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August 2009

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Geotechnical and Structure Laboratory

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# Evaluation of Supa-Trac Matting for Expeditionary Roads

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Final report

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**Abstract:** The Supa-Trac commercial matting system was evaluated for use as an expedient road surfacing for both beach and mudflat crossing scenarios. Full-scale test sections of the mat systems were constructed over sand and mud in both temperate and cold climates. Temperate tests were conducted at the U.S. Army Engineer Research and Development Center, Vicksburg, MS, and cold climate tests were conducted at Fort McCoy, WI. The cold climate test was conducted to determine if the mat exhibited brittle failure behavior when trafficked in sub-freezing temperatures. The mats were trafficked with a fully loaded 7-ton (~6350-kg) military truck. Mat deformation and damage were monitored at traffic intervals up to 3,500 truck passes. The performance data were analyzed, and the mats were evaluated on their ability to sustain traffic. The mat system was further evaluated on the basis of rate of deployment, logistical footprint, and cost. Based on the results of the full-scale test sections, the matting performed satisfactorily in the beach crossing scenario, but failed to achieve the desired results for the mudflat crossing. Additionally, the matting system exhibited brittle failure behavior when trafficked in sub-freezing temperatures.

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# Preface

The investigation reported herein was conducted as part of the "Expeditionary Road Construction Materials" project under the sponsorship of the U.S. Marine Corps Systems Command (MarCorSysCom). The U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, was directed by the MarCorSysCom to evaluate the commercial-off-the-shelf Supa-Trac matting system as an expedient road construction material. The purpose of this investigation was to support acquisition decisions on materials used for expeditionary maneuver operations.

This publication was prepared by personnel of the ERDC, Geotechnical and Structures Laboratory (GSL). The findings and recommendations presented in this report are based upon the evaluation of controlled test section experiments conducted at the ERDC-Vicksburg site and Fort McCoy, WI, from September 2008 to March 2009. The principal investigators for this study were Timothy W. Rushing and Jeb S. Tingle, Airfields and Pavements Branch (APB), GSL. Other ERDC personnel who assisted with the test sections include Timothy J. McCaffrey, Quint S. Mason, Jay Rowland, and Matt Norris, APB, and Leroy Hardin, Stacy Washington, and Charles Wilson, ERDC Directorate of Public Works. T. W. Rushing, Tingle, McCaffrey, and Todd S. Rushing prepared this publication under the supervision of Dr. Gary L. Anderton, Chief, APB; Dr. Larry N. Lynch, Chief, Engineering Systems and Materials Division; Dr. William P. Grogan, Deputy Director, GSL; and Dr. David W. Pittman, Director, GSL.

COL Gary E. Johnston was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

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# Unit Conversion Factors

| Multiply | By | To Obtain |
|---|---|---|
| cubic feet | 0.02831685 | cubic meters |
| cubic yards | 0.7645549 | cubic meters |
| degrees Fahrenheit | (F-32)/1.8 | degrees Celsius |
| feet | 0.3048 | meters |
| inches | 0.0254 | meters |
| miles per hour | 0.44704 | meters per second |
| pounds (force) | 4.448222 | newtons |
| pounds (force) per square foot | 47.88026 | pascals |
| pounds (force) per square inch | 6.894757 | kilopascals |
| pounds (mass) | 0.45359237 | kilograms |
| pounds (mass) per cubic foot | 16.01846 | kilograms per cubic meter |
| pounds (mass) per square foot | 4.882428 | kilograms per square meter |
| square feet | 0.09290304 | square meters |
| square inches | 6.4516 E-04 | square meters |
| square yards | 0.8361274 | square meters |
| tons (force) | 8,896.443 | newtons |
| tons (long) per cubic yard | 1,328.939 | kilograms per cubic meter |
| tons (2,000 pounds, mass) | 907.1847 | kilograms |
| yards | 0.9144 | meters |

# 1 Introduction

## Background

The U.S. Marine Corps' (USMC) mission includes the requirement to support expeditionary maneuver forces and sustainment activities. The USMC's broad mission requires operations in all types of terrain including beaches, marshes, mudflats, urban terrain, and mountains. While initial tactical forces are equipped with high mobility vehicles, follow-on sustainment vehicles have reduced mobility characteristics relative to forward units. While poor terrain conditions may not cause vehicle immobilization due to the capabilities of the USMC equipment, they may result in reduced logistical throughput and excessive wear on the equipment. For this reason, expeditionary road surfaces have been used to assist vehicle mobility and expedite throughput across difficult terrain.

One category of expeditionary road surfaces includes lightweight matting, such as MO-Mat or aluminum matting. Unfortunately, MO-Mat is no longer manufactured, and aluminum matting is logistically burdensome. Recent operations have identified potential replacement mat systems for temporary roads across sandy soils and mudflats, prompting inquiries into performance of commercial-off-the-shelf (COTS) mat systems. Many COTS mat systems have been identified that are capable of supporting a limited number of vehicle crossings; however, detailed analyses that consider the optimization of performance, durability, and logistics of these systems are lacking. Therefore, there is a need to perform detailed testing and analyses of candidate mat systems to understand the advantages and limitations of the available technologies.

## Objective

The objective of this project was to evaluate the COTS Supa-Trac mat system for use as an expeditionary road surface in both beach and mudflat terrain environments. This project generated performance, durability, and logistics information to support USMC acquisition decisions concerning the Supa-Trac system.

The project objective was accomplished by constructing full-scale test sections representative of beach sand and mudflat subgrades in both temperate and cold weather environments. All temperate tests were performed at the ERDC, Vicksburg, MS, and cold weather test were performed at Fort McCoy, WI. For the basis of this study, temperate refers to climates that are absent of extreme annual temperature changes. The intent was to test the matting system during temperature ranges of 50°F to 85°F. For the cold weather climate, testing was intended to be conducted during temperatures from 0°F to 20°F.

The beach sand test section consisted of a loose concrete sand, classified as poorly graded sand (SP), procured from a source local to Vicksburg, MS. All subgrade soils were classified by the American Society for Testing and Materials (ASTM) D 2487. Three mudflat test sections in the temperate environment consisted of a natural, low-plasticity clayey silt (ML-CL) subgrade that was loosely tilled and wetted to achieve the desired condition for testing. One temperate mudflat test was performed over a high-plasticity clay (CH) subgrade that remained in place from a previous test section. The mudflat test sections conducted at Fort McCoy, WI, in the cold weather environment consisted of silty sand (SM) subgrade that was tilled in place for consistency. Matting was placed directly on top of the test beds and trafficked with a fully loaded 7-ton military truck to evaluate the mats under realistic loading conditions. The performance of the mat systems was monitored in terms of the development of permanent deformation or rutting. The durability of the mat system was evaluated by closely monitoring the deterioration of the mats during traffic and quantifying the accumulation of damage. The results of this analysis were used to develop specific conclusions regarding the suitability of the Supa-Trac system for military use as well as recommendations to support future acquisition strategies.

Chapter 2 provides a detailed description of the Supa-Trac system and the materials used to construct the full-scale test sections. Chapter 3 describes the construction and trafficking of the test sections, while Chapter 4 reports the analysis of the data. Chapter 5 summarizes the conclusions and recommendations resulting from the evaluation.

# 2 Materials

## Subgrade soils

### Sand (SP)

The sand subgrade used for evaluation of the beach crossing scenario was reconstituted from a 2006 off-road test section conducted at the ERDC by Rushing et al. (2007). The SP subgrade consisted of a material local to Vicksburg, MS, normally used as a fine aggregate in concrete. The sand was pit-run washed sand containing approximately 4% gravel and 2% fines minus No. 200 U.S. standard sieve size material. It was classified as poorly graded (SP) sand, ASTM D 2487 (ASTM 1992).

### Clayey silt (ML-CL)

The mudflat test section site for the temperate climate formerly served as a dredge fill containment area at the ERDC. The existing subgrade consisted of soils dredged from Brown's Lake that were dumped there in the 1980s. Local soils in the Vicksburg, MS, area are loess deposits. Subgrade sediments in the containment area are classified as low-plasticity clayey silt (ML-CL). Classification data for the soil in the test location are given by Santoni (2003).

### High-plasticity clay (CH)

The high-plasticity clay test site for the temperate climate was constructed in the ERDC Hangar 4 pavement evaluation test facility. The CH subgrade remained in place from the evaluation of an airfield matting system, and was reused for this project. The section consisted of a 3-ft-deep layer of CH that had been processed to achieve a desired strength. The CH material was procured from a local source to Vicksburg, MS, that has been used for test section construction at the ERDC since the 1940s.

### Silty sand (SM)

The silty sand subgrade used for the cold climate mudflat scenario was typical of soils found on Fort McCoy, WI. The SM material consisted of natural deposits of sand from weathered sandstone. The SM layer was greater than 60 ft deep according to a U.S. soil survey in the area and was extremely fast draining. The material froze rapidly during periods of sub-freezing temperatures.

## Mat system – Supa-Trac

Supa-Trac was developed by Rola-Trac, County Cork, Ireland (Figure 1). Two grades of Supa-Trac are available for use as temporary roadways,

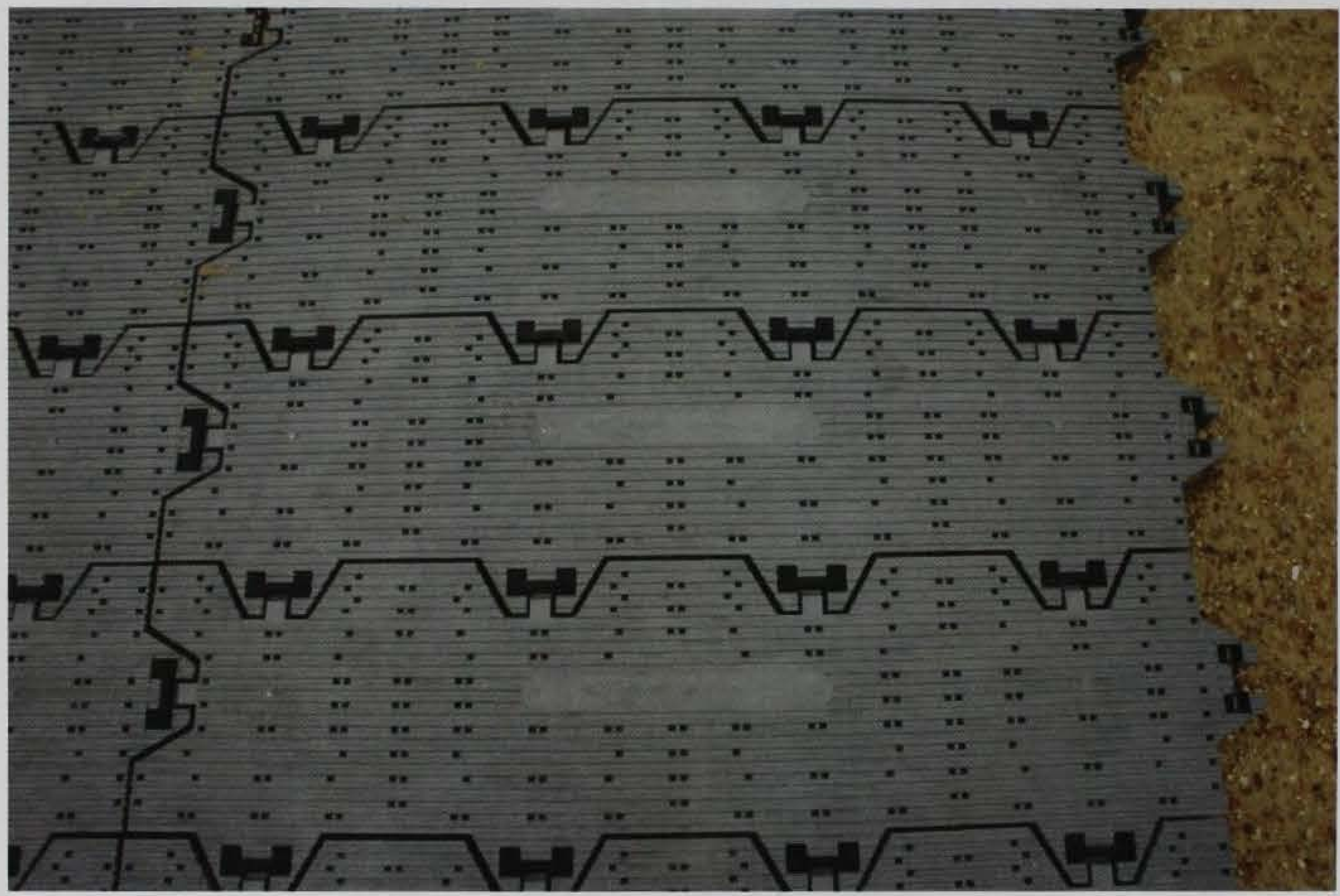

Figure 1. Supa-Trac matting with straight longitudinal joints.

standard and economy. The economy version, made with recycled material, was not deemed robust enough for military use and was not included in this evaluation. The standard Supa-Trac is made of a nucleated copolymer polypropylene. The mat system consists of individual panels with dimensions of approximately 36 × 9 × 1.4 in. and weighing 5.5 lb, or 2.5 lb per square foot. The panels are joined by a system of T-bars and receptors with locking clips to hold the connections in place. The panels can be assembled in multiple size configurations for delivery on pallets, or they can be rolled in 60- or 80-ft rolls for quick deployment. Assembly of individual panels requires connector clips and a rubber mallet or boot heel. A flat screw driver or similar tool is required for disassembly of panels.

The Supa-Trac matting used in this evaluation was procured by the USMC and delivered to the ERDC for testing in two shipments. The first Supa-Trac shipment arrived as two 80-ft rolls and two 60-ft rolls of matting, each 15-ft wide (Figure 2) and configured with continuous longitudinal joints. The second shipment consisted of five 80-ft rolls and five 60-ft rolls of matting, each 15-ft wide and configured with staggered longitudinal joints (Figure 3). The 80-ft rolls weighed approximately 3,000 lb and were about 4 ft in diameter. The 60-ft rolls weighed approximately 2,250 lb and were about 3.5 ft in diameter. Each roll of mat was wrapped around a high-density polyethylene (HDPE) culvert with spare panels and a tool kit packaged inside. The tool kit contained a rubber mallet, a flat screwdriver, extra locking clips, edge stake points, stakes, two ratcheting straps, a product brochure with installation instructions, and an instructional DVD video (Figure 4). Storage racks were delivered that could be used to prevent the rolls from moving or for stacking one roll on top of another. Pertinent properties are listed in Table 1.

Figure 2. Rolls of Supa-Trac matting as delivered to the ERDC for testing.

Figure 3. Supa-Trac configured with staggered longitudinal joints.

Figure 4. Supa-Trac matting installation kit.

Table 1. Mat properties on a per-square-foot basis.

| Mat Item | Description As Tested | Weight lb/ft$^2$ | Packed Volume ft$^3$/ft$^2$ Road | Cost \$/ft$^2$ |
|---|---|---|---|---|
| Supa-Trac | 36 × 9 × 1.4-in. HDPE panels with T-shaped connectors. Panels were pre-assembled in 60- and 80-ft rolls for quick installation. | 2.5 | 0.16[a] | 5.25 |

[a] Volume for rolled configuration only. Will decrease for palletized configuration.

# 3 Experimental Methods

Full-scale test sections were constructed and evaluated during the period September 2008 through March 2009 at the ERDC and Fort McCoy, WI. All tasks associated with the experimentation, including construction, testing, and analysis, were accomplished by ERDC personnel. Construction activities were performed using conventional construction equipment.

## General description

The full-scale Supa-Trac mat testing consisted of seven individual subgrade sections. One section of Supa-Trac was trafficked over a loose sand representative of a beach crossing scenario. Three tests were conducted over an ML-CL material and one over a CH material, with various subgrade strengths, to represent mudflat crossing scenarios. Two additional tests were conducted over SM material at Fort McCoy to determine the impact of using the system in sub-freezing temperatures. One section was partially frozen, and the second was completely frozen. All test sections were trafficked until failure or 2,000 truck passes were achieved. Failure was defined as 3 in. of rutting or 20% mat system breakage. Table 2 defines the subgrade type and condition for each of the full-scale tests conducted.

Table 2. Properties of individual Supa-Trac test sections.

| Test Name | Location | Avg. Temp., °F | Subgrade Type | CBR % | Joint Configuration | Scenario |
|---|---|---|---|---|---|---|
| SS-1 | Vicksburg, MS | 85 | Poorly graded sand (SP) | 15 | Straight | Beach crossing |
| SM-1 | | 85 | Clayey silt (ML-CL) | 1-3 | Straight | Mudflat |
| SM-2 | | 85 | Clayey silt (ML-CL) | 5 | Straight | Mudflat |
| SM-3 | | 65 | Clayey silt (ML-CL) | 5 | Staggered | Mudflat |
| SM-4 | | 55 | High plasticity clay (CH) | 7 | Staggered | Mudflat |
| SC-1 | Fort McCoy, WI | 25 | Silty sand (SM) | 5 | Staggered | Partially frozen |
| SC-2 | | 15 | Silty sand (SM) | 80 | Staggered | Completely frozen |

## Test section construction

### Site descriptions

The field experiments for this evaluation were conducted at outdoor test sites at the ERDC and an outdoor engineer site at Fort McCoy. The site of sections SS-1, SM-1, SM-2, and SM-3 were located at the ERDC on the northeast end of Brown's Lake within a dredge fill containment area, which was encircled by a gravel-surfaced road (Susquehanna Circle). The existing soil at the site was described in Chapter 2. The topography of the containment area was relatively flat, with the surrounding roadway elevated 3 to 5 ft. The sand test section remained in place from a 2006 beach mat evaluation and spanned east to west on the north side of the site. The sites for mudflat test sections were chosen just south of and parallel to the existing sand section. The site of section SM-4 was the Hangar 4 pavement test facility at the ERDC. The facility is a covered hangar with open ends to facilitate construction of roadway sections and full-scale trafficking. The CH used for the test remained in place from a previous traffic test of an airfield matting system. The site of sections SC-1 and SC-2 was the Engineer Dig Site 09 at Fort McCoy, WI. This site was pre-approved for digging operations, had a flat topography, and had a very consistent natural SM subgrade material.

### Sand

The sand subgrade used for evaluation of the beach crossing, SS-1, was reconstituted from a 2006 beach mat test section. Details of the original construction can be found in the report by Rushing et al. (2007). The test section was reconstituted by tilling 16 in. deep with a rotary mixer to remove any vegetation and return the sand to a loose condition. A 15-ft-wide by 80-ft roll of Supa-Trac matting with straight longitudinal joints was placed directly on top of the sand subgrade and trafficked with a fully loaded 7-ton military transport truck (Figure 5). AM2 aluminum airfield mat was used on each end of the Supa-Trac test section as stable on and off ramps. Since the 2006 beach mat test by Rushing et al. (2007) used the same subgrade and test vehicle, the control data presented in this report were reproduced from that report.

Figure 5. Supa-Trac matting on sand subgrade prior to trafficking.

### Mudflat

The mudflat test sections SM-1 and SM-2 were constructed by pulverizing the existing subgrade material with a rotary mixer to a depth of 16 in. and wetting the subgrade to achieve the desired moisture content and California Bearing Ratio (CBR) (Figures 6 and 7). The first test section, SM-1, was constructed to a 1 to 3 CBR strength to simulate an extreme condition. This section consisted of two test items. The test items were a 15-ft-wide by 60-ft-long section of Supa-Trac with straight longitudinal joints over subgrade and an identical section installed over a geotextile material (Figure 8). Both systems were trafficked in one continuous traffic lane until failure. Once failure had occurred, the Supa-Trac mat systems were removed, and a control section was conducted with the truck trafficking directly over the subgrade while straddling the ruts from the mat test.

After completion of the SM-1 test section, the ML-CL subgrade was allowed to dry for several days, was pulverized again to create a uniform subgrade, and was covered with a 15-ft-wide by 80-ft-long roll of Supa-Trac matting with straight longitudinal joints. The SM-2 subgrade was constructed to a 5 CBR to simulate a moderate to dry mudflat condition. An additional 80 ft of the ML-CL subgrade was left uncovered and was trafficked as a second control section for the dryer subgrade condition (Figure 9).

Figure 6. SM-1 test section subgrade construction.

Figure 7. SM-1 test section prior to mat installation.

Figure 8. SM-1 test section prior to trafficking.

Figure 9. SM-2 and control test sections prior to trafficking.

SM-3 was constructed west of sections SM-1 and SM-2 by removing only the first 2 in. of grass from an area of natural subgrade with a 5 CBR. This test was conducted using a 15-ft-wide by 60-ft-long roll of Supa-Trac with staggered longitudinal joints for comparison to the SM-2 section (Figure 10).

Figure 10. SM-3 section prior to traffic.

SM-4 was constructed in Hangar 4 by removing the upper 3 in. of an in-place CH test section with a motor grader and placing a 15-ft-wide by 60-ft-long roll of Supa-Trac with staggered longitudinal joints directly on top of the prepared subgrade (Figure 11). Field CBR tests showed that the CH had a CBR of 7.5%.

### Cold climate tests

SC-1 and SC-2 were constructed at Engineer Dig Site 09 at Fort McCoy by tilling the existing SM subgrade 16 in. deep with a rotary mixer to ensure consistency. The material was then bladed smooth with a bulldozer. Two 15-ft-wide by 60-ft-long rolls of Supa-Trac with staggered longitudinal joints were installed. Field tests indicated the CBR of the prepared SM subgrade was 5 CBR prior to freezing (Figures 12 through 14).

Figure 11. SM-4 prior to traffic.

Figure 12. Subgrade preparation at Engineer Dig Site 09, Fort McCoy, WI.

Figure 13. SC-1 prior to traffic.

Figure 14. SC-2 prior to traffic.

## Mat installation

Since the Supa-Trac systems were delivered to the ERDC in large rolls, no assembly was required. The manufacturer recommended leaving adjacent sections of matting disconnected to allow for relief of bow waves that may form in front of moving vehicles. Additionally, the manufacturer did not recommend staking the edges of the mat to allow for stress relief at the free edges. The rolls were aligned on the test subgrades by an all-terrain fork lift, and rolled out by three men (Figure 15). The process was simple and required little or no training. For the SM-1 test section, a light-weight geotextile fabric was placed underneath one roll of Supa-Trac matting to determine if the system benefitted from its application.

## Mat evaluation under traffic

### Traffic

Channelized truck traffic was applied using a 7-ton, 6-wheeled truck (Figure 16). The truck was loaded with a 7-ton payload consisting of distributed lead blocks. The tire pressures were adjusted to 28 lb/in.$^2$ in the two front tires and 35 lb/in.$^2$ in the four rear tires, the recommended pressures for "cross-country" driving conditions. The front axle of the loaded truck weighed 15,290 lb, and the two rear axles combined weighed 29,310 lb.

Figure 15. Installation of Supa-Trac matting on SM-1 test section.

Figure 16. Seven-ton military transport truck used to traffic the mat test sections.

Assuming that the tire-to-soil contact pressure was equal to the air pressure, the front and rear tire footprints were calculated to be 270 and 210 $in.^2$, respectively. Normally, a tire's actual contact pressure is somewhat higher than the internal air pressure owing to the rigidity of the sidewall. The measured footprint area was within 10% of the predicted value, so the contact pressures were estimated at 28 to 32 $lb/in.^2$ and 35 to 40 $lb/in.^2$ in the front and rear, respectively.

The truck was driven alternately forward and backward over the test roadway in the same wheel paths at approximately 5 to 10 mph. The necessary decelerations and accelerations were performed on the end ramps beyond the ends of the mat items being evaluated. The wheel path was reasonably consistent throughout the experiment, with an average wander width of less than 6 in.

Traffic was paused intermittently to evaluate and document the condition of the matted sections. Data were collected at the following traffic intervals where applicable: 0, 10, 20, 50, 100, 200, 500, 1000, 1500, 2000, 2500, 3000, and 3500. Prior experience suggested that the rut development would be closely exponential, so intervals were selected to have a near logarithmic distribution.

### Failure criteria

Typically, a test item is considered failed when it reaches one of the following two criteria: (1) the rut depth in the wheel path exceeded 3 in. or (2) more than 20% of the mat surface sustained physical damage. For this experiment, both criteria were used to determine failure.

### Maintenance

The maintenance plan was to perform repairs on the test sections as necessary to maintain trafficability. Unless it posed a hazard to the truck, mat damage was allowed to progress under continuous traffic conditions.

In practice, very little maintenance was necessary. Occasionally, the AM2 end ramps on the sand test section had to be repositioned with a front end loader. No other maintenance was required.

### Dynamic cone penetrometer (DCP) measurements

A DCP was used, according to the procedure described in Webster et al. (1992) (ASTM D6951), to measure the subgrade soil strength under each test section prior to trafficking, with the exception of SM-4. The 10-lb hammer configuration was employed. Generally, the method assesses soil strength by measuring the depth of penetration of a cone-tipped rod as a function of the number of blows of the hammer dropped from a pre-determined height. DCP data are reported in Chapter 4.

