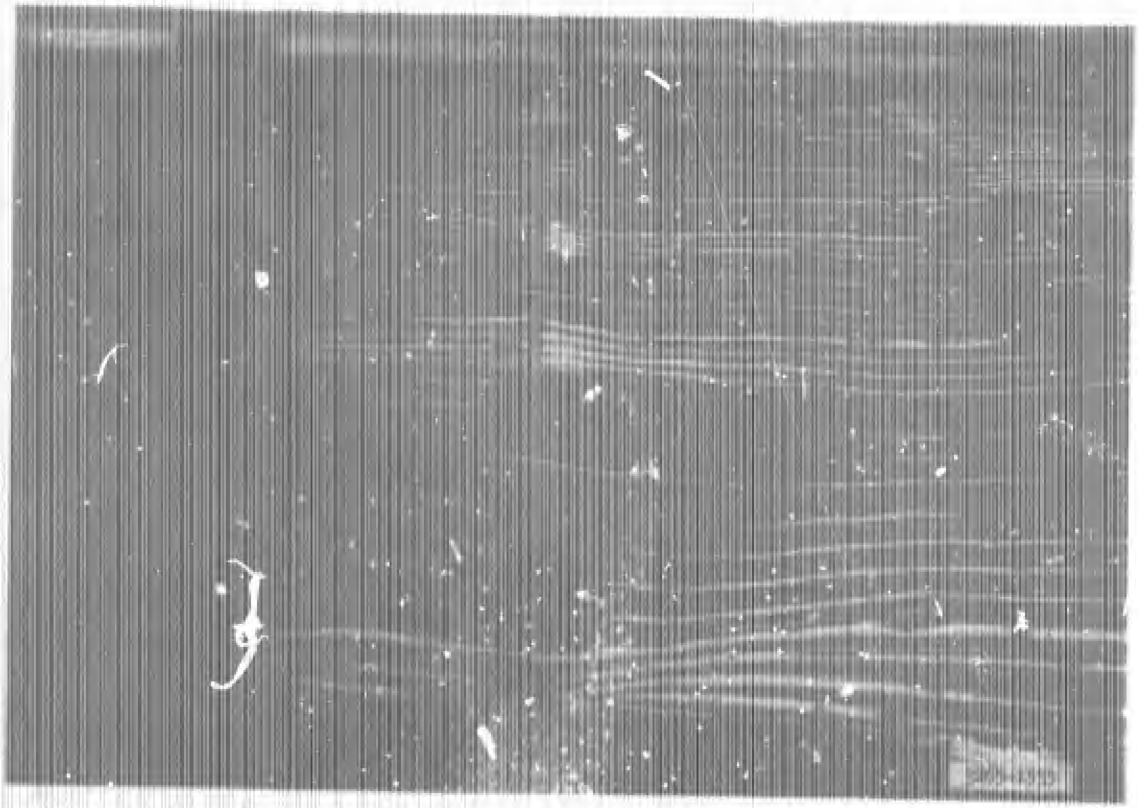
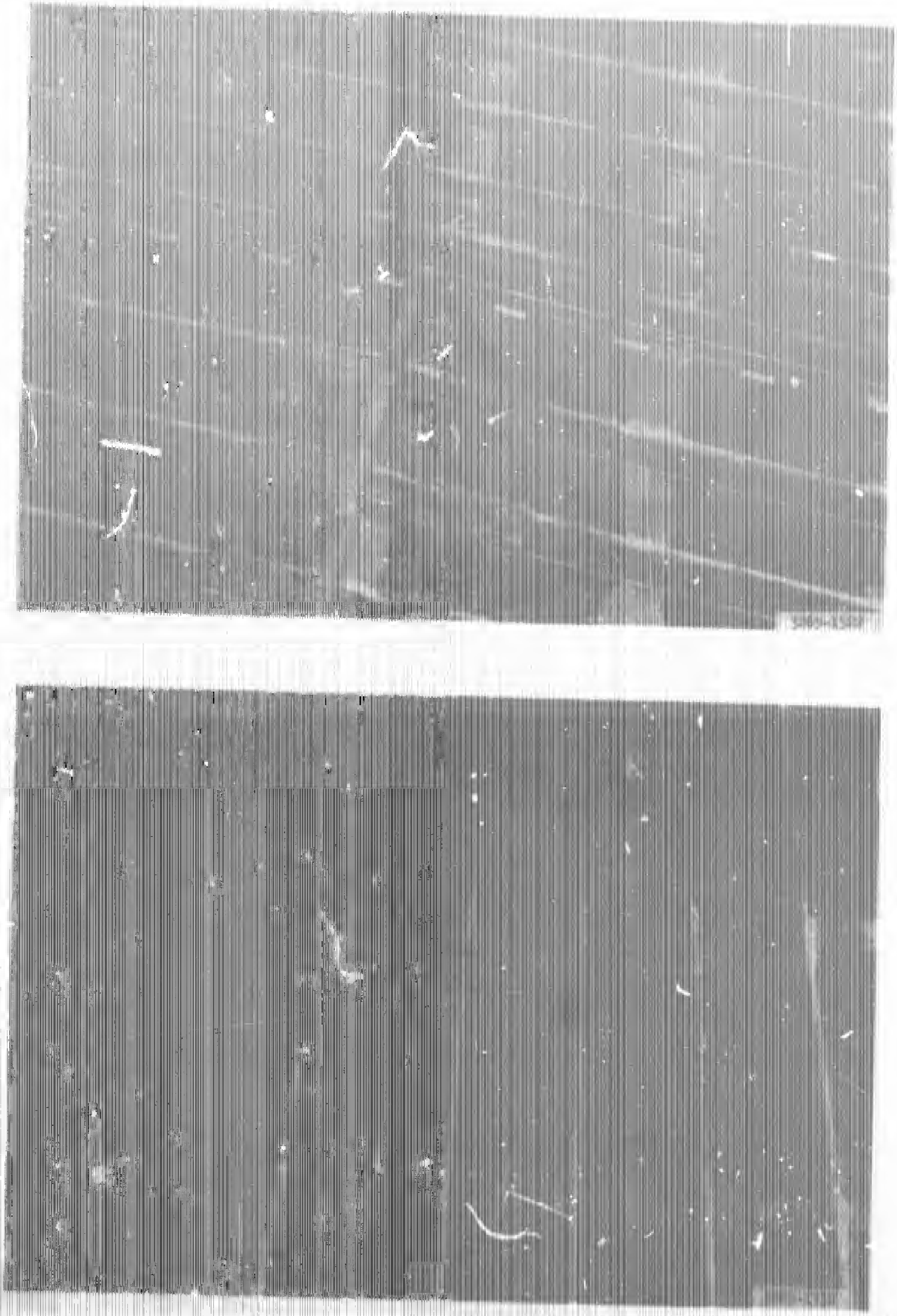
* Data from Engineering Tests of T10 Steel Airplane Landing Mat (Modified M8), Dust-Alleviation Type, U. S. Army Engineer Waterways Experiment Station Technical Report [illegible], June [illegible].



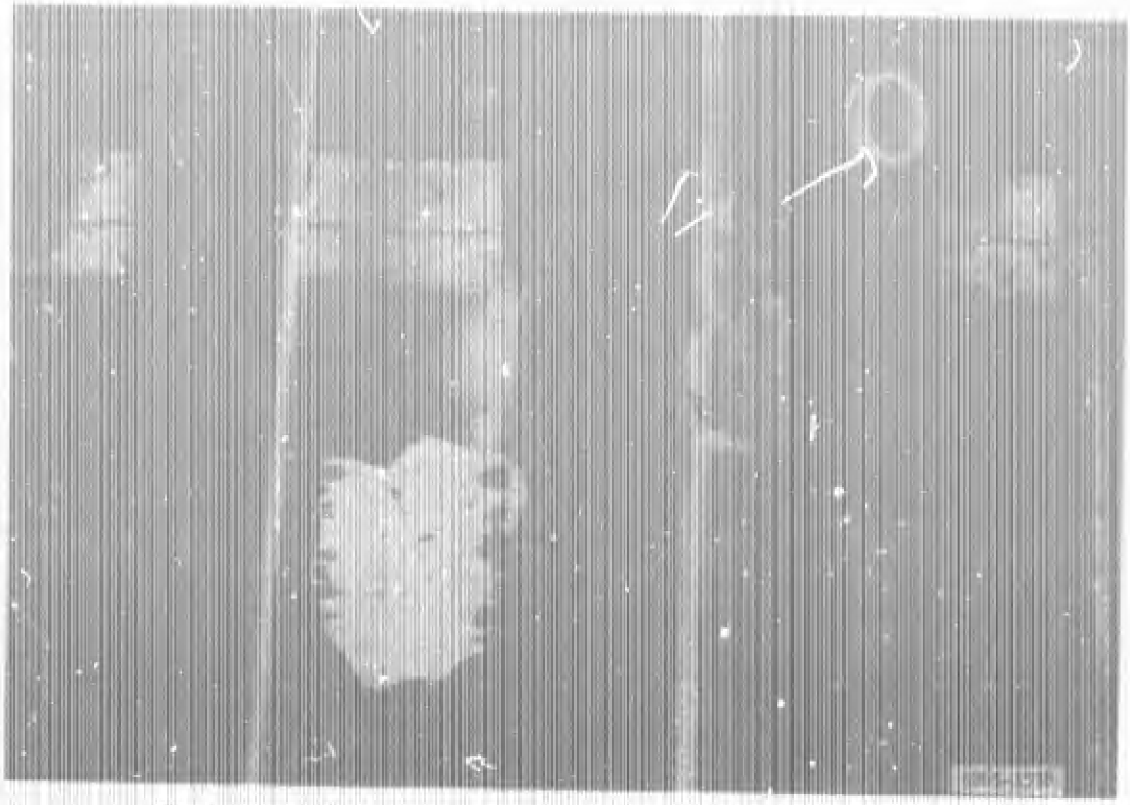
Photograph 1. M8A1 mat in test 5 after 76 coverages of 25,000-lb single-wheel load and 300-psi tire inflation pressure



