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MISCELLANEOUS PAPER S-69-10

**EVALUATION OF SURFACING MATERIALS
FOR FIRM BASE TACTICAL AIRFIELDS
BARE BASE SUPPORT**

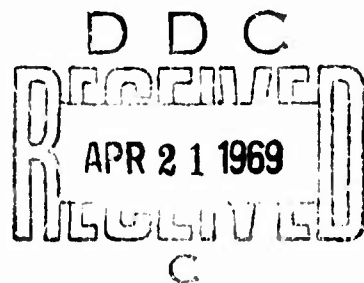
by

**C. D. Burns
W. N. Brabston**



March 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 second of a number of reports 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-6-266, dated 19 April 1966, and was conducted by the WES during the period June 1967-January 1968.

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.

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

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	2.54	centimeters
feet	0.3048	meters
mils	0.0254	millimeters
square yards	0.836127	square meters
gallons (U. S.)	3.785412	cubic decimeters
ounces	28.3495	grams
pounds	0.45359237	kilograms
kip	453.59237	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
feet per second	0.3048	meters per second

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SUMMARY

The objective of the project reported herein was to find a means of rapidly establishing surfacing on a stable base on tactical assault airfields. Specifically, it was desired to evaluate several types of production and experimental membranes to determine the ability of each membrane to withstand the abrasive and tearing effects caused by aircraft tires during ground operations of fighter and heavy cargo aircraft.

The objective was accomplished in two general steps. First, related programs and research conducted by the U. S. Army Engineer Waterways Experiment Station (WES) were examined to determine existing or potential techniques or materials that could be adapted to the Bare Base requirements for surfacing, and secondly, field tests were conducted on the items selected. Investigations conducted for the U. S. Army Materiel Command indicated that WX18, a four-ply neoprene-coated nylon membrane, was capable of withstanding C-130 traffic; thus this membrane was a primary test item. Other materials selected for testing included T16 single ply neoprene-coated nylon membrane, T1 vinyl-coated duck membrane with a double bituminous surface treatment (DBST), and an 11-mil-thick high-strength steel membrane.

Field tests consisted of subjecting the surfacings to locked-wheel skid and short-radius turn tests utilizing equivalent F-4C and C-130 aircraft wheel loads. Equivalent F-4C loads consisted of a 25,000-lb single-wheel load (SWL) on a 30x11.5, 24-ply rating (PR) tire inflated to 250 psi. Equivalent C-130 loads consisted of a 30,000-lb SWL on a 20x20, 22-PR tire inflated to 100 psi.

Initial locked-wheel skid tests utilizing F-4C loadings were conducted on a subgrade designed for static and rolling F-4C wheel loads (strength of top 12 in. of soil was approximately 24 CBR). However, the additional load generated by the locked-wheel skid tests caused severe rutting and subsequent immobilization of the load wheel. Subsequent tests were conducted successfully in areas having a higher subgrade strength (strength of top 12 in. of soil was 45 to 50 CBR).

All materials were subjected to one or more locked-wheel skid tests using F-4C loads. WX18, the only membrane that withstood the initial tests, was subjected to locked-wheel skid loads using C-130 loads and to short-radius turn tests using F-4C loads. The WX18 membrane successfully withstood all the tests, although the neoprene coating was worn off the WX18 in several areas. The T16, T1 with DBST, and 11-mil steel membranes ruptured during skid tests with F-4C loadings.

From the results of this study, it was concluded that

- a. WX18 membrane can be used as an expedient surfacing material on an assault airfield having adequate soil strength and will withstand the abrasions of ground operations of fighter and heavy cargo aircraft. However, minor maintenance will be required in areas subjected to severe abrasions.
- b. T1 overlaid with DBST, T16, and 11-mil steel membranes cannot withstand the abrasive effect of locked-wheel skids of fighter aircraft.

- c. The soil strength stipulated by design criteria for assault fields based on static and rolling loads may not be adequate in all cases to provide surfacing that will withstand the increased loads caused by locked-wheel skids. Therefore, additional investigation should be conducted in this area.

EVALUATION OF SURFACING MATERIALS FOR FIRM BASE TACTICAL AIRFIELDS

Bare Base Support

BACKGROUND

1. The U. S. Air Force (USAF) 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 up to 180 days, and still retain the capability of deploying 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*.

3. Obviously, these are minimum criteria, and any type of usable runway, from operational airport facilities to newly constructed tactical assault airfields, can be utilized by Bare Base forces. Since there will not always be a usable Bare Base existing in an operational area under consideration, the need exists to have the capability to construct a runway, taxiway, and apron, or to upgrade existing but substandard facilities to the strength and configuration needed to support tactical aircraft.

4. Sites to be considered under this concept must cover a wide range of categories and physical states of repair—such as operational airports, abandoned or deteriorated runways, highway pavements, existing or newly constructed landing mat surfaces, membrane-covered or unsurfaced soil assault strips, and unimproved areas where a complete landing facility will have to be constructed. Thus, Bare Base construction effort can range from negligible in areas where a usable facility exists to major in areas where a new Bare Base must be established.

5. The construction effort involved in the establishment of a Bare Base in forward or remote areas must be accomplished with a minimum of men, equipment, and material in the least amount of time. Experience has shown that an assault-type airfield having a relatively low-strength subgrade surfaced with metal landing mat can be constructed by expedient methods in the field. It has also been demonstrated that a tactical airfield can be constructed expediently at many sites by using only the existing in-place soils without the use of landing mat. This technique involves construction of a high-strength base course with the materials at the site, and maintaining the strength of the base throughout the life of the facility. This method requires that the soil be properly compacted to develop adequate base strength, and that the base course be protected from rainfall and runoff in order to prevent saturation of the base and subsequent strength loss.

6. In the past several years, the U. S. Army Engineer Waterways Experiment Station (WES) has been involved in research projects to test different materials to be used as waterproof surfacings on assault airfields having high-strength base courses. The most feasible method found to date appears to be the use of a prefabricated membrane that can be placed directly on a hard base with a reasonable effort and that requires a minimum amount of maintenance.

7. Major research in this area by the WES has been conducted under the sponsorship of the U. S.

Army Materiel Command (AMC). Basic objectives in these tests were to obtain a membrane that would serve not only as a waterproofer on hard-base assault fields but would also withstand the tire abrasions associated with ground operations of heavy cargo aircraft. Since initiation of the program, approximately 27 membrane-type materials have been tested. All membranes were subjected to locked-wheel skid tests of a load equivalent to the single-wheel load on a C-130 main gear tire. Most of the membranes tested did not meet minimum performance criteria due to tensile failure during the skid tests. However, as a result of these tests, several years ago the Army adopted T17 membrane as the standard membrane for use on hard-base assault fields. T17 is a two-ply neoprene-coated nylon fabric. Operations on T17 are limited to C-130 or lighter aircraft, and experience has indicated that T17 is not fully satisfactory for C-130 operations. Locked-wheel engine runup and locked-wheel turns of heavy cargo aircraft tear the membrane due to excessive tensile stress.

8. Under the Bare Base concept, assault fields having a high-strength base protected with a waterproof surfacing material must not only be capable of withstanding the abrasions associated with ground operations of C-130 aircraft but also must be capable of withstanding the more severe effects of heavy fighter (F-4C) aircraft. Due to this additional requirement, a more durable material is needed.

9. During the period July 1966-October 1967, investigations were conducted by the WES for the USAF to evaluate several types of experimental and production membranes. The investigations, which are reported herein, consisted essentially of (a) a monitoring phase, during which AMC-sponsored membrane tests were observed to determine whether any materials tested under that program might be suitable for use in Bare Base construction; and (b) a test phase, during which locked-wheel skid and short-radius turn tests utilizing equivalent C-130 and F-4C loadings were conducted on selected membranes.

OBJECTIVE

10. The overall objective of this project was to test and evaluate various surfacing materials to be used as a waterproof surface on an assault airfield having adequate soil strength, and which would withstand the abrasive and tearing effects associated with ground operations of heavy cargo and fighter aircraft. The specific objective of the WES investigation was to evaluate several types of prefabricated membranes in order to determine their ability to withstand such abrasions when used on assault airfields.

SCOPE

11. The objective was accomplished by:

- a. Monitoring a membrane test program sponsored by AMC and conducted by WES to determine whether any materials tested under the AMC project were suitable for use under the Bare Base program.
- b. Subjecting several membranes from various manufacturers to locked-wheel skid and short-radius turn tests utilizing equivalent F-4C and C-130 loadings. The F-4C loading consisted of a 25,000-lb* single-wheel load (SWL) on a 30x11.5, 24-ply rating (PR) tire inflated to 250 psi. The C-130 loading consisted of a 30,000-lb SWL on a 20x20, 22-PR tire inflated to 100 psi.

12. A description of the membranes and test sections, a description of tests conducted, results of tests, an analysis of the test results, and conclusions are presented herein.

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

SURFACING MATERIALS

Selection

13. During recent AMC-sponsored tests at the WES, approximately 27 membrane-type surfacing materials were subjected to locked-wheel skid tests. The test load used was the equivalent C-130 SWL, i.e., a 30,000-lb SWL on a 20x20, 22-PR tire inflated to 74 psi. Results of these tests were monitored to determine if any of the experimental materials were suitable for testing under the Bare Base program. Of the membranes observed, only WX18 appeared to be satisfactory for use under the Bare Base concept.

14. Other membranes and surfacing materials tested in this project include T16 membrane, double bituminous surface treatment (DBST) over T1 membrane, and a high-strength thin steel membrane. The T16 and DBST over T1 were in-place materials on an existing test section that was constructed under a related Bare Base test project. Skid tests were performed on the DBST over T1 to determine if any benefit could be derived from the use of asphaltic cement and aggregate on an inferior membrane. Skid tests were also conducted on the T16 primarily because of the availability of the in-place material and to obtain base data for drawbar pull comparison. The high-strength steel membrane was furnished by the Inland Steel Co., Chicago, Ill., without cost to the Government.

Description

15. Various membranes and surfacing materials tested in this investigation are described below:

- a. *T1 with double bituminous surface treatment.* T1 is a vinyl-coated 17.9-oz cotton duck material weighing approximately 0.24 psf. It was factory fabricated in 3-ft-wide strips that were field bonded to form a single sheet coated with a double bituminous surface.
- b. *T16.* T16 is a neoprene-coated 3.2-oz nylon material weighing approximately 0.13 psf. It was fabricated in 5-ft-wide strips that were factory bonded to form a single sheet.
- c. *WX18.** WX18 is a neoprene-coated 4-ply, 5.1-oz nylon material weighing approximately 0.44 psf. It was fabricated in 4-ft-wide strips that were factory bonded to form a single sheet.
- d. *Steel membrane.* This material was a high-strength steel membrane approximately 11 mils thick. It was fabricated in 30-in.-wide strips that were factory soldered to form a single sheet. The tensile yield strength of the steel was 200,000 psi, and the ultimate strength was 206,000 psi.