### Field CBR measurements

A field CBR procedure was used, according to the procedure outlined in ASTM D4429-04, to measure the subgrade soil strength under test section SM-4 prior to trafficking. The field CBR method was used instead of the DCP for this test section due to the inability of the DCP method to accurately predict CBR values in CH materials. In general, the field CBR method measures the rate of penetration of a standard piston in to the surface of the subgrade material and compares this rate to that of a crushed limestone standard. An average of three field CBR tests conducted on the SM-4 test section indicated a value of 7 CBR.

### Cross-section measurements

At each traffic interval, the mat surface topography was measured at each of the cross sections positioned at the mat quarter points. These data were acquired using a rod and level. Elevations relative to a bench mark were recorded at 1-ft intervals along each cross section. Measurements spanned 20 ft beginning on the subgrade shoulder, progressing across the mat item, and ending on the opposite shoulder. Thus, the cross-section data captured elevation changes across each mat as well as on the adjacent subgrade shoulder to include the entire region influenced by traffic. This method ensured that elevations were taken at the same points each time, so that the changes in the cross-section elevations could be tracked as a function of the number of truck passes. Cross-section data are reported in Chapter 4.

### North wheel path profile

In addition to cross-section elevations, rod and level elevations were collected along the entire north wheel path at 1-ft intervals to establish longitudinal profiles and monitor rut formation on all mat items. The traffic levels at which these data were recorded were 0, 1000, 2000, and 3000 truck passes, or at the completion of the tests. These profiles are reported in Chapter 4.

### Rut depth measurements

Rutting in the mats was quantified and recorded at each traffic interval to supplement the cross-section data. The mats were depressed in the wheel path to promote contact with the subgrade before measurement. A metal straight edge, 8 ft in length, was laid across each wheel path at the quarter points. A rigid ruler was used to measure the distance from the straight edge to the lowest point on the mat surface (the deepest point of the rut). Rut depth data are reported in Chapter 4.

## Control experiments

Control experiments were conducted on SS-1, SM-1 (Figure 17), SM-2 (Figure 9), SM-4, and SC-2 to assess the ability of the subgrade to support the same truck traffic that was applied to the mat sections. Control sections were not performed over sections SM-3 and SC-1 due to time constraints and redundancy of subgrade types and strengths. The SS-1 sand control


Figure 17. SM-1 subgrade prior to control trafficking.

experiment was conducted during the 2006 beach mat evaluation and is detailed in the report by Rushing et al. (2007).

Before beginning the control traffic, the bearing strength of the subgrade was measured. A rod and level survey of the subgrade surface was performed to establish cross sections at quarter points by recording elevations at 1-ft intervals along each cross section. Truck traffic was applied, pausing intermittently to measure rut depths and to resurvey the cross sections. Traffic was continued until enough information was gathered for comparison to the matted traffic sections, or the axle of the truck began dragging on the subgrade.

After trafficking, final data collection was performed to characterize the post test condition. Results and analysis of the control experiments are presented in Chapter 4.

# 4 Results and Analysis

## Dynamic cone penetrometer measurements

The raw data were interpreted and plotted to reveal the soil strength as a function of depth in terms of CBR. Figures 18 through 23 are representative plots of the DCP results from six of the seven test section subgrades. Plots produced from additional DCP measurements exhibited the general shape and features of the ones included in this report. The bold vertical blue line on each of these plots indicates the average CBR for data shown. In some cases, the entire depth is approximately the same strength, but in others the strength increases beyond the depth of the prepared material. Field CBR tests were conducted in section SM-4 due to the inability of the DCP to yield accurate results in CH material; therefore this data is not included in this report.


Figure 18. Typical DCP result for the SS-1 test section SP subgrade.

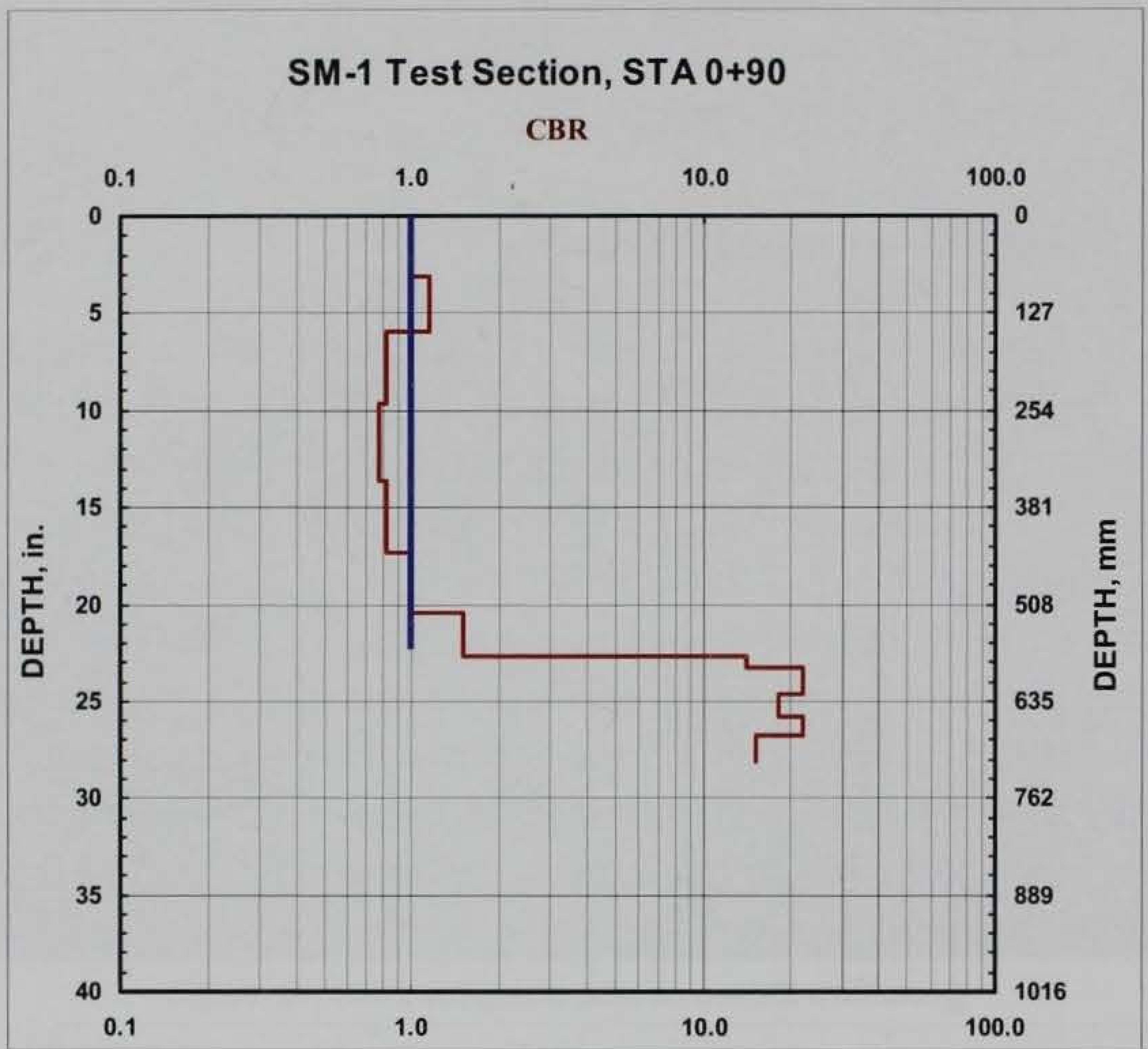


Figure 19. Typical DCP result for the SM-1 test section ML-CL subgrade.

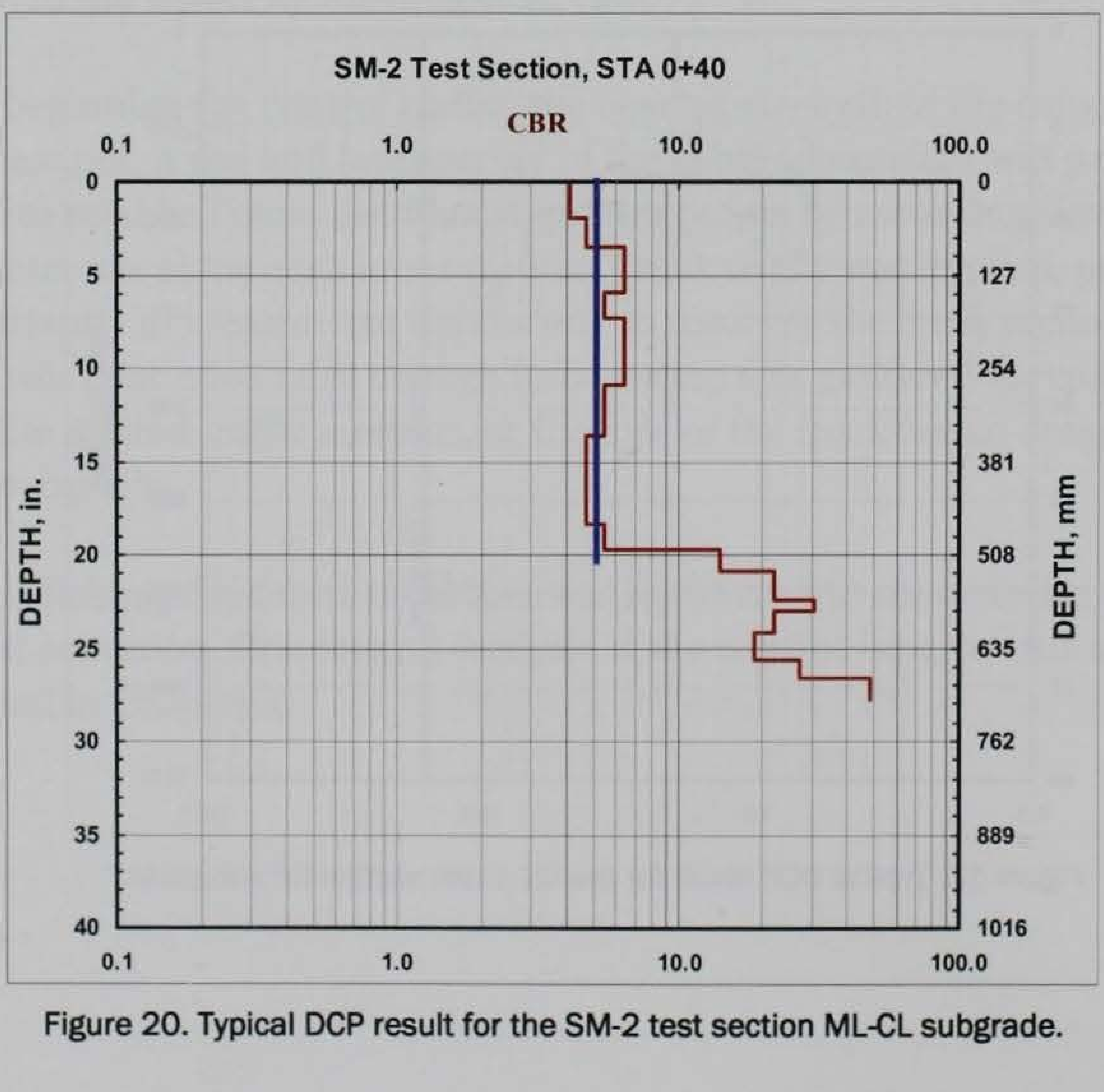


Figure 20. Typical DCP result for the SM-2 test section ML-CL subgrade.

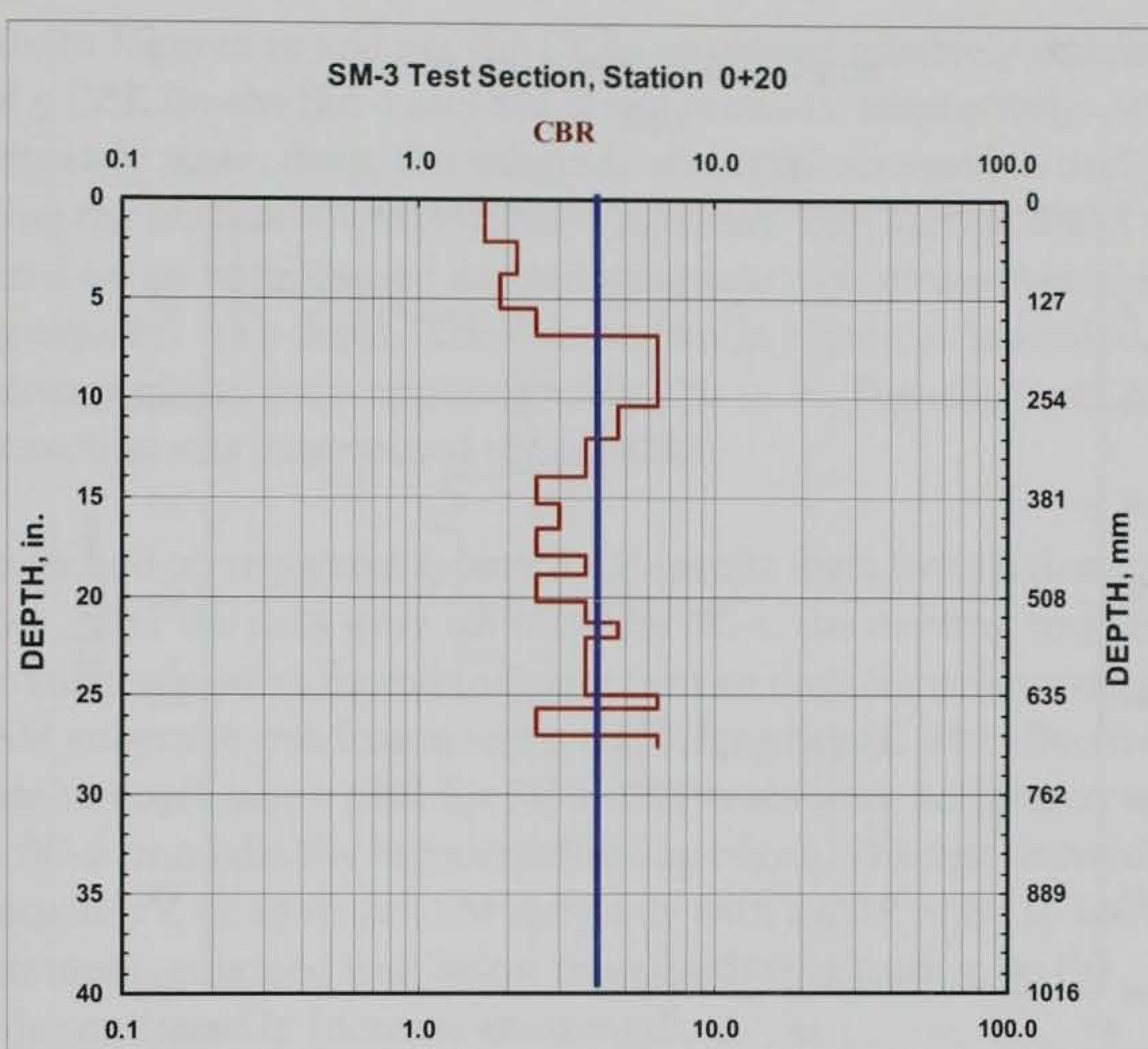


Figure 21. Typical DCP result for the SM-3 test section ML-CL subgrade.

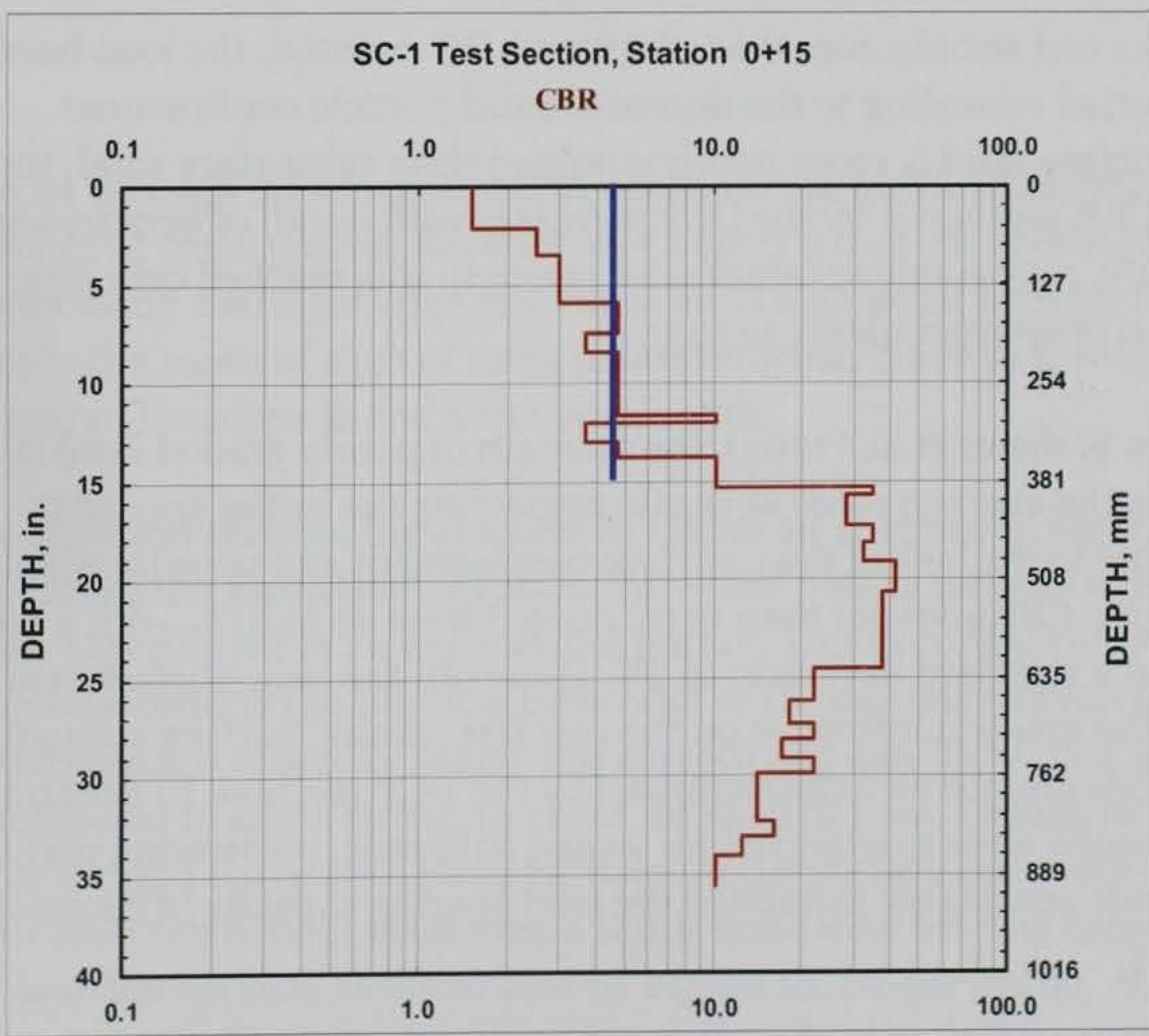


Figure 22. Typical DCP result for the SC-1 test section SM subgrade.

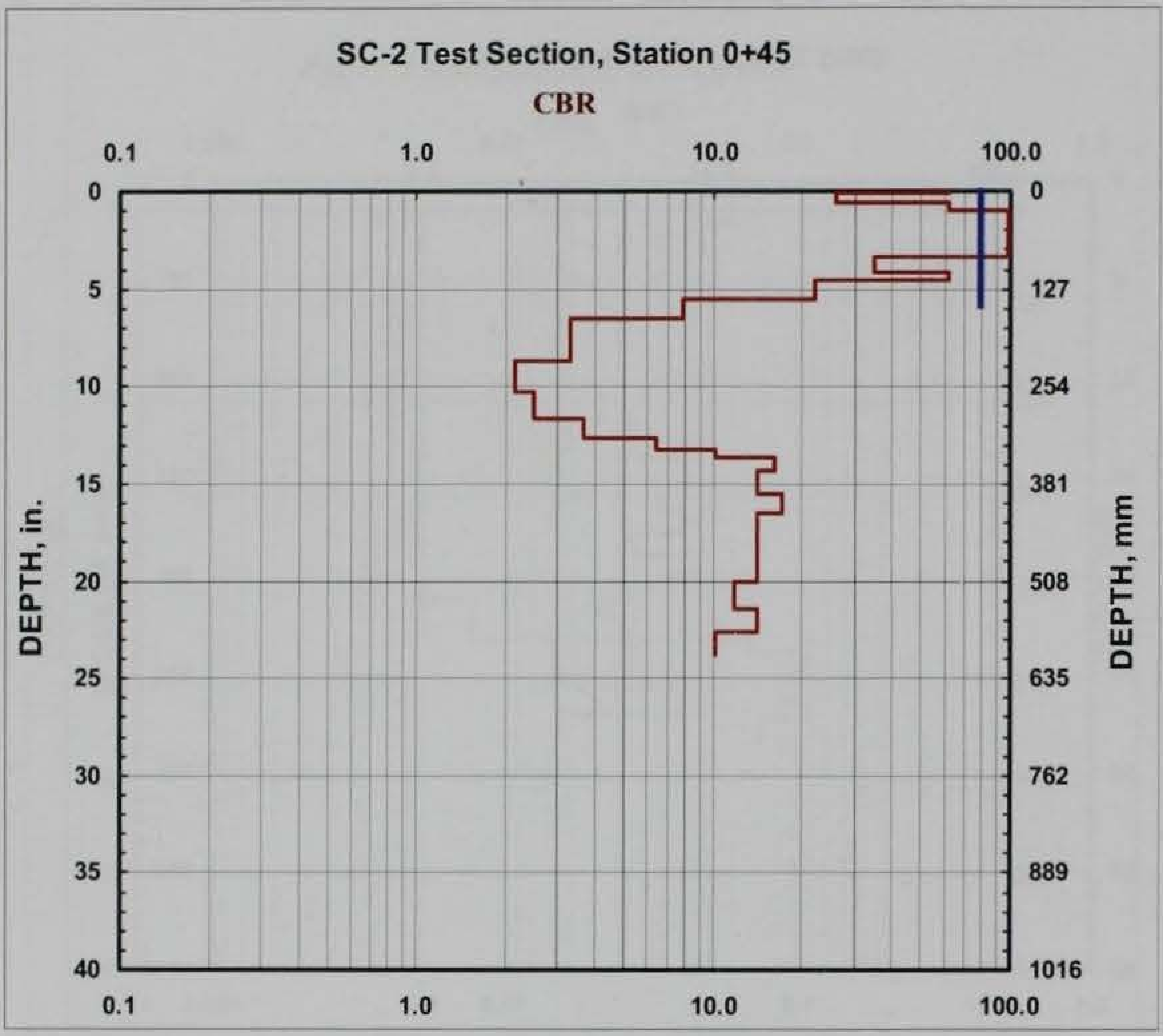


Figure 23. Typical DCP results for the SC-2 test section SM subgrade.

For the SS-1 test section constructed from an SP material, the load bearing capacity varied according to the degree of sand particle confinement. Because surface sand is more poorly confined than subsurface sand, the apparent CBR measured by the DCP increases with depth of penetration. In this study, reasonably constant sand strength was reached only after penetration of approximately 12 to 15 in.

As noted in Webster et al. (1992), the strength of poorly graded sand is reported as the average value at depth, neglecting the initial apparent build-up due to the lack of near-surface confinement and poor inherent soil cohesion. CBRs deeper than 15 in. ranged from 10 to 21%, with a mean of 15%, and a standard deviation of 3%. However, the near-surface sand exercised the greatest influence on the mat test results. Surface strengths of sandy soils are not well characterized by the DCP method. In general, the DCP results were as expected for a sand subgrade, confirming that the test subgrade acceptably simulated the load bearing capacity of common beach sand.

For the SM-1, SM-2, and SM-3 test sections constructed from a ML-CL material, the DCP results appear to be reasonable indicators of the bearing strength. In Figures 19 and 20, the CBRs remained relatively consistent at 1 and 5 CBR for the SM-1 and SM-2 test sections, respectively. After approximately 20 in. deep, the subgrade strength increased to 20 CBR, indicating the bottom of the processed material. Test section SM-3 was conducted on an unprocessed natural subgrade with greater variability in bearing capacity with depth. The data shown in Figure 21 indicated there was a stronger layer from approximately 7 to 14 in. The effective CBR of the test section was determined to be 5 CBR.

Figures 22 and 23 represent typical DCP results from test sections SC-1 and SC-2. After the data were collected for SC-1, the matting was installed, and the subgrade was allowed to freeze for two days. Approximately 2 in. of the SM subgrade was frozen when trafficking began. The effective subgrade strength was 5 CBR for SC-1. DCP tests were performed on section SC-2 immediately before trafficking began. The test showed approximately 6 in. of frozen SM subgrade with a CBR of 80 to 100%. Temperatures remained well below freezing during testing, so the subgrade continued to increase in strength.

A summary of average subgrade CBR values is presented in Table 2 above.

## Rut depths

Figures 24 through 30 are plots of rut depth versus traffic level defined by the number of truck passes. Recall from Chapter 3 that rut depths were measured using a straight edge and ruler. Each data point in these figures represents the mean of a set of three measurements, taken at the three quarter point locations in the north wheel path.