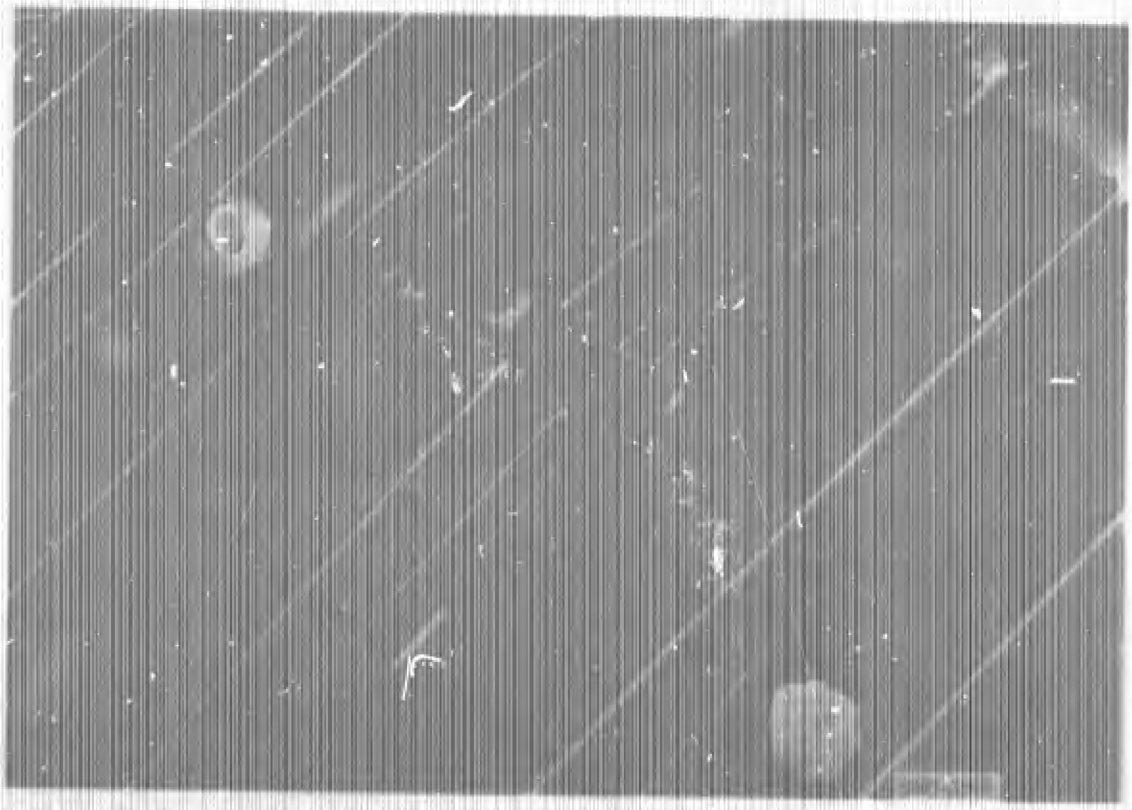
Photograph 2. M8A1 mat in test 15 after 66 coverages of 50,000-lb single-wheel load and 300-psi tire inflation pressure



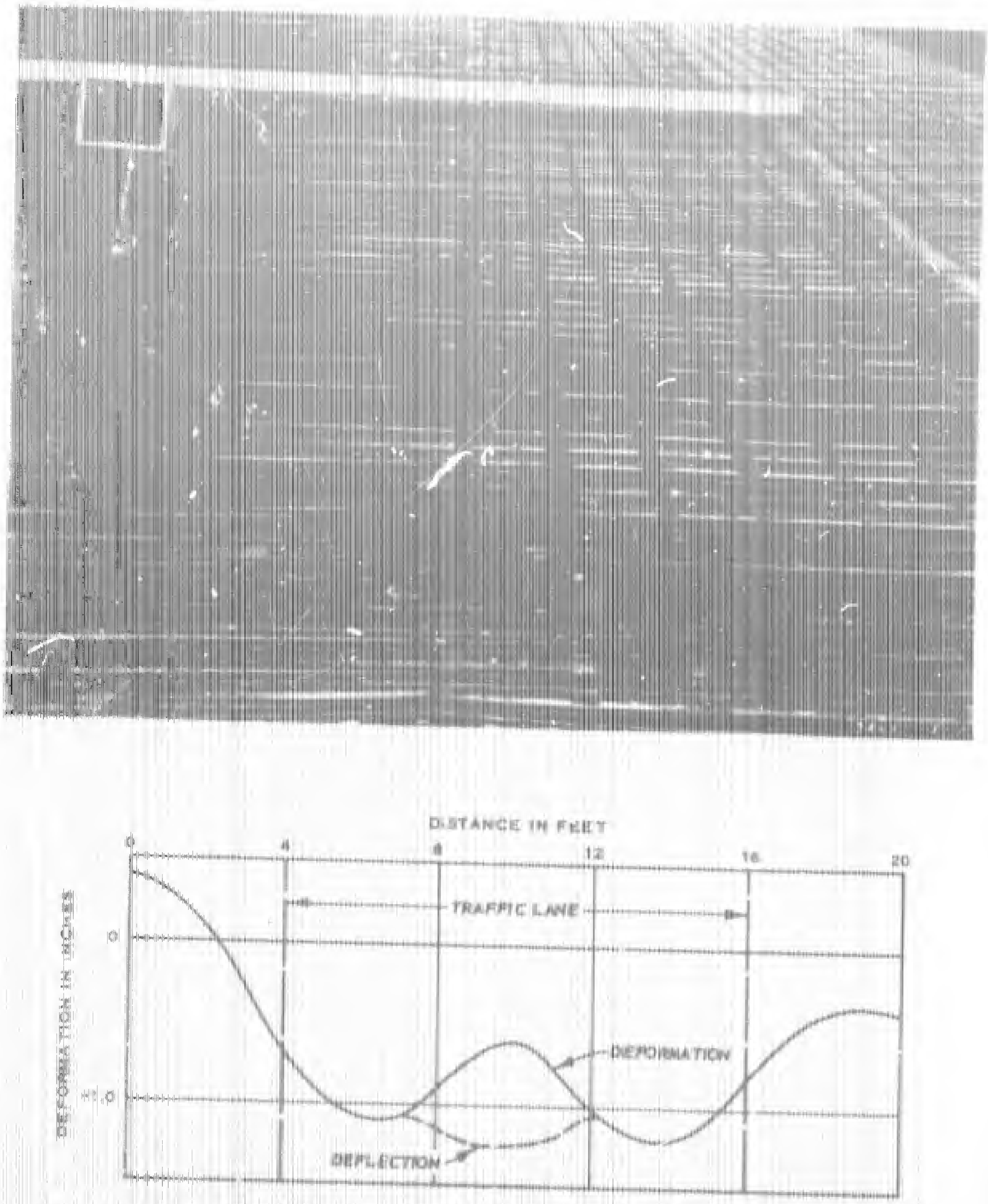
Photograph 3. Typical overlapping edge breaks adjacent to an end joint



Photograph 4. Typical break at the side locking lug

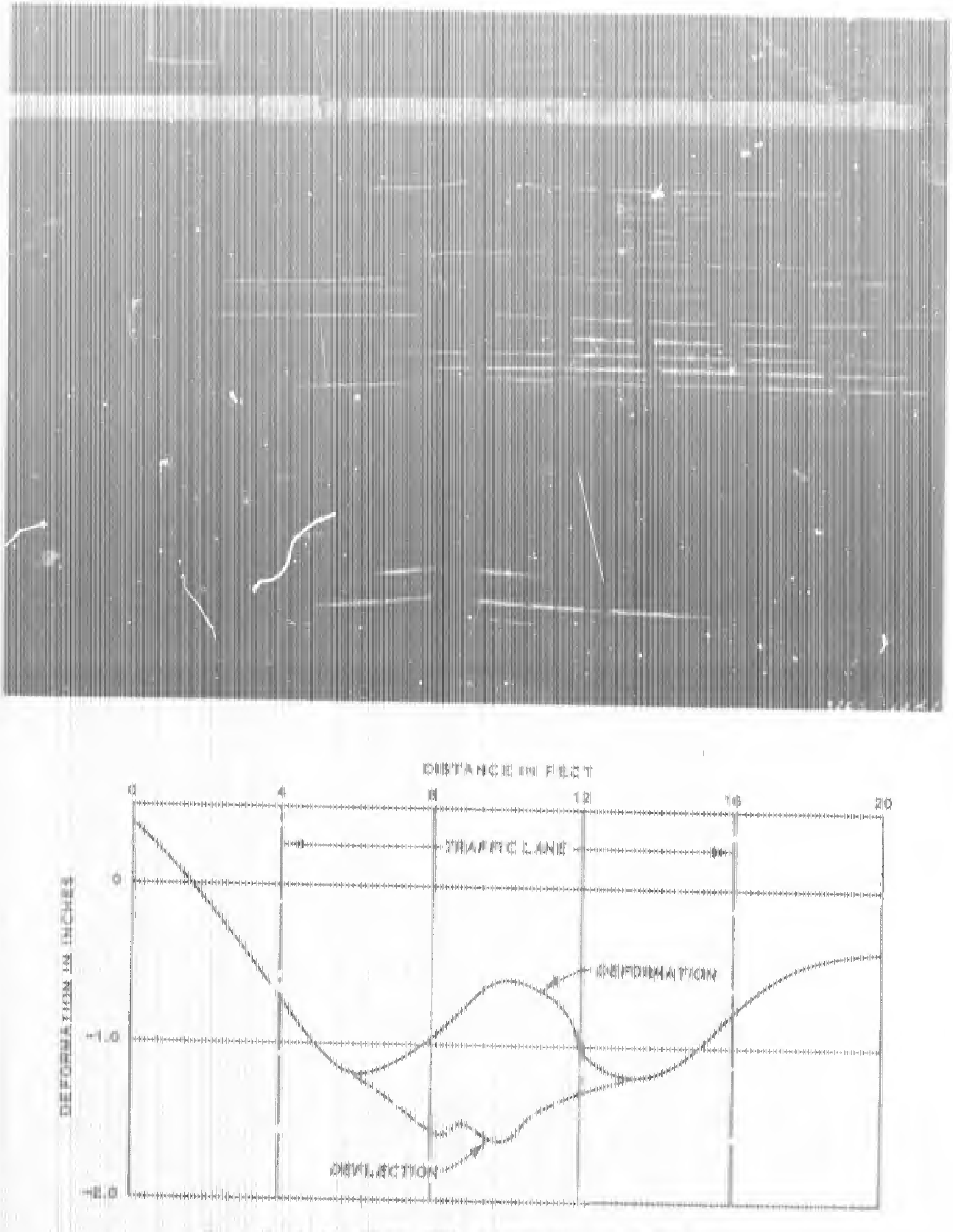


Photograph 5. Break which originated in the locking lug slot and extended into the overlapping panel



