Technical Report GL-93-20
August 1993

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Effects of Variable Tire Pressure on Road Surfacings

Volume I: Design, Construction, Behavior Under Traffic, and Test Results

by Robert W. Grau
Geotechnical Laboratory

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Prepared for U.S. Department of Agriculture Forest Service

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3909 Halls Ferry Road
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Final report

Prepared for U.S. Department of Agriculture Forest Service
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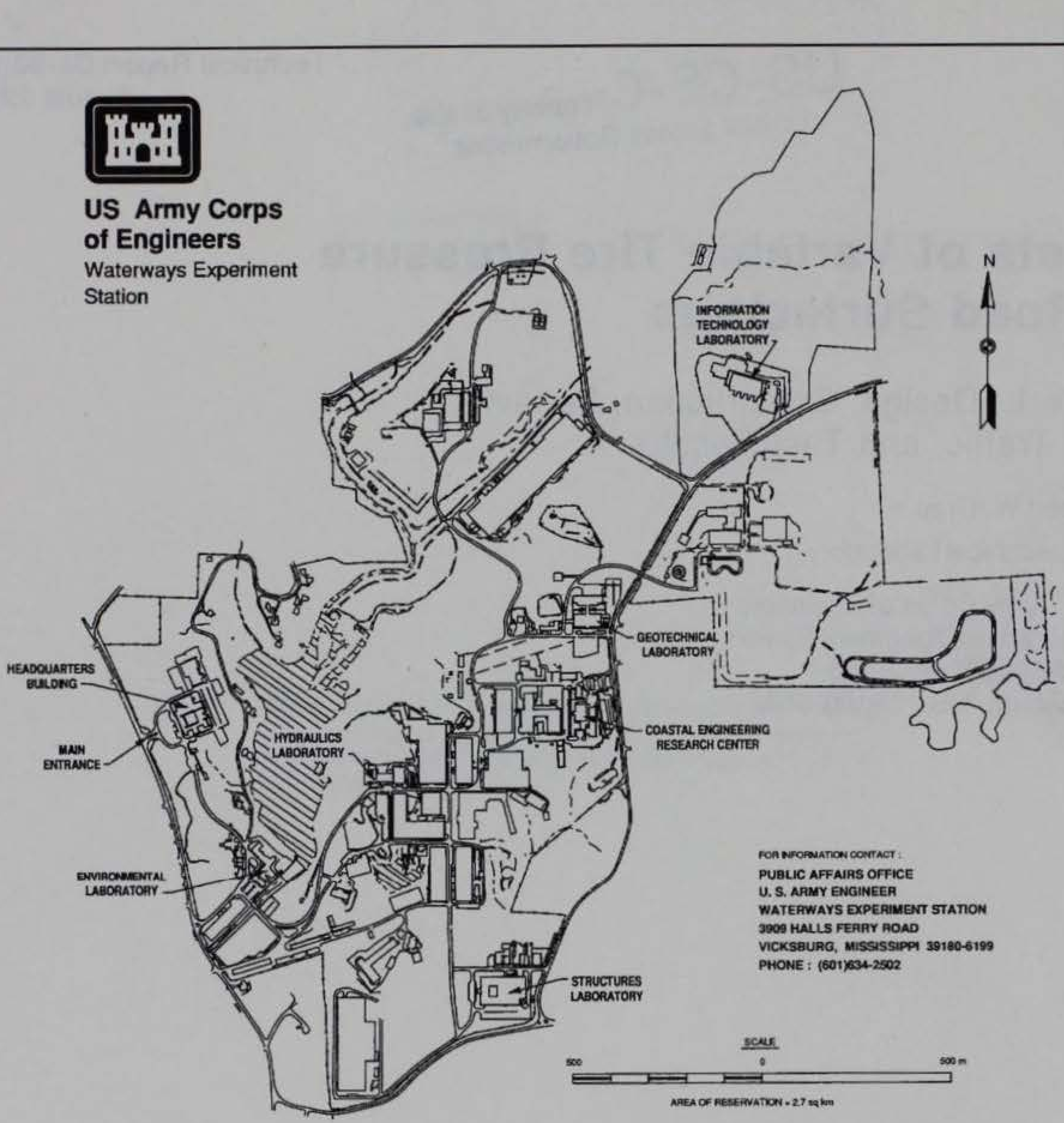
Waterways Experiment Station



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Waterways Experiment Station Cataloging-in-Publication Data

Grau, Robert W. (Robert Walter)

Effects of variable tire pressure on road surfacings. Volume I, Design, construction, behavior under traffic, and test results / by Robert W. Grau ; prepared for U.S. Department of Agriculture Forest Service, Technology and Development Center.

152 p. : ill. ; 28 cm. -- (Technical report ; GL-93-20 v. 1)

1. Pavements, Asphalt concrete -- Testing. 2. Automobiles -- Tires -- Inflation pressure -- Environmental aspects. 3. Roads, Gravel -- Testing. 4. Roads -- Testing. I. Technology & Development Center (San Dimas, Calif.) II. U.S. Army Engineer Waterways Experiment Station. III. Title. IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; GL-93-20 v. 1.
TA7 W34 no.GL-93-20 v.1

Contents

Preface

The authority for performance of this investigation is contained in a Technical Support Agreement to construct and operate a low-speed, low-standard test road at the U.S. Army Engineer Waterways Experiment Station (WES). This agreement between the U.S. Department of Agriculture Forest Service, Technology and Development Center (TDC), San Dimas CA, and WES, Vicksburg, MS, is dated 22 August 1986. This agreement was amended on 18 September 1990 to document, reduce, and analyze the data gathered during the operation of the test road. The software containing these data is included in the inside cover of this report. The Federal Highway Administration (FHWA) Pavement Division, McLean, VA, provided funding for the instrumentation effort and for a portion of the construction and testing. This investigation was conducted from August 1986 to September 1992.

The testing and report preparation for this investigation were accomplished by a WES evaluation team. The team consisted of Messrs. J. W. Hall, Jr., R. W. Grau, J. A. Harrison, S. J. Alford, P. S. McCaffrey, Jr., D. D. Mathews, and Dr. A. J. Bush, Jr., Pavement Systems Division (PSD), Geotechnical Laboratory (GL), WES. This report, the first of two on this project, was prepared by Mr. Grau under the supervision of Messrs. J. W. Hall, Jr., Chief, System Analysis Branch, PSD, and H. H. Ulery, Jr., former Chief, PSD, and Dr. G. M. Hammitt II, Chief, PSD. The work was under the general supervision of Dr. William F. Marcuson III, Director, GL, WES. Messrs. Ed Gililland and Paul H. Greenfield were Program Leaders for TDC.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or kelvins[1]
feet	0.3048	meters
gallons per square yard	4.5273	cubic decimeters per square meter
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square inches	6.4516	square centimeters
tons (2,000 pounds, mass)	907.1847	kilograms

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the formula: $C = (5/9)(F - 32)$. To obtain kelvin (K) reading, use: $k = (5/9)(F - 32) + 273.15$.

1 Introduction

Background

The U.S. Department of Agriculture Forest Service is responsible for approximately 360,000 miles[1] of roads in the National Forests. The vast majority of these roads are low-volume, one-lane, native- or gravel-surfaced roads. In 1983 the Forest Service San Dimas Technology and Development Center, California, began to study the effects of variable tire pressure on the cost of transporting forest products and whether central tire inflation (CTI) systems that allow a driver to adjust a vehicle's tire pressure while in motion will be cost-effective. Structured tests were conducted at the Nevada Automotive Test Center to quantify the effect of lower tire pressure on tire and truck performance and at the U.S. Army Engineer Waterways Experiment Station (WES) to quantify the effect of lower tire pressure on road surface deterioration and pavement thickness requirements. It is hoped that the results from this study will show major benefits of CTI and thus encourage the development and use of CTI equipment in the forest commodity hauling industry. This, in turn, will result in increased net income from timber sales for the Forest Service Regions by reducing the Government's effort required to maintain the roads during timber hauling. Considerable savings should be realized in the construction and maintenance of roads, by the reduction of truck and tire wear, and from the extension of haul seasons.

Objective

The objective of this investigation was to quantify the effect of lowered tire pressure (increase tire deflection) on road deterioration rates, road maintenance, and pavement thickness requirements.

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page v.

Scope

The purpose of this investigation was accomplished by the construction and traffic testing of a specially designed test road. This two laned test road was subdivided into nine asphalt concrete (AC) surfaced and six aggregate or native surfaced test items. A plan view of the test road is shown in Figure 1. The test road was subjected to both loaded and unloaded 18-wheeled log trucks operating in two distinct traffic lanes. Test traffic was applied with the trucks operating at low and high tire pressures. Testing consisted of laboratory tests on the soil, aggregate and asphalt pavement elements; instrumentation measurements of pavement temperature, and deflection and strain resulting from applied dynamic (test traffic and falling weight deflectometer) loads; and field-in-place measurements before, during, and after traffic to document the performance of the test road.

This study represented such an extensive effort that the report of the study was divided into two volumes:

Volume I - Design, Construction, Behavior under Traffic and Test Results
Volume II - Analysis of Test Results

This volume is limited to a detailed description of design, construction, instrumentation, tests, test procedures, test results, and behavior of the various pavement sections under traffic. Examples of the measurements recorded during traffic are presented in tabular and graphical form. All of the measurements taken during this investigation are in either ASCII or LOTUS 1-2-3 spread sheet format on the enclosed 3-1/2 in. high density diskettes. A listing of all directories and their contents is presented in Table 1. Detailed plots of the measurements recorded during traffic testing and considered variables in the design and prediction models used in the analysis phase of this project are included in Volume II.

2 Design, Pavement Elements, and Instrumentation

Design

General

The test road was designed to determine the effect of tire pressure (deflection) on road surface deterioration and thickness design of low-volume roads. This road was approximately 0.7 mile in circumference with parallel 12-ft-wide traffic lanes. It was divided into 15 items and included curves and grades. The surfaces of these items were constructed of either native soil, crushed aggregate, or AC. The total pavement thickness or layer thicknesses were varied for each of the 15 items in order that failures or different amounts of distress would occur throughout the proposed traffic period. The primary variable in both the AC and aggregate test items was thickness. All of the items were designed for a constant-strength subgrade. A plan view of the test road is shown in Figure 1. The type and thickness of the various pavements or surfacing layers for each item are also shown in Figure 1.

Test site

The test road was located at WES utilizing an area which had previously been used for demonstrating rapid road (membrane-enveloped soil layer (MESL)) construction technique. Items 1 and 15 were located in a low-lying area subject to flooding. Portions of the road, items 2 to 6, were constructed in a hilly section with items 2 and 6 being built on slopes. The remainder of the test track (items 7 to 14) was located on a relatively flat area between the toe of the hilly area and a creek. The soil at the test site is a lean clay (loess) deposit.

Pavement Elements

In design and construction of aggregate and AC surfaced roads, experience has shown that good performance can be expected if certain procedures are followed. First, it is necessary that the aggregate and AC are of acceptable quality and, secondly, proper procedures are followed during construction. This section addresses the laboratory properties of the subgrade material, various tests and results used to evaluate the quality of aggregate, and quality of AC mix.

Subgrade material

The natural soil at and near the test site was utilized for the bottom portion of the controlled-strength subgrade. The soil had a liquid limit (LL) of 32 and plasticity index (PI) of 12 and was classified as a lean clay (CL). Classification data are shown as sample 1 in Figure 2. Laboratory compaction and California Bearing Ratio (CBR) data for this material were determined according to AASHTO methods T-180 and T-193-81, respectively, and are shown in Figures 3 and 4. The CBR data in Figure 3 are for specimens tested in the as-molded unsoaked condition, and the data in Figure 4 are for specimens tested after soaking. These data indicate that the strength of the lean clay soil is very sensitive to molding water content and density. By comparison of the data in Figures 3 and 4, it can be noted that for specimens compacted on the dry side of optimum a loss of strength occurs due to soaking. The results of soaking had very little effect on CBR for the specimens compacted on the wet side of optimum. Resilient modulus test was performed on five specimens according to the Willamette National Forest's procedure for testing resilient modulus of subgrade soils. This procedure is very similar to AASHTO T 274-82. Results of these tests performed at confining pressures of 0, 3, and 6 psi are presented in Table 2. In order to encompass all typical stresses on the subgrade for forest roads, the resilient modulus was calculated at deviator stresses of 2, 4, 6, 10, 14, and 18 psi.

Aggregate elements

The tests for aggregate quality included gradation, Los Angeles abrasion, fractured faces, liquid limit, plasticity index, compaction and CBR, and dust ratio. The same crushed limestone aggregate was used for the base material beneath the AC and for the aggregate surfacing. This aggregate met all requirements set forth in EM 7720-100R Forest Service Specifications for Construction of Roads and Minor Drainage Structures, United States Department of Agriculture, April 1985, for base or surface courses. A grading curve for this material is shown as curve 2 in Figure 2. The minus No. 40 fraction of this aggregate had a LL of 15 and PI of 4. The aggregate was classified as a gravely silty sand (SW-SM) according to the Unified Soil Classification System. The percent wear according to AASHTO T-96 was 27, the dust ratio was 0.43, and 100 percent of the particles had at least one fractured face. Laboratory compaction and CBR data for this material were determined according to AASHTO T-180 (method D) and AASHTO T 193-81, respectively. Results of these tests are shown in Figure 5. These data indicate that maximum density by T-180 (method D) equals 143 pcf at a moisture content of about 4 percent. The as-molded strength at optimum moisture content for this compaction effort was 120 CBR.

Asphalt concrete

The mix design for the AC surfacing layer was in accordance with that required by the Louisiana Department of Transportation and Development 1982. The mix consisted of a 3/4-in. maximum size crushed limestone, a coarse and fine sand, and an AC-30 asphalt cement. A combined grading curve for the AC mixture and the gradation specification limits are shown in Figure 6. The job-mix limits are percent asphalt, 4.5 to 4.7; stability, 1,200-lb minimum; flow, 15 maximum; percent voids total mix, 3 to 4; and percent voids filled, 71 to 80. The same mixture was used for AC placed on the test road.

Instrumentation

Devices for the measurement of vertical deflection, strain, and temperature were installed in the AC portion of the test road. The types and location of instrumentation installed in the various test items are shown in Figure 7. A weather station was also erected at the test site. A detailed discussion of the instrumentation results is presented in Chapter 4.

Deflection gages

Multidepth deflectometers (MDD) were installed in the pavement layers of items 10 and 12 to measure transient relative vertical deflection under actual truck loadings and during falling weight deflectometer (FWD) tests. The MDD is typically installed at the layer interfaces. Figure 8 shows a schematic of a typical MDD which consists of modules with linear variable differential transformers (LVDT's). The modules are locked into position by turning the clamping nut, which forces the steel balls outward, clamping them against the sides of the hole at the depth the deflection measurement is desired. The interconnecting rod is adjustable and contains LVDT cores at spacings which coincide with the module placement. A typical MDD installation is shown in Figure 9. The interconnecting rod is fixed to an anchor located approximately 7 ft below the pavement surface. When data are being collected, a reinforced connector cable is attached which links to the data-collection system. When data are not being collected, the connector cable is replaced with a cap which is water tight and flush with the pavement surface. A 386/20 microcomputer with a data translation circuit board was used as the data acquisition system.

Strain gages

Strain gages were placed on the bottom of four 3-in.-diam AC cores. Three of the gaged cores were located in the high pressure lane and the fourth in the low pressure lane. The gages were manufactured by Measurements Group Inc., Raleigh, NC. They were of open-faced construction with a 1 mil tough, flexible polyamide film backing. These gages are designated as type EA-06-20 CBW-120 and had a gage length of 2.0 in. Electrical termination was through flexible waterproof cables to a solar powered Campbell Scientific Inc. CR21XL datalogger which was attached to the weather station stand. The CR21XL is a microprocessor-based system which permits unattended data acquisition utilizing various internal data processing procedures in conjunction with a variety of sensors to output final engineering unit results or measurements. For this particular installation a sensor interrogation interval of 60 sec was selected with an hourly average output for each sensor. Maximum and minimum values were also provided. These values and the sensor readings were stored in a Campbell Scientific storage module, Model SM192. These data were periodically downloaded to a microcomputer.

Thermistors

General purpose Yellow Springs Instrument Co. thermilinear 701 probes were installed in items 6, 10, and 12 (see Figure 7). The guaranteed accuracy of these probes was ± 0.15°C between -30 to + 100°C. Surface temperatures were measured in all items while measurements were also recorded at the bottom and middle of the thicker AC layers. The results of these measurements were processed through the CR21XL datalogger.

Weather station

The weather station shown in Photo 1 was erected alongside item 11. Sensors were installed to monitor ambient temperature, relative humidity, solar radiation, rainfall, wind speed, and barometric pressure. These measurements were also processed through the CR21XL datalogger. Sensor description/identification is as follows:

a. Air temperature/humidity - Campbell Scientific, Inc., Model 207 containing a Phys-Chemical Research Corp. PCRC-11 RH sensor and a Fenwal Electronics UUT51J1 thermistor. Temperature accuracy is typically better than ± 0.2 degrees C from -33.0 to +48.0 degrees C. Humidity sensor accuracy is typically better than ± 5 percent from 12 to 100 percent.

b. Solar radiation - Li-Cor, Inc. Model LI-200SZC, wavelength response 400 to 1,000 nanometers. Maximum error ± 5 percent.

c. Barometric pressure - Kavlico pressure transducer, Model P550 - 15 AA2A, 0-15 PST absolute pressure sensor. Accuracy is ± 0.02 psi.

d. Wind speed - Met-One Inc., Model 014A, calibrated range 0 to 100 mph, Accuracy is 1.5 percent.

e. Precipitation - Sierra Misco, Inc., Model RG2501, accuracy, 1.0 percent at 2 in./hr or less.

3 Construction

The test road was constructed in two phases during the period September 1986 through September 1988. Phase I consisted of removing the existing MESL test road from the site, clearing the brush and top soil and then constructing the subgrade to within 1 ft of the top of the final subgrade elevation. The second phase included the construction of the top 1 ft of subgrade over the entire roadway, the aggregate surfacing of items 1, 2, and 13 through 15, the native surfacing of item 3, and the bituminous pavement for items 4 through 12. Seeding of the shoulders and ditches was also included in Phase II. All work was accomplished under contract by Lewis Miller Construction Company Inc., Vicksburg, MS. The contract was issued by the U.S. Department of Agriculture Forest Service, Kisatchie National Forest (KNF). WES and KNF provided inspectors during the construction of the test road.