For the sand test section, the abscissa in Figure 24 is scaled in logarithmic space because the formation of ruts in the wheel path is initially rapid, gradually tapering off in an exponential nature. This observed rut development pattern reflects the physical behaviors of the materials involved. Sand particles are generally round and smooth and can "flow" in a sense when subjected to shear stress. In order for sand to flow, a space must be available for it to move into. Sand particles at the surface can move laterally with little restriction; therefore, a sandy soil's load bearing capacity is lowest near the surface, as illustrated by Figure 18. Under traffic, ruts form as the surface sand is shifted to the sides of the wheel path. The surface sand is displaced, and the load is applied to deeper sand. Because the space around the deeper sand is occupied by other sand, deeper sand is

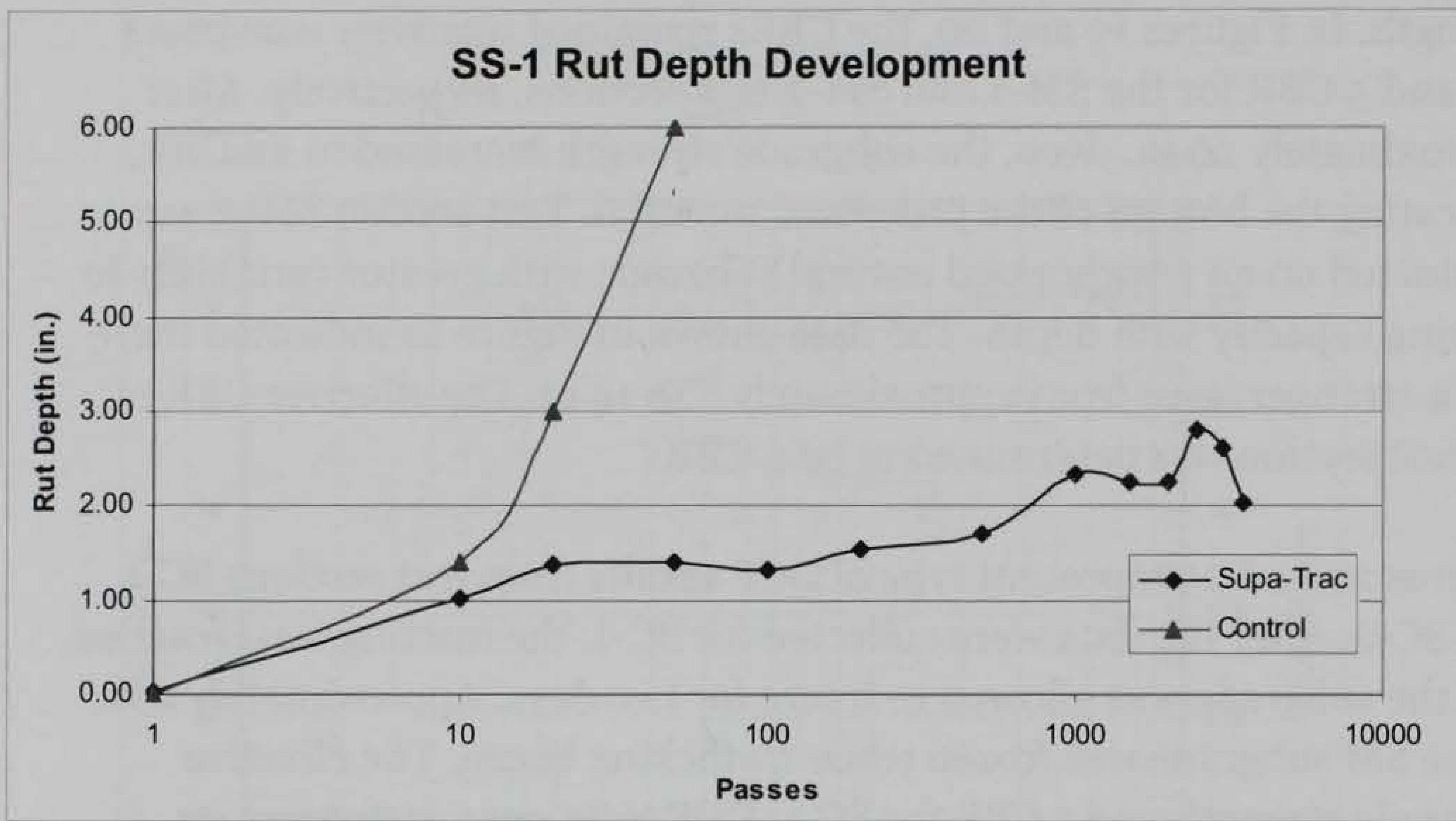


Figure 24. SS-1 rut development in log scale.

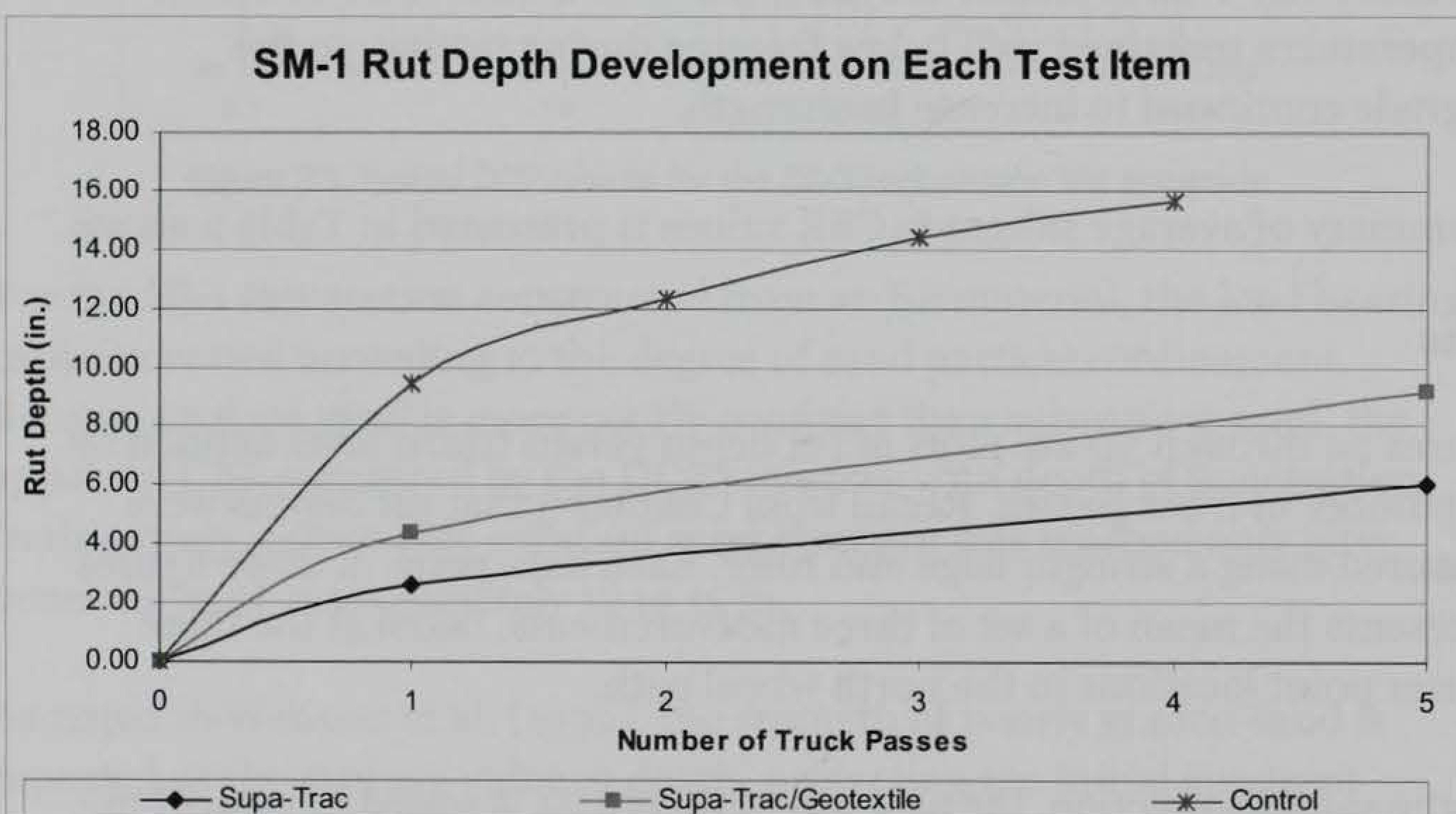


Figure 25. SM-1 rut development on each test item.

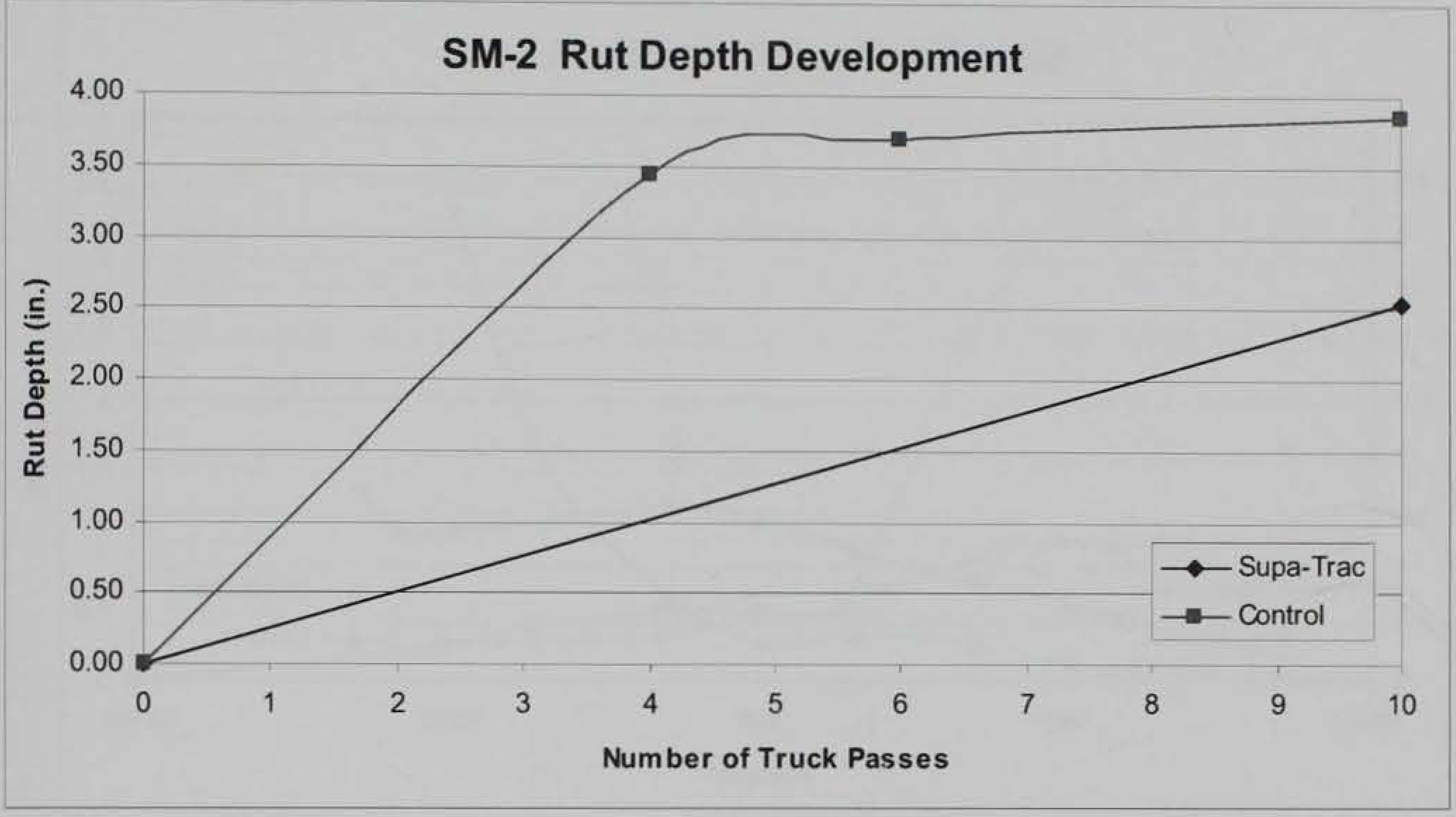


Figure 26. SM-2 rut development.

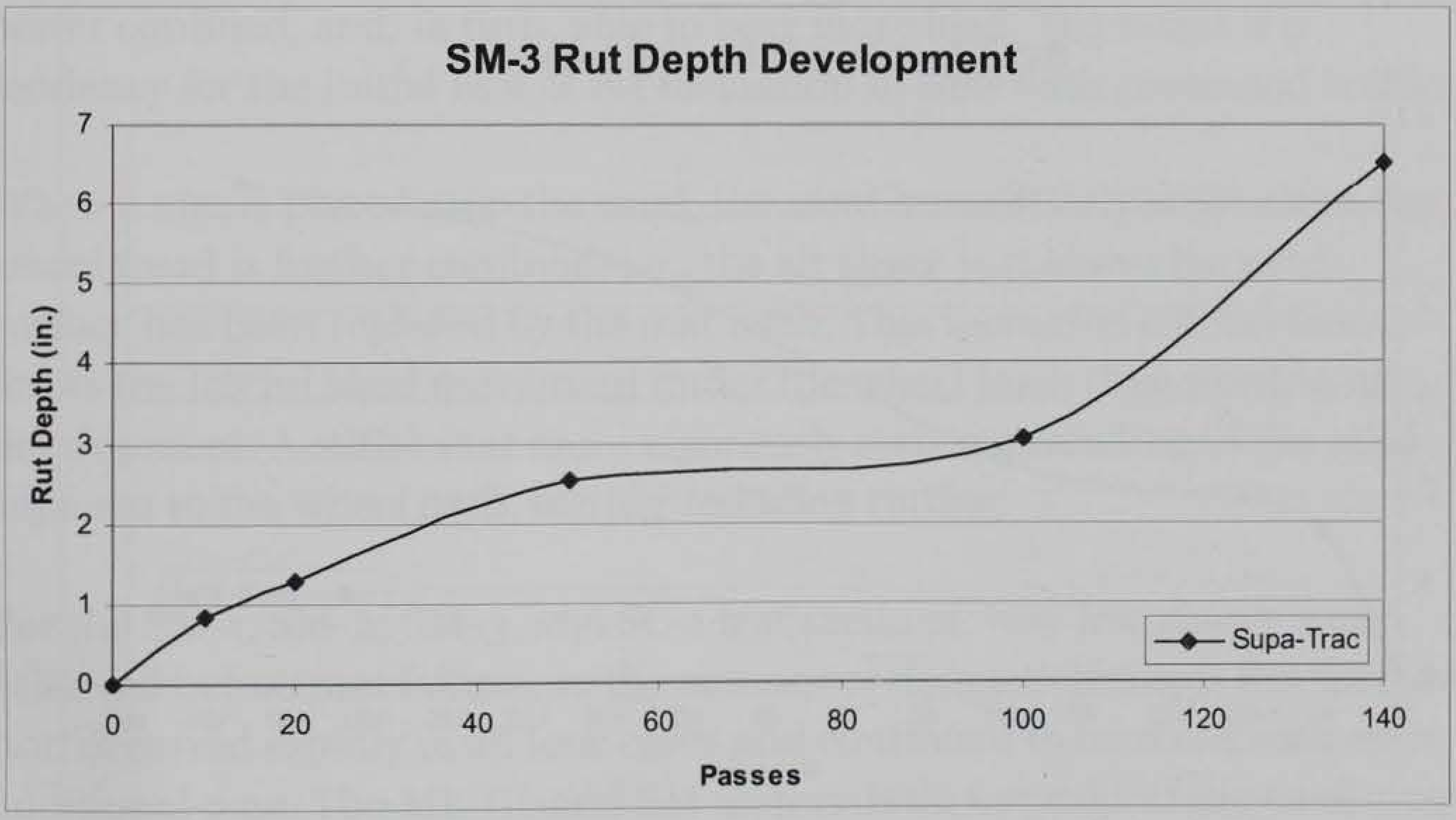


Figure 27. SM-3 rut development.

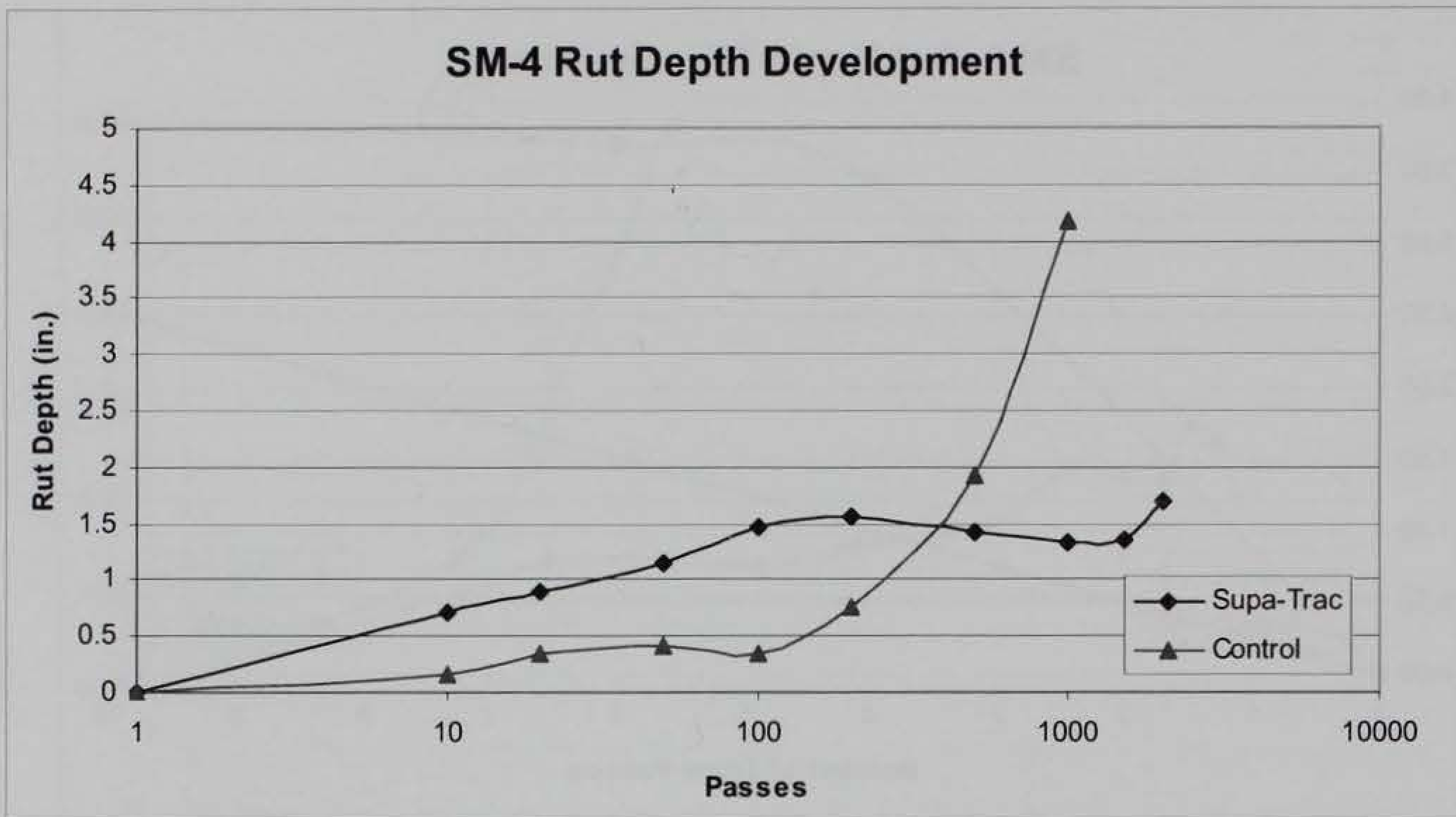


Figure 28. SM-4 rut development in log scale.

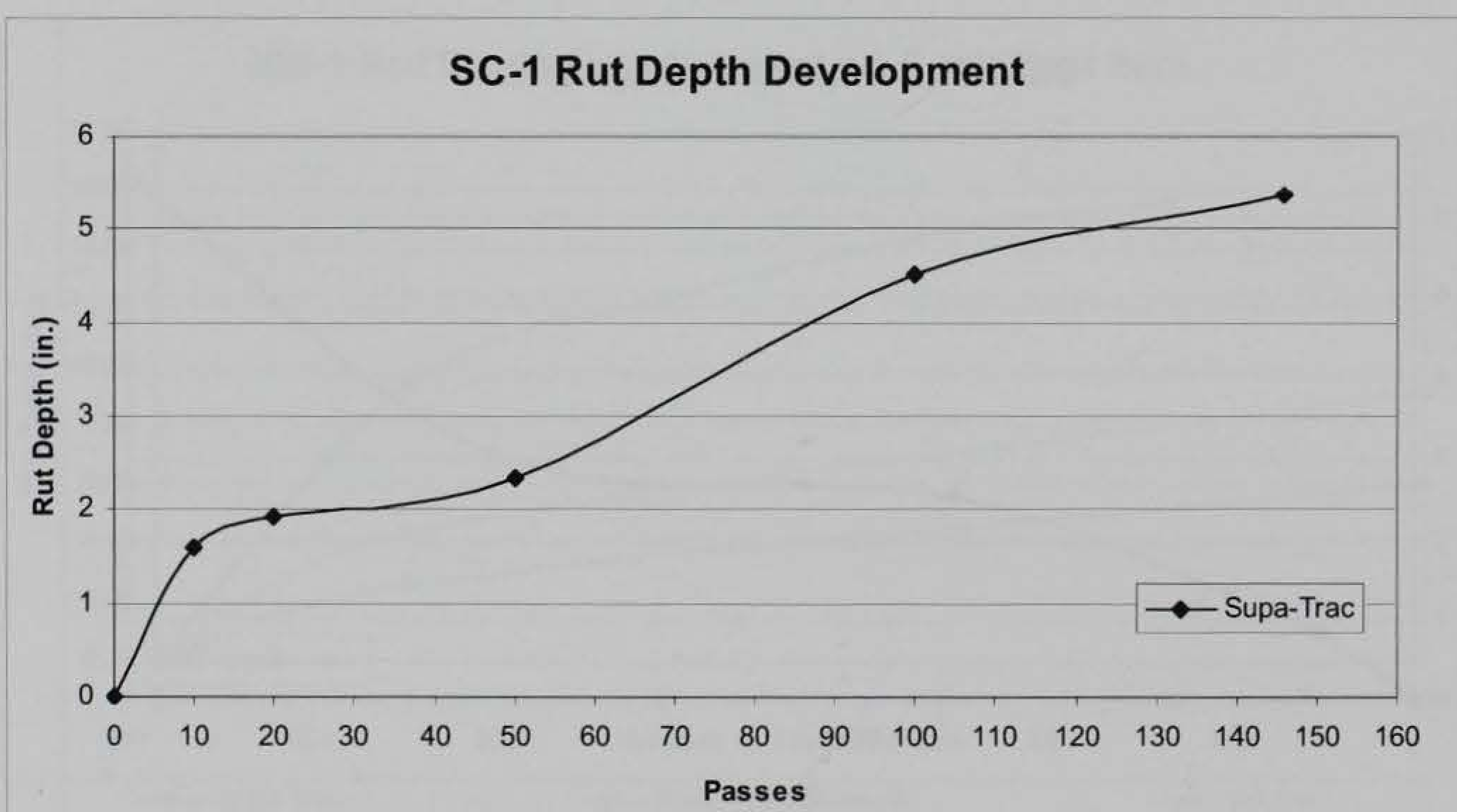


Figure 29. SC-1 rut development.

