MISCELLANEOUS PAPER S-69-27

LANDING MAT OVERLAY ON DETERIORATED PAVEMENT

BARE BASE SUPPORT

by

C. D. Burns
W. N. Brabston

June 1969

Sponsored by

U. S. Air Force

Conducted by

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

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FOREWORD

This report is the third in a series covering investigations conducted by the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Air Force (USAF) under the general project title Bare Base Support. The investigation reported herein was authorized by USAF MIPR No. AS-7-203, dated 19 April 1966, and was conducted by the WES during the period June-November 1967.

Engineers of the WES Soils Division who were actively engaged in the planning, testing, analyzing, and reporting phases of this study were Messrs. W. J. Turnbull, A. A. Maxwell, R. G. Ahlvin, C. D. Burns, and W. N. Brabston. This report was prepared by Messrs. Burns and Brabston.

Directors of the WES during the conduct of this investigation and preparation of the report were COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE. Technical Directors of the WES during this period were Mr. J. B. Tiffany and Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square inches	6.4516	square centimeters
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per square foot	4.88243	kilograms per square meter
pounds per cubic foot	16.0185	kilograms per cubic meter
kips	453.59237	kilograms

SUMMARY

The objective of this study was to develop procedures for overlaying rough, deteriorated pavements, such as old, abandoned airfields or highways, with new landing mat in order to provide an adequately smooth runway or taxiway for the operation of tactical aircraft. The objective was accomplished by constructing an overlay test section consisting of six test items on a rough, deteriorated asphaltic concrete surface and applying test traffic with a 25,000-lb single-wheel load on a 30x11.5, 24-PR tire inflated to 250 psi.

The test section was initially constructed as follows:

Item 1 - a thin leveling course of sand surfaced with XM18 mat.

Item 2 - a thin leveling course of sand surfaced with XM19 mat.

Item 3 - a thin leveling course of clay gravel surfaced with XM19 mat.

Item 4 - a 4-in.-thick (minimum) cushion of clay gravel surfaced with XM19 mat.

Item 5 - a 4-in.-thick (minimum) cushion of compacted lean clay protected with T16 membrane and surfaced with XM19 mat.

Item 6 - a 4-in.-thick (minimum) cushion of compacted lean clay protected with WX18 membrane (not surfaced with landing mat).

A total of 2170 coverages of test traffic was applied to items 1-5 and 510 coverages to item 6. Test traffic was applied in both dry and wet weather. During the test period, several modifications were made in items 1-4 in order to prevent soil pumping under traffic in wet weather. In items 1 and 2, T16 membrane was placed between the sand leveling course and the landing mat. A piece of WX18 membrane was placed on half of the clay gravel leveling course under the XM19 in item 3. The clay gravel in the remainder of item 3 and all of item 4 was stabilized with 6 percent portland cement by soil weight.

From the results of this test, it was concluded that:

a. Rough, deteriorated pavements can be overlaid with a soil cushioning layer and new landing mat to provide an adequate

surface for the operation of tactical aircraft.

b. Both fine-grained and granular soils can be used as the leveling or cushioning layer. However, both types of material will require protection to prevent pumping of the fines through mat joints during wet-weather traffic operations.

c. T16 membrane placed between soil and mat is quite effective in protecting fine-grained cohesive soil or fine sand from moisture infiltration and pumping action during wet weather. However, when used between soil and mat, neither the T16 nor the heavier WX18 membrane is adequate to withstand the abrasive action of sharp objects in the soil, such as the coarse aggregate in the clay gravel material. For this reason, care must be taken to remove roots, rocks, and other sharp objects from soils used under waterproof membrane in overlay construction.

d. A clay gravel cushion can be effectively protected from water infiltration by stabilization with 6 percent portland cement by soil weight.

e. The optimum thickness of leveling or cushioning material needed for mat overlay construction is the minimum thickness that will: (1) provide uniform bearing for the mat, (2) provide an adequate transverse slope or crown (approximately 2-1/2 to 3 percent), and (3) allow a sufficient quantity of soil so that the material can be easily placed and compacted with the available construction equipment.

LANDING MAT OVERLAY ON DETERIORATED PAVEMENT

BARE BASE SUPPORT

PART I: INTRODUCTION

Background

1. The U. S. Air Force must possess a high mobile capability in order to maintain the operational readiness required in rapidly changing strategic and tactical situations. A concept now being developed under the name "Bare Base" is designed to enhance the mobility of tactical Air Force units of squadron size so that they can deploy from home base to anywhere in the world with no more than 24 hours notice, commence air operations within 8 hours after arrival, sustain operations at wartime sortie rates for up to 180 days, and still retain the capability to deploy at any time to another Bare Base.

2. Specifically, Bare Base means a facility consisting of a runway, taxiway, and parking apron capable of supporting a tactical combat force of squadron size for at least 30 days, and having a source of water that can be made potable, and nothing else. There will not always be a usable Bare Base in the operational area under consideration. The need exists, therefore, to have the capability to construct or upgrade a runway, taxiway, and apron to the strength and configuration needed to support tactical aircraft. Obviously, a wide range of operational areas and sites must be considered under this concept--such as operational airport facilities, abandoned or deteriorated runways, existing or newly constructed landing mat-surfaced, membrane-covered, or unsurfaced-soil assault strips, and areas with no existing facilities whatsoever. Thus, Bare Base construction effort can range from negligible in areas where a complete landing facility exists to total where a complete tactical airfield must be constructed in a forward or remote combat area. The specific type of site with which the investigation reported herein was concerned is the deteriorated pavement area on which a certain amount of construction would be required to provide an operational facility.

3. Deteriorated pavements of abandoned airfields or highways that are too rough for aircraft operations will have to be overlaid quickly in order to provide an adequately smooth aircraft landing surface. Placement of airfield landing mat directly over the rough existing pavement would result in point loadings of the mat, which would lead to early failure. It is desirable, therefore, to develop procedures for placing new airfield matting over old, deteriorated pavements in order to provide a satisfactory landing facility under the Bare Base concept. Techniques that appear feasible include placing a thin leveling course or a thick cushion of soil over the deteriorated pavement prior to placement of the new overlay mat. These techniques were tested at the U. S. Army Engineer Waterways Experiment Station (WES) during the period June-November 1967.

Objectives and Scope of Investigation

4. The general objective of this study was to develop a procedure for overlaying rough, deteriorated pavements with new landing mat in order to provide adequately smooth runway and taxiway facilities for the operation of tactical aircraft. It was specifically desired to: (a) determine the optimum thickness and type of soil to be placed between the deteriorated pavement and the new landing mat, and (b) develop a method to protect the overlay soil from moisture during wet-weather conditions in order to prevent soil pumping.

5. The objectives were accomplished by:

- a. Overlaying a rough, deteriorated asphaltic concrete surface with soils of several types and thicknesses and surfacing with new landing mat.
- b. Performing accelerated traffic tests on the overlaid test section using a 25,000-lb* single-wheel load on a 30x11.5, 24-PR aircraft tire, inflated to 250 psi, which simulates the load on a main gear wheel of the F-4C aircraft.
- c. Observing the behavior of the test section under traffic and recording pertinent test data.

This report contains a description of the test section, tests conducted, and results, and an analysis of the results.

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

Materials

Soils

6. The three types* of soils used in construction of the test section were: lean clay (CL), clay gravel (GP), and clean sand (SP). Classification data for these soils are shown in plate 1. The lean clay was obtained from a hill deposit on the WES reservation and had a liquid limit of 35 and a plasticity index of 12. The clay gravel, a pit-run material obtained locally, had a plasticity index of 3 and approximately 7 percent passed the No. 200 sieve. The sand was a clean, nonplastic, uniformly graded material obtained from a local creek bar deposit.

7. Laboratory compaction and CBR data for the lean clay are shown in plate 2. The data in plate 2 are for the as-molded condition, which is analogous to field soil conditions as constructed. The curves of the lower left graph indicate the relation between soil water content and dry density. The three curves shown were developed by 12, 26, and 55 blows per layer of a 10-lb hammer with an 18-in. drop for the soil placed in five equal layers in a 6-in.-diam mold. The graph in the upper left of the plate indicates the relation between water content and soil strength (CBR). The curves shown to the right, dry density versus CBR and molding water content versus CBR, were derived from the first two relations.

8. Laboratory compaction and CBR data for the clay gravel are shown in plates 3 and 4. The data in plate 3 are for the as-molded condition, and the CBR values in plate 4 were obtained on soaked specimens.

Membranes

9. T16 and WX18 neoprene-coated nylon membranes were used in this study. The T16 membrane is a single-ply nylon and weighs approximately 0.13 psf. The WX18 is four-ply nylon and weighs approximately 0.44 psf. The membranes are factory-fabricated from 4- to 5-ft-wide strips that are bonded together to form sheets of specified size. Both membranes have

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* Classified according to "Unified Soil Classification System," Department of Defense, MIL-STD-619A, Mar 1962, Washington, D. C.

been utilized in previous tests conducted by the WES under the Bare Base program.

Landing mats

10. Two types of landing mats, XM18 and XM19, were used. Both mats are used operationally by the Air Force and have been evaluated at the WES in earlier tests. The XM18 is fabricated from extruded aluminum into 2- by 12-ft and 2- by 6-ft planks that have a unit weight of approximately 4.9 psf. A view of a full and a half plank of XM18 is shown in photograph 1. The XM19, which has an aluminum honeycomb core structure, is fabricated in full panels that measure approximately 4.1 ft square and half panels that are 2 by 4.1 ft and have a unit weight of approximately 4.1 psf. A view of a full and a half panel of XM19 is shown in photograph 2.

Test Section

Location

11. The test section was located in an unsheltered area on an existing deteriorated asphaltic concrete pavement on the WES reservation.

Description

12. The asphaltic concrete pavement had been constructed at the WES in 1944 as part of a comprehensive field study of paving mixtures and consists of a sand asphalt wearing course that varies from 2 to 6 in. in thickness over an 8- to 10-in.-thick sand and loess base. The base has an in-place strength of 40 to 80 CBR. The pavement was badly rutted and deformed during previous traffic tests and is considered to be a typical deteriorated asphaltic concrete pavement (see photograph 3). A representative area, 180 ft long and 36 ft wide, was selected on the deteriorated pavement as the site for construction of the overlay test section.

13. The design objective for the test section was to extend the service life of the deteriorated area by means of overlay construction consisting of a leveling course or cushion of soil surfaced with landing mat. The primary purpose of the overlay soil was to fill surface irregularities and to provide a relatively smooth surface on which to place the landing mat. Since the base course of the original pavement still was quite strong,

40 to 80 CBR, the thickness of the soil overlay in excess of minimum leveling thickness was not a critical factor with respect to load-carrying capability.

14. The test section consisted of six test items, each 30 ft long and 36 ft wide (see plate 5). Item 1 consisted of a loose, dry sand leveling course surfaced with XM18 landing mat. Item 2 had a loose, dry sand leveling course and was surfaced with XM19 mat. Item 3 had a thin clay gravel leveling course and was surfaced with XM19 mat. Item 4 consisted of a 4-in.-thick (minimum) clay gravel cushion surfaced with XM19 mat. Item 5 had a 4-in.-thick (minimum) lean clay cushion protected with T16 membrane and surfaced with XM19 mat.

15. Since the original base course was still relatively strong and stable, it was desired to evaluate the performance of an area having a soil overlay without a landing mat surface. Therefore, item 6 consisted of a 4-in.-thick (minimum) cushion of highly compacted lean clay that was surfaced with WX18 membrane.

16. The basic performance requirements for the overlay soils in items 1 through 5 were that they provide sufficient support to the landing mat to prevent point loading of the mat on the ridges of the deteriorated pavement and remain stable during wet weather conditions. In item 6, the overlay soil was required to actually support direct test traffic.

17. It was expected that the sand in items 1 and 2 would be somewhat confined under the landing mat and would, therefore, remain relatively stable. An examination of the laboratory CBR curves for the clay gravel (plates 3 and 4) indicated that if the clay gravel was compacted at a water content of 3.5 to 4.5 percent using a field compaction effort about equal to the lowest laboratory effort shown, a soil strength in the range of 45 to 55 CBR could be obtained. The soaked CBR data (plate 4) indicated that if this soil was then subjected to soaking, an acceptable strength loss to the range of 10 to 20 CBR would result. Therefore, it was decided to place the clay gravel in items 3 and 4 at a water content of 3.5 to 4.5 percent, since if the soil became soaked during rainy weather, the resulting strength loss would not be particularly detrimental to the performance of the overlay cushion.

18. The as-molded laboratory compaction curves for the lean clay soil (plate 2) indicated that the optimum water content for the maximum compaction effort was 13 percent. It was expected that in item 6, the additional compaction applied to the soil as a result of repetitive loadings of test traffic would be of about the same magnitude as that produced by the maximum laboratory effort. From the graph of molded dry density versus CBR shown in plate 2, it can be seen that if the soil is molded at a water content only slightly higher than modified optimum, say 15 percent, then the effect of additional compaction, indicated on the graph by increasing density, is an eventual decline in CBR. On the other hand, the graph also indicates that the effect of increasing dry density of the soil molded at something less than modified optimum, say 12 percent, is a continual increase in CBR. Thus, it was decided to place the lean clay soil in items 5 and 6 at about 12 percent water content. It was recognized that since the lean clay cushion in item 5 was to be surfaced with XM19 landing mat, there would be little additional increase in soil density as a result of test traffic; however, it was decided to select a uniform water content for both items in order to facilitate soil processing during construction.

19. In both items 5 and 6, the overlay soils were covered with waterproof membranes in order to prevent soaking and deterioration during periods of wet weather. From prior field experience, it was realized that unless some protection was provided for the overlay soil in item 5, the introduction of water through the joints of the landing mat during wet-weather periods would cause soaking of the material and subsequent pumping action of the liquified soil through the mat joints under traffic. It was obvious that the exposed soil layer in item 6 would deteriorate rapidly under direct traffic in wet weather and that some waterproof protection would be required there. Therefore, in item 5, T16 membrane was placed over the compacted lean clay before placement of the XM19 landing mat. In item 6, the soil cushion was protected with WX18 membrane. Since the membrane in item 6 was to be subjected to direct traffic, it was decided that WX18, which is the heavier of the two membranes, would be more suitable for use in that item. The membranes were bonded together at the transition between items 5 and 6 and were buried in anchor trenches along the sides

and at the end of the test section. As mentioned earlier, item 1 was surfaced with XM18 landing mat, items 2-5 were surfaced with XM19 mat, and item 6 was surfaced with WX18 membrane only. The test section had a 10-ft-wide traffic lane laid out down the center (see plate 5).

Construction

20. A general view of the deteriorated pavement prior to construction of the overlay test section is shown in photograph 3. The area had a continuous slope of about 1.1 percent from south to north (plate 5). A section measuring 180 ft long and 36 ft wide was laid out on the deteriorated pavement and was divided into six test items, each 30 ft long and 36 ft wide. The entire soil overlay was constructed prior to placement of the landing mat.

21. In order to provide drainage, the test section was constructed with a transverse slope from south to north. Items 1-3 had a 1.5 percent slope, and items 4-6 had a 2 percent slope. The quantity of soil placed in items 1-3 was that amount that would provide a minimum leveling thickness under the mat so as to provide uniform bearing of the mat. The quantity of soil placed in items 4-6 was that amount that would provide a minimum 4-in. thickness under the mat at any point in the traffic lane and a 2 percent transverse slope from south to north. Thus, the thickness of the soil layer in each item increased slightly toward the south edge of the test section.

22. The sand for construction of the leveling course in items 1 and 2 was processed to a water content of about 3.5 percent, transported to the site by truck, and dumped onto the section. The sand was leveled with a bulldozer and smoothed by hand raking.

23. The clay gravel used for construction of the leveling course in item 3 and the 4-in.-thick cushion in item 4 was processed to a water content of about 3.1 percent, transported to the site by truck, dumped onto the section, and spread with a dozer (see photograph 4). Both items 3 and 4 were compacted with four coverages of a 50,000-lb towed roller having four pneumatic tires, each inflated to 90 psi (photograph 5). After compaction, the soil was cut to final grade with a road grader.

24. It was desired to process the soil in items 5 and 6 to a water

content of about 12 percent; however, tests after placement of the soil indicated a water content slightly higher than desired. The in-place soil was aerated by means of a rotary tiller to reduce moisture and then compacted with eight coverages of the 50,000-lb roller. After compaction, the lean clay was cut to final grade with a road grader (photograph 6). Next, membrane anchor trenches were cut alongside items 5 and 6 and across the end of the test section at item 6. The trenches were cut with a road grader and were about 2 ft deep. A sheet of T16 membrane was placed over the lean clay in item 5, and a sheet of WX18 was placed over item 6. The two membranes were bonded together at the transition between items 5 and 6 by means of a glued lap joint, using 3M EC 1099 cement. The edges of the membranes were placed in the anchor trench (photograph 7) where they were pinned securely, and the anchor trench was backfilled.

25. XM18 mat was placed on item 1, and items 2-5 were surfaced with XM19. A 10-ft-wide traffic lane and traffic guidelines were painted on the test section. A general view of the test section after construction is shown in photograph 8.

Test Vehicle

26. A specially designed test vehicle having a single-wheel load of 25,000 lb was used in the traffic tests (photograph 9). The test cart, equipped with an outrigger wheel to prevent overturning, was powered by the front half of a four-wheel-drive truck. The load cart was equipped with a 30x11.5, 24-PR tire inflated to 250 psi. For the 25,000-lb load, the tire had a contact area of about 111 sq in. and an average contact pressure of 225 psi.

PART III: TESTS AND RESULTS

Traffic Tests

27. Traffic was applied to the test section using the vehicle described in paragraph 26. To apply the test traffic, the vehicle was driven forward and backward along the same path, then shifted laterally a distance equal to one tire width, and the process repeated. Therefore, when the test vehicle had traversed the full distance across the test lane, a total of two coverages of traffic had been applied over the test lane. Traffic was applied in an approximately normal distribution pattern (fig. 1). The

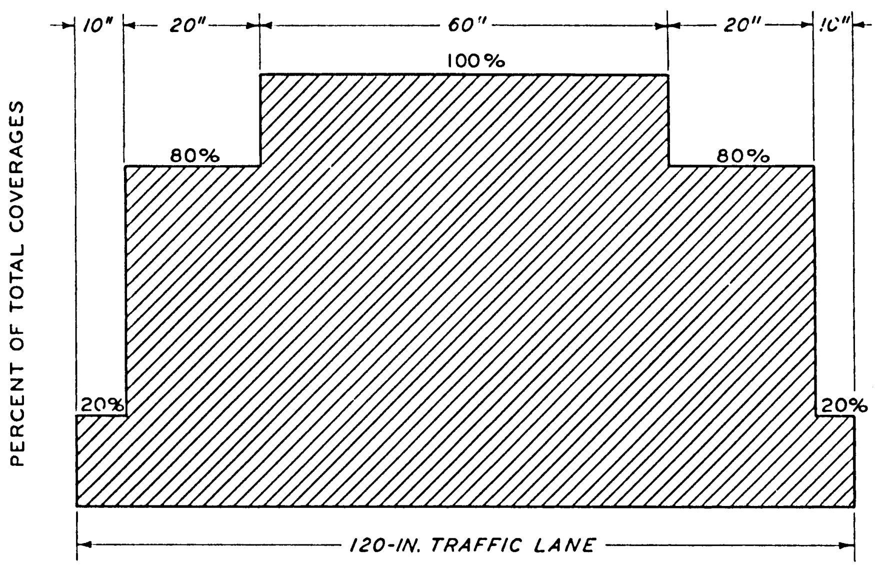


Fig. 1. Traffic distribution pattern

interior 60 in. of the traffic lane received 100 percent of the applied traffic and the exterior portions of the lanes received 80 and 20 percent, as shown. This pattern is similar to the distribution occurring on runways during actual aircraft operations. Each coverage level referred to herein is the total number of coverages applied in the 100-percent-coverage zone.