In November 1987 the subgrade and base course or aggregate surfacing had been completed and the AC paving was begun. Beginning on 15 November 1987, the Vicksburg area received approximately 11 in. of rain during a 24 hr period. The damage caused by the flash flooding required reconstruction of all of the completed aggregate and asphalt constructed layers and portions of the subgrade. The flood water overtopped and caused severe erosion of the aggregate on items 1 and 15 and portions of items 2 and 14. Severe erosion also occurred in the native soil item 3, and in the aggregate base and/or subgrade of items 4 to 12 which had yet been overlaid with AC. All in-place AC had been undermined to some extent and the outside shoulders including portions of the adjacent high pressure test lane of items 6 to 13 were washed away.

Subgrade

Prior to subgrade construction, trees were removed and vegetation stripped from a 100- to 150-ft-wide path along the center line of the test road. After removing the MESL from the low-lying area, a geotextile was placed over the existing wet weak material before the beginning of subgrade construction. Subgrade construction consisted of rough grading and placement and compaction of fill material to at least 90 percent of AASHTO T 180 to an elevation of 1 ft below finish subgrade along the entire roadway. Borrow material was then brought in and the entire road bed was elevated 1 ft. The borrow and existing subgrade material were the lean clay described under "Laboratory Tests." The borrow material was hauled and spread with self-loading scrapers into an 8- to 10-in. loose lift. The material was then processed to a water content of within 2 percent of the desired construction moisture. A sheepsfoot and self-propelled rubber-tired roller were then used to compact the loose material. A nuclear moisture density meter was used to monitor the density during compaction. Rolling was continued until either the desired density, 95 percent of AASHTO T 180 was achieved or when the in-place density did not increase with additional compactive effort. During compaction pumping was observed in localized areas. As can be determined from Table 2 the desired 95 percent density was not achieved in 10 of the 16 items. The O pass data in Table 3 is considered to be the "as-constructed" data. Measurements were taken at two locations in item 1 because of lane separation to provide for the same radius of curvature. After the final lift had been compacted to maximum density, it was fine bladed to the desired elevation and sealed with the rubber-tired roller.

Aggregate Material

The base material for the AC-surfaced sections and aggregate surfacing material is the crushed limestone described under "Aggregate Elements." The source of this material is the Three Rivers Rock Co., Smithland, Kentucky quarry. This material was nearly saturated in the stockpile prior to loading on dump trucks for transport to the test road. The aggregate was placed in one to three lifts of approximately 3 in. each by use of an asphalt paving machine to prevent segregation. Each lift was compacted with a single-drum vibratory roller as shown in Photo 2. A nuclear moisture density meter (Photo 3) was also used to measure the density during compaction. Generally, the desired density, 95 percent of AASHTO T 180, was not obtained. Seven of twelve density determinations made at the O pass level (see Table 3) were less than the desired degree of compaction. This is attributed to the fact that the high quality crushed limestone material was, in some cases, relatively thin and, in all cases, being placed directly on a relatively weak subgrade with no intermediate strength subbase material. After compaction, the items to be surfaced with AC were primed with approximately 0.30 gal/sq yd of MC-70 cutback asphalt.

Asphalt Concrete

The AC hot mix was placed with an asphalt paving machine as shown in Photo 4 in two 12-ft-wide lanes and one 10-ft-wide lane. The 2-in.-thick pavement (items 4 to 6) was placed in one lift, while the 4- and 5-in.-thick pavements (items 7 to 10 and 12) were placed in two lifts. The 6-in-thick AC in item 11 was placed in three 2-in.-thick lifts. A light application of MC-70 was hand-sprayed between the lifts as a tack coat. Compaction of each lift was obtained by breakdown rolling with a 12-ton tandem steel-wheeled roller (Photo 5), followed by a self-propelled, rubber-tired roller (Photo 6) loaded to 25,000 lb and having a tire pressure of 85 psi. Final rolling was accomplished with the tandem steel-wheel roller. Periodically, plant-mixed samples were taken from the trucks for laboratory extraction, gradation, and Marshall compaction tests to ensure uniformity and compliance with the job-mix design. The results of the laboratory tests are summarized on Table 4. The properties of the mix were within the job-mix limits except the percent total voids which averaged 2.8. Three percent was the lower limit of the voids total mix. The gradation of the in-place mix is shown in Figure 6. After compaction, cores were cut and tested for density. Results from these tests (Table 4) indicate that the average percent density of the in-place mix to the remolded specimens was 97.5 which is slightly less than the 98 percent required.

Properties of As-Constructed Pavements

A summary of the as-constructed (O pass data) thickness, CBR, water content, and density of the various pavement layers in each test section is given in Table 3. The field measurements were obtained from test pits excavated from the surface of the pavement to 6-in. below the surface of the subgrade. The test pits were located in a nontraffic area along the center line of the roadway (designated as wheel path 5) at about the midpoint of each test item. These data for each test item are considered the as-constructed properties for both traffic lanes in each respective item. The relatively low CBR values (21 to 47) indicated for the crushed stone base and surfacing material were due to the thin (3 to 7.5 in) layers of this material being placed over the subgrade which had CBR values ranging between 7 and 22. Pumping was observed during compaction of the crushed aggregate material, which indicates deflection and yielding of the subgrade under the roller, thus the inability to obtain the desired density and resulting strength. The field in-place densities are shown in column A of Table 3. The laboratory densities shown in column B are the T 180 densities corresponding to the field in-place water contents for the aggregate and subgrade materials. Column A/B indicates the percent of laboratory density obtained by field compaction. During construction only an average of 93.8 percent of T-180 was obtained in the crushed aggregate and 94.6 percent in the top foot of the subgrade. The required density was obtained in the aggregate in only four of twelve items and in the top foot of the subgrade in nine of the sixteen test pit locations.

4 Traffic Test and Results

Test Conditions and Procedures

Test traffic was applied in two separate traffic lanes in 15 different test items. The test vehicles (which varied in tire pressure), test lanes and traffic patterns, and test measurements, including results which were pertinent to all test items are discussed in the following paragraphs.

Test vehicles

Traffic was applied to the test road with the two western-style 400 hp 18-wheeled log trucks, shown in Photo 7, running in separate test lanes (low and high pressure) around the test track. Test traffic included both loaded and unloaded passes of the log trucks. Utility poles rather than actual logs were used to load the trucks. This helped prevent a decrease in weight during the traffic period due to the drying of freshly cut timber; therefore, the gross load stayed constant throughout testing. To apply the unloaded traffic, the trailer, including utility poles and the front bunk assembly, was disconnected at the drive axle assembly of each truck. Ballast was then loaded on the drive axles to simulate an empty truck returning to the forest with its trailer loaded piggy back. A specially designed hydraulic lift was used to disconnect the loaded bunk assembly and then store the loaded trailer and bunk until loaded traffic was required. This hydraulic lift assembly is shown in Photo 8. Three bays are empty, and one is holding the ballast which simulates an empty trailer load.

Dimensions were the same for both trucks. Axle and wheel spacings can be determined from Figure 10. Table 5 shows the weights of each side of the five axles under the loaded trucks and estimated weights of the three axles under the unloaded truck. The loaded high and low pressure trucks operated at total gross weights of 76,600 and 77,390 lb, respectively. Both trucks were operated at unloaded gross weights of 26,000 lb (estimated). All wheels on both trucks were equipped with 11R24.5 XZY, load rating G, 14-ply tires. The truck designated as the high pressure truck was operated at typical highway pressure, 100 psi, and all tires which resulted in tire deflections of about 10 and 7 percent when loaded and unloaded, respectively. The low pressure truck was operated at a constant tire deflection of 21 percent. This required tire pressures of 43, 39, and 38 psi for the tires on the steering, drive and trailer axles, respectively, during the loaded traffic. The unloaded low pressure traffic was applied with the steering axle tires inflated to 45 psi and the tires on the drive axle lowered to 18 psi. Tire foot prints were made for all tires on both loaded trucks. A summary of these measurements showing tire print length, width, and area for each respective tire in the loaded condition is shown in Table 6. As can be determined from these data, the average tire print length and area are considerably longer and larger when comparing the low pressure truck to the high pressure truck. The average tire print length and area for the low pressure truck are 12.1 in. and 94.8 sq in. as compared to 9.0 in. and 63.2 sq in. for the high pressure truck.

Test lanes and traffic patterns

The test road was divided into two lanes (high and low tire pressure) and two loops (the entire test road and the AC sections only). Figure 1 depicts these lanes and loops. A 5-ft-wide nontraffic area separated the two lanes in 14 of the 15 test items. Item 1 was constructed to determine the effect of tire pressure while the vehicles are traversing a horizontal curve. Therefore, this item was constructed with each lane having a 90-ft radius, which resulted in two separate road beds spaced about 140 ft apart. The high tire pressure truck operated in the outside lane at all times and the low tire pressure truck operated in the inside lane. Each truck traversed the loops in their respective lane with as little wander as possible, which resulted in four distinct wheel paths across the roadway. These wheel paths are numbered one through four with wheel path 1 located in the high pressure lane adjacent to the outside edge of the roadway (see Figure 1) and wheel path 4 in the low pressure lane and near the inside edge of the test track. Narrow (14.5-ft wide) traffic lanes with no outside shoulders helped keep the wander to a minimum. The loaded traffic was run in a counterclockwise direction while unloaded traffic ran in the clockwise direction. This traffic pattern resulted in simulating typical forest harvest conditions in that the loaded trucks are traveling down an aggregate grade and the unloaded trucks up the grade. During the trafficking of the aggregate sections, loaded and unloaded traffic were alternated on a daily basis until significant data were obtained to determine the difference in performance. Loaded traffic was then applied full-time. As can be determined from the traffic data in computer file (B:\TRAFFIC), the unloaded traffic was only run on 11 occasions or days in the high pressure lane and on 13 days in the low pressure lane. After the 12-in.-thick aggregate overlay had been placed on items 1 and 2, the traffic averaged 85 and 126 passes, respectively, on the high- and low-tire pressure lanes. The average speed during testing was approximately 20 mph. Applying traffic in this manner (alternating on a daily basis) was not representative of actual forest harvest conditions. Usually, only two to six trucks would be used in hauling which would result in only a few loaded and then several unloaded passes. Loaded and unloaded traffic was applied on a daily basis rather than 6 to 8 passes loaded and then the same number unloaded to obtain the maximum number of passes during a given time period. Approximately 8 hr was required to change the trucks from one loading mode to another. When measurements or repair was required on the aggregate portion of the test road, the asphalt cutoff was utilized and only the AC portion or items 4 to 12 trafficked with loaded trucks. Traffic was begun on 10 October 1988 and was intermittently applied through 22 November 1989. A daily traffic log is retrievable from the computer disk. An example of the type of traffic data available is shown in Table 7. These type data are stored for all items. The first and second columns of Example 1 are labeled date. The first date represents the number of days from 1 January 1900 to the respective day-month-year date in column 2. A summary of the total traffic applied is shown in Table 8.

Permanent pavement deformation

Rod and level readings were taken prior to traffic and at various intervals of traffic across the test lanes at predetermined stations. Similar readings were taken along the center of a high and low pressure wheel path in each item. These observations were made to determine the magnitude of pavement deformation resulting from traffic. The results of these measurements are stored on the computer diskettes in ASCII format.

The cross-section measurements, which were taken at three locations per item are stored on diskette 2 in a directory, XSECT, which contains the 16 files shown in Table 9. The measurements for each item is in a separate file with the exception of item 1. These data were divided into two files, I1HPLXS and IlLPLXS, because the two traffic lanes were not adjacent to each other. The AC, aggregate, and native surfaced cross-section measurements are stored in the XSECT directory. The results of the measurements taken in item 8 (File I8XC.ASC) have been selected at random for example purposes. A portion of these data is shown in Table 10. The first seven columns of data in this file indicate (1) test item, (2) location by station as to where the measurements were made, (3) date and cumulative traffic at the time measurements where recorded for (4) loaded traffic in WPs' 3 and 4, (5) unloaded traffic in WPs' 3 and 4, (6) loaded traffic in WPs' 1 and 2, and (7) unloaded traffic in WPs' 1 and 2. The remaining columns are the actual relative elevations calculated for rod readings recorded across the two test lanes on 0.5-ft intervals. The data points across the items were referenced to the center of the item at each particular station. The data in column 8, labeled 16.0, are the elevations determined for a spot located in the low pressure lane near the shoulder and 16 ft from the center of the item. Then each consecutive column of data is 0.5 ft nearer to the center of the item until column "0" is reached. The data to the right of column "0" are elevations for the high pressure lane and continue towards the outside shoulder for 16 ft. Only portions of the low pressure measurements are shown in Table 10 example. Plots such as that shown in Figure 11 for item 8, sta 18+81 can be generated from these x-section files to present graphically pavement deformation at various traffic levels.

Results of the profile measurement taken during traffic are stored in a 14 file directory labeled PROF. See Table 11 for a listing of these files. Rod and level readings were taken at predetermined 1 ft intervals for a length of 100 ft in one wheel path of each lane per item at various traffic levels. If failure occurred, measurements were taken in the failed wheel path. The format of a profile file is shown in Table 12. This table shows a portion of the I8PROF.ASC file which lists the results of the measurements taken in item 8. The first column of this example indicates the foot interval at which the reading was taken. The remaining columns of data are the relative elevations calculated for each predetermined location for the wheel path, date, and traffic indicated. For example, the elevations shown in the far right column were determined from readings made on 28 November 1989 (32,840 days from 1 January 1900) and after 8,333 passes of the loaded and 1,385 passes of the unloaded trucks had been applied in wheel path 3 of item 8. Generally all of the profile results indicate uniform settlement or permanent deformation during the traffic period. These data plot as a smooth curve even in the failed areas.

Profilometer measurements

Several types of automated equipment and rod and level measurements were used to monitor the change in profile or roughness of the pavement surface during traffic. Only the rod and level measurements are reported and considered worthy of analysis. These results were discussed in the previous three paragraphs and the measurements stored in the data files of the PROF directory. Although attempts were made with the Mays Ridemeter, FHWA PRORUT device, and WES Ridemeter to make these measurements, the results were discarded for the following various reasons. The shortness (125 ft) of the AC items and severe roughness (> 6-in. washboarding) caused problems with the use of the Mays Ridemeter and FHWA device. An internal filter in the WES device automatically filtered out the measurements most important in analyzing pavement performance and recorded those values required for mobility analysis.

Nondestructive tests

Nondestructive tests (NDT) were performed on the pavements with the Dynatest model 8000 FWD shown in Photo 9. The FWD is an impact load device that applies a single-impulse transient load of approximately 25 to 30 millisecond duration. With this trailer mounted device, a dynamic force is applied to the pavement surface by dropping a weight onto a set of rubber cushions which results in an impulse loading on an underlying circular plate 11.8 in. in diameter in contact with the pavement. The applied force and pavement deflections are respectively measured with load cells and velocity transducers. The drop height of the weights can be varied from 0 to 15.7 in. to produce a force from 0 to approximately 25,000 lb. The system is controlled with a microcomputer which also records the output data. Velocities were measured and deflections computed at the center of the load plate (D1) and at distances of 12, 24, 36, 48, 60, and 72 in. (D2-D7) from the center of the load plate in order to obtain deflection basin measurements. Data were collected at a minimum of three force levels. The highest force level was set to be less than that required to produce a deflection of 80 mils at D1. The maximum range of the velocity transducers is 80 mils.

The NDT were conducted intermittently throughout traffic at predetermined locations. Testing was performed in each wheel path at the three cross section locations in each test item and at 10-ft intervals along the center of wheel path 5. Wheel path 5 is a nontraffic area approximately 5 ft wide separating the two traffic lanes. NDT were also performed adjacent to the MDD during instrumentation runs. These tests will be discussed later. The output data recorded on the FWD microcomputer was converted to ASCII files. A listing of these files is shown in Table 13. The file name identifies the date NDT were performed. The test locations (items and wheel paths tested) are listed for each file. An example of an NDT file is shown in Table 14. This example is a portion of the measurements recorded on 10 July 1989 (file 10JUL89.NDT) in item 8 and in wheel paths 1, 2, and 3. The station where the tests were performed is listed in column one. Example 18.81 is sta 18+81. In these files lane and wheel paths are the same; therefore, the wheel path in which the NDT were performed is identified in column 2. The pavement surface temperature in degrees F at the time of testing is listed in column 3 and the time in column 4. Column 5 is the load in pounds and the remaining seven columns give the deflection of the pavement computed at distances D1 to D7 from the center of the load plate in mils.

Weather station and thermistors

An hourly average output for each of the sensors installed on the weather station plus the output of the thermistors installed in items 10 and 12 were stored on the data logger and then downloaded to a microcomputer. Data files containing these hourly outputs are in the directory labeled TEMP and when downloaded, they are in the form shown in Table 15. As can be determined from this example data file, some of the pavement temperature averages are omitted. Voids in the downloaded data are intermittent and only occur in the pavement temperature averages for no apparent reason. It is also noted that the negative solar radiation values should be considered as a zero. All other values in the files of the TEMP directory appear to be reasonable and correct. A daily record of precipitation recorded during traffic is stored in the RAIN directory. See Table 16 for an example of this directory.

Performance of Asphalt Concrete Surfaced Items Under Traffic

General

Visual observations of the behavior of the test items were recorded throughout the traffic test period of each lane. These observations were supplemented by photographs and a limited amount of videotape recording. Level readings, nondestructive testing utilizing an FWD, condition surveys, roughness measurements, asphalt strain, deflection at various depths in items 10 and 12, dynamic cone penetrometer (DCP) readings, pavement temperature, and various climatic data obtained from an onsite weather station were recorded prior to and at intervals during traffic to show the development of pavement distress. A discussion and results of the cross section, profile, profilometer, nondestructive and weather station measurements are included under "Test Conditions and Procedures." After failure, a thorough investigation was made by excavating test trenches across the wheel paths to observe the various layers in the structure along with CBR measurements and other pertinent tests in these layers. A summary of the maximum rut depth and general remarks for the failures occurring in the AC items is given in Table 17. All failures occurred during the initial loaded traffic period when only the AC items were being trafficked.

Failure criteria

In judging failure of the AC test items, the performance of the surface course and underlying layers was considered. Base course and subgrade failures due to shear deformation were anticipated because it was not possible to apply a heavy compaction effort in the thinner pavement sections. The term shear deformation as used herein refers to excessive plastic movement or, in the extreme, the rupture of any element in the pavement structure. This was evident when severe rutting and longitudinal cracking of the surface course were observed. Rut depths are defined as the maximum vertical distance from the bottom edge of a straightedge placed on the shoulders (upheaval) of the rut to the bottom of the rut. Shoving was also a major type of distress observed during the trafficking of the test section. Shoving occurred in the outside wheel path of a horizontal curve and could be detected by either the outward movement of the total thickness of AC or of the top layer in relation to the underlying layer.