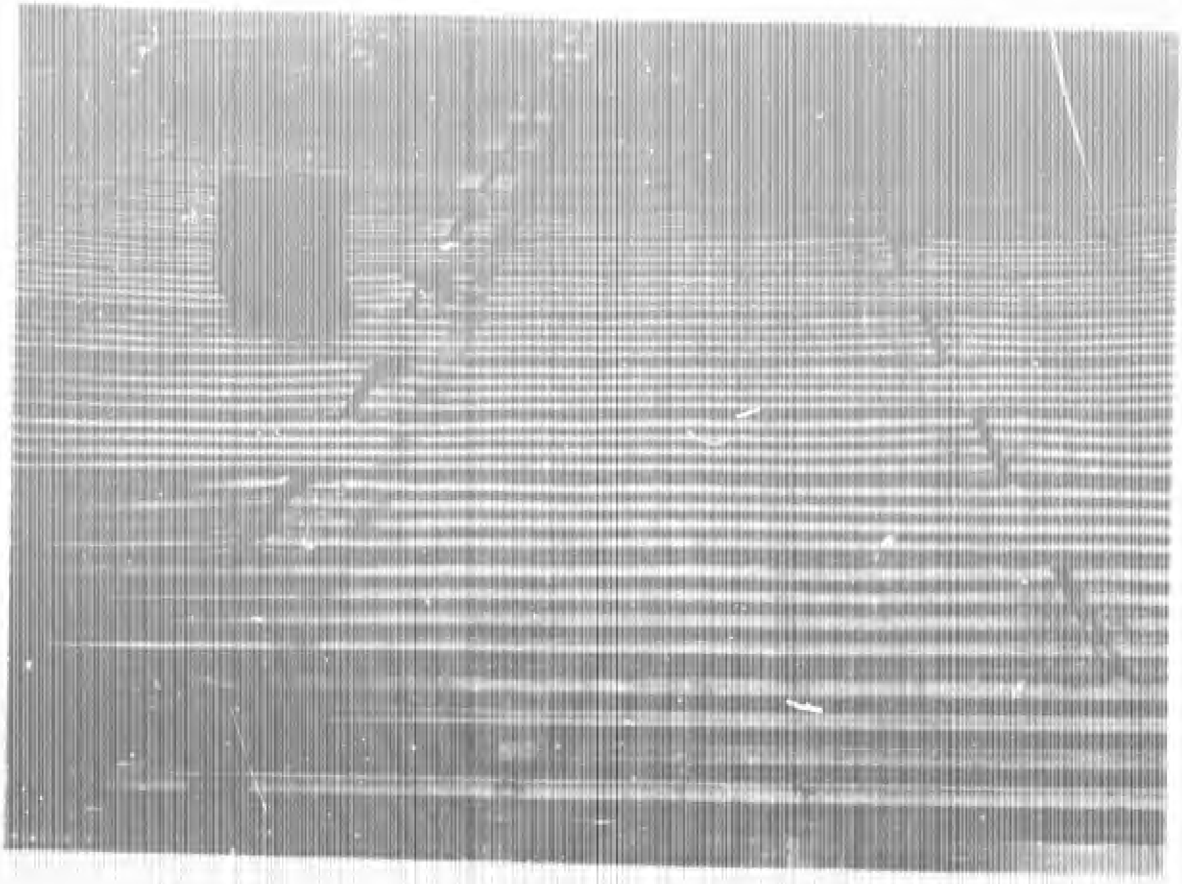
a. Test 2 after 200 coverages, before failure

Photograph 5. Typical views and plots of deformation and deflection data of test section prior to and after failure, test 2 (sheet 1 of 2)



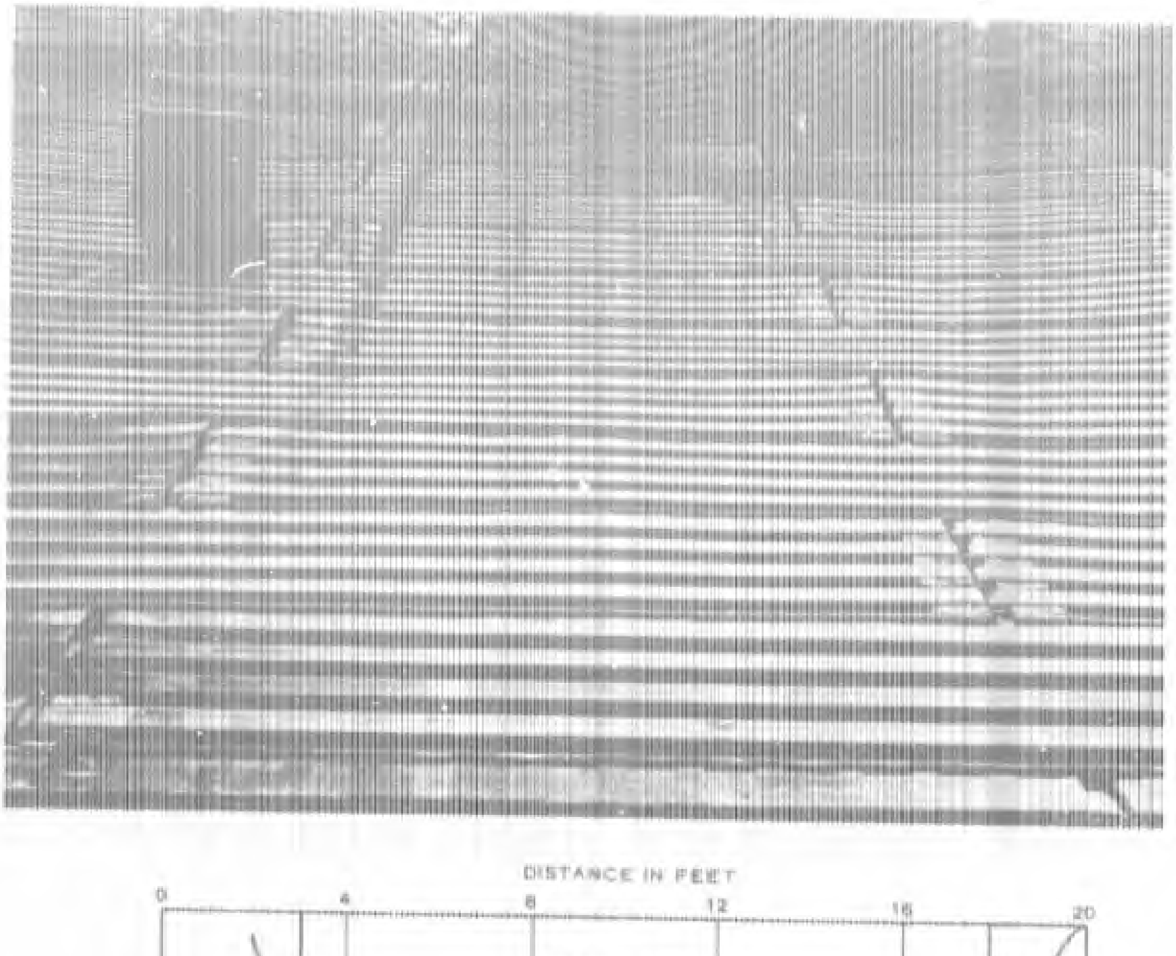
b. Test 2 after 276 coverages, at failure

Photograph 6 (sheet 2 of 2)