Soil Tests and Miscellaneous Observations

28. In-place CBR, water content, and dry density tests were conducted

prior to and at the end of traffic. Data obtained are shown in table 1. At least three tests were made at each level indicated, and the data shown are the averages of these tests.

29. Visual observation of the behavior of the test items under traffic and other pertinent factors were recorded throughout the test period. These observations were supplemented by photographs. Level readings were taken prior to and at intervals during traffic to show the condition of the surface of each item.

Behavior of Test Section Under Traffic

30. The traffic test phase of this investigation was conducted from 30 June to 30 October 1967, during which time a total of 2170 coverages of traffic was applied over most of the test section. At two points in the traffic phase, i.e. after 330 and 696 coverages, secondary construction work was performed to improve certain features in the test section. As can be seen in the following paragraphs, the secondary work could well have been included in the initial construction effort. However, it was intended in this test to develop construction techniques that would give satisfactory results with a minimum expenditure of time and effort. Therefore, it was apparent from the beginning of the test that additional work might be required as traffic was applied under various weather conditions. The following narrative is divided into units to describe the traffic and reconstruction sequences as follows: test traffic, 0-330 coverages; secondary construction I; test traffic, 331-696 coverages; secondary construction II; and test traffic, 697-2170 coverages.

Test traffic, 0-330 coverages

31. Test traffic was begun on 30 June 1967. General views of items 1 through 6 prior to traffic are shown in photographs 10 through 15. Rutting began to develop in item 6 at about 10 coverages. By 16 coverages there was an average rut depth of approximately 2.5 in. as shown in photograph 16. Investigation of the lean clay leveling material revealed that the in-place moisture content was approximately 16.5 percent, which was too high for the compaction effort being exerted by the simulated F-4C test

load. The high soil moisture resulted in the development of pore pressure in the soil under the high-pressure tire traffic with a resultant loss in strength. Therefore, at this stage of the test, it was necessary to remove the WX18 membrane from item 6 and to dry the lean clay soil to a lower water content. The soil was dried back to about 11.5 percent moisture and compacted with 16 coverages of the 50,000-lb roller described in paragraph 23. The compacted clay overlay was then proofrolled with four coverages of the test load vehicle, after which an average surface CBR of 44 was indicated. The compacted clay was then fine bladed with a road grader, the WX18 membrane was replaced on the item and anchored, and the traffic test was resumed.

32. On 12 July, 64 coverages of traffic were applied to the test section for a total of 80 coverages. During these 64 coverages, there was a light rainfall in the test area, and it was observed that a slight amount of soil (i.e. the fines in the clay gravel) was pumping up through the mat joints in item 3. The pumping was minor, however, and did not affect the serviceability of the item. The remainder of the test section indicated no signs of soil pumping and was quite serviceable at this time.

33. On 13 and 14 July, 120 coverages were applied to the test section (total 200). During this time, light rainfall in the test area resulted in soil pumping in items 3 and 4. The pumping consisted mainly of washing a small amount of fines from the clay gravel and was not considered particularly detrimental to these items. Items 1, 2, 5, and 6 all remained stable during this period with no apparent ill effects from the rainfall. General views of items 1 through 6 after 200 coverages are shown in photographs 17 through 22, respectively. As can be seen, the test section was quite serviceable at this time.

34. From 14 to 18 July, the test section received 100 coverages (total 300) and no difficulties were experienced. On 19 July, 26 coverages were applied during a heavy rainstorm. Severe pumping of the sand in items 1 and 2 and of the clay gravel fines in items 3 and 4 occurred. No soil pumping was observed in items 5 and 6. Views of items 1 through 6 at 326 coverages are shown in photographs 23 to 28, respectively. A close-up of sand pumped through the mat joints between items 1 and 2 is shown in

photograph 29. After 330 coverages, it was decided that major maintenance would be required to prevent further deterioration of items 1 through 4; therefore, test traffic was suspended.

Secondary construction I

35. All mat was removed from the test section. A view of the exposed sand and the results of soil pumping in item 2 is shown in photograph 30. The overlay soils were allowed to air-dry for several days before remedial construction began.

36. Two basic methods of protecting the overlay soils from water saturation during rainfall were selected: membrane covering and portland cement stabilization. It was proposed to place T16 membrane over the sand in items 1 and 2 and the clay gravel in the first 15 ft of item 3 and to stabilize the clay gravel in the remainder of item 3 and in item 4 with portland cement at the rate of 6 percent by soil weight. A plan and profile of the test section indicating these revisions are shown in plate 6.

37. Work was begun on 10 August. The average water contents of the sand and clay gravel overlay soils at this time were 4.3 and 5.8 percent, respectively. The sand in items 1 and 2 was smoothed by hand raking, and a continuous sheet of T16 membrane was placed over these items and half of item 3 (photographs 31 and 32). The clay gravel overlay in item 4 and the adjacent half of item 3 were stabilized with about 6 percent portland cement by weight of dry soil. Bags of portland cement first were spotted on the clay gravel, as shown in photograph 33. The cement was spread by hand and mixed into the soil with a small, portable rotary tiller (photograph 34). The clay gravel was then compacted with 16 coverages of the 50,000-lb roller. After compaction, the soil was fine bladed with a road grader and smoothed with a steel-wheeled roller. Landing mat was then replaced on the test section, with each panel being replaced into its original position. The T16 membrane that was placed on the sand in items 1 and 2 extended 3 to 4 ft beyond the landing mat at the sides of the test section, and, as shown in photograph 35, landing mat was placed on the free edge of the membrane for anchorage. A general view of the test section at this time is shown in photograph 36.

Test traffic, 331-696 coverages

38. Traffic was resumed on 14 August. On 14 and 15 August, 60 coverages were applied to the test section (total 390). No distress of the test section was observed, and all items were in excellent condition. From 16 to 18 August, 100 coverages were applied (total 490), during which time approximately 1.04 in. of rain fell in the test area. Trafficking was accomplished during periods of heavy rainfall, and although water was observed to pump from under the mat in items 1 and 2, the underlying sand was well protected by the T16 membrane. No soil pumping was observed in items 3-5, and item 6 appeared to remain quite dry and stable during trafficking. By 21 August, 500 coverages had been applied, and all items remained quite serviceable. After 510 coverages, it was decided to suspend further trafficking on item 6 since it was felt that the overlay concept being tested in this item had been substantially proven.

39. On 22 August, 54 coverages were applied to items 1-5 for a total of 564 coverages and no difficulties were observed. On 23 August, 44 coverages were applied (total 608), many of which were accomplished during heavy rainfall. Pumping of clear water from between the mat and membrane was observed in items 1 and 2, but the sand remained quite stable. In the first 15 ft of item 3 where the clay gravel leveling course was covered with T16 membrane, a slight amount of soil pumping (i.e. the fines from the clay gravel) was observed at this time, indicating that leaks had developed in the membrane. The remainder of item 3 and items 4 and 5 remained in excellent condition, and no soil pumping was observed. On 24 August, the test section received 56 coverages (total 664) and little change was observed. On 25 August, trafficking was accomplished during a particularly heavy rainfall. Thirty-two coverages were applied for a total of 696. During this period, it became apparent that rainwater was leaking through or under the T16 membrane in item 3 and progressing under the membrane into the sand in item 2. This was evidenced by additional pumping of soil in the area of item 3 covered with T16 membrane and the development of a longitudinal depression in this same area. During trafficking, the depression in the surface of item 3 progressed steadily into item 2 as a result of the sand becoming saturated and being displaced laterally. The bottom of the

depression was coincidental with the longitudinal joint in the XM19 mat on the north side of the traffic lane. At 696 coverages, the depression was about 5 in. deep in both items 2 and 3. At this time, it was also observed that a small depression and slight soil pumping had developed in item 5 near the transition to item 4, indicating leakage in that area. Therefore, it was decided to suspend trafficking at 696 coverages in order to make repairs on the test section. General views of items 1-5 at this time are shown in photographs 37-41.

Secondary construction II

40. All mat was removed from the test section. A view of the membrane in item 2 after removal of the mat is shown in photograph 42. A view of the sand overlay in item 1 after removal of the mat and membrane is shown in photograph 43. From these photographs it can be seen that the sand leveling course in item 1 was still quite serviceable but that there was a severe depression in item 2. The sand in both items was quite wet from seepage under the T16 membrane. This indicates that the 2- by 12-ft XM18 mat planks provide better confinement over a saturated sand than the 4- by 4-ft XM19 panels. Photograph 44 shows a view of the T16 membrane before its removal from item 3. It can be seen from this photograph that numerous holes had been worn in the membrane as a result of the abrasive action of the mat on the clay gravel. The exposed clay gravel in item 4 is shown in photograph 45, indicating that the soil was still quite stable. Photograph 46 shows the depressed area that developed in item 5 during trafficking; note the free water ponded on the membrane. The compacted lean clay directly below the ponded water was relatively soft, indicating leakage through the membrane or under the free end of the membrane. However, the soil in the remainder of item 5 was quite dry and hard. Since, as shown in photograph 46, the clay gravel near the transition indicated signs of having been washed, i.e. the fines having been flushed out during trafficking, it was decided that the water had entered under the free edge of the membrane.

41. In order to prevent water entry under the T16 membrane on items 1 and 2, it was decided to anchor the membrane in a trench cut laterally at the transition between items 2 and 3. In addition, further

anchorage would be provided on the south side of the test section by means of an anchor trench running along the south edge of items 1 and 2 and intersecting the lateral anchor trench. It was also decided to stabilize the clay gravel in the first 15 ft of item 3 with portland cement at the rate of 6 percent by soil weight, and to place a loose piece of WX18 membrane on this area in order to determine the ability of the membrane to withstand the abrasive effect of the mat and the clay gravel. In item 5, it was decided to anchor the T16 membrane in a trench cut laterally at the transition between items 4 and 5. This anchor trench was to intersect the existing anchor trenches at the sides of the test section. A plan and profile of the test section indicating the revisions are shown in plate 7.

42. Work was begun on 31 August. The sand in items 1 and 2 had been allowed to air-dry for several days and was leveled by hand raking. Anchor trenches, as described in paragraph 41, were cut by hand and the T16 membrane was replaced on items 1 and 2. The south and west edges of the membrane were placed in the trench and secured to the bottom with anchor pins. The clay gravel in the first 15 ft of item 3 was stabilized with portland cement and compacted using the methods described in paragraph 37. A piece of WX18 membrane was placed on this area with one edge of the membrane in the lateral anchor trench between items 2 and 3. Both trenches were then backfilled, and the soil was well compacted. A view of the T16 membrane on items 1 and 2 at this time is shown in photograph 47. A view of the WX18 membrane is shown in photograph 48.

43. Repairs were then made in item 5. The wet soil was removed from the area in which leakage had occurred and was replaced with dry lean clay. The replacement soil was well compacted and leveled with hand tools. As described in paragraph 41, a membrane-anchor trench was cut laterally at the transition between items 4 and 5 (see photograph 49). The free edge of the membrane was placed in the trench and secured with anchor pins, the trench was backfilled, and the soil was well compacted. All mat was then replaced on the test section, and again each mat panel was laid in its original position. A view of the test section after replacement of the mat is shown in photograph 50.

Test traffic, 697-2170 coverages

44. Test traffic was resumed on 11 September. From 11 to 26 September, 548 coverages were applied to the test section for a total of 1244. During this period no difficulties were experienced with any item.

45. On 27 September, 44 coverages were applied (total 1288) during a heavy rain. Very slight pumping of the anchor-trench backfill soil was observed near the transition between items 4 and 5; however, no major areas of distress were observed, and overall the test section remained in excellent condition.

46. From 28 September to 11 October, an additional 502 coverages were applied for a total of 1790. During this period, several panels of XM19 mat appeared to be developing core damage; however, no difficulties were experienced with the overlay soil courses. On 12 October, 60 coverages were applied for a total of 1850. At this time, it was observed that a panel of XM19 located at the northwest corner of item 5 had developed core failure. The failed panel and several adjacent panels were removed. An inspection of the underlying membrane revealed that several holes had been abraded in the T16 membrane, which during previous showers had resulted in leakage to the soil immediately under the failed panel (photograph 51). The wet soil was removed and replaced with soil cement, the membrane was replaced, the holes were patched with waterproof tape, and the landing mat was relaid. The failed panel was replaced with a new XM19 panel. Test traffic was resumed on 18 October. By 24 October, 2149 coverages (total) had been applied to the test section. No damage to or pumping of the overlay soils was observed; however, several panels of XM19 began to indicate signs of fatigue.

47. On 30 October, 21 coverages were applied for a total of 2170. During this traffic period, heavy rain occurred in the test area. Some pumping of the sand in items 1 and 2 was observed, indicating that membrane leakage had occurred. Slight pumping also was observed in item 3, but the test section generally was still quite serviceable. General views of items 1-5 after 2170 coverages are shown in photographs 52-56. At this time, it was decided to terminate the traffic phase of the test since it was felt that the test objectives had been accomplished.

Condition of Membranes and Overlay Soils

48. All mat was removed from the test section. Inspection of the test section revealed that the continual movement of the individual mat planks during trafficking had caused a pinching action on the T16 membrane directly below the mat joints in items 1 and 2. The pinching had cut the membrane in several locations, which allowed water to enter the sand and cause subsequent pumping. Closeup views of the result of the pinching action of the mat in items 1 and 2 are shown in photographs 57 and 58, respectively. The soil pumping had not been particularly severe, and as shown in photographs 59 and 60, the underlying sand was still relatively smooth and stable. An examination of the WX18 membrane in item 3 revealed that the WX18 fared little better than the T16 membrane when exposed to the abrasive action of the mat and clay gravel. Photograph 61 shows that numerous holes were worn in the WX18 membrane.

49. The clay gravel in item 4 that had been stabilized with portland cement is shown in photograph 62. The lower part of the photograph actually shows part of the clay gravel leveling course in item 3, which was also stabilized with portland cement. From this photograph, it can be seen that the stabilized clay gravel was still quite stable. Soil tests at this time indicated that the surface strength of the material in item 4 was in excess of 300 CBR.

50. Examination of the T16 in item 5 after removal of the mat revealed that, generally, the membrane had remained intact throughout the test. In a small area near the transition to item 4, it was found that several small holes had been cut in the membrane due to point abrasion of the membrane on pebbles and small rocks between the membrane and hard soil surface during traffic (see photograph 63). The exposed lean clay in the area directly below the location of the holes in the T16 is shown in photograph 64. It can be seen from the heel prints on the soil that the lean clay had become wet in this particular area. Soil tests in this area indicated an average surface strength of about 3.2 CBR.

51. Overall, the condition of item 5 was good. During trafficking there had been no evidence of soil pumping or surface deformation. An

exposed area of the lean clay considered to be typical of the item is shown in photograph 65. The top 1/8 to 1/4 in. of soil was moist due to condensation under the membrane; however, the underlying material was quite dry and hard. Soil tests in this area indicated soil strength below the moist zone to be about 49 CBR.

52. The WX18 membrane on item 6 was not removed until all test traffic had been completed, although traffic was stopped on item 6 at 510 coverages. A view of the exposed lean clay after removal of the membrane is shown in photograph 66. The soil was stable, and tests indicated the strength of the lean clay at the surface and 4 in. below the surface to be 94 and 85 CBR, respectively.

Surface Deformation

53. Plots of typical cross-section elevations in each item before, during, and after traffic are shown in plates 8 and 9. For items 1-5, typical cross sections indicating surface elevations before traffic, at 330 coverages, after the first maintenance effort, at 696 coverages, after the second maintenance effort, and at 2170 coverages are shown. For item 6, typical cross sections at 0 and 16 coverages, after reconstruction, and at 500 coverages are shown. The elevations shown are based on a relative datum of 100 ft.

54. From plate 8, it can be seen that there was little change or deformation in the surface of item 1 throughout the entire traffic period. Item 2 cross sections indicate the deformation occurring at the north side of the traffic lane due to soil pumping at 330 and 696 coverages to be 0.08 and 0.18 ft, respectively. From 697 to 2170 coverages there was about 0.08-ft deformation in item 2. The cross sections for item 3 also indicate the deformations at 330 and 696 coverages, which measure a maximum of 0.10 and 0.08 ft, respectively. No significant change occurred in item 3 from 697 to 2170 coverages.

55. The cross sections shown in plate 9 for item 4 indicate that the deformation due to soil pumping at 330 coverages measured about 0.09 ft maximum; however, there was little change in the surface of the item after

the gravel was stabilized at 330 coverages. The cross sections for item 5 indicate that there was little change in the surface of this item throughout the entire test period. Item 6 cross sections indicate that at 16 coverages there was a maximum rut depth of about 0.21 ft. This severe rutting was due to the initially high moisture content of the soil and the development of pore pressure under the high tire pressure (250 psi) of the simulated F-4C aircraft loading. After reconstruction of the subgrade at a lower water content, the maximum deformation at the end of 510 coverages was only 0.05 ft.

PART IV: DISCUSSION OF TEST RESULTS AND CONCLUSIONS

Discussion

56. A summary log of test traffic is shown in table 2, which indicates chronologically the application of test traffic, cumulative rainfall, and a summarization of maintenance performed and condition of the test section at the time indicated.

57. Test results in items 1 and 2 indicate that a thin sand leveling course can adequately provide the necessary support to prevent point loading of the landing mat on the ridges of deteriorated pavement, but the sand must be protected from water intrusion in order to prevent soil pumping. After installation of the T16 membrane in items 1 and 2 at 330 coverages, no leakage problems were encountered until 696 coverages, at which time water was observed to have permeated under the edges of the membrane in those items. This condition was remedied by anchoring the membrane edges in trenches. It should be noted that the test section was constructed on a one-way slope to conform to the existing pavement, and this resulted in drainage across the entire test section. If this method of construction is used on a runway having a center-line crown with drainage to both sides, the need for anchor trenches may be eliminated by using sheets field-bonded at transverse joints and extending the membrane on the sides of the runway into lateral drainage ditches. Thus, the T16 membrane will provide adequate protection for overlay sand from direct rainfall and a crown or slope of about 2 to 3 percent on a runway would expedite runoff. The variable of mat type seemed to indicate that the 2- by 12-ft XM18 planks in item 1 resulted in somewhat better confinement of the sand subgrade than did the square XM19 panels in item 2.

58. The service life of the T16 membrane when used between a sand overlay and landing mat appears to be about 2000 coverages. When traffic was stopped at 2170 coverages, it was found that several holes had been worn in the T16 by the pinching action of the mat joint flexure during traffic. Since no evidence of pumping of either dry powdery material during dry weather or wet sand during wet weather was found prior to this

time, it is felt that the majority of holes in the T16 probably appeared at about 2000 coverages.

59. The first 15 ft of item 3 was utilized to determine the capability of T16 and WX18 membranes to withstand the abrasions under traffic when situated between landing mat and a clay gravel overlay. The results of this test indicated that both membranes were severely damaged as evidenced by the numerous holes found in the membranes when the mat was removed. Even the heavy WX18 membrane cannot withstand the extreme point loading of sharp angular objects in the soil as traffic is applied to the overlying mat.

60. The behavior under traffic of the latter 15 ft of item 3, the clay gravel leveling course, and of item 4, the 4-in.-thick clay gravel cushioning course, indicated that a clay gravel material is somewhat susceptible to pumping during wet weather, but can be stabilized with portland cement. Prior to stabilization at 330 coverages, both items showed evidence of pumping of the fines through the mat joints during trafficking. After stabilization, however, little significant soil pumping was observed. After the mat was removed, a soil strength in excess of 300 CBR was determined in item 4. Neither item indicated superior performance in relation to the other. The leveling course requires less material for construction, however.

61. One point that should be emphasized at this time is the performance of the XM19 mat on the clay gravel. During the latter part of the test, it was observed that a number of panels in items 3 and 4 had developed shallow depressions 4 to 8 in. in diameter in the upper surface, which indicated that core failure was developing in these areas. Upon removal of the mat after testing was completed, it was found that the panels had been subjected to point loading in areas of contact between the mat and the larger aggregate in the clay gravel. This was evident from the numerous indentations found on the underside of the panels after their removal from the clay gravel items (see photograph 67). The results of this point loading were localized failures of the mat core that progressed to form large depressed areas. Photograph 68 shows a cut section of mat in an area where a surface depression had

developed. It can be seen that the lower part of the internal core had failed and separated from the panel skin.