Since hot bituminous mixes are placed to provide a smooth riding surface and waterproof the base against the penetration of surface water, a pavement item was considered failed when any of the following conditions occurred:

a. Surface rutting of 2 in. or more along a continuous 20-ft-long rut.

b. Surface cracking to the extent that the pavement was no longer waterproof.

c. Severe shoving which resulted in 2-in.-deep ruts or severe cracking of the AC surface.

Throughout the traffic period, rut depth measurements were taken in all four wheel paths at the predetermined cross section locations in each test item. Also, when maximum rutting occurred at some other location (not the cross section locations) the depth of rutting, station, and wheel path were noted. The results of all rut depth measurements are in computer file labeled "Rut."

An example of these data showing a portion of the measurements taken in item 8 is shown in Table 18.

Visual observations

General views prior to traffic of the items (4, 5, and 6) surfaced with a 2-in.-thick AC layer are shown in Photos 10, 11, and 12, respectively. At the beginning of traffic, slight pumping of the AC surface was observed as the high-tire-pressure truck traversed these three items. Surface deformation and pumping were most evident in the outside wheel paths of the horizontal curves. After about 71 passes, distinct rutting and hairline longitudinal cracking along the outside edges of wheel path 2 were noticed in item 4. As traffic continued, the rutting and cracking in item 4 became more severe; one area was rated as failed after 158 passes. This failure occurred in wheel path 2 and was attributed to a 2.25-in. rut running approximately 30 ft in length. Also, the cracking in this area had progressed into medium severity alligator cracking. Photo 13 depicts a general view of this initial failure. It should be noted that in item 4, wheel path 2 is located in the outside portion of the horizontal curve. The inside wheel path (wheel path 1) was rutted from 0.5- to 0.75-in. for a length of about 120 ft. Low severity rutting was detected in wheel path 1 of items 5 and 6 after 180 passes of the loaded truck. The depth of this rutting averaged 0.2 in. and the maximum was 0.75-in. in a localized spot at sta 21+65 in item 6. After an additional 165 passes, for a total of 323 passes, a second failure occurred in item 4, wheel path 2. Photo 14 shows a general view of this second failure. Again the majority of the rutting occurred in wheel path 2, and very little distress had occurred in wheel path 1. Both failures in item 4 are attributed to overloading or failure of the subgrade. Photo 15 which is a view of a test pit excavated in the failed area, indicates severe rutting of the subgrade. At the time of this second failure in the high-tire-pressure lane (323 passes), very little distress was present in the low pressure lane. There was no cracking evident, and the maximum rut depth was only 0.5 in. In item 5 after 323 passes the rutting in the high pressure lane averaged about 0.5 in. with the maximum being 1.0-in. as shown in Photo 16. There was no surface cracking at this time. The rutting in wheel path 4 of item 5 had increased to 1.4 in. Although most of the rutting in item 6 was 1 in. or less in wheel paths 1 and 2 after 323 passes, rutting up to 2.25 in. as shown in Photo 17 was detected in a localized 14-ft long area. Rutting in the low pressure lane measured 0.75 in. maximum. As shown in Photo 18 severe rutting and cracking were present along a 50- to 60-ft localized area of wheel path 4, item 5 after 323 passes. Only slight rutting and no cracking was detected in the wheel path adjacent to these localized weak areas in items 5 and 6. There was also very little distress present 5- to 10-ft before or after these highly distressed areas within the same wheel path. The poor performance of these areas was attributed to a wet weak subgrade which was not detected and repaired after the November 1987 flash flood. The pavement performance in these areas was not considered representative of the test item and was therefore disregarded. In order to prevent the migration of pavement distress in these weak areas to the sound adjacent area, major maintenance was required. This entailed sawing around the perimeter of the distressed AC, removing the AC, base material, and wet subgrade and then back filling the excavation with full-depth AC. The high pressure lane of item 4 was also patched and overlaid with 7 in. of AC at this time. The overlay was to prevent further deterioration during the remainder of the scheduled traffic period. After patching and overlaying traffic was continued, the rate of pavement deterioration decreased with the continuation of traffic. The next failures in the road occurred after 1,104 and 1,414 passes in wheel path 1 of items 6 and 5, respectively. A general view of the failure in item 6 is shown in Photo 19. As can be determined from this photo, the failure was due to rutting and severe cracking in the outside wheel path of a horizontal curve. There was no cracking and only 0.5-in. maximum rutting in wheel path 2 at this time. The failure in item 5 after 1,414 passes was very similar to the failure in item 6. When these first two items were judged failed in the high-tire-pressure lane, only hairline cracking and minor rutting were detected in the adjacent low pressure lanes. The average rut depth in the low-tire-pressure lane of item 6 after 1,104 passes was about 0.7 in. and in item 5 about 0.4 in. after 1,414 passes. Throughout the remainder of traffic in the high-tire-pressure lane (6,764 loaded and 1,113 unloaded passes) only one additional failure occurred in item 5 and none in item 6. The portion of wheel path 1, item 5 shown in Photo 20 was judged failed (second failure) after 2,210 passes. The mode of failure was the same as that in the previous failures. Four failures, two in item 4 and one each in items 5 and 6 occurred in the low-tire-pressure lane of the 2-in.-thick AC items. In addition to rutting and cracking, raveling was also observed at the time item 6 was judged failed. Views of the failed areas in Items 5 and 6 are shown in Photo 21 and 22, respectively. The failures in item 4 occurred at 3,324 and 3,845 passes. As can be determined from Photo 23 and 24 rutting was more evident in both wheel paths at the time of these failures as compared to the previous failures.

General views of the 4- to 6 in. thick AC surfaced items (items 7 through 12) before traffic are shown in Photos 25 through 30, respectively. The performance of these items during traffic was about the same with exception of items 9 and 10. Raveling was more evident in item 9 because horizontal curve and shoving occurred in both lanes of item 10. Rut measurements were first taken after 323 passes. The maximum rutting was 0.5 in., and it was located in wheel path 3 of item 12 at sta 13+81. This is the area in which the low pressure truck is beginning to straighten out after coming down the 16 percent grade asphalt cutoff. It is also in the outside wheel path of a horizontal curve. Slight raveling was detected in this area at this time. As traffic was continued over these items, the rate of rutting and/or other types of distress was very slow. Medium severity rutting (1/2 to 1 in.) first occurred in the high pressure lane of item 8 after 773 passes and in the low pressure lane of item 10 after 3,128 passes. High severity rutting, greater than 1 in., occurred after 1,712 passes of the high pressure truck in item 10 and after 4,045 passes of the low pressure truck over item 12. During the entire traffic period there was no high severity rutting in item 11 and in only a localized area at sta 20+70 in wheel path 3 of item 7. The distress in this area was not representative of the entire 125-ft-long item and therefore not considered in the overall performance of item 7 during traffic. The subgrade in this area was weak due to the previous flooding. Medium-severity rutting as defined in TM 5-623 (Headquarters, Department of the Army 1982)[1] occurred first only 50 percent of the time in the high pressure lane. However, high-severity rutting was detected first in the high pressure lane as compared to the low pressure lane in all items. Other than the distress which occurred in item 10, raveling was the only other notable distress measured in items 7 through 12 throughout the traffic period. Again, raveling was more severe in the horizontal curves of the low pressure lane. A portion of wheel path 1 in item 10 was considered failed after 2,210 passes. This failure was attributed to severe shoving of the top lift of AC after 1,812 passes (see Photo 31) and then severe cracking and rutting of the surface after 2,210 passes as shown in Photo 32. This failure occurred in an area where the traffic was entering a horizontal curve and at the beginning of warm weather traffic. Test traffic was applied to the AC section of the roadway during two periods from October 1988 to February 1989 and from June to November 1989. The shoving, shown in Photo 31, occurred after 245 passes had been applied in June 1989. Shoving (Photo 33) was detected in the low-tire-pressure lane of item 10 after 1,200 passes of warm weather traffic or a total of 4,200 passes.

Although the same criteria were used in judging failure in both traffic lanes, the rutting at failure in the high-tire-pressure lane appeared more pronounced. Generally there was very little upheaval associated with the ruts in the low-tire-pressure lane. Also, the ruts caused by the low-tire-pressure truck were 6 to 12 in. wider than those in the opposite lane.

Condition survey

A condition survey of the test road was made in accordance with TM 5-623 (Headquarters, Department of the Army 1982) to monitor the change in surface condition during traffic. A pavement condition survey is a visual inspection to determine the present surface condition. The condition survey consists of inspecting the pavement surface for the various types of distresses, determining the severity of each distress, and measuring the quantity of each distress. The result of the condition survey is the pavement condition index (PCI) of each sample unit. Each test item was divided into two sample units. The low pressure lane was one sample unit, and the high pressure lane was the other unit. The PCI is a numerical indicator based on a scale from 0 to 100 and is determined by measuring pavement surface distress that reflects the surface condition of the pavement. Based on its PCI each sample unit was rated as excellent (85-100), very good (70-85), good (55-70), fair (40-55), poor (25-40), very poor (10-25), or failed (0-10). A condition survey was performed at various intervals throughout the traffic period and at failure or the end of traffic. A summary of the pavement condition survey results is in the PCI directory and is identified as file "Summary PCI." An example of the data in the "Summary PCI" file is shown in Table 19. Table 19 lists the test item number, traffic lane, date at which the survey was

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[1] Headquarters, Department of the Army. 1982. "Pavement Maintenance Management," Technical Manual TM 5-623, Washington, DC.

made, the loaded and total traffic (loaded and unloaded), and PCI of each sample unit inspected. The distress measurements for all surveys were entered into a pavement management computer program, Micro PAVER. The inspection report for each sample unit surveyed is stored in file "CTI PCI" and directory PCI. An example inspection report is presented as Table 20. In these reports the item is identified opposite the branch name and the lane H or L for high or low opposite item number. Also identified are the date of inspection, size of sample unit, PCI, rating, distress quantity, and distress mechanism. The major distress types observed on the AC pavements were rutting, shoving, alligator cracking, and raveling. All distress measured during this investigation was attributed to traffic.

Instrumentation measurements

Dynamic and NDT load tests were made on the instrumented test items, and the response of the pavement-soil system was monitored by the in-place instrumentation. This instrumentation consists of the MDDs, strain gages, and thermistors discussed in Chapter 2. The strains on the bottom of the AC measured during this investigation were very inconsistent, positive and negative values for no apparent reason; therefore, these measurements were considered inaccurate and are not included as results of this investigation.

The loaded log trucks were used to apply dynamic loads to the MDDs. Both trucks were operated at various speeds over the MDDs installed in the high pressure and low pressure lanes in item 10 and over the MDDs positioned in the high pressure lane of item 12. Results of the measurements recorded during these tests are stored in the MDD1212 and MDD1111 directories. Each file in directory MDD1212 and MDD1111 are identified in Tables 21 and 22, respectively. These tables indicate the location of the MDDs (both item and lane) and the method of loading (FWD, HPT, or LPT) for the measurements recorded in each file. An example showing a portion of the measurements recorded by the MDD installed in item 10 is shown in Table 23. The first column of data in Table 23 indicates the time in milliseconds from the beginning to the end of testing and the remaining columns list the deflection in mils measured by the LVDTs during the test. Tests performed in item 10 have three columns of LVDT measurements while those performed in item 12 have two columns of LVDT measurements. LVDTs were installed at depths of 4.3-, 10.4-, and 24.2-in. at both MDD locations in item 10 and at depths of 5.0- and 17.3- in. for the MDD located in the high pressure lane of item 12. A typical response of the MDD in item 10 under loading of the high-tire-pressure truck operating at 2.1 mph is shown in Figure 12. Figure 13 shows plots of truck speed versus deflection based on the response of the MDD in the high pressure lane of item 10 loaded by both the high- and low-tire pressure trucks. As can be determined from these plots, the deflection of the pavement layers decreased as speed increased and also with lower tire pressures for the same gross loads. Approximately 10 percent more maximum deflection was measured in the high pressure lane of item 10 under the loads applied by the high-tire-pressure truck as compared to the deflections measured under the low-tire-pressure truck loads.

The FWD was also used as a loading device on the MDD instrumented test items. During these tests the FWD was operated at three drop heights and with the edge of the load plate located about 2 in. from the MDD. The loads produced at the three drop heights were about 6,000, 9,000, and 15,000 lb. The exact loads and corresponding deflection basin measurements recorded during these tests are presented in Table 24. The LVDT measurements recorded during each FWD test are stored in the file identified in the first column of Table 24. A typical response of the MDD in item 10 under a FWD loading is shown in Figure 14.

Failure investigations

After failure, a trench was usually cut across the traffic lane to determine the extent of distortion of the various elements of the pavement structure. In-place CBR tests and water content and density determinations were also made of the different elements of the test item as the trench was excavated.

Rod and level readings were made of each of the investigation trenches so that pit profiles such as that shown in Figure 15 for the test pit excavated in item 4 after 323 passes can be plotted. These data are in the XSECT directory. A view of the test pit excavated in item 4 is shown in Photo 15. CBR test results, layer thicknesses, and other pertinent data for all failures are presented in Table 3. The layer thicknesses presented in Table 3 were determined from rod and level readings taken as each layer was removed. Severe shear deformation developed in the base and subgrade materials of all failures except the failure in item 10. Shear deformation was also indicated by the loss of strength of the subgrade material at failure as compared to the before traffic strengths. The average as-constructed strengths of the subgrade material for items 4, 5, and 6 were 10, 12, and 13 CBR, respectively, as compared to 7.5, 5, and 6 CBR at failure. The base material strengths in items 4 and 5 were low after construction and at failure. The strengths before traffic averaged 23 CBR and at failure 22 CBR. The base course in item 6 had a strength of 24 CBR before traffic and 49 CBR at failure. The failure in the high pressure lane of Item 10 was attributed to severe shoving of the AC. The average respective strengths of the base and subgrade materials after construction were 39 and 21 CBR, while those after failure were 21 and 16 CBR.

Performance of Aggregate and Native Surfaced Items Under Traffic

General

Traffic was applied in three phases. The initial traffic was applied when the subgrade was very wet and resulted in premature failure in Items 1, 2, and 3. After reconstruction of these items, performance data were obtained until the subgrade began to dry out and gain strength which resulted in no additional distress as traffic was continued. Therefore, phase 3 or the induced failure plan was introduced. The plan called for controlled irrigation to weaken the subgrade and then applying test traffic. Visual observations of the behavior of the test sections were recorded throughout the entire traffic period. Level readings, NDT, condition surveys, DCP measurements, and rut depth measurements were taken during traffic to document the performance of the various test items during traffic. A discussion of the level readings (cross section and profile), profilometer, NDT, and weather station measurements recorded during traffic testing are included in Chapter 4 under "Test Conditions and Procedures." After failure, test trenches were excavated across the wheel paths to observe the various layers in the structure along with CBR measurements and other pertinent tests in the layers. A summary of the maximum rut depth, degree of washboarding, and general remarks for the failures occurring in the aggregate sections is given in Table 25.

Failure criteria

Aggregate is placed on a gravel-surfaced road to protect the subgrade from being overloaded and to make the surface more resistant to the abrasive effects of traffic. The ability of the aggregate layer to carry heavy sustained traffic mainly depends upon the thickness of the layer. Reduction in thickness, such as by rutting, decreases the load-carrying capacity of an aggregate-surfaced road. Gravel roads require considerable maintenance such as blading, addition of replacement aggregate, and dust control to correct rutting and washboarding. Ruts are defined and measured for gravel roads, as described in the failure criteria for AC-surfaced roads. Washboarding is a series of closely spaced ridges and valleys perpendicular to the direction of traffic and at fairly regular intervals. Washboarding is measured in inches and is the vertical distance between the top of the ridge and bottom of the valley. The aggregate sections were considered failed when any of the following conditions existed for a 20-ft-long section of a wheel path:

a. Three-inch ruts in test sections 1, 2, and 13.

b. Four-inch ruts in test sections 14 and 15.

c. Washboarding of 3 in. or more.

The 3-in. rut depth failure criteria were used for items 1, 2, and 13 because the total thickness of the aggregate layer was only 3 in. A greater degree of rutting in these items would result in the bottom of the rut possibly being below the aggregate/subgrade interface. Grading would then result as a soil aggregate layer rather than an aggregate surface. After several grading cycles, the original aggregate would be of little benefit structurally or as a surfacing material because of contamination. Condition "b" was selected as the failure criteria for the native section. However, premature failure occurred in item 3 which resulted in no analysis for the testing of the native surfaced item. Rut measurements were taken and recorded in the manner discussed previously for the AC items. The results of these measurements are in the same computer file (RUT) as are the AC rut depth measurements.

