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DEVELOPMENT OF CBR DESIGN CURVES FOR HARVEY ALUMINUM LANDING MAT

MISCELLANEOUS PAPER NO. 4-615

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U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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PREFACE

The investigation reported herein was authorized by the Naval Air Material Center, Philadelphia, Pa., in Project Order No. 3-4019, dated 29 October 1962. Responsibility for prosecution of the investigation was assigned to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The investigation was conducted by WES during the period October through December 1962.

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

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

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SUMMARY

This study was conducted to develop CBR design curves for an aluminum landing mat fabricated by Harvey Aluminum, Inc., Torrance, Calif. The design curves were to represent 1600 operational cycles of an aircraft having a 60,000-lb gross weight with a single-wheel main gear assembly load of 27,000 lb and a 30-7.7 tire inflated to 400 psi. CBR design curves were also desired for 1600 passes of a 39,000-lb single-wheel load applied in a single track to represent the calculated loading imposed on the landing mat during launching of the 60,000-lb aircraft by catapult.

A test section consisting of five items with different subgrade materials at different strengths and surfaced with the Harvey mat was constructed and subjected to accelerated traffic of single-wheel loads ranging from 27,000 to 39,000 lb with a 30-7.7 tire inflated to 400 psi.

It is concluded that:

a. The Harvey aluminum mat will sustain 1600 cycles (188 coverages) of aircraft operations with a 27,000-lb single-wheel load and 400-psi tire inflation pressure when placed on a subgrade having a CBR of 6.3 or greater throughout the period of traffic.

b. The Harvey aluminum mat will sustain 1600 passes of a 39,000-lb single-wheel load with tire inflation pressure of 400 psi applied in a single path when placed on a subgrade having a CBR of 7.4 or greater throughout the period of traffic, based on the equivalent-wheel-load concept described in this report. However, this concept is not a precise method of analysis, and based on (1) the mat breakage that occurred in the 39,000-lb traffic tests, and (2) the use of some judgment, it is concluded that the mat core design is borderline in ability to sustain 1600 passes of a 39,000-lb single-wheel load with tire inflation pressure of 400 psi applied in a single path, regardless of subgrade strength.

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DEVELOPMENT OF CBR DESIGN CURVES FOR HARVEY ALUMINUM LANDING MAT

PART I: INTRODUCTION

Background

1. Since August 1961 the U. S. Army Engineer Waterways Experiment Station (WES) has been engaged in a comprehensive test program for the Naval Air Material Center of evaluating various types of landing mats for use in surfacing small airfields for tactical support (SATS) in amphibious operations. A SATS has been defined as a small, quickly constructed, tactical support airfield of temporary nature, capable of handling modern jet aircraft of the Marine Corps, employing assisted takeoffs and arrested landings. The minimum operational installation must be ready for use in the objective area within the first three to five days of an amphibious assault. The runway must be capable of withstanding the heavy wheel loads of the using jet aircraft, arresting-hook impacts of aircraft making arrested landings, and heat blasts from tailpipes of jet engines during takeoffs, and it must remain serviceable with minimum maintenance for 1600 aircraft operation cycles during a 30-day period (a cycle is one takeoff and one landing). 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 gear wheel) with a 30-7.7, 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 to exceed 27,000 lb per main gear wheel. Present plans for assisted takeoffs are to employ 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, and for a given aircraft, the landing gear wheels will run in the same tracks on each takeoff. Also, a vertical load in addition to the static load of the plane will be applied during launching operations. For a 60,000-lb aircraft with 27,000-lb single-wheel static load, the Naval Air Engineering Laboratory has calculated that the effective single-wheel load on the mat during catapult launching will be about 39,000 lb.

Objectives and Scope of Investigation

2. The primary objective of this study was to develop a CBR design curve that would indicate the subgrade strength required, when the subgrade is surfaced with the aluminum landing mat fabricated by Harvey Aluminum, Inc., Torrance, Calif., to support 1600 cycles of operations of a 60,000-lb aircraft having a 27,000-lb single-wheel main gear load and 400-psi tire inflation pressure. A design curve also was desired for the 39,000-lb single-wheel load that, according to calculations, will develop during assisted takeoffs.

3. The objectives were accomplished by:

a. Constructing a test section that consisted of a range of subgrade materials and strengths, and surfacing the section with the Harvey aluminum landing mat.

b. Performing accelerated traffic tests with 27,000- to 39,000-lb single-wheel loads and 400-psi tire inflation pressure.

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

d. Observing the behavior of the mat during traffic and analyzing the test data.

4. This report describes the landing mat, test section, tests, and results obtained, and includes the analysis of the data and the CBR design curves developed therefrom.

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

Test Section

Location

5. All traffic 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

6. The test section, a layout of which is shown in plate 1, consisted of five test items, each approximately 24 ft wide and 30 ft long. Items 1-3 were constructed of a heavy clay soil, item 4 of an uncompacted crushed rock (limestone), and item 5 of a loose sand. Classification data for the subgrade soils are shown in plate 2.

7. This test section had initially been constructed and used for traffic test on the Butler mat (designated AM1). At the end of the AM1 mat tests, in-place CBR tests made in each item of the test section showed some increase in strength over the as-constructed strength in all test items, with a considerable increase in strength in items 4 and 5. However, it was concluded that the test section retained a sufficient range of subgrade strength to provide the necessary data for evaluating the Harvey mat. Therefore, to expedite the tests on the Harvey mat, the same subgrades were used. The surfaces of items 1-3 of the test section were quite smooth at the end of tests on the AM1 mat and required little or no preparation for laying the Harvey mat. However, there was some rutting and settlement in items 4 and 5 (limestone and sand subgrades) from the previous traffic. Therefore, a sufficient quantity of new material was added in these items to provide a level surface at the original elevation of the test section prior to placing the Harvey mat. A complete description of the subgrade materials and the construction of the subgrades is given in WES Miscellaneous Paper No. 4-599, Development of CBR Design Curves for AM1 Landing Mat, dated September 1963.

Mat

Description

8. The Harvey aluminum landing mat planks were made with a single

extrusion. Full-size planks are 11.98 ft long and 2.05 ft wide, with average thickness of 1.44 in.; the average weight of a full plank is about 143 lb. Fig. 1 shows a full and a half plank with the end-connecting rod.

Fig. 1. Harvey aluminum landing mat

Placement procedures

9. The Harvey mat was placed on the test section by a crew of seven experienced laborers working under the supervision of a foreman. The mat bundles were placed alongside the test section by a forklift, and the laborers carried the individual mats about 30 ft into place. One laborer placed the end-connecting rods. No difficulties were encountered during the laying operation. The laying speed, based on eight men and including opening the bundles, carrying the mat into position, and placing connecting rods, was approximately 225 sq ft per man-hour.

10. The entire test section was surfaced with the Harvey mat placed perpendicular to the center line of the test section to provide a surfaced width of 24 ft (plate 1). Views of the test section before and after placement of the mat are shown in photographs 1 and 2, respectively. Fifteen runs of mat were used in surfacing each test item, or a total of 75 runs for the entire test section (plate 3). As seen in photograph 2, the mat was laid with the end joints staggered. This was achieved by alternating runs of mat consisting of two whole planks with runs consisting of one whole and two half planks.

Test Load Cart

11. A specially designed single-wheel test cart, which can be loaded to provide single-wheel loads up to 39,000 lb, was used in the traffic tests (see fig. 2). It was fitted with an outrigger wheel (not visible in

Fig. 2. Test cart with 27,000-lb single-wheel load with tire inflated to 400 psi

fig. 2) to prevent overturning and was powered by the front half of a four-wheel-drive truck. The load cart wheel was equipped with a 30-7.7, 18-ply tire, inflated to 400 psi. For the 27,000-lb load, the tire contact area was about 82 sq in., and the average contact pressure 330 psi; for the 39,000-lb load, the tire contact area was about 103 sq in., and the average contact pressure about 378 psi.

PART III: TESTS AND RESULTS

Traffic Tests

Uniform-coverage traffic

12. A statistical study of aircraft landings on a 78-ft-wide runway by the Marine Corps Equipment Board* indicated that with a probability of 100 percent, a main landing gear wheel path would not vary more than 25 ft laterally from the runway center line. For about 90 percent of the landings, the main gear load was fairly evenly distributed over a 10-ft width. For the uniform-coverage traffic tests reported herein, it was assumed that in traversing the runway 100 percent of the main gear load operations of the design aircraft would be evenly distributed over about a 10-ft width of runway, which may be slightly conservative based on the statistical landings referenced above. However, for test purposes this assumption was considered reasonable. Therefore, a 10-ft-wide traffic lane was laid out down the center of the test section. Traffic was applied by driving the load cart first forward and then backward the length of the test section, shifting the path of the cart laterally about 7.3 in. on each successive forward pass. This procedure resulted in two complete coverages each time the load cart maneuvered from one side of the traffic lane to the other.

13. The objective of this test was to develop a CBR design curve for 1600 cycles of aircraft operations. As stated earlier, one aircraft cycle comprises one takeoff and one landing; therefore, 1600 cycles are equivalent to 3200 passes of the load wheel. For tests with the 27,000-lb single-wheel load, 3200 passes of the load wheel were evenly distributed over the 10-ft-wide traffic lane. Since the tire print was 7.3 in. wide, about 17 passes were required to obtain one complete coverage of the 10-ft-wide traffic lane, and 3200 passes resulted in 188 coverages.

Single-track traffic

14. 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

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* Marine Corps Equipment Board, Small Airfield for Tactical Support (SATS) Concept, Second Interim Report, Project No. 51-58-01 (Quantico, Va., 5 March 1960).

given type of aircraft will run in the same path during each takeoff and an added vertical load will be imposed on the mat in addition to the static load of the aircraft. It has been calculated that during the catapult launching of a 60,000-lb aircraft, this single-wheel load may be as much as 39,000 lb. To simulate 1600 cycles of such aircraft operations (in which 1600 launchings would be required), traffic was applied in a single path with the single-wheel test cart.

15. The primary objective of this test was to determine the minimum subgrade strength required, when the subgrade is surfaced with the Harvey mat, to sustain 1600 passes of a 39,000-lb single-wheel load with 400-psi tire pressure. In accordance with instructions from the Naval Air Engineering Laboratory (NAEL), the single-track traffic was initiated with 600 passes of a 27,000-lb single-wheel load, followed by 600 passes of a 30,000-lb load, 300 passes of a 33,000-lb load, 300 passes of a 36,000-lb load, and finally, a sufficient number of passes of a 39,000-lb load to induce failure or to provide a total number of passes of the mixed loads that would be approximately equivalent to 1600 passes of a 39,000-lb single-wheel load. By use of the CBR equation,* the proposed passes of the various wheel loads of less than 39,000 lb were converted to equivalent passes of a 39,000-lb wheel load. A summary of the traffic load schedule is given below.

Actual Load lb	Actual Passes of Test Load	Equivalent Passes of 39,000-lb Load	Equivalent Accumulative Passes of 39,000-lb Load
27,000	600	185	185
30,000	600	252	437
33,000	300	177	614
36,000	300	226	840
39,000	760	760	1600

This schedule of staggered loads was designed to provide more specific information on the load-carrying capabilities of the mat in the event that mat failure occurred prior to the end of the scheduled trafficking.

16. In the application of traffic, the load cart was driven forward and backward in the same track. The center line of the traffic path was

* U. S. Army Engineer Waterways Experiment Station, CE, Development of Set of CBR Design Curves, Instruction Report No. 4 (Vicksburg, Miss., November 1959).

located 2 ft outside the uniform-coverage traffic lane and 5 ft from the outside edge of the test section, as shown in plate 1. The traffic path was also about 1 ft from an end joint on every other run of mat.

Soils Tests and Miscellaneous Observations

17. Water content, density, and in-place CBR tests were conducted prior to and at various stages during traffic in each test item. Data obtained are summarized in tables 1 and 2 for the 27,000-lb uniform-coverage traffic and the 27,000- through 39,000-lb single-track traffic, respectively. In general, these tests were made at depths of 0, 6, 12, and 18 in. in the clay and sand items, and on the surface only in the limestone item. At least three tests were made at each depth, and the values listed in tables 1 and 2 are the averages of the values measured at each particular depth. Plate 3 shows the test section plan and the location and number of each test pit. The same test pit numbers are used in tables 1 and 2.

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, and permanent deformation and deflection of the mat under the wheel load.

Behavior of Mat Under Traffic

Failure criteria

19. The criteria for failure of the Harvey mat were essentially the same as those used for the M9M2 mat, as reported in WES Miscellaneous Paper No. 4-501, Development of CBR Design Curve for M9M2 Landing Mat, dated June 1962. However, some slight modifications had to be made because of the differences in the design and performance of the Harvey mat. The failure criteria used for the Harvey mat were based on the following:

a. Excessive mat breakage.

(1) End-joint failures.

(2) Core failures.

b. Deflection (1 in. maximum).

20. It was assumed that a certain amount of maintenance would be performed in the field during actual usage, and that short weld breaks, overlapping corner breaks, etc., could be repaired rather easily. However, when an end-connector joint sheared off or a mat core failed completely, the mat plank would be considered failed and should be replaced. Partial core failures did not result in an unserviceable plank immediately, but in some cases the failures progressed to the point where the plank was considered unserviceable. It was considered feasible to replace up to 10 percent of the mat with new planks during the design service life of the runway. For replacement of more than 10 percent of the planks, the maintenance effort would be excessive. Therefore, for the test section, it was assumed that up to 10 percent of the mat planks could be replaced; when an additional 10 percent (a total of 20 percent) of the planks had failed, the entire item was considered failed.

21. The deflection criterion of 1 in. maximum is based on previous experience in mat testing in which it has been observed that deflections in excess of 1 in. cause the mat to break up at a rapid rate and also create a high rolling resistance.

22. The degree of roughness is also normally used in judging failures; however, it was not pertinent in this study since the surface remained quite smooth throughout the period of traffic, except when a failure occurred.