TEST VEHICLE

16. The vehicle used for skid and short-radius turn tests is shown in fig. 1. The vehicle had a load wheel centered in the rear of the frame, an outrigger wheel to prevent overturning, and two front wheels by which the vehicle is normally powered. For the skid tests, the vehicle was pulled by a powered mover, and for the short-radius turn tests, the vehicle was rotated by a forklift. For the C-130 loading, the vehicle had a 30,000-lb SWL on a 20x20, 22-PR tire inflated to 100 psi. For the F-4C loading, the vehicle had a 25,000-lb SWL on a 30x11.5, 24-PR tire inflated to 250 psi.

* Initially, membranes tested by WES were designated by the prefix T (for test) and numbered serially, e.g. T1, T2, etc. Later, this prefix was changed to WX (for waterproof, test), but the serial numbers were kept continuous.



Fig. 1. Skid cart with F-4C loading

TESTS PERFORMED

Locked-Wheel Skid Tests

17. Locked-wheel skid tests were designed to simulate locked-wheel engine runup and the skid effects common to initial touchdown. The skid tests were performed by locking the load wheel of the test vehicle securely to prevent slipping, then pulling the test vehicle forward with a powered mover for a distance of 10 to 20 ft at a rate of about 1 fps. Skid tests were conducted using both C-130 and F-4C loadings in test 1, and only the F-4C loading in tests 2 and 3.

Short-Radius Turn Test

18. A short-radius turn test was conducted to simulate the abrasive action of the pivot wheel of an aircraft during short-radius turnarounds and taxiway turnoffs. The test was conducted by lifting the front end of the load vehicle with a forklift and rotating the vehicle through an angle of about 180 deg while pivoting on the load wheel. The load wheel was not locked during the short-radius turn and actually inscribed a short-radius arc instead of pivoting about a single point. The short-radius turn test was conducted during test 2.

Drawbar Pull Tests

19. In tests 2 and 3, the horizontal force, or drawbar pull, required to pull the test vehicle during skid tests was measured by means of a dynamometer.

Soils Tests and Miscellaneous Observations

20. Soil water content, dry density, and in-place CBR tests were conducted at the time of skid tests in each test section. Tests were conducted at various depths in the soils, and at least three tests were made at each depth. These data are presented in table 1. The values listed in table 1 corresponding to the various depths of soil are averages of the values measured at each particular depth. Visual observations of the behavior of each membrane were recorded throughout the test period. These observations were supplemented with photographs.

TEST 1: TEST SECTION AND TEST RESULTS

Test Section

21. The test section was located in a shelter on the WES reservation. A plan and profile of the test section are shown in plate 1. The test section was 32 ft long and 46 ft wide and was divided into four test lanes, each approximately 11.5 ft wide. The section had a 12-in.-thick subgrade constructed of highly compacted silt (ML). Classification data for this soil are shown in plate 2. The subgrade had an average strength of approximately 24 CBR. The test section was surfaced with WX18 membrane. The membrane was anchored at a depth of approximately 1 ft in a trench around the entire perimeter of the test section. The membrane was pinned in the bottom of the trench, which was backfilled, and the fill soil was well compacted. In anchoring the WX18, it was desired to eliminate as many wrinkles as possible from the membrane to provide a relatively plane test surface. A view of the test section prior to testing is shown in photograph 1.

Test Results

22. *C-130 loadings on WX18.* Initial skid tests were conducted in lane 1 using the C-130 loading. Two skid pulls were conducted, and the WX18 withstood both tests quite well. Only slight superficial abrasions of the WX18 were observed, although there was noticeable tire abrasion (photograph 2).

23. *F-4C loadings on WX18.* Skid tests were then conducted in lane 2 using the F-4C loading. About halfway through the first skid, the load wheel sank into the subgrade, immobilizing the vehicle (photograph 3).

24. Although the subgrade had been designed for static and rolling F-4C loadings, it was obvious at this time that a higher soil strength would be required to support the additional load generated by a locked-wheel skid. Although there was no damage to the WX18, the skid test was not considered successful. The WX18 was then removed from the test section, and the subgrade soil was further compacted to obtain higher soil strength.

25. *F-4C loading on bare soil.* After additional compaction, the average strength of the top 12 in. of soil was approximately 28 CBR, or slightly higher than the strength as originally constructed. Another skid test using the F-4C loading was then attempted on the bare soil, but the load wheel became immobilized in the subgrade.

26. At this time it was decided to conduct further skid tests on the bare soil surrounding the test section in areas that indicated higher soil strength. The area adjacent to the test section was lean clay soil. The first skid test was conducted in an area in which a cursory check had indicated a surface soil strength of 43 CBR. However, subsequent tests indicated that at 6 in. below the surface, the soil strength was 9 CBR, and the average soil strength was approximately 26 CBR. As the skid pull was begun, the load wheel sank into the soil and became immobilized (photograph 4). A second pull was performed in an area

in which a surface strength of 93 CBR was indicated. However, subsequent soil tests indicated the soil strength at 6 in. below the surface to be 66 CBR, and the average strength was 80 CBR. The test vehicle was pulled approximately 15 ft, and no sinkage or rutting was observed (photograph 5).

TEST 2: TEST SECTION AND TEST RESULTS

Test Section

27. Based on the results of test 1, it was decided that further skid tests would have to be conducted on a subgrade having relatively high soil strengths for a depth of at least 12 in. A test section with a high-strength subgrade that had been constructed and utilized earlier for a related Bare Base test* at the WES was selected as a site for additional skid tests.

28. The test section was located in an unsheltered area on the WES reservation and consisted essentially of two highly compacted fine-grained soil base courses encased completely in waterproof membrane envelopes and overlying specially constructed subgrades. After original construction, the test section had been subjected to 580 coverages of equivalent F-4C traffic during which time several changes had been made in the surface membranes. Test traffic had significantly increased the strength of the base course due to the additional compaction caused by the load vehicle. Thus, the description of the test section given below indicates the condition of the test section after the related Bare Base test had been completed.

29. A plan and profile of the test section are shown in plate 3. The test section was 150 ft long and 30 ft wide and was divided into six test items, each 25 ft long and 30 ft wide. Items 1-3 had a common and continuous base course approximately 30 in. thick, which was constructed of a highly compacted lean clay. Classification data are shown in plate 2. Below the base was a specially constructed 12-in.-thick lean clay subgrade. The average strength of the top 15 in. of soil in the base was approximately 52 CBR.

30. Items 4-6 had a common and continuous base course approximately 18 in. thick, which was constructed of highly compacted heavy clay (CH). Classification data are shown in plate 2. The average strength of the top 15 in. of soil in the heavy clay base was approximately 44 CBR. Below the base course was a specially constructed subgrade of a loose dry sand (SP). Classification data are shown in plate 2.

31. Items 1 and 2 were covered with a double bituminous surface treatment (DBST) over T1 membrane. The T1 membrane was joined to T16 membrane, which covered items 3 and 4. Items 5 and 6 were surfaced with WX18, which was joined to the T16 membrane. The bottom surfaces of the base soil in items 1 and 2 were protected with T16 and 6-mil polyethylene membrane, respectively. The bottom surfaces of items 3 and 4 were protected with Griffolyn membrane, a nylon-reinforced plastic material. The bottom surfaces of items 5 and 6 were protected with 6-mil polyethylene and T16 membrane, respectively. All subsurface membranes were bonded together to form one integral sheet, and all membranes continued up the sides, and in items 1 and 6, up the ends of the base course to the surface of the test section where they were bonded to the surface membranes to form a complete watertight envelope. A 10-ft-wide traffic lane and traffic guidelines were painted on the test section for the traffic tests of the related Bare Base project. General views of each test surface just prior to skid tests are shown in photographs 6-8.

* C. D. Burns and W. N. Brabston, "Membrane-Envelope Technique for Waterproofing Soil Base Courses for Airstrips Bare Base Support," Miscellaneous Paper S 66-13, July 1968, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Test Results

32. All tests were conducted with the F-4C loading only. Results are presented in the following paragraphs.

33. *Skid tests on WX18.* Two locked-wheel skid pulls were made initially on the WX18 membrane. The skid tests caused only slight abrasion of the WX18, although there was noticeable wear of the load tire (photograph 9).

34. *Skid test on T16.* One skid pull tore the T16 membrane severely, exposing the underlying base soil (photograph 10).

35. *Skid tests on DBST over T1.* Two skid pulls were conducted on the DBST over T1. Both the DBST and the T1 failed on both occasions, exposing the underlying base soil (photograph 11).

36. *Skid test on wet WX18.* The next skid test was conducted on wet WX18 membrane to determine the effects on skid resistance of a water film on the membrane surface. One pull was conducted, and there was little abrasion of the membrane (photograph 12).

37. *Skid tests on painted WX18.* During the initial skid tests on the WX18 membrane, it had been observed that, although membrane damage was slight and generally superficial, there were a few small areas in which the neoprene had been abraded off the membrane, exposing the internal nylon cord. To protect the nylon cord from possible damage due to prolonged exposure to sunlight, it is necessary to maintain an opaque coating over the cord in these areas. Therefore, a coat of common black enamel paint was applied over one of the initial skid areas, and after the paint had dried, three additional skid tests were conducted on the painted area. Each skid caused abrasion of the painted surface, and after the third skid, it was observed that a considerable amount of the paint had been removed (photograph 13).

38. *Short-radius turn test on WX18.* One short-radius turn test was conducted on dry WX18 membrane using the procedure described in paragraph 18. The result was slight abrasion of the membrane and a noticeable amount of tire abrasion, as can be seen in photograph 14.

39. *Drawbar pull.* As noted in paragraph 19, a dynamometer and strip recorder were used to obtain values of the horizontal forces required to pull the test cart over the various membranes in test section 2. These values are summarized in table 2. From table 2 it can be seen that on the dry WX18, a horizontal force of about 10 kips was required to pull the test vehicle. On the T16 and on the T1 with DBST, the average horizontal forces required to pull the test vehicle measured 8.1 and 9.1 kips, respectively. A horizontal force of about 4.6 kips was required to pull the test vehicle on the wet WX18.

TEST 3: TEST SECTION AND TEST RESULTS

Test Section

40. Test 3 was performed on the same site as test 2. A plan and profile of the test section are shown in plate 4. For test 3, the membranes that had been on the section for use in test 2 were removed, and 11-mil steel membrane was placed on the heavy clay base. The membrane was approximately 30 ft long and 25 ft wide. Prior to placement of the membrane, the bare soil was treated with 85-100 penetration asphaltic cement, which was distributed at the rate of approximately 0.5 gal per sq yd. The asphaltic cement was used to provide a bonding agent between the soil and the membrane. The membrane was anchored at one end in a trench cut laterally across the test section (photograph 15). Steel plates were bolted to the membrane, and anchor spikes were driven through the plates into the ground (photograph 15), thus securely pinning the membrane in the trench. After the trench had been backfilled, the membrane was anchored by means of steel plates and pins on the surface around the remaining perimeter. The membrane

was treated with an antiskid compound in a strip approximately 10 ft wide down the center of the membrane. All skid tests were run in this area. The membrane was placed so that the lapped joints lay transversely on the section, with the overlapping edge in the direction of the skid pulls. A general view of the membrane during the conduct of a skid test is shown in photograph 16.