Visual observations

General views of the high pressure lane and low pressure lane of Item 1 before traffic are shown in Photos 34 and 35, respectively. A view of both lanes of item 2 before traffic is shown in Photo 36, and a view of the native portion of the test road, item 3, before traffic is shown in Photo 37. The tracks in the high pressure lane of item 3 were made by the CBR test truck when it was accidently driven onto the section after a rain. Overall views of items 13 through 15 prior to traffic are shown in Photos 38 through 40, respectively. As can be determined from these photos, the two traffic lanes were separated by traffic cones. Traffic was initiated on 10 October 1988 and stopped after one pass because of wet and weak subgrades in items 1, 2, 3, and 15. With the outlook of winter and spring rains ahead, it was decided to postpone traffic on all the aggregate sections until the following summer. This delay should give the subgrade time to dry out and gain strength which would result in at least a limited amount of performance data from the thinner aggregate and native items. On 23 June 1989 it was decided to include the aggregate sections in the traffic pattern. Only a trace of rain had been recorded during the past 8 days, and dry weather was in the forecast. With the initial pass, it was evident that items 1 to 3 would withstand very few passes of the 80,000-lb log trucks. After 10 passes severe rutting was observed in items 1 to 3. As shown in Photo 41, rut depths of 5.5 in. were measured in item 1 after 10 passes. Rutting up to about 3 in. was measured in items 2 and 3 after 10 passes. The maximum rutting in items 13 to 15 at this time was only 1 in. or less. After a total of 58 passes in the high-tire-pressure lane and 66 passes in the low-tire-pressure lane, traffic was discontinued because of 2-in.-deep or greater ruts for a 20 ft length in the wheel paths of these three items. Photos 42 and 43 show views of the low-and high-tire pressure lanes of item 1 at failure. Severe rutting as shown in Photos 44 and 45 had also developed in the high-and low-tire pressure lanes of item 2. Shearing of the subgrade was evident in both lanes of items 1 to 3 at this time. As can be seen in Photo 44 the subgrade had sheared and was visible from the surface. The only difference in the performance of the two lanes is items 13 to 15 at this time was low-severity washboarding in the high-tire-pressure lane of item 15 (see Photo 46) as compared to none in the other items. It was determined that because of the weak subgrade beneath items 1 to 3, very little additional information could be gained by blading and applying more traffic. Therefore, they were overlaid with enough aggregate (12-in.-thick layer) to bridge the weak subgrade and withstand the scheduled test traffic. During the remainder of traffic, these items were monitored to determine the effect of tire pressure on maintenance requirements. As traffic was continued, loaded and unloaded traffic was alternated on a daily basis. Very little distress was noticed during the first day of traffic, which totaled 60 and 72 passes of loaded trucks over the high-and low-tire-pressure lanes, respectively. The next day the unloaded trucks operated, and washboarding was very noticeable in item 2 in the high-tire-pressure lane after about

50 passes. The corrugation was 2.5 in. deep, and the truck driver reduced speed in order to safely maneuver over item 2. After 112 passes, severe washboarding was measured throughout the high-tire-pressure lane of item 2. At this time, this item was judged as failed and required blading. An overall view of the high-tire-pressure lane of item 2 after the 112 unloaded passes is shown in Photo 47, and a close-up of the washboarding is shown in Photo 48. Unloaded traffic was applied directly after blading which resulted again in washboarding. After 10 passes, the high-tire-pressure truck again had to reduce speed and after 35 passes the corrugations were 2.5 in. deep. When traffic was switched to loaded (trucks running downhill), the maximum depth of washboarding decreased about an inch. The high-tire-pressure unloaded traffic continued to cause severe distress in item 2, and after 584 loaded and 556 unloaded passes this item was graded for the fourth time. Monitoring performance of this item and lane was discontinued after the fourth failure. The maximum rut depth was measured at each time, and item 2 was judged failed as shown in Table 25. Very little distress was observed in the low-tire-pressure lane of Item 2, and grading was never required. The greatest distress occurred when a pothole occurred in the no-test-section area adjacent to this item which resulted in washboarding migrating into item 2. However, as shown in Photo 49, the low-pressure tires seemed to dampen out the bouncing of the truck which resulted in no corrugation 15 to 20 ft from the pothole. The horizontal curves in item 1 performed approximately the same under low- and high-tire-pressure traffic. Neither required grading after being overlaid. The high-pressure-tire lane received 2,586 and 1,172 passes of loaded and unloaded traffic, respectively, and the low-tire-pressure lane received a total of 3,023 loaded and 1,384 unloaded passes of the log truck. By the end of traffic, the only distress observed was minor rutting in both lanes and low-severity corrugation in the high-tire-pressure lane. Photos 50 and 51 show general views of the high-and low-tire-pressure lane, respectively, of item 1 depicting the above distresses.

Due to the higher subgrade strengths and no vertical or horizontal curves, items 13 to 15 performed quite a bit better during traffic than did items 1 to 3. Very little distress was detected in items 13 to 15 until about 90 passes of loaded traffic was applied to both lanes during a light drizzle on 29 September 1989. Traffic had not been applied the previous day due to a heavy (1.22-in.) rain. A considerable increase in rutting of all wheel paths of each test item resulted from the 90 passes applied after this rain. The maximum rutting in item 13 increased from 1.5-in. to 4.75-in. In items 14 and 15 the rutting increased from 3.0-in. and 1.75-in. to 4.25- and 5.75-in., respectively. General views of the high-and low-tire-pressure lanes of item 14 at this time are shown in Photos 52 and 53. A total of 883 loaded and 672 unloaded passes had been applied in the high-tire-pressure lane and 1,077 loaded and 838 unloaded passes in the low-tire-pressure lane of these items. Each item was rated as failed due to severe rutting and required grading. It should be noted that these failures were attributed to a wet subgrade, and there was no notable differences between the performance of the various items or test lanes. The aggregate thicknesses of 3, 6, and 9 in. were not sufficient to protect the weak wet subgrade. Grading as shown in Photo 54 removed the ruts in all items. After grading, unloaded traffic was first applied to compact the loose material on the surface and then the loaded and unloaded traffic was alternated. In order to prevent another premature failure, test traffic (loaded and unloaded) was only applied during dry conditions. Very little distress was observed with traffic being applied under these conditions; therefore, it was decided to discontinue the unloaded traffic. After 530 loaded passes in the high-tire-pressure lane and 590 loaded passes in the low-tire-pressure lane, the rut depths in all wheel paths of items 13 to 15 averaged about 1.5 in. with little indication of increasing. During the combination of loaded and unloaded traffic, medium severity corrugations would develop in the high-tire-pressure lane of all three items under unloaded traffic, and then the severity level would decrease to low under loaded traffic conditions. During this same traffic period washboarding was detected in the low-tire-pressure lane only in item 15. The severity level was low during both loaded and unloaded traffic.

Since the surface distress was not increasing with traffic in items 13 to 15 and it was very desirable to obtain failure in these items before the winter rains set in, an induced failure plan was implemented on 24 October 1989. This plan called for an irrigation system to simulate rainfall to weaken the roadway structure at a controlled rate, to apply only loaded traffic, and to take DCP and rut depth measurements. Before the first watering cycle each lane was graded and then trafficked with 25 passes of the log trucks to compact the loose material in the wheel paths before watering. After each rain simulation, DCP measurements were taken in order to monitor the aggregate and subgrade strengths. On 31 October 1989 watering and traffic testing was begun under this plan and continued until all test traffic was stopped on 22 November 1989. A summary showing dates, water applied, amount of traffic, and general remarks made during this period is shown in Table 26. Low-severity rutting developed in all items after 0.75 in. of simulated rainfall and 10 passes in each lane. The only other distress observed at this time was a high severity pothole in the low-tire-pressure lane of items 13 and 14. Very little additional distress was observed during the next 120 passes and 1.00 in. of rain. Overall the rutting rated as low severity in the high-tire-pressure lane of items 13 and 15 and as medium in all other lanes and items. The maximum distress observed at this time was the high-severity rutting in wheel path 3 of item 14 as shown in Photo 55. Overall views of items 13 to 15 after 130 passes in the low-tire-pressure lane under the induced failure plan are shown in Photos 56 to 58. General views of the high-tire-pressure lane of items 13 to 15 at this time are shown in Photos 59 to 61. As can be detected from these six photos, the surfaces of each item and lane were relatively smooth with no major rutting or washboarding. As additional traffic was applied, the distresses became more pronounced, and failure was reached once in the high-tire-pressure lane of item 14 after 491 passes due to high-severity rutting and washboarding. Failures also occurred in the high-tire-pressure lane of item 15 after 506, 855, and 1,035 passes. There were no failures in the low-tire-pressure lane. Photo 62 shows the high-severity washboarding detected in the high-tire-pressure lane of item 14 at failure. For comparison purposes, a view of the maximum distress in the low-tire-pressure lane of Item 14 at the same time the high-tire-pressure lane was rated as failed is shown in Photo 63. This high-severity pothole shown in Photo 63 originally developed after about 10 passes and was only about a foot long. As traffic continued, this pothole became longer, and as shown in Photo 64 after 570 passes, it had developed into a low-severity depression instead of a high-severity pothole. The failures in item 15 were attributed to high-severity rutting with medium-to high-severity washboarding. A typical view of washboarding after item 15 was rated as failed and is shown in Photo 65. At this same time the washboarding in the low-tire-pressure lane was measured as low-severity (see Photo 66). As traffic continued, the majority of additional distress occurred in the high-tire-pressure lane of item 15. The aggregate became very loose and deep ruts developed. A general view of item 15 depicting this condition is shown in Photo 67. Although rutting up to 6.5 in. was measured in item 13 the maximum length never measured 20 ft; therefore, the failure criteria were not met. On 22 November 1989 the decision was made to stop all test traffic. At this time a total of 3,698 and 4,407 passes had been applied to the high- and low-tire-pressure lanes, respectively. The total traffic applied to the high- and low-tire-pressure lanes under the induced failure plan was 1,135 and 1,309 passes, respectively.

Condition survey

A condition survey of the aggregate portion of the test road was made in accordance with Special Report 87-15 (Eaton, Gerard, and Cate 1987)[2] to monitor the change in surface condition during traffic. The method of performing this survey, making measurements and calculating the unsurfaced road condition index (URCI) is very similar to that described previously for determining the PCI of AC surfaced items. The major differences are the types of distress. For unsurfaced roads the distress types are (a) improper cross section, (b)inadequate roadside drainage, (c) corrugations, (d) dust, (e) potholes, (f) ruts, and (g) loose aggregate as compared to 19 distresses for AC surfaced roads. The measurement recorded in the field at the various traffic intervals was entered into a pavement management computer program "Micro PAVER." These data and a summary of the URCI's for each inspection are stored in computer file "PCI." The actual types of distress observed including severity and quantity for each inspection interval is stored in this file and can be retrieved as an inspection report. An example inspection report indicating the distresses measured in the high-tire-pressure lane of item 1 on 29 November 1989 is shown in Table 27. The summary of results are in the same format as shown in Table 19 for the example PCI summary. The major distresses observed during traffic were rutting, corrugations, and potholes.

DCP and Clegg hammer measurements

The DCP consists of a steel rod with a cone at one end which is driven through the pavement structure by means of a sliding hammer (Figure 16).

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[2] R. A. Eaton, S. Gerard, and D. W. Cate. 1987. "Rating Unsurfaced Roads, A Field Manual for Measuring Maintenance Problems," Cold Regions Research and Engineering Laboratory, Hanover, NH.

The material resistance to penetration is recorded in terms of inches penetrated per hammer blow. For this investigation the cone of the DCP was placed on top of the aggregate base, and the number of blows versus depth was recorded. CBR was then determined based on a correlation of inches/blow and CBR. DCP testing was performed at every test pit location before pit excavation was begun, at various intervals during traffic, and at four locations in each item once the induced failure plan was implemented. The tests during the induced failure plan were performed to monitor the reduction in strength as water was applied. Clegg hammer tests were performed on the top of the upper material being tested by the DCP. The Clegg Impact Soil Tester consists of a 10-lb compaction hammer with a guide tube and a specially designed electronic meter. An accelerometer fastened to the hammer measures the peak deceleration in units of Clegg impact value (CIV) as the hammer drops 18 in. Results of the DCP and Clegg hammer tests are in the DCP directory. A listing of the files in this directory is shown in Table 28. An example of a DCP file is presented in Table 29. As can be determined from Table 29 the DCP results include the test location (item, station, and wheel path) date tests were performed, traffic at time of testing (both loaded and unloaded passes), CBR determinations versus depth, and Clegg hammer results in terms of CIV. Three or four Clegg hammer tests were performed on the surface of the upper layer. The results of each of these tests are listed in the far right column on Table 29.

Maintenance requirements

Two types of maintenance, adding aggregate and blading, were required during traffic. After 58 passes in the high-tire-pressure lane and 66 passes in the low-tire-pressure lane items 1, 2, and 3 were judged failed due to high-severity rutting. The subgrades in these items were wet and weak and would not support either the high-or low-tire-pressure traffic. Therefore, a 12-in.-thick layer of aggregate was placed on each of these items to bridge over the weak subgrade material. Throughout the remainder of the traffic period blading was the only type maintenance activity required and was performed after an item was judged as failed or after uniform rutting in both lanes due to a weakened subgrade. Grading consisted of either blading or scarifying the aggregate down to the bottom of the ruts across the entire lane and then reshaping the roadway to its original cross section. After fine blading, test traffic was continued. Compaction was achieved from the application of test traffic and not from equipment such as rubber tired or vibratory rollers. Vehicular traffic is the general method of obtaining density after blading on forest haul roads, therefore compaction equipment was not used during maintenance performed in this investigation. Grading was most often required in the high-tire-pressure lane of item 2 and always due to high severity rutting and washboarding. Failure always occurred in item 2 during the unloaded traffic period. The unloaded truck was driven up the 12 percent grade and once the drive wheels began to slip, severe corrugations and rutting would develop. The speed of the truck would then have to be reduced in order that the truck could traverse the item safely. Grading was never required in the low-tire-pressure lane of item 2. The grading increments are documented in the remarks column of Table 25. It should be pointed out that the only time grading was required in the low-tire-pressure lane was when traffic was applied after or during a rain and severe rutting occurred in both lanes due to a weak subgrade.

Failure investigations

After most of the failures, the rut depth measurements were complimented with one or more of the following: photos, cross section and profile measurements, condition survey, DCP measurements, and/or NDT. A discussion or description of many of the failures is in the "visual observations" section of this report and include typical photos of areas judged failed. Cross section and profile measurements, condition survey results, and DCP and NDT measurements taken after failure of a particular item are stored in enclosed computer files. Test trenches were not excavated across the traffic lane after it was judged failed. Therefore, CBR, water content, and density measurements were not available for the failed areas. Once test traffic was applied on a regular bases, the top priority was to fail as many items as possible in a short time period because of limited funds and the possibility of damaging and uncontrollable rainfall. Therefore, test trenches were omitted and only limited data were taken after each failure. Traffic was discontinued on the 22 November 1989, and in early December test trenches were excavated in items 13, 14, and 15. At this time CBR, moisture content, density, and thickness determinations were made in the second and third wheel paths of the aggregate and subgrade materials. These data are summarized in Table 3. A general view of the post traffic test pit excavated in item 13 is shown in Photo 68.

5 Summary of Findings and Recommendations

Summary of Findings

The findings from the traffic testing of the CTI test road showed that:

a. The failures or distresses in the high-tire-pressure lane of the AC sections were more pronounced than those in the low-tire-pressure lane.

b. When failures occurred in both lanes of the same AC item, the ratio of low-tire-pressure to high-tire-pressure traffic to initial failure ranged between 1.5 and 21.

c. More raveling was observed in the low-tire-pressure lane in the horizontal curves of the AC sections than in the high-tire-pressure lane.

d. Comparative pavement performance of the thicker AC items is unavailable because traffic was stopped before failures occurred. Only minor low severity distresses was present at this time.

e. The first failures which occurred in Items 1 to 3 and 13 to 15 should not be considered in the analysis of the test results. These failures occurred in both lanes after the same amount of traffic had been applied directly after a rain. All of these failures were attributed to subgrade failure.

f. Considerable maintenance will be required on aggregate-surfaced grades receiving high-tire-pressure unloaded traffic because of the severe washboarding. This type of distress is not a factor under low-tire-pressure traffic regardless of being loaded or unloaded.

g. There was no appreciable difference in the performance of aggregate-surfaced horizontal curves due to the different tire pressures.

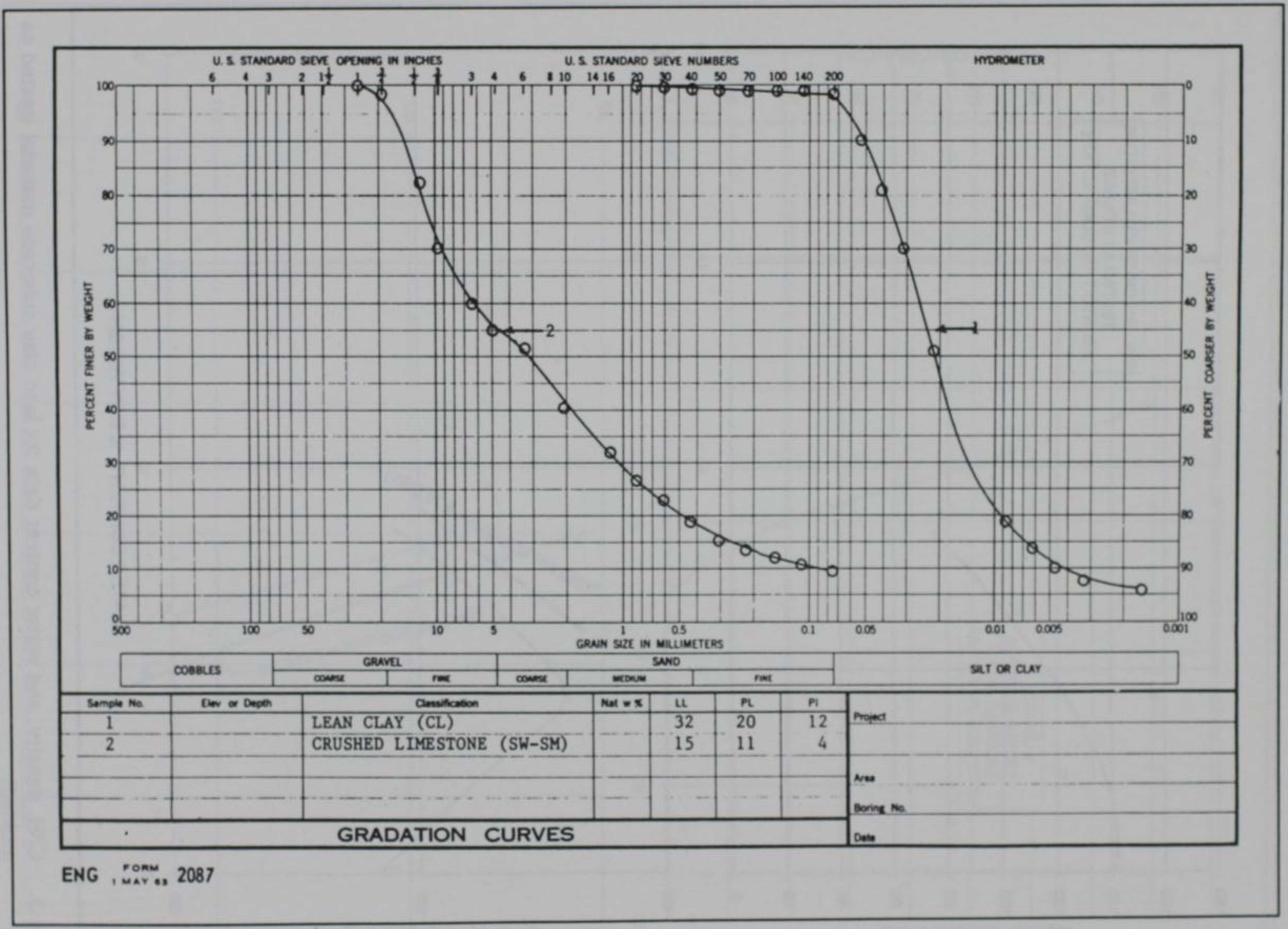
h. The performance of the straight and flat aggregate items was considerably better in the low-tire-pressure lane as compared to the high-tire-pressure lane.