27,000-lb uniform-coverage traffic

23. Mat performance. The Harvey aluminum mat performed very well under the uniform-coverage traffic of the 27,000-lb single-wheel load. All test items withstood the full 188 coverages and were considered to be satisfactory at the end of the test. However, some distress developed in test item 1, which had the weakest subgrade. In this item considerable flexing and slight end curling of the mat were noted throughout the traffic period. Mat failure developed in one plank of run 10 in item 1; this failure started with a partial core failure after about 132 coverages of traffic. As traffic continued, a noticeable depression developed in the mat plank, and by the end of 188 coverages, the end-connector joint had sheared off, as shown in fig. 3. At the end of traffic this failed plank was sawed

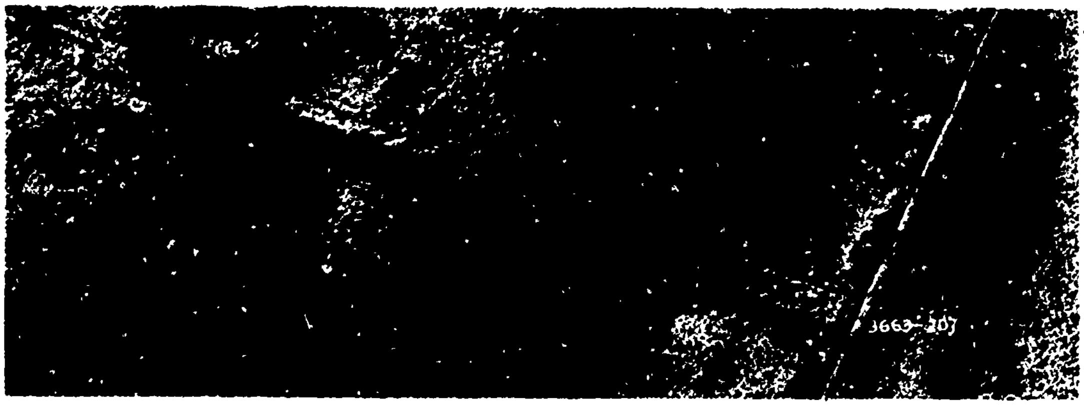
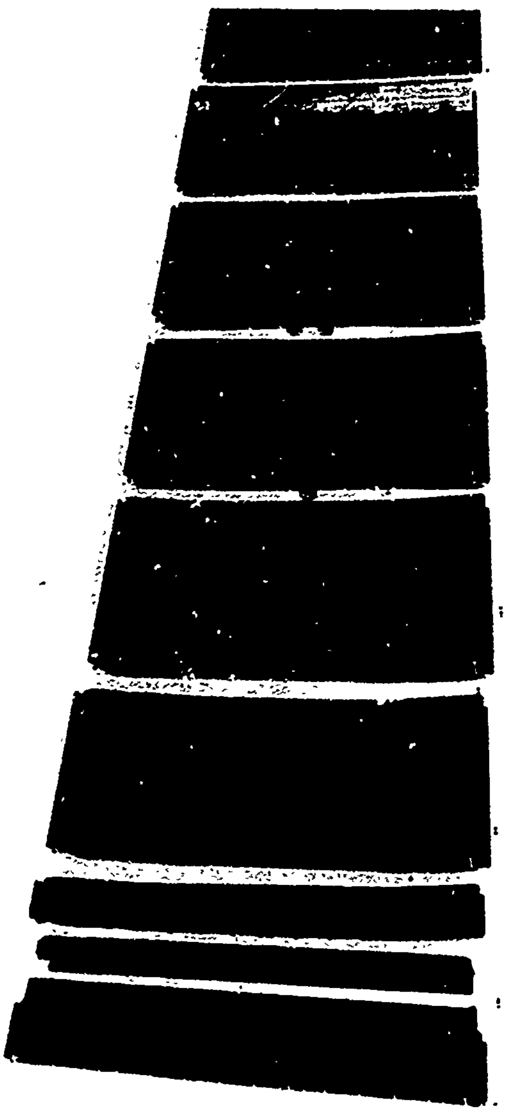


Fig. 3. Sheared end-connector joint in test item 1 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)



in sections to observe the extent of the core failure (see fig. 4). Close-ups of the core failure and the sheared end joint are shown in fig. 5. Minor breaks were noted in three other mat planks in item 1 at the end of traffic. However, these breaks had not progressed far enough to affect the performance of the mat. Items 2-5 remained in excellent condition throughout the period of traffic, with no evidence of distress. General views of items 1-5 after 188 coverages are shown in photographs 3-7.

24. Permanent deformation. Plots showing permanent deformation of the mat as determined from level readings taken prior to and at the end of uniform-coverage traffic are shown in plate 4. Since the mat was

Fig. 4. Sawed plank showing core failure

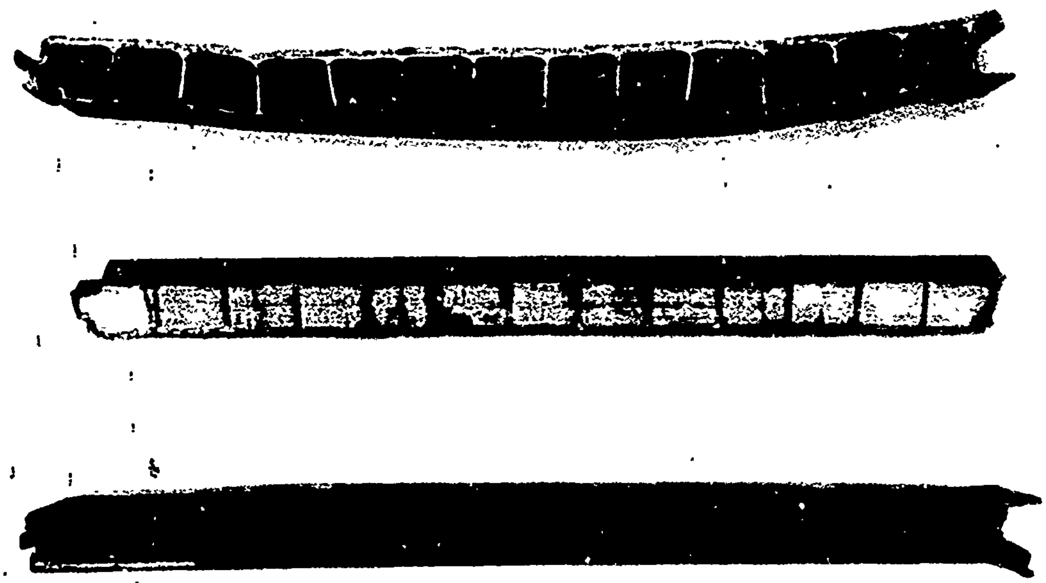


Fig. 5. Close-up of core failure and end-joint failure

laid in a staggered pattern, every other run of mat consisted of two whole planks with an end joint located on the center line of the traffic lane. The adjacent runs consisted of two half planks, one on each side of the lane, with a whole panel in the center so that the center of the plank was located on the center line of the traffic lane. Plate 4 shows average cross sections for both conditions for each item of the test lane. These data indicate that the deformation across the traffic lane is generally about the same, regardless of where the joint is located. From plate 4 it can also be noted that the permanent deformation in items 1-3, the clay subgrade items, was about the same in all three items, and did not exceed 1/2 in. The greatest deformation occurred in test item 4, the limestone subgrade, and the least deformation in item 5, the sand subgrade. It should be pointed out that the sand subgrade used in these tests had been highly densified in prior tests on the Butler AM1 mat and had a relatively high strength at the start of traffic, as indicated in table 1. Therefore, the performance of the Harvey mat on the sand subgrade was much better than could be expected if the mat is placed on a loose, uncompacted sand.

25. Center-line profiles illustrating deformation of the mat down the center of each test item are shown in plate 5. These profiles show slight deviations in deformation among the various test items. However,

the surface grade remained quite smooth throughout the traffic period.

26. Elastic deflection. Deflections of the mat surface under load, determined from level readings, are shown in plate 6 indicating the elastic deflection or rebound of the mat as the wheel load moved over the surface. Deflections are shown for three mat plank locations in each test item: at an end joint, at the center point, and at a quarter point. Data are shown for deflections at the start of traffic (0 coverages) and at the end of traffic (188 coverages). From these data no consistent difference is apparent in mat deflection in relation to the point of load, i.e. on the joint, center of plank, or quarter point. The magnitude of the deflection was about the same in all test items and generally less than 1 in. Also, there was only a slight increase in deflection during the traffic period.

Single-track traffic

27. As stated previously, the single-track traffic was applied with a range of specific single-wheel loads varying from 27,000 to 39,000 lb. The behavior of the mat under the various wheel loads is discussed in the following paragraphs.

28. 27,000-lb load. A total of 600 passes of the 27,000-lb single-wheel load applied in a single path resulted in no apparent damage to the mat in any of the test items. There was no mat breakage, and the surface of the mat remained smooth throughout this phase of traffic. However, considerable flexing or canting of the mat was noted in item 1 (which had the weakest subgrade) as the load wheel traversed the surface.

29. 30,000-lb load. A total of 600 passes of the 30,000-lb single-wheel load applied in the same path as that used for the 27,000-lb traffic resulted in no apparent damage to the mat in items 2-4. However, between 400 and 500 passes of the load wheel, a slight depression was noted in four mat planks in item 1 and in one plank in item 5. By the end of 600 passes, the magnitude of the depressions had increased in all five planks. The maximum depression was about 0.35 in. in mat run 6 of item 1, near the center of the panel (see fig. 6). Occurrence of these depressions indicated that the mat core was shearing and collapsing under the load. To observe the condition of the mat core, the p[illegible]n in fig. 6 was removed and sawed through the depressed area. The [illegible]ed members of the core can be seen in fig. 7. In addition to the core failure, one end-joint

Fig. 6. Depression of 0.35 in. in mat plank, indicating core failure

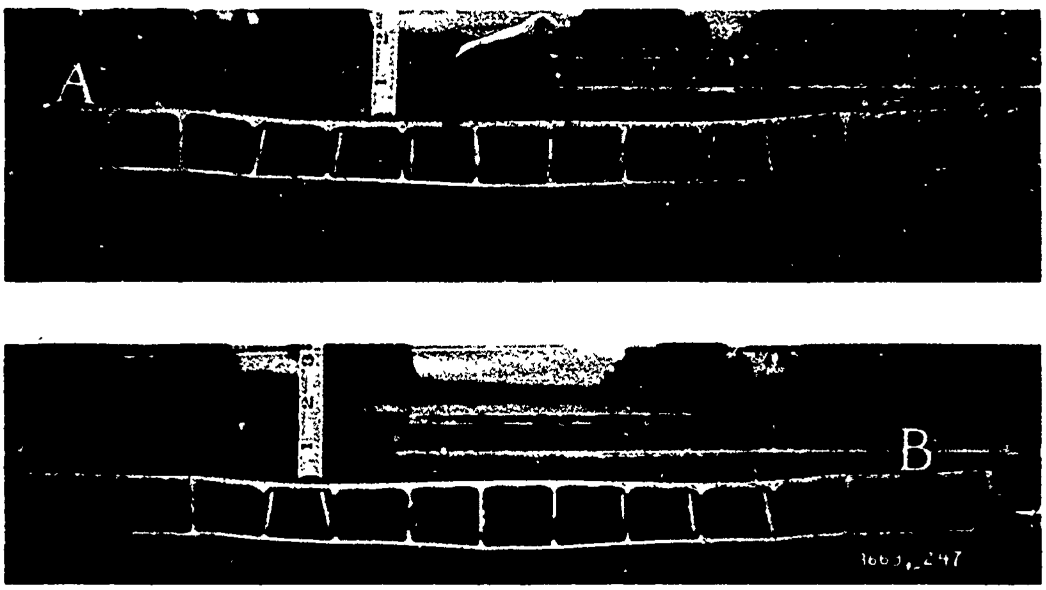


Fig. 7. Sawed section through depressed area, showing core failure

failure developed in item 1 at about the end of the 600 passes of the 30,000-lb load (see fig. 8). This plank was removed and replaced with a new mat. Considerable flexing or canting of the mat continued throughout the traffic period.

30. The mat plank in item 5 which developed a slight depression under the 30,000-lb load was located in mat run 64. This run had been laid

Fig. 8. End-joint failure in test item 1 after 600 passes of 30,000-lb single-wheel load (single-track traffic)

over test pit 16 (see plate 3) which had been excavated for CBR tests prior to start of the single-track traffic. The test pit had been backfilled with loose sand with very little compaction. Thus, the initial strength of the subgrade under this plank at the start of the single-track traffic was probably much less than that under the adjacent planks. As discussed previously, the sand subgrade had consolidated appreciably under the initial traffic test on the AM1 mat and had developed a relatively high strength. The measured CBR of the sand in the single-track traffic path prior to traffic on the Harvey mat was about 15.

31. At the end of the 30,000-lb single-wheel load traffic, all mat in item 5 was in excellent condition except for the depression in the mat plank in run 64, and indications were that the mat would sustain 1600 passes of a 39,000-lb single-wheel load with no difficulty when placed over sand with an initial CBR of 15 or greater. However, the NAEL wished to know the capability of the mat to support the 39,000-lb single-wheel load when placed over a loose, uncompacted sand. Therefore, at the request of NAEL, the mat on the sand subgrade was removed at the end of the 30,000-lb load traffic, the sand was loosened to a depth of about 18 in. and leveled to the initial grade, and the original mat was relaid. The leveling and grading of the sand were accomplished with a D4 tractor, which produced some compaction in the sand. The in-place CBR of the sand prior to relaying the mat was about 6.5. The mat planks were laid in their original position so that the wheel path would fall in the same position on the mat planks as it had in the preceding tests. The mat was seated in the loose sand by the application of 100 passes of the 27,000-lb single-wheel load

followed by 100 passes of the 30,000-lb single-wheel load prior to beginning traffic over the entire test lane with the 33,000-lb single-wheel load.

32. 33,000-lb load. During the application of 300 passes of the 33,000-lb single-wheel load, a second end joint sheared in test item 1, and the failed plank was removed and replaced. A depression also developed in two additional planks, indicating partial core failure. However, the depressions were not severe enough to cause any operational problems. No distress was noted in any of the mat planks in items 2-4. In item 5, depressions varying from 0.20 to 0.37 in. developed in five additional mat planks, indicating partial core failures. However, these planks were still considered serviceable at the end of the 33,000-lb single-wheel load c.

33. 36,000-lb load. During the application of 300 passes of the 36,000-lb single-wheel load, partial core failures developed in five additional planks in each of items 1 and 5. One of the planks in item 5 which had developed partial core failure earlier in the traffic program deteriorated to the point of failure. This plank was removed and replaced at the end of the 36,000-lb single-wheel load traffic. All mat in items 2-4 remained in good condition.

34. 39,000-lb load. During the first 90 passes of the 39,000-lb single-wheel load, an additional end-joint failure developed in test item 1, and core failures developed in all mat planks in this item. These failures resulted in a relatively rough surface with a noticeable rut along the traffic path, as shown in photograph 8. At this stage of traffic, item 1 was considered unserviceable and traffic on the item was discontinued.

35. Items 2-4 withstood the scheduled 760 passes of the 39,000-lb single-wheel load and remained in a satisfactory condition throughout the period of traffic, although partial core failures developed in most of the mat planks. A general view of item 2 at the end of traffic is shown in photograph 9. The appearance of items 3 and 4 was about the same as that of item 2.

36. The mat in item 5 performed satisfactorily up to about 300 passes of the 39,000-lb single-wheel load, at which point it began to

deteriorate quite rapidly. At the end of 300 passes, cracks had developed at two end-connector joints, and by 380 passes, four complete end-joint failures had developed. Also, the core failures progressed quite rapidly. Fig. 9 shows a split in the surface of a mat plank, at the end of 308 passes, where core failure had developed. Fig. 10 shows a similar view of a split on the bottom of a mat plank, after 380 passes, where core failure developed. Traffic was discontinued on item 5 at the end of 380 passes. A general view of item 5 at the end of traffic is shown in photograph 10.

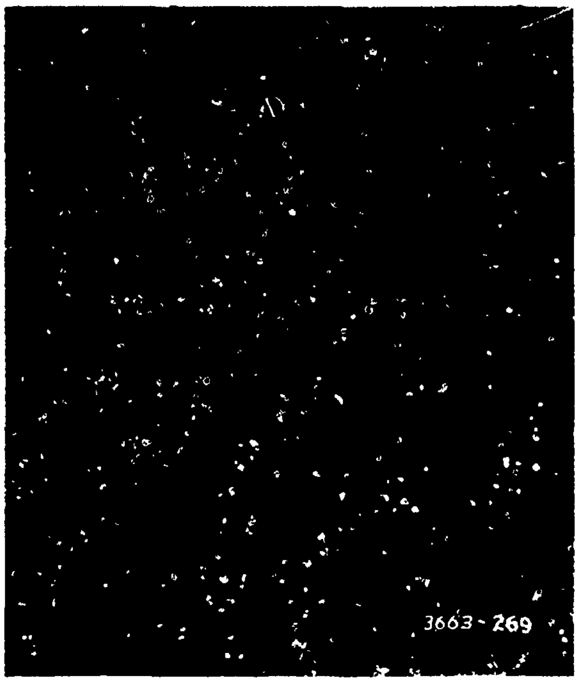


Fig. 9. Split in surface of mat plank in test item 5 after 308 passes of 39,000-lb single-wheel load (single-track traffic)

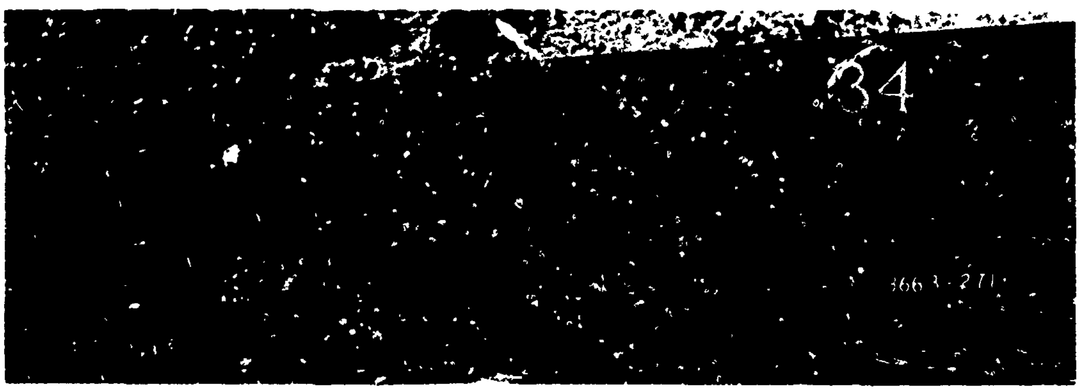


Fig. 10. Split in bottom of mat plank in test item 5 after 380 passes of 39,000-lb single-wheel load (single-track traffic)

Summary and Analysis of Test Results

Uniform-coverage traffic

37. A summary of the test results for the 27,000-lb single-wheel load traffic applied uniformly over the 10-ft-wide traffic lane is shown in

table 3, which presents the rated subgrade CBR and data on mat breakage and deflection at various stages of traffic. The last column in table 3 indicates the rating of the test item, based on the failure criteria described in paragraphs 19-22.