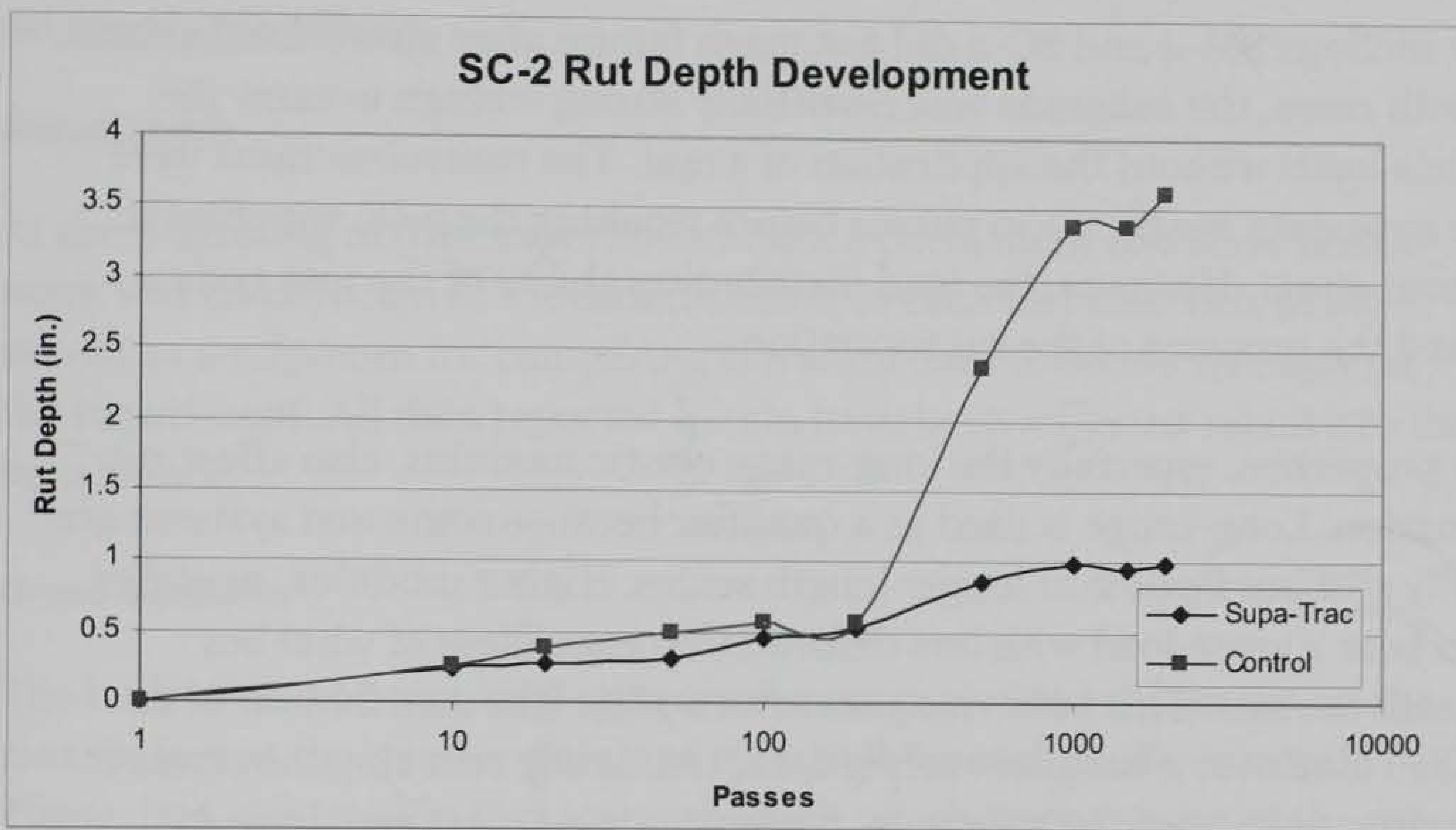


Figure 30. SC-2 rut development in log scale.

better confined, and, in turn, able to bear more load. The result is a tendency for the initial rate of rut formation to slow with continued traffic.

When a mat is placed atop the sand, the sand immediately adjacent to the wheel tread is further confined, i.e., the air space just above the sand surface has been replaced by the mat itself. This increased confinement limits the lateral sand movement under the wheel load, thus slowing rut development. A stiffer mat more vigorously resists mounding of the sand adjacent to the wheel path, further reducing rutting.

For the SM-1, SM-2, SM-3, and SC-1 test sections, very few passes were achieved before mat failure, so the amount of data was limited. Rut formation occurred rapidly in all four cases and continued to increase with each additional pass. The ML-CL and SM materials do not exhibit the confining effects of granular materials such as sand. Due to the limited bearing strength of the materials, the failure was most likely due to both compaction of the particles and shear failure. Compaction is simply the removal of air voids in the material by applying a vertical load. Shear failure is characterized by the outward and upward movement of material underneath the wheel path of the test vehicle. This particle movement causes upheaval between the two wheel paths and outside each wheel path. This type of behavior was noted in all four of these tests.

Test sections SM-4 and SC-2 did not reach failure after 2,000 truck passes. In both cases, the subgrade was essentially strong enough to carry the vehicle loads without the application of a mat. The control sections were able to sustain nearly 1,000 passes before reaching the 3-in. rut criteria without a mat. However, the load distribution ability of the mat system slowed the progress of the rut formation.

Mat properties, especially the long-range elastic modulus, also affect rut formation. Long-range is used as a qualifier because some mat systems are locally stiff but flexible at longer length scales. Higher modulus, or stiffer, mats bear a given load with less deformation regardless of what lies beneath the mat. This behavior generates a plate-like distribution of an applied load over a broader surface area, ultimately reducing the stress in the upper portion of the subgrade. Lower modulus mats may have to deform or rut much more before they reach the same load bearing capacity.

Rut depth data were normalized relative to pre-traffic data so that each curve in Figures 24 and 30 terminates at the origin in linear space, i.e., zero depth at zero passes. Because the origin cannot be shown on a semi-logarithmic plot, the curves in Figures 24, 28, and 30 have been artificially forced to terminate at the coordinate (1,0) to aid visualization (i.e., pass number 0 was changed to pass number 1). The curves are observed to be closely linear, indicating that rut formation was indeed a nearly exponential occurrence.

Overall, the mat and subgrade properties worked cooperatively to increase the ability to support the traffic load, although only test sections SS-1, SM-4, an SC-2 achieved desirable results. Figures 24 through 30 reveal some clear trends in reduction in the rate of rut formation. The poorest performance was realized when the subgrade was left unprotected as in the control experiments.

Note that in addition to stiffness, a high-performing mat must be durable enough to resist breakage. Also, for some materials (especially thermoplastics such as HDPE), stiffness is a function of temperature.

## Rod and level elevations

### Benchmark

At the beginning of field experimentation, a permanent elevation benchmark was constructed at a location central to each test site. This point served as a reference for comparing elevation data collected throughout the experiment. All data reported herein have been adjusted relative to the benchmark.

### Cross sections

The bulk of the rod and level data are the cross sections measured on the mat surface at the quarter points of each mat for each traffic interval. These data, depicted in Figures 31 through 38, show the shape of the rut development on each test section during trafficking are discussed individually below.

In addition to cross sections measured atop the mat surfaces, cross sections of the subgrades measured after testing and removal of the mats are shown in Figures 39 through 45. Mostly, the trend in rutting correlates to what was observed on the mat surfaces. However, the cross sections under Supa-Trac reveal more severe rutting than was observed on the mat itself. The stiffness of the mat panels kept the mat from being pressed down until it contacted the subgrade, which allowed the mat to bridge across a portion of the rut. The 7-ton truck flexed the mat much more when it traveled across the mat.

### North wheel path profile

Figures 46 through 52 show the overall elevation profiles of the northernmost wheel paths on all seven test sections as determined by rod and level measurements. The profile was first assessed prior to traffic to establish a baseline. The profile survey was repeated at 1,000-pass intervals, or at the conclusion of the test. The data were normalized relative to the pre-traffic profile survey. The normalization shows changes in elevation, not an actual surface profile. Therefore, the plots look more uneven than the actual mat surface during the test.

For sections SS-1, SM-4, and SC-2 shown in Figures 46, 50, and 52, respectively, the Supa-Trac profile remained relatively constant from 1,000 to 2,000 passes. This observation, as expected, reflects the nearly

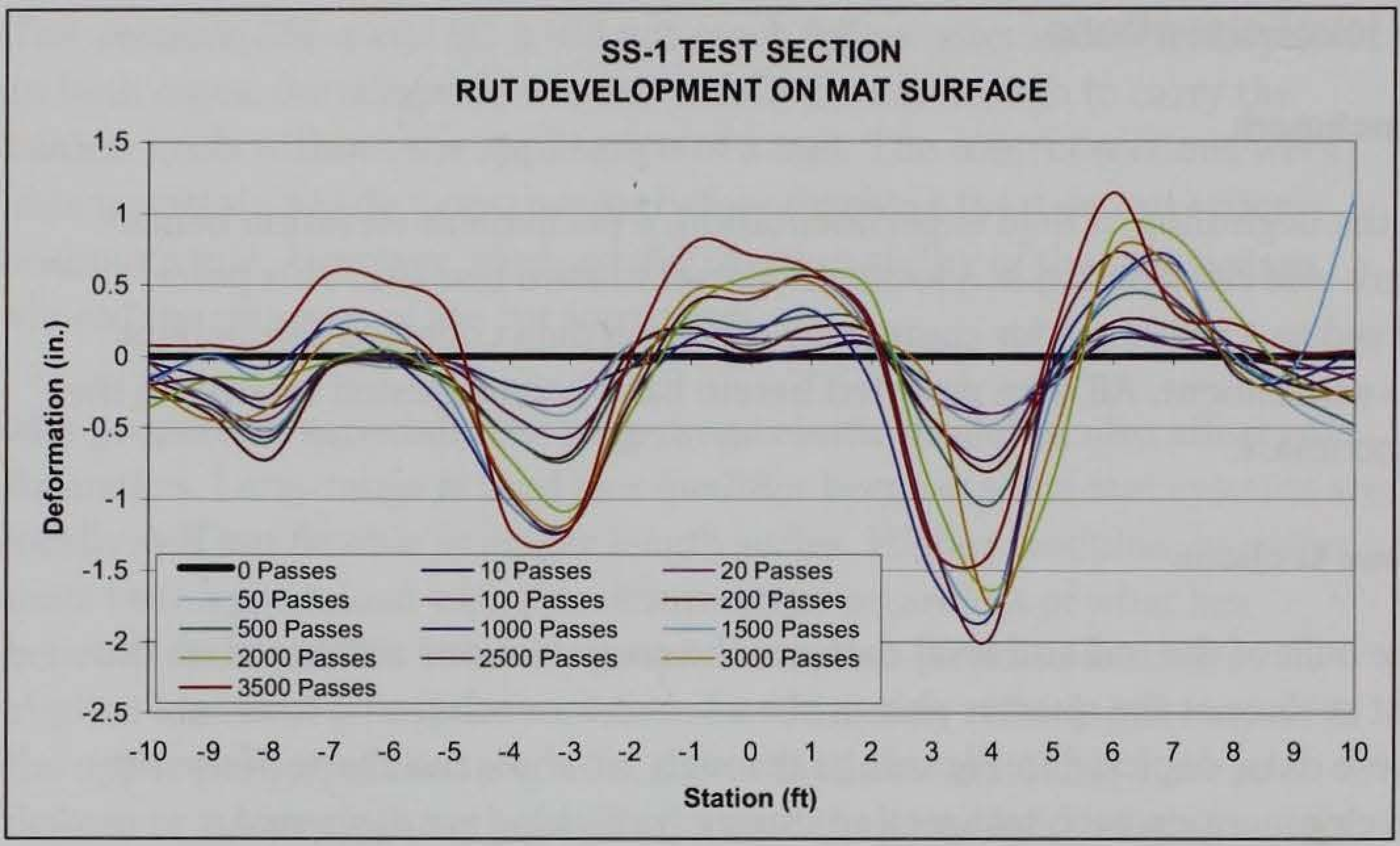


Figure 31. SS-1 cross-section rut development on mat surface.

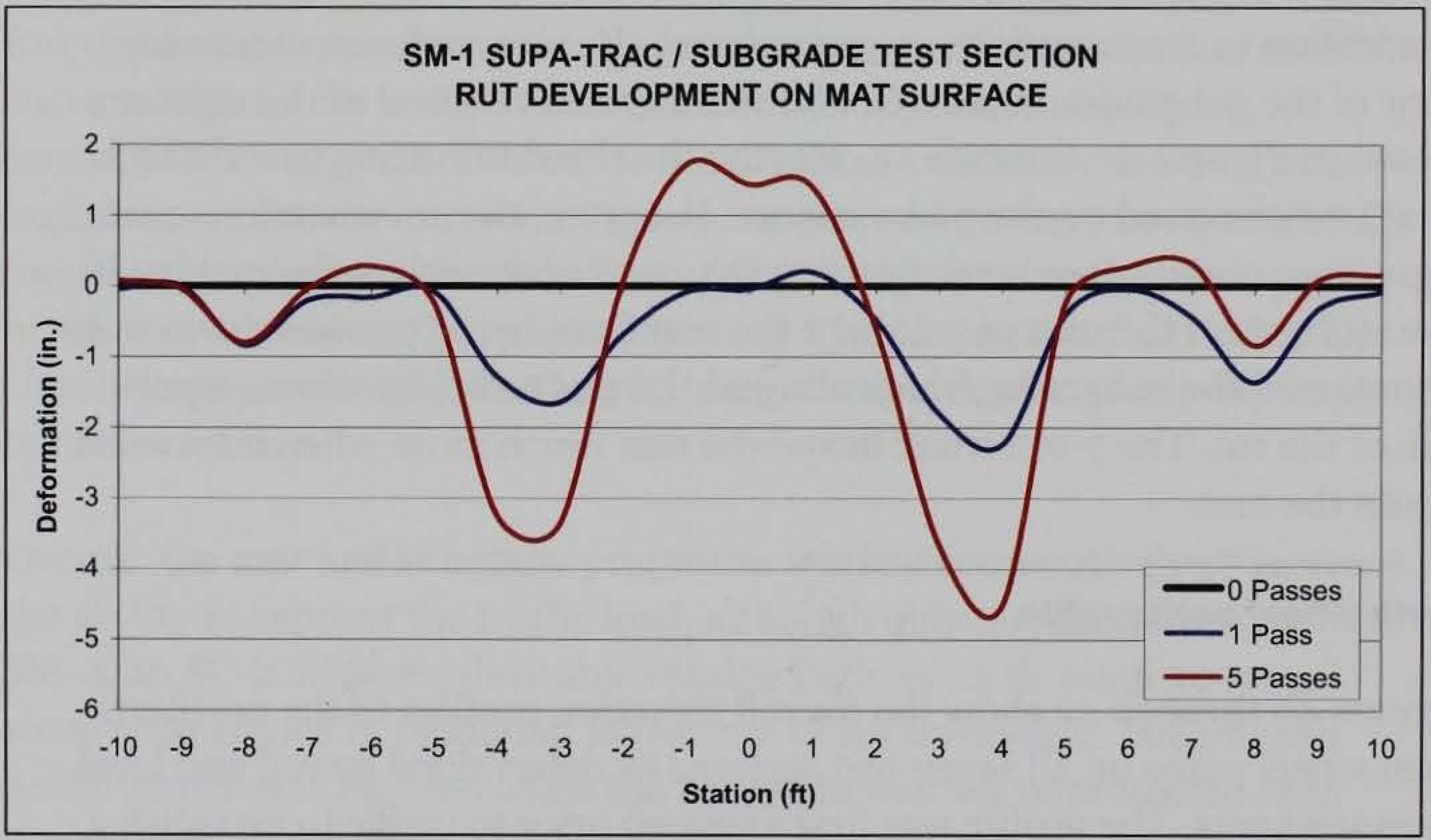


Figure 32. SM-1 cross-section rut development on the Supa-Trac/subgrade test section.

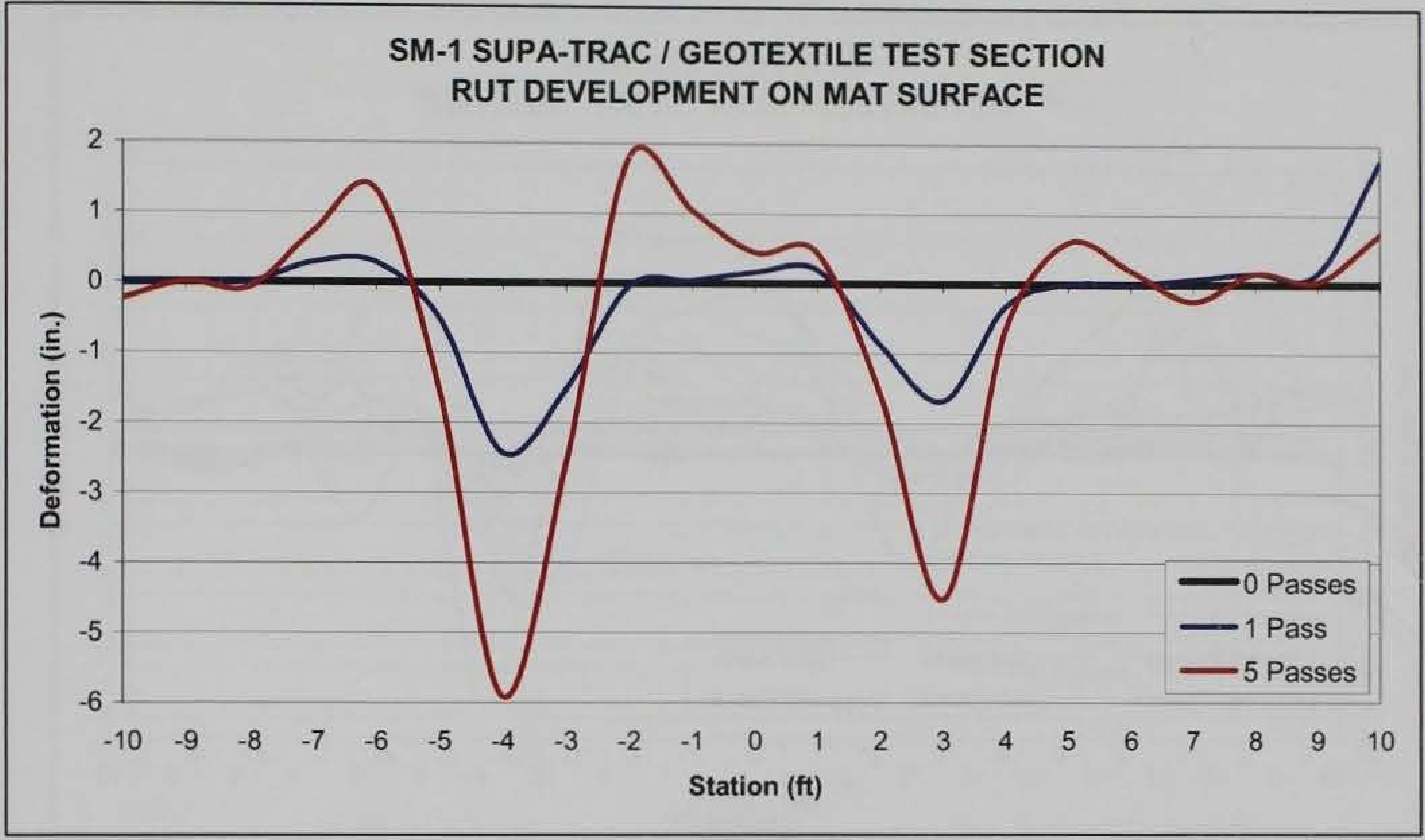


Figure 33. SM-1 cross-section rut development on the Supa-Trac/geotextile test section.

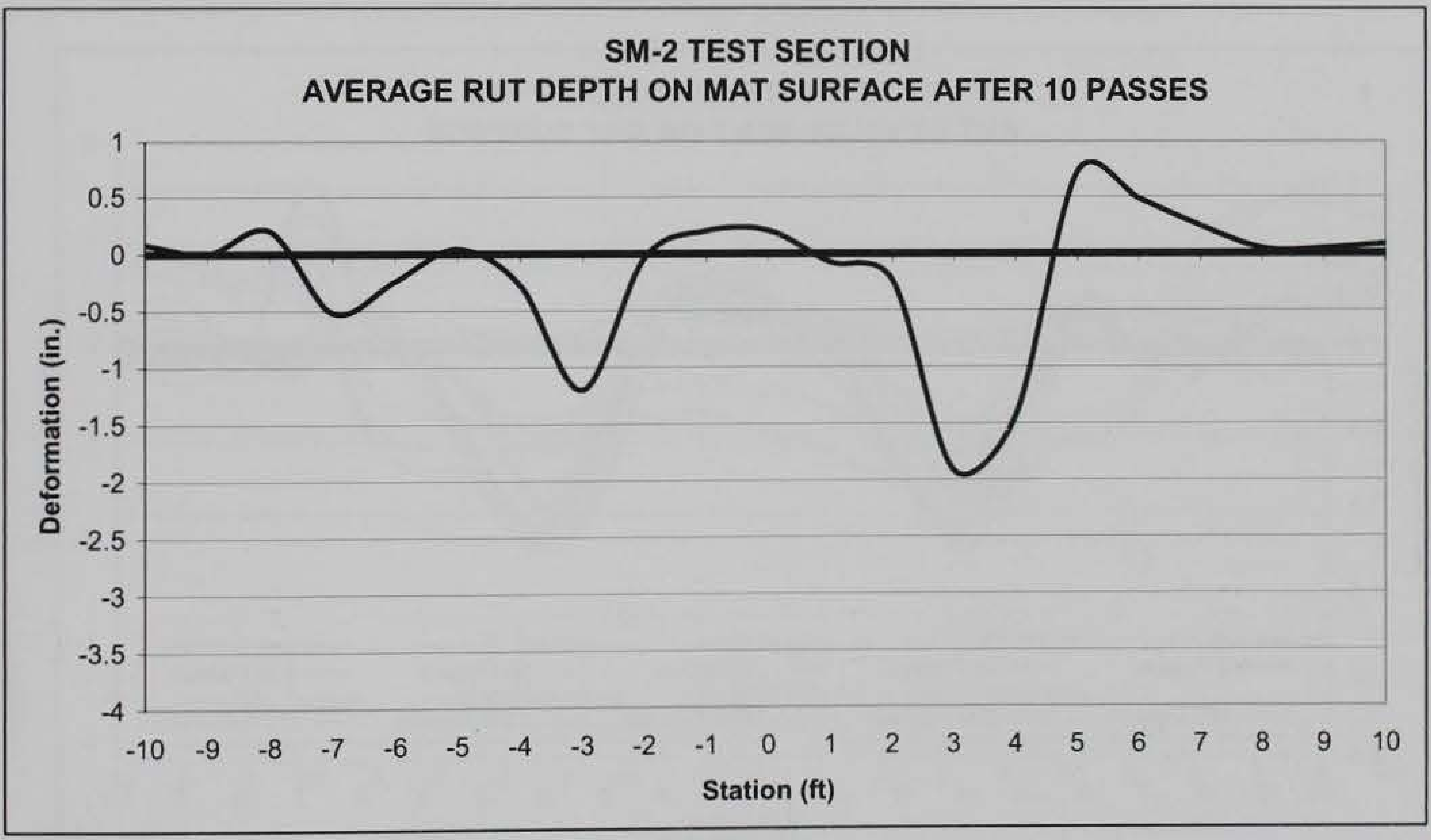


Figure 34. SM-2 cross-section rut development on the mat surface.

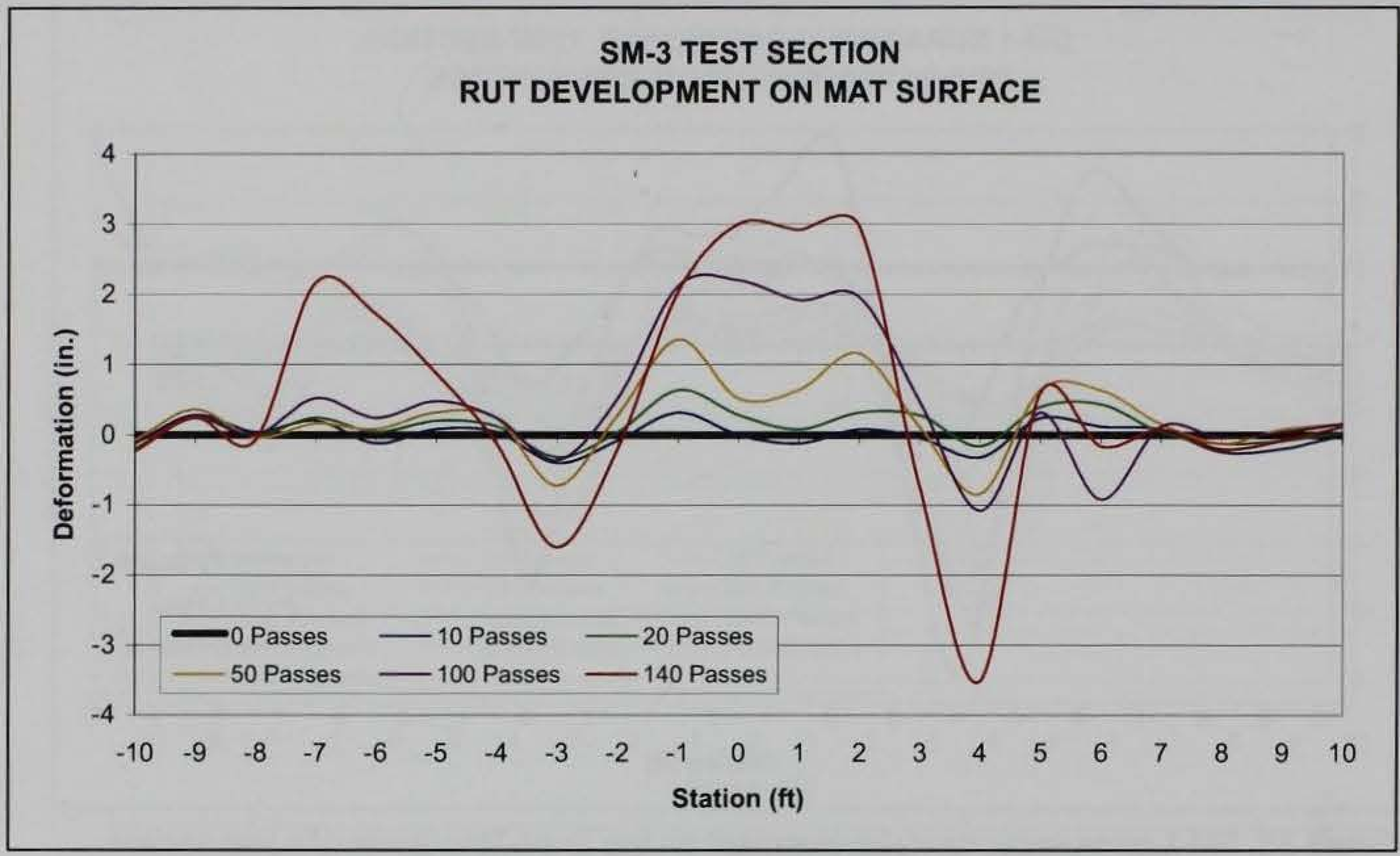


Figure 35. SM-3 cross-section rut development on the mat surface.