Recommendations

Based on the performance or lack of performance of the 15 items under the loading conditions as reported herein, it is recommended that:

- *a.* Additional traffic be applied. Only one failure occurred in the thicker AC sections, and very little comparative data with the exception of some maintenance data were obtained during the trafficking of the aggregate items.

- *b.* Consideration be given to alternating the loaded and unloaded traffic after 10 passes or whatever the normal interval is when harvesting a forest when and if additional traffic is applied. Continuous unloaded traffic of the high-tire-pressure truck was very severe on the aggregate-surfaced items.



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1		LEAN CLAY (CL)		32	20	12
2		CRUSHED LIMESTONE (SW-SM)		15	11	4

Project

Area

Boring No.

Date

GRADATION CURVES

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Figure 2. Classification data for subgrade and base materials

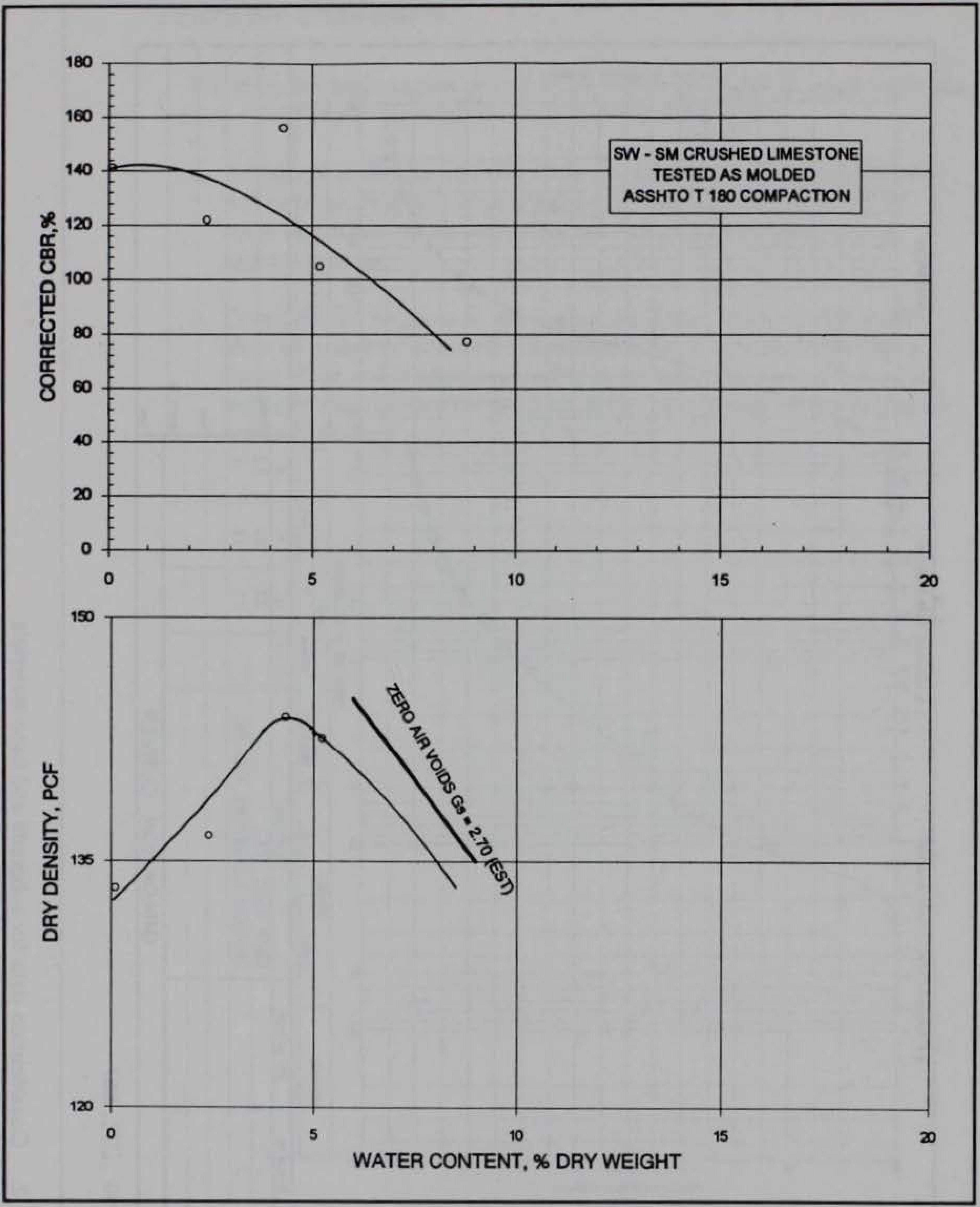


Figure 3. CBR, density, and water content data for lean clay subgrade material (tested as molded)

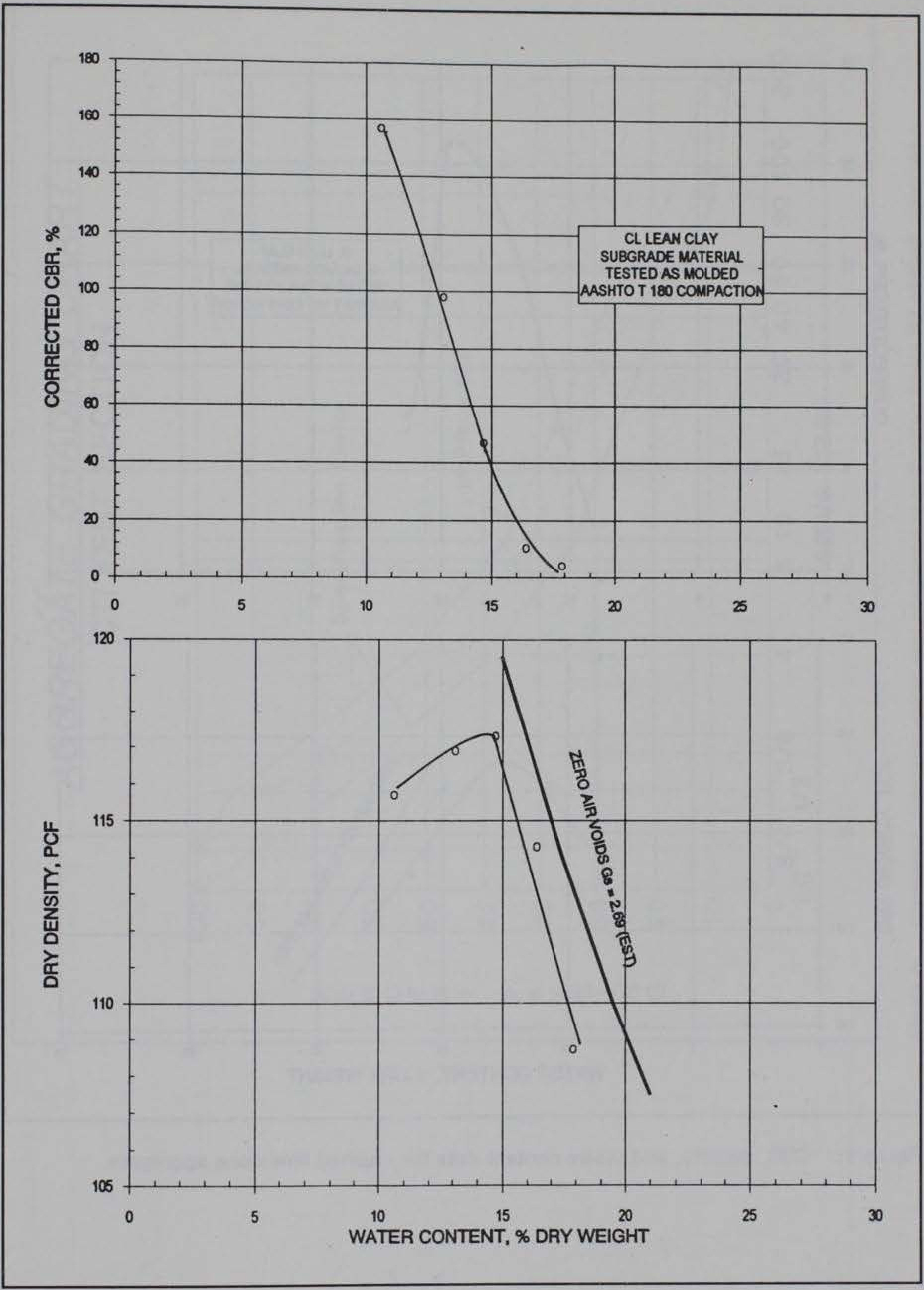


Figure 4. CBR, density, and content data for lean clay subgrade material (tested after soaking)

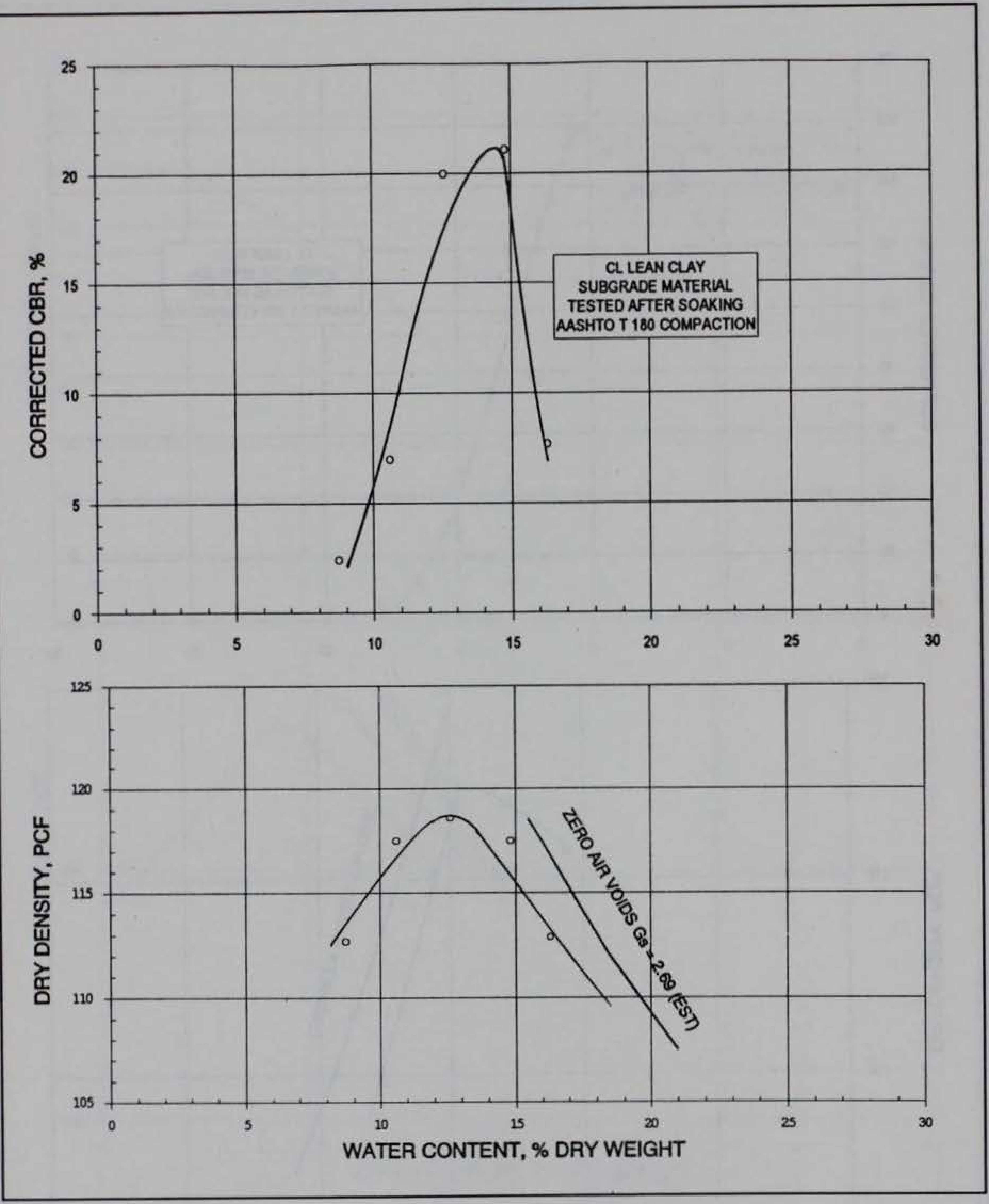


Figure 5. CBR, density, and water content data for crushed limestone aggregate

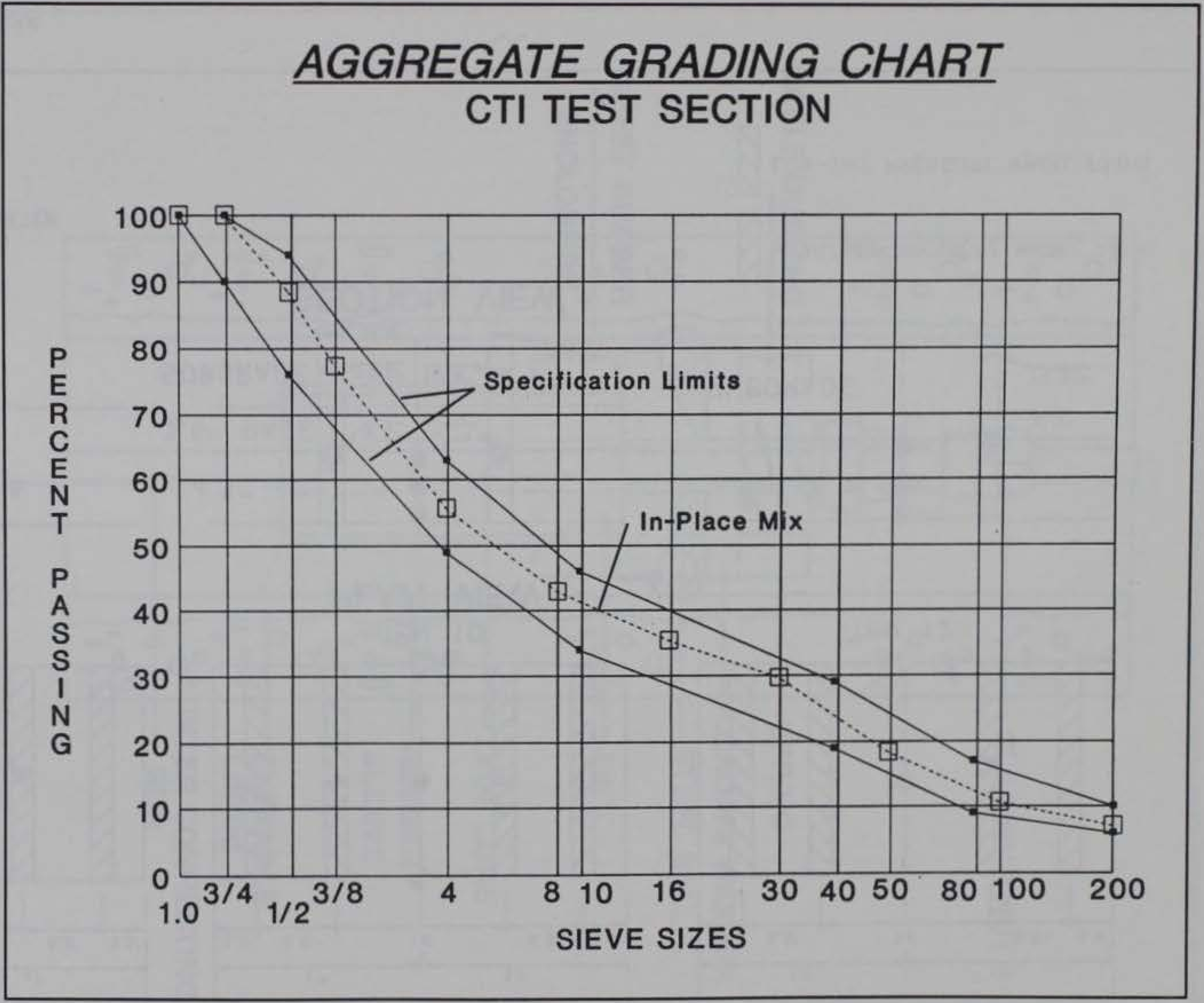


Figure 6. Combined gradation curve and gradation specification limits for asphalt concrete