62. Excellent performance was obtained in item 5. In this item, the only major change made after initial construction was the installation of the membrane anchor trench at the transition between items 4 and 5 at 696 coverages. Of the few difficulties experienced in item 5, most of the trouble resulted from water permeating under the free edge of the membrane at the transition to item 4. This condition was rectified by installation of the anchor trench, however. Some pumping of the anchor-trench backfill soil was experienced, but this condition was considered to be peculiar to the test section alone. It was noted upon removal of the damaged XM19 panel in item 5 at 1850 coverages that there were several holes in the T16 membrane that had allowed slight water leakage in this area. The presence of small holes in the T16 was also detected after the mat was removed from the test section at 2170 coverages. Although the lean clay surface provided a relatively smooth seating area for the mat, there obviously had been a few small rocks or pebbles in the soil surface which had cut the membrane as a result of point loading in these areas. An examination of the membrane did not reveal that there had been sufficient flexure of the mat in item 5 to cause pinching of the membrane under the mat joints during trafficking. Generally, the overlay soil was in excellent condition after traffic despite the presence of a few holes. The average soil moisture content before and after traffic was 15.5 and 15.9 percent, respectively. Soil tests after completion of traffic indicated an average surface soil strength of about 49 CBR.

63. In item 6, no difficulties were encountered after reprocessing the silt overlay at 16 coverages. Examination of the WX18 membrane at 500 coverages and of the overlay soil after traffic tests were completed indicated that there had been no leakage through the membrane at any time. Under traffic the strength of the overlay soil had shown a significant increase, measuring 44 CBR at the surface after reconstruction and 94 CBR after traffic was completed. The average soil moisture content after reconstruction at 16 coverages and after traffic measured 11.5 and 11.4 percent, respectively. Although the method of deteriorated pavement overlay

used in item 6 does not require the use of landing mat, it should be noted that this method requires very close control of soil moisture content during construction in order to prevent strength loss under traffic as explained in paragraph 18. In addition, a soil-membrane overlay can be employed only if the underlying deteriorated pavement has adequate strength to support aircraft traffic since the soil layer offers little, if any, structural improvement and serves mainly as a leveling course.

Conclusions

64. From the results of the investigation reported herein it is concluded that:

- a. Rough, deteriorated pavements can be overlaid with a soil cushioning layer and new landing mat to provide an adequate surface for the operation of tactical aircraft.
- b. Both fine-grained and granular soils can be used as the leveling or cushioning layer. However, both types of material will require protection to prevent pumping of the fines through mat joints during wet-weather traffic operations.
- c. T16 membrane placed between soil and mat is quite effective in protecting fine-grained cohesive soil or fine sand from moisture infiltration and pumping action during wet weather. However, when used between soil and mat, neither the T16 nor the much heavier WX18 membrane is adequate to withstand the abrasive action of sharp objects in the soil such as the coarse aggregate in the clay gravel material. For this reason, care must be taken to remove roots, rocks, and other sharp objects from soils used under waterproof membrane for overlay construction.
- d. A clay gravel cushion can be effectively protected from water infiltration by stabilization with 6 percent portland cement by soil weight.
- e. The optimum thickness of leveling or cushioning material needed for mat overlay construction is the minimum thickness that will: (1) provide uniform bearing for the mat, (2) provide an adequate transverse slope or crown (approximately 2-1/2 to 3 percent), and (3) allow a sufficient quantity of soil so that the material can be easily placed and compacted with the available construction equipment.

Table 1

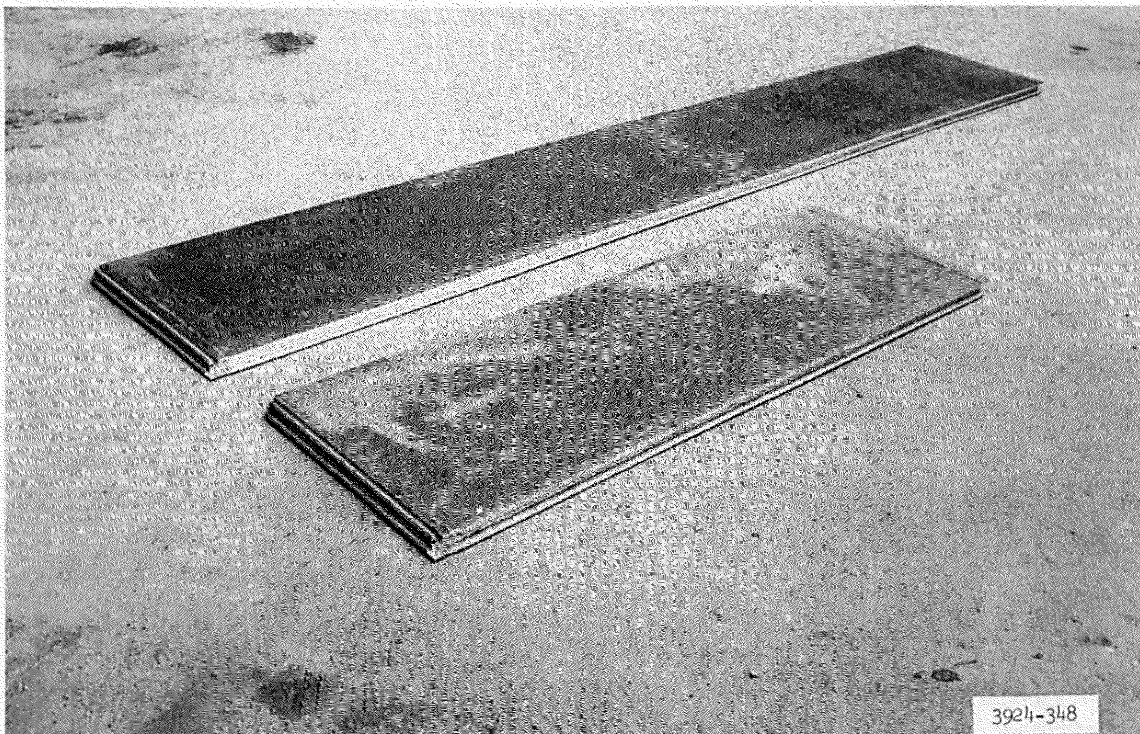
Summary of CBR, Water Content, and Dry Density Data

Material	Item	No. of Coverages	Depth in.	CBR	Water Content %	Dry Density pcf	Remarks
Clay gravel	4	0	Sfc	30	3.1	131.1	
		2170	Sfc	300+	--	--	Stabilized with portland cement at 330 coverages. Item not failed
Lean clay	5	0	Sfc	30	15.0	105.4	
			4	21	15.9	102.5	
		2170	Sfc	49	15.9	105.6	In localized wet spot 3.2 surface CBR indicated; item not failed
Lean clay	6	0	Sfc	29	15.8	105.8	Failed 16 coverages
			4	20	17.3	103.3	
		16	Sfc	44	11.5	--	Reconstructed
		2170	Sfc	94	10.2	122.0	Item not failed
			4	85	12.5	121.4	

Table 2

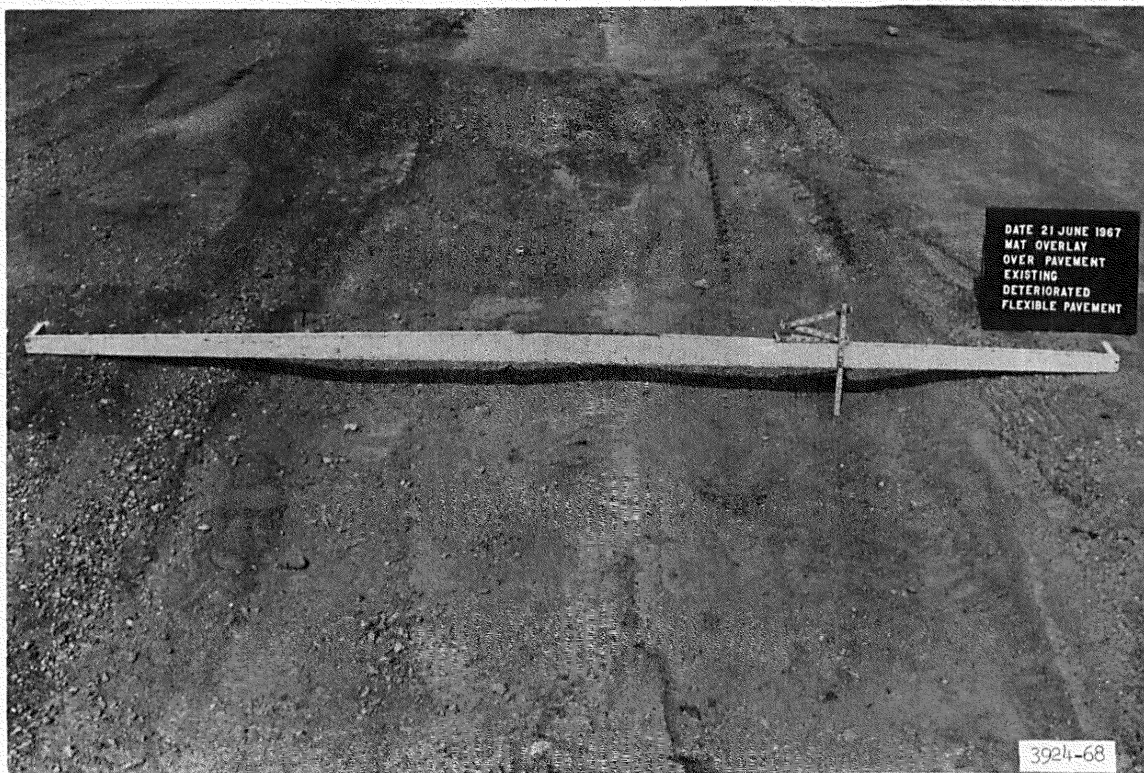
Traffic Log

1967 Month	Day	Cumulative Coverages	Cumulative Rainfall, in.	Traffic Log
				0 to 330 Coverages
June	30	10	0	Items 1-5 in excellent condition. Item 6 rutting
July	3	16	0.20	Item 6 failed due to excessive rutting. Items 1-5 in excellent condition
	4-11	16	2.25	Item 6 reconstructed. In-place soil removed and replaced with lean clay at 11.5% water content. Compacted with 16 coverages of 50-kip rubber-tired roller having four tires, each inflated to 90 psi, plus four coverages of load cart. Surface CBR of 44 indicated
	12	80	2.26	Light rainfall in test area. Minor soil pumping in item 3. All other items quite serviceable
	13-14	200	2.34	Light rainfall in test area. Minor soil pumping in items 3 and 4. All other items remained stable
	14-18	300	2.37	All items in excellent condition. No pumping
	19	330	2.54	Heavy rain in test area. Sand pumping in items 1 and 2. Fines in clay gravel pumping in items 3 and 4. Items 5 and 6 in excellent condition
				Secondary Construction I
July Aug	20 13			All mat removed from test section. Sand in items 1 and 2 air-dried, covered with T16 membrane. Membrane extended into adjacent 15 ft of item 3. Remainder of item 3 and all of item 4 stabilized with portland cement at 6% by soil weight. Soil compacted with 16 coverages of 50-kip drawn roller having four pneumatic tires, each inflated to 90 psi. All mat replaced
				331 to 696 Coverages
Aug	14-15	390	5.44	All items in excellent condition
	16-18	490	6.48	Traffic in heavy rainfall. No soil pumping in any item
	19-21	510	7.20	All items in excellent condition. Test traffic suspended in item 6
	22	564	7.20	All items quite serviceable
	23	608	8.79	Trafficking performed in heavy rainfall. Only water on top of membrane pumping in items 1 and 2. Slight pumping of fines in first 15 ft of item 3. No pumping in remainder of test section
	24	664	8.79	No change in test section
	25	696	9.75	Traffic in heavy rainfall. Considerable pumping of fines in first 15 ft of item 3. Longitudinal depression developed in this area and progressed into item 2 as result of sand in item 2 becoming wet and being pumped laterally under membrane. Pumping and depression in item 5 near transition to item 4. Items 1 and 4, and last 15 ft of item 3 in excellent condition
				Secondary Construction II
Aug Sept	26 10			All mat removed from test section. Sand in items 1 and 2 air-dried and leveled. T16 membrane replaced and anchored in trench on south side of items 1 and 2 and at transition between items 2 and 3. T16 that had been on first 15 ft of item 3 was severely abraded. First 15 ft of item 3 stabilized with portland cement at 6% by soil weight. Loose piece of WX18 membrane placed in this area. Remainder of item 3 and all of item 4 in excellent condition. Small wet spot in lean clay in item 5 near transition to item 6. Membrane pulled back. Wet soil removed and replaced with dry material. Membrane replaced and anchored in trench at transition between items 4 and 5. All mat replaced on test section
				697 to 2170 Coverages
Sept	11-26	1244	10.99	All items in excellent condition
	27	1288	11.30	Traffic in heavy rainfall. Very slight pumping at transition between items 4 and 5
	28	1790	11.30	Several panels of XM19 appeared to be developing core depressions. Otherwise test section in excellent condition
Oct	11	1790	11.30	Several panels of XM19 appeared to be developing core depressions. Otherwise test section in excellent condition
	12	1850	11.30	Failed panel in item 5. Panel removed. T16 below panel had developed holes. Soil in this area slightly wet and soft. Soil removed and replaced with dry soil cement. Membrane patched. Panel replaced
	18-24	2149	11.88	Several panels of XM19 showing signs of fatigue. Otherwise test section in excellent condition
	30	2170	12.44	Traffic in heavy rain. Slight pumping of sand in items 1 and 2, indicating leakage through membrane. Not severe. Very slight pumping of fines in item 3. Overall test section in excellent condition. Test traffic terminated



Photograph 1. Full and half planks of XM18

Photograph 2. Full and half panels of XM19



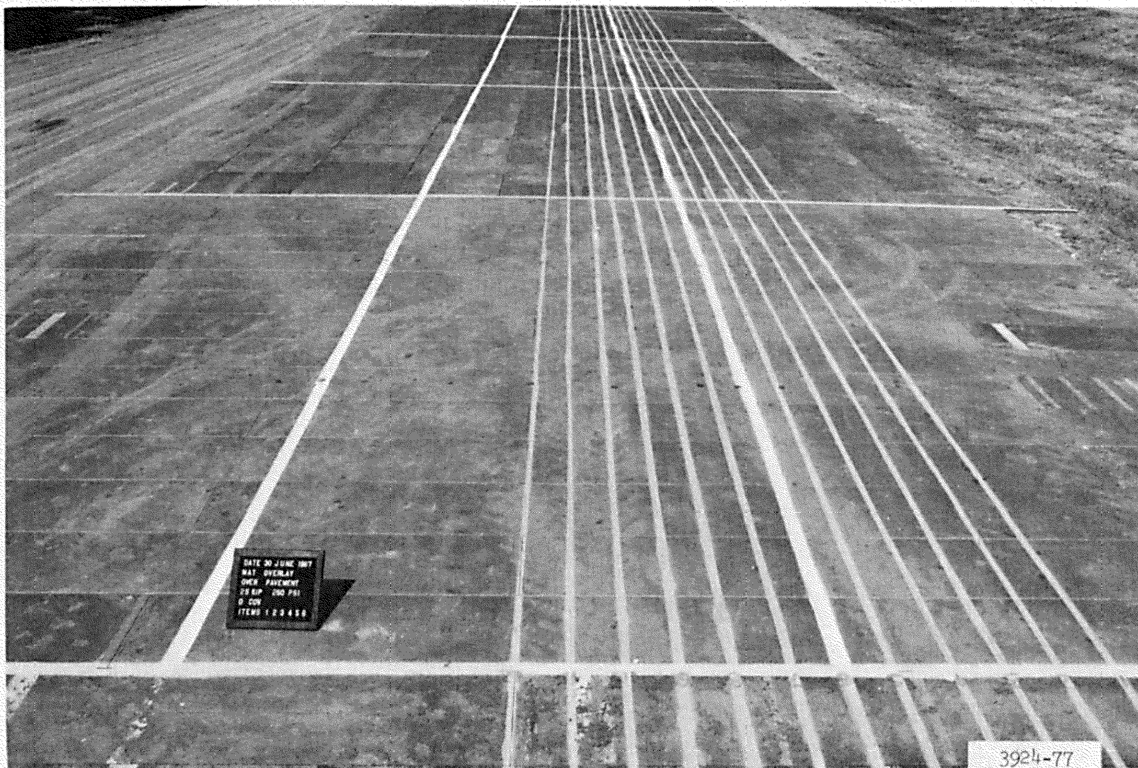
Photograph 3. Deteriorated asphaltic concrete pavement used for test section

Photograph 4. Spreading clay gravel in items 3 and 4 with bulldozer

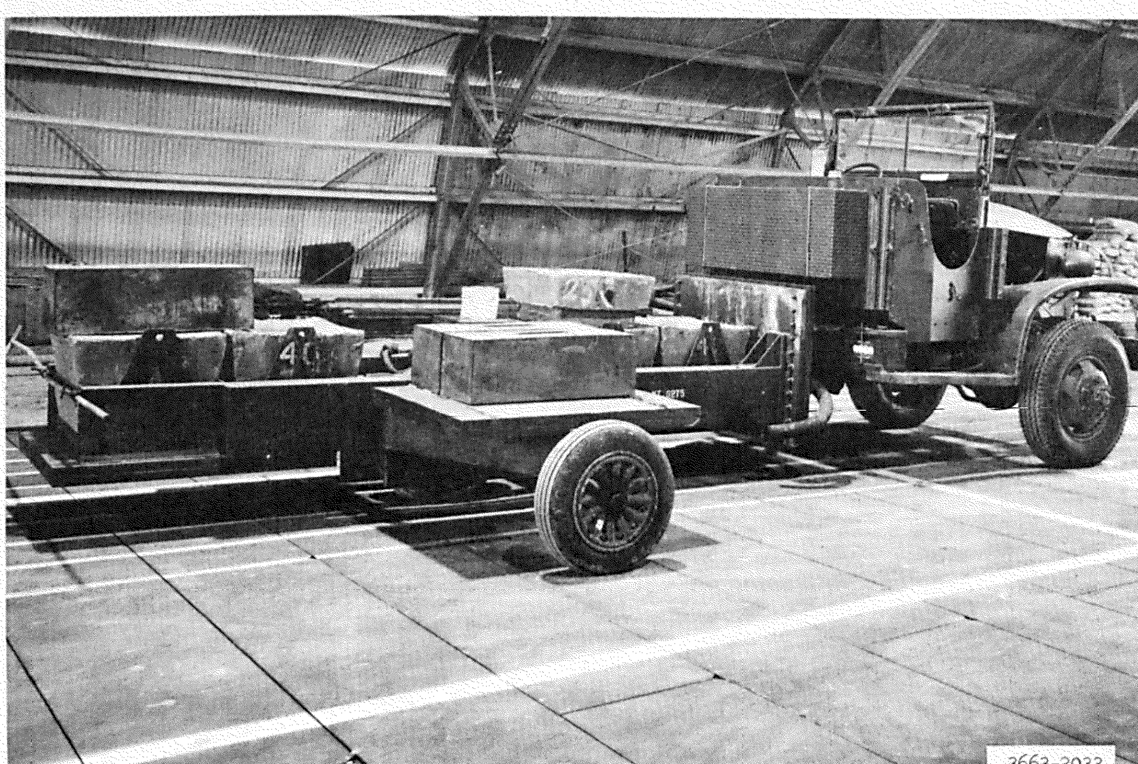
Photograph 5. Compacting clay gravel with 50,000-lb towed roller

Photograph 6. Cutting lean clay to final grade with road grader

Photograph 7. Edges of membrane placed in anchor trench prior to pinning and backfilling