38. The rated CBR for the clay subgrades, items 1-3, is based on the numerical average of the CBR values measured at 0-, 6-, and 12-in. depths prior to traffic and after 188 coverages (see table 1). The rated CBR for the limestone subgrade, item 4, is based on the average surface value obtained prior to traffic, and the rated CBR for the sand subgrade, item 5, is based on the average value for the top 12 in. measured prior to traffic. The rated CBR of the sand subgrade, 42, is quite high; this high strength was developed from densification of the sand during prior tests on the AM1 mat, as previously discussed.

39. As can be noted from table 3, all test items were considered satisfactory for the entire period of traffic. No mat breakage or distress of any type was noted in test items 2-5. However, one plank failure developed in test item 1, and minor breaks were noted in three additional mat planks. Therefore, if traffic had been continued beyond 188 coverages, some maintenance would have been required on test item 1.

Single-track traffic

40. Table 4 presents a summary of the test results for the 27,000- through 39,000-lb single-wheel load traffic applied in a single track. Although most of the data presented in this table are self-explanatory, some columns need further explanation as follows:

a. Column 1. Test item 5 is subdivided into items 5 and 5a, because the initial traffic with the 27,000- and 30,000-lb single-wheel loads was applied on the mat when the rated CBR of the sand subgrade was 15. When the sand was loosened at the end of the 30,000-lb single-wheel load traffic, a reduction of the subgrade strength to a CBR of 6.5 resulted. The behavior of the mat on the loose sand was entirely different from that on the denser, higher strength sand.

b. Column 3. The rated subgrade CBR values were derived from the data in table 2 in the same manner as those for the uniform-coverage traffic lane, as discussed in paragraph 38, except for item 4. For this item the rated CBR is based on the average of the CBR values measured prior to and at various intervals of traffic.

c. Column 9. The indicated core failures are based on observations of a number of planks which were sawed through at depressed areas. From these observations it was determined that when a depression of 0.2 in. or more developed in a mat plank, one or more core members had failed.

d. Columns 12 and 13. These columns indicate the maximum elastic deflection of the mat under the wheel load, but at two different locations on the mat. The traffic path was located so that for every other run of mat the load wheel passed over a 6-ft-long half mat plank 1 ft from an end joint (see plate 3). Column 12 indicates the maximum deflection at this point. For the adjacent runs of mat, the load wheel passed over a whole plank 5 ft from the edge or 1 ft from the center of the plank. Column 13 indicates the deflection at this location.

e. Column 14. This column indicates dishing across individual mat planks (i.e. magnitude of depressions as referred to in subparagraph c above). The measurements were made by placing a straightedge across a mat plank, as shown in fig. 6, page 13, and measuring the maximum distance from the bottom of the straightedge to the surface of the mat.

f. Columns 15 and 16. Column 15 indicates the cant, or the change in elevation of one edge of a mat plank as the load wheel moved from that edge to the opposite edge of the plank. Column 16 indicates the angle of tilt.

g. Column 17. The ratings of the test items are based on the failure criteria discussed in paragraphs 19-22.

41. Although the mat in test items 2-4 was considered satisfactory after mixed traffic of loads of 27,000 through 39,000 lb, a high percentage of core failures developed under the 36,000- and 39,000-lb single-wheel loads in all test items. This indicates that the mat core may not be adequately designed to support a 39,000-lb single-wheel load with 400-psi tire inflation pressure for 1600 passes in a single track regardless of subgrade strength.

PART IV: DEVELOPMENT OF CBR DESIGN CURVES

Approach

42. In the derivation of CBR design curves for the Harvey mat, the mat was considered to behave similar to a base course in distributing load over a subgrade, and thus, in a sense, to replace a certain thickness of base course. Therefore, a standard flexible pavement CBR design curve for the required number of coverages of the indicated wheel load with tire pressure of 400 psi was used as a basis, and the reduction in thickness of base course that could be applied to the flexible pavement design curve was determined from the landing mat test data.

CBR Design Curves

43. A plot of CBR versus coverages for the 27,000-lb single-wheel load traffic is shown in plate 7. The CBR values are those listed in table 3. The solid symbol indicates an assumed failure, and the open symbol indicates a satisfactory condition at the end of traffic. Table 3 shows that although item 1 was in satisfactory condition at the end of 188 coverages, some mat breakage had occurred and one plank had completely failed. Table 4, which summarizes the test results for the 27,000- through 39,000-lb single-track traffic, shows that item 1 was in about the same condition after 600 passes of the 30,000-lb single-wheel load as it was after 188 coverages of the 27,000-lb uniform-coverage traffic. Furthermore, 600 passes of a 27,000-lb load plus 600 passes of a 30,000-lb load is equivalent to 437 passes of a 39,000-lb load, as shown in table 4. It is also seen in table 4 that with 10 percent mat replacement, item 1 withstood an equivalent of 840 passes of the 39,000-lb load before failure occurred; thus, approximately 100 percent more traffic was applied to this item after it achieved approximately the same condition of mat distress as it had developed in the uniform-coverage traffic tests after 188 coverages of traffic. Based on this comparison, it was assumed that item 1 in the 27,000-lb uniform-coverage traffic tests would have reached a failed condition after about 390 coverages of traffic (approximately 100 percent more

than 188 coverages). Therefore, the failure point in plate 7 was plotted at 390 coverages and a CBR of 7.7. To determine the minimum subgrade CBR required to support the load for 188 coverages, the failure point at 390 coverages was translated to 188 coverages by use of the CBR equation, which was written in the general form:*

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

where

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

The t value obtained from equation 1 indicates the total thickness of base course and pavement construction which would be required to support the load for a given number of coverages on a given-strength subgrade. In the case of the landing mat, the t value indicates the thickness of base course and pavement construction replaced by the mat. For the data shown in plate 7, the t value was computed for the failure point at 390 coverages. Then, on the assumption that the thickness of pavement replaced by the mat was constant throughout the range of coverages from those at failure to 188 coverages, the minimum subgrade CBR that would support 188 coverages on the mat was computed as follows:

Known

P = 27,000 lb
p = 400 psi
CBR = 7.7
C = 390

* This is a combination of equation 2 and the equation for slope of curve, page 2 and plate 6, respectively, of Instruction Report 4 referenced on page 7 of this report.

Then

$$\frac{t}{0.23 \log 390 + 0.15} = \sqrt{27,000 \left(\frac{1}{8.1 \ (7.7)} - \frac{1}{400\pi} \right)}$$

$$\frac{t}{0.23 \ (2.59) + 0.15} = \sqrt{27,000 \ (0.0160 - 0.0008)}$$

$$t = 0.75 \sqrt{411} = 15.2 \text{ in.}$$

Rearranging equation 1

$$\frac{1}{8.1 \text{ CBR}} = \frac{t^2}{P(0.23 \log C + 0.15)^2} + \frac{1}{p\pi}$$

Then

$$\frac{1}{8.1 \text{ CBR}} = \frac{(15.2)^2}{27,000 \ (0.23 \log 188 + 0.15)^2} + \frac{1}{400\pi}$$

$$\frac{1}{8.1 \text{ CBR}} = 0.0190 + 0.0008 = 0.0198$$

Then

$$\text{CBR} = 6.3$$

The dashed line in plate 7 indicates the CBR required for any coverage level between 10 and 188 coverages.

44. Plate 8 shows a CBR design curve for 188 coverages of a 27,000-lb single-wheel load with a tire pressure of 400 psi. The lower curve is a standard flexible pavement CBR design curve. The curve for the Harvey mat was developed as follows: In plate 7, it was shown that a subgrade with a CBR of 6.3 would satisfactorily support the 27,000-lb wheel load for 188 coverages when surfaced with the Harvey mat. It can be seen from plate 8 that a flexible pavement design based on a subgrade CBR of 6.3 would require 15.2 in. of base course. Thus, the Harvey mat is equivalent to 15.2 in. of base course. The design curve for the Harvey mat, also shown in plate 8, was obtained by taking 15.2 in. from the thickness indicated on the flexible pavement design curve for all CBR's less than 6.3.

45. A plot of the CBR values shown in table 4 versus passes for a

39,000-lb single-wheel load at 400-psi tire pressure is shown in plate 9. As can be noted from these data, all items with a subgrade CBR of 11.5 or greater were in satisfactory condition at the end of 1600 passes. A failure developed in item 1 (rated CBR of 6.5) at about 840 passes. By using the technique described in paragraph 43, the failure point plotted at 6.5 CBR and 840 passes was translated in plate 9 to a CBR of 7.4 at 1600 passes.

46. Data from test items 5 and 5a (the sand subgrade) are not plotted in plate 9. However, in table 4 it can be noted that mat failure developed in item 5a after about 700 equivalent passes of the 39,000-lb single-wheel load applied after the sand was loosened and its strength reduced to a CBR of 6.5. The mat in this item was subjected to an equivalent of 437 passes of a 39,000-lb single-wheel load over the high-strength sand (CBR of 15) in addition to the 700 passes required to produce failure when the mat was placed on the loose sand with a CBR of 6.5. This initial traffic probably used up some of the life of the mat. Therefore, it is believed that if traffic had been begun with the mat placed over the loose sand, the mat would have carried at least as much traffic on the sand subgrade with an initial CBR of 6.5 as it did on the clay subgrade with a CBR of 6.5 (item 1).

47. A CBR design curve for 1600 passes of a 39,000-lb single-wheel load with 400-psi tire inflation pressure for the Harvey mat is shown in plate 10. This curve was developed, using the data in plate 9, in the same manner as that described in paragraph 44 for the 27,000-lb single-wheel load.

PART V: CONCLUSIONS

48. The following conclusions are drawn from the data presented in this report:

a. The Harvey aluminum mat will sustain 1600 cycles (188 coverages) of aircraft operations with a 27,000-lb single-wheel load and 400-psi tire inflation pressure when placed on a subgrade having a CBR of 6.3 or greater throughout the period of traffic.

b. The Harvey aluminum mat will sustain 1600 passes of a 39,000-lb single-wheel load with tire inflation pressure of 400 psi applied in a single path when placed on a subgrade having a CBR of 7.4 or greater throughout the period of traffic, based on the equivalent-wheel-load concept described in paragraph 15. However, the equivalent-wheel-load concept is not a precise method of analysis, and based on (1) the breakage mentioned in paragraph 41, and (2) the use of some judgment, it is concluded that the mat core design is borderline in ability to sustain 1600 passes of a 39,000-lb single-wheel load with tire inflation pressure of 400 psi applied in a single path, regardless of subgrade strength.

Table 1

Summary of CBR, Density, and Water Content Data

Uniform-Coverage Traffic, 27,000-lb Single-Wheel Load, 400-psi Tire Pressure

Test Item	Subgrade Material	0 Coverages: Pit No.* and Location	Depth in.	CBR	Water Content, %	Dry Density lb/cu ft	183 Coverages: Pit No.* and Location	Depth in.	CBR (1)	CBR (2)	Water Content, % (1)	Water Content, % (2)	Dry Density lb/cu ft (1)	Dry Density lb/cu ft (2)	Mat Performance
1	Clay	Pit 1	0	8.2	25.1	94.0	Pit 6	0	2.6	6.1	31.8	27.4	--	--	Core failure and end-joint weld failure on overlapping plank in run 10. (Failure started at about 100 coverages.) Minor weld break in runs 4, 6, and 14. Overall performance satisfactory
		Sta 0+11	2	--	--	---	Sta 0+20	2	6.1	7.3	25.1	25.3	98.1	95.4	
		Run 6	6	5.7	24.5	95.0	Run 10	6	7.8	6.9	24.1	26.5	96.5	96.3	
			12	9.3	24.7	95.6		12	7.1	10.8	25.0	24.7	96.5	97.5	
			18	8.3	25.0	95.1		18	9.8	7.8	23.0	24.4	98.2	95.6	
2	Clay	Pit 2	0	16.0	21.9	101.3	Pit 7	0	13.2		22.8		102.6		No distress, satisfactory
		Sta [illegible]+40	6	15.0	23.1	98.2	Sta 0+38	6	14.8		21.6		99.3		
		Run 20	12	12.0	22.5	97.7	Run 18	12	13.8		22.2		99.8		
			18	14.0	23.4	98.0		18	14.3		22.9		98.9		
3	Clay	Pit 3	0	19.0	19.3	95.6	Pit 8	0	31.0		18.3		104.7		No distress, satisfactory
		Sta 0+72	6	22.0	20.2	99.8	Sta 0+70	6	19.3		17.1		101.8		
		Run 36	12	10.0	22.5	95.9	Run 34	12	13.2		15.2		95.3		
			18	12.0	22.1	97.2		18	16.7		18.5		95.1		
4	Limestone	Pit 4	0	25.0	--	---	Pit 9	0	29.0		--		---		No distress, satisfactory
		Sta 1+02					Sta 1+10								
		Run 50					Run 54								
5	Sand	Pit 5	0	30.0	3.2	109.4	Pit 10	0	19.7		2.4		108.6		No distress, satisfactory
		Sta 1+30	6	48.0	3.8	106.6	Sta 1+30	6	54.0		3.4		107.2		
		Run 64	12	45.0	4.2	106.1	Run 64	12	53.0		4.0		105.4		
			18	27.0	3.8	105.6		18	21.0		3.2		---		

Note: All values tabulated are averages of three or more tests.

The rated subgrade CBR's shown in table 3 are based on the average strength of top 12 in. of subgrade at start and end of traffic.

Column (1) under 183 coverages for test item 1 shows test values obtained under failed plank. The values under column (2) were obtained under unfailed plank in same run of mat. (See plate 3 for CBR test locations.)

* Corresponds to CBR pit number in plate 3.