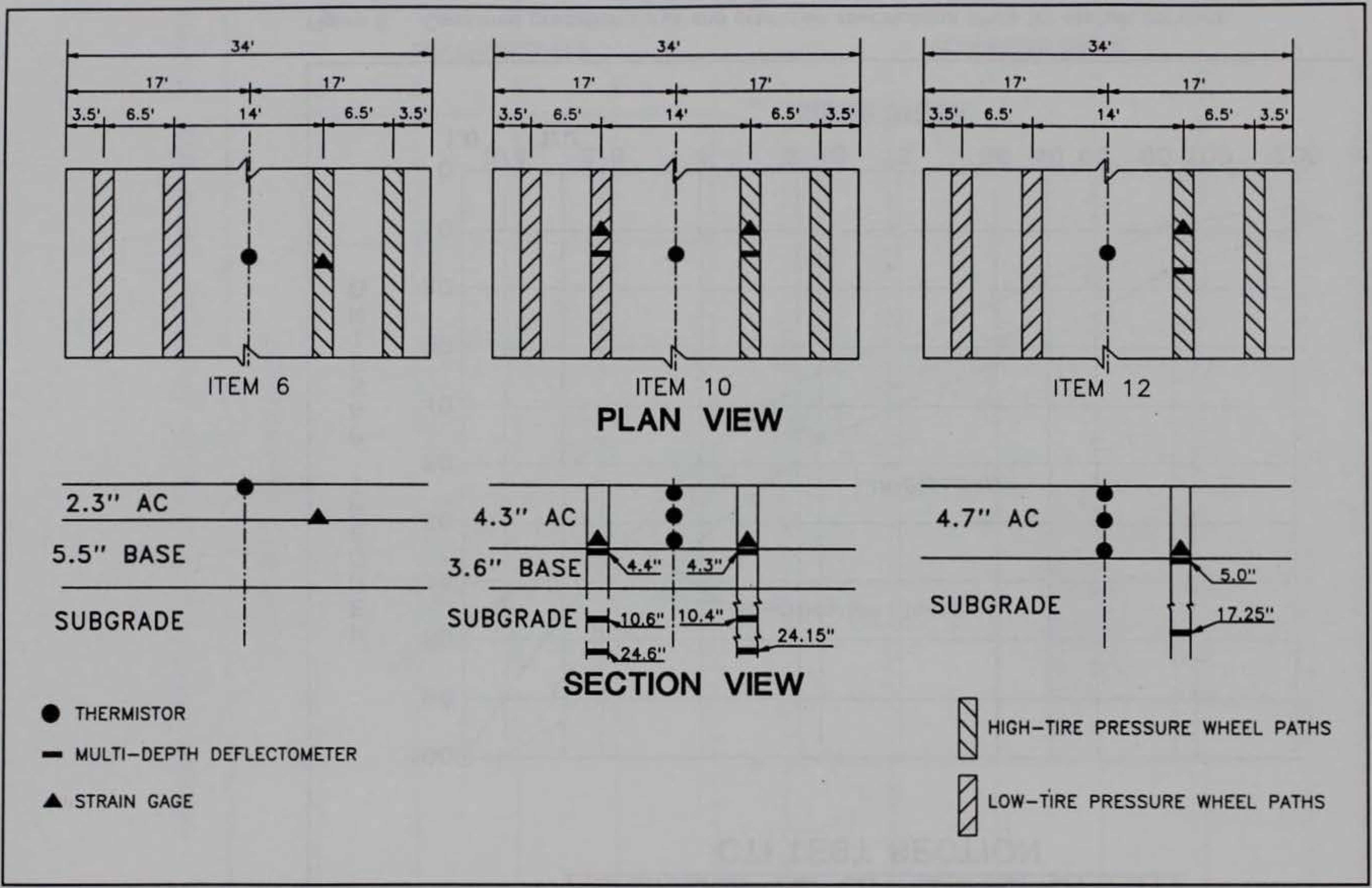


Figure 7. Instrumentation layout

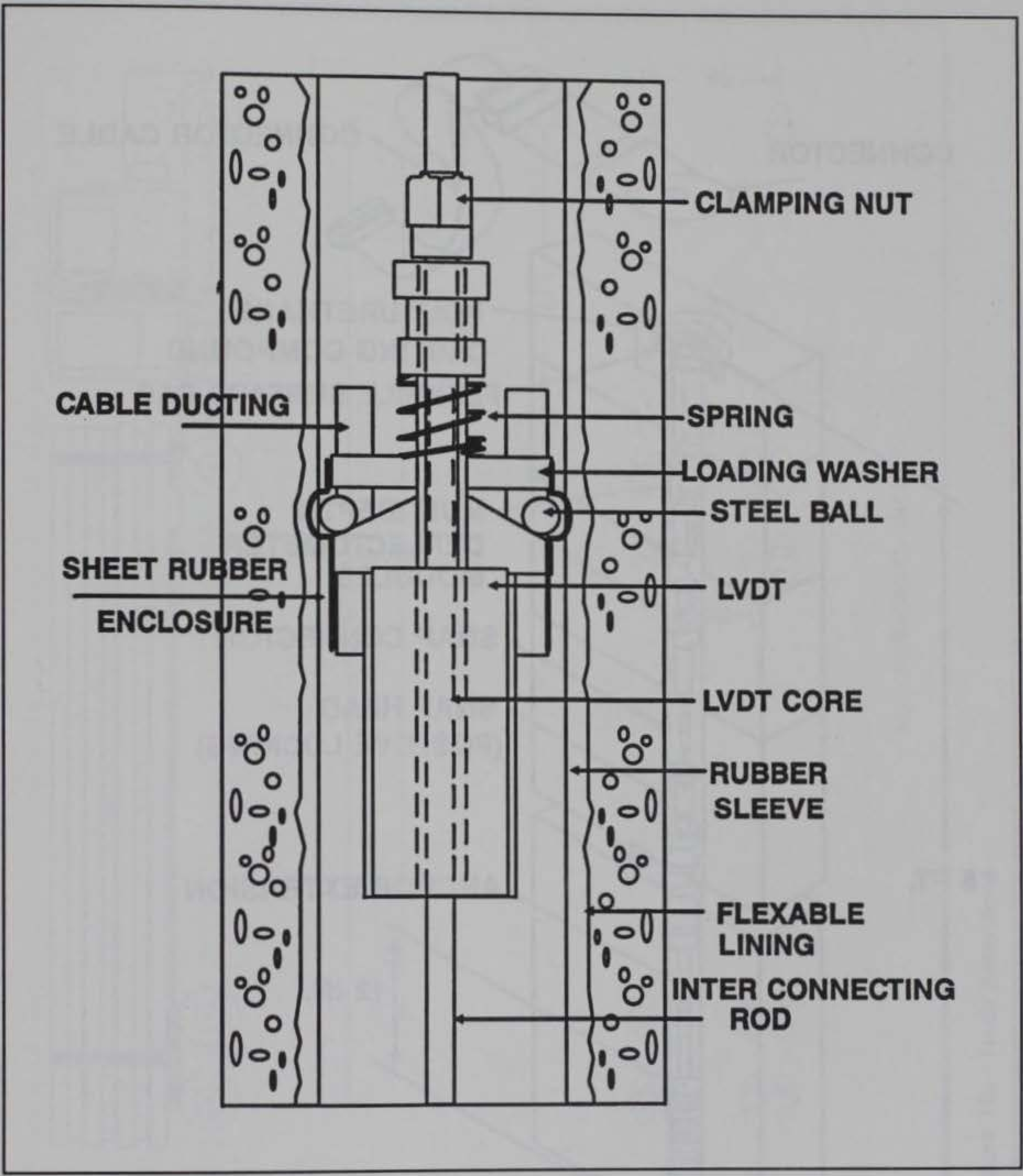


Figure 8. Components of an MDD module

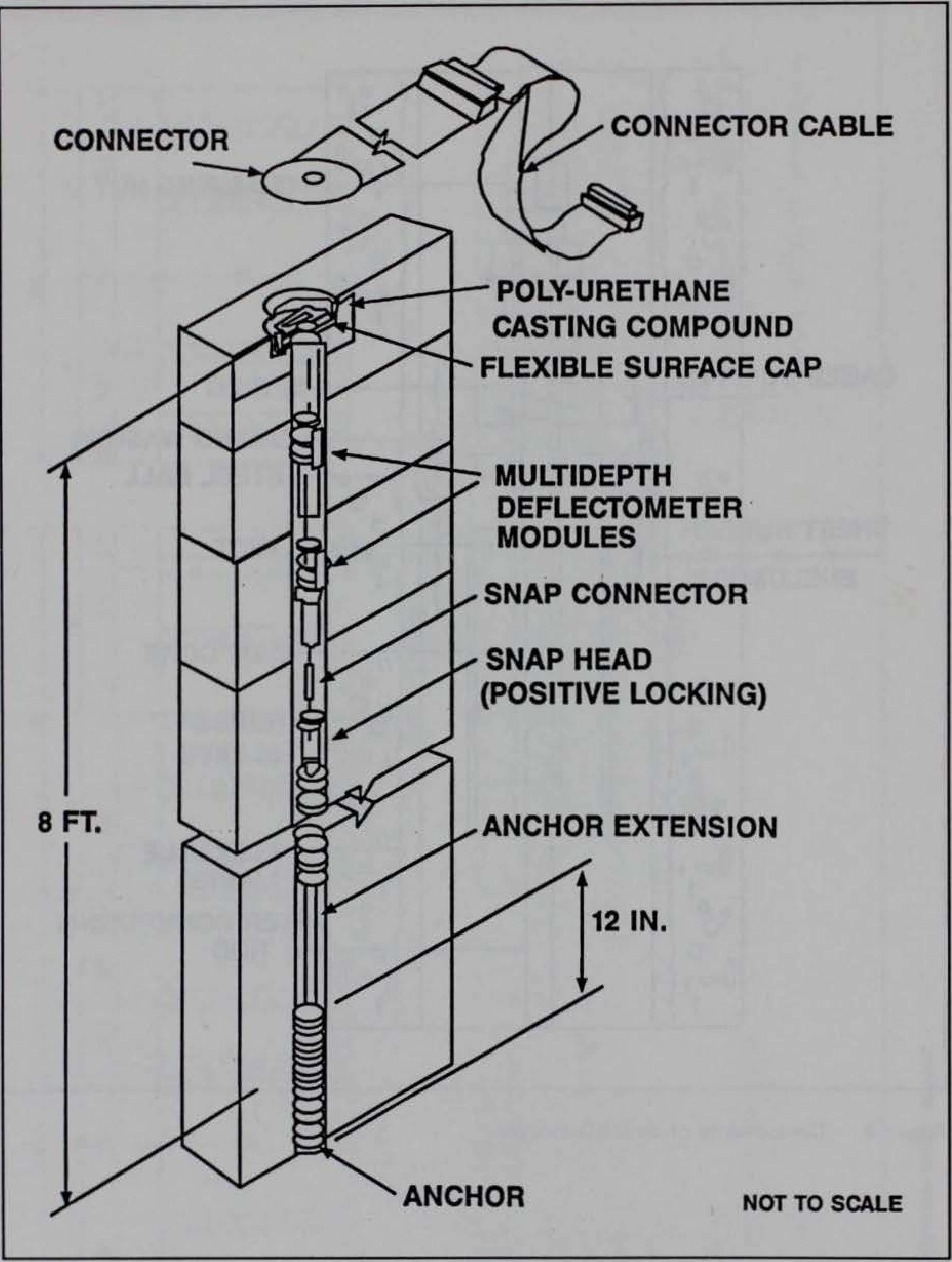


Figure 9. Typical cross section of a MDD after installation

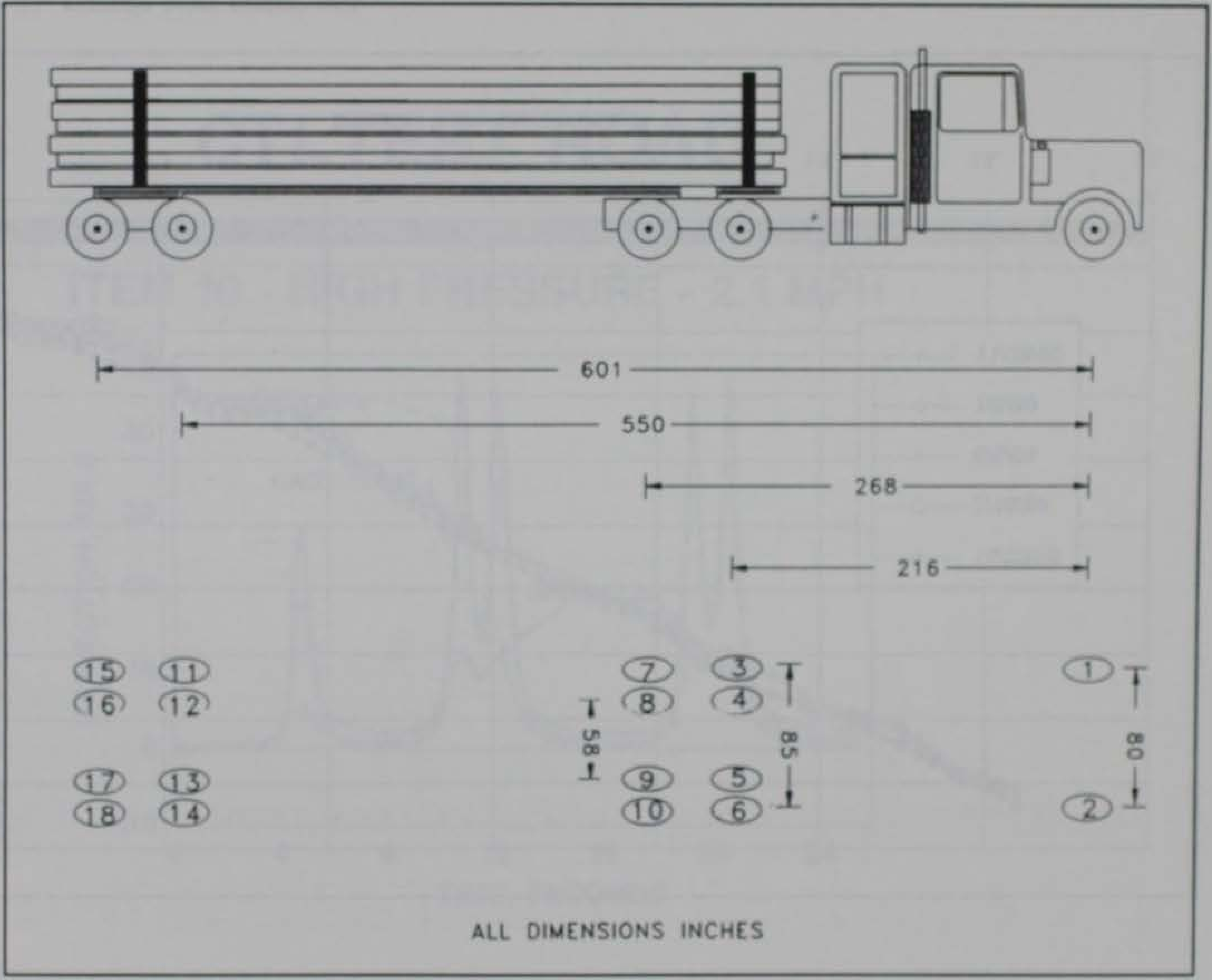


Figure 10. Truck dimensions

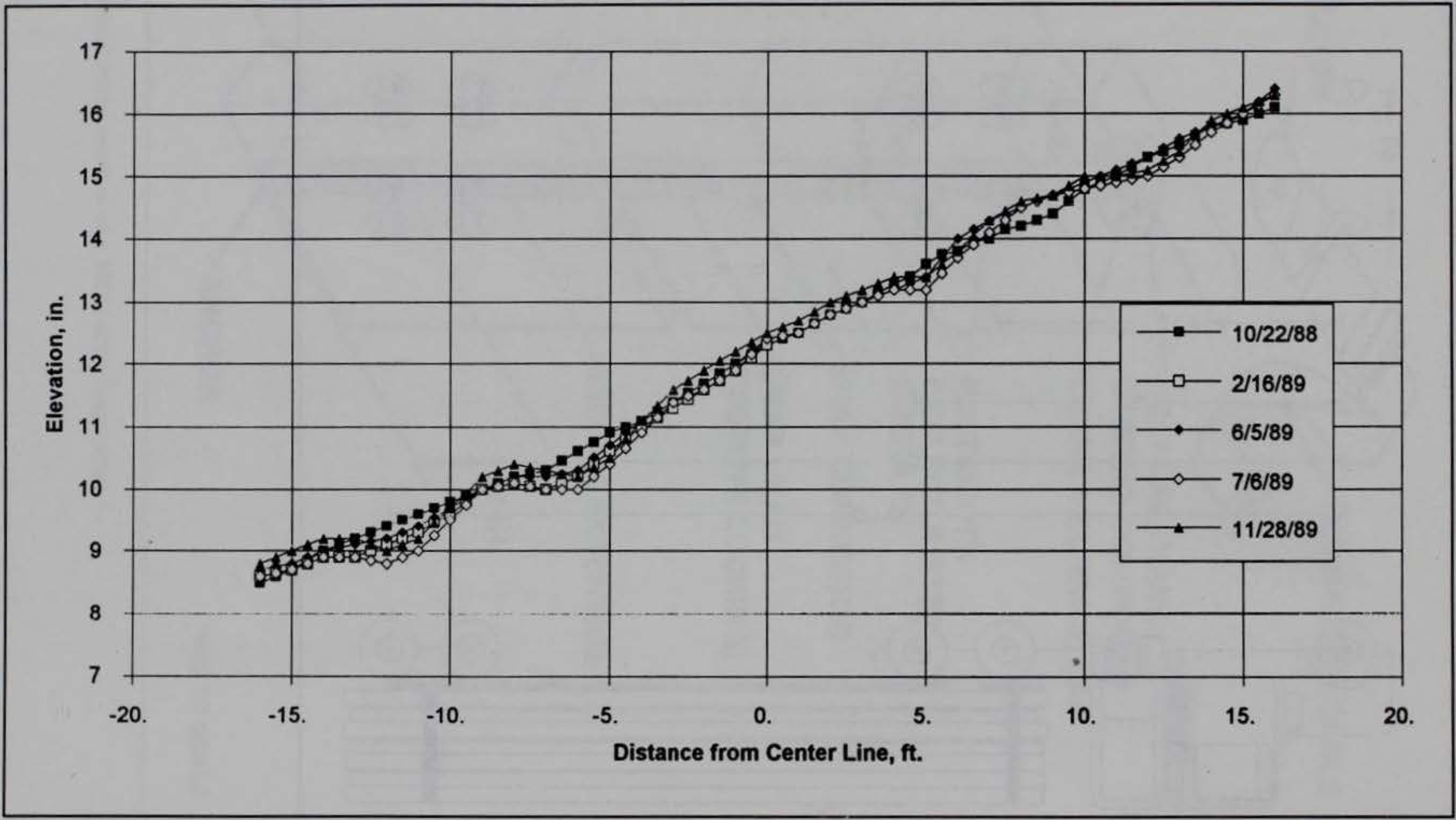


Figure 11. Item 8, sta 18+81, example cross section plot

CTI TEST ROAD

ITEM 10 - HIGH PRESSURE - 2.1 MPH

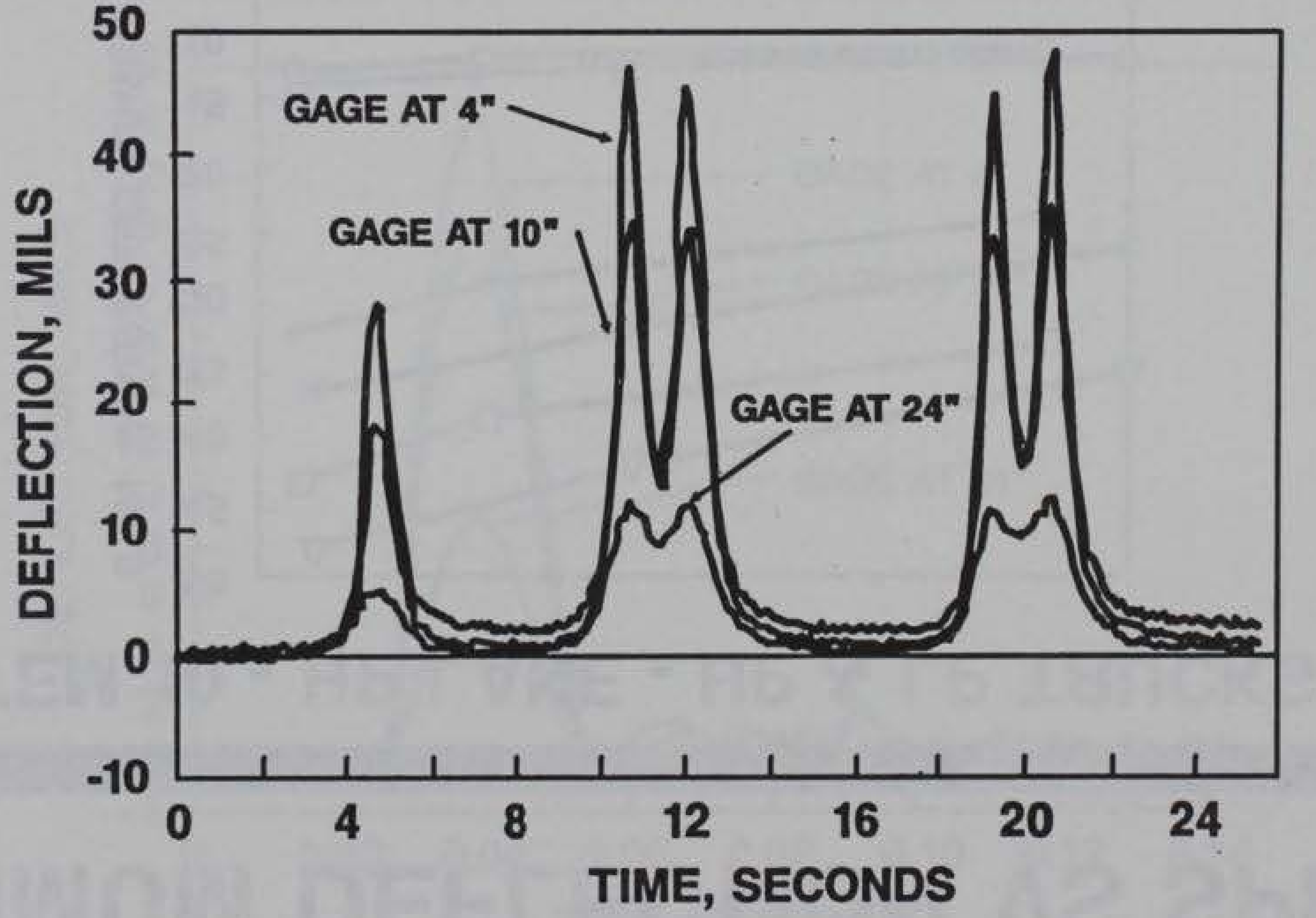
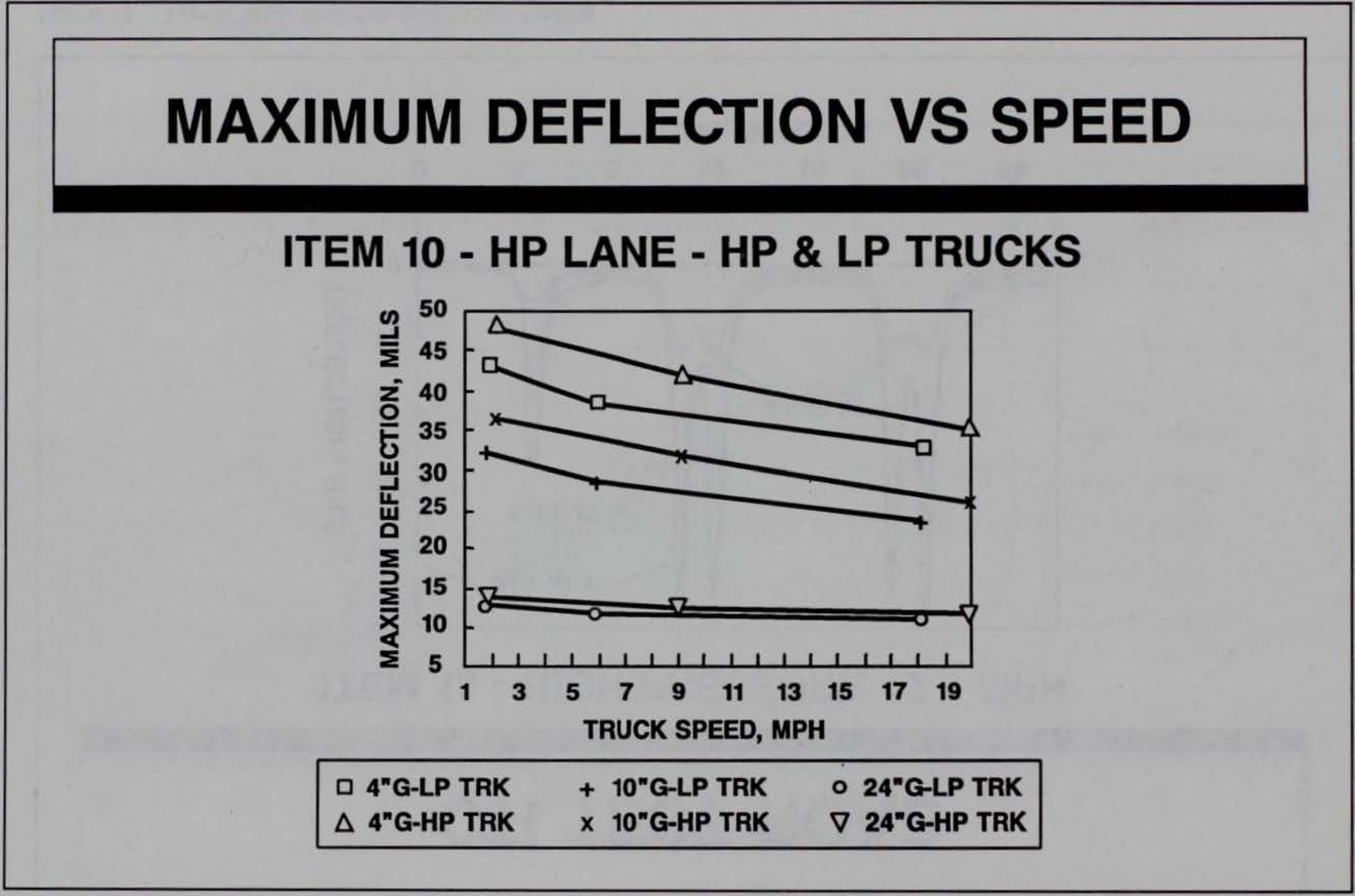


Figure 12. Typical MDD response under truck loading



MAXIMUM DEFLECTION VS SPEED

ITEM 10 - HP LANE - HP & LP TRUCKS

Figure 13. Typical MDD speed versus deflection for Item 10

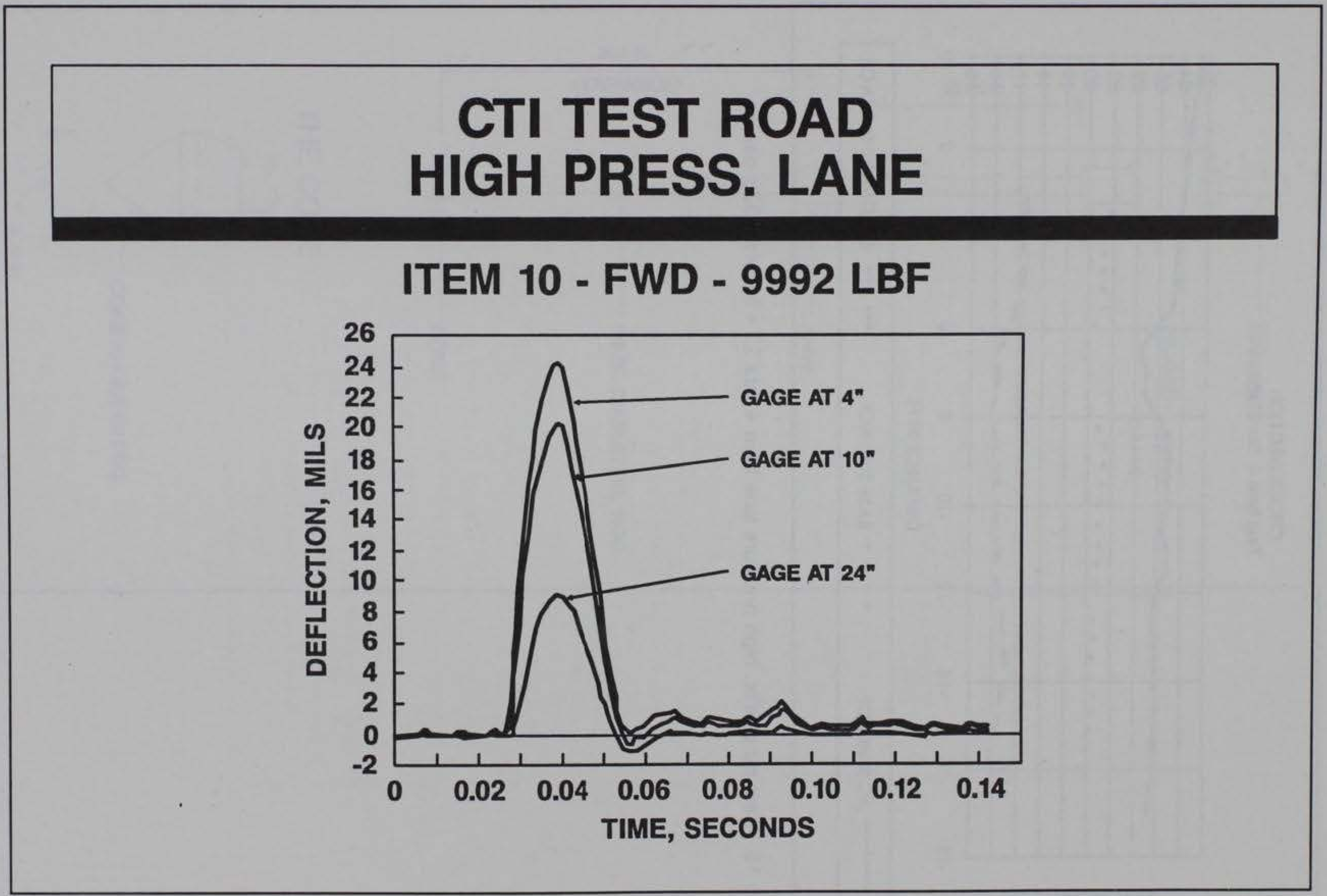


Figure 14. Typical MDD response under FWD loading

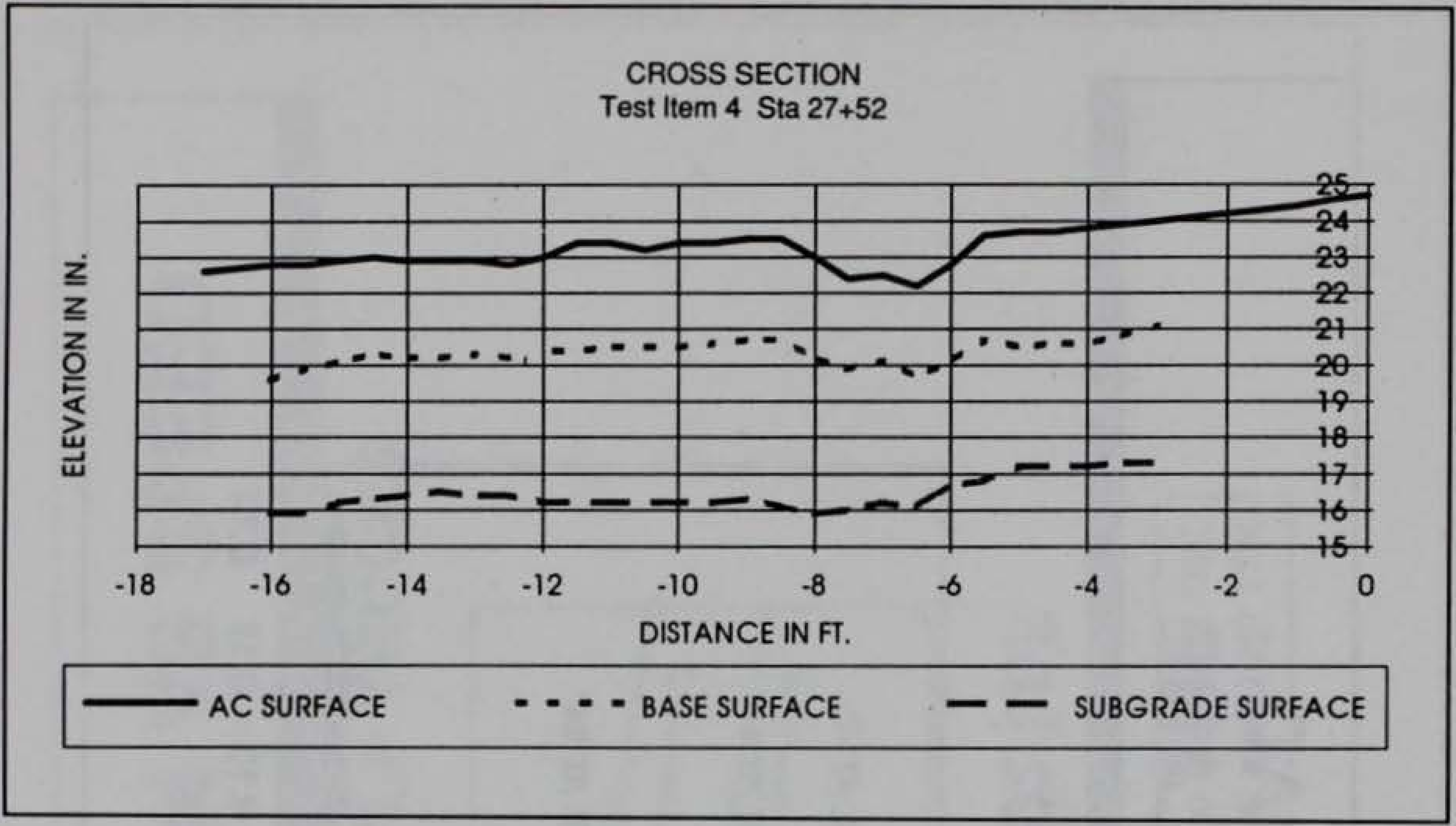


Figure 15. Test pit profile, high pressure lane Item 4, sta 27 + 52 after 323 passes

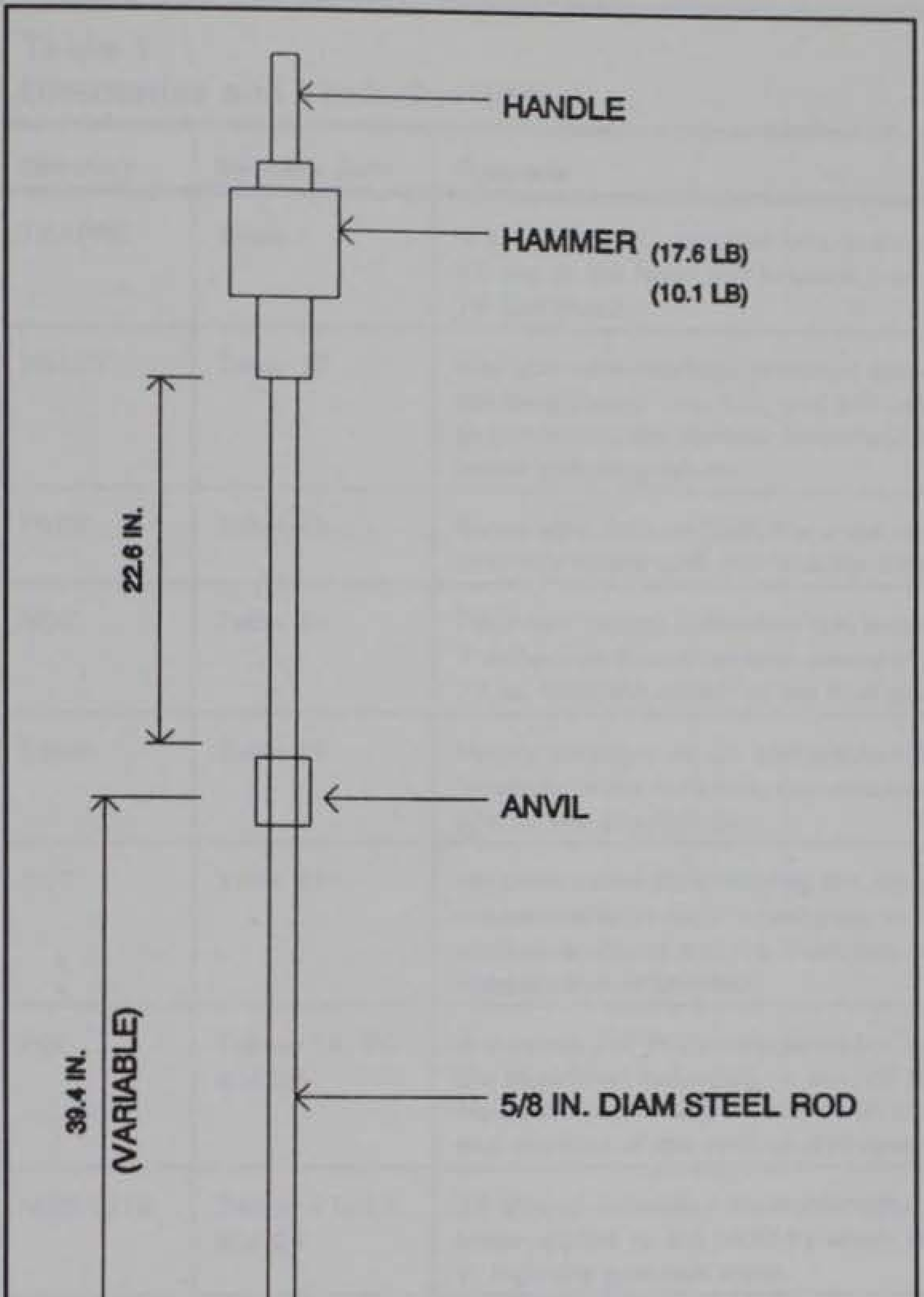


Figure 16. Plan view of dynamic cone penetrometer

Table 1
Directories and Their Contents

Directory	Example Data	Contents
TRAFFIC	Table 7	A daily traffic log divided into loaded and unloaded passes of the high- and low-tire pressure truck over the 15 test items.
XSECT	Table 10	Rod and level readings recorded across the test lanes at the longitudinal 1/4, 1/2, and 3/4 points of each item, documenting the surface deformation at various traffic levels including failure.