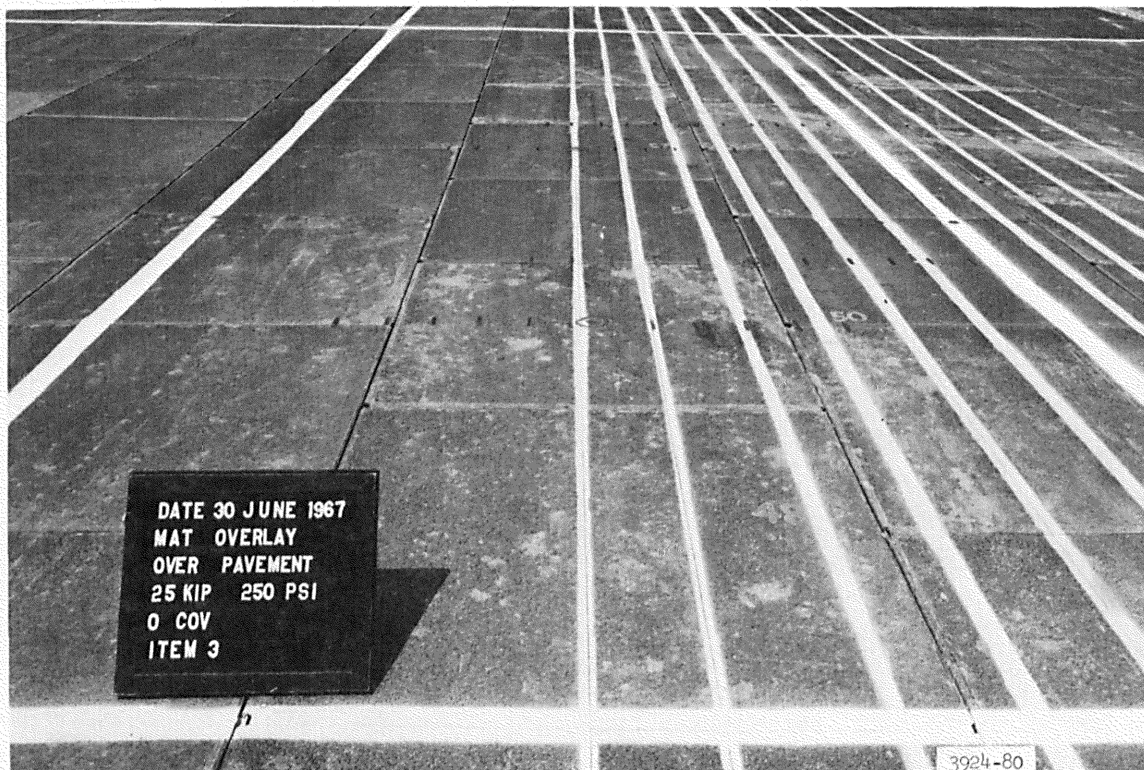
Photograph 8. General view of test section prior to traffic



Photograph 9. Load cart with 25,000-lb single-wheel load

Photograph 10. Item 1 prior to traffic

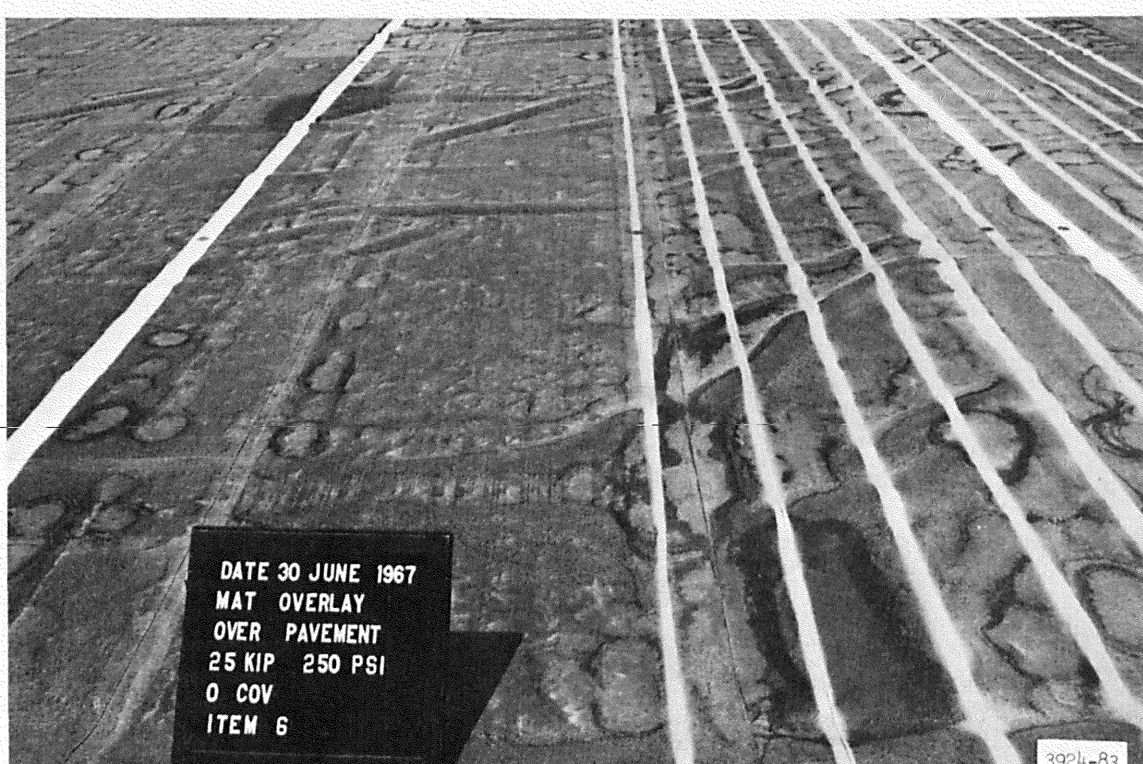
Photograph 11. Item 2 prior to traffic



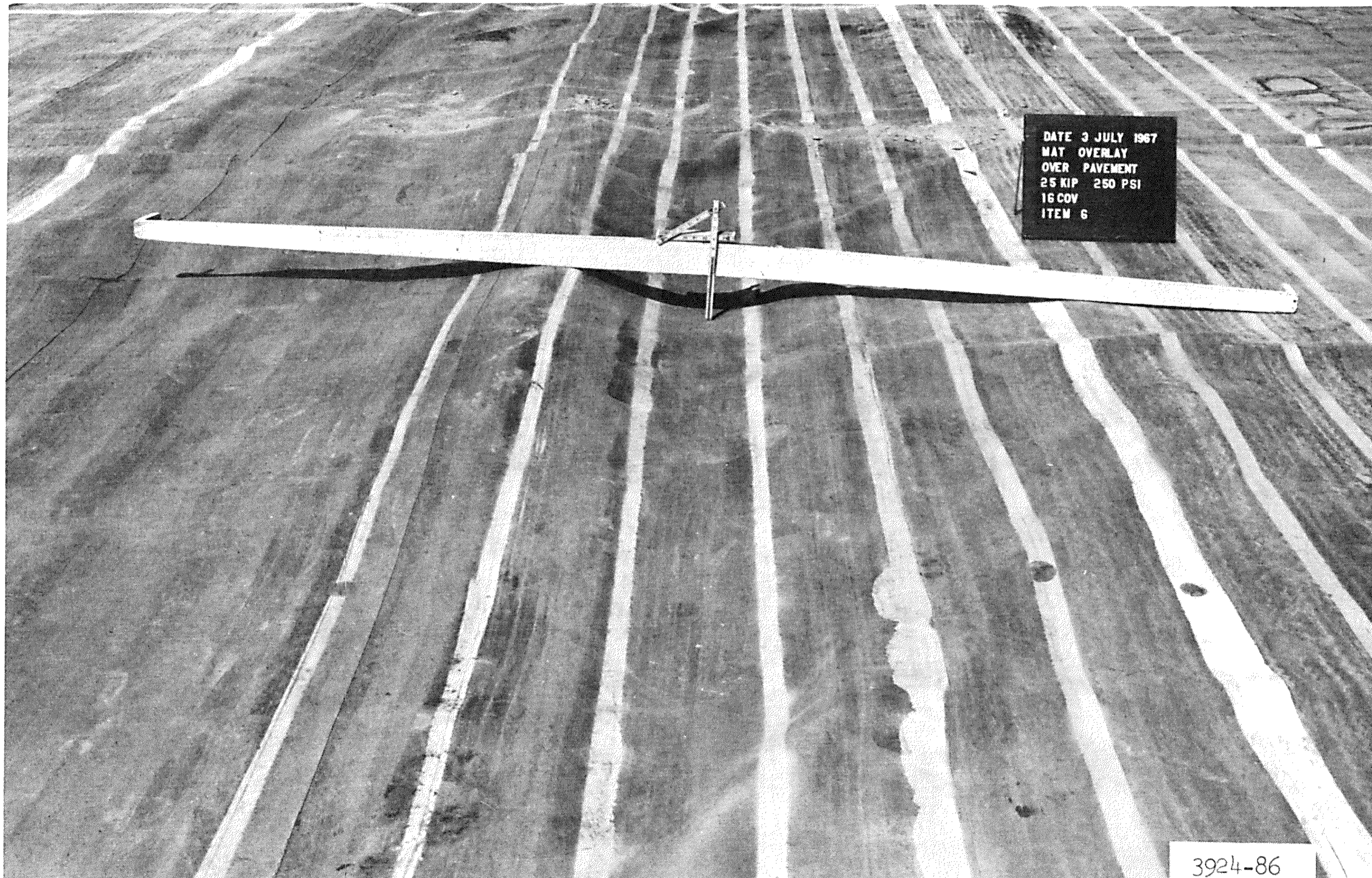
Photograph 12. Item 3 prior to traffic

Photograph 13. Item 4 prior to traffic

Photograph 14. Item 5 prior to traffic

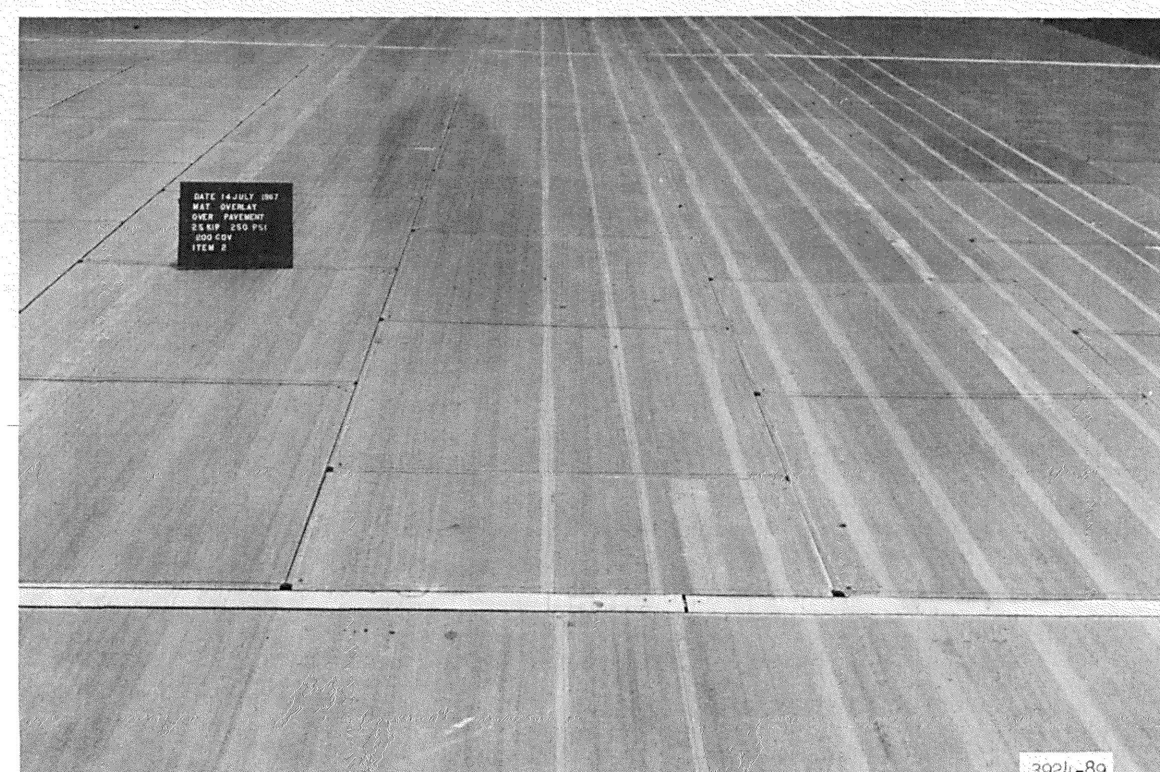


Photograph 15. Item 6 prior to traffic

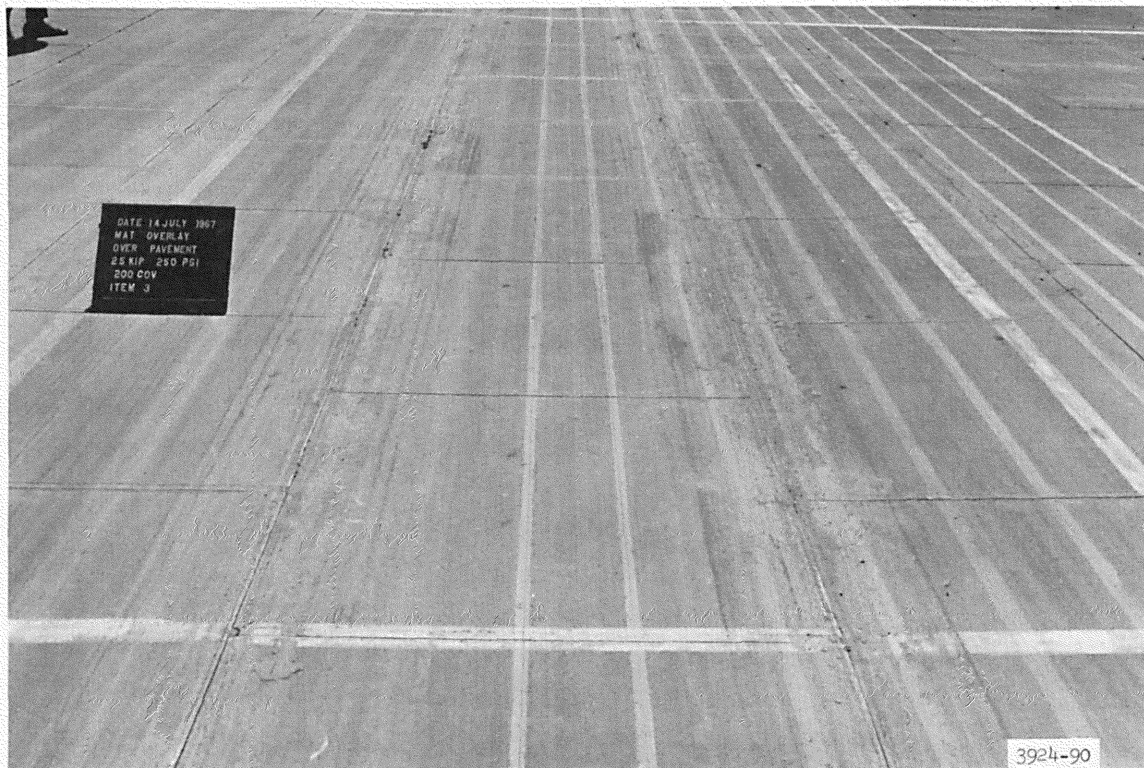


Photograph 16. Item 6 after failure at 16 coverages

Photograph 17. Item 1 after 120 coverages applied during light rainfall (200 coverages total)

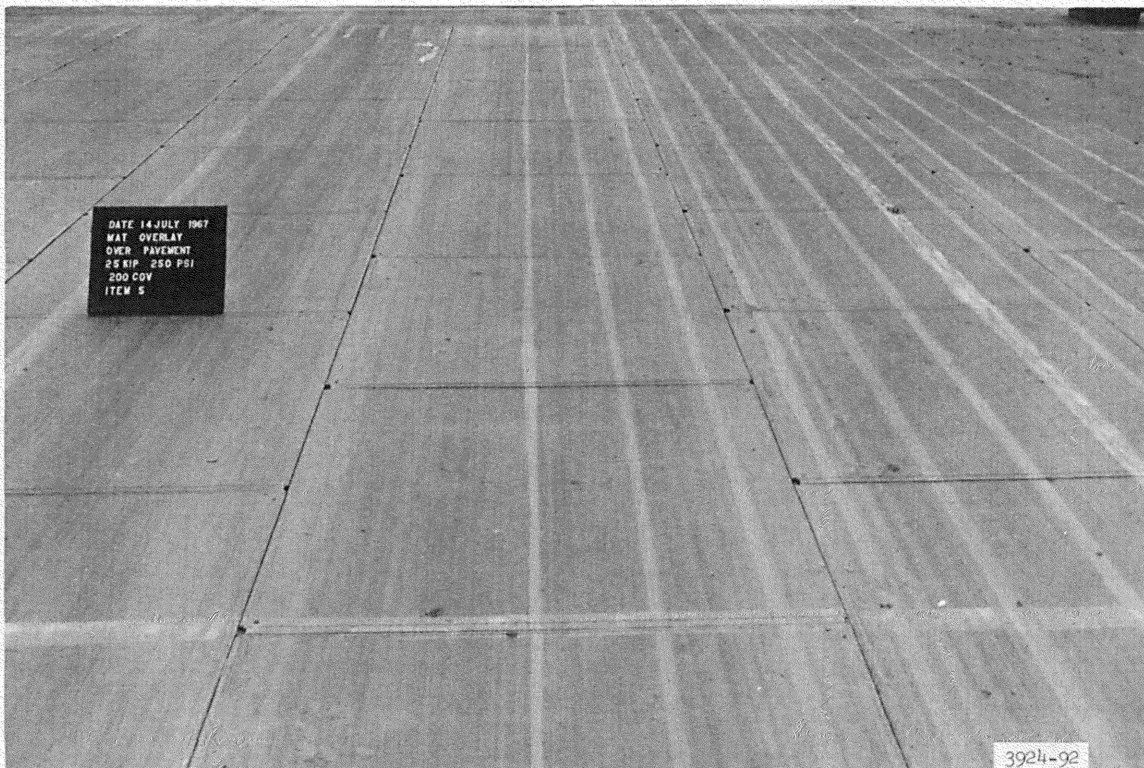


Photograph 18. Item 2 after 120 coverages applied during light rainfall (200 coverages total)



Photograph 19. Item 3 after 120 coverages applied during light rainfall (200 coverages total). Note soil pumped onto mat surface

Photograph 20. Item 4 after 120 coverages applied during light rainfall (200 coverages total). Note soil pumped onto mat surface



Photograph 21. Item 5 after 120 coverages applied during light rainfall (200 coverages total)

Photograph 22. Item 6 after 120 coverages applied during light rainfall (200 coverages total)

Photograph 23. Item 1 after 26 coverages applied during heavy rainfall caused severe pumping (326 coverages total)