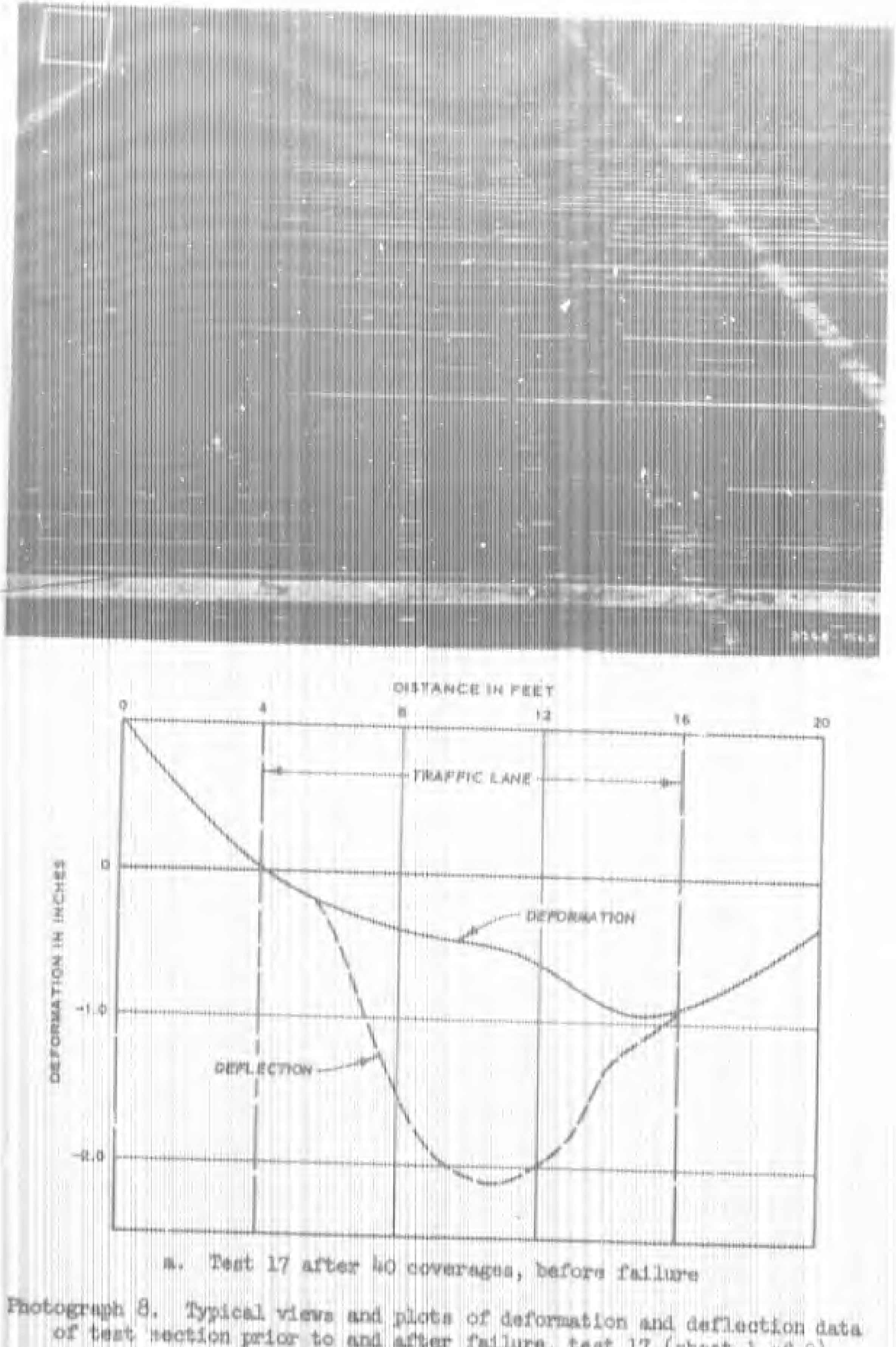
a. Test 8 after 200 coverages, before failure

Photograph 7. Typical views and plots of deformation and deflection data of test section prior to and after failure, test 8 (sheet 1 of 2)



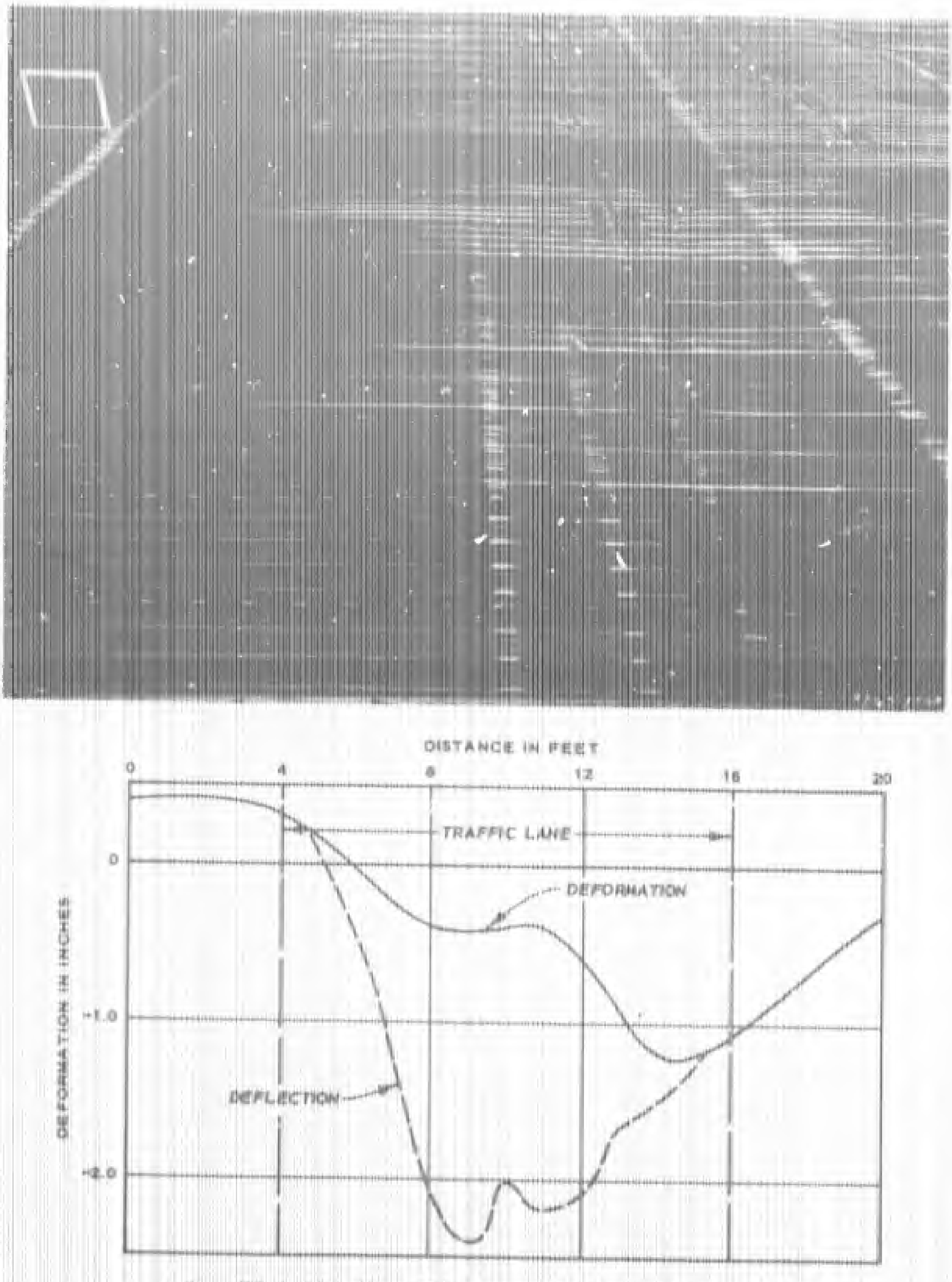
b. Test 8 after 300 coverages, at failure

Photograph 7 (sheet 2 of 2)



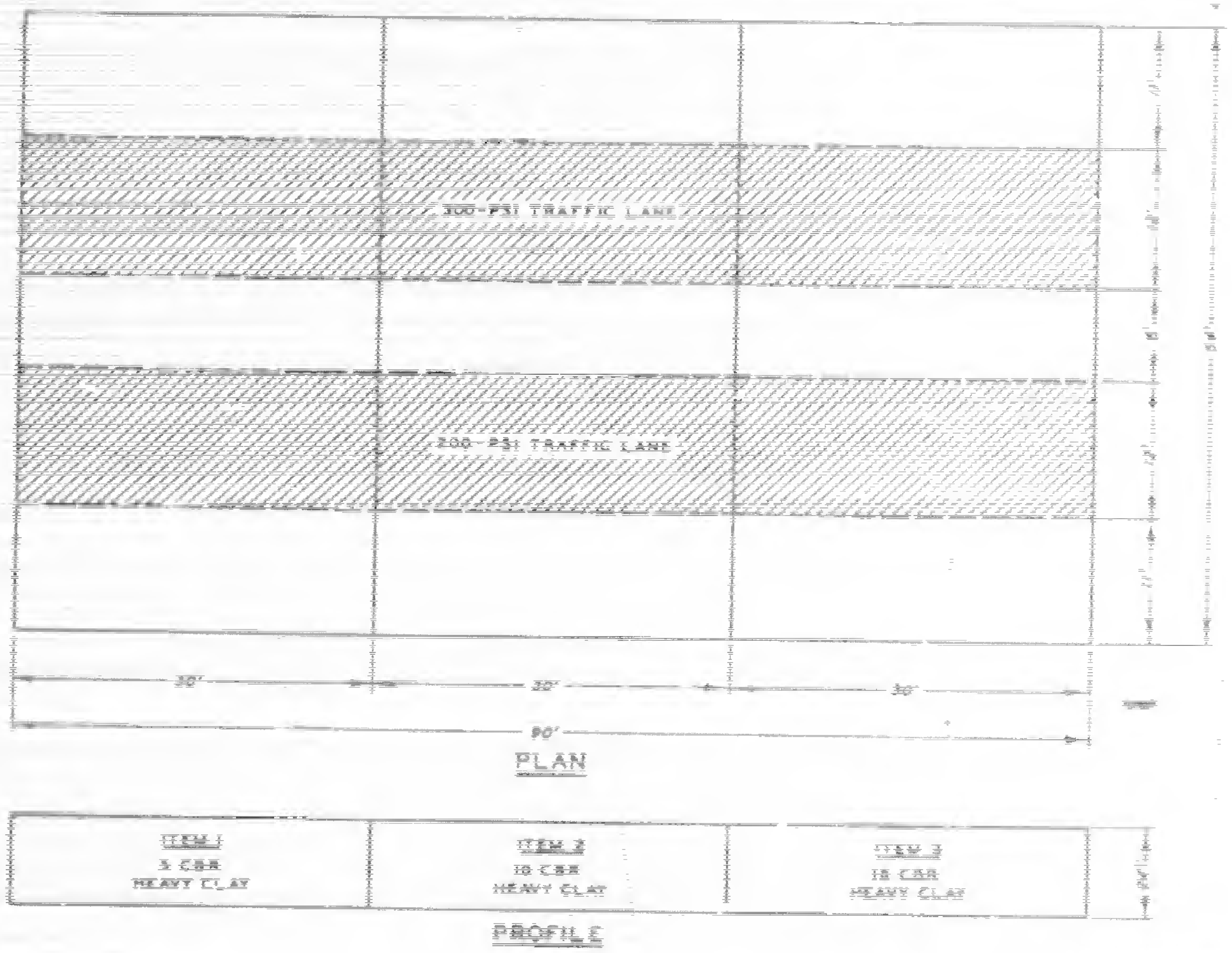
a. Test 17 after 40 coverages, before failure