Test Results

41. All skid tests were made with the equivalent F-4C loading.
42. *Dry membrane.* Two skid tests were made on the membrane in a dry condition. During each pull, a bow wave developed in front of the locked load wheel, causing a buildup of membrane that eventually led to tensile rupture under and slightly ahead of the load wheel. Photograph 17 shows a close up of the load wheel and the ruptured membrane after the first skid. Photograph 18 shows a close-up of the failure area in the membrane after the second skid, and photograph 19 shows a general view of the membrane after both skids.
43. *Wet steel membrane.* Two skid tests were conducted on the membrane in a wet condition. The first pull produced no damage to the membrane, although there was a bow wave buildup of membrane in front of the load tire. On the second pull, a slight tear developed near a lapped joint, as can be seen in photograph 20.
44. *Drawbar pull.* Drawbar pull values, i.e. the horizontal force required to pull the skid vehicle across the steel membrane, are shown in table 2. These values indicate that average horizontal forces of 10.8 and 7.8 kips were required to pull the test vehicle across the dry and wet surfaces, respectively.

ANALYSIS AND CONCLUSIONS

Analysis

45. Test results are summarized in table 2. For each test conducted, the following data are shown: pull number, test load, type and surface condition of membrane, CBR of top 12 in. of subgrade soil, drawbar pull required to conduct skid tests, rating of membrane, and effect of test on membrane.
46. The primary objective of the tests reported herein was to evaluate several types of surfacing to determine their ability to withstand the abrasive effects of locked-wheel skids and short-radius turns of fighter and heavy cargo aircraft. The load used primarily in the tests reported herein was the equivalent of the F-4C single-wheel load, which is the more severe of the two types of aircraft loads. Of the membranes tested, only the WX18 successfully withstood the skid and short-radius turn tests of the F-4C load. The T16, T1 with DBST, and the 11-mil steel membranes all failed due to tensile rupture during skid tests.
47. Five locked-wheel skid pulls were performed on the dry WX18 utilizing the F-4C loading, four of which were conducted in the same location, and no tears or failures of the WX18 were observed. The last three WX18 skid pulls were made in an area that had been painted after the original skid test; however, the paint had little noticeable abrasion resistance. The T1 with DBST, T16, and 11-mil steel membranes each failed on the first pass of the skid vehicle.
48. The water film on the surface of the WX18 during skid 6 of test 2 resulted in a significant reduction in skid resistance, as can be seen from the drawbar pull values noted in table 2. The average dry-surface and wet-surface drawbar pull values obtained on the WX18 were 10.3 and 4.6 kips, respectively.
49. The short-radius turn test performed on the WX18 was quite successful, indicating that this type maneuver can be executed on the membrane by an F-4C with little detrimental effect.
50. During the skid and short-radius turn tests on the WX18 membrane, it was observed that

although there was no failure, the WX18 received considerable abrasion that removed much of the uppermost coating of neoprene, resulting in exposure of the internal nylon cord. Because excessive exposure of the nylon to sunlight can weaken the cord, it is necessary to maintain an opaque coating on the membrane in areas where the cord has been exposed. In this investigation, the abraded areas were satisfactorily coated with common black enamel paint. This was not particularly skid resistant; however, various antiskid compounds are available commercially and can be used to provide skid resistance.

51. During the skid tests in test 1, it became apparent that soil strength design criteria for membrane-surfaced assault fields subject to F-4C static and rolling loads may not be adequate for F-4C locked-wheel skid loads. From table 1, it can be seen that a soil strength of 26 CBR for the top 12 in. of subgrade is not adequate to support F-4C skid loads. However, this strength, if maintained, is adequate to support rolling and static F-4C loading.

Conclusions

52. From the tests reported herein, the following conclusions can be drawn:

- a. WX18 membrane can be used as an expedient surfacing material on an assault airfield having adequate soil strength and can withstand the abrasion of ground operations of fighter and heavy cargo aircraft; however, minor maintenance will be required in areas subjected to severe abrasions, and some patching may be needed.
- b. T1, T16, and 11-mil steel membranes cannot withstand the abrasive effect of locked-wheel skids of fighter aircraft.
- c. The soil strength stipulated by design criteria for assault fields based on static and rolling loadings may not be adequate in all cases to provide surfacing that will withstand the increased loadings caused by locked-wheel skids. Therefore, additional investigations should be conducted in this area.

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Table 1
Summary of CBR, Water Content, and Dry Density Data

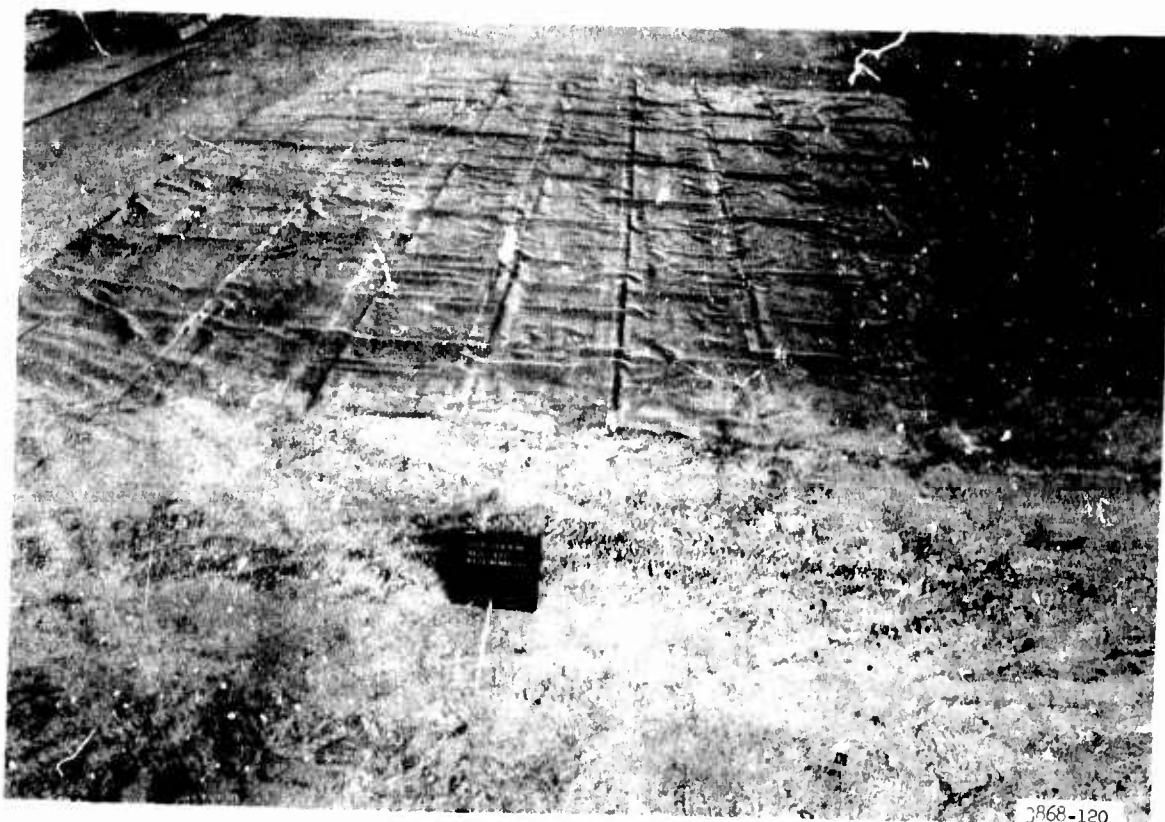
Test No.	Item No.	Subgrade	Surfacing	Depth in.	Test Data		
					CBR	Water Content percent	Dry Density pcf
1	--	Silt (ML)	WX18 membrane	Sfc	25	15.1	101.9
				6	23	14.7	100.6
		Silt (ML)	Unsurfaced recompactd	Sfc	30	11.3	103.3
				6	27	13.6	103.5
		Lean clay (CL)	Unsurfaced 26-CBR area	Sfc	43	12.4	101.2
				6	9	17.9	101.2
		Lean clay (CL)	Unsurfaced 80-CBR area	Sfc	93	6.3	102.4
				6	66	12.5	114.9
2	1	Lean clay (CL)	DBST over T1 membrane	Sfc	76	9.2	111.4
				6	30	14.1	104.6
				12	17	13.4	102.2
	2	Lean clay (CL)	DBST over T1 membrane	Sfc	87	10.6	111.4
				6	58	13.5	105.8
				12	21	14.5	92.3
	3	Lean clay (CL)	T16 membrane	Sfc	92	9.1	111.5
				6	57	11.2	106.2
				12	25	12.0	104.1
	4	Heavy clay (CH)	T16 membrane	Sfc	70	13.1	117.2
				6	46	16.7	108.3
				12	20	17.9	100.8
	5	Heavy clay (CH)	WX18 membrane	Sfc	70	12.1	117.4
				6	59	13.8	111.6
				12	14	16.7	96.8
	6	Heavy clay (CH)	WX18 membrane	Sfc	59	15.4	120.2
				6	37	13.6	112.7
				12	17	16.5	97.1
3	--	Heavy clay (CH)	11-mil steel membrane	Sfc	70	10.6	114.5
				6	53	12.5	108.9
				12	17	14.4	100.5

Note: Each value represents an average of three or more measurements.