[illegible]

Soil	Location*	Depth in.	CBR	Water Content %	Dry Density lb/cu ft	Wheel Load lb	Passes	Location*	Depth in.	CBR	Water Content %	Dry Density lb/cu ft	Mat Performance
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						[illegible]	[illegible]	Pit [illegible] Sta [illegible] Run [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Pit [illegible] Sta [illegible] Run [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						[illegible]	[illegible]	Pit [illegible] Sta [illegible] Run [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Pit [illegible] Sta [illegible] Run [illegible]; Pit 24 Sta [illegible] Run [illegible] **	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Pit [illegible] Sta [illegible] Run [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	No [illegible]
						[illegible]	[illegible]	Pit 25 Sta 1+03 Run 56	[illegible]	[illegible]	[illegible]	[illegible]	Depression ... initial CBR ... removed and replaced
						[illegible]	[illegible]	Pit 2? Sta [illegible] Run [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Depression ... and ... planks ... and replaced
						30,000	70?	Pit 2? Sta ?+?? Run 47	0, ?, 6, 12, 18	17.0, 19.?, 17.7, 16.7, 15.3	[illegible], [illegible], 21.1, 21.7, 21.0	---, [illegible], 9?.?, [illegible], [illegible]	... failure ... planks removed and replaced. Overall condition ... factory
[illegible]	Pit 15 Sta 1+07 Run 54	[illegible]	10	--	---	30,000	600	Pit 2? Sta 1+00 Run 5?	0	26.6	--	---	No distress
						39,000	700	Pit 30 Sta 1+12 Run 56	0	62.0	--	---	Overall condition of item satisfactory. However, a slight depression developed in several places, indicating core failure
Sand	Pit 16 Sta 1+23 Run 64	0, 6, 12, 18	13.4, 15.3, 14.0, 9.6	3.8, 3.7, 4.0, 4.4	102.1, 101.3, 101.0, 97.7	30,000	600	Pit 21a Sta 1+28 Run 64	0, 6, 12	29, 23, 17	4.5, 4.7, 3.4	105.3, 104.7, 101.3	Run 64, permanent ... in., indicating core failure
						30,000	600	Pit 21b Sta 1+34 Run 65	0, 6, 12	32, 25, 17	3.3, 4.1, 3.3	105.?, 104.7, 101.8	No distress in run 65. Overall condition of item good
						33,000	0	Pit 22 Sta 1+62 Run 71	0, 6, 12	4.7, 9.0, 5.7	3.7, 3.8, 4.1	101.5, 99.0, 100.7	Mat removed, sand ... and mat relaid prior to traffic with 33,000-lb single-wheel load
						39,000	390	Pit 27 Sta 1+60 Run 7?	0, 6, 12, 18	29, 37, 32, 15	2.8, 3.7, 3.7, 4.6	103.1, 103.3, 107.1, 100.4	Traffic discontinued at end of 390 passes. However, section was considered failed at about ... passes due to excessive mat breakage and roughness. Five planks completely failed

Note: All values tabulated are averages of three or more tests.
* Corresponds to CBR pit number in plate 4.
** Test values are averages from two test pits (13 and 14).

Table 3

Summary of Traffic Test Results

Uniform-Coverage Traffic, 27,000-lb Single-Wheel Load, 400-psi Tire Pressure

Test Item (1)	Subgrade Material (2)	Rated Subgrade CBR (3)	No. Mat Runs in Item (4)	Traffic Coverages (5)	Mat Breakage: End-Joint Weld Failures (6)	Mat Breakage: Planks with Core Failure (7)	Mat Breakage: Planks with Breaks (8)	Mat Breakage: Planks Failed (9)	Maximum Mat Deflection, in.: 1/4-Point (10)	Maximum Mat Deflection, in.: 1/2-Point (11)	Maximum Mat Deflection, in.: Joint (12)	Rating of Item (13)
1	Clay	7.7	15	0	0	0	0	0	0.6	0.6	0.6	
				20	0	0	0	0	0.6	0.7	0.7	
				50	0	0	1	0	0.5	0.6	0.7	
				100	0	0	3	0	0.6	0.6	0.6	
				188	1	1	4	1	0.6	0.7	0.3	Satisfactory
2	Clay	14.1	15	0		No mat breakage			0.2	0.5	0.4	
				20	↓	↓	↓	↓	0.3	0.5	0.6	
				50					0.3	0.5	0.5	No distress
				100					0.3	0.5	0.6	
				188					0.4	0.7	0.5	Satisfactory
3	Clay	19.1	15	0					0.9	0.4	0.6	
				20					0.9	0.4	0.5	
				50					1.0	0.4	0.4	No distress
				100					1.0	0.5	0.4	
				188					1.2	0.7	0.5	Satisfactory
4	Limestone	25.0	15	0					0.6	0.4	0.4	
				20					0.8	0.4	0.4	
				50					0.9	0.5	0.5	No distress
				100					1.0	0.5	0.6	
				188					1.1	0.8	0.7	Satisfactory
5	Sand	42	15	0					0.2	0.3	0.4	
				20					0.3	0.4	0.5	
				50					0.4	0.4	0.5	No distress
				100					0.4	0.4	0.5	
				188					0.5	0.5	0.6	Satisfactory

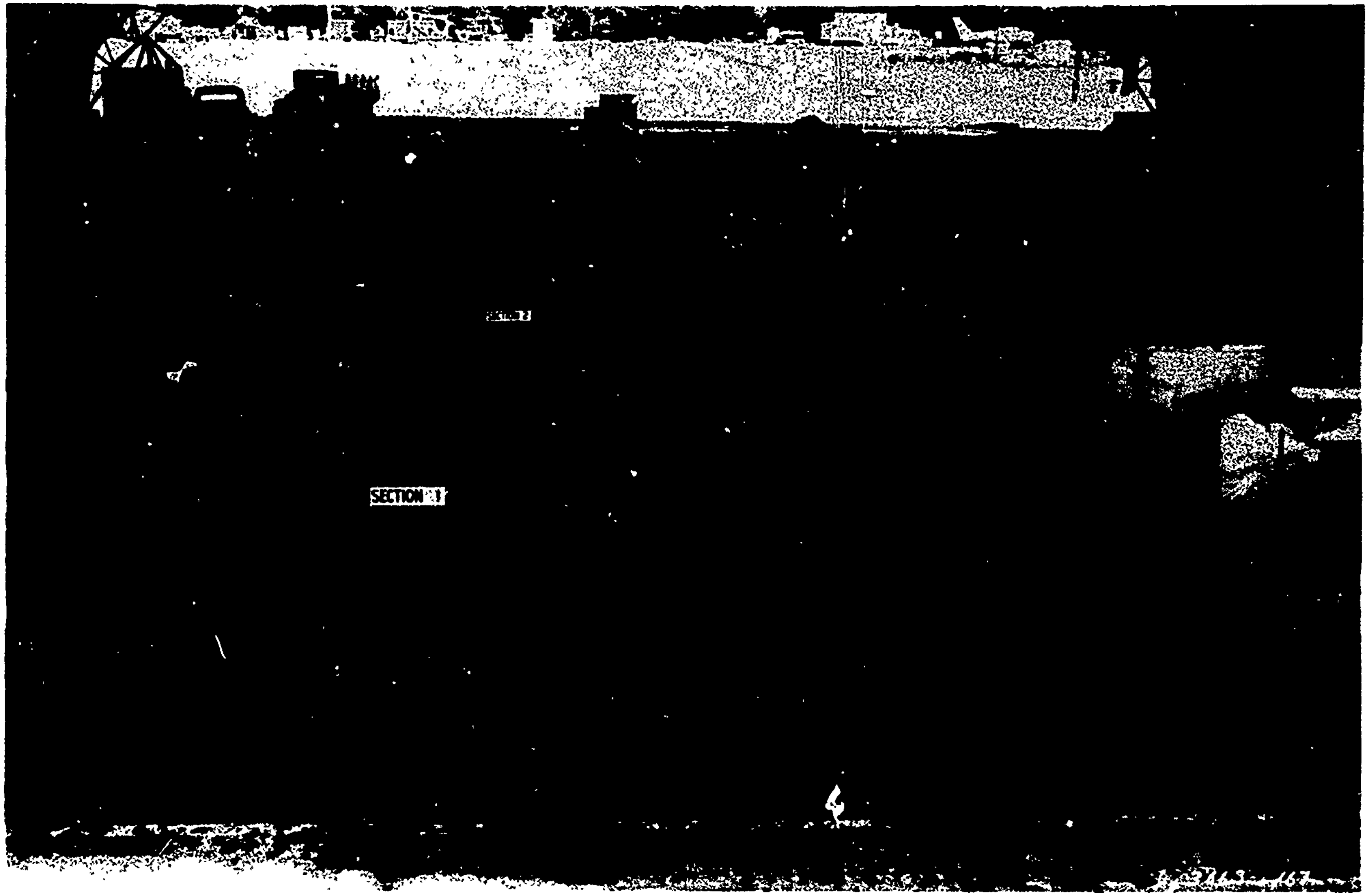
Table 4

Summary of Traffic Test Results

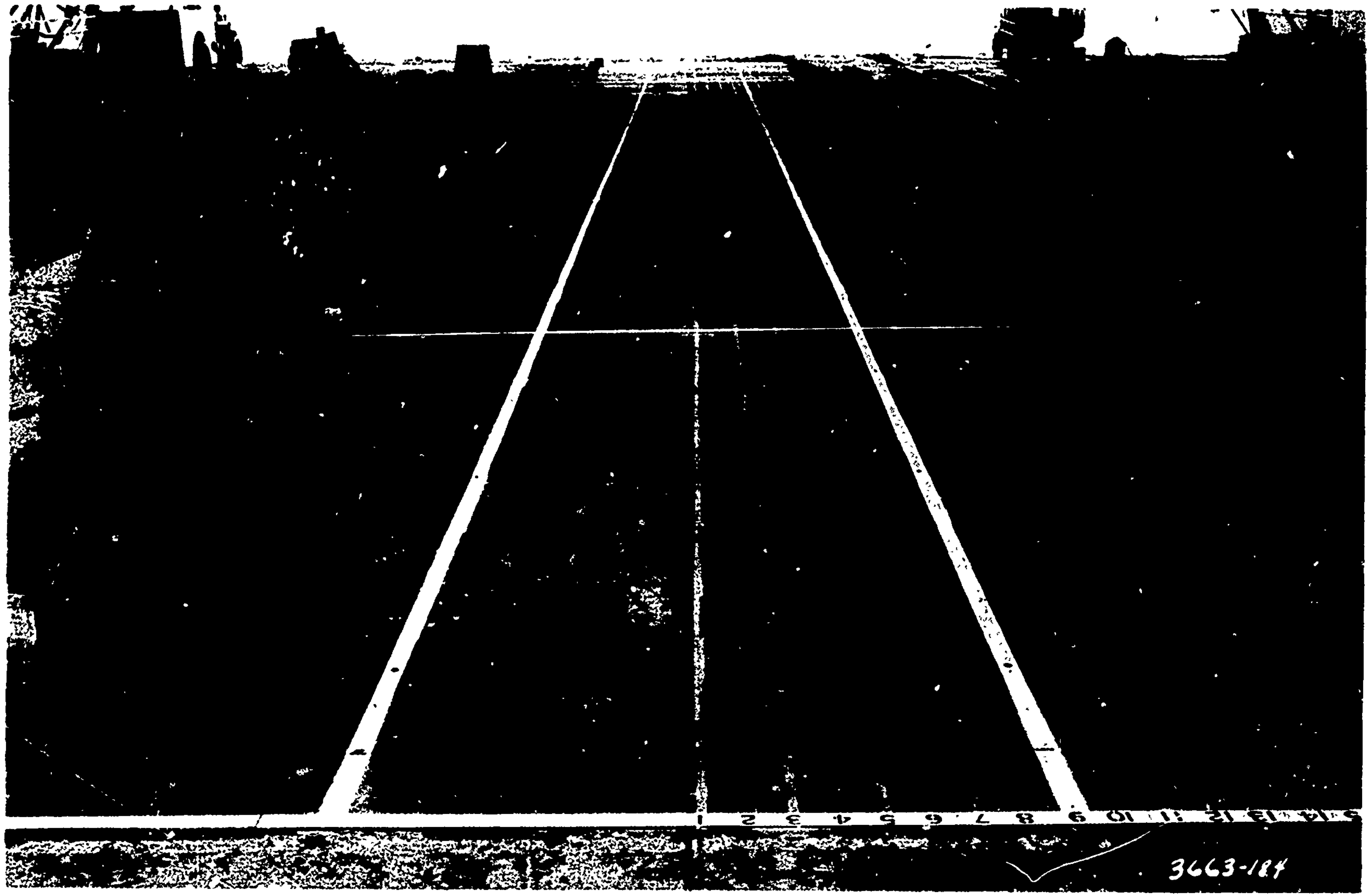
Single-Track Traffic, 27,000- Through 39,000-lb Single-Wheel Loads, 400-psi Tire Pressure

Test Item (1)	Subgrade Material (2)	Rated Subgrade CBR (3)	No. Mat Runs in Item (4)	Traffic Single-Wheel Load lb (5)	Actual Passes of Test Load (6)	Equivalent Accumulative Passes of 39,000-lb Load (7)	Mat Breakage: End-Joint Weld Failures (8)	Mat Breakage: Planks with Indicated Core Failures (9)	Mat Breakage: Planks with Breaks (10)	Mat Breakage: Planks Failed (11)	Mat Deflection Data: Maximum Deflection, in. 1 ft from Joint (12)	Mat Deflection Data: Maximum Deflection, in. 1 ft from Center (13)	Mat Deflection Data: Dishing Across Planks, in. (14)	Mat Deflection Data: Cant In. (15)	Mat Deflection Data: Cant Angle (16)	Rating of Item (17)
1	Clay	6.5	15	27,000	0	0	-	--	--	--	0.6	0.5	---	---	--	
				27,000	600	135	0	0	0	0	0.7	0.6	< 0.2	---	--	
				30,000	600	437	1	[illegible]	5	1	0.9	1.0	0.2 to 0.35	---	--	
				33,000	300	614	2	6	8	2	1.0	---	0.2 to 0.42	1.4	3°2[illegible]'	
				36,000	300	840	2	11	13	2	1.3	1.1	0.2 to 0.61	1.5	3°40'	Failed at about 840 passes
				39,000	90	930	3	15	15	4	---	---	---	---	--	
2	Clay	11.4	15	27,000	0	0	0	0	0	0	0.5	0.4	---	---	--	
				27,000	600	135	0	0	0	0	0.5	0.5	< 0.2	---	--	
				30,000	600	437	0	0	0	0	0.5	0.6	< 0.2	---	--	
				33,000	300	614	0	0	0	0	0.6	0.5	< 0.2	---	--	
				36,000	300	840	0	0	0	0	0.8	0.5	< 0.2	0.6	1°30'	
				39,000	760	1600	0	15	15	0	0.5	0.8	0.2 to 0.6	---	--	Satisfactory
3	Clay	15.5	15	27,000	0	0	0	0	0	0	0.3	0.25	---	---	--	
				27,000	600	135	0	0	0	0	0.3	0.3	< 0.2	---	--	
				30,000	600	437	0	0	0	0	0.4	0.5	< 0.2	---	--	
				33,000	300	614	0	0	0	0	0.5	0.5	< 0.2	---	--	
				36,000	300	840	0	0	0	0	0.6	0.5	< 0.2	0.5	1°10'	
				39,000	308	1148	1	6	7	1	0.7	0.6	0.2 to 0.4	---	--	
				39,000	760	1600	2	10	12	2	0.7	---	0.2 to 0.45	---	--	Satisfactory
4	Limestone	32	15	27,000	0	0	0	0	0	0	0.5	0.7	---	---	--	
				27,000	600	135	0	0	0	0	0.4	0.8	< 0.2	---	--	
				30,000	600	437	0	0	0	0	0.6	0.8	< 0.2	---	--	
				33,000	300	614	0	0	0	0	0.8	0.8	< 0.2	---	--	
				36,000	300	840	0	0	0	0	0.9	1.0	< 0.2	0.5	1°10'	
				39,000	308	1148	0	6	6	0	0.9	---	0.2 to 0.35	---	--	
				39,000	760	1600	0	12	12	0	1.1	0.7	0.2 to 0.45	---	--	Satisfactory
5	Sand	15.2	15	27,000	0	0	0	0	0	0	0.3	0.3	---	---	--	
				27,000	600	135	0	0	0	0	0.5	0.5	< 0.2	---	--	
				30,000	600	437	0	1	1	0	0.6	0.7	0.2	---	--	Satisfactory
5a	Sand	6.5	15	33,000	0	0	0	1	1	0	1.2	0.8	0.2	---	--	
				33,000	300	177	0	6	6	0	0.9	1.1	0.2 to 0.37	0.6	1°30'	
				36,000	300	403	2 cracks	11	11	1	1.5*	0.8	0.2 to 0.47	0.6	1°30'	
				39,000	330	733	4	12	16	5	---	---	0.2 to 0.50	---	--	Failed at about 700 passes

* Partial failure at end joint.