Photograph 8. Typical views and plots of deformation and deflection data of test section prior to and after failure, test 17 (sheet 1 of 2)



b. Test 17 after 200 coverages, at failure

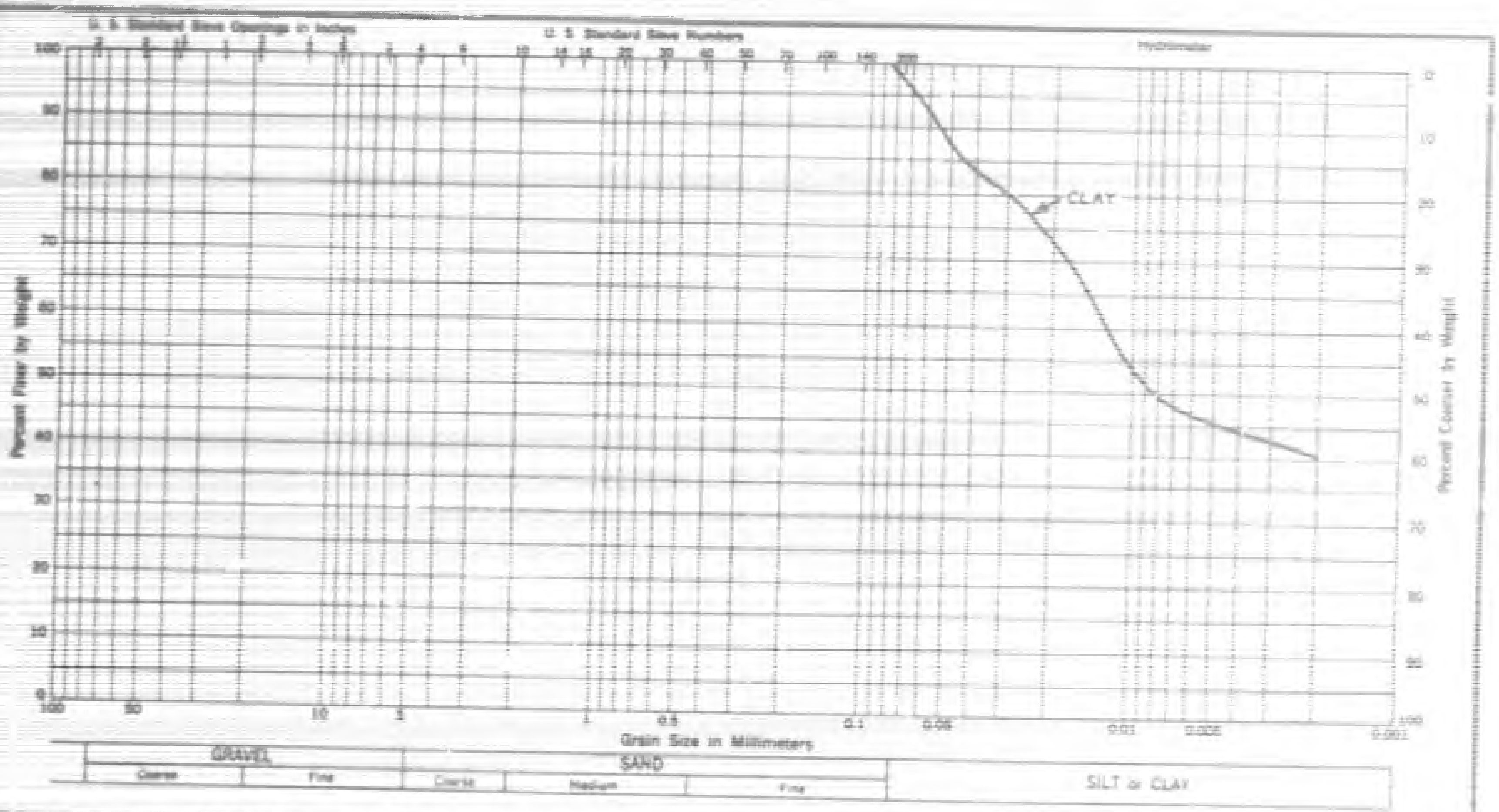
Photograph 5 (sheet 2 of 2)



LAYOUT OF
TYPICAL TEST SECTION
25,000-LB SINGLE-WHEEL LOAD

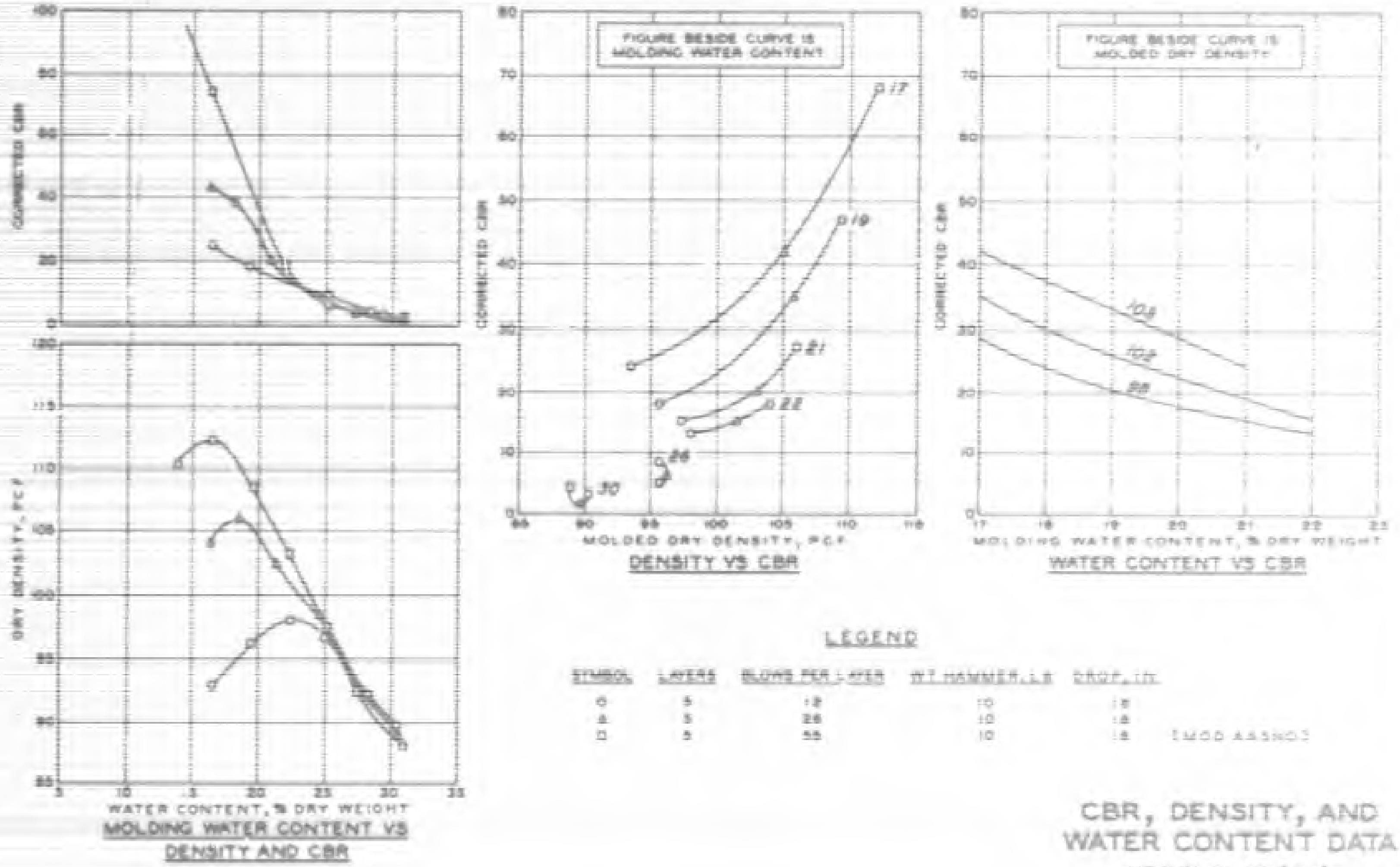
PLATE 1

PLATE 2



Number	Depth	Natural Moisture	L.L.	P.L.	P.I.	Classification
			56	23	33	HEAVY CLAY (BUCKSHOT) CH