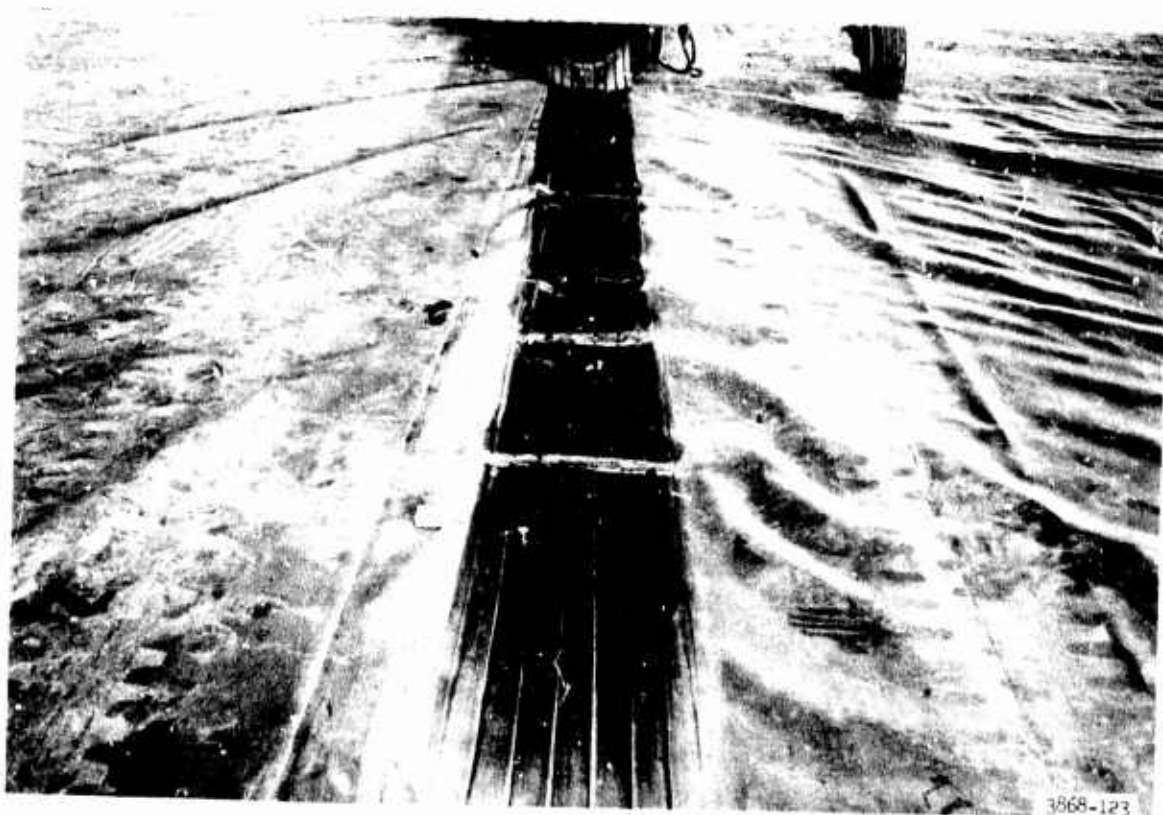
Table 2
Summary of Test Results

Test No.	Pull No.	Test Load	Membrane		Subgrade		Drawbar Pull kips	Membrane Rating*	Results
			Type	Surface Condition	Soil Type	CBR in Top 12 in.			
1	1	C-130	WX18	Dry	ML	24	--	S	Slight surface abrasion
	2	C-130	WX18	Dry	ML	24	--	S	Slight surface abrasion
	3	F-4C	WX18	Dry	ML	24	--	NR	Subgrade failed
	4	F-4C	None	Dry	ML	28	--	NR	Unsurfaced subgrade failed
	5	F-4C	None	Dry	CL	26	--	NR	Unsurfaced subgrade failed
	6	F-4C	None	Dry	CL	80	--	NR	No failure
2	1	F-4C	WX18	Dry	CH	43	10.5	S	Slight surface abrasion
	2	F-4C	WX18	Dry	CH	43	10.0	S	Slight surface abrasion
	3	F-4C	T16	Dry	CH	52	8.1	U	Membrane failed
	4	F-4C	T1	DBST	CL	48	11.0	U	Membrane failed
	5	F-4C	T1	DBST	CL	48	7.3	U	Membrane failed
	6	F-4C	WX18	Wet	CH	43	4.6	S	Slight surface abrasion
	7	F-4C	WX18	Painted	CH	43	10.5	S	Paint coating worn
	8	F-4C	WX18	Painted	CH	43	--	S	Additional paint wear
	9	F-4C	WX18	Painted	CH	43	--	S	Paint worn off
	SRT	F-4C	WX18	Dry	CH	43	--	S	Slight surface abrasion
3	1	F-4C	11-mil steel	Dry	CH	47	11.5	U	Membrane failed
	2	F-4C	11-mil steel	Dry	CH	47	10.0	U	Membrane failed
	3	F-4C	11-mil steel	Wet	CH	47	8.0	M	No membrane failure; large bow wave
	4	F-4C	11-mil steel	Wet	CH	47	7.5	U	Membrane failed

* Membrane ratings: S, satisfactory; NR, not rated; U, unsatisfactory; M, marginal.



Photograph 1. WX18 membrane prior to test 1



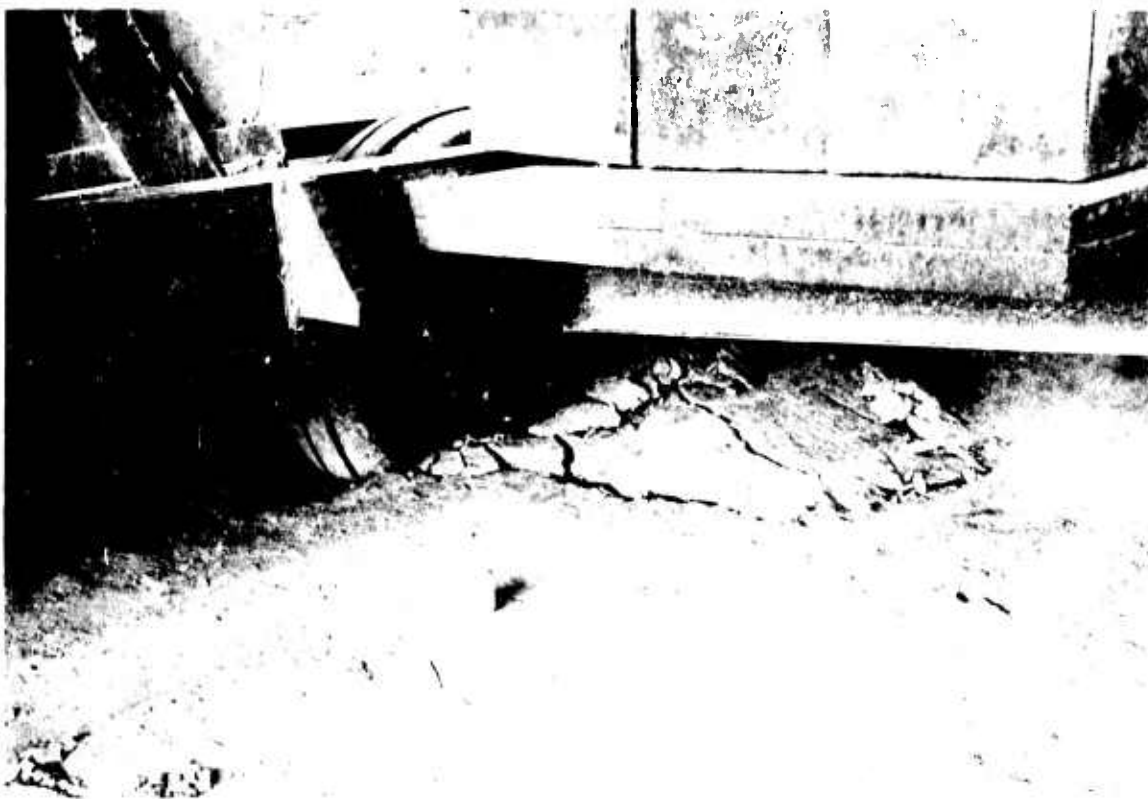
Photograph 2. Test 1; WX18 after second pull with C-130 loading

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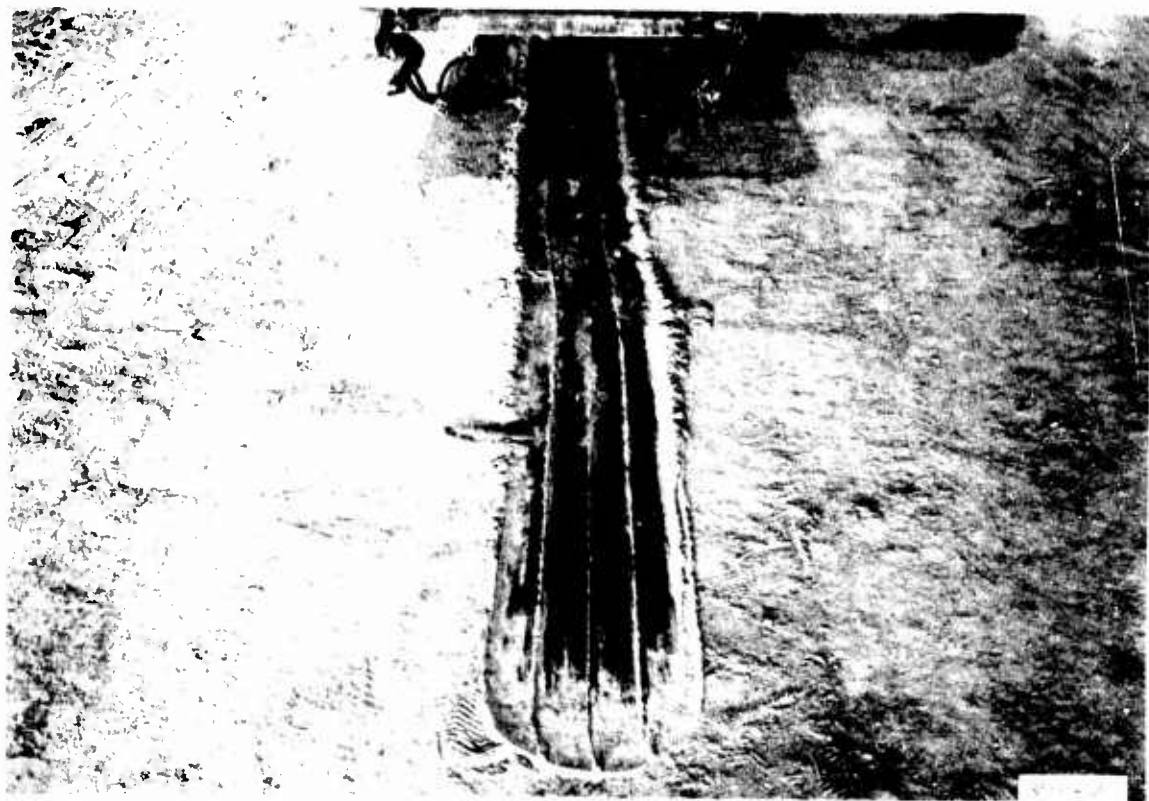
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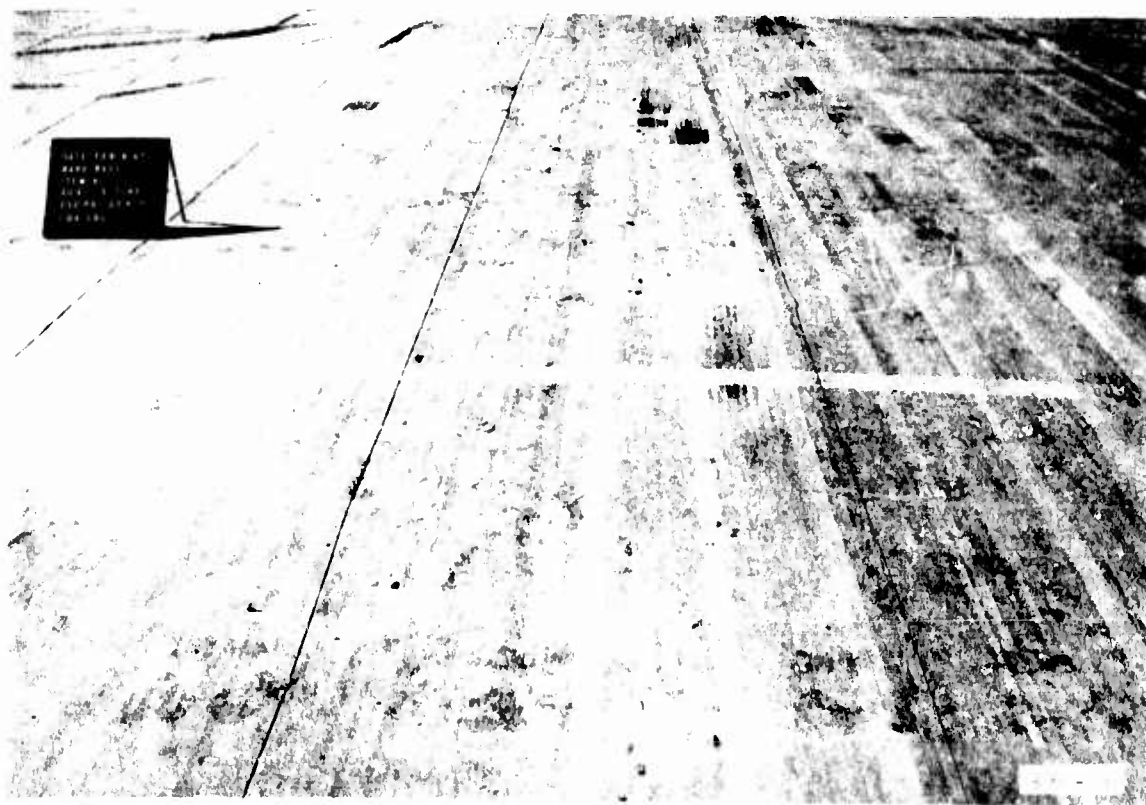
Photograph 3. Test 1; vehicle immobilized during first pull with F-4C loading on WX18 over 24-CBR subgrade