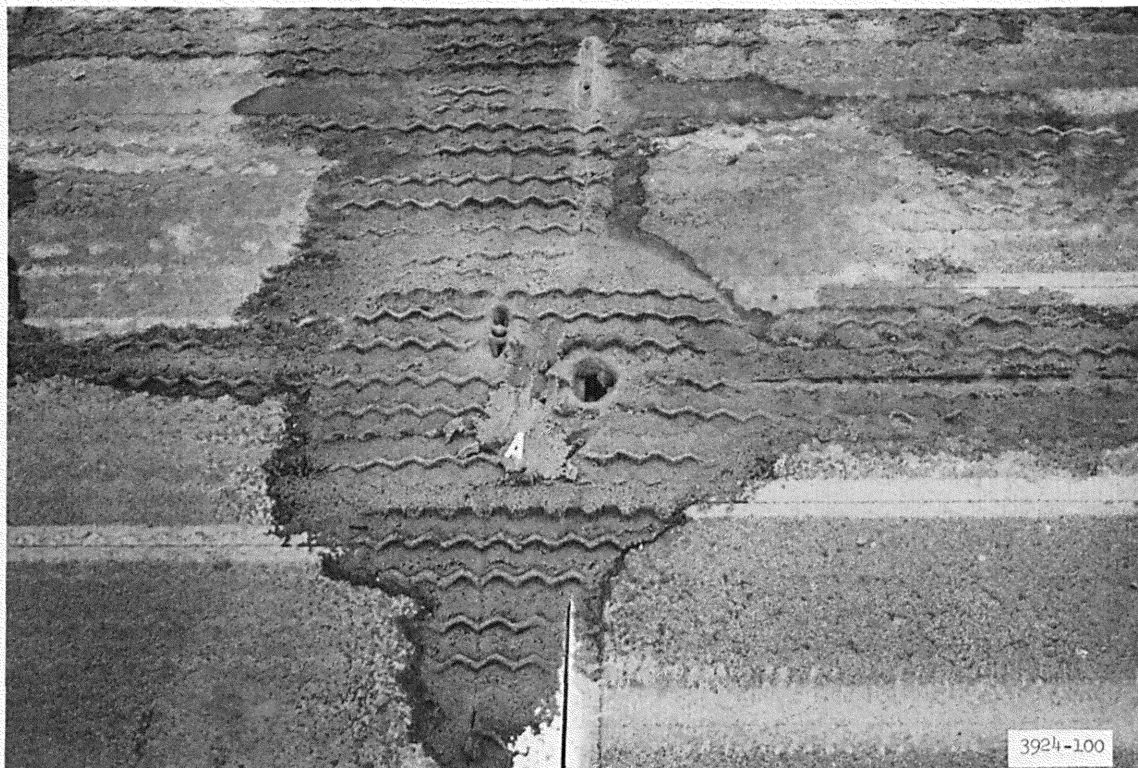
Photograph 24. Item 2 after 26 coverages applied during heavy rainfall caused severe pumping (326 coverages total)

Photograph 25. Item 3 after 26 coverages applied during heavy rainfall caused severe pumping (326 coverages total)

Photograph 26. Item 4 after 26 coverages applied during heavy rainfall caused severe pumping (326 coverages total)

Photograph 27. Item 5 after 26 coverages applied during heavy rainfall (326 coverages total)

Photograph 28. Item 6 after 26 coverages applied during heavy rainfall (326 coverages total)



Photograph 29. Sand that pumped through the mat joints between items 1 and 2 when section was trafficked during heavy rainfall

Photograph 30. Condition of sand overlay after 330 coverages

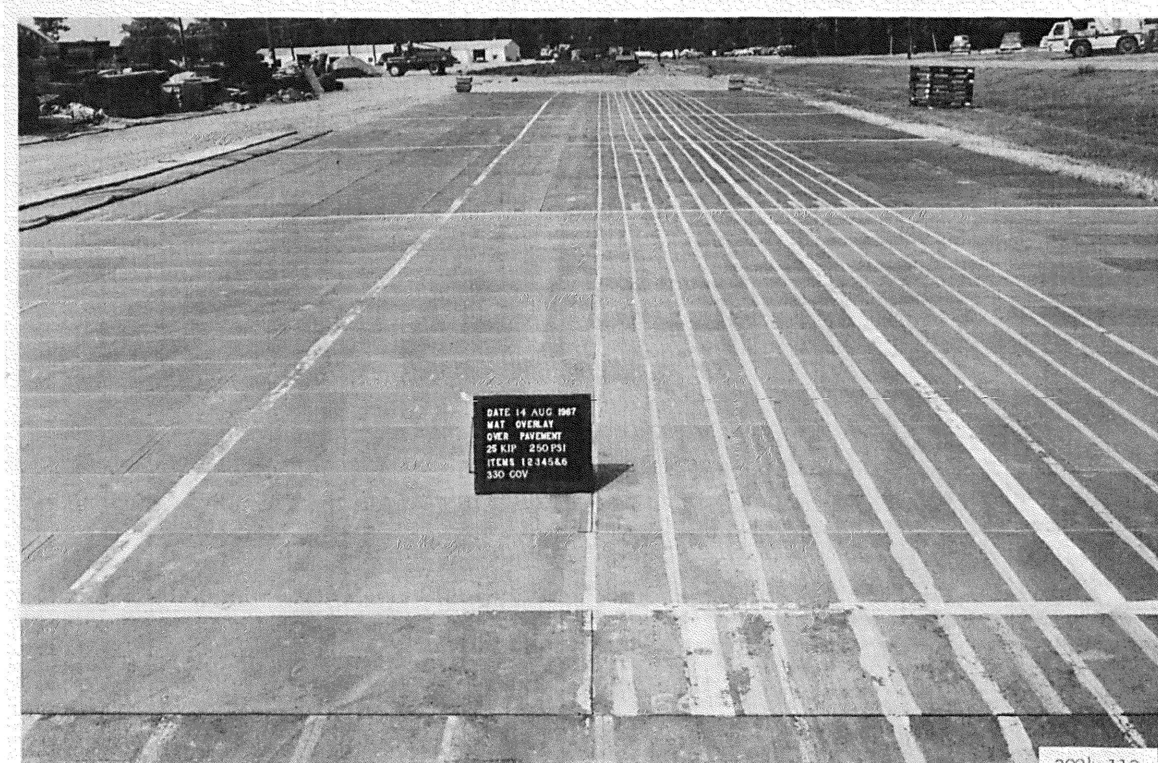
Photograph 31. Sand in items 1 and 2 after secondary construction I

Photograph 32. T16 membrane placed over items 1 and 2 and half of item 3

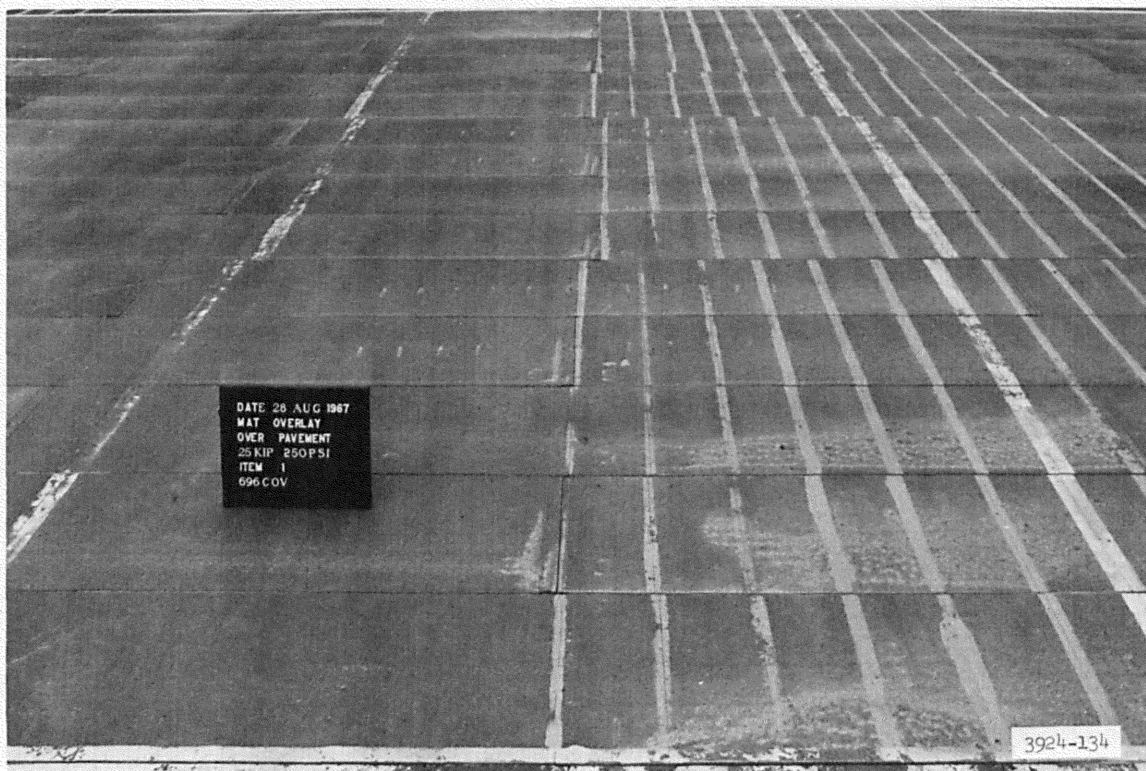
Photograph 33. Bags of cement on section preparatory to stabilizing clay gravel

Photograph 34. Mixing cement into soil with a rotary tiller

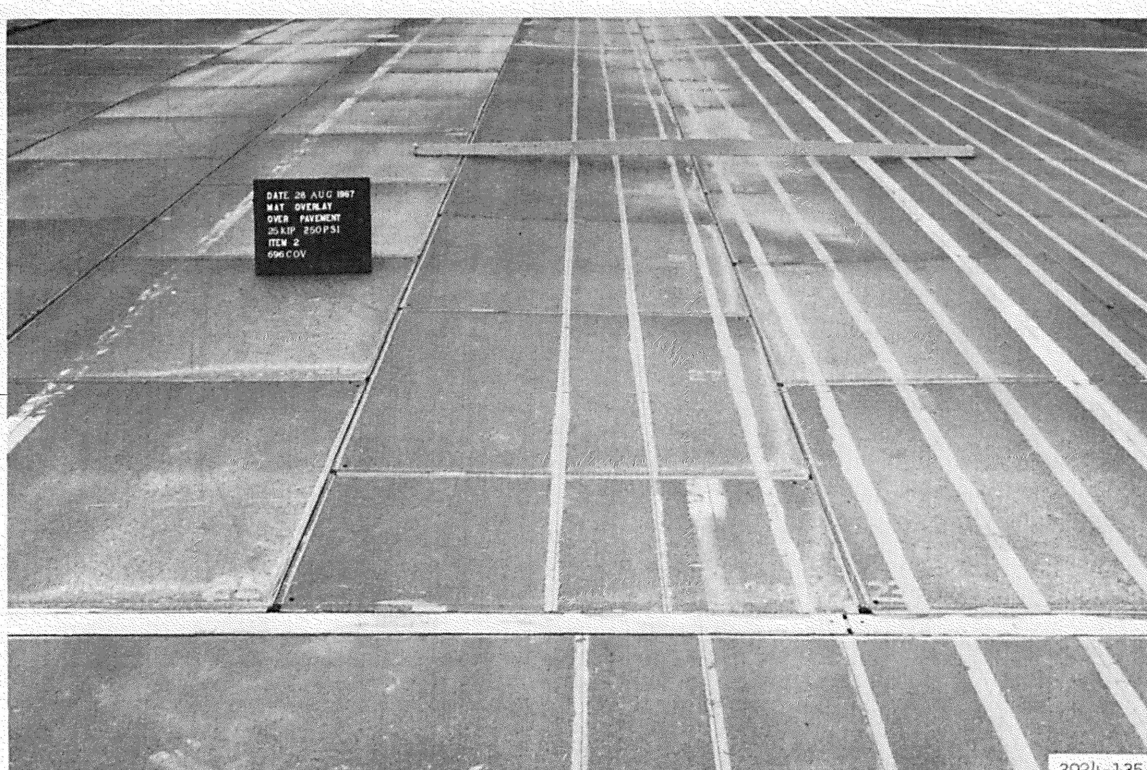
Photograph 35. Free edge of T16 membrane anchored with landing mat



Photograph 36. General view of test section after completion of secondary construction I



Photograph 37. Item 1 after 696 coverages



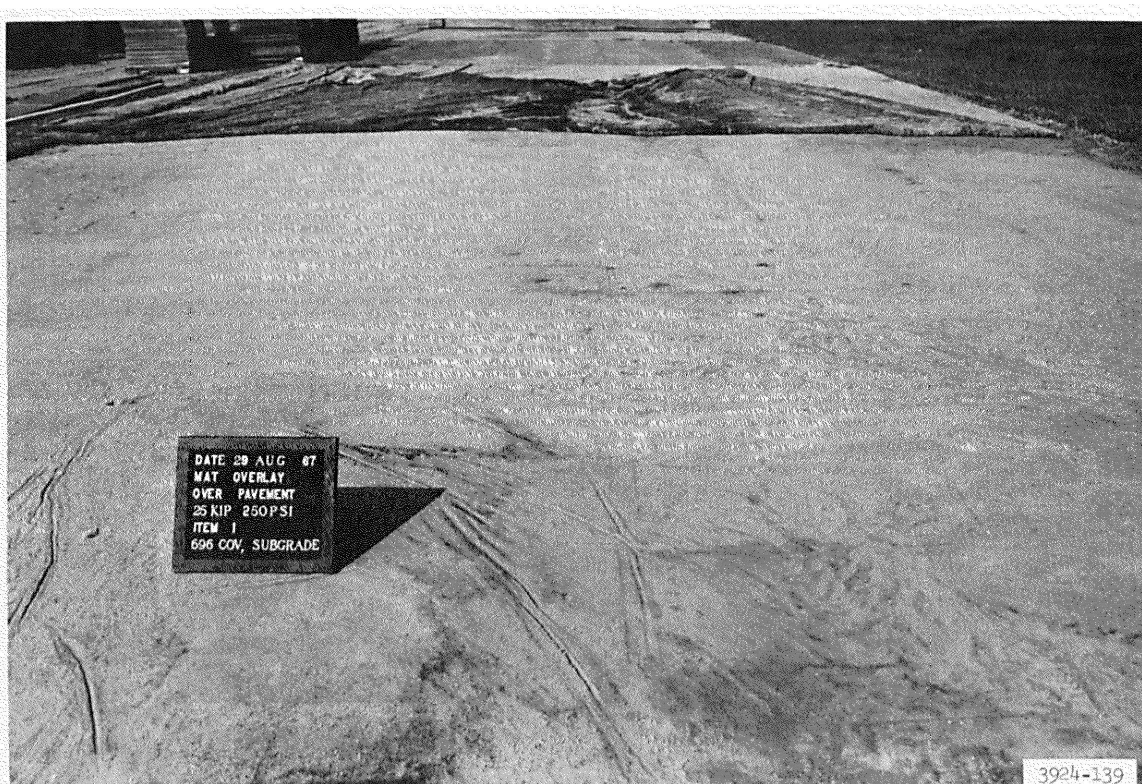
Photograph 38. Item 2 after 696 coverages

Photograph 39. Item 3 after 696 coverages

Photograph 40. Item 4 after 696 coverages

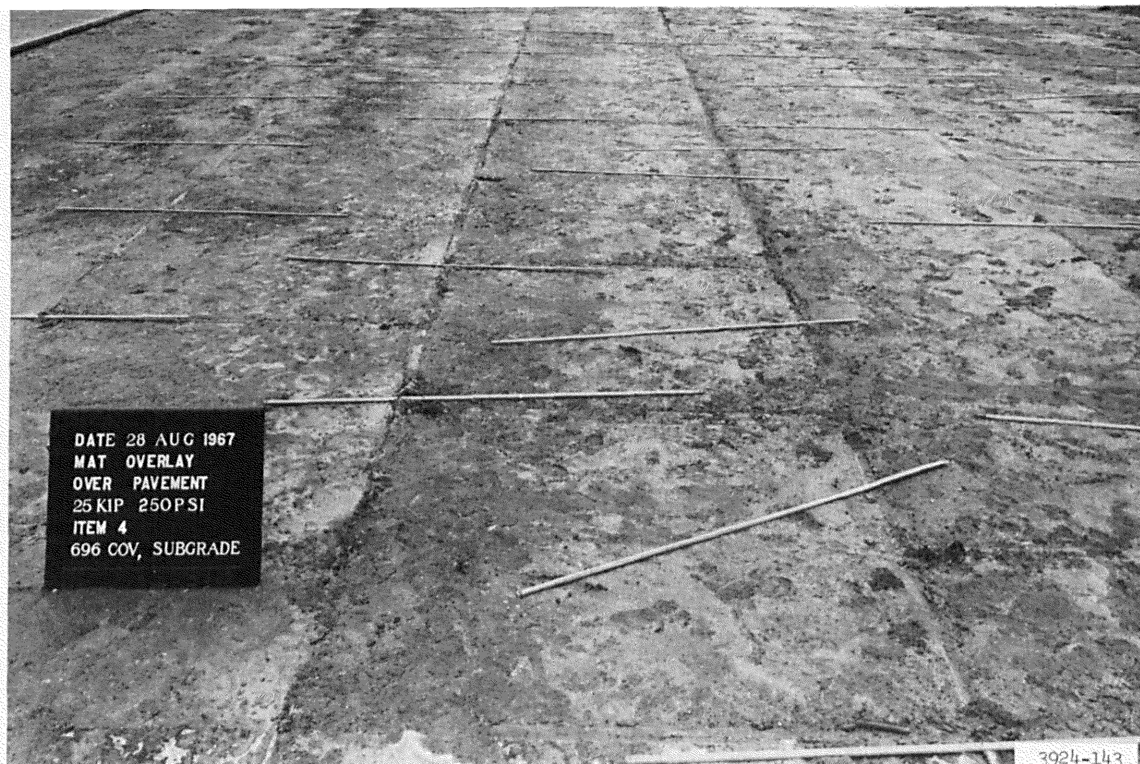
Photograph 41. Item 5 after 696 coverages

Photograph 42. T16 membrane in item 2 after mat was removed after 696 coverages (rods are XM19 connector bars)



Photograph 43. Condition of sand overlay in item 1 after 696 coverages

Photograph 44. Numerous holes worn in T16 membrane on item 3 during 366 coverages (696 total coverages on section)



Photograph 45. Condition of clay gravel overlay after stabilization and subsequent 366 coverages (696 total coverages on section)

Photograph 46. Washed clay gravel between items 4 and 5 (rods are XM19 connector bars)

Photograph 47. T16 membrane on items 1 and 2 after secondary construction II

Photograph 48. WX18 membrane on item 3 after secondary construction II

Photograph 49. Anchor trench cut laterally between items 4 and 5 in secondary construction II

Photograph 50. General view of test section after completion of secondary construction II

Photograph 51. Condition of soil under failed panel of XM19 (1850 coverages)

Photograph 52. Item 1 after 2170 coverages

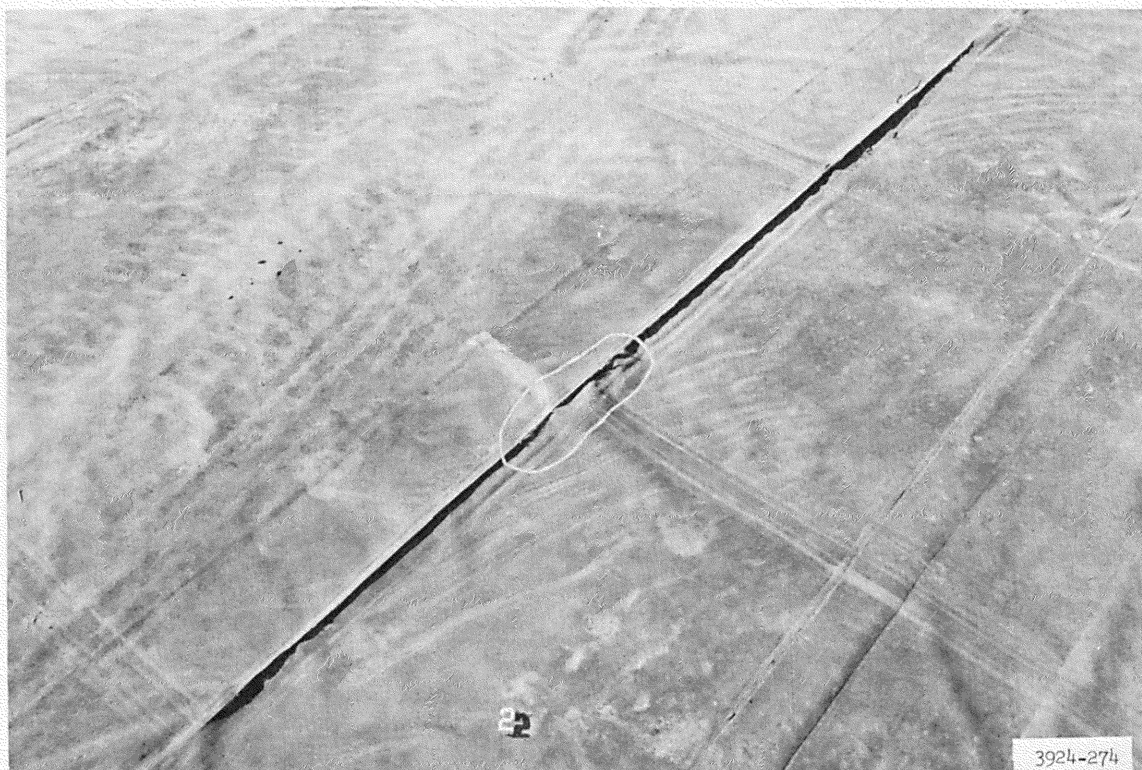
Photograph 53. Item 2 after 2170 coverages