PROF	Table 12	Same type data as XSECT except readings were taken in only one wheel path per lane per item.
NDT	Table 14	FWD test results indicating test location, load, 7 deflection measurements recorded at distances of 0 to 72 in. from the center of the load plate.
TEMP	Table 15	Hourly averages of AC and ambient temperatures, humidity, solar radiation, barometric pressure, wind speed, and precipitation.
RUT	Table 18	Measurements documenting the progression of rutting versus traffic in each wheel path at the three cross-section locations and the maximum rut depth independent of location.
PCI	Tables 19, 20, and 28	A summary of PCI's calculated for the item and lane at the pass level indicated. A second file is the inspection report for each sample unit which lists the type, amount, and severity of the various distresses measured.
MDD1212	Tables 21, 23, and 24	26 files of deflection measurements versus time due to loads applied to the MDD by either the FWD or the low- or high-tire pressure truck.
MDD1111	Tables 22, 23, and 24	20 additional files of the same type of measurements stored in the MDD1212 directory.
RAIN	Table 16	Daily precipitation recorded during traffic.
DCP	Table 29	Calculated CBR's versus depth based on hammer blows per penetration and Clegg Impact Values recorded on the surface of the upper layer tested with the DCP.
CBR	Table 3	CBR, moisture content, density, and layer thickness determinations made before traffic (lane 5) and areas judged failed.