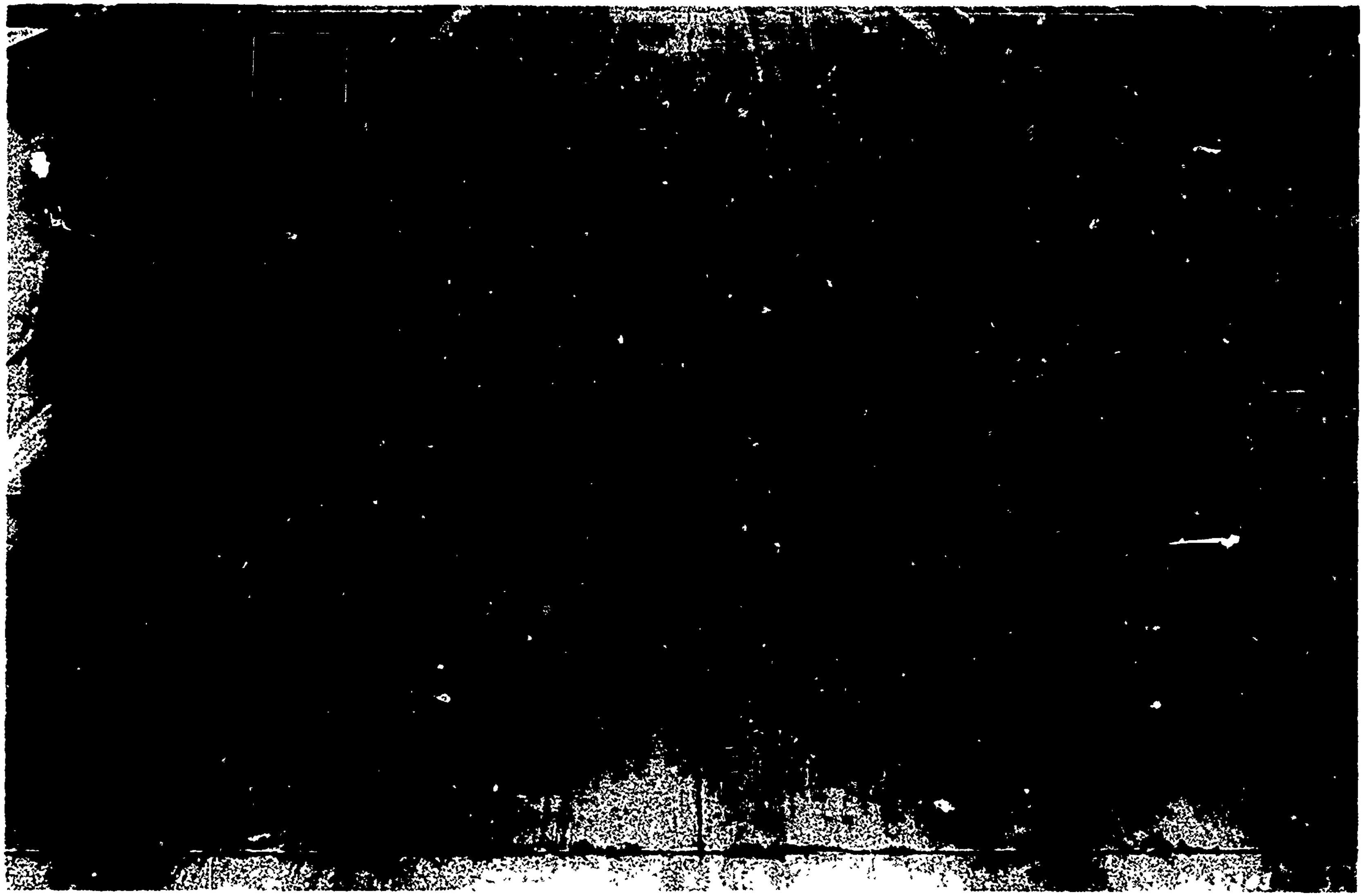


Photograph 1. Test section prior to placement of mat

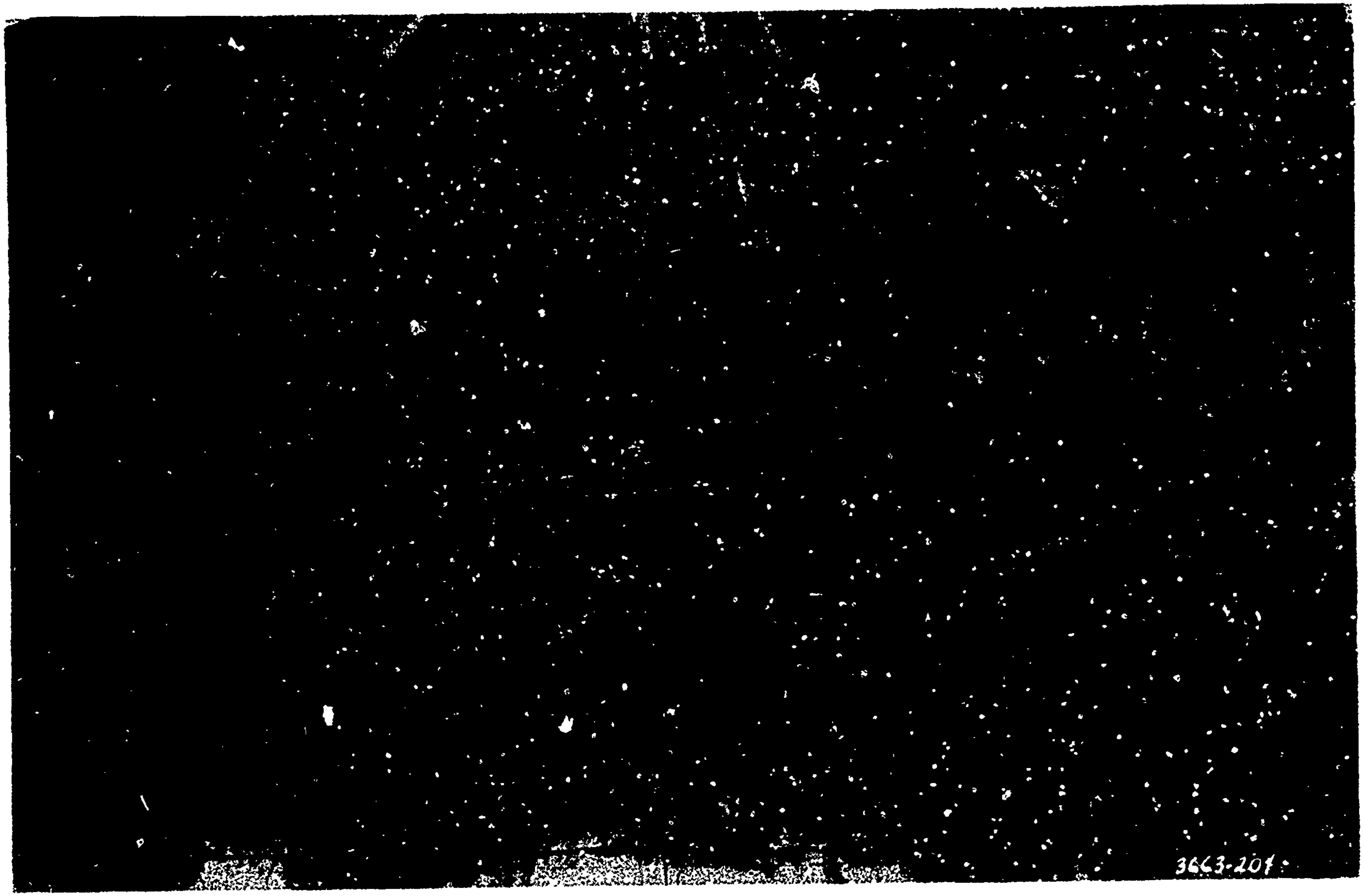


Photograph 2. Test section after placement of mat

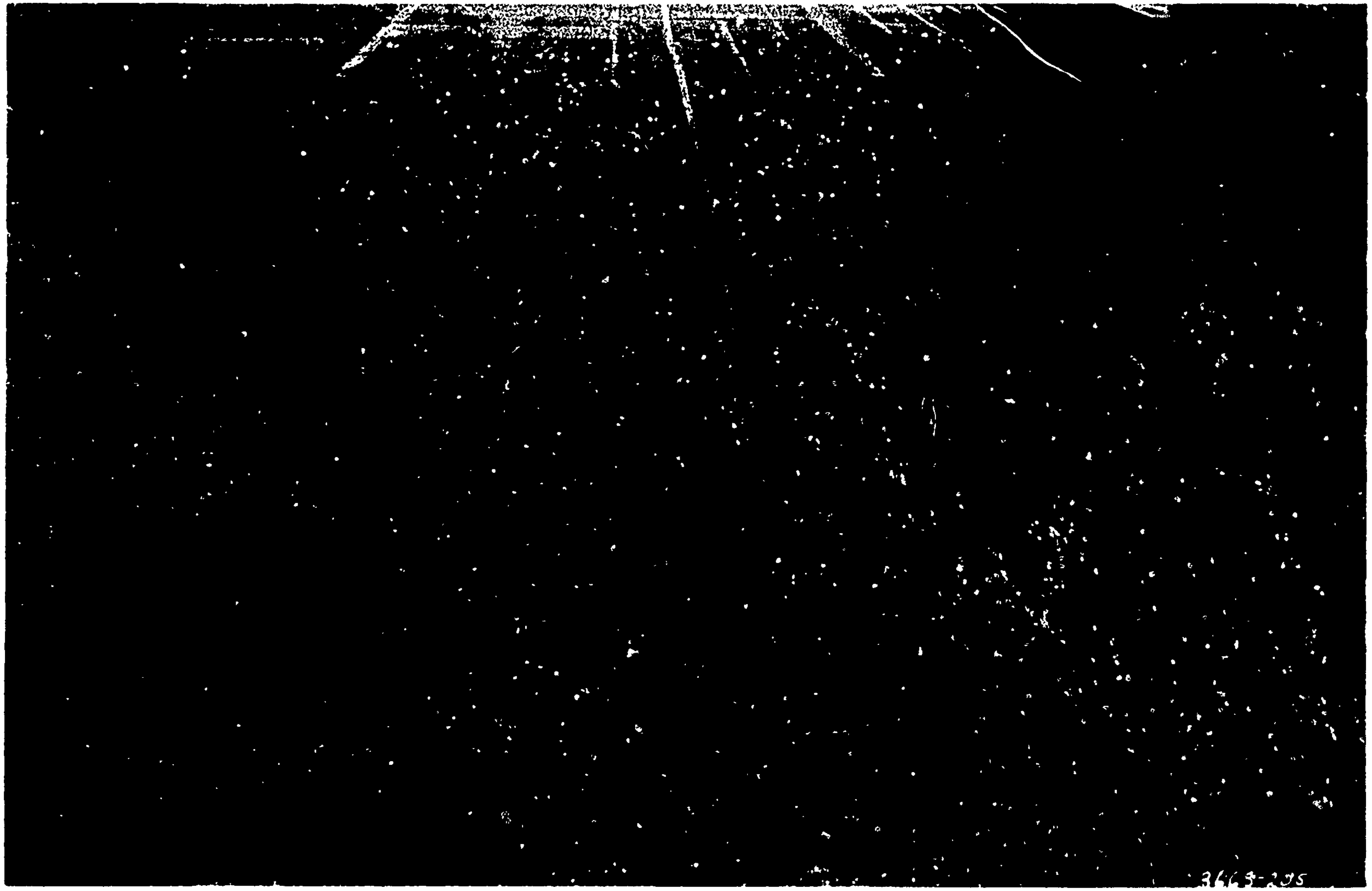
Photograph 3. Test item 1 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)



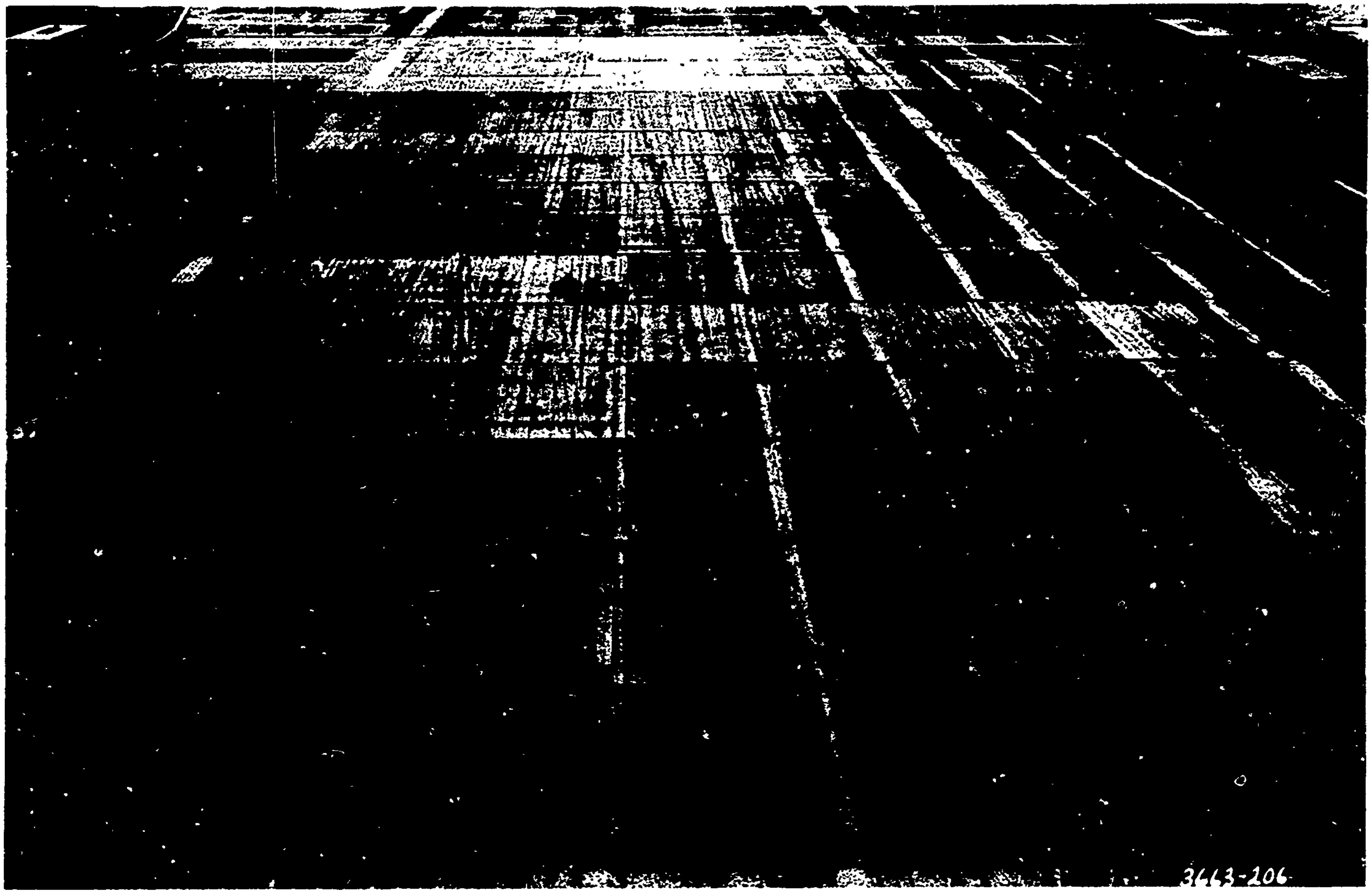
Photograph 4. Test item 2 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)