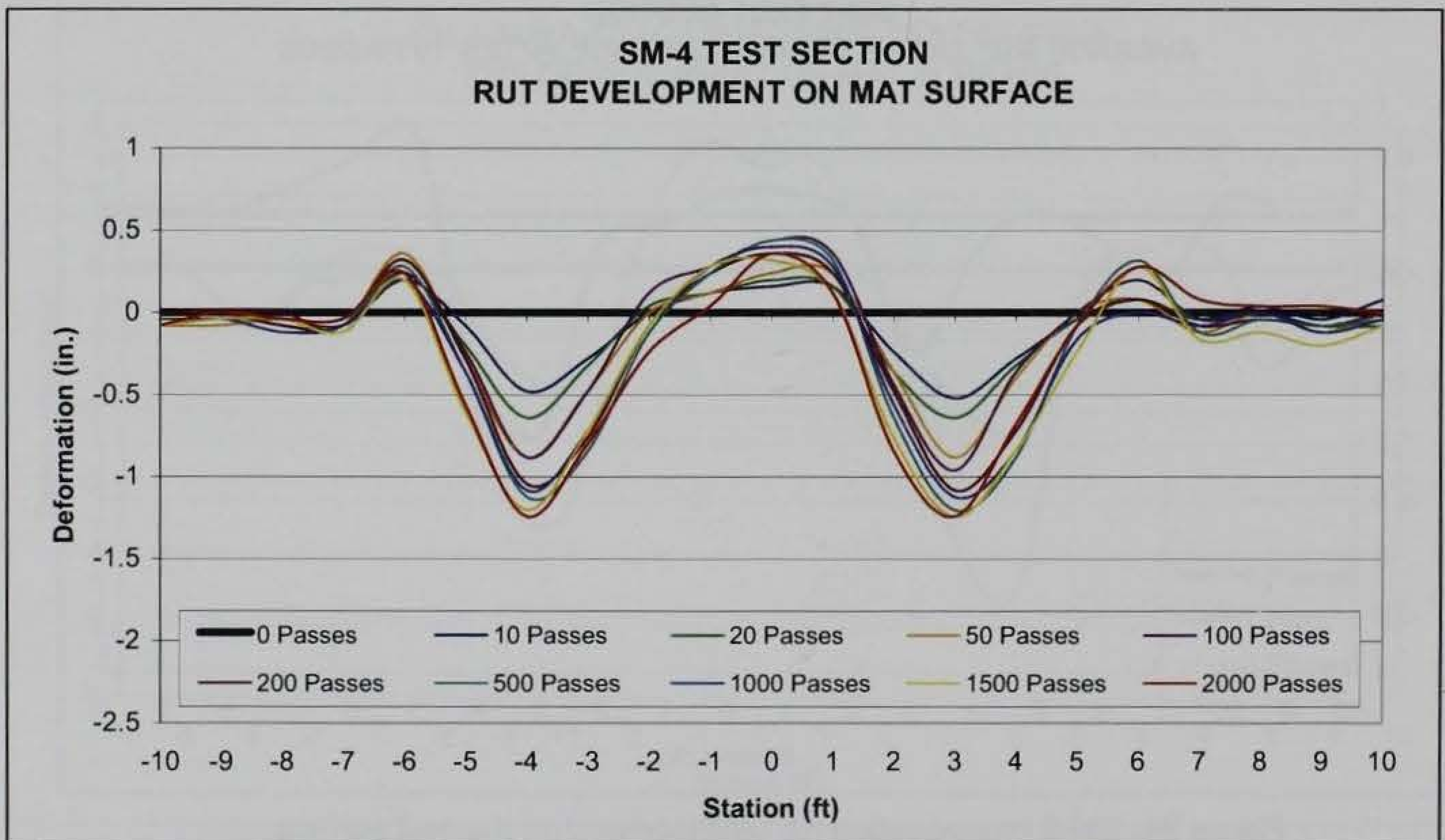


Figure 36. SM-4 cross-section rut development on the mat surface.

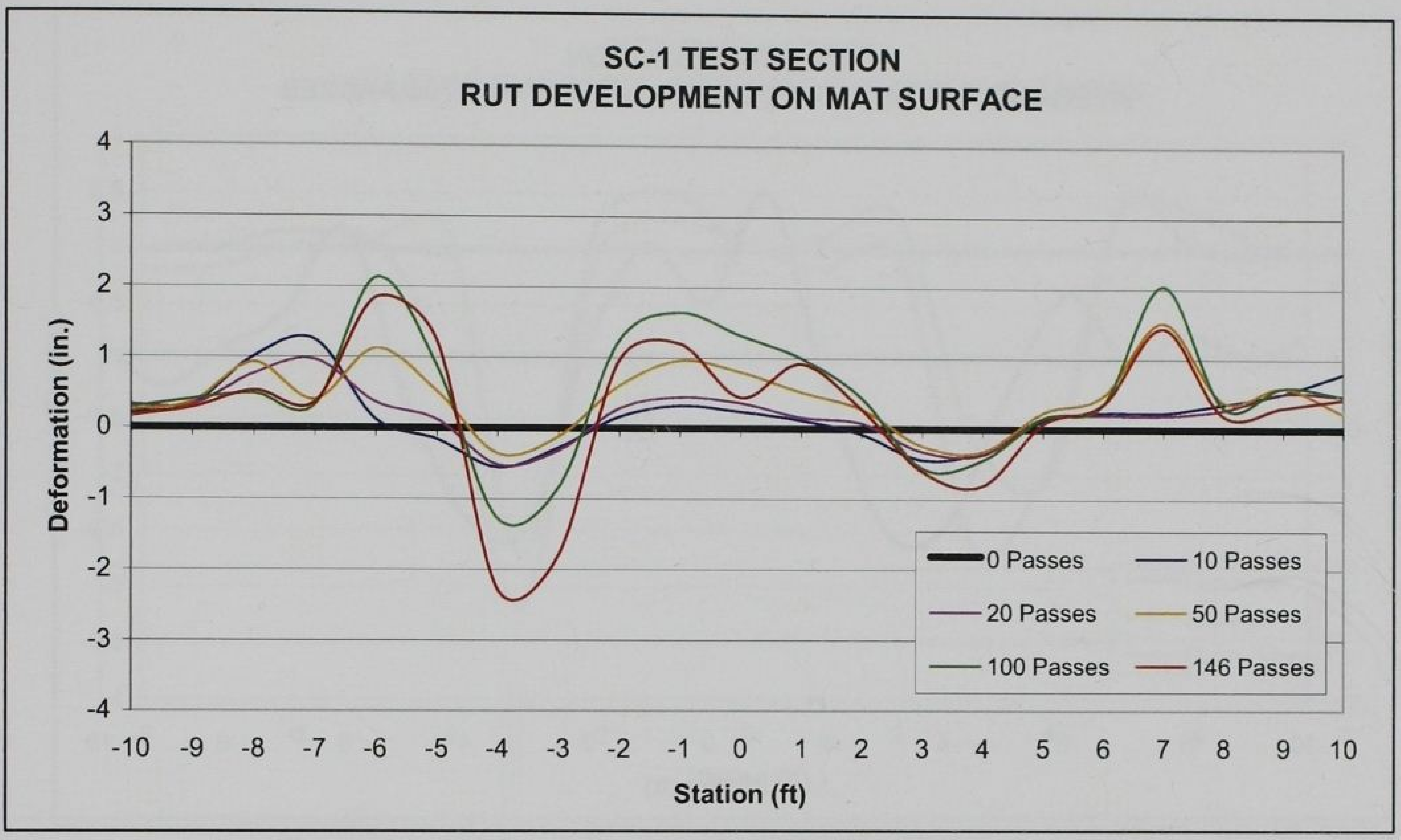


Figure 37. SC-1 cross-section rut development on mat surface.

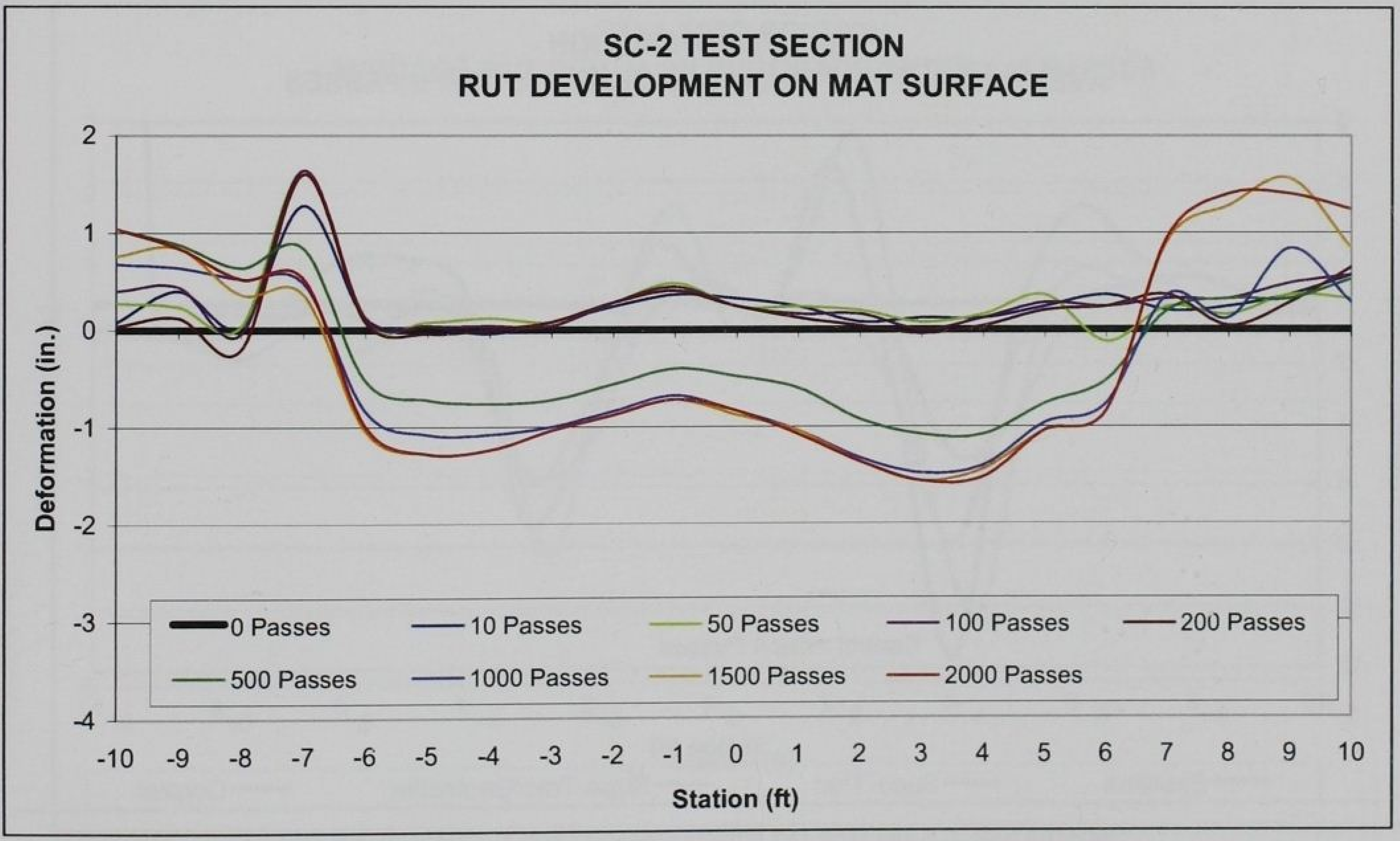


Figure 38. SC-2 cross-section rut development on the mat surface.

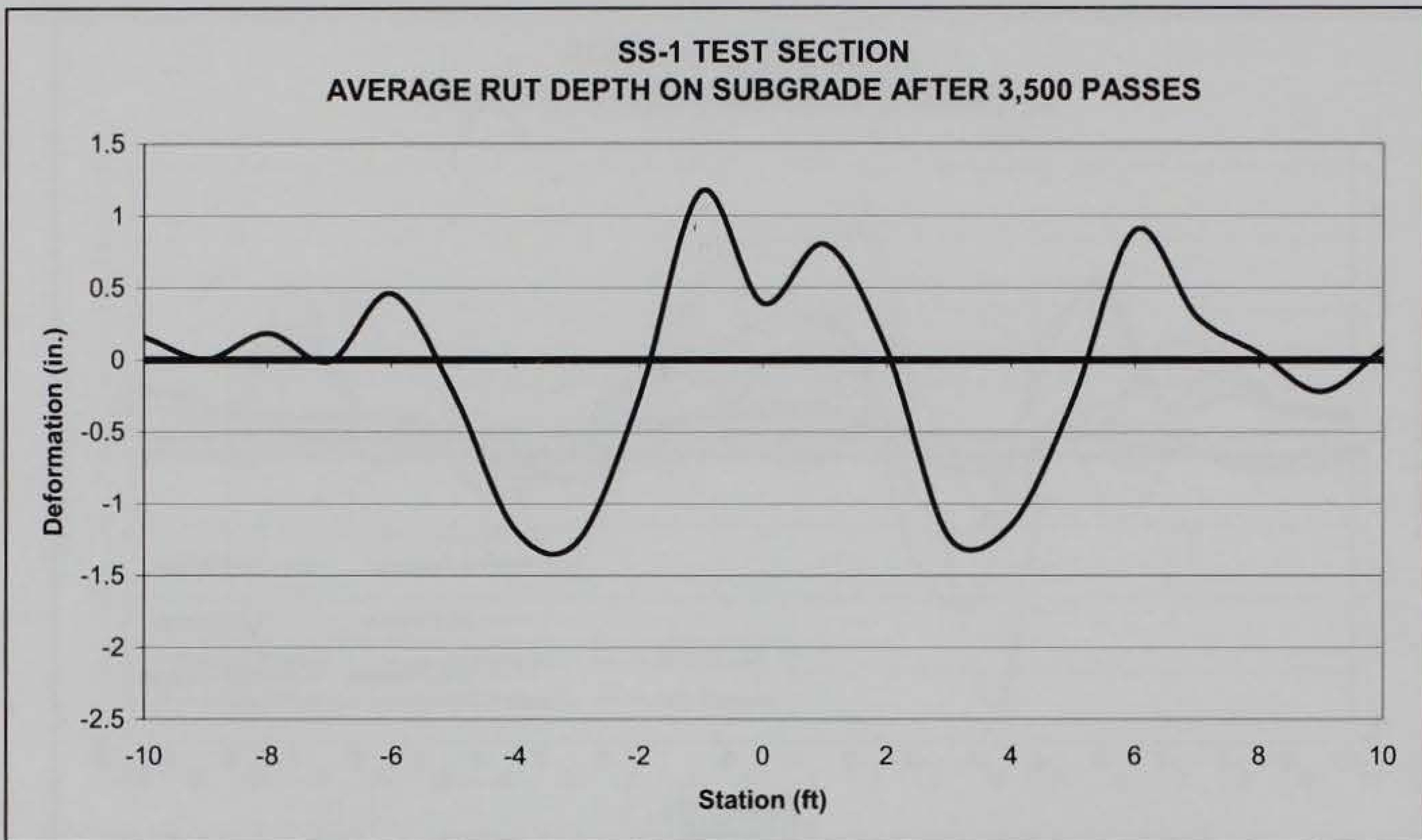


Figure 39. SS-1 rut development on the SP subgrade.

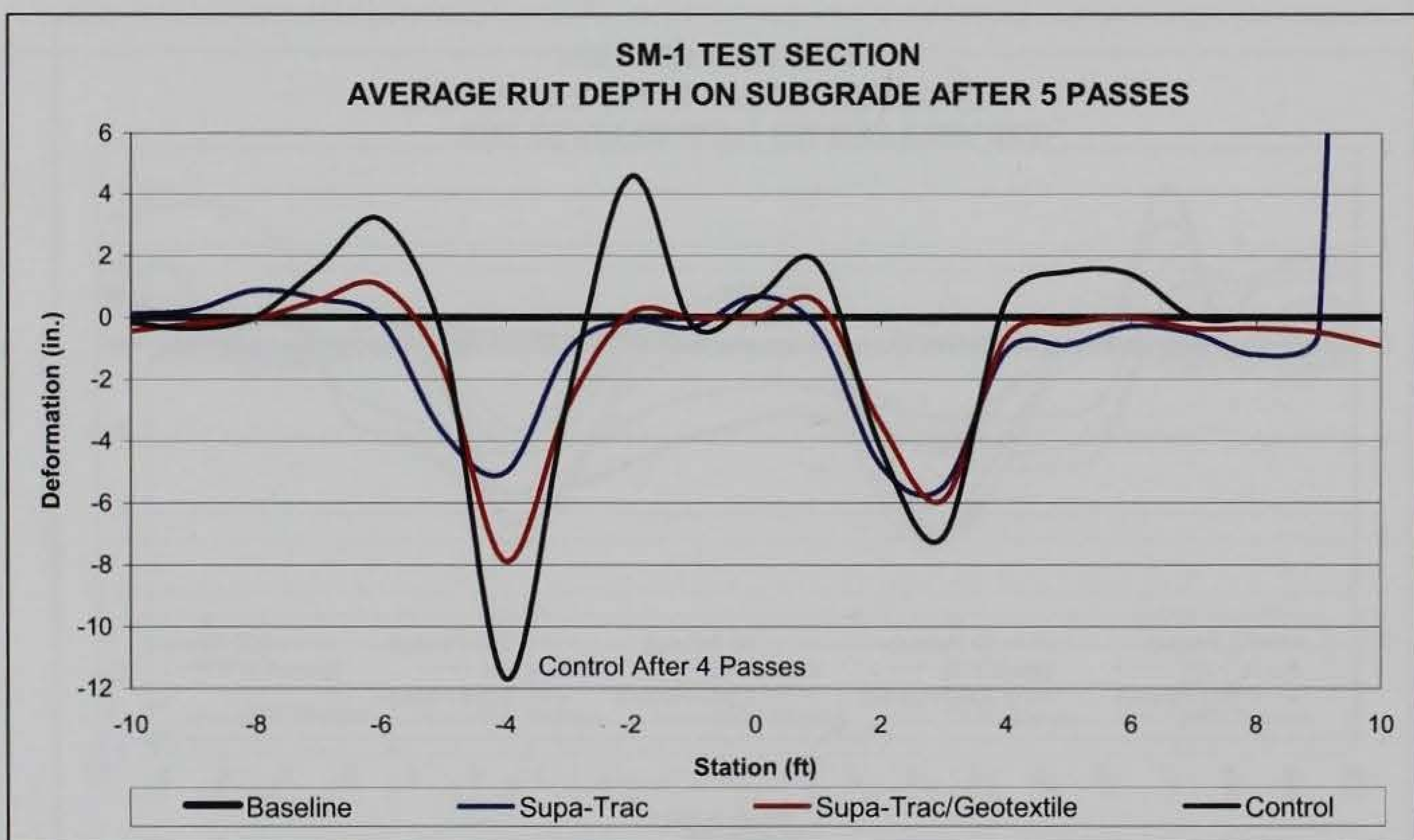


Figure 40. SM-1 rut development on the ML-CL subgrade.

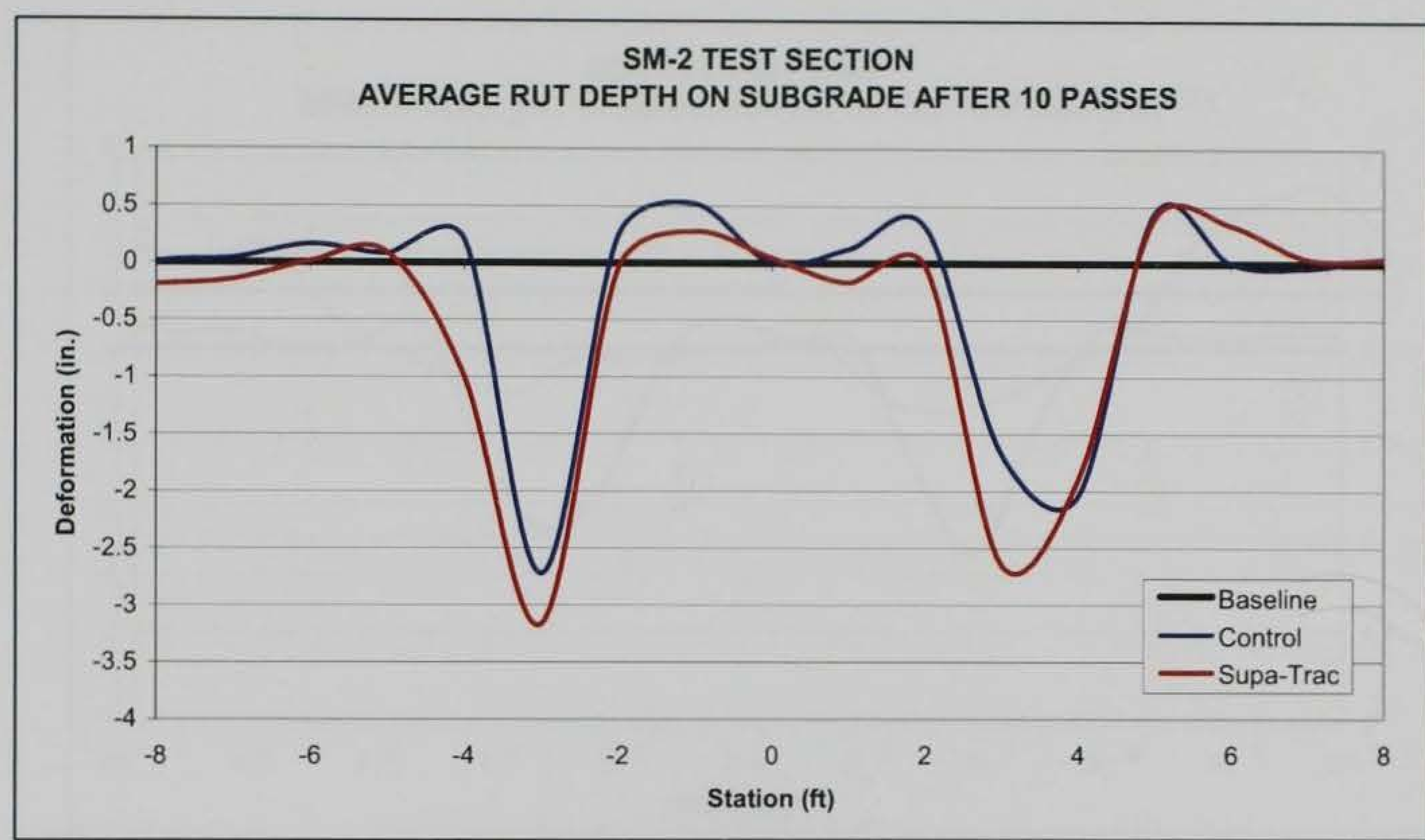


Figure 41. SM-2 rut development on the ML-CL subgrade.