Photograph 54. Item 3 after 2170 coverages

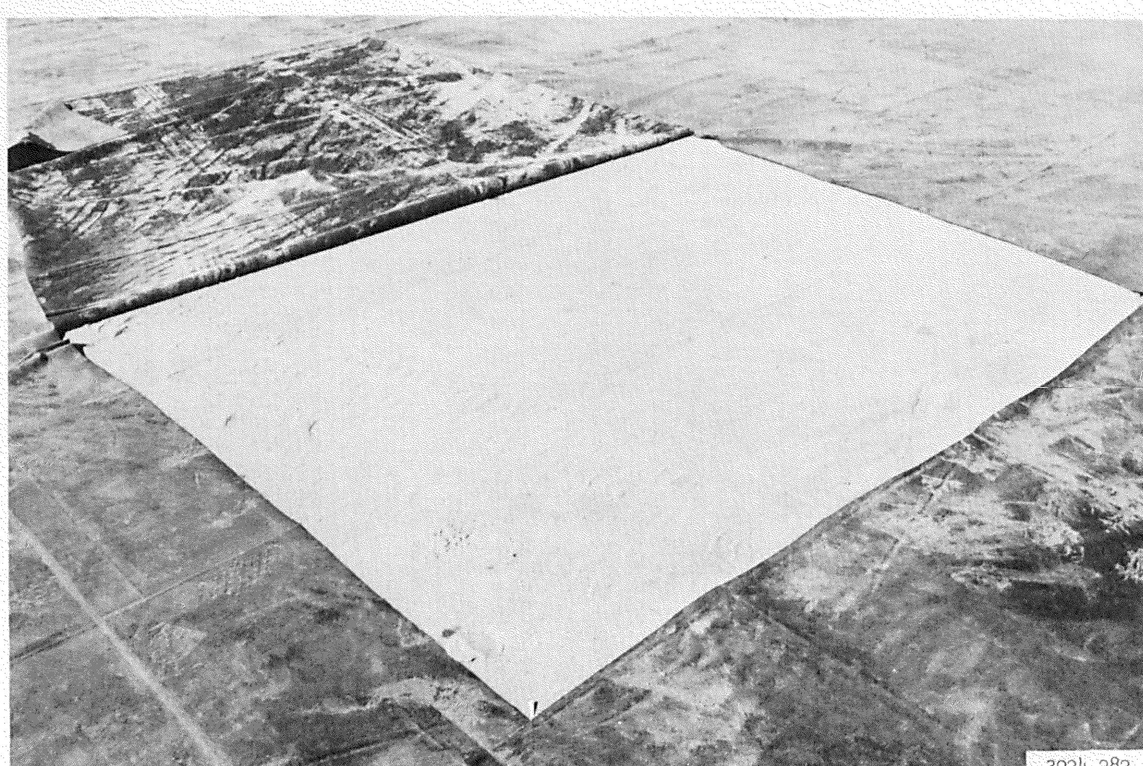
Photograph 55. Item 4 after 2170 coverages

Photograph 56. Item 5 after 2170 coverages

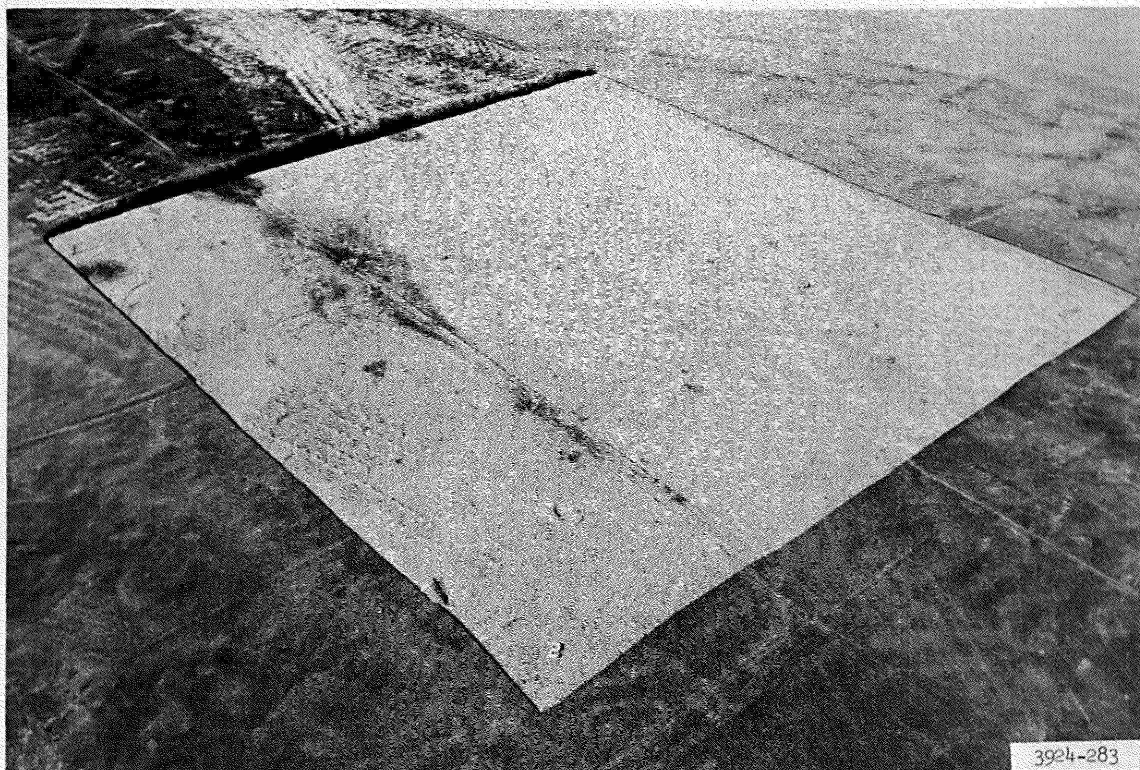
Photograph 57. Membrane cut by pinching action of mat in item 1



Photograph 58. Membrane cut by pinching action of mat in item 2



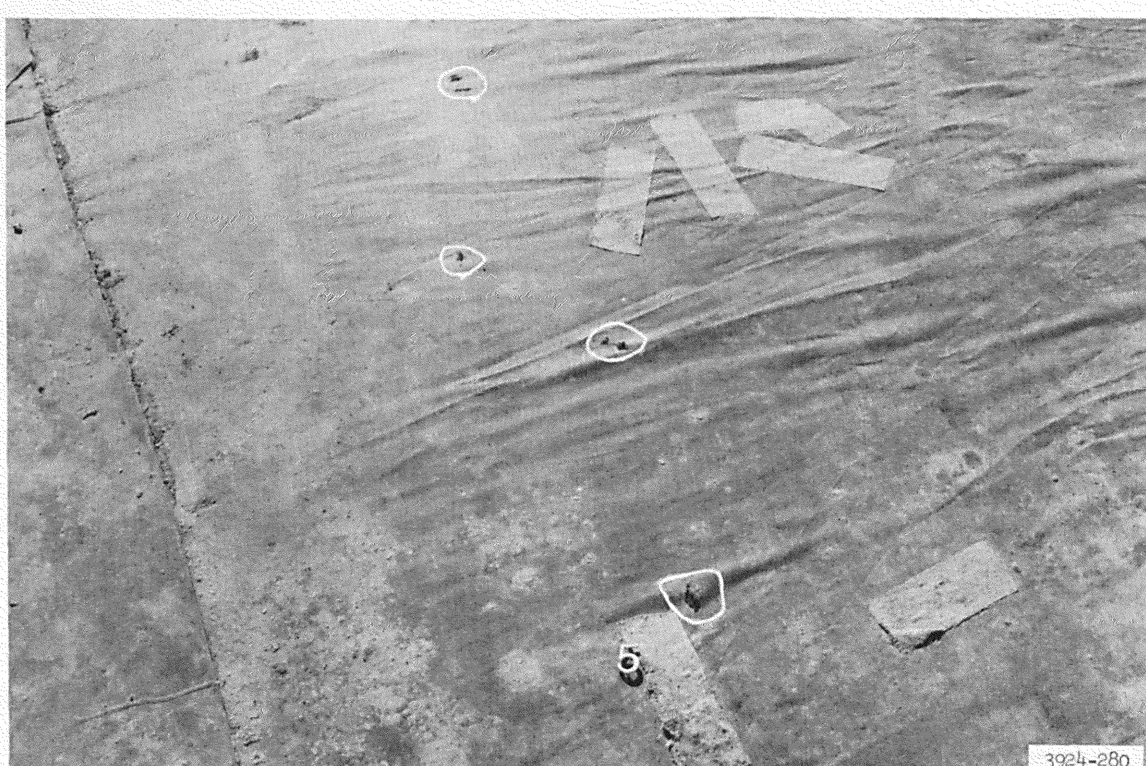
Photograph 59. Condition of sand in item 1 after 2170 coverages



Photograph 60. Condition of sand in item 2 after 2170 coverages

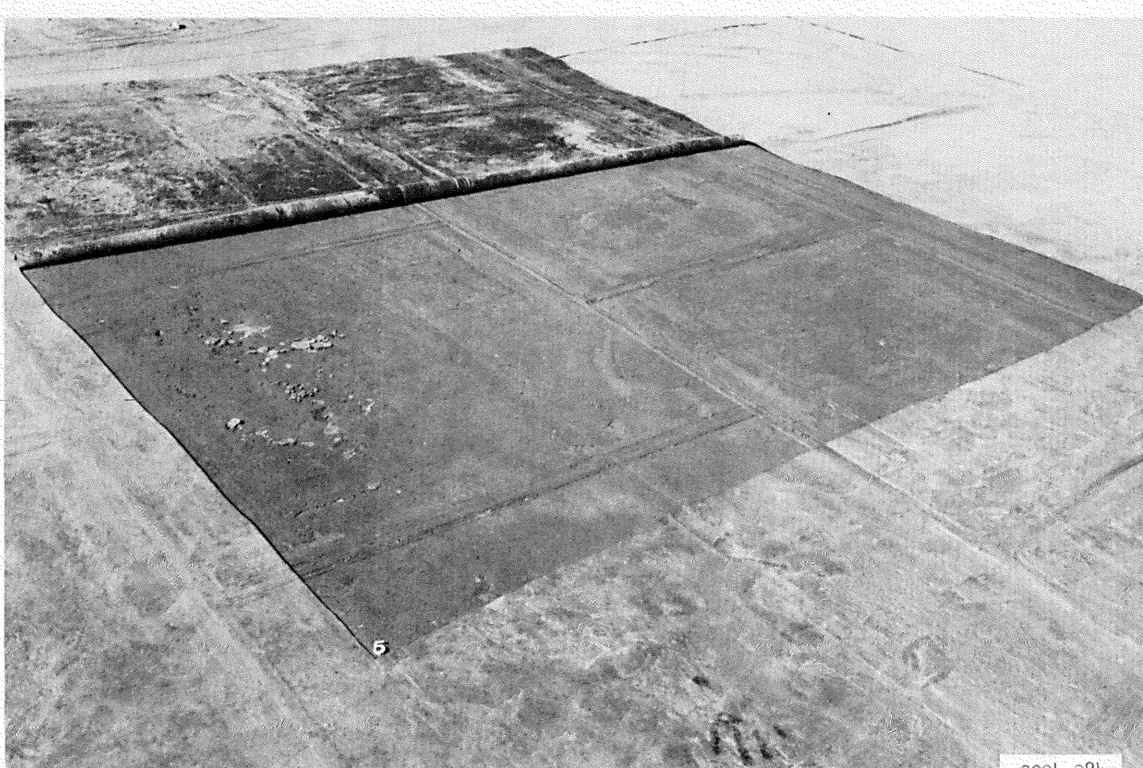
Photograph 61. Holes worn in WX18 by abrasive action of mat and clay gravel

Photograph 62. Condition of stabilized clay gravel in item 4 after 2170 coverages

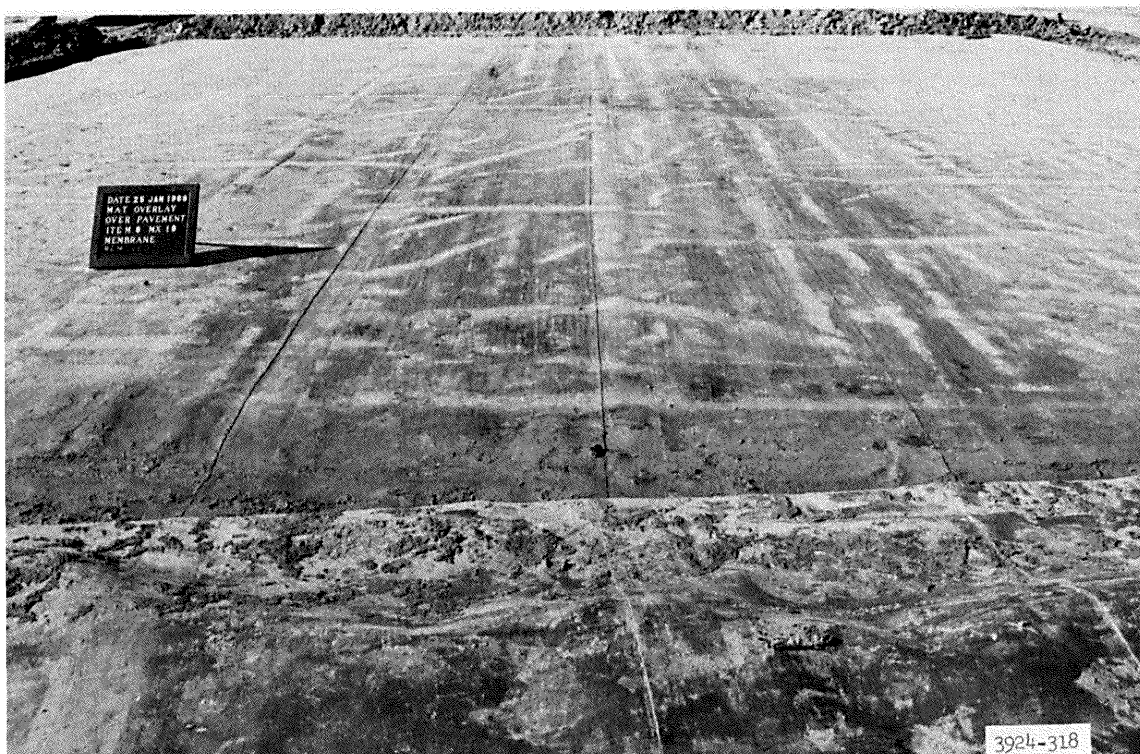


Photograph 63. Small holes cut in T16 membrane in item 5

Photograph 64. Lean clay directly under holes shown in photograph 63

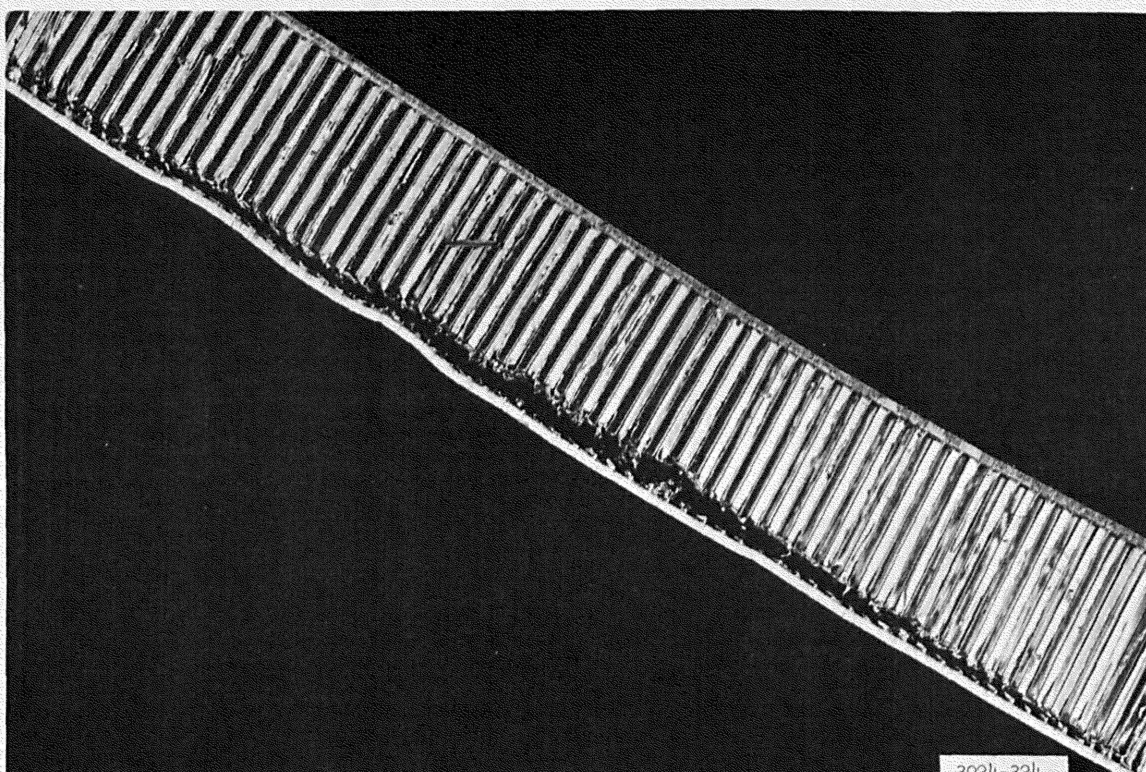


Photograph 65. Stable condition of lean clay considered typical of item 5

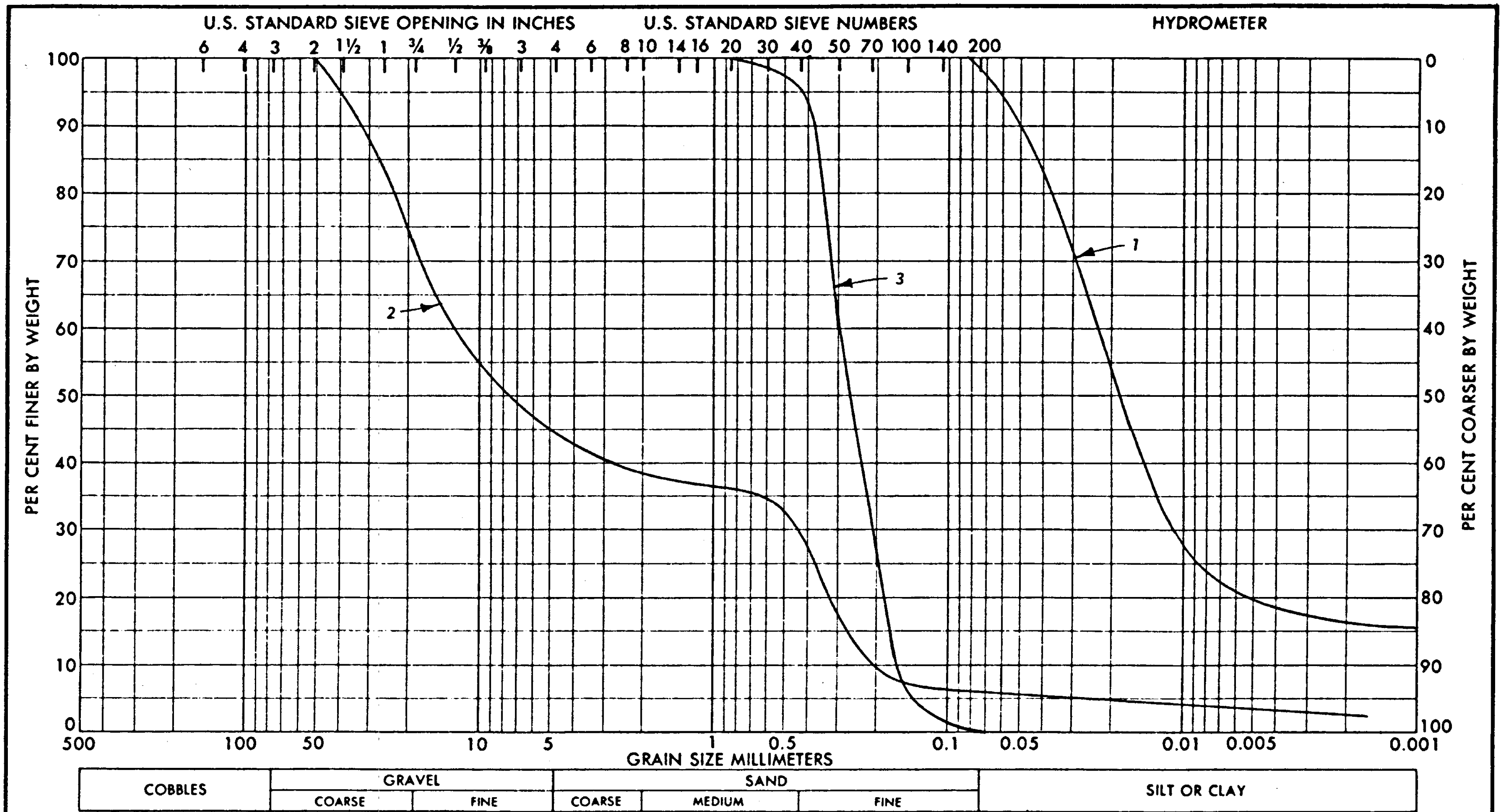


Photograph 66. Lean clay in item 6 after removal of membrane

Photograph 67. Indentations on underside of mat that had been placed on clay gravel