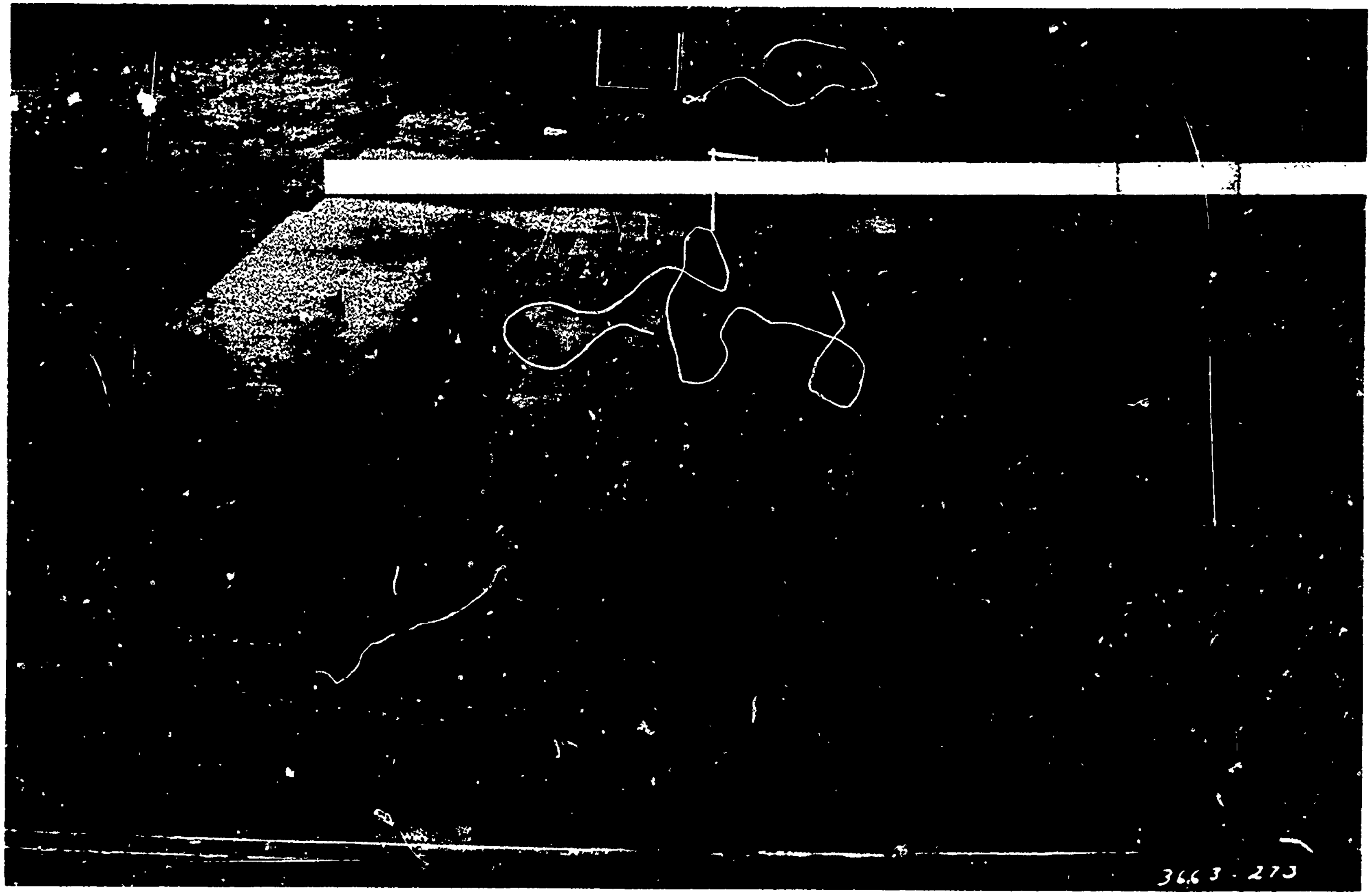
Photograph 5. Test item 3 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)



Photograph 6. Test item 4 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)

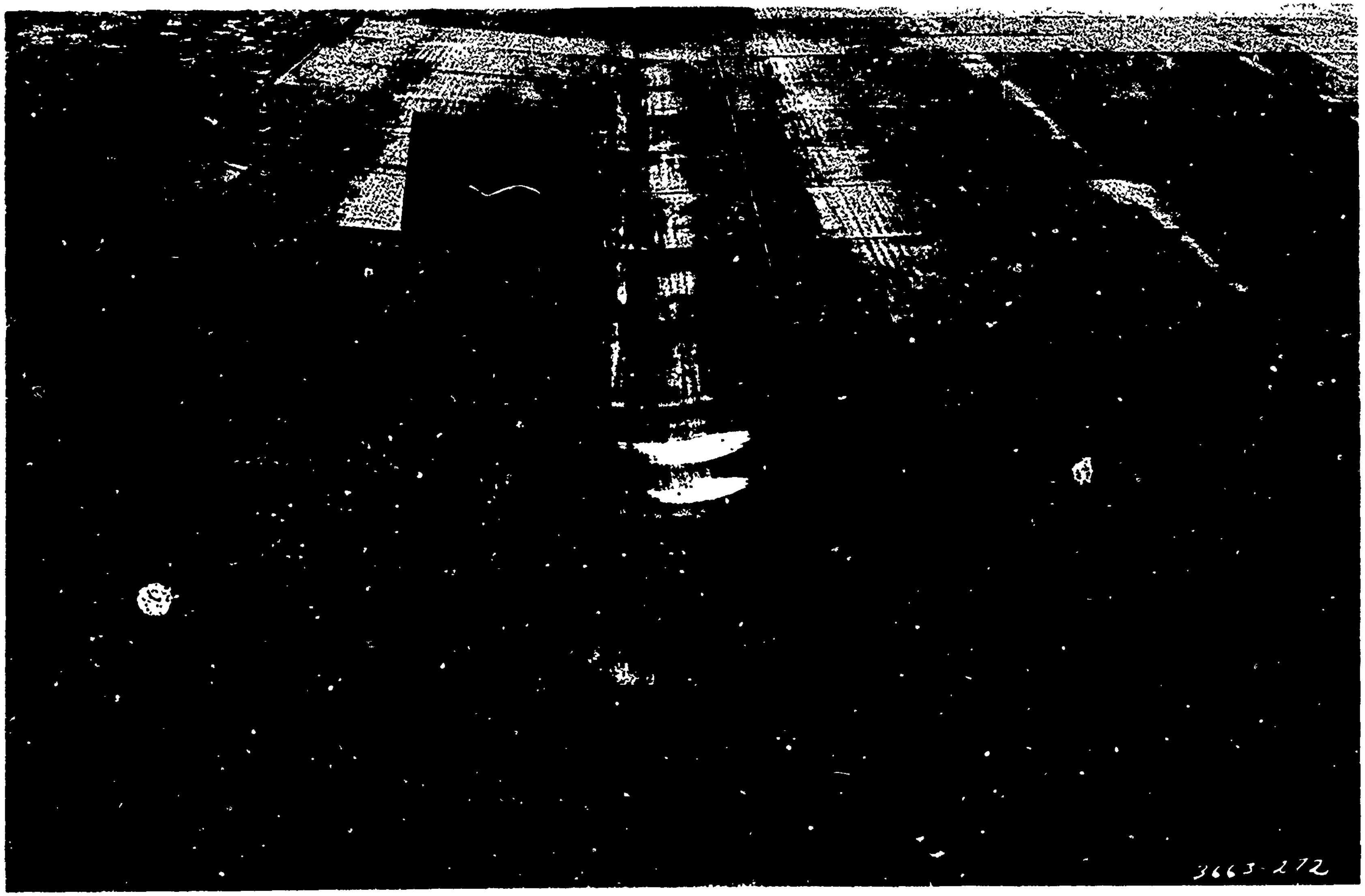


Photograph 7. Test item 5 after 188 coverages of 27,000-lb single-wheel load (uniform-coverage traffic)



Photograph 8. Rut along traffic path in test item 1 after 90 passes of 39,000-lb single-wheel load (single-track traffic)

Photograph 9. Test item 2 after 760 passes of 39,000-lb single-wheel load (single-track traffic)



Photograph 10. Test item 5 after 380 passes of 39,000-lb single-wheel load (single-track traffic)

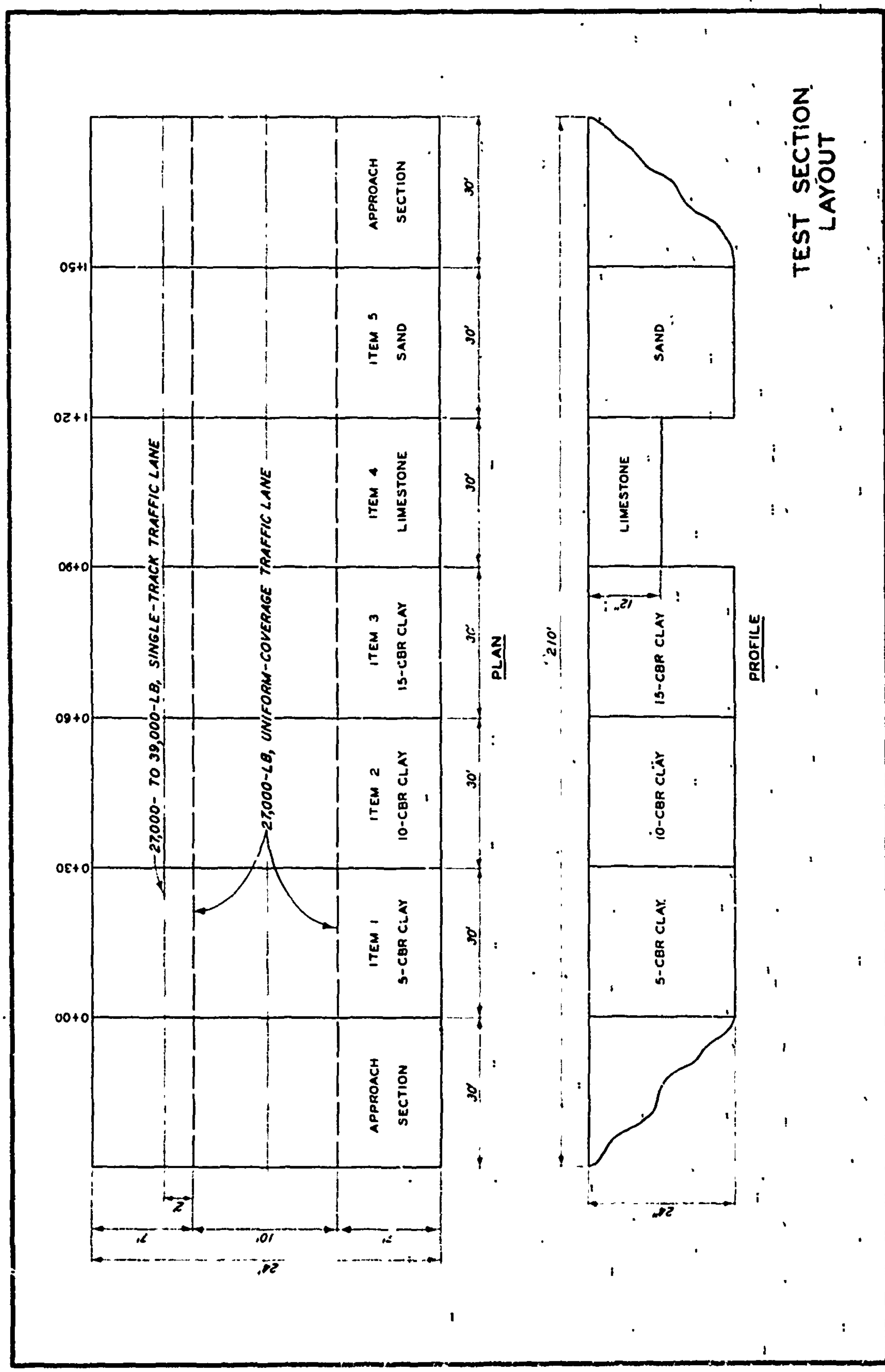
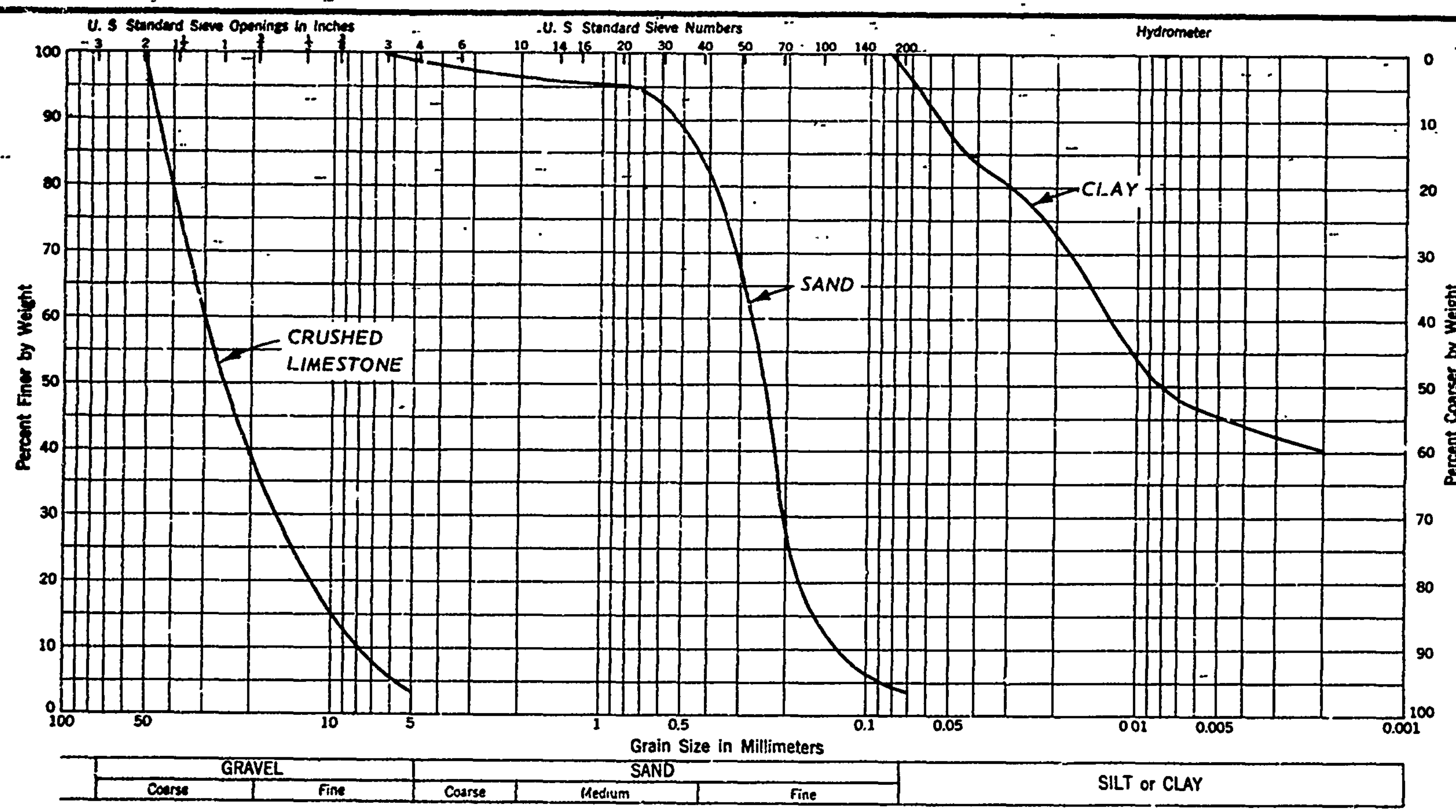