Photograph 4. Test 1; vehicle immobilized during skid pull with F-4C loading on unsurfaced 26-CBR subgrade



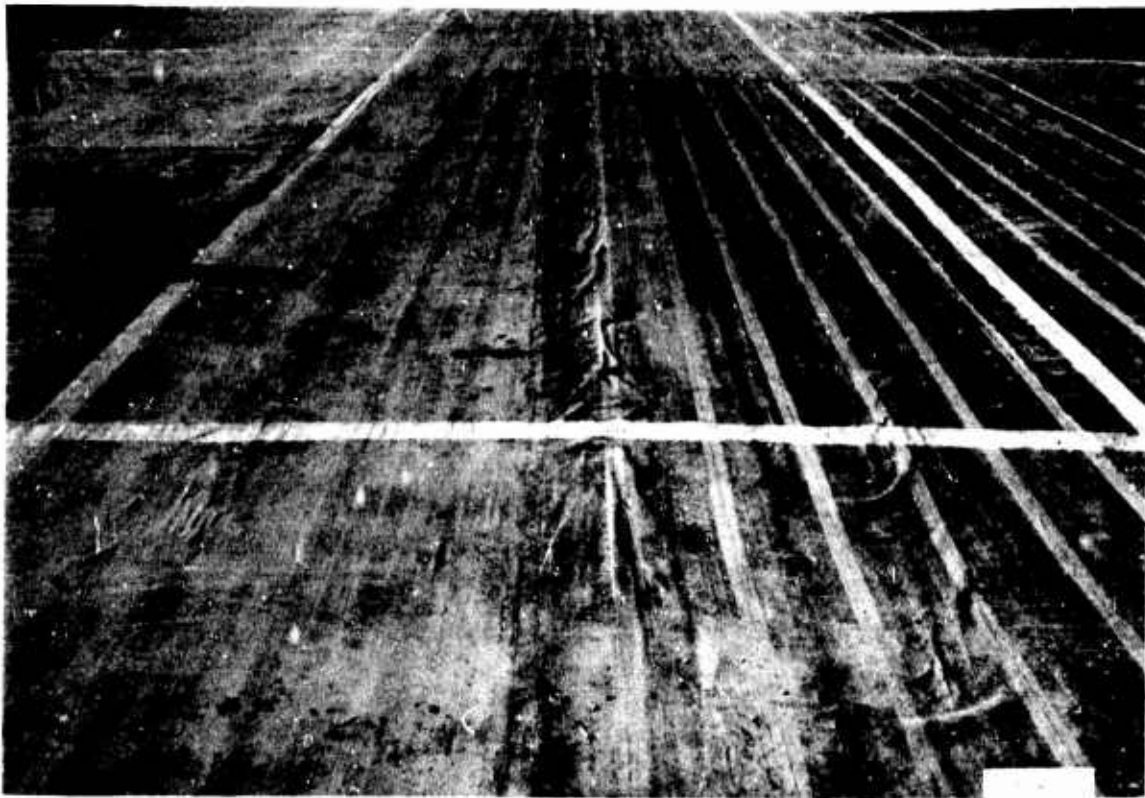
Photograph 5. Test 1: unsurfaced 80-CBR area after pull with F-4C loading



Photograph 6. Test 2: WX18 membrane prior to skid tests

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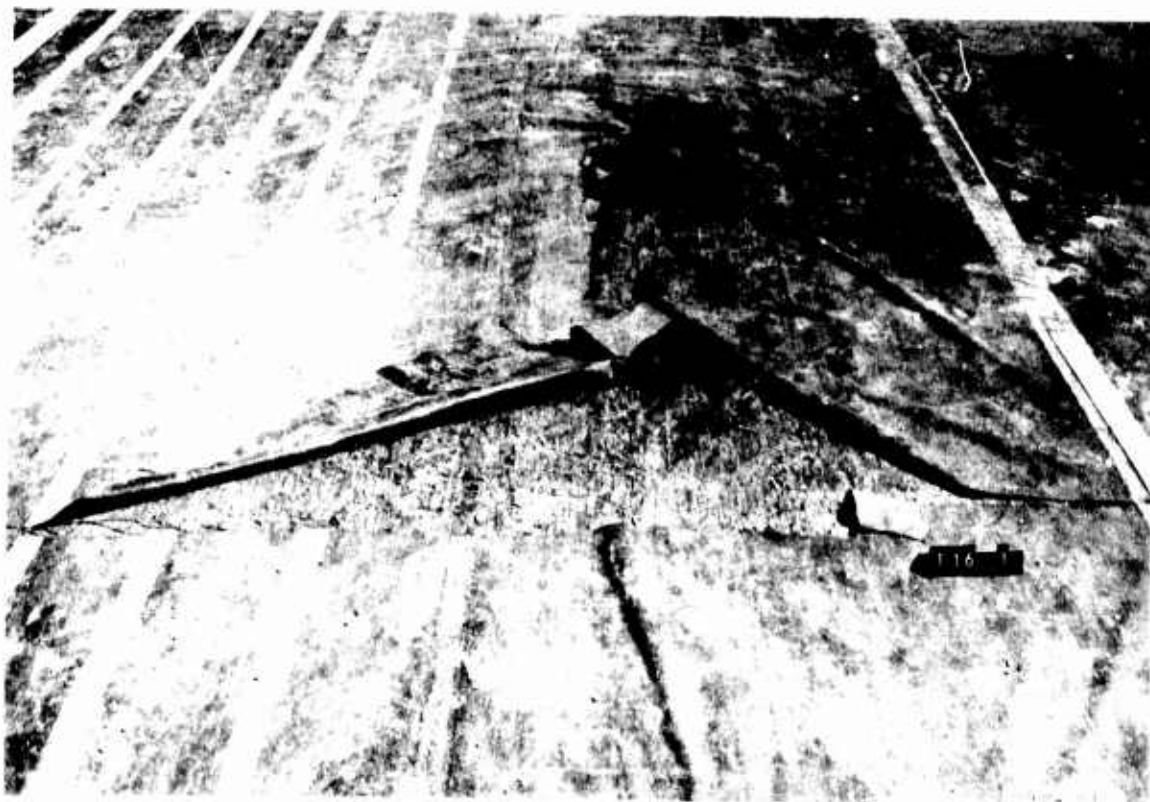
Photograph 7. Test 2; T16 membrane prior to skid tests



Photograph 8. Test 2; DBST over T1 membrane prior to skid tests



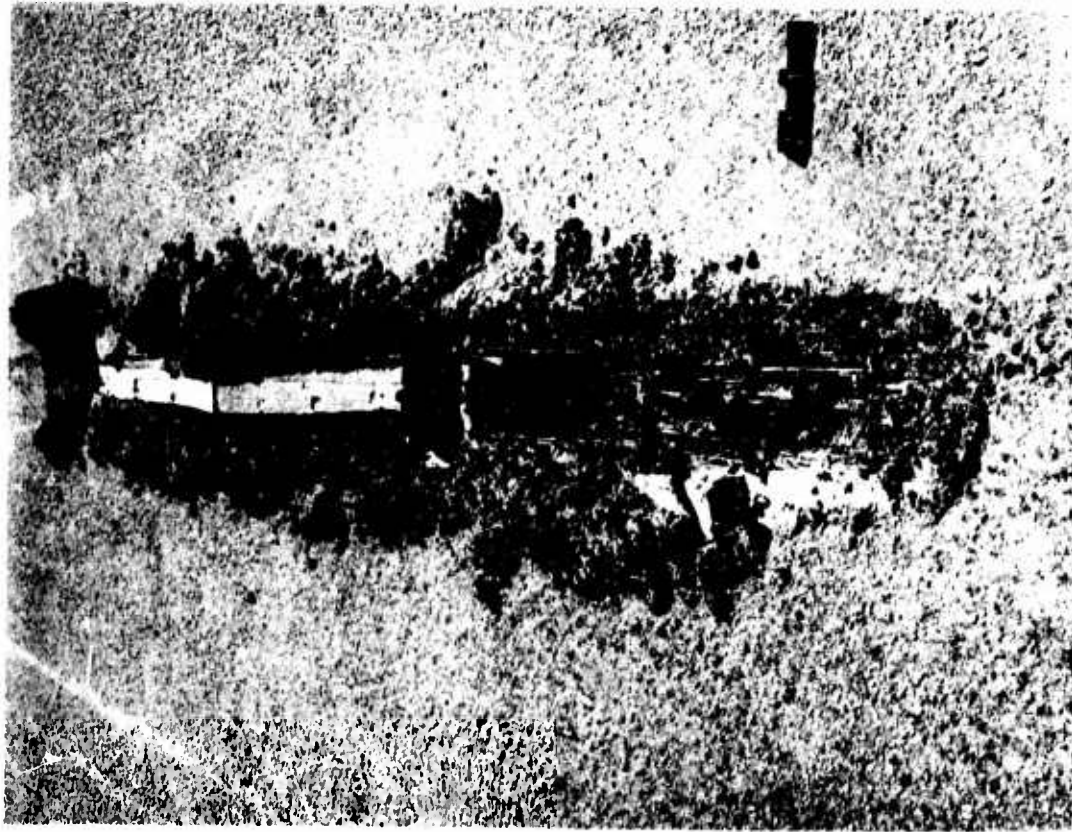
Photograph 9. Test 2; WX18 after second pull with F-4C loading