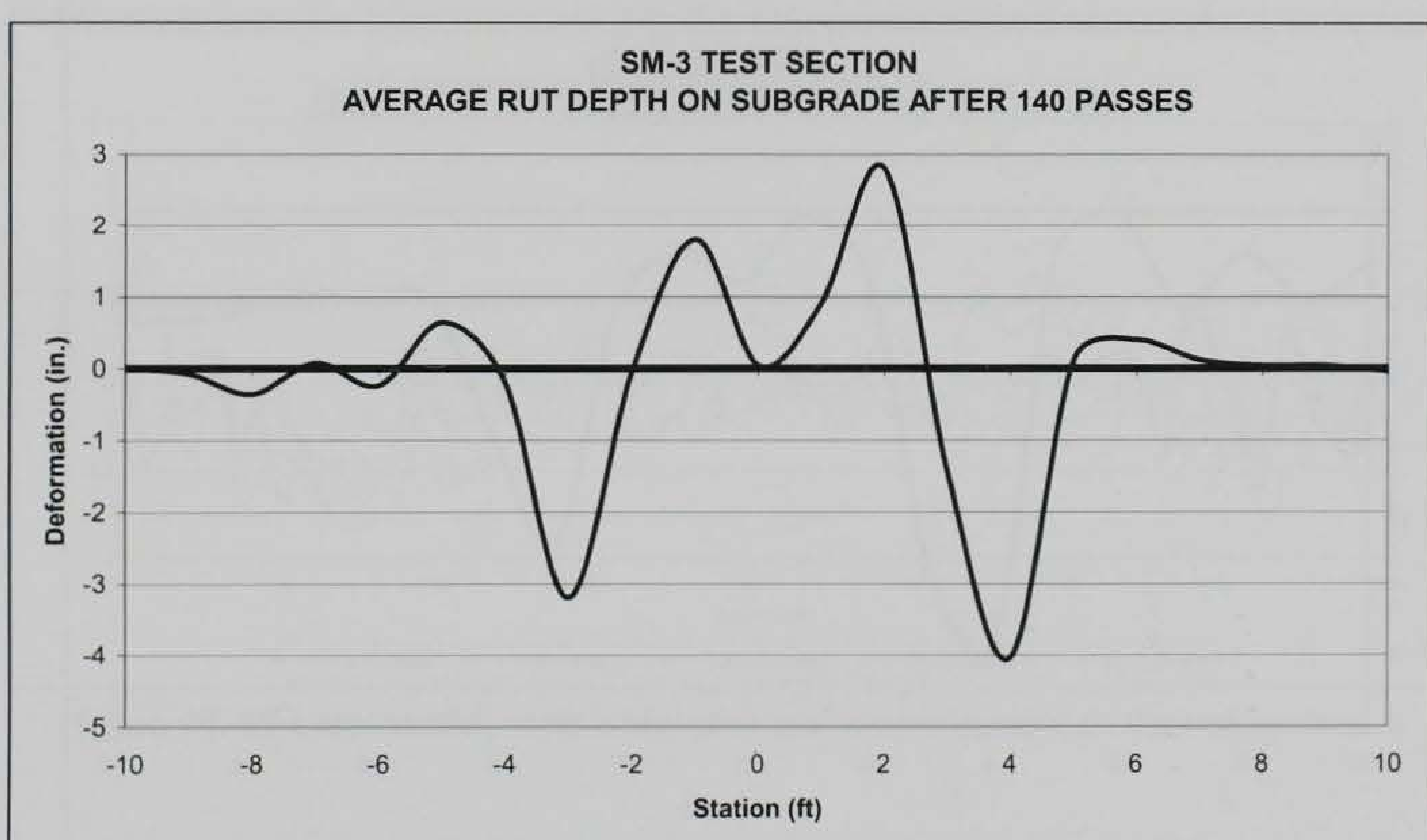


Figure 42. SM-3 rut development on the ML-CL subgrade.

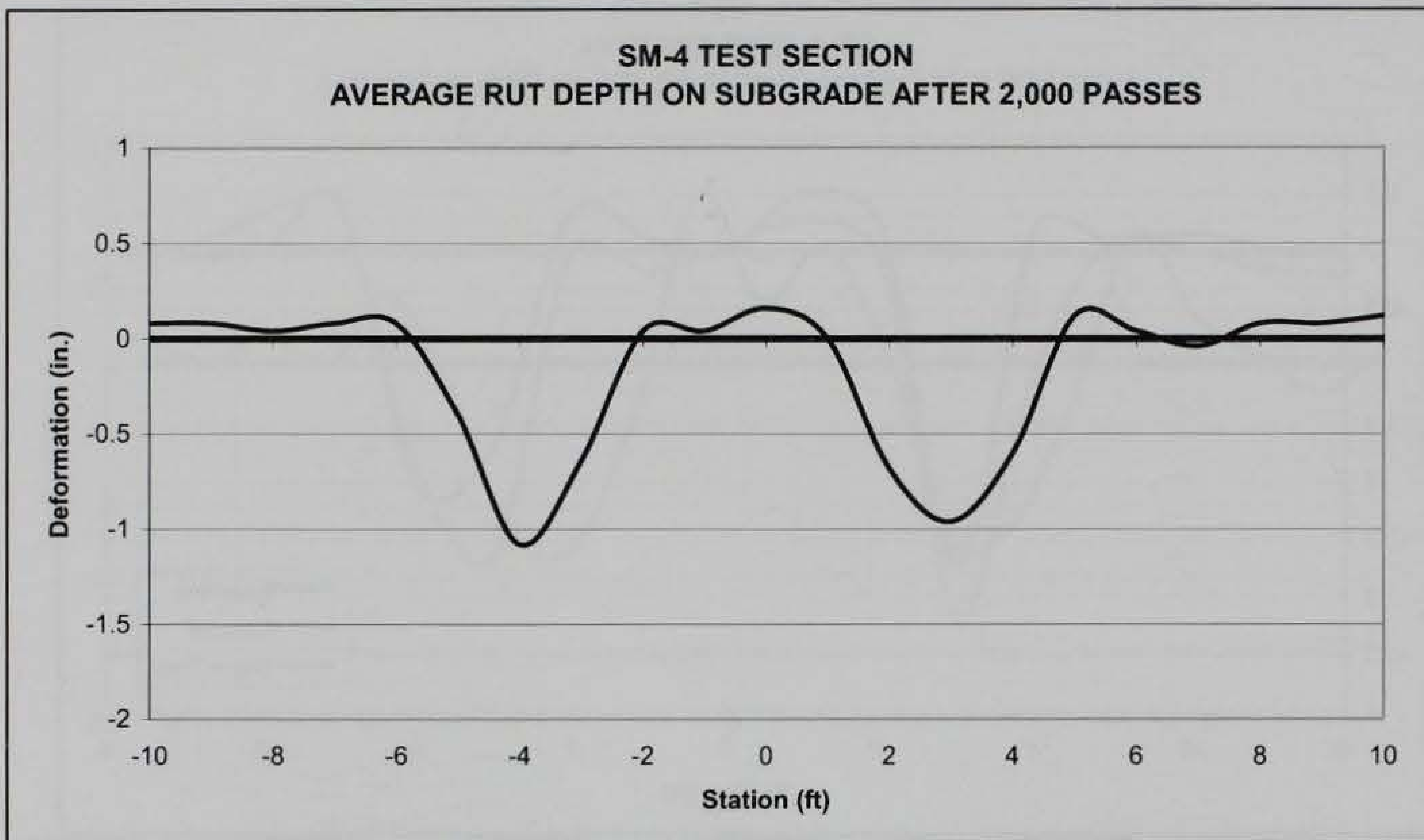


Figure 43. SM-4 rut development on the CH subgrade.

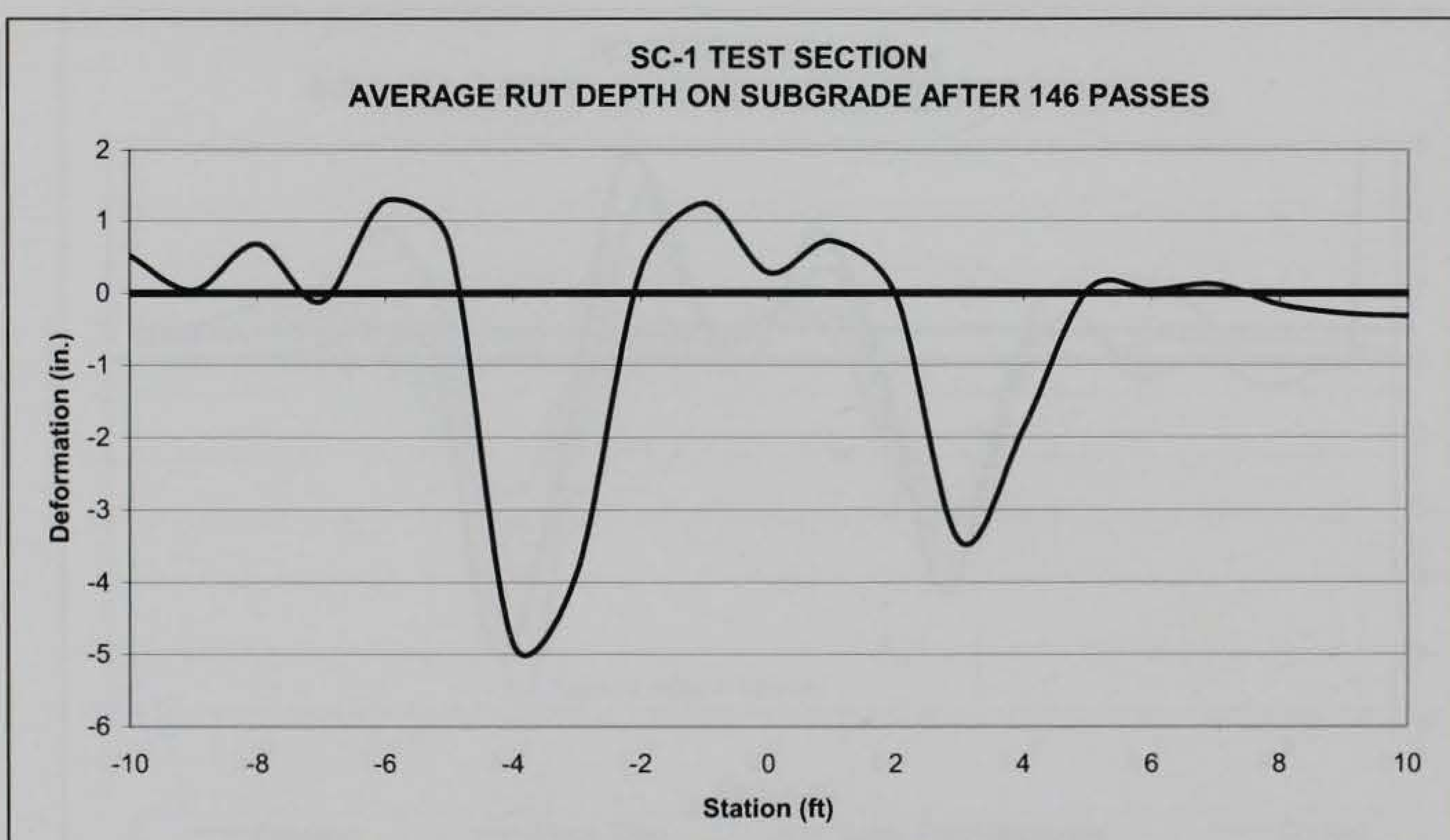


Figure 44. SC-1 rut development on the SM subgrade.

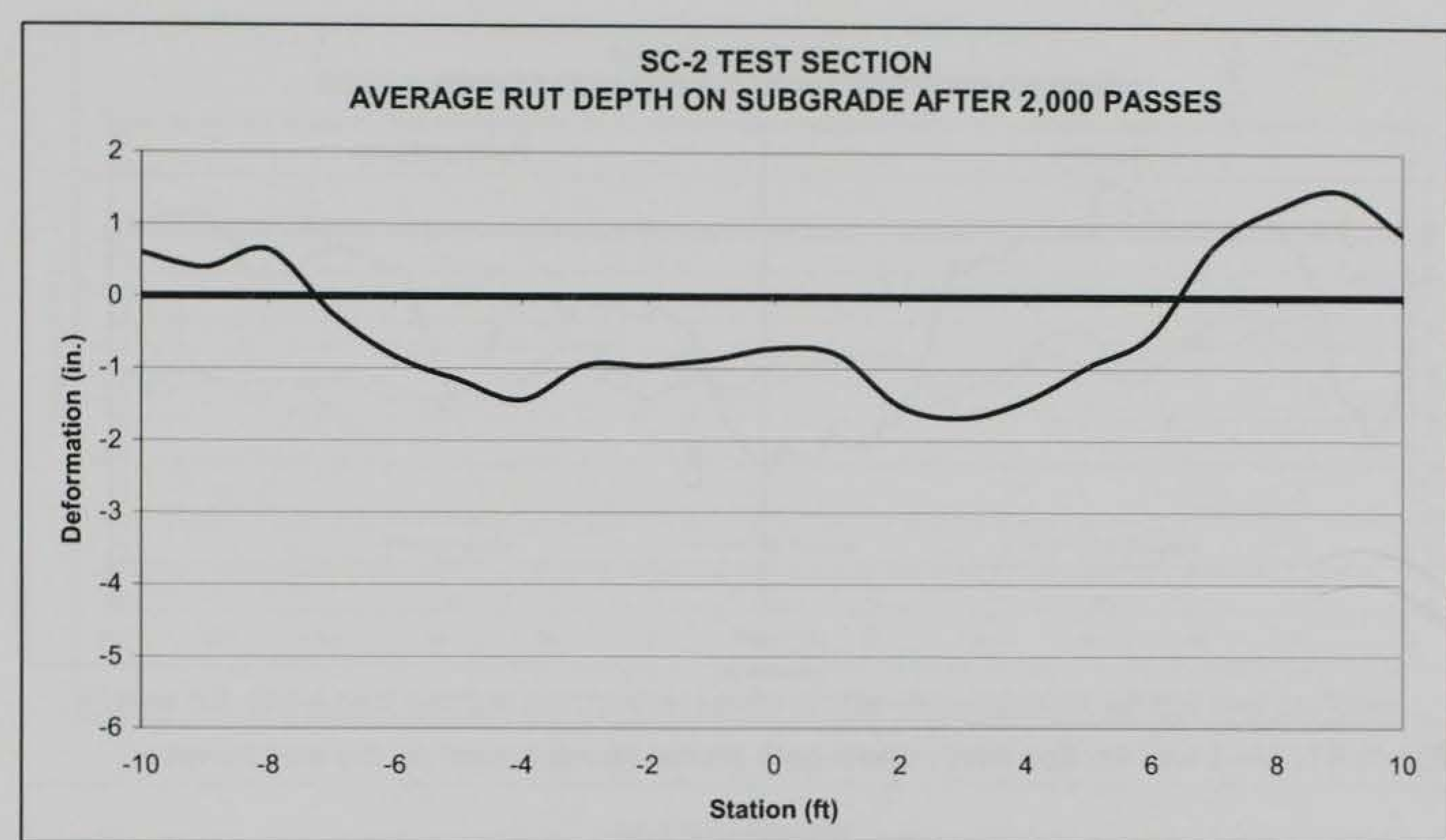


Figure 45. SC-2 rut development on the SM subgrade.

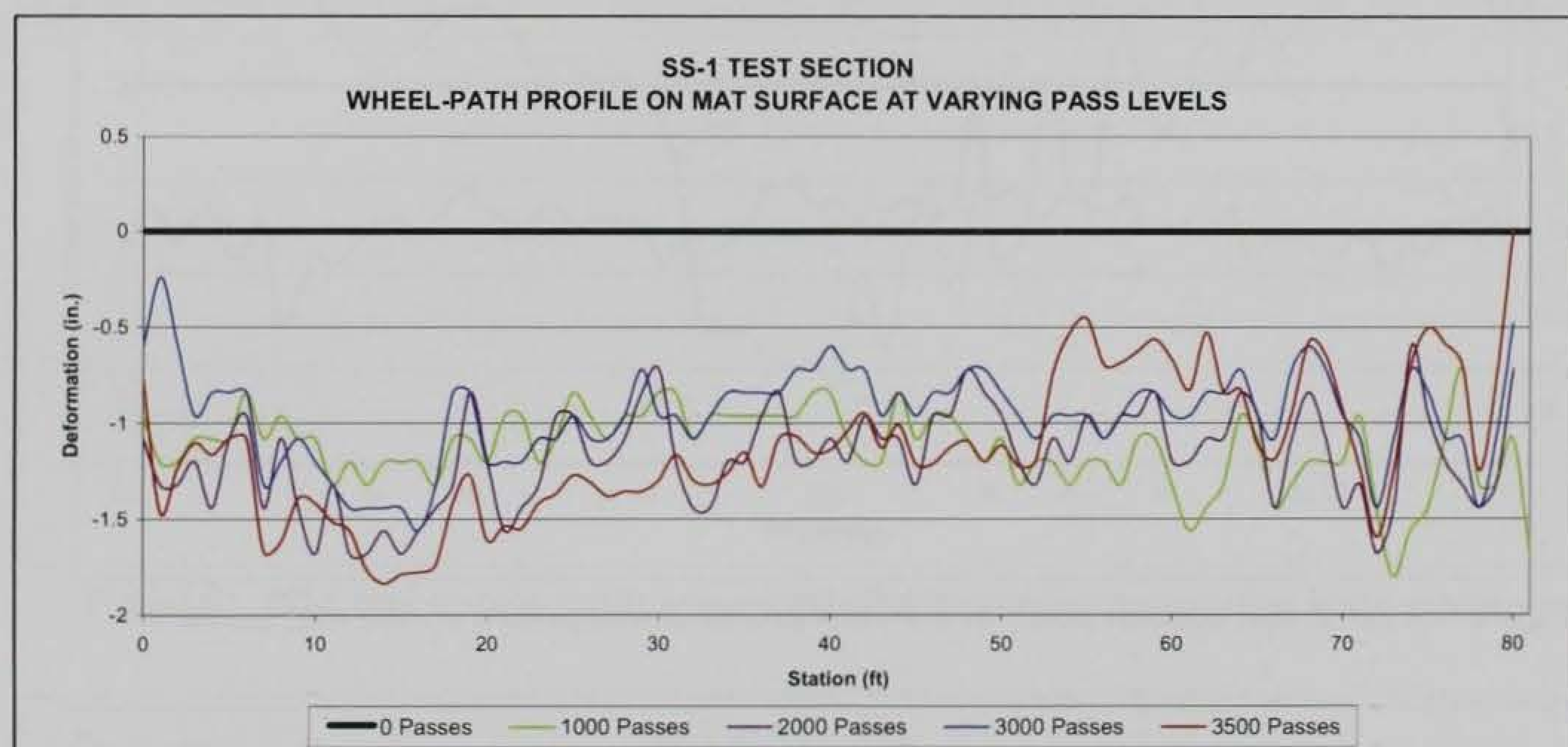


Figure 46. SS-1 test section north wheel-path profile development on the mat surface.

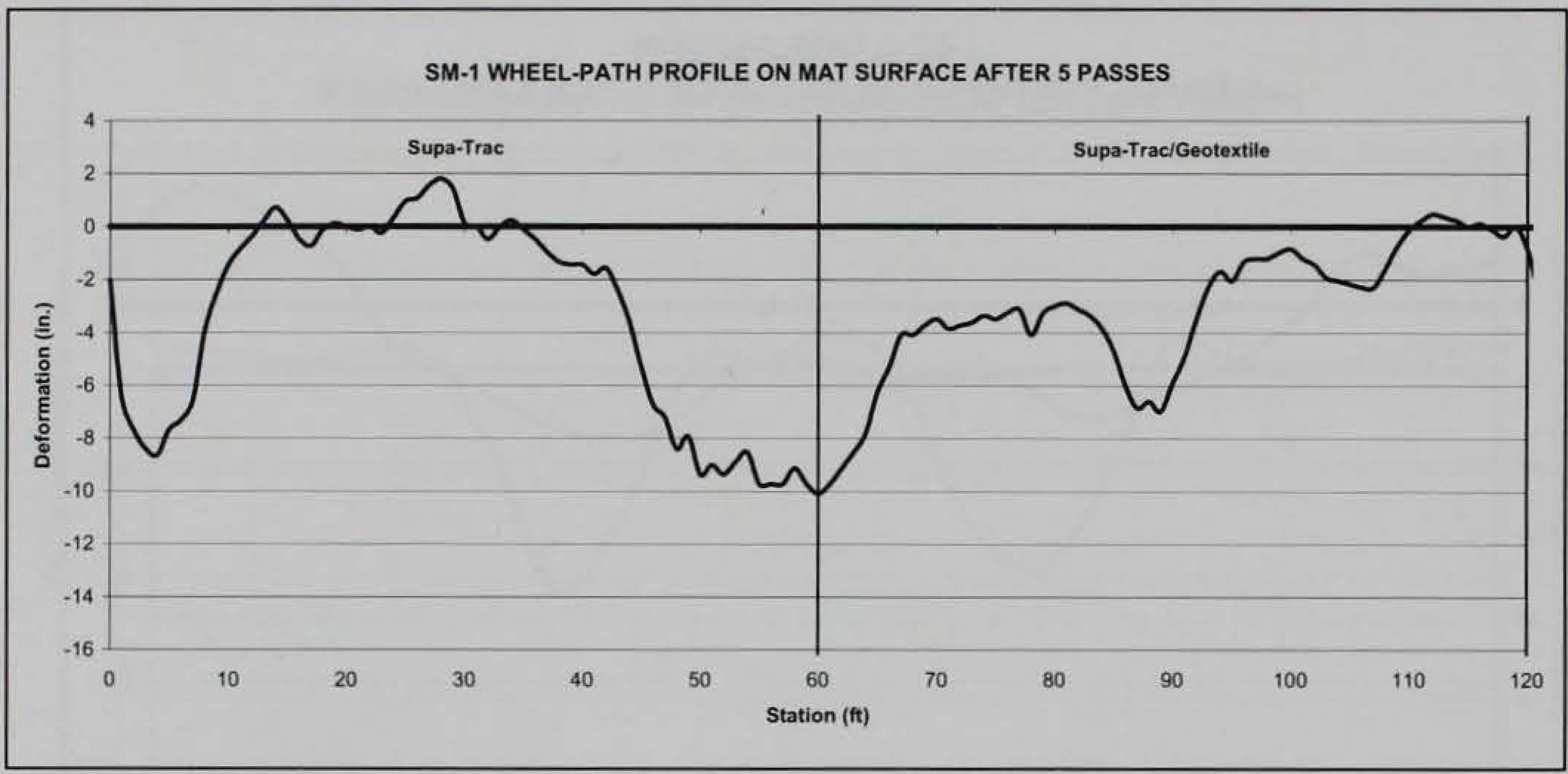


Figure 47. SM-1 test section north wheel-path profile development on the mat surface.

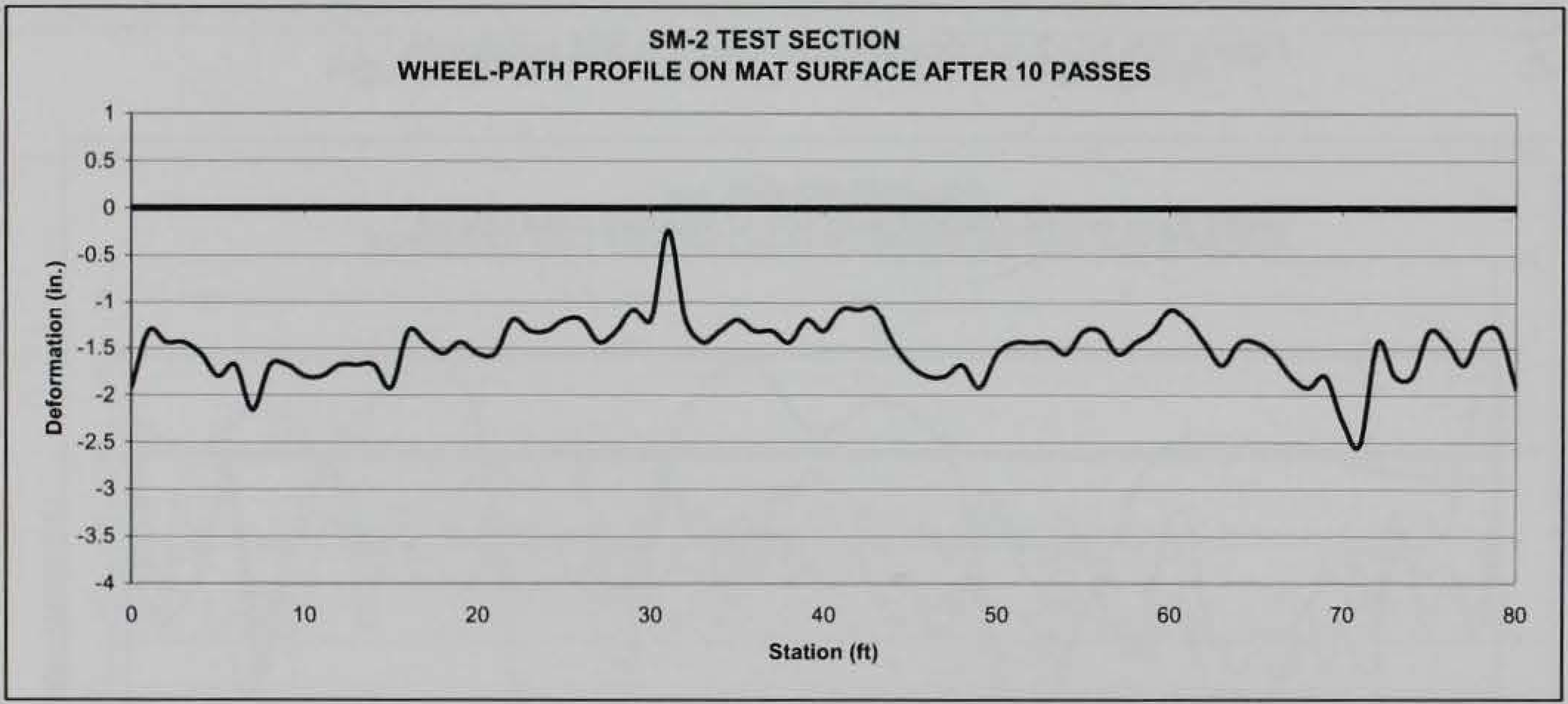


Figure 48. SM-2 test section north wheel-path profile development on the mat surface.