TEST SECTION LAYOUT
PLAN
PROFILE
27,000- TO 39,000-LB, SINGLE-TRACK TRAFFIC LANE
27,000-LB, UNIFORM-COVERAGE TRAFFIC LANE
APPROACH SECTION
ITEM 1 5-CBR CLAY
ITEM 2 10-CBR CLAY
ITEM 3 15-CBR CLAY
ITEM 4 LIMESTONE
ITEM 5 SAND
0+00
0+30
0+60
0+90
1+20
1+50
30'
210'
24'
7'
10'
2'
12'
5-CBR CLAY
10-CBR CLAY
15-CBR CLAY
LIMESTONE
SAND

PLATE 1

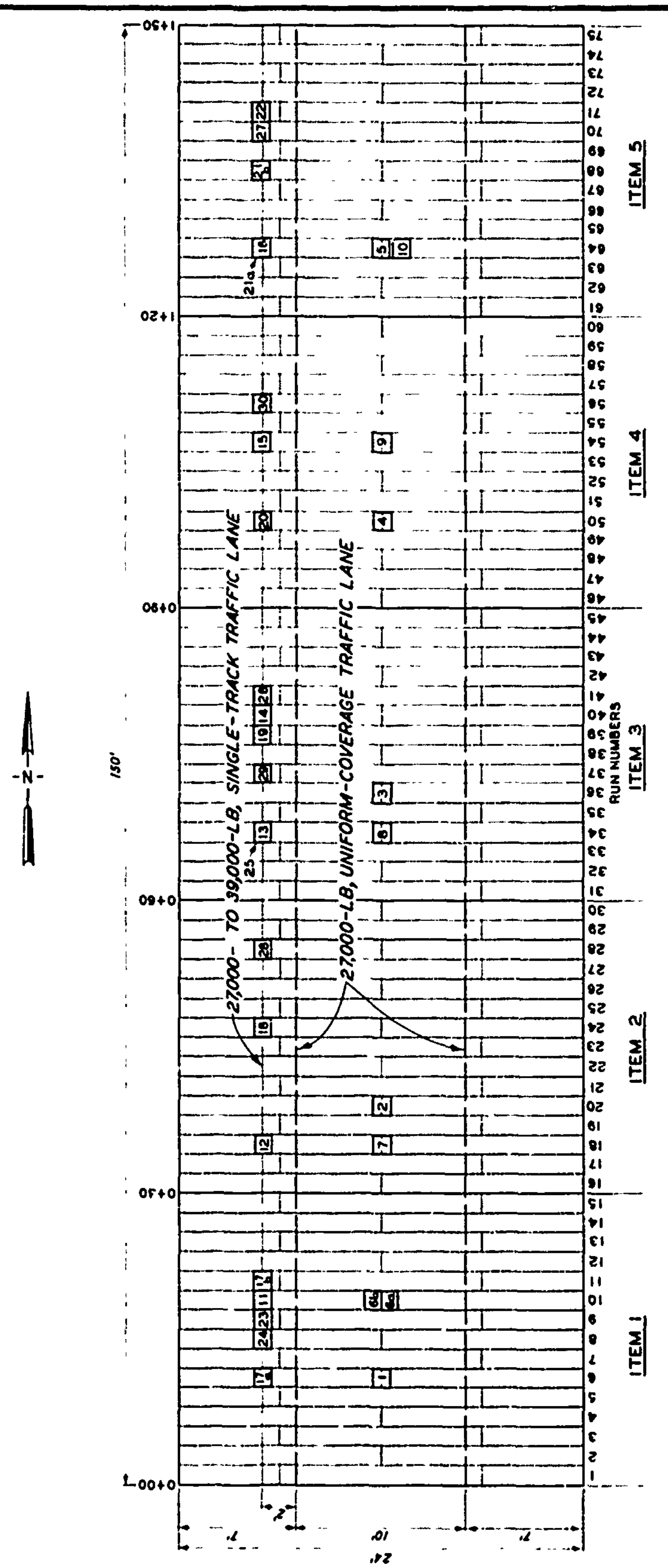


Number	Depth	Natural Moisture	L. L.	P. L.	P. I.	Classification
			56	23	33	HEAVY CLAY (BUCKSHOT), CH