SOIL CLASSIFICATION DATA



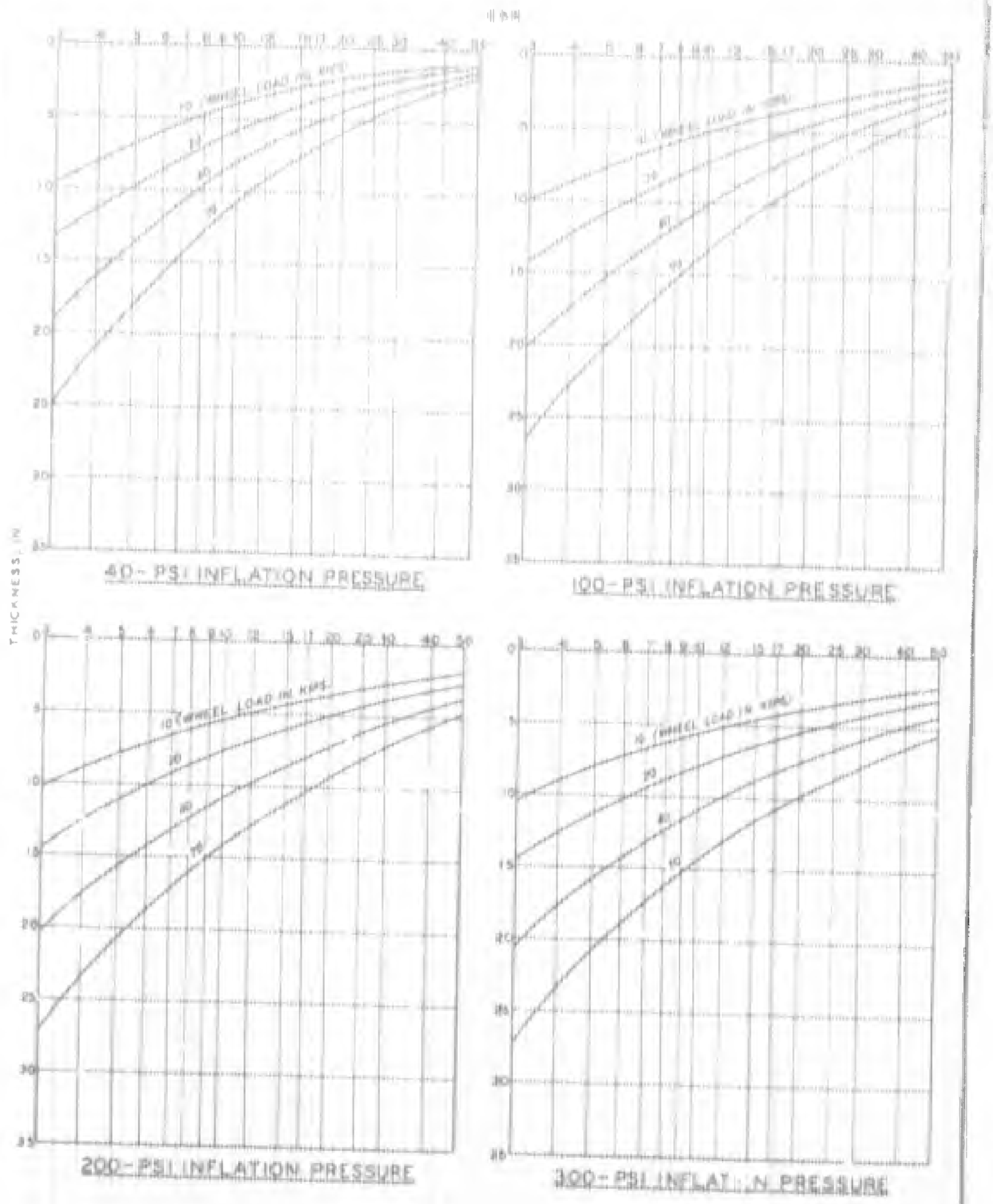
LEGEND

SYMBOL	LAYERS	BLOWS PER LAYER	WT HAMMER, LB	DROP, IN.	
○	5	12	10	18	
△	5	26	10	18	
□	5	55	10	18	(MOD AASHO)

CBR, DENSITY, AND WATER CONTENT DATA

HEAVY CLAY (CH)
(UNSOAKED)