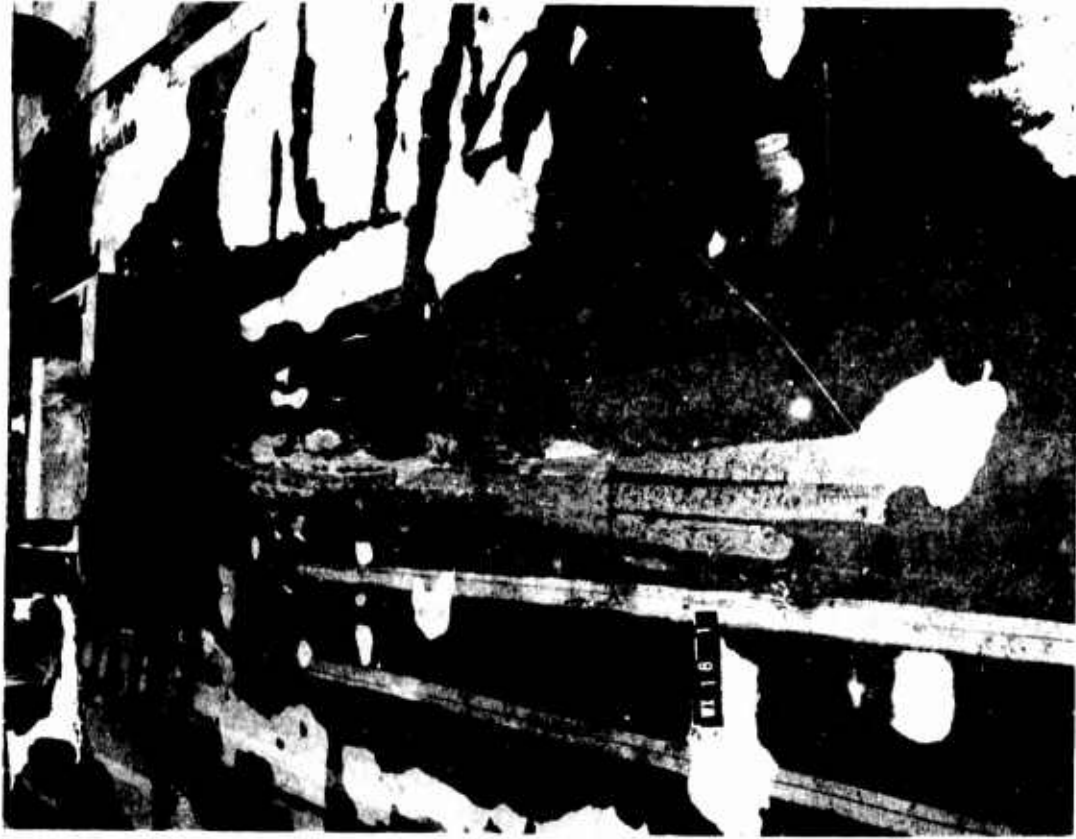
Photograph 10. Test 2; T16 after one pull with F-4C loading

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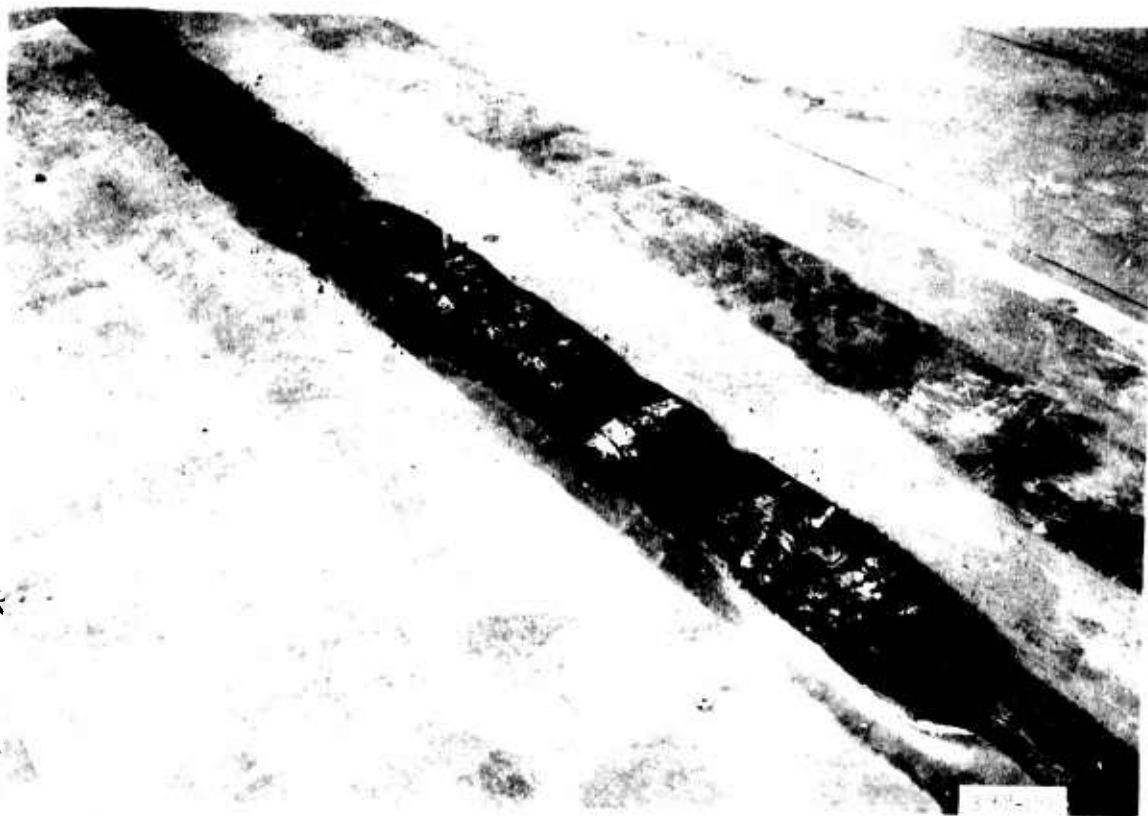
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Photograph 11. Test 2: DBST over T1 after
pull with F-4C loading



Photograph 12. Test 2: WX18 after wet surface skid test
with F-4C loading



Photograph 13. Test 2; WX18 with black enamel paint after third skid (F-4C loading)



Photograph 14. Test 2; WX18 after short-radius turn test with F-4C loading

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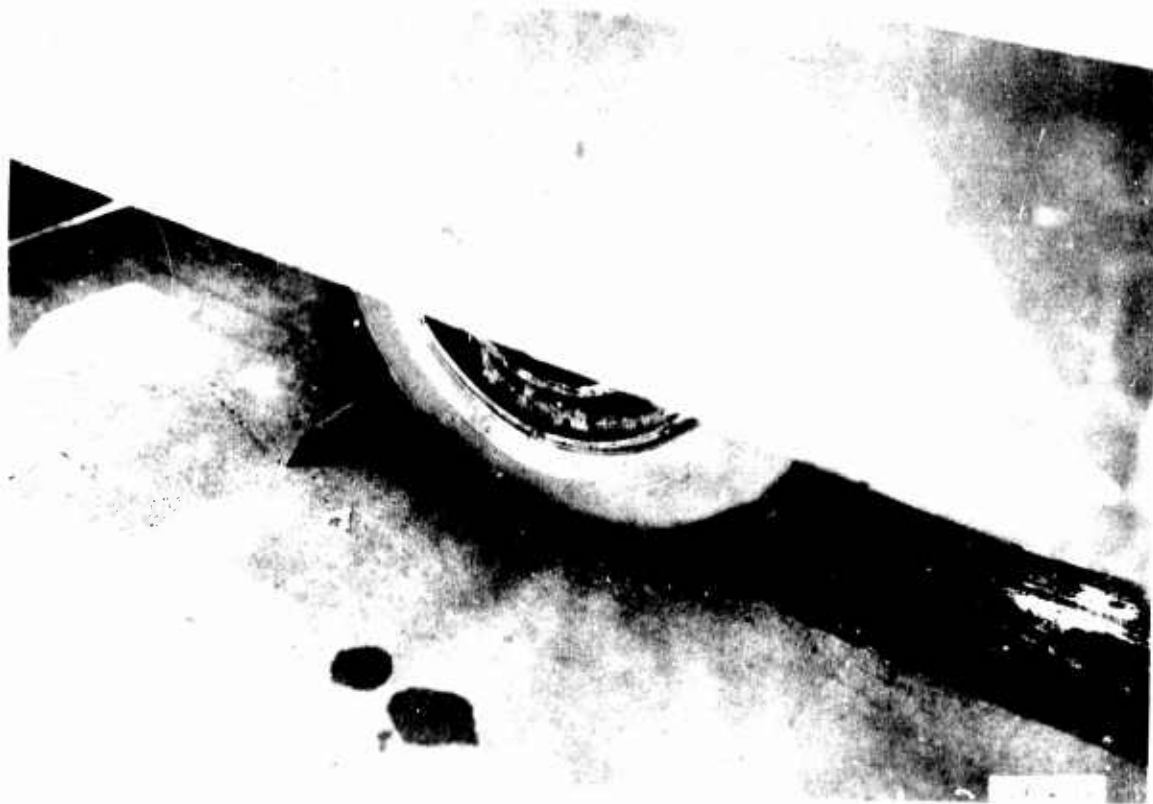
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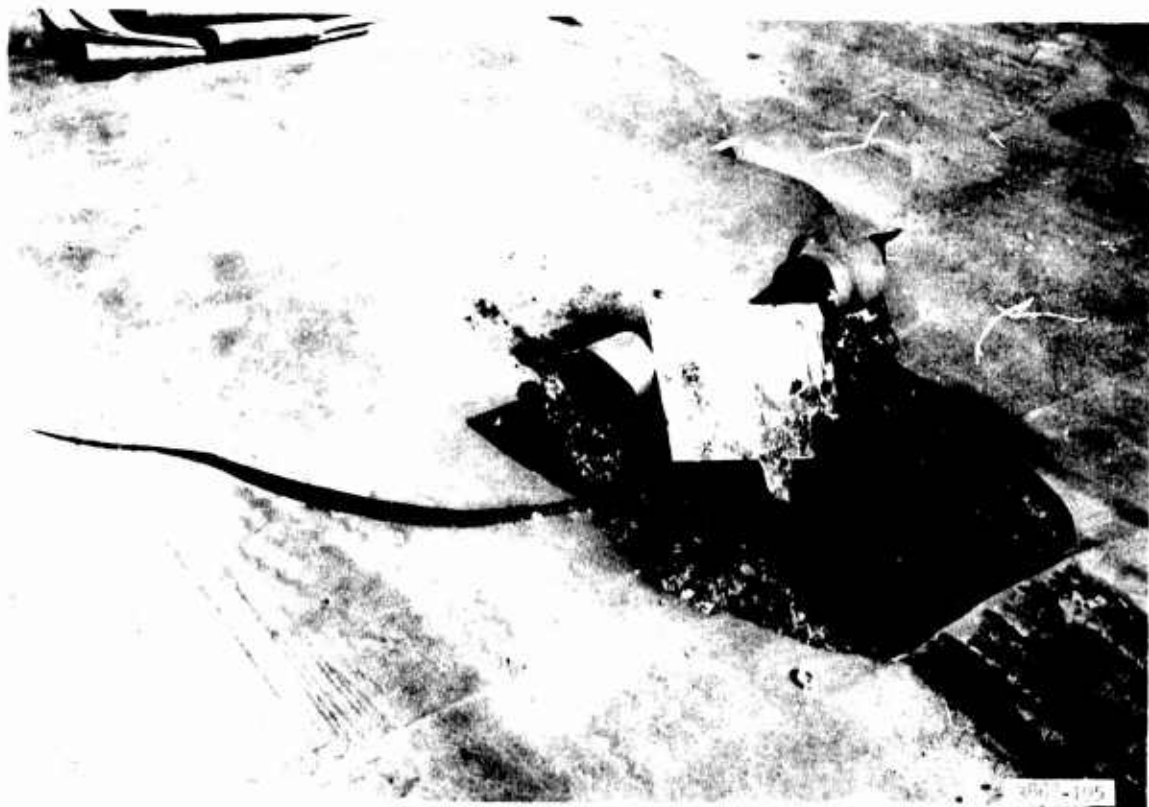
Photograph 15. Test 3; steel membrane anchored in trench