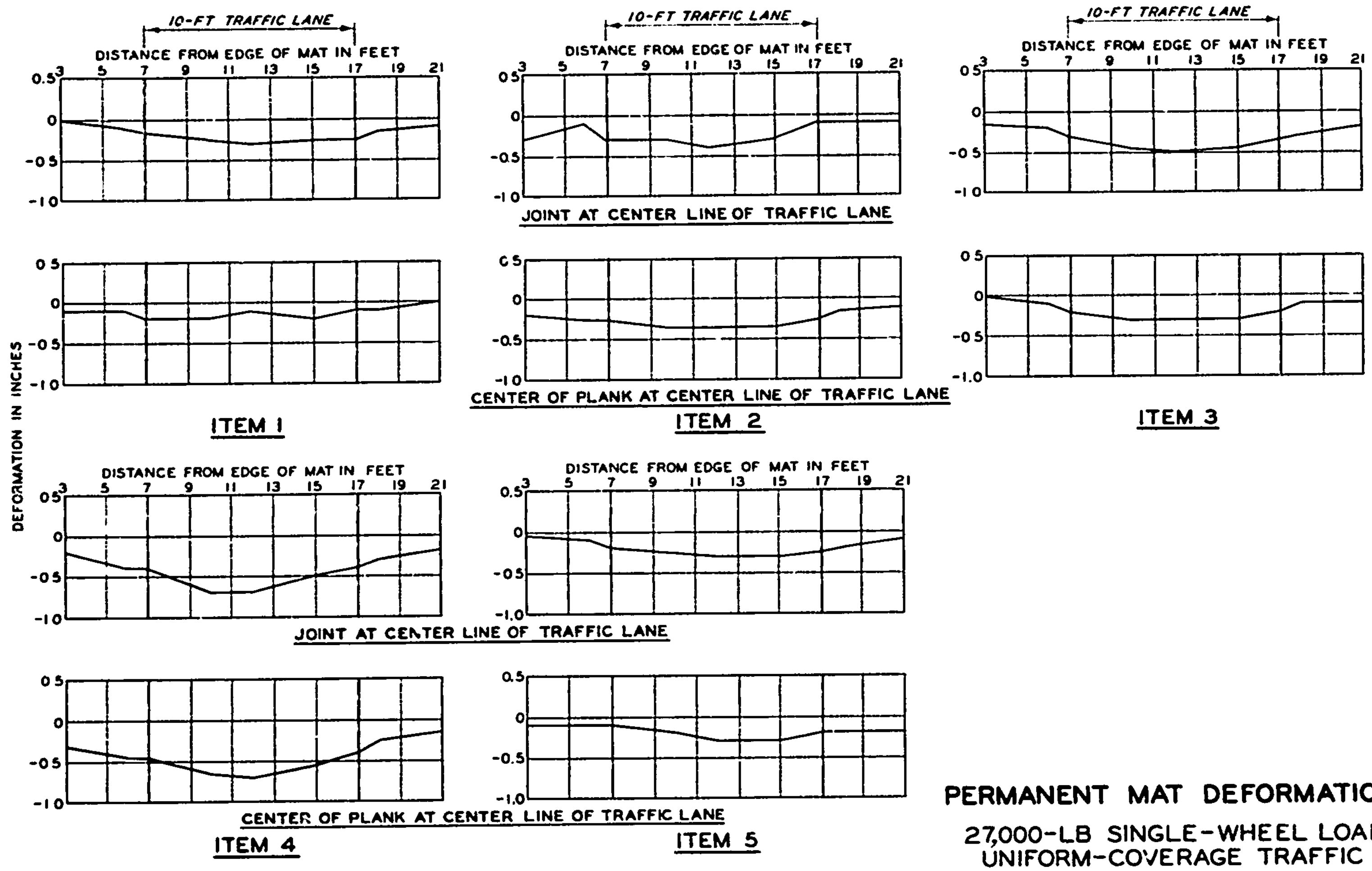
CLASSIFICATION DATA

SUBGRADE SOILS

PLATE 2

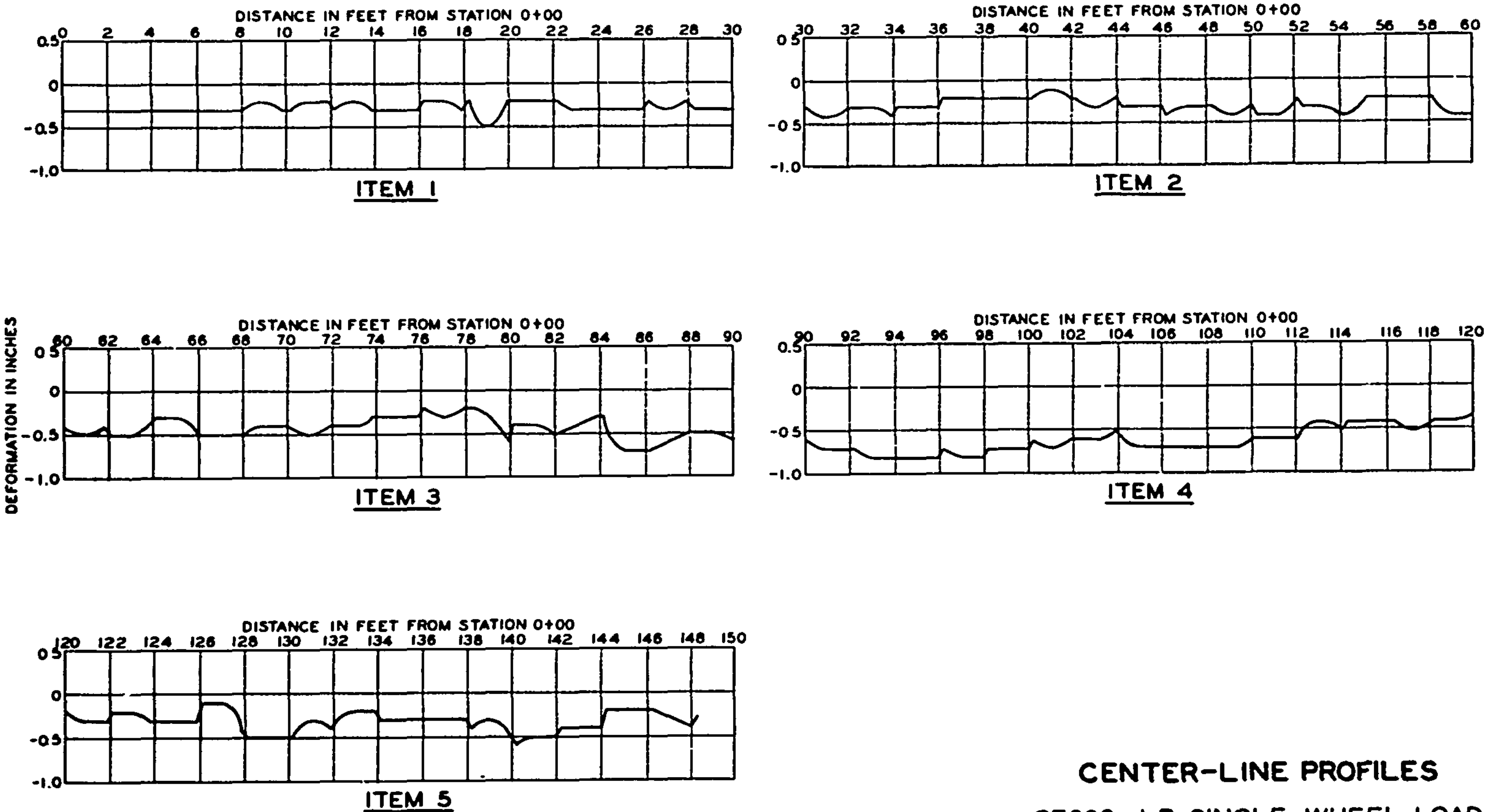


LAYOUT OF CBR PITS



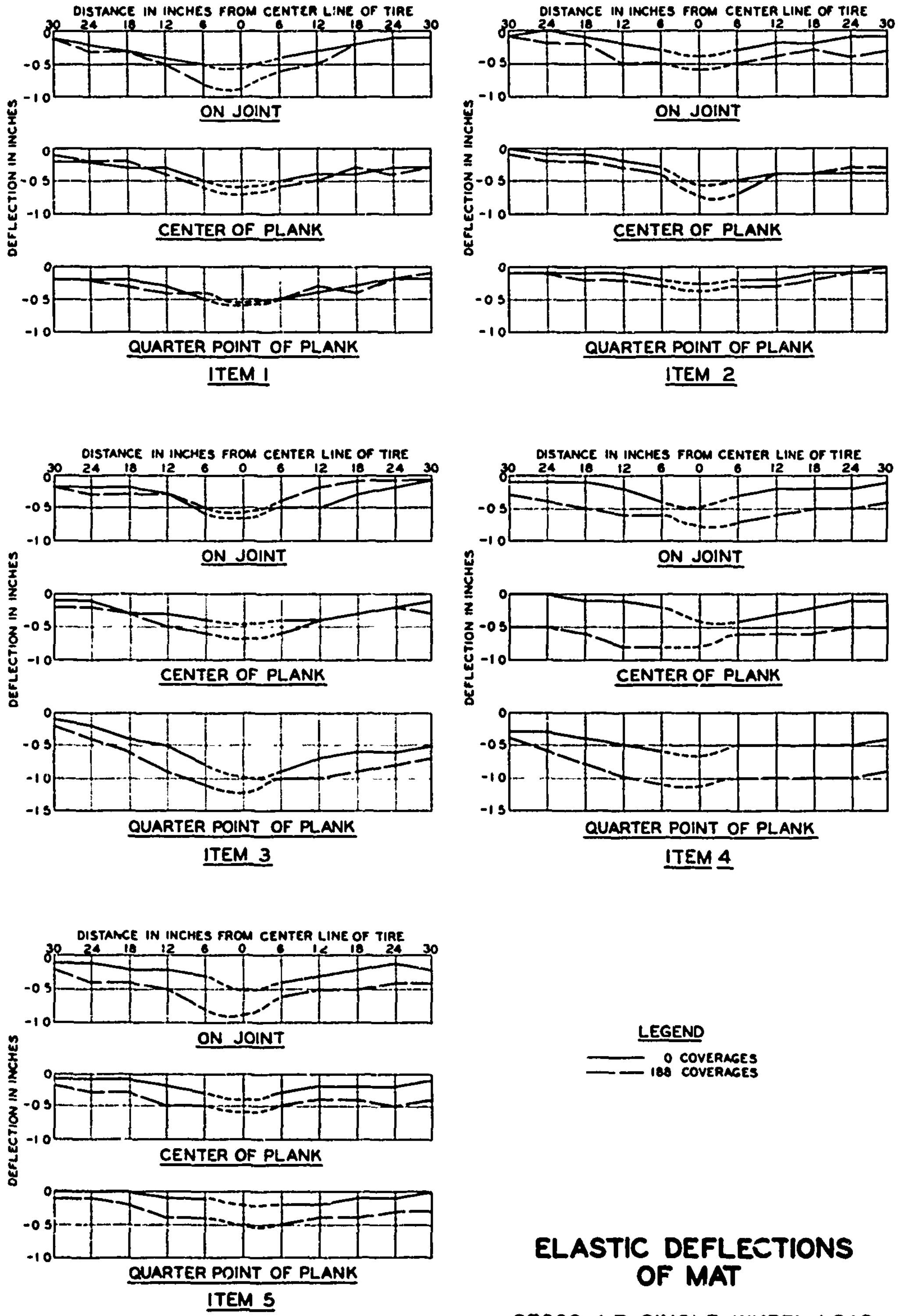
PERMANENT MAT DEFORMATION

27,000-LB SINGLE-WHEEL LOAD
UNIFORM-COVERAGE TRAFFIC
188 COVERAGES



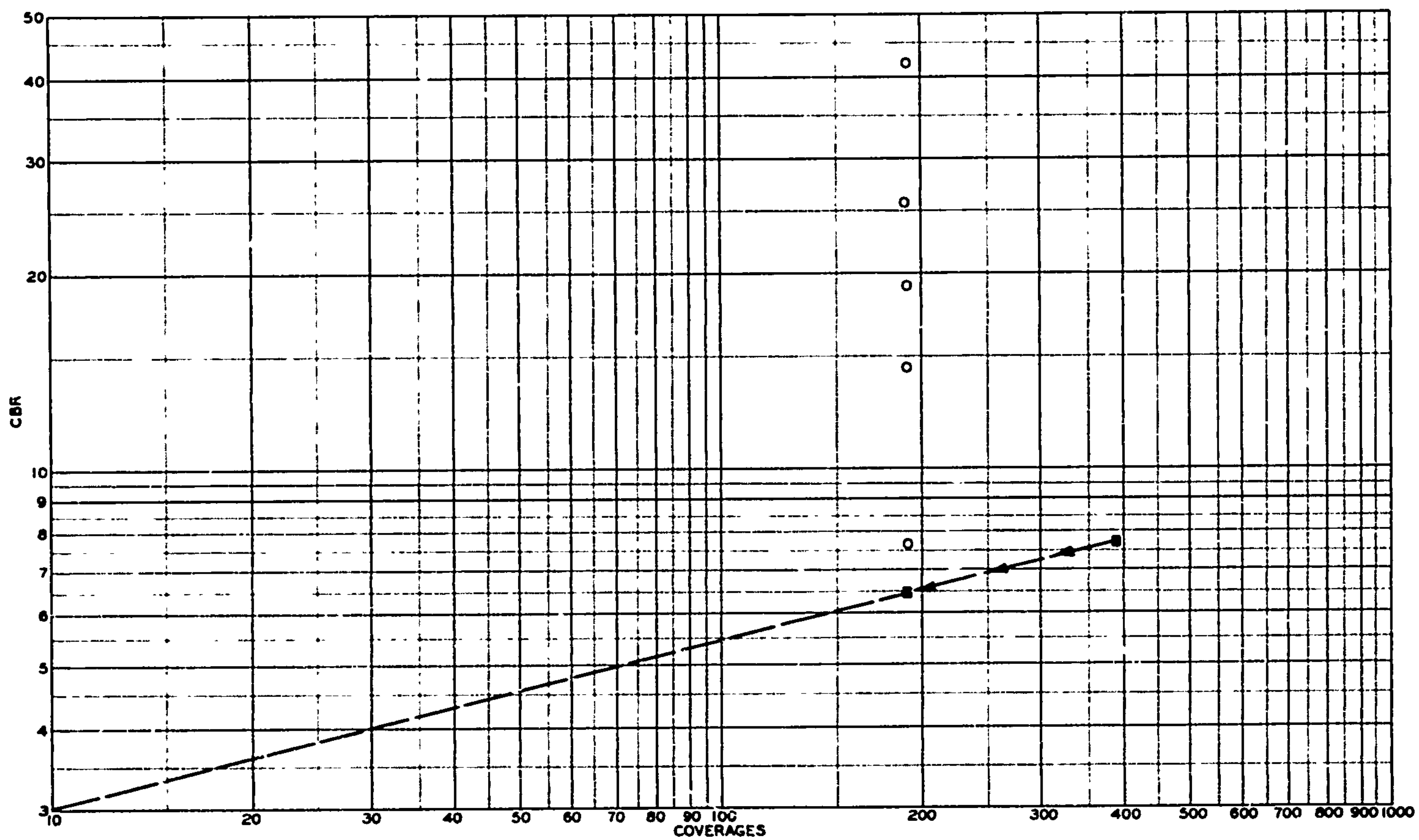
CENTER-LINE PROFILES

27,000-LB SINGLE-WHEEL LOAD
UNIFORM-COVERAGE TRAFFIC
188 COVERAGES



ELASTIC DEFLECTIONS OF MAT

**27,000-LB SINGLE-WHEEL LOAD
UNIFORM-COVERAGE TRAFFIC**



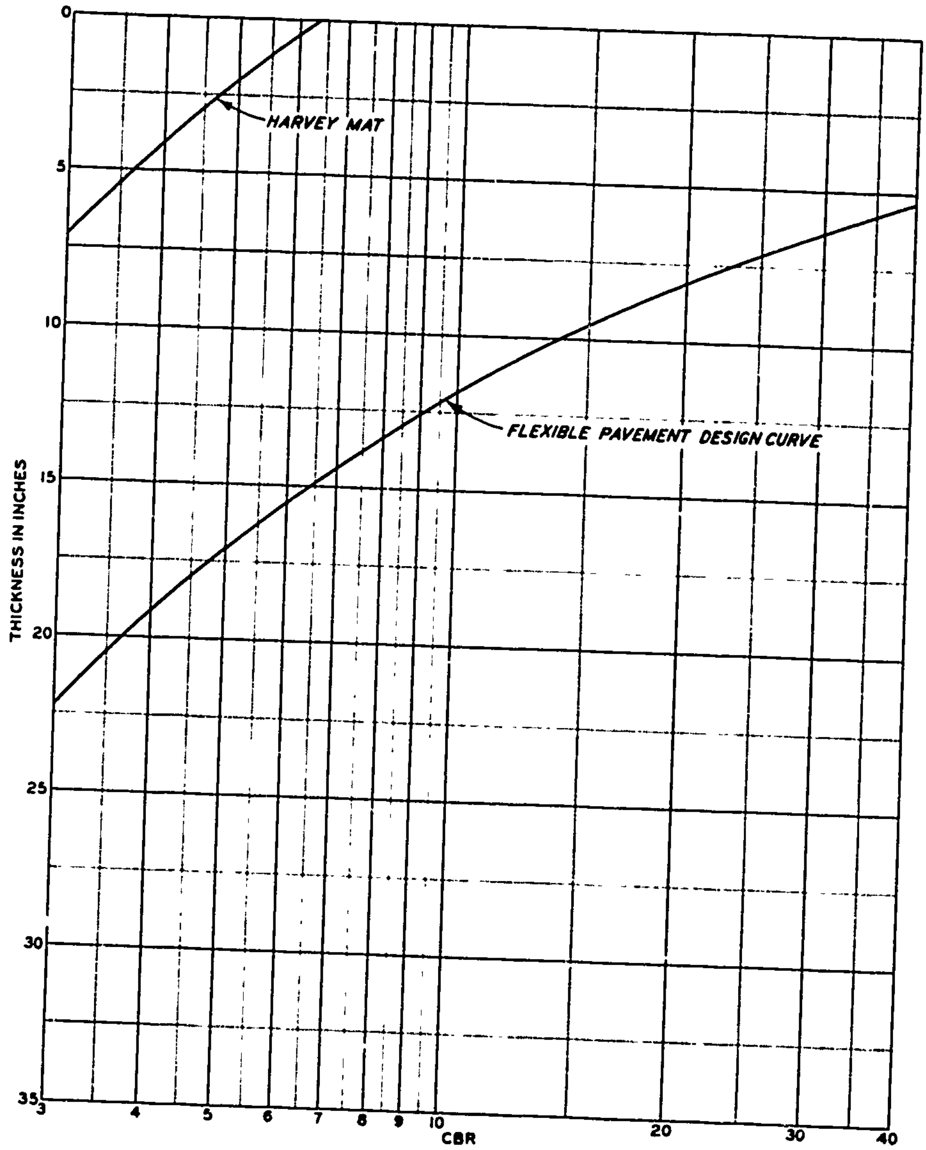
LEGEND

O POINTS FROM ACTUAL TRAFFIC TEST DATA
□ EXTRAPOLATED FAILURE POINT
NOTE: SOLID SYMBOLS INDICATE FAILURE
OPEN SYMBOLS INDICATE SATISFACTORY CONDITION AT END OF TEST

HARVEY ALUMINUM MAT

CBR VS COVERAGES

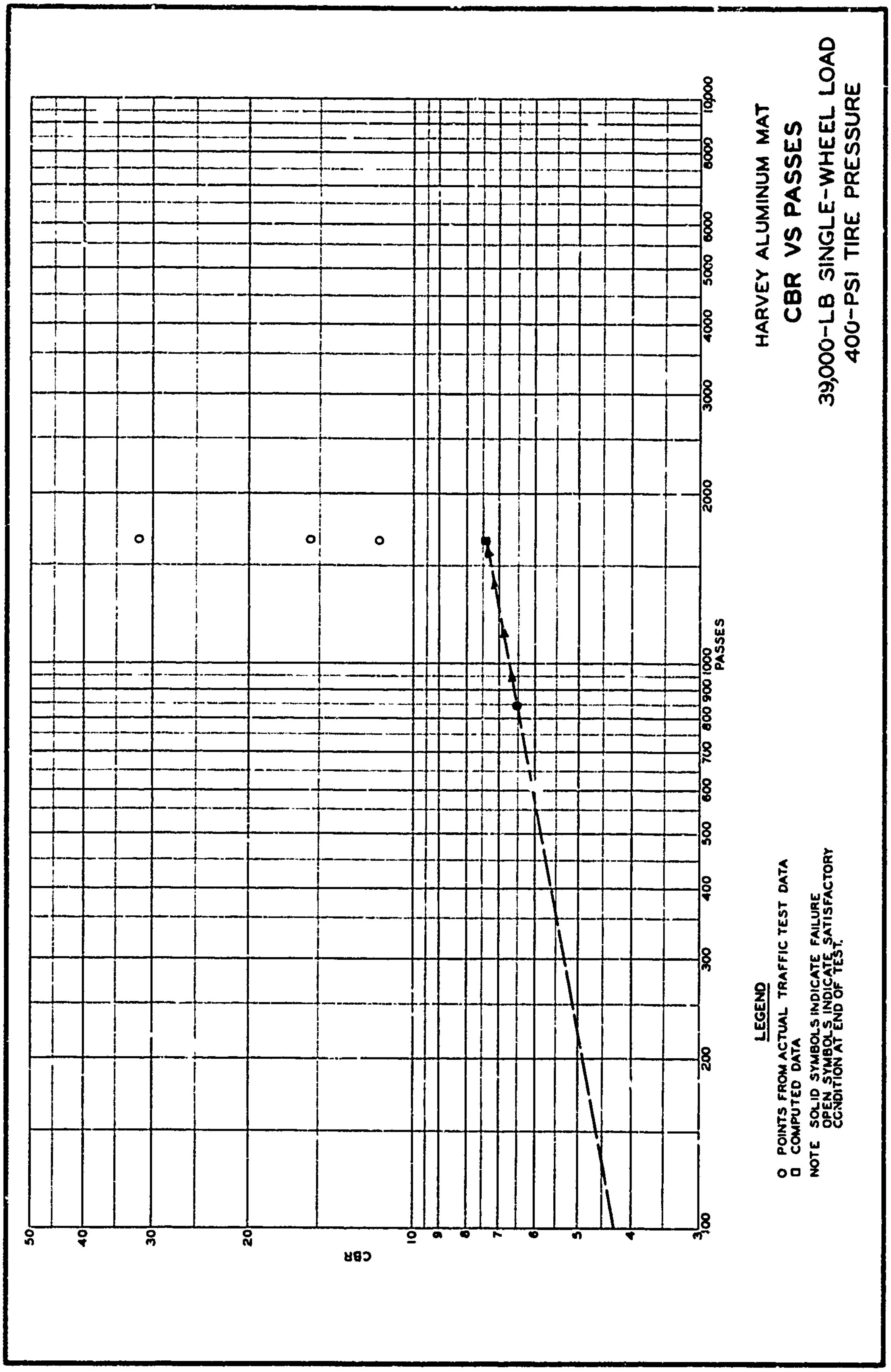
27,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE PRESSURE

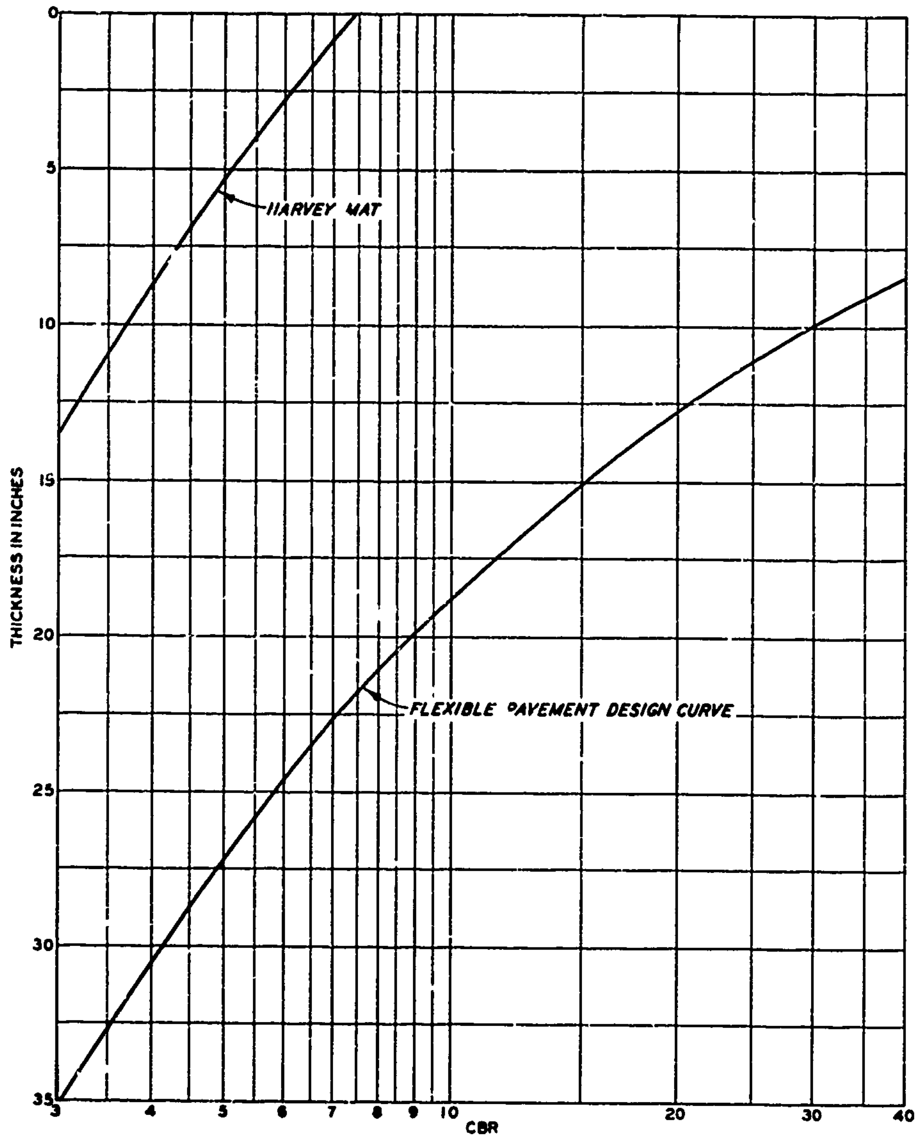


HARVEY ALUMINUM MAT

CBR DESIGN CURVE

27,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE PRESSURE
188 COVERAGES


HARVEY ALUMINUM MAT
CBR VS PASSES
39,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE PRESSURE
LEGEND
○ POINTS FROM ACTUAL TRAFFIC TEST DATA
□ COMPUTED DATA
NOTE SOLID SYMBOLS INDICATE FAILURE
OPEN SYMBOLS INDICATE SATISFACTORY CONDITION AT END OF TEST.
CBR
PASSES
3
4
5
6
7
8
9
10
20
30
40
50
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
8000
10,000



HARVEY ALUMINUM MAT

CBR DESIGN CURVE

39,000-LB SINGLE-WHEEL LOAD
400-PSI TIRE PRESSURE
1600 PASSES

PLATE 10