012-83 C



40-PSI INFLATION PRESSURE

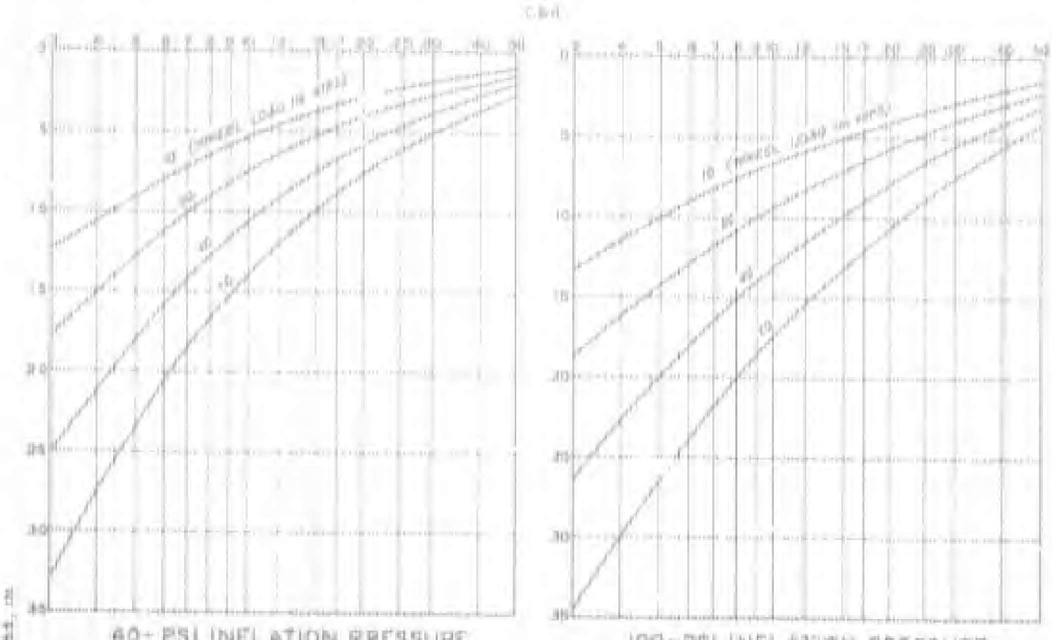
100-PSI INFLATION PRESSURE

200-PSI INFLATION PRESSURE

300-PSI INFLATION PRESSURE

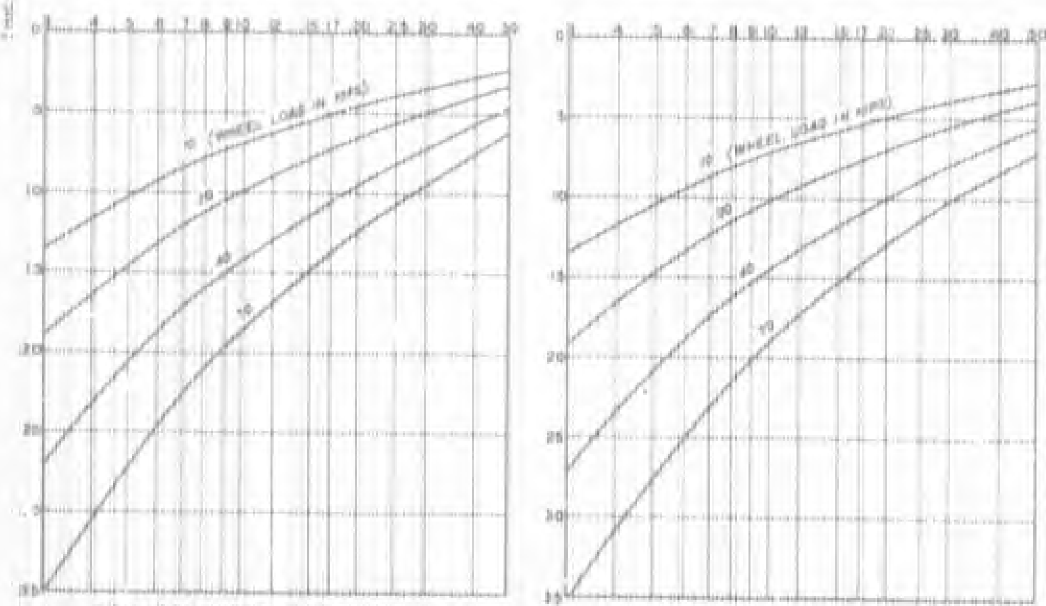
FLEXIBLE PAVEMENT
DESIGN CURVES
SINGLE WHEEL
EMERGENCY
OPERATIONAL CATEGORY

PLATE 4



40- PSI INFLATION PRESSURE

100-PSI INFLATION PRESSURE

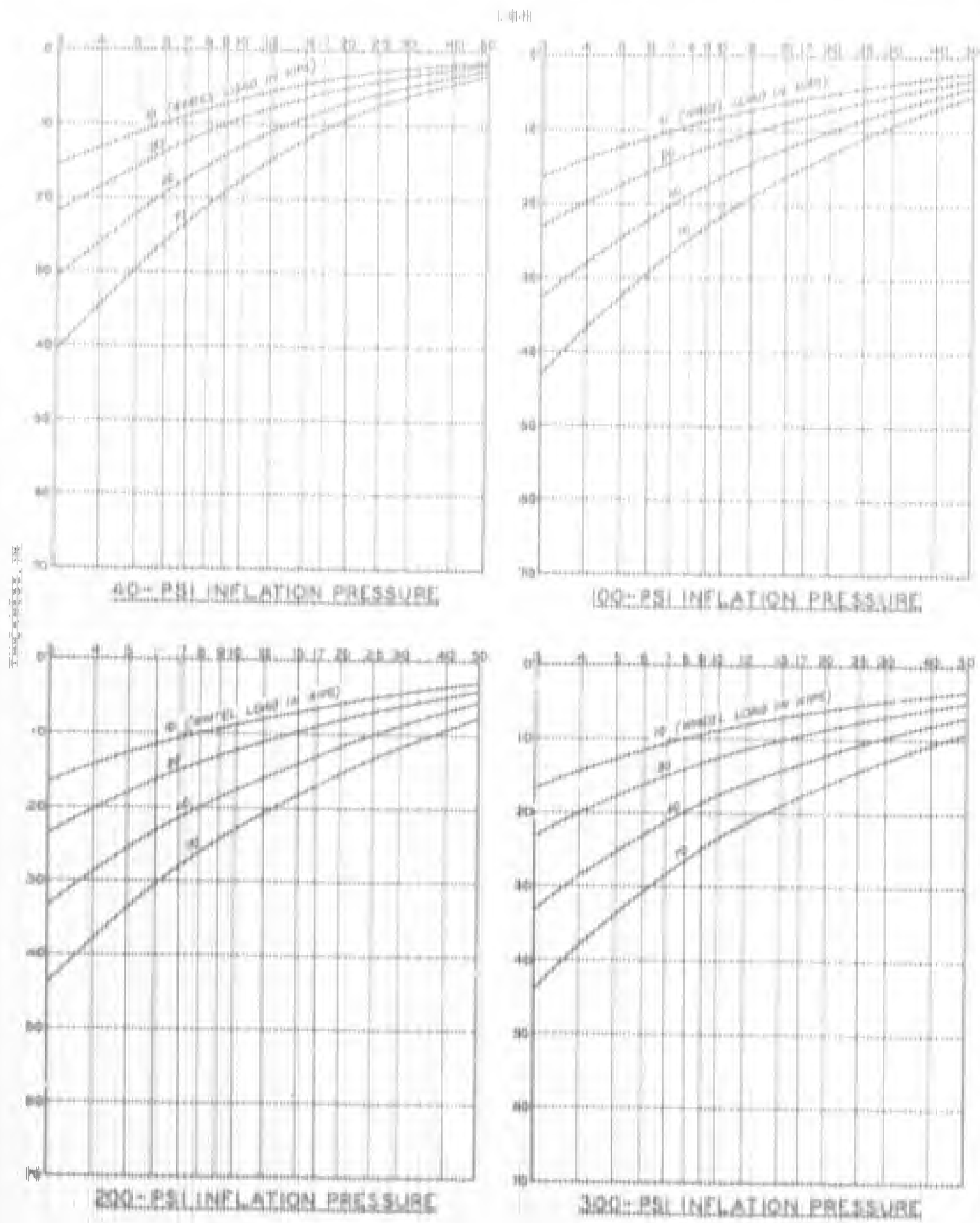


200-PSI INFLATION PRESSURE

300-PSI INFLATION PRESSURE

FLEXIBLE PAVEMENT
DESIGN CURVES
SINGLE WHEEL
MINIMUM
OPERATIONAL CATEGORY

PLATE 5



40- PSI INFLATION PRESSURE

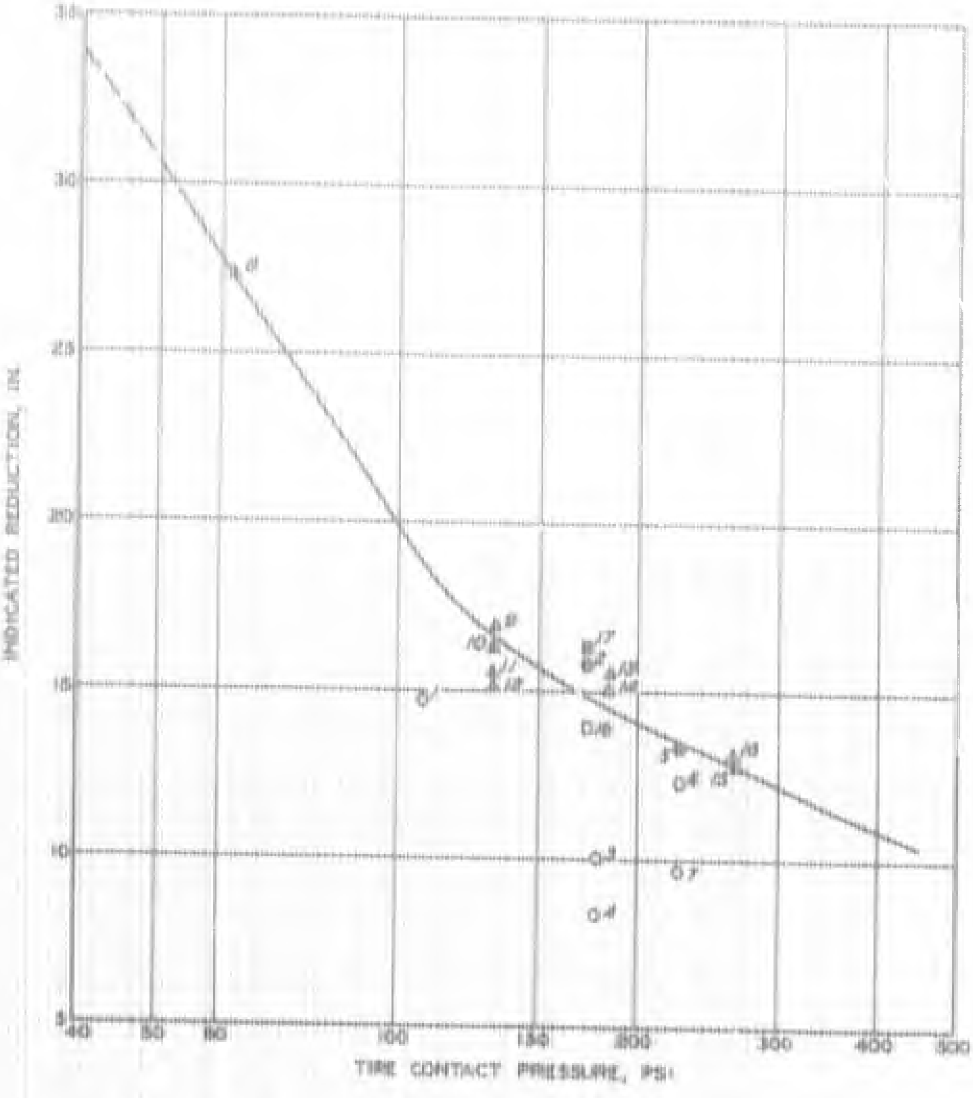
100- PSI INFLATION PRESSURE

200- PSI INFLATION PRESSURE

300- PSI INFLATION PRESSURE

FLEXIBLE PAVEMENT
DESIGN CURVES
SINGLE WHEEL
FULL
OPERATIONAL CATEGORY

PLATE 6



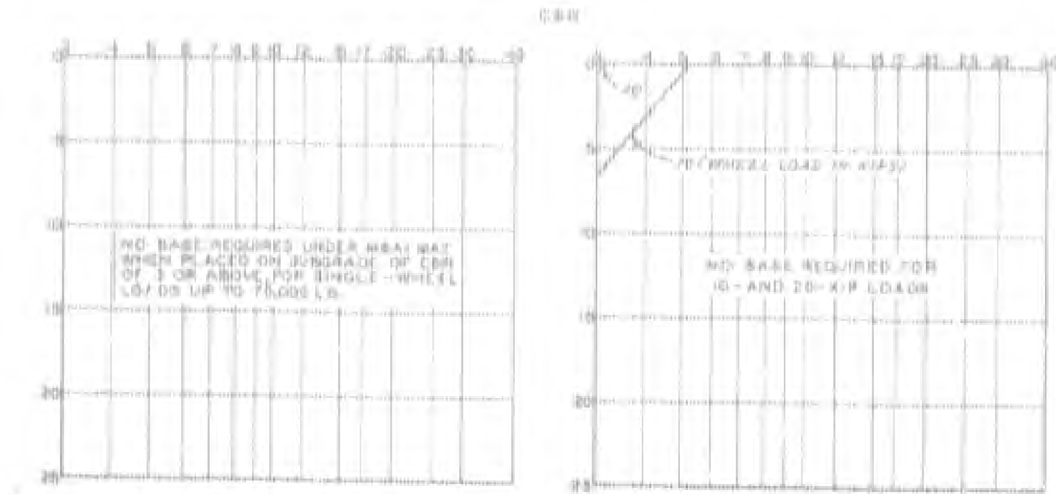
LEGEND

○ 25,000-LB SINGLE-WHEEL LOAD
△ 50,000-LB SINGLE-WHEEL LOAD
□ 50,000-LB TWIN-WHEEL LOAD

NOTE: FIGURE BY SYMBOL INDICATES TEST NUMBER. CLOSED SYMBOL INDICATES FAILURE OCCURRED. OPEN SYMBOL INDICATES NO FAILURE OCCURRED, AND A GREATER REDUCTION WOULD BE PERMISSIBLE.