Photograph 68. Internal failure of XM19 mat

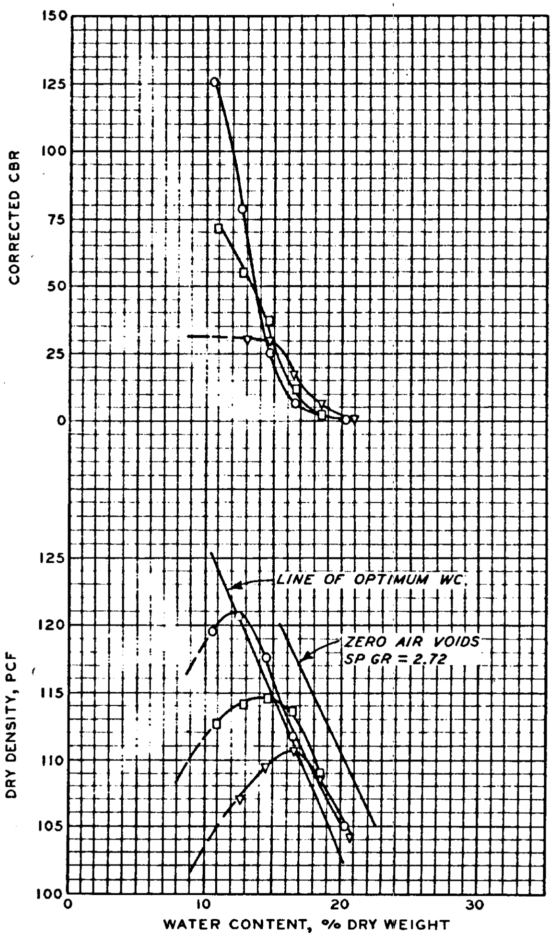


SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
1		LEAN CLAY (CL)		35	23	12
2		CLAY GRAVEL (GP)		19	16	3
3		SAND (SP)		NONPLASTIC		

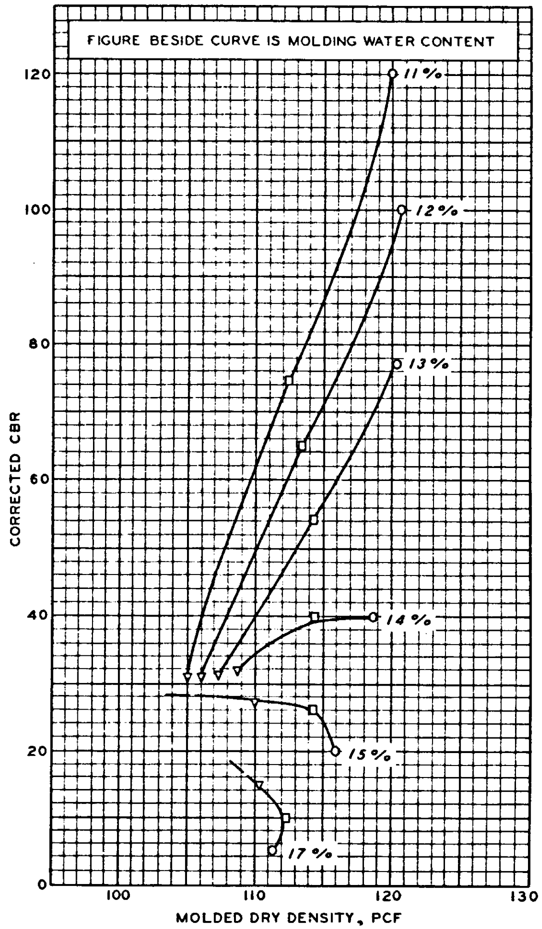
GRADATION AND CLASSIFICATION DATA

PLATE I

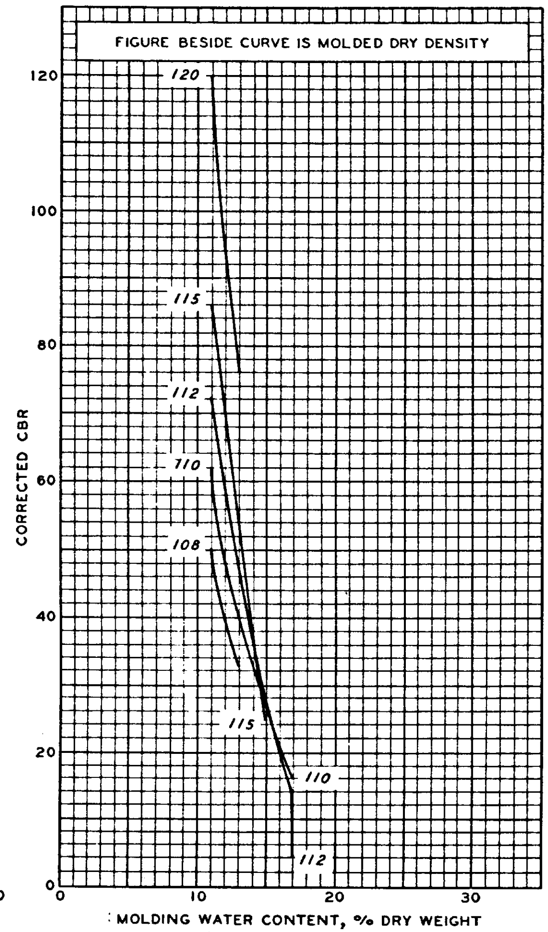
PLATE 2



MOLDING WATER CONTENT VS DENSITY AND CBR



DENSITY VS CBR

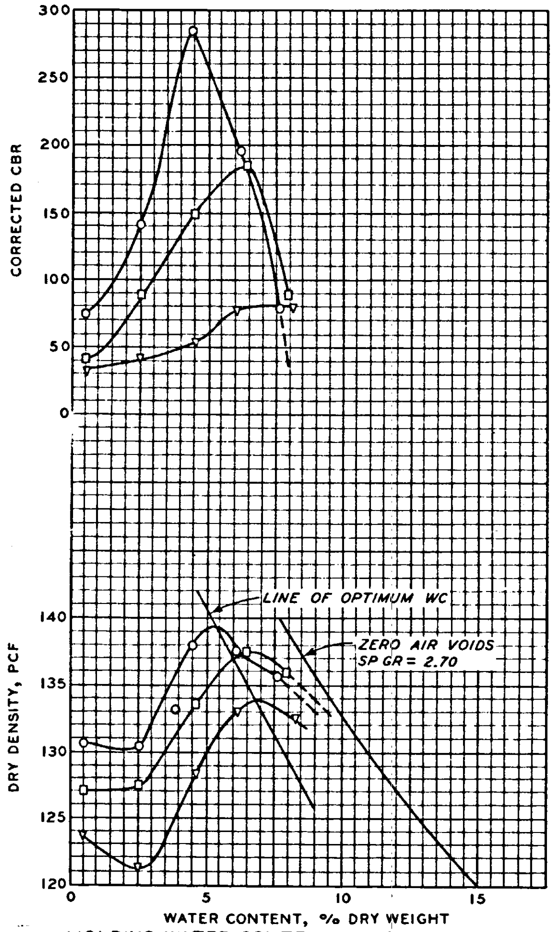


WATER CONTENT VS CBR

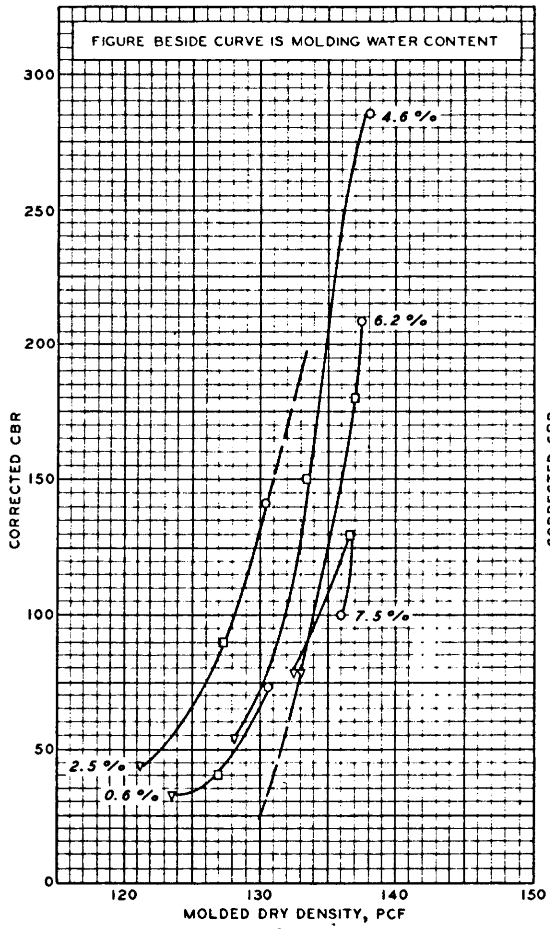
LABORATORY COMPACTION:

	COMPACTION EFFORT	NUMBER OF BLOWS/LAYER
▽	STD AASHO	12
□	INTERMEDIATE	26
O	MODIFIED AASHO	55

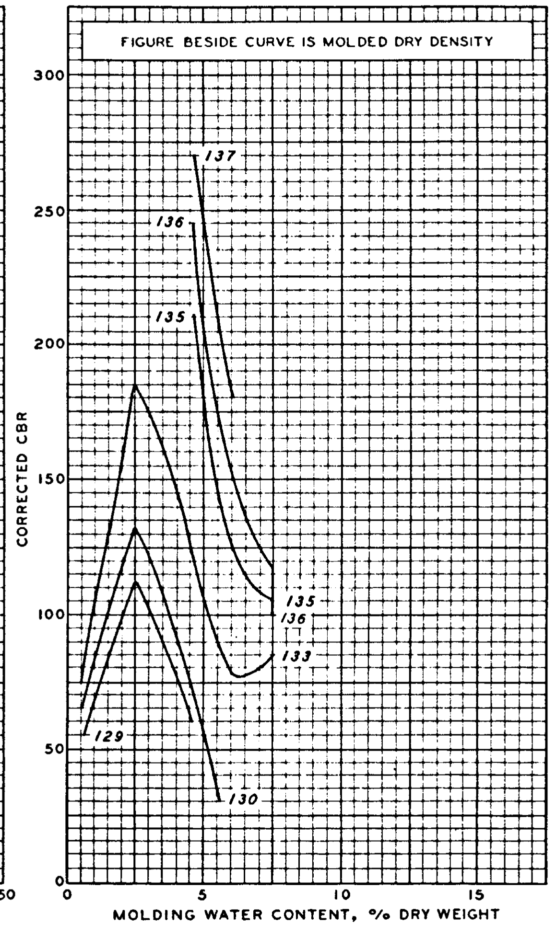
CBR, DENSITY, AND WATER CONTENT DATA
LEAN CLAY-AS MOLDED



MOLDING WATER CONTENT VS DENSITY AND CBR



DENSITY VS CBR



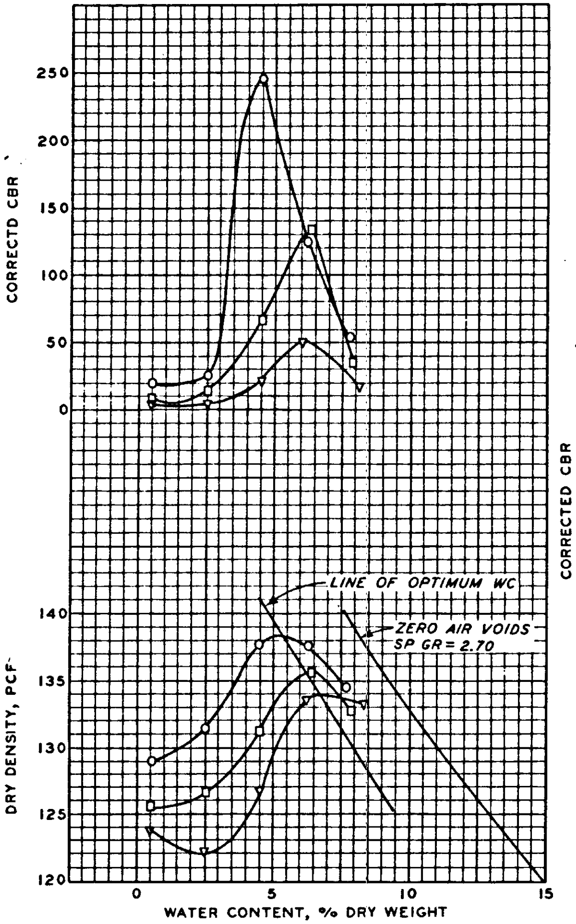
WATER CONTENT VS CBR

LABORATORY COMPACTION:

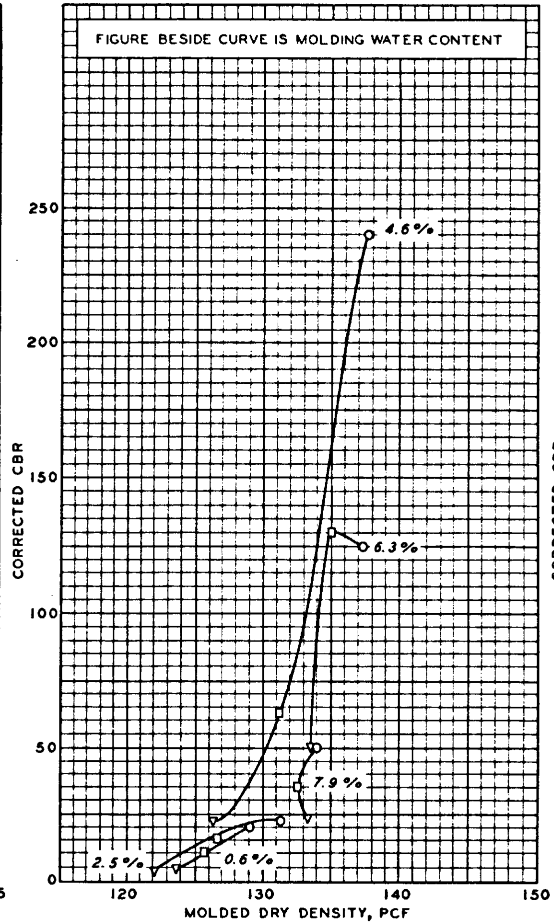
	COMPACTION EFFORT	NUMBER BLOWS/LAYER
▽	STD AASHO	12
□	INTERMEDIATE	26
○	MODIFIED AASHO	55