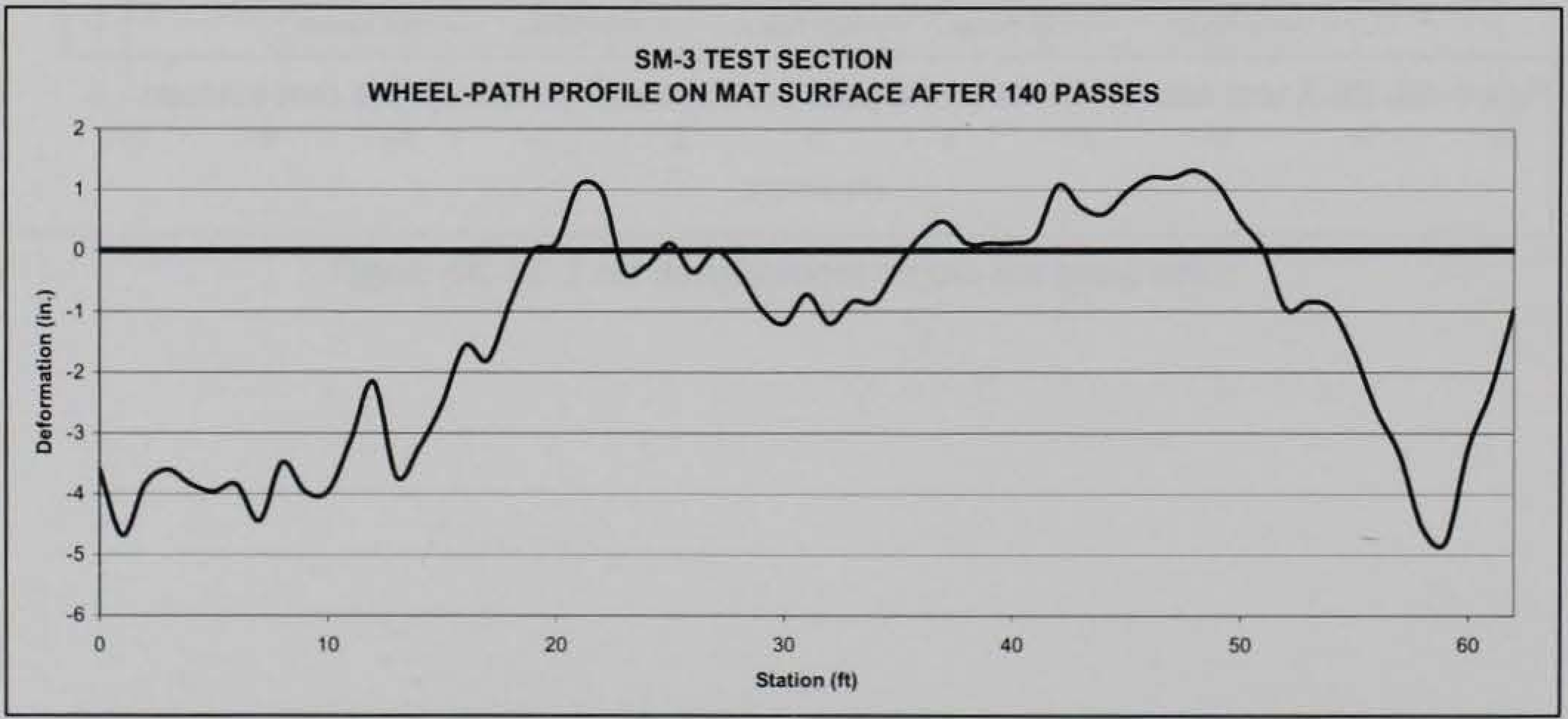


Figure 49. SM-3 test section north wheel-path profile development on the mat surface.

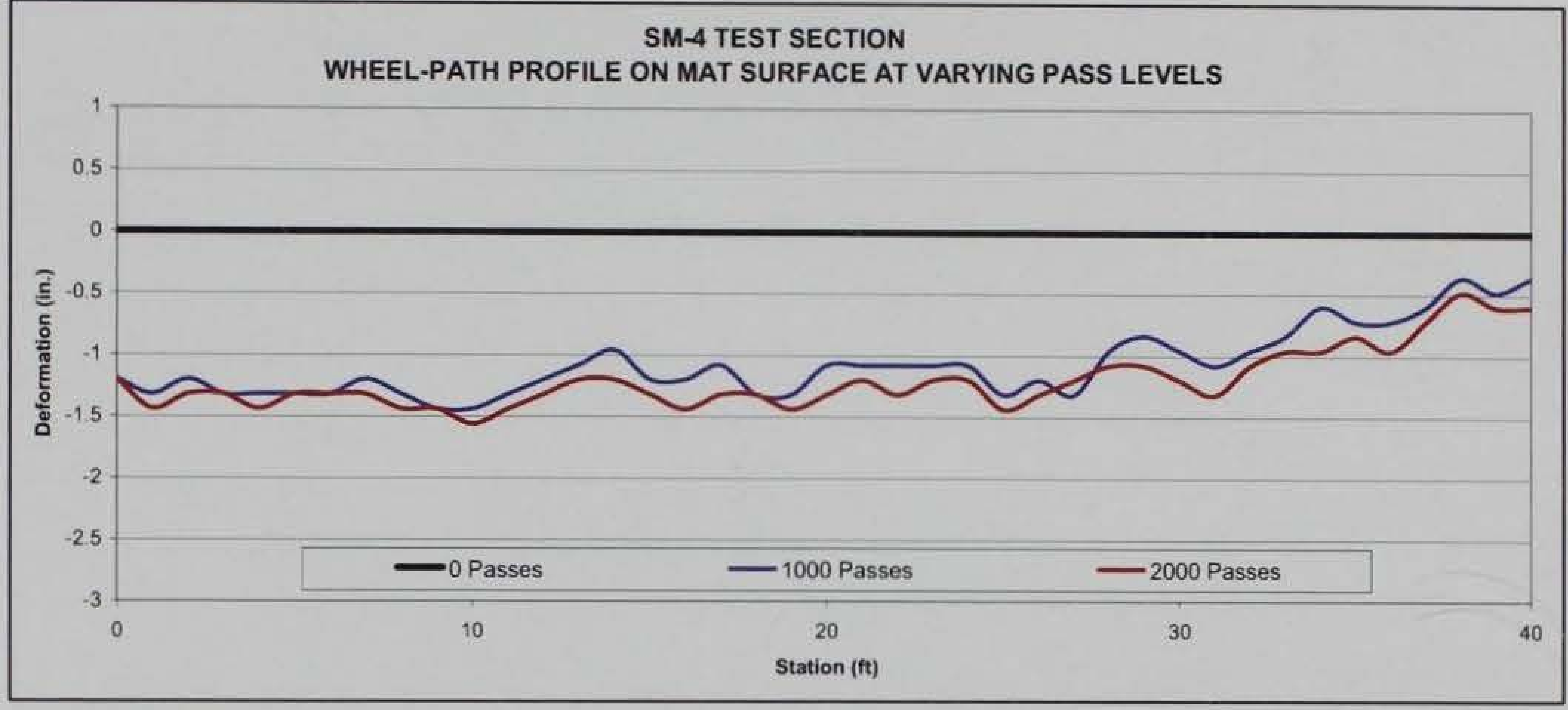


Figure 50. SM-4 test section north wheel-path profile development on the mat surface.

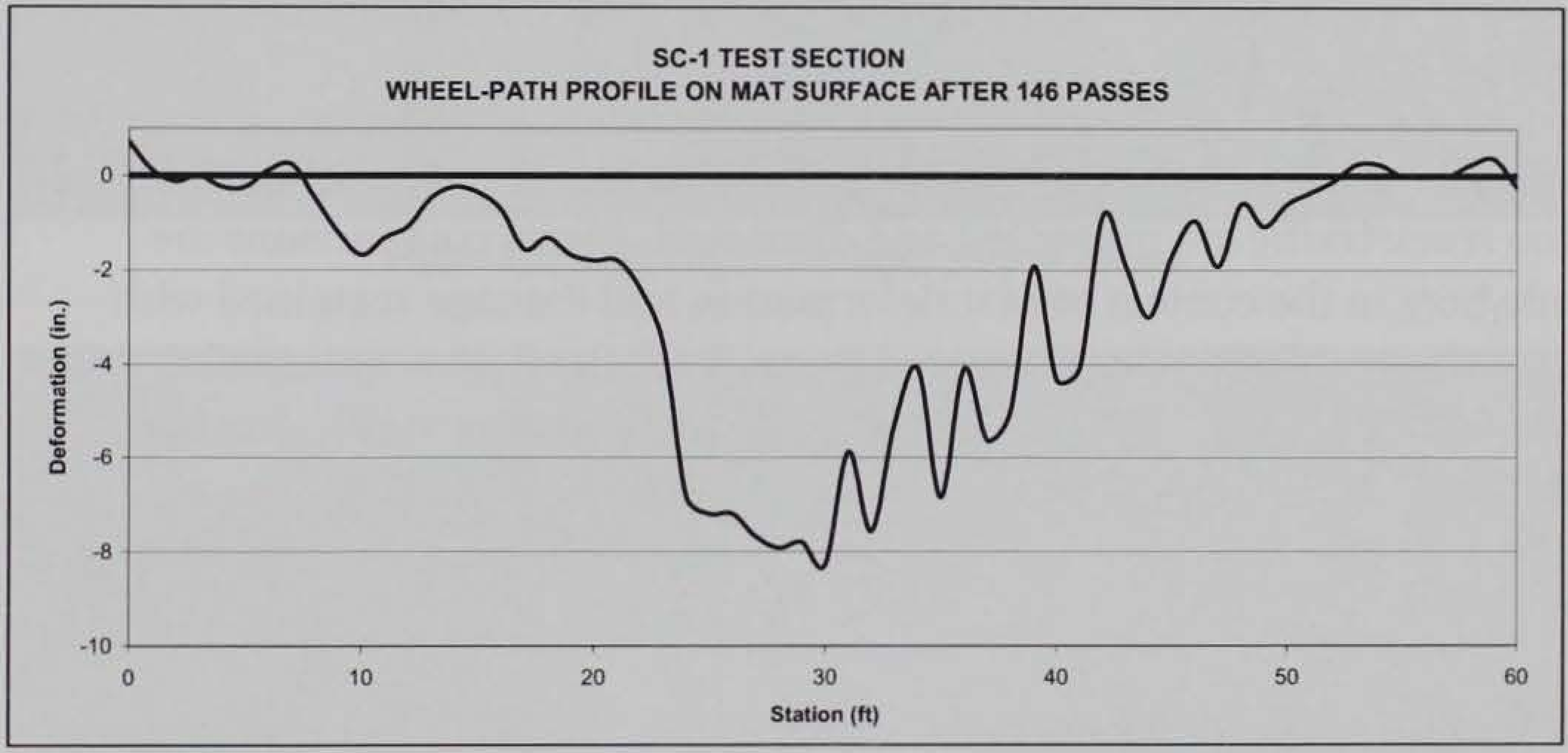


Figure 51. SC-1 test section north wheel-path profile development on the mat surface.

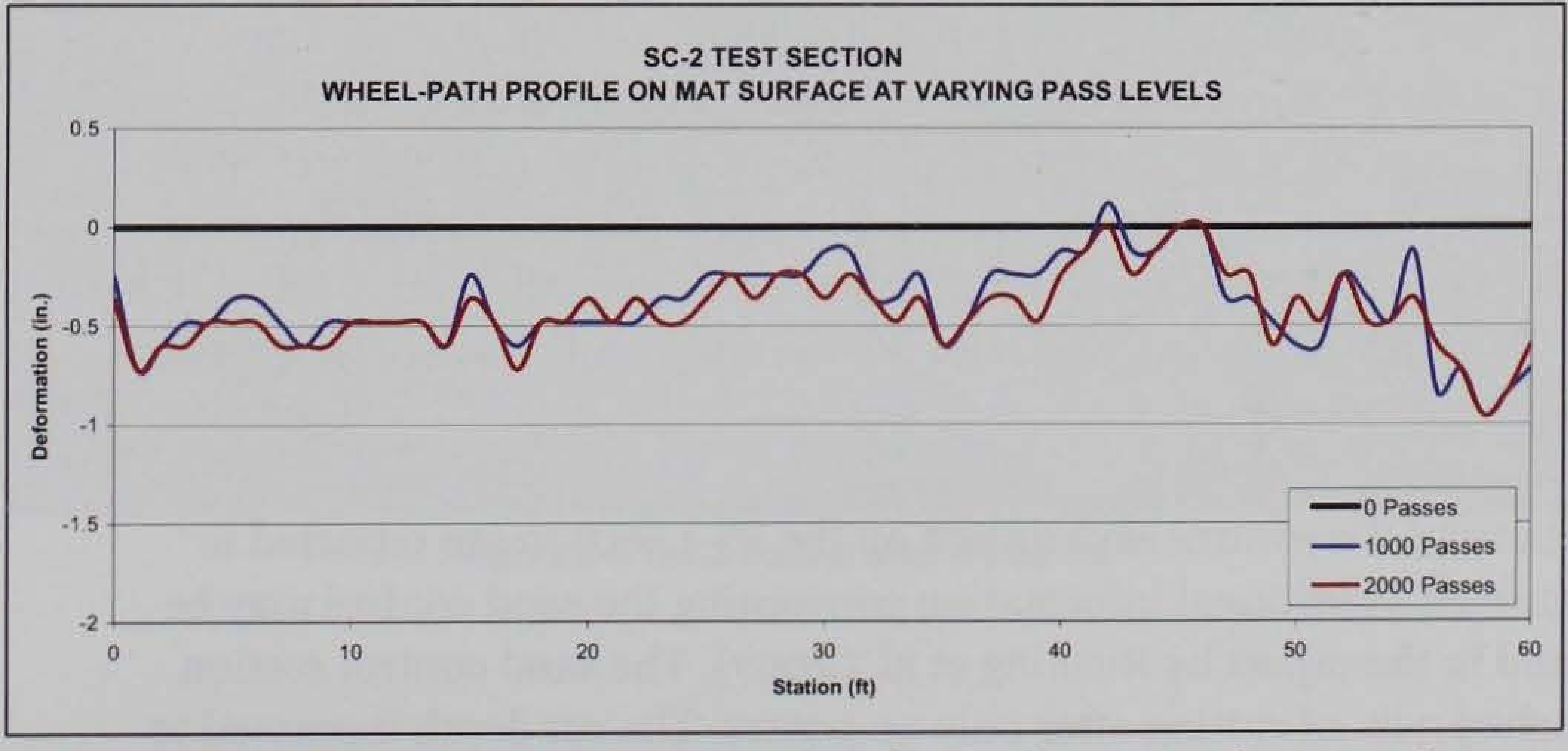


Figure 52. SC-2 test section north wheel-path profile development on the mat surface.

exponential slowing of rut development in the absence of mat damage. Once the rut depth reached a certain level, it stabilized and did not continue to increase. For the SM-1, SM-2, SM-3, and SC-1 sections, very few passes were achieved before failure, so trends could not be determined. Ruts formed rapidly and increased in depth until the mats were destroyed. For sections SM-1 and SM-3, the profiles increased in elevation in the center. Once the mat system began to fail on the approach and departure ends, the mat system arched in the center and could not be easily pressed down into the rut underneath for an accurate rod and level reading. Therefore, the actual amount of rutting could not be inferred for the center portions of SM-1 and SM-3 from the profile plots.

## Individual mat evaluations

### General

In this section, the performance of the individual mat test sections under 7-ton truck traffic are presented and discussed. Direct comparisons are made here in the context of mat deformation and damage sustained with increasing traffic level, as measured throughout the field experimental phases of this work. Photos of each item before and after trafficking are included.

### Control

The control experiments were conducted to provide reference points for mat performance evaluation. The Supa-Trac system was designed to provide improvement of a subgrade's load bearing capability; thus, the bearing characteristics of the subgrade were determined to facilitate a quantitative comparison. An initial control test was performed on the sand test section, SS-1, by Rushing et al. in 2006. Control sections were performed on the SM-1, SM-2, SM-4, and SC-2 test sections, but not on sections SM-3 and SC-1 due to redundancy and time constraints. Photos of the failed SM-1, SM-2, SM-4, and SC-2 control sections are presented in Figures 53 through 56.

Data from the control experiment on the SS-1 section are reported in Figure 24. Additional information concerning the sand control may be found in the report by Rushing et al. (2007). The sand control section reached 3 in. of rutting after only 20 passes. The rut depth increased to

Figure 53. SM-1 control rut depth after 4 passes.

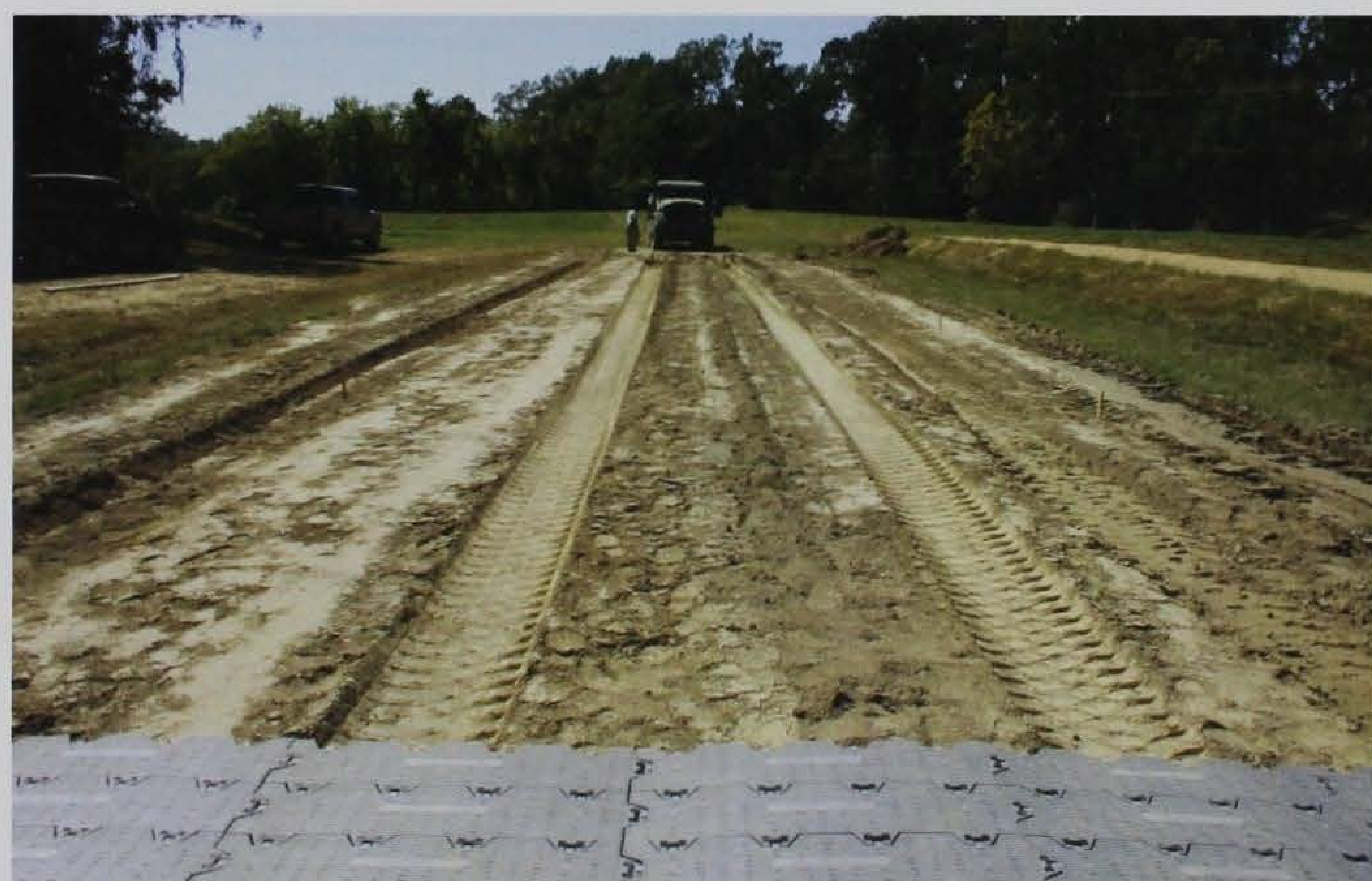

Figure 54. SM-2 control after 6 passes.

Figure 55. SM-4 control after 1,000 passes.

Figure 56. SC-2 control after 2,000 passes.

6 in. after 50 passes, and the test was concluded. The Supa-Trac system offered significant improvement in maneuverability over the subgrade since 3 in. of rut were reached after 3,500+ passes. The control section on the sand proved that the Supa-Trac system could be used to significantly increase the number of passes the subgrade may sustain in a beach-crossing scenario.

Data from the SM-1 control experiment are reported in Figures 25 and 40. After one pass, the rut depth on the control section averaged 9.5 in. After four passes, the average rut depth had increased to 15.7 in. The high rate of rut formation is typical for a 1-CBR muddy soil. The mat system offered some improvement to the rate of rut formation, although not nearly as significant as for the sand section. For comparison, the rut depths measured on the mat systems after one pass were 2.6 and 4.3 in., respectively, for the Supa-Trac and Supa-Trac over geotextile systems. The control experiment on the SM-1 section proved that the 1-CBR subgrade is difficult to traverse with military truck traffic due to the high rate of rut formation. Also, the Supa-Trac system offered some improvement, although not significant.

Data from the SM-2 control experiment are reported in Figures 26 and 41. After four passes, the rut depth on the control section averaged 3.4 in. This average rut depth increased to 3.9 in. after 10 passes. The rate of rut formation on the SM-2 test section (approximately 5 CBR) was much lower than that of the SM-1 test section, as was expected. The subgrade did not inhibit vehicle movements after 10 passes, but the test was concluded due to failure of the matted section. The Supa-Trac matting reduced the rate of rut formation, with an average of 2.5 in. after 10 passes. Therefore, the mat system offered some improvement over the control section, although the control was capable of sustaining several passes without the inclusion of the mat system.

Control sections for SM-4 and SC-2 exhibited similar behavior as shown in Figures 28 and 30. In both of these tests, the control sections performed similarly to the matted sections for the first 200 passes. The rate of rut formation then increased substantially until the tests were concluded. The 3-in. rut limit was achieved on both control sections after approximately 800 passes, while the matted sections sustained 2,000 passes without reaching the 3-in. limit. Therefore, in both sections, the subgrade was essentially strong enough to carry the vehicle loads without the application of the matting system. However, the addition of the matting system increased the number of passes required to achieve 3 in. of rutting due to its ability to distribute the applied load over a larger area.

### Supa-Trac on SS-1

The Supa-Trac rolls were moved into place with a forklift, aligned, and unrolled by three personnel. No special installation requirements were encountered. The rolls were moderately easy to unroll but required MHE for placement. One 80-ft-long roll was installed directly over the SP subgrade for trafficking. Anchor stakes were included in the installation kit, but the system manufacturer suggested that they were not necessary and did not recommend their use. Figure 5 shows the Supa-Trac system on the SS-1 prior to trafficking.

#### *SS-1 rut depth results*

Rut depth results of the Supa-Trac testing are shown in Figures 24, 31, 39, and 46. Rut development was slow on the Supa-Trac system. Over 500 passes of truck traffic were completed before a 2-in. rut was measured, and the 3-in. failure mark had not been achieved after traffic was concluded at 3,500 passes. The voids underneath the mat system filled with sand particles. The sand-filled voids worked to quickly stabilize the system against further rut formation. As the mat system settled into the sand, some sand material was pushed outward and caused the edges of the outermost panels to lift off the ground, as seen in Figure 31. This did not cause any problems with trafficking nor did it cause any mat breakage. The raised edges could be a concern if vehicles were to cross the mat perpendicular to the direction of normal travel.

#### *SS-1 mat breakage results*

After 3,500 passes, almost no mat damage was noted to the Supa-Trac mat system. Only five plastic retainer clips were broken, and all remained in place. Therefore, no functionality of the mat system was lost. Additional replacement clips were included in the mat installation kit, although none were required to be replaced (Figure 4). A photo of the Supa-Trac system after 3,500 passes is shown in Figure 57. The Supa-Trac system performed adequately to prevent rut formation and to sustain 3,500 truck passes with only minor damage.

Figure 57. SS-1 after 3,500 passes.

### Supa-Trac on SM-1

Two 60-ft rolls of Supa-Trac were installed as described previously for SS-1. One roll was placed directly on top of the SM subgrade, and one was placed over a geotextile fabric. Figure 8 shows the Supa-Trac system on the SM-1 subgrade prior to trafficking.

*SM-1 rut depth results*

Rut depth results of the Supa-Trac testing on SM-1 are shown in Figures 25, 32, 33, 40, and 47. Ruts formed rapidly during trafficking, reaching an average of 2.5 and 4.0 in. over the mat/subgrade and mat/geotextile sections, respectively, after one pass. The faster rate of rutting over the section with the geotextile, when compared to the other Supa-Trac section, was determined to be a function of subgrade strength variability, not application of the geotextile. However, it was noted that neither section was able to withstand truck traffic over the subgrade with a CBR of one or less. After five passes, the test was concluded due to failure of the entire test section. The rut depths on the Supa-Trac sections had increased to 6.0 and 9.0 in., respectively, for the mat/subgrade and mat/geotextile sections. Once the matting was removed, final average rut depths on the subgrade also measured approximately 6.0 and 9.0 in., respectively, for the subgrade and geotextile sections.