Photograph 16. Test 3; skid test in progress on steel membrane

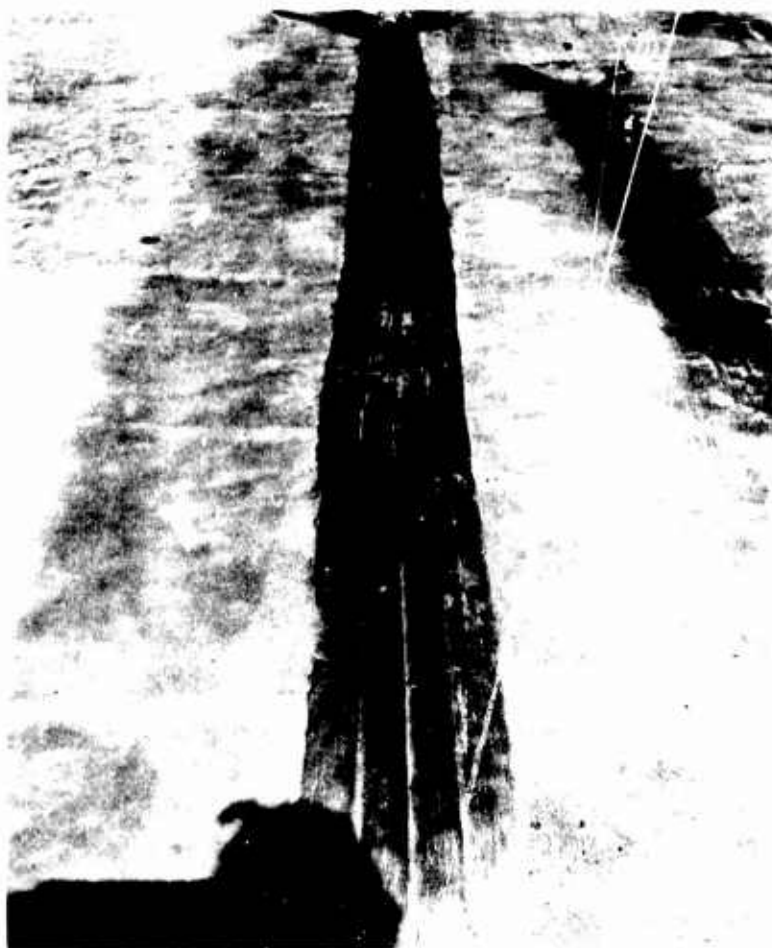


Photograph 17. Test 3; load wheel and steel membrane after first dry-surface skid with F-4C loading



Photograph 18. Test 3; close-up of steel membrane after second dry-surface skid test with F-4C loading

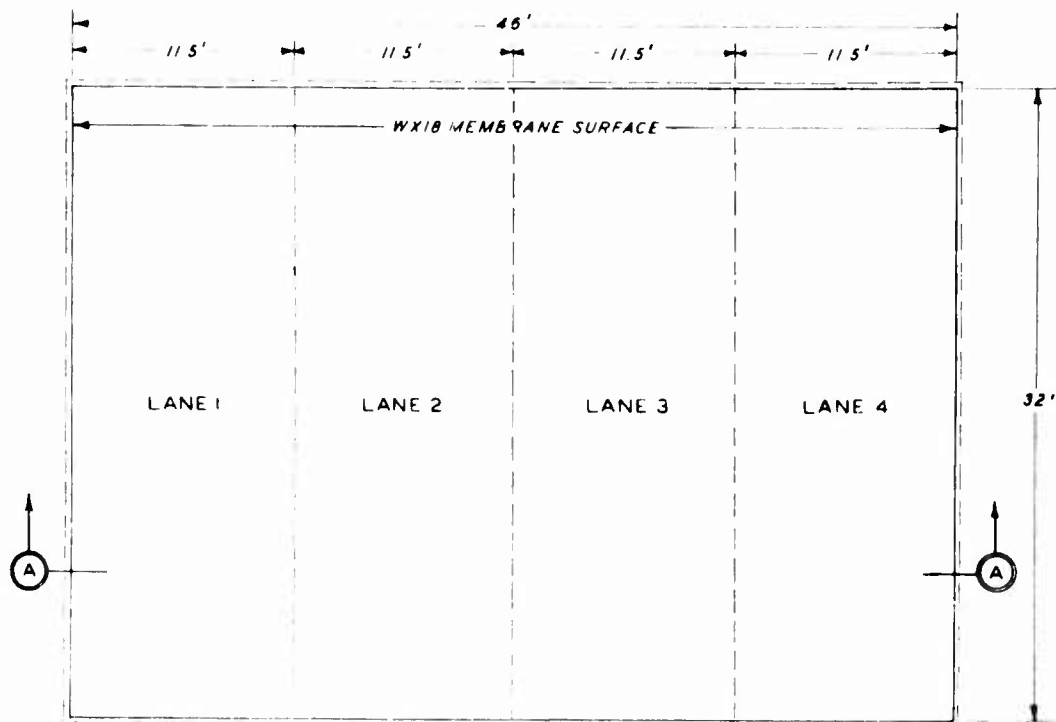
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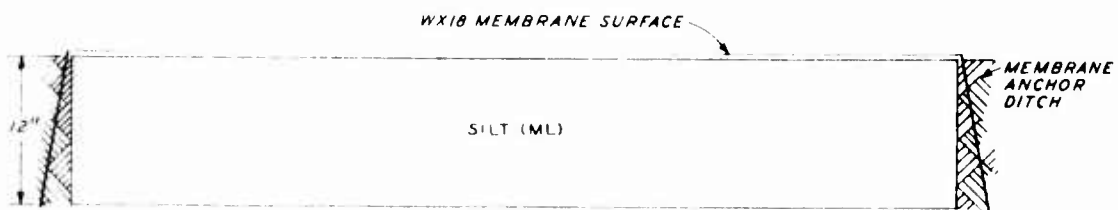
Photograph 19. Test 3; general view of steel membrane after second dry-surface skid test with F-4C loading



Photograph 20. Test 3; steel membrane after second wet-surface skid with F-4C loading