CBR, DENSITY, AND WATER CONTENT DATA
CLAY GRAVEL–AS MOLDED

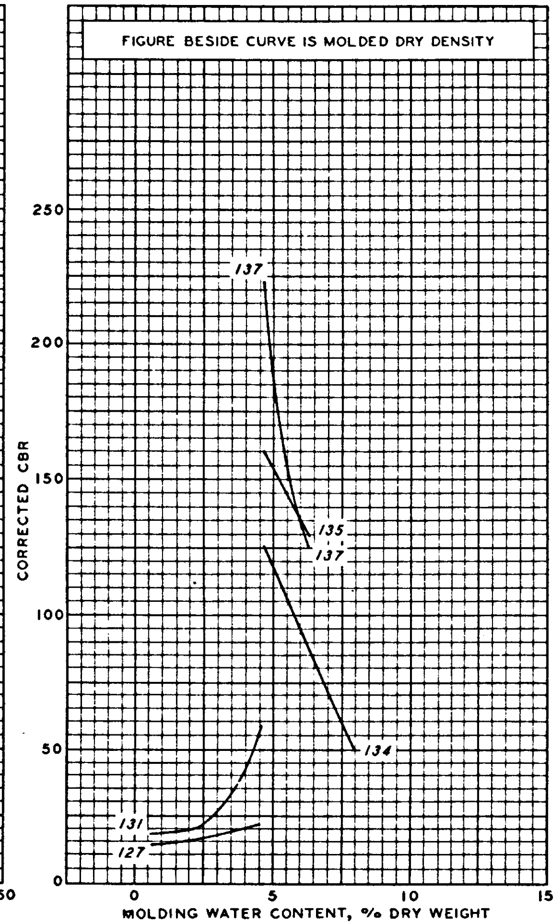
PLATE 4



MOLDING WATER CONTENT VS DENSITY AND CBR



DENSITY VS CBR

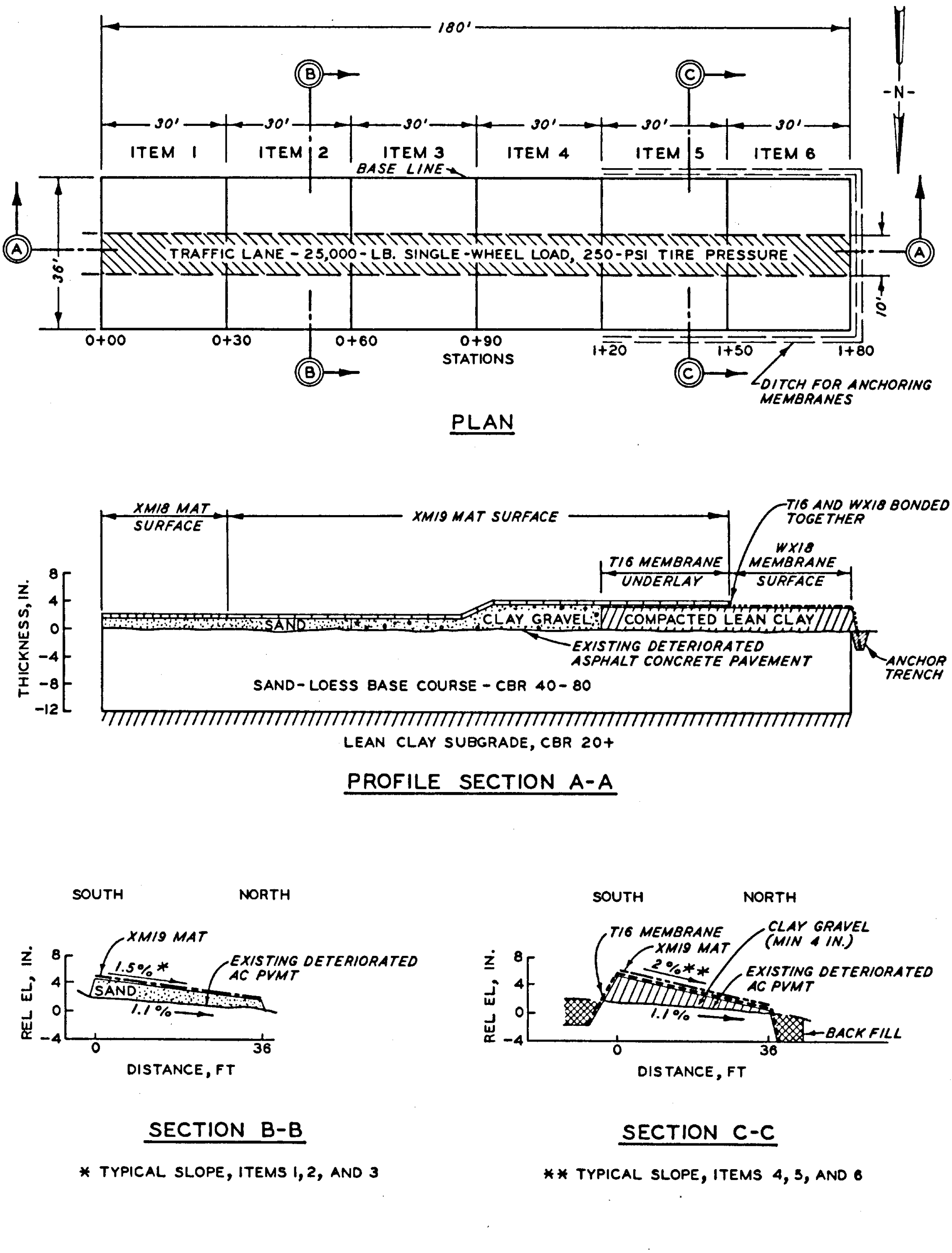


WATER CONTENT VS CBR

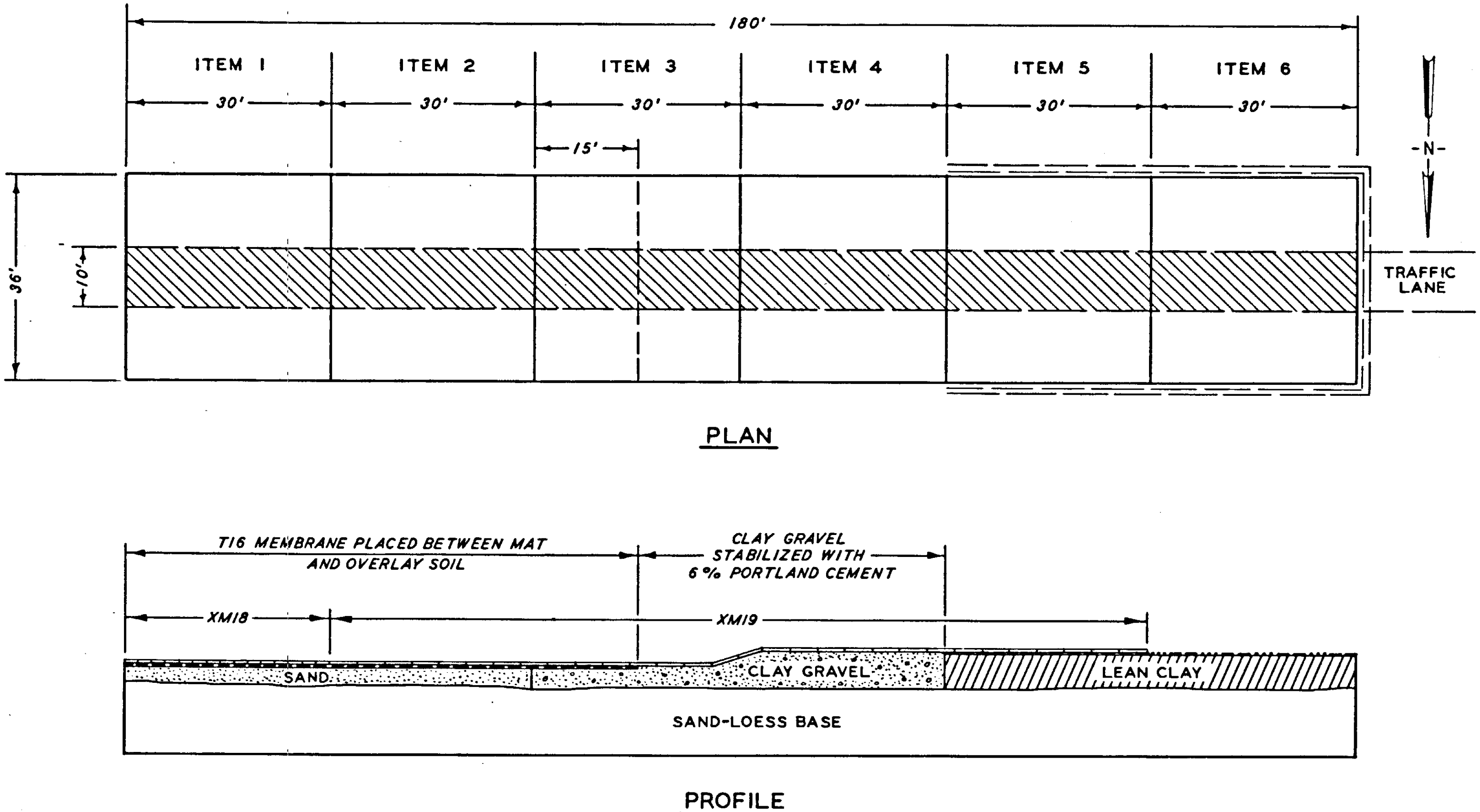
LABORATORY COMPACTION:

	COMPACTION EFFORT	NUMBER OF BLOWS/LAYER
▽	STD AASHO	12
□	INTERMEDIATE	26
O	MODIFIED AASHO	55

CBR, DENSITY, AND WATER CONTENT DATA
CLAY GRAVEL—AFTER SOAKING

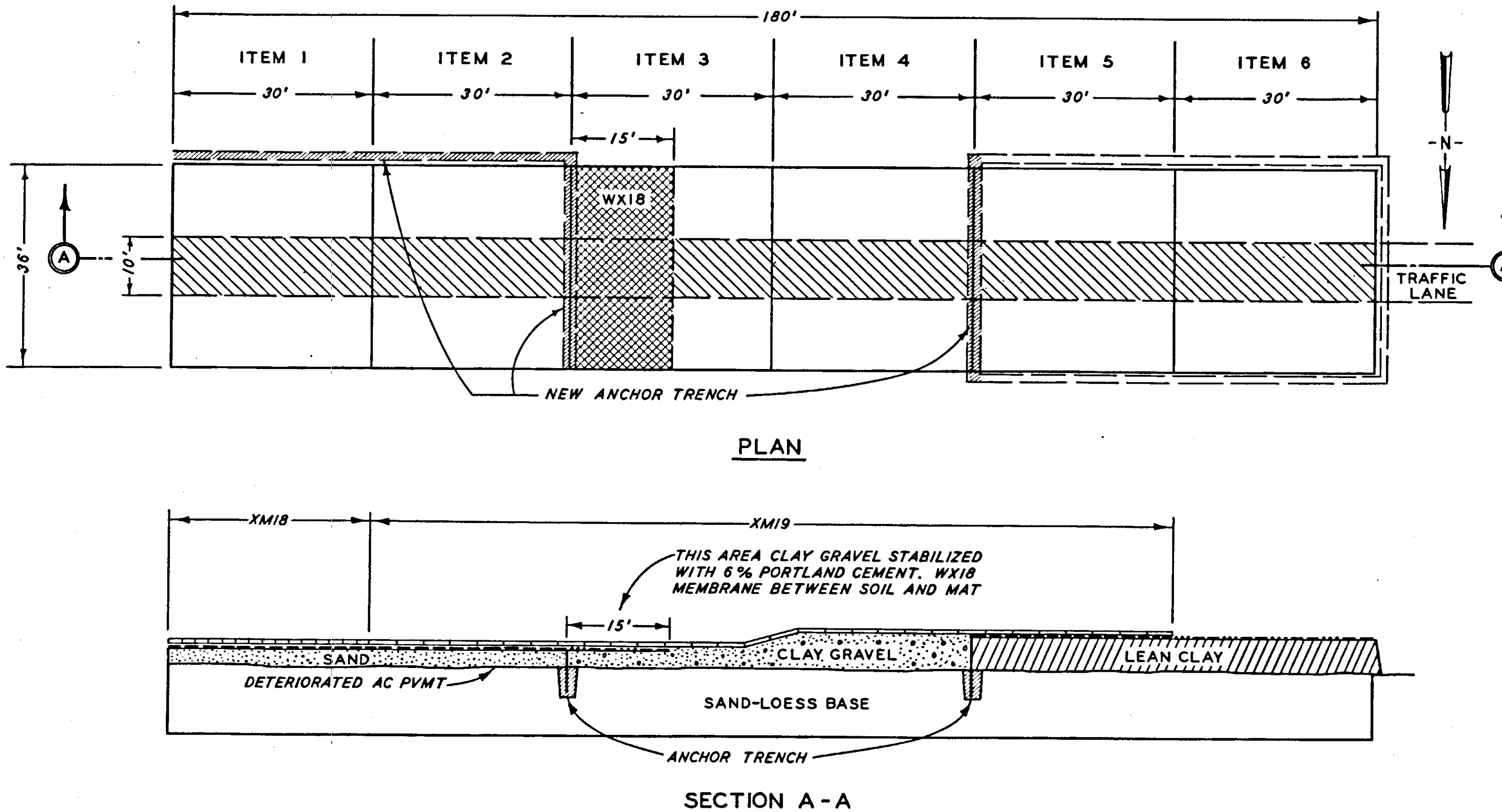


MAT OVERLAY
TEST SECTION



NOTE: ONLY CHANGES IN ORIGINAL STRUCTURE IDENTIFIED.

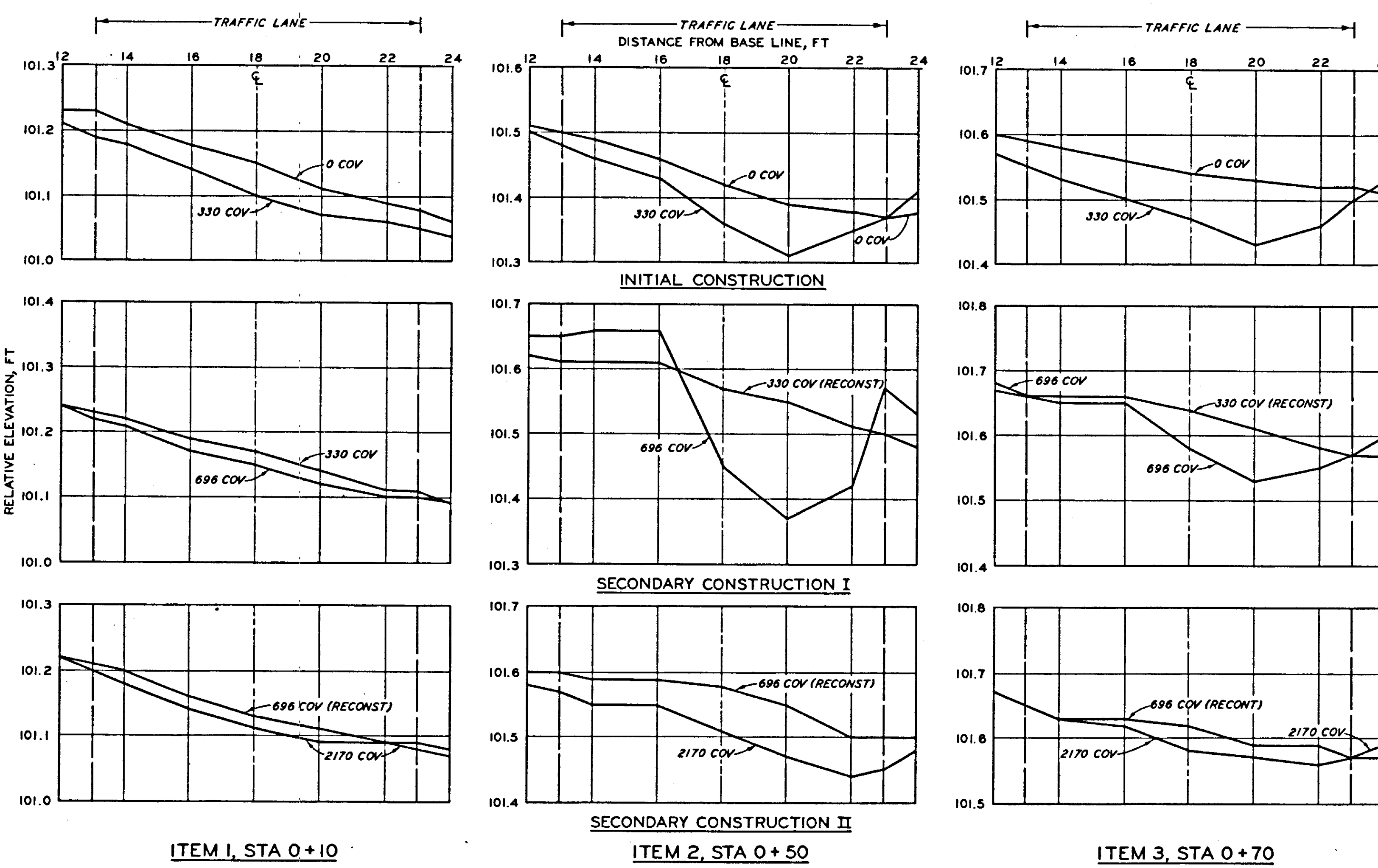
LAYOUT OF TEST SECTION
SECONDARY CONSTRUCTION I
AFTER 330 COVERAGES



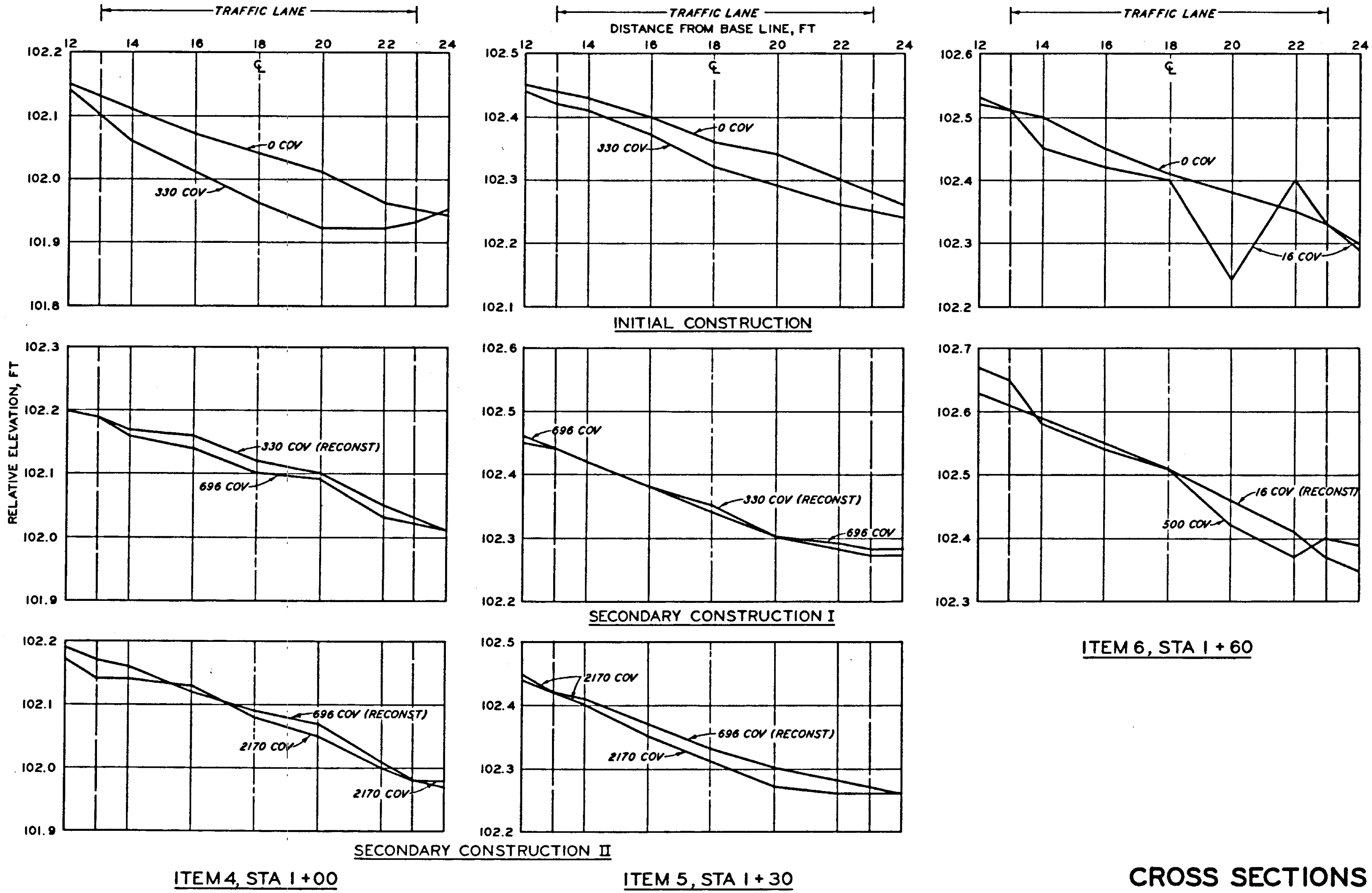
NOTE: ONLY CHANGES IN ORIGINAL STRUCTURE IDENTIFIED.

LAYOUT OF TEST SECTION
SECONDARY CONSTRUCTION II
AFTER 696 COVERAGES

PLATE 7



CROSS SECTIONS
ITEMS 1, 2, AND 3



CROSS SECTIONS
ITEMS 4, 5, AND 6

PLATE 9

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)

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3. REPORT TITLE

LANDING MAT OVERLAY ON DETERIORATED PAVEMENT; BARE BASE SUPPORT

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

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

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
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b. PROJECT NO. 3782	Miscellaneous Paper S-69-27
c. Task 63	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Air Force

13. ABSTRACT

This study was conducted to develop procedures for overlaying rough, deteriorated pavements, such as old, abandoned airfields or highways, with new landing mat in order to provide an adequately smooth runway or taxiway for the operation of tactical aircraft. An overlay test section was constructed, and traffic simulating the load on a main gear wheel of the F-4C aircraft was applied. The test section comprised six items that involved various combinations of soil overlays which were in turn overlaid by XM18 and XM19 mats and T16 and WX18 membranes. Tests showed that: (a) deteriorated pavements can be overlaid with a soil cushioning layer and new landing mat to provide an adequate surface for operation of aircraft; (b) both fine-grained and granular soils can be used as the leveling or cushioning layer, but both types of material will require protection to prevent pumping of the fines through mat joints during wet-weather traffic operations; (c) T16 membrane placed between soil and mat is quite effective in protecting fine-grained cohesive soil or fine sand from moisture infiltration and pumping action during wet weather; however, when used between soil and mat, neither the T16 nor the heavier WX18 membrane is adequate to withstand the abrasive action of sharp objects in the soil, such as roots, rocks, etc.; (d) a clay gravel cushion can be effectively protected from water infiltration by stabilization with 6 percent portland cement by soil weight; and (e) the optimum thickness of leveling or cushioning material needed for mat overlay construction is the minimum thickness that will (1) provide uniform bearing for the mat, (2) provide an adequate transverse slope or crown (about 2-1/2 to 3 percent), and (3) allow a sufficient quantity of soil so that the material can be easily placed and compacted with the available construction equipment.

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

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Bare base support						
Base courses						
Landing mats						
Membranes						
Overlays (pavements)						
Pavements						
Runways						

Unclassified

Security Classification