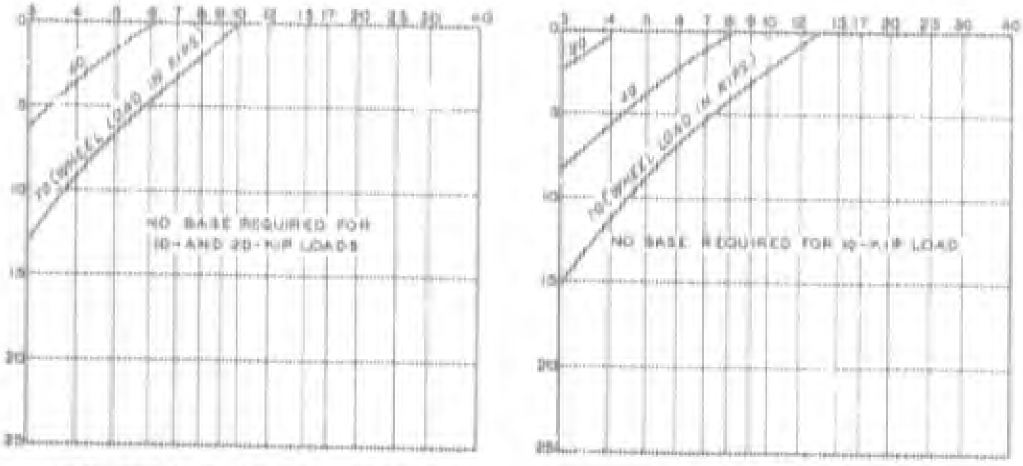
TIRE CONTACT PRESSURE VS THICKNESS REDUCTION

M8A1 MAT



40-PSI INFLATION PRESSURE

100-PSI INFLATION PRESSURE



200-PSI INFLATION PRESSURE

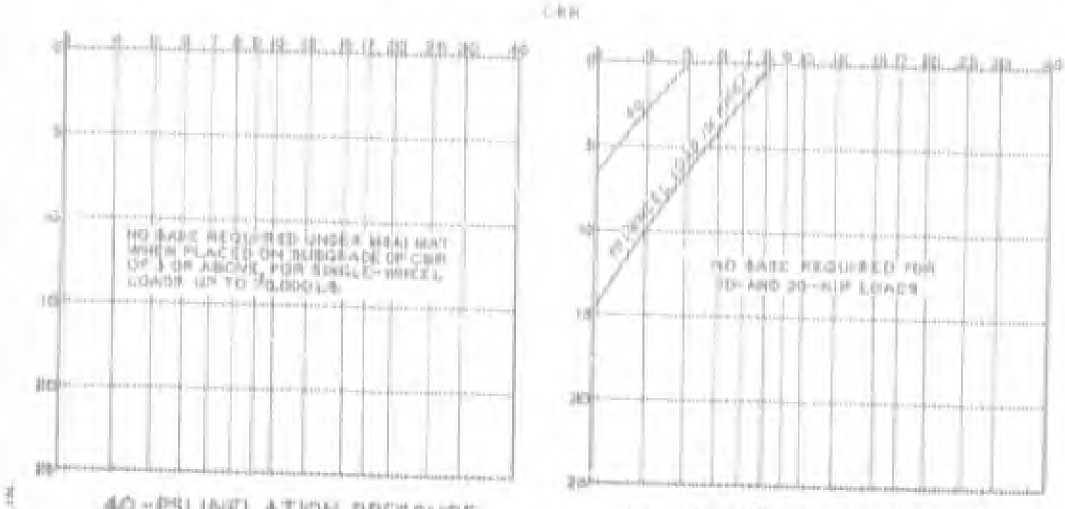
300-PSI INFLATION PRESSURE

M8A1 (0.125 IN.) LANDING MAT DESIGN CURVES

SINGLE WHEEL

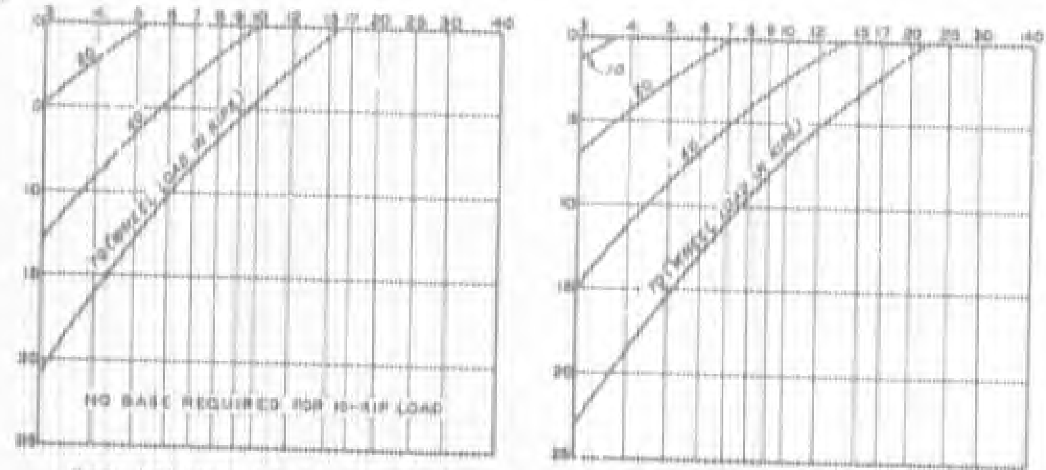
EMERGENCY
OPERATIONAL CATEGORY

PLATE 8



40-PSI INFLATION PRESSURE

100-PSI INFLATION PRESSURE



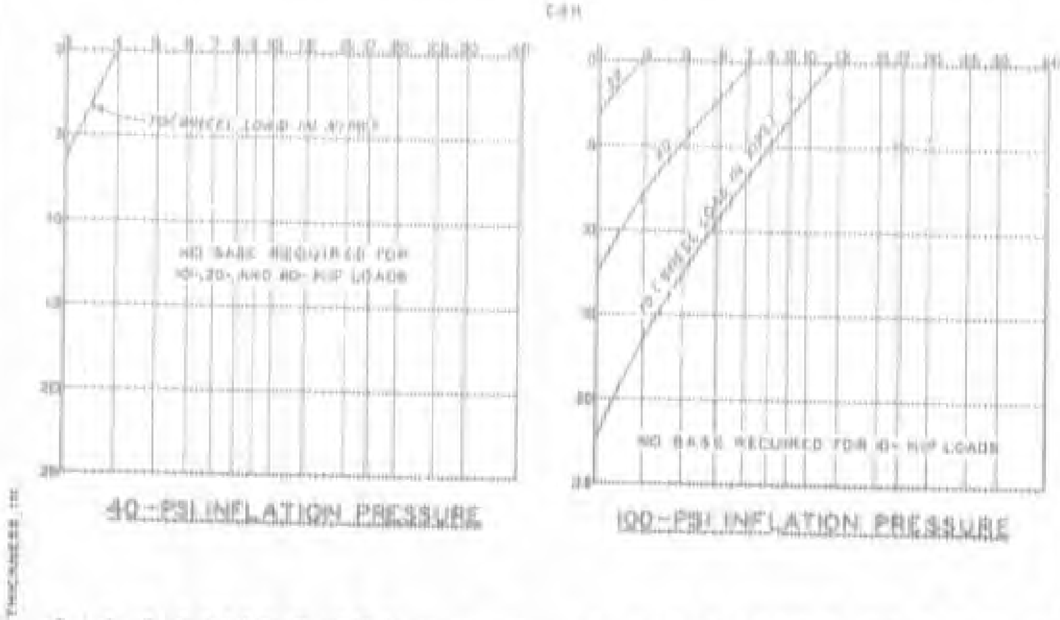
200-PSI INFLATION PRESSURE

300-PSI INFLATION PRESSURE

M8A1 (0.125 IN.) LANDING MAT DESIGN CURVES

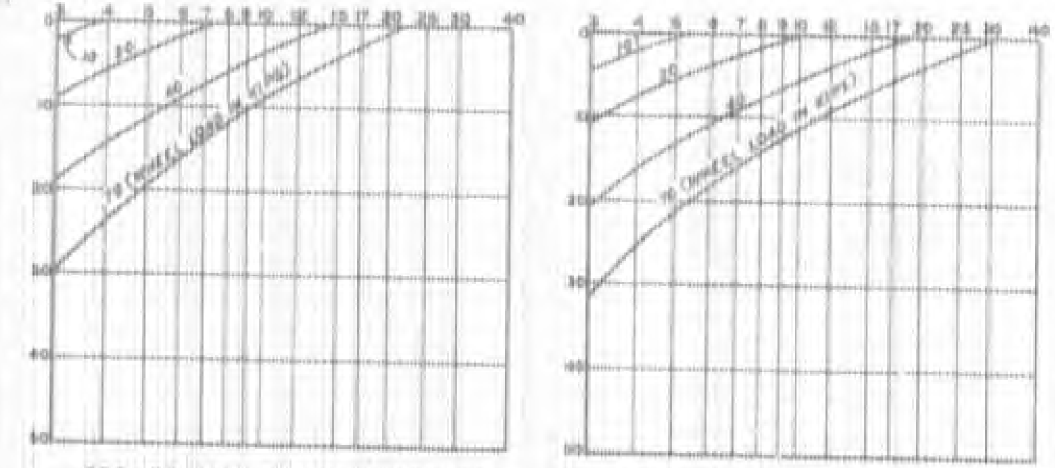
SINGLE WHEEL

MINIMUM
OPERATIONAL CATEGORY



40-PSI INFLATION PRESSURE

100-PSI INFLATION PRESSURE



200-PSI INFLATION PRESSURE

300-PSI INFLATION PRESSURE

MBAI (0.125 IN.) LANDING MAT DESIGN CURVES

SINGLE WHEEL

FULL
OPERATIONAL CATEGORY

PLATE 10

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, Mississippi

2a. REPORT SECURITY CLASSIFICATION
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DEVELOPMENT OF CBR DESIGN CURVES FOR RUNWAYS TO BE SURFACED WITH M8A1 (FORMERLY T10) STEEL LANDING MAT

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11. SUPPLEMENTARY NOTES

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13. ABSTRACT

Accelerated traffic tests, which simulated aircraft taxiing operations, were conducted on test sections constructed on subgrades of various strengths and surfaced with M8A1 (formerly T10) steel landing mat. The purpose of the tests was to obtain data on the service life of the M8A1 mat under various conditions of wheel load, tire pressure, and subgrade strength. From these data, CBR design curves for runways surfaced with M8A1 mat, similar to CBR design curves for bituminous pavements, have been developed. Operations of military aircraft with single-wheel loads ranging from 25,000 to 50,000 lb and tire pressures ranging from 60 to 300 psi and aircraft with twin-wheel assembly loads of 50,000 lb were simulated by means of a test load cart. CBR, water content, and density of the subgrade were measured before and during the traffic tests, and the condition of the test sections was recorded. Traffic was applied until the test sections failed or until it was evident that 700 coverages could be completed by the test load cart. The design curves, which were developed by correlating the M8A1 test data with flexible pavement design relations, are considered adequate for use in designing landing strips to be surfaced with M8A1 steel landing mat.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Runways						
Soil mechanics						
Subgrades						

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