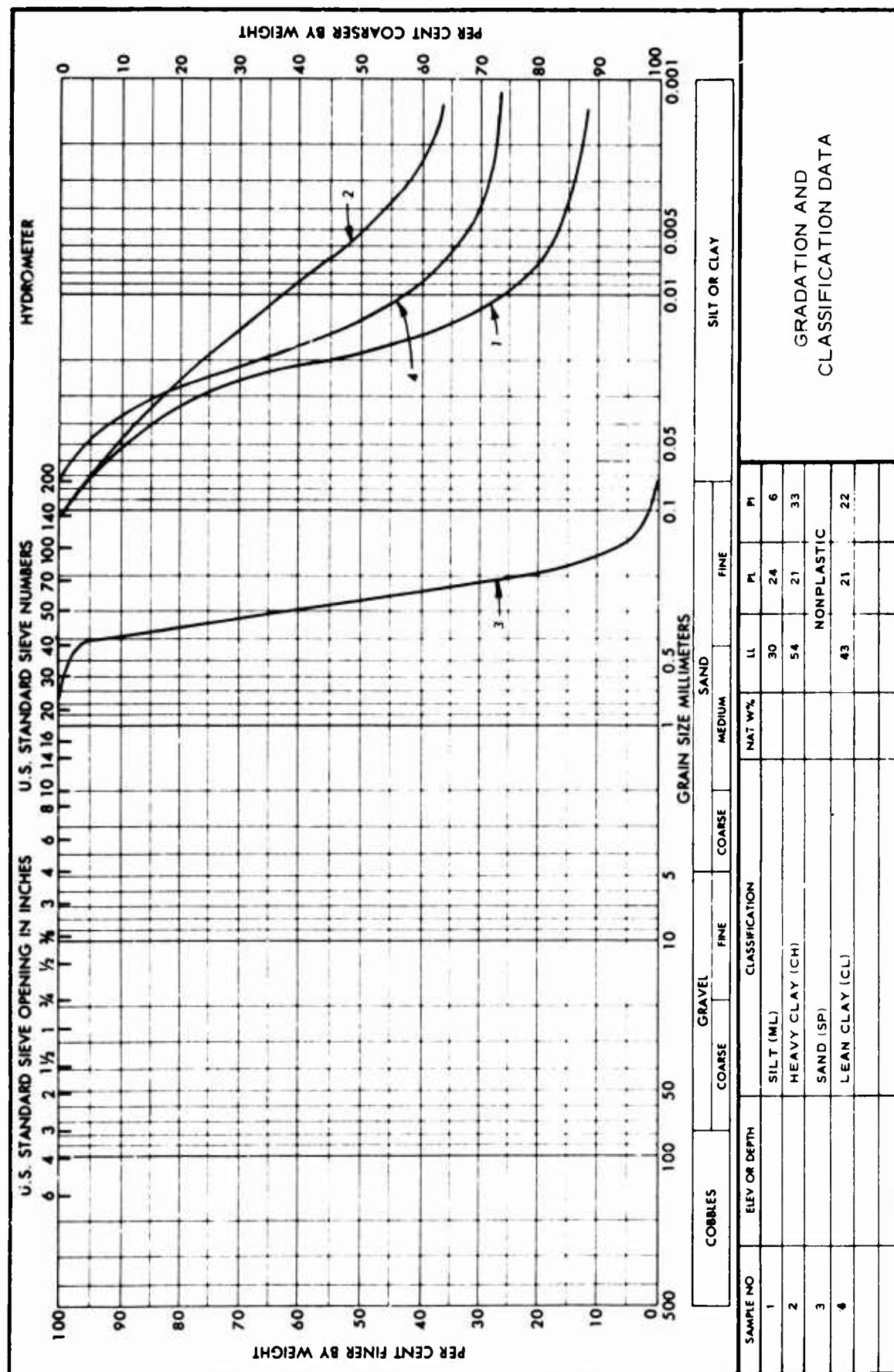
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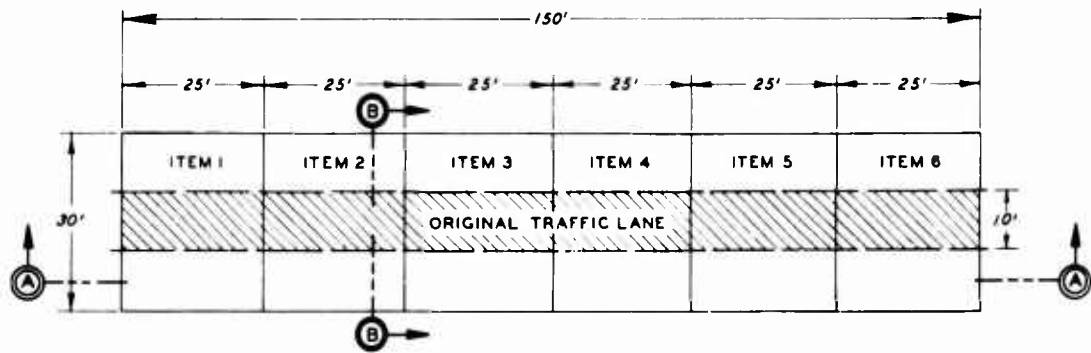
SECTION A-A

TEST SECTION I

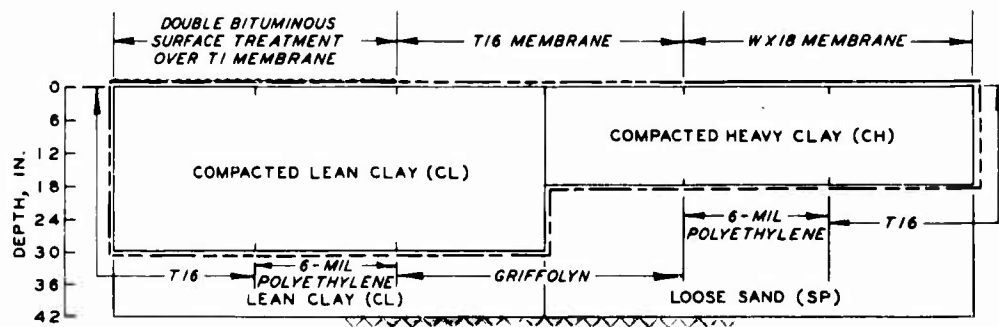
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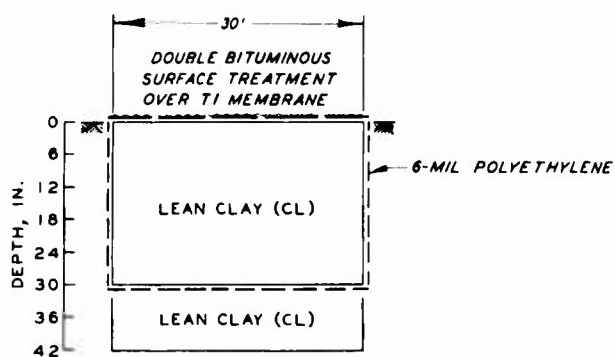
GRADATION AND CLASSIFICATION DATA



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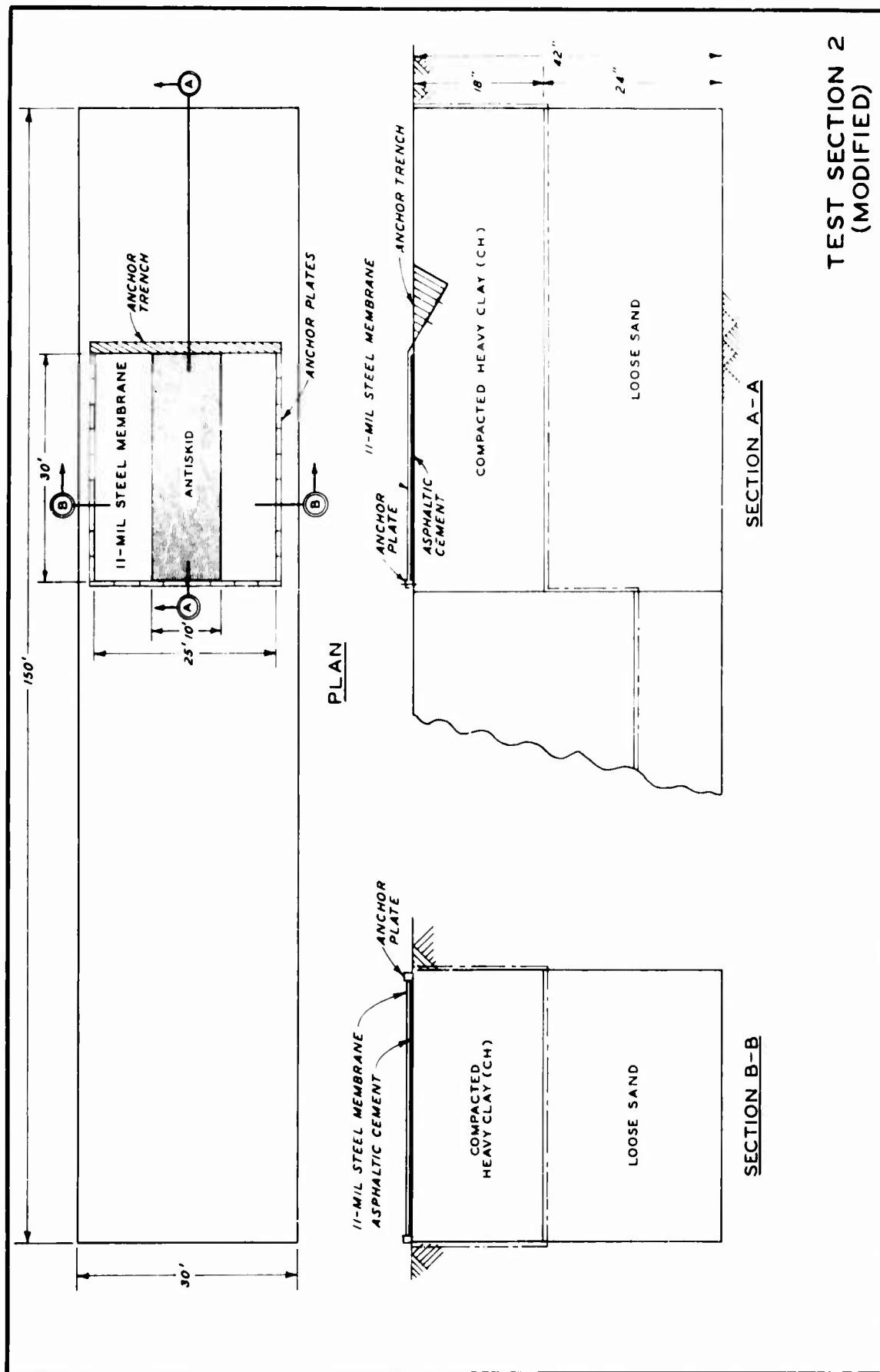
SECTION A-A



SECTION B-B

TEST SECTION 2

PLATE 4



TEST SECTION 2
(MODIFIED)

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13. ABSTRACT		
This project was conducted to find a means of rapidly establishing surfacing on a stable base on tactical assault airfields. Several types of production and experimental membranes were evaluated to determine their ability to withstand abrasive and tearing effects caused by fighter and heavy cargo aircraft tires during ground operations. Related programs and research conducted by the U. S. Army Engineer Waterways Experiment Station were examined to determine existing or potential techniques or materials that could be adapted to the Bare Base requirements for surfacing, and field tests were conducted on the items selected. Materials tested were WX18, a neoprene-coated membrane, T16 membrane, T1 membrane with a double bituminous surface treatment (DBST), and an 11-mil-thick high-strength steel membrane. The materials were subjected to locked-wheel skid and short-radius turn tests using equivalent F-4C and C-130 aircraft wheel loads. Initial skid tests with the F-4C loading were conducted on a subgrade designed for static and rolling F-4C wheel loads. The additional load generated by the locked wheels caused severe rutting and subsequent immobilization of the load wheel. Subsequent tests were conducted successfully in areas with a higher subgrade strength. All materials were subjected to one or more skid tests using F-4C loads. WX18 was also subjected to locked-wheel skid tests using C-130 loads and to short-radius turn tests using F-4C loads. The WX18 membrane successfully withstood all the tests, although the neoprene coating was worn off in several areas. The T16, T1 with DBST, and 11-mil steel membranes were ruptured during skid tests with F-4C loadings. From the results of this study, it was concluded that: (a) WX18 can be used as an expedient surfacing material on an assault airfield with adequate soil strength and will withstand the abrasions caused by ground operations of fighter and heavy cargo aircraft, with minor maintenance required in areas with severe abrasions; (b) T1 with DBST, T16, and 11-mil steel membranes cannot withstand the abrasive effect of locked-wheel skids of fighter aircraft; and (c) the soil strength stipulated by design criteria for assault fields based on static and rolling loads may not be adequate in all cases to provide surfacing that will withstand the increased loads caused by locked-wheel skids. Therefore, additional investigations should be conducted in this area.		

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