*SM-1 mat breakage results*

Mat breakage exceeded the 20% failure criteria of both Supa-Trac test sections after only one pass. The T-shaped connectors tore from the receptor pieces, leaving small pieces of plastic littered over the surface of the mats. The amount of damage increased rapidly. After five passes, nearly 100% of the connections parallel to the direction of traffic had failed. Individual mat panels crushed under the weight of the vehicle and were mashed into the subgrade in the wheel paths of the truck. Small sections of matting broke completely free from the original roll and began to overlap other portions of the test section. Photographs of the trafficked Supa-Trac sections are shown in Figures 58 through 60.

**Supa-Trac on SM-2**

One 80-ft roll of Supa-Trac was installed as described previously for SS-1. The roll was placed directly on top of the prepared SM subgrade. Figure 9 shows the Supa-Trac system on the SM-2 subgrade prior to trafficking.

*SM-2 rut depth results*

Rut depth results of the Supa-Trac testing are shown in Figures 26, 34, 41, and 48. Ruts formed steadily during trafficking, reaching an average of 2.5 in. after 10 passes. At this point, the test was concluded due to failure of the Supa-Trac mat system by mat breakage. Once the matting system was removed, the rut depth on the subgrade measured approximately 3.5 in. The 5-CBR subgrade used in the SM-2 test section was much stiffer than the 1 CBR in the SM-1 section. The reduced rate of rut formation proves the strength was greatly increased. The mat system was able to slow the formation of ruts when compared to the control section, but the mat itself was unable to withstand even this small amount of rutting.

*SM-2 mat breakage results*

After 4 passes, 19 panel connections broke completely from the Supa-Trac system in the center along the wheel path of the truck. After 6 passes, 55 panel connections were broken. The number of connections continued to increase until over 200 connections, or greater than 50% of the mat section, were destroyed after 10 passes. The T-shaped connectors tore from the receptor pieces, leaving small pieces of plastic littered over the surface of the mats. This was the same failure mechanism seen in the SM-1 test section. At this point, the test section was considered failed due to mat

Figure 58. SM-1 after 1 pass.

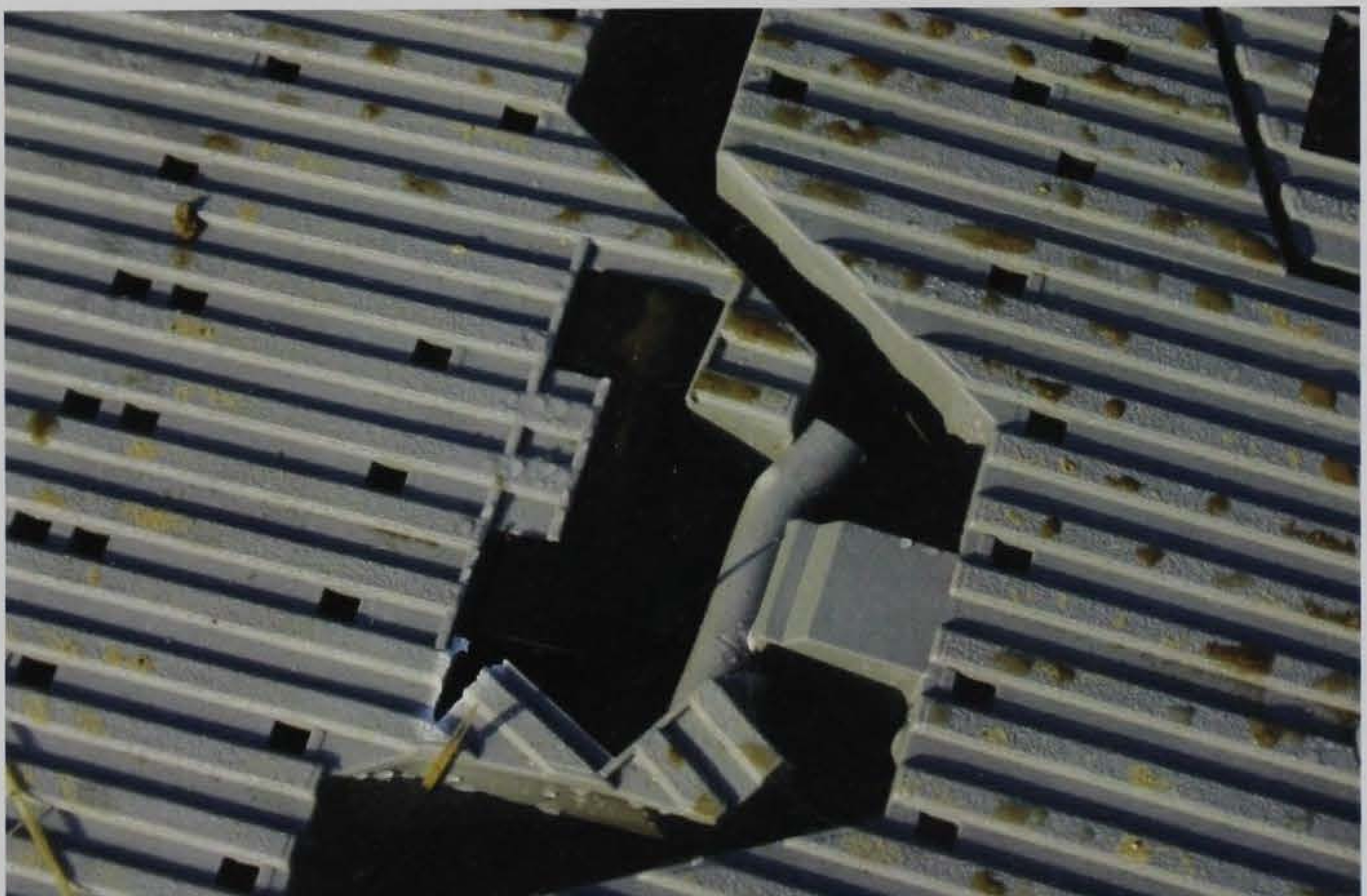

Figure 59. Typical broken connection on Supa-Trac matting.

Figure 60. SM-1 after 5 passes.

breakage greater than 20%. The connections were unable to withstand the applied stresses when the subgrade rutted from underneath the mat system. The subgrade rut depth after the mat was removed revealed an average rut depth of approximately 3 in. Since only a minimal rut was discovered under the mat, and the control system was capable of sustaining several additional passes, it was concluded that that any deformable nongranular subgrade would yield similar results. A photograph of the trafficked Supa-Trac section is shown in Figure 61.

### Supa-Trac on SM-3

One 60-ft roll of Supa-Trac was installed as described previously for SS-1. The roll was placed directly on top of the prepared SM subgrade. Figure 10 shows the Supa-Trac system on the SM-3 subgrade prior to trafficking.

#### *SM-3 rut depth results*

Rut depth results of the Supa-Trac testing are shown in Figures 27, 35, 42, and 49. Ruts formed steadily during trafficking, reaching an average of 3 in. after 100 passes. After 100 passes, the rate of rut formation increased due to failure of the mat and its inability to further distribute load to the subgrade. The average rut depth reached 6.5 in. after 140 passes when

Figure 61. SM-2 after 6 passes.

traffic was concluded due to total failure of the Supa-Trac system. Once the matting system was removed, the final average rut depth on the subgrade measured nearly 7.0 in. Since the ML-CL subgrade strength was similar to that of the SM-2 test section, it can be concluded that the brickwork panel configuration of the matting system better distributes the applied load, slows the rut formation, and therefore extends the number of passes the mat can sustain before failure. The brickwork configuration prevented the "unzipping" effect seen along the panel joints of sections SM-1 and SM-2.

*SM-3 mat breakage results*

After 10 passes, 8 black plastic retainer clips dislodged from the mat, and 3 panel connections were broken. After 20 passes, 15 panel connections were broken on one end of the test section. After 50 passes, 34 panel connections were failed. The T-shaped connectors tore from the receptor pieces, leaving small pieces of plastic littered over the surface of the mats. After 100 passes, approximately 60% of the mat panels were broken. Pieces of the mat were breaking off with each pass and entire panel sections were unattached. This was the same failure mechanism seen in the SM-1 and SM-2 test sections. At this point, the test section was considered failed due to mat breakage greater than 20%. The connections were unable to withstand the applied stresses when the subgrade rutted from underneath the mat system. Trafficking was continued until the mat was completely destroyed after 140 passes. Nearly every connection in the wheel path of the test vehicle was cracked or broken. A photograph of the SM-3 Supa-Trac section after 140 passes is shown in Figure 62.

Figure 62. SM-3 test section after 140 passes.

### Supa-Trac on SM-4

One 60-ft roll of Supa-Trac was installed as described previously for SS-1. The roll was placed directly on top of the prepared CH subgrade. Figure 11 shows the Supa-Trac system on the CH subgrade prior to trafficking.

#### *SM-4 rut depth results*

Rut depth results of the Supa-Trac testing are shown in Figures 28, 36, 43 and 50. The rut on the SM-4 section developed slowly over the first 100 passes to 1.5 in. After the first 100 passes, very little increase in rut depth was recorded. When trafficking was concluded after 2,000 passes, the final average rut depth on the mat surface measured 1.75 in., so the failure mark was never achieved. Once the matting system was removed, the final average rut depth on the subgrade measured approximately 1.5 in. A combination of the load distribution of the matting system and the bearing capacity of the 7-CBR CH subgrade kept the rut depth within acceptable limits. From the SM-4 test section, it can be concluded that the system will performed satisfactorily over a CBR of 7 or greater.

*SM-4 mat breakage results*

After 2,000 passes, no mat damage was noted to the Supa-Trac mat system. A photo of the Supa-Trac system after 2,000 passes is shown in Figure 63. The Supa-Trac system performed adequately to prevent rut formation and to sustain 2,000 truck passes with no damage.

Figure 63. SM-4 test section after 2,000 passes.

### Supa-Trac on SC-1

One 60-ft roll of Supa-Trac was installed as described previously for SS-1. The roll was placed directly on top of the prepared SM subgrade. After the mat was installed, the subgrade was allowed to freeze partially for 36 hr prior to trafficking. The temperature when trafficking began was 24°F, with a daily high of 28°F. The first 2 to 3 in. of subgrade was frozen surrounding the matted area, and the mat was encrusted in ice. Figure 13 shows the Supa-Trac system on the SC-1 subgrade prior to trafficking.

*SC-1 rut depth results*

Once testing began, it was apparent the mat insulated the subgrade underneath and kept it from freezing the same depth as the surrounding material. Ruts formed more rapidly on the test area than the unprotected subgrade on each end of the mat. The decrease in strength underneath the mat is shown in the profile plot in Figure 51, where the rut is much deeper under the center of the mat than the ends. This effect is opposite of what was noted for the temperate test sections. Rut depth results of the Supa-Trac testing are shown in Figures 29, 37, 44, and 51. Ruts formed rapidly during trafficking, reaching an average of 3.0 in. after 65 passes. The average rut depth continued to increase to nearly 5.5 in. after 146 passes when the test was concluded. Once the matting was removed, the final average rut depth on subgrade was nearly 6.5 in.

*SC-1 mat breakage results*

After 10 passes, small plastic clips began to break from the Supa-Trac panels as seen in Figure 64. This type of damage was not seen in any of the previous tests at the ERDC and was concluded to be a function of increased brittleness of the system due to the cold temperatures. After 20 passes, 3 black plastic retainer clips were noted as cracked. After 30 passes, several retainer clips began to crack and dislodge from the matting system. After 50 passes, 28 panels were broken. Some of the panels were completely broken in half, and end or side connectors were broken on others. The "T" inserts tore from the receptor portions rendering the panels unusable. The system was failing rapidly with additional damage noted after every pass.

After 100 passes, approximately 40% of the panels were broken. Most of the damage was located on the east side of the test section where the rut depth was deeper, but panels were also beginning to break on the west side as well. After 120 passes, the amount of damage had increased to approximately 60% (Figure 65). Major damage had occurred on the west side of the section. Pieces of panels were breaking off with each pass, and entire panel sections were unattached. The connections were unable to withstand the stress when the subgrade rutted from underneath the mat system. Trafficking was continued until the mat was completely destroyed after 146 passes. Nearly every connection in the wheel path of the test vehicle was cracked or broken. A photograph of the SC-1 Supa-Trac section after 146 passes is shown in Figure 66.

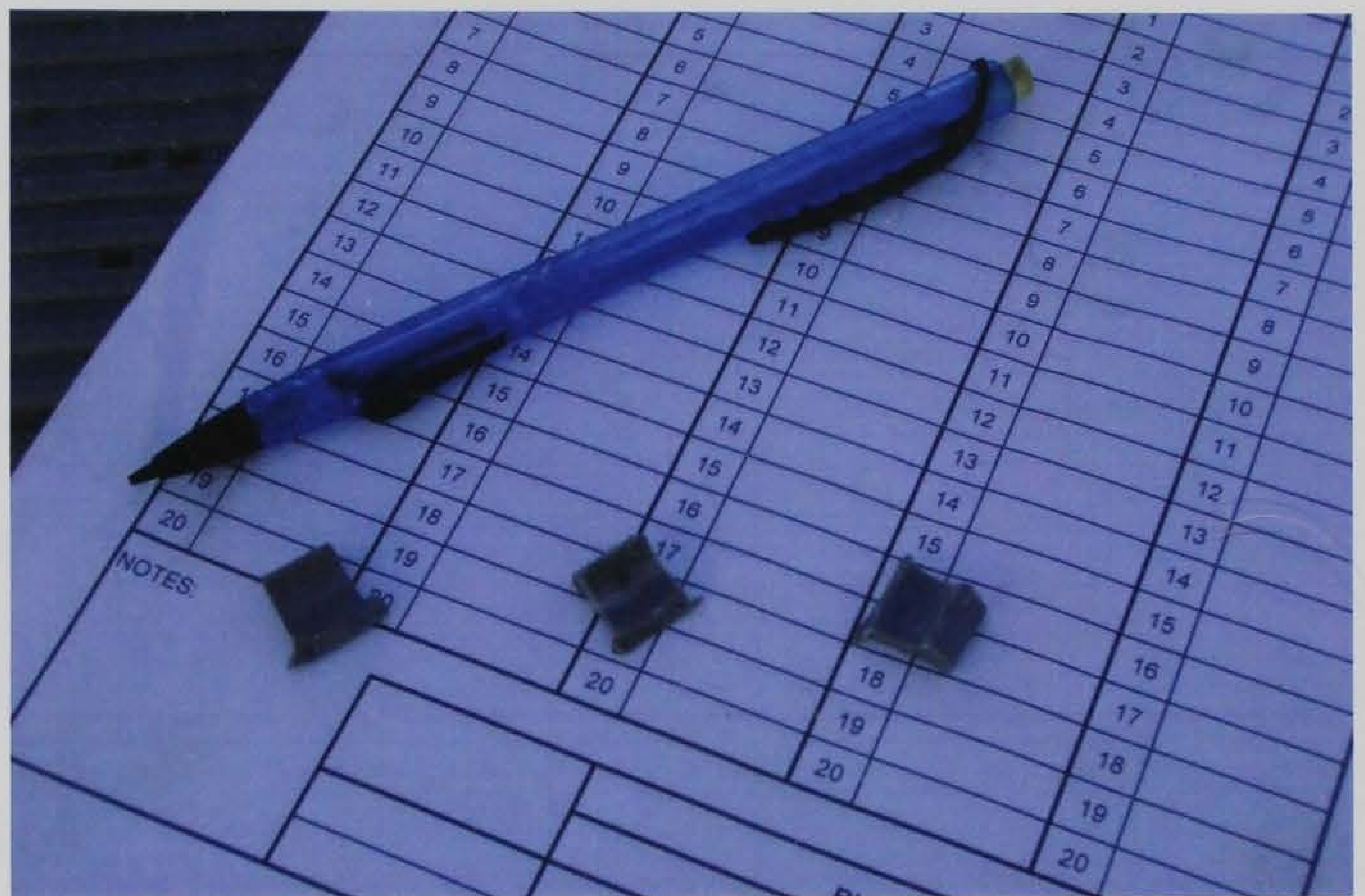


Figure 64. Small pieces of matting broken free after 10 passes of SC-1.

Figure 65. SC-1 test section after 120 passes.

Figure 66. SC-1 test section after 146 passes

**Supa-Trac on SC-2**

One 60-ft roll of Supa-Trac was installed as described previously for SS-1. The roll was placed directly on top of the prepared SM subgrade. Before the mat was installed, the subgrade was allowed to freeze for 60 hr prior to trafficking. The temperature when trafficking began was 8°F. DCP measurements showed that the first 6 to 8 in. of subgrade was frozen underneath the matted area, and the mat was encrusted in ice. Figure 14 shows the Supa-Trac system on the SC-2 subgrade prior to trafficking.

*SC-2 rut depth results*

Rut depth results of the SC-2 test are shown in Figures 30, 38, 45, and 52. Ruts formed very slowly during trafficking, only reaching an average of 1.5 in. after 2,000 passes and the conclusion of trafficking. After removal of the mat, the post test cross-section measurement on the subgrade only revealed a slightly higher average rut depth of 1.75 in. (Figure 45). The frozen subgrade was very strong and was capable of sustaining the vehicle traffic without the application of the mat.

*SC-2 mat breakage results*

After 10 passes, small plastic clips began to break from the Supa-Trac panels as observed in SC-1 and shown in Figure 64. As noted for SC-1, this type of damage was not seen in any of the previous tests at the ERDC and was concluded to be a function of increased brittleness of the system due to the cold temperatures. After 16 passes, the tire blew on the test vehicle, and traffic was paused until a repair could be completed. Trafficking resumed with an ambient temperature of 0°F. After 50 passes, 10 black plastic retainer clips were cracked. No additional damage was noted.

At this point in the test, snow began to fall and accumulate on and around the mats. The snow had to be shoveled from the mat surface at intervals so the driver could see the mat and drive in the same wheel paths. Temperatures ranged from -2°F to 22°F during trafficking over three days. After 2,000 passes, no additional damage was noted on the mat system. The matted area was completely encased in packed snow and ice. A photograph of the SC-1 Supa-Trac section after 2,000 passes is shown in Figure 67.

Although there was almost no damage to the system, it was impossible for three personnel to roll the mat for recovery. A forklift was used to free one end of the mat. When the personnel attempted to roll the mat, it shattered at the connections and fell apart. A forklift was used to loosen additional panel rows. When the mat was lifted from the subgrade, it again shattered and fell apart. Removal could only be achieved by removing small sections with the forklift while destroying the mat (Figure 68). The connections had become very brittle and could not handle even small amounts of stress. After removal, small pieces of broken matting had to be picked up by hand as seen in Figure 69. Figure 70 shows the completely frozen subgrade after removal of the Supa-Trac matting.

Figure 67. SC-2 test section after 2,000 passes.


Figure 68. Removal of matting with a forklift on SC-2 test section.

Figure 69. Bucket full of broken pieces of Supa-Trac collected after removal.

Figure 70. Frozen subgrade after removal of matting from SC-2.

A summary of the results of all seven Supa-Trac test sections is presented in Table 3.

Table 3. Summary of Supa-Trac test results.

| Test Section | CBR, % | Avg. Temp., °F | Scenario | Passes at Failure | | Notes |
|---|---|---|---|---|---|---|
| | | | | 20% Breakage | 3-in. Rut | |
| SS-1 | 15 | 85 | Beach | 3,500+ | 3,500 | |
| SM-1 | 1-3 | 85 | Mudflat | 1 | 1 | |
| SM-2 | 5 | 85 | Mudflat | 10 | 10 | |
| SM-3 | 5 | 65 | Mudflat | 100 | 100 | Staggered joints |
| SM-4 | 7 | 55 | Mudflat | 2,000+ | 2,000+ | Staggered joints |
| SC-1 | 5 | 25 | Partially Frozen | 100 | 70 | Staggered joints |
| SC-2 | 80 | 15 | Completely Frozen | 2,000+ | 2,000+ | CBR 1 when unfrozen; staggered joints |

## Other mat properties

Additional information relating to the utility of the Supa-Trac mat is provided in Table 4. Properties are reported on a value per square foot basis. The reported values include measured values such weight, installation rate, and packaged volume of the Supa-Trac system. The cost of the system was based on a quotation from the product vendor to the USMC in 2008.

Table 4. Mat performance properties on a per-square-foot basis.

| Mat Item | Performance Rating (0-10)[a] | Weight lb/ft$^2$ | Packed Volume ft$^3$/ft$^2$ road | Install Rate ft$^2$/man-hour | Traffic Benefit Ratio[a] | Cost \$/ft$^2$ |
|---|---|---|---|---|---|---|
| Supa-Trac | 9, 0 | 2.5 | 0.16 | 4800 | >175[b], 2.5,1 | 5.25 |

[a] Two values are grouped as 1. SS-1, SM-4, and SC-2 and 2. SM-1, SM-2, SM-3, and SC-1, respectively.

[b] Value for SS-1 only.

Table 4 lists two performance ratings for Supa-Trac for comparison to values described for additional matting systems in Rushing et al. (2007). These ratings were determined based on both rut and damage resistance. The Supa-Trac performed very well on the SS-1, SM-4, and SC-2 test sections but failed rapidly on the SM-1, SM-2, SM-3, and SC-1 test sections. The given ratings reflect the judgment of the project engineers and are not determined algorithmically.

An installation rate estimate is listed in Table 4 for Supa-Trac. The installation was performed by three personnel. The installation time assessment began after the mat was delivered and positioned with the forklift and ceased after the mat had been installed on the subgrade. The time for section layout was not included. The installation rate was likely inflated, since only the time needed to unroll and straighten one roll of matting was recorded. In a real field exercise, multiple rolls would be deployed end-to-end. Additional time would be required to align the ends of adjacent items. The degree of inflation of the mat installation rate was not known.

Table 4 also includes a listing of traffic benefit ratio (TBR). This value is calculated for each test item as the ratio of the number of passes-to-failure of the item to that of the control. The TBR of the Supa-Trac mat that survived all 3,500 truck passes on the sand section is only known to be greater than 175 (recall that the control failed at 20 passes).

# 5 Conclusions and Recommendations

## Conclusions

The Supa-Trac expeditionary mat surfacing evaluation reported herein suggested the following conclusions regarding the individual items tested:

- Supa-Trac performed satisfactorily over the loose sand subgrade with no permanent damage. Its good performance on sand was due to its ability to confine the sand in the cells underneath the mat panels.
- A minimum of a 7 CBR is required for Supa-Trac operations over most nongranular subgrades in order to achieve 2,000 vehicle passes prior to failure. In most cases, a CBR of 7 or greater will support military vehicles without the application of a matting system.
- The brickwork panel configuration showed improved performance over in-line panel configuration.
- Supa-Trac connections are not capable of withstanding military vehicle traffic over areas with rutting greater than 2 in.
- Supa-Trac is difficult to recover and reuse due to soil embedding in the cells underneath the mat, especially in subfreezing climates.
- The Supa-Trac system can be deployed rapidly, but will damage itself if unrolled quickly.
- Small plastic parts constantly break from the system with traffic and are tedious to recover upon removal.
- Supa-Trac becomes brittle in cold weather environments with subfreezing temperatures. Further testing in a controlled environment is necessary for a complete temperature/behavior profile of the material.

## Recommendations

Recommendations based on the results of this investigation are as follows:

- For an expedient beach crossing in loose sand, the Supa-Trac mat system should perform satisfactorily, and is therefore recommended.
- For a mudflat crossing scenario where subgrade strengths of 0 to 6 CBR are expected, the Supa-Trac matting system is not recommended.

- If Supa-Trac is considered for use in a beach landing situation, it should be evaluated for its permanence in terms of flotation resistance, especially if exposed to wave action or tidal movements.
- For a complete and definitive evaluation of the Supa-Trac matting system under field conditions, additional testing in an actual field environment is recommended to address the following issues: terrain including roughness and incline, curvature, braking, tracked vehicles, weathering, and others as applicable.

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**14. ABSTRACT**

The Supa-Trac commercial matting system was evaluated for use as an expedient road surfacing for both beach and mudflat crossing scenarios. Full-scale test sections of the mat systems were constructed over sand and mud in both temperate and cold climates. Temperate tests were conducted at the U.S. Army Engineer Research and Development Center, Vicksburg, MS, and cold climate tests were conducted at Fort McCoy, WI. The cold climate test was conducted to determine if the mat exhibited brittle failure behavior when trafficked in sub-freezing temperatures. The mats were trafficked with a fully loaded 7-ton (~6350-kg) military truck. Mat deformation and damage were monitored at traffic intervals up to 3,500 truck passes. The performance data were analyzed, and the mats were evaluated on their ability to sustain traffic. The mat system was further evaluated on the basis of rate of deployment, logistical footprint, and cost. Based on the results of the full-scale test sections, the matting performed satisfactorily in the beach crossing scenario, but failed to achieve the desired results for the mudflat crossing. Additionally, the matting system exhibited brittle failure behavior when trafficked in sub-freezing temperatures.

**15. SUBJECT TERMS**

| | | |
|---|---|---|
| Beach crossing | Mat | Matting |
| Expeditionary road | Mat road | Supa-Trac |
| | Mat system | Temporary road |

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