Table 2
Resilient Modulus Test Results on Subgrade Material

Confining Pressure, σ_3 psi	Range of Resilient Modulus for Deviator Stress (σ-σ_3) varying from 2 to 18-psi psi	Average Resilient Modulus psi	Remarks
0 3 6	6,482 - 10,886 6,822 - 12,479 7,488 - 14,212	8,037 8,983 10,250	Specimen molded to maximum density[1] at optimum moisture content
0 3 6	7,112 - 15,505 7,974 - 17,797 8,688 - 20,065	10,579 12,220 13,712	Specimen molded to 95 percent maximum density[1] at optimum moisture content
0 3 6	6,160 - 13,324 7,139 - 15,273 8,079 - 18,404	9,222 10,676 12,550	Specimen molded to 90 percent maximum density[1] at optimum moisture content
0 3 6	5,033 - 7,033 4,767 - 6,436 5,749 - 8,492	5,871 5,402 7,021	Specimen molded to 95 percent maximum density[1] at moisture content halfway between optimum moisture and saturation
0 3 6	15,350 - 30,007 15,879 - 31,584 15,453 - 33,551	21,901 23,042 23,806	Specimen molded to 95 percent maximum density[1] and dry of optimum moisture content

[1] AASHTO 180 compaction.

Table 3
Summary of Moisture, Density, and CBR Measurements

			Thickness, in.						Dry Density, pcf			
Test Item	Wheel Path	Material	Design	Actual	Passes	Depth (in.)	CBR (%)	Water Content (%)	In-Place A	AASHTO[1] T 180 B	Percent T 180 Density A/B	Clegg Impact Value (CIV)
1	3 & 4	Aggregate	3	4.8	0	0.0	47	1.4	128.5	135.4	95	24
		Subgrade	--[2]	--		4.8	12	18.4	102.8	109.1	94	11
					0	10.8	7	20.5	100.0	104.1	96	6
	1 & 2	Aggregate	3	4.0	0	0.0	23	1.6	124.4	135.8	92	13
		Subgrade	--	--		4.0	8	18.5	105.2	108.9	97	11
						10.0	25	16.5	106.5	113.3	94	18
2	5	Aggregate	3	3.8	0	0.0	22	1.7	125.4	136.0	92	13
		Subgrade	--	--		3.8	15	20.1	99.5	105.1	95	11
						9.8	10	18.5	103.5	108.9	95	--
3	5	Subgrade	--	--	0	0.0	18	17.3	103.0	111.6	92	17
						6.0	25	18.1	106.8	109.8	97	18
4	5	AC	2	2.8	0	--	--	--	--	--	--	--
		Aggregate	4	3.8		2.8	25	3.5	131.4	142.6	92	19
		Subgrade	--	--		6.6	7	19.2	106.7	107.2	100	7
						12.6	13	21.4	100.2	101.7	99	--
4	2	AC	2	2.0	158	--	--	--	--	--	--	--
		Aggregate	4	2.0		2.0	11	4.6	136.9	143.6	95	--
		Subgrade	--	--		4.0	6	19.6	105.5	106.3	99	--
						10.0	7	22.5	101.5	99.0	103	--
4	1	AC	2	3.5	323	--	--	--	--	--	--	--
		Aggregate	4	3.5		3.5	23	3.6	134.0	143.0	94	20
		Subgrade	--	--		7.0	7	17.2	108.4	111.8	97	8
						13.0	15	19.0	102.9	107.7	96	12

(Sheet 1 of 5)

[1] Based on ASSHTO T 180 maximum density at field-in-place water content.

[2] A dash (--) indicates not applicable.

Table 3 (Continued)

Test Item	Wheel Path	Material	Thickness, in.		Passes	Depth (in.)	CBR (%)	Water Content (%)	Dry Density, pcf		Percent T 180 Density A/B	Clegg Impact Value (CIV)
			Design	Actual					In-Place A	AASHTO[1] T 180 B		
4	2	AC	2	3.0	323	--	--	--	--	--	--	--
		Aggregate	4	3.5		3.0	32	4.5	143.2	143.7	100	28
		Subgrade	--	--		6.5	18	19.0	104.3	107.7	97	13
						12.5	8	19.6	104.1	106.3	98	9
4	3	AC	2	4.0	3,324	--	--	--	--	--	--	--
		Aggregate	4	2.5		4.0	20	4.6	143.2	143.5	100	25
		Subgrade				6.5	5	19.8	104.7	105.8	99	6
						12.5	7	20.1	102.5	105.1	98	8
4	4	AC	2	4.0	3,845	--	--	--	--	--	--	--
		Aggregate	4	2.5		4.0	23	3.6	142.6	143.0	100	25
		Subgrade				6.5	5	19.0	105.8	107.7	98	6
						12.5	8	19.6	102.7	106.3	97	8
5	5	AC	2	2.7	0	--	--	--	--	--	--	--
		Aggregate	6	5.8		2.7	21	3.4	129.1	142.3	91	22
		Subgrade	--	--		8.5	10	18.5	105.6	108.9	97	--
						14.5	14	16.5	97.4	113.3	86	12
5	4	AC	2	3.5	2,076	--	--	--	--	--	--	--
		Aggregate	6	4.5		3.5	33	4.1	145.5	143.6	101	42
		Subgrade	--	--		8.0	3	19.4	104.8	106.7	98	6
						14.0	8	20.6	100.5	103.8	97	11
5	1	AC	2	2.3	1,414	--	--	--	--	--	--	--
		Aggregate	6	6.0		2.3	20	4.9	142.6	143.1	100	31
		Subgrade	--	--		8.3	3	20.7	103.2	103.6	100	6
						14.3	6	21.0	100.2	102.8	97	8

(Sheet 2 of 5)

Table 3 (Continued)												
			Thickness, in.						Dry Density, pcf			
Test Item	Wheel Path	Material	Design	Actual	Passes	Depth (in.)	CBR (%)	Water Content (%)	In-Place A	AASHTO[1] T 180 B	Percent T 180 Density A/B	Clegg Impact Value (CIV)
5	1	AC	2	2.6	2,210	--	--	--	--	--	--	--
		Aggregate	6	5.1		2.6	39	4.1	145.7	143.6	101	39
		Subgrade				7.7	7	17.6	106.7	110.9	96	8
						13.7	8	19.9	104.8	105.5	99	8
6	5	AC	2	2.3	0	--	--	--	--	--	--	--
		Aggregate	8	5.5		2.3	24	3.4	137.4	142.3	97	27
		Subgrade	--	--		7.8	16	18.1	104.6	109.8	95	11
						13.8	10	18.3	106.0	109.3	97	11
6	1	AC	2	2.5	1,104	--	--	--	--	--	--	--
		Aggregate	8	6.5		2.5	52	4.6	149.0	143.6	104	52
		Subgrade	--	--		9.0	4	17.8	105.7	110.4	96	8
						15.0	6	19.4	102.6	106.7	96	7
6	3	AC	2	2.5	2,076	--	--	--	--	--	--	--
		Aggregate	8	7.0		2.5	46	4.7	143.3	143.5	100	41
		Subgrade	--	--		9.5	6	19.1	103.9	107.5	97	8
						15.5	8	19.9	100.4	105.5	95	9
7	5	AC	4	5.2	0	--	--	--	--	--	--	--
		Subgrade	--	--		5.2	22	15.8	109.1	114.6	95	18
						11.2	19	17.6	106.3	110.9	96	17
8	5	AC	4	5.0	0	--	--	--	--	--	--	--
		Aggregate	8	6.3		5.0	34	2.3	130.7	138.6	94	32
		Subgrade	--	--		11.3	16	16.2	108.1	114.0	95	17
						17.3	10	17.4	107.8	111.4	97	11

(Sheet 3 of 5)

Table 3 (Continued)

Test Item	Wheel Path	Material	Thickness, in.		Passes	Depth (in.)	CBR (%)	Water Content (%)	Dry Density, pcf		Percent T 180 Density A/B	Clegg Impact Value (CIV)
			Design	Actual					In-Place A	AASHTO[1] T 180 B		
9	5	AC	4	4.7	0	--	--	--	--	--	--	--
		Aggregate	6	5.5		4.7	44	2.4	130.2	138.8	94	24
		Subgrade	--	--		10.2	19	16.3	108.0	113.8	95	15
						16.2	17	16.8	103.1	112.6	92	15
10	5	AC	4	4.3	0	--	--	--	--	--	--	--
		Aggregate	4	3.6		4.3	39	2.3	129.6	138.6	94	22
		Subgrade	--	--		7.9	20	15.4	105.9	115.4	92	--
						13.9	21	18.4	103.7	109.1	95	16
10	1	AC	4	3.5	2,210	--	--	--	--	--	--	--
		Aggregate	4	2.8		3.5	21	3.8	137.9	143.2	96	23
		Subgrade				6.3	7	19.0	106.8	107.7	99	10
						12.3	25	17.8	105.7	110.4	96	17
11	5	AC	6	5.7	0	--	--	--	--	--	--	--
		Subgrade	--	--		5.7	16	16.3	104.3	113.8	92	14
						11.7	15	19.0	100.2	107.7	93	14
12	5	AC	5	4.7	0	--	--	--	--	--	--	--
		Subgrade	--	--		4.7	16	17.8	100.3	110.4	91	13
						10.7	27	17.2	100.0	111.8	89	19
13	5	Aggregate	3	3.0	0	0.0	35	2.8	133.4	139.6	96	20
		Subgrade	--	--		3.0	15	18.9	103.9	107.9	96	14
						9.0	31	17.4	104.4	111.4	94	21
13	2	Aggregate	3	2.5	3,757	0.0	58	3.7	136.3	143.1	95	52
		Subgrade	--	--		2.5	34	15.6	114.8	114.8	100	22
						8.5	31	15.8	110.2	114.6	96	20

(Sheet 4 of 5)

Table 3 (Concluded)

			Thickness, in.						Dry Density, pcf			
Test Item	Wheel Path	Material	Design	Actual	Passes	Depth (in.)	CBR (%)	Water Content (%)	In-Place A	AASHTO[1] T 180 B	Percent T 180 Density A/B	Clegg Impact Value (CIV)
13	3	Aggregate	3	2.0	4,473	0.0	74	2.8	133.4	139.3	96	33
		Subgrade				2.0	40	15.6	112.1	114.4	98	25
14	5	Aggregate	6	5.8	0	0.0	32	2.8	135.0	139.6	97	24
		Subgrade				5.8	12	20.2	103.0	104.8	98	11
						11.8	12	17.8	100.9	110.4	91	11
14	2	Aggregate	6	5.8	3,757	0.0	14	6.8	132.5	139.6	95	77
		Subgrade				5.8	30	16.9	107.8	112.4	96	18
						11.8	25	23.3	88.9	96.8	92	23
14	3	Aggregate	6	5.8	4,473	0.0	18	3.8	141.0	143.2	98	91
		Subgrade				5.8	21	16.5	105.8	113.3	93	17
						11.8	31	21.6	100.2	101.2	99	15
15	5	Aggregate	9	7.5	0	0.0	32	3.3	129.0	141.9	91	31
		Subgrade				7.5	17	18.1	107.8	109.8	98	14
						13.5	22	18.3	104.7	109.3	96	15
15	2	Aggregate	9	7.5	3,757	0.0	28	4.6	141.6	143.6	99	27
		Subgrade				7.5	9	17.6	107.2	110.9	97	12
						13.5	12	20.3	100.6	104.6	96	11
15	3	Aggregate	9	7.5	4,473	0.0	20	2.6	141.0	138.5	102	64
		Subgrade				7.5	11	17.7	108.1	110.6	98	11
						13.5	22	18.7	104.4	108.4	96	19

(Sheet 5 of 5)

Table 4
Properties of Bituminous Mixture

Test Item	Asphalt Content Percent Total Mix	Stability (lb)	Flow 1/100 (in.)	Percent Voids		Unit Weight Total Mix (pcf)	Percent Plant Laboratory Density
				Total Mix	Filled		
Plant-Mixed Laboratory Compacted Samples[1]							
--[2]	4.4	2,736	11	2.8	78.3	147.9	--
--	4.9	2,319	12	2.4	82.4	147.8	--
--	4.4	2,359	12	3.1	76.5	147.5	--
Field Cores[3]							
4	--	--	--	--	--	145.5	99
	--	--	--	--	--	145.4	99
	--	--	--	--	--	142.2	96
5	--	--	--	--	--	143.3	97
	--	--	--	--	--	146.5	99
	--	--	--	--	--	145.5	99
6	--	--	--	--	--	141.8	96
	--	--	--	--	--	144.8	98
	--	--	--	--	--	141.7	96
7	--	--	--	--	--	141.7	96
	--	--	--	--	--	145.2	98
	--	--	--	--	--	144.4	98
8	--	--	--	--	--	144.7	98
	--	--	--	--	--	143.5	97
	--	--	--	--	--	146.5	99
9	--	--	--	--	--	145.9	99
	--	--	--	--	--	144.2	98
	--	--	--	--	--	144.5	98
10	--	--	--	--	--	145.0	98
	--	--	--	--	--	143.6	97
	--	--	--	--	--	140.0	95
11	--	--	--	--	--	142.9	97
	--	--	--	--	--	140.5	95
	--	--	--	--	--	143.1	97
12	--	--	--	--	--	146.4	99
	--	--	--	--	--	141.3	96
	--	--	--	--	--	144.4	98

[1] Specimens compacted by the 75-blow Marshall method.

[2] A dash (--) indicates not applicable.

[3] Field cores obtained before traffic testing.

Table 5
Truck Loadings

Axle	Axle Loads (lb)			
	Loaded		Empty[1]	
	Left	Right	Left	Right
High Pressure Truck				
Steering	4,920	4,670	5,000	5,000
Front Drive	8,625	8,180	4,000	4,000
Rear Drive	8,230	8,200	4,000	4,000
Front Trailer	7,835	8,520	--	--
Rear Trailer	8,415	9,005	--	--
Low Pressure Truck				
Steering	4,880	4,650	5,000	5,000
Front Drive	8,635	8,675	4,000	4,000
Rear Drive	8,450	8,565	4,000	4,000
Front Trailer	8,265	8,115	--	--
Rear Trailer	8,655	8,500	--	--

[1] Estimated.

Table 6
Summary of Tire Measurements

			Tire Print Dimensions		
Axle	Location[1]	Pressure (psi)	Length (in.)	Width (in.)	Area (in^2)
		High Pressure Truck, Loaded			
Steering	1	100	8.9	8.1	61.4
	2	100	8.9	8.4	62.8
Drive	3	100	7.9	8.1	54.0
	4	100	8.9	8.2	63.4
	5	100	9.6	8.4	69.0
	6	100	8.8	8.2	61.7
	7	100	7.4	7.9	45.9
	8	100	9.3	9.0	69.4
	9	100	9.4	8.8	72.6
	10	100	8.5	8.7	62.1
Trailer	11	100	8.1	7.8	52.2
	12	100	9.9	8.1	66.8
	13	100	8.8	8.1	62.9
	14	100	9.9	8.2	70.6
	15	100	8.5	8.3	58.5
	16	100	9.7	8.5	65.3
	17	100	9.4	8.9	70.0
	18	100	9.7	8.7	69.2
			9.0	8.4	63.2
		Low Pressure Truck, Loaded			
Steering	1	43	14.4	8.9	105.6
	2	43	12.7	8.7	92.0
Drive	3	39	12.7	8.7	99.5
	4	39	12.7	8.6	97.0
	5	39	11.6	8.7	84.6
	6	39	11.2	8.3	80.9
	7	39	11.4	9.0	97.6
	8	39	13.9	8.9	106.0
	9	39	12.9	9.0	95.7
	10	39	11.8	8.9	89.4
Trailer	11	38	12.7	8.5	92.5
	12	38	13.0	8.4	98.7
	13	38	12.2	8.5	89.2
	14	38	12.6	8.5	90.7
	15	38	13.0	8.2	83.3
	16	38	13.3	8.5	95.8
	17	38	14.0	8.8	104.9
	18	38	14.2	8.7	102.3
			12.1	8.7	94.8

[1] See Figure 10 for tire location.

Table 7
Example of the Daily Traffic Log (File Traffic) CTI Traffic Asphalt

		High Pressure Lane		Low Pressure Lane		Total Passes	
Date	**Date**	**Loaded Passes**	**Unloaded Passes**	**Loaded Passes**	**Unloaded Passes**	**HPL**	**LPL**
32426	10-Oct-88	2	0	2	0	2	2
32443	27-Oct-88	21	0	21	0	23	23
32448	01-Nov-88	48	0	48	0	48	48
32449	02-Nov-88	87	0	87	0	158	158
32450	03-Nov-88	22	0	22	0	180	180
32451	04-Nov-88	143	0	143	0	323	323
32459	12-Nov-88	10	0	3	0	333	326
32483	06-Dec-88	101	0	108	0	434	434
32484	07-Dec-88	101	0	101	0	535	535
32485	08-Dec-88	22	0	22	0	557	557
32489	12-Dec-88	9	0	9	0	566	566
32490	13-Dec-88	1	0	1	0	567	567
32491	14-Dec-88	2	0	26	0	569	593
32492	15-Dec-88	0	0	165	0	569	758
32493	16-Dec-88	0	0	225	0	569	983
32498	21-Dec-88	0	0	94	0	569	1,077
32499	22-Dec-88	203	0	218	0	772	1,295
32500	23-Dec-88	1	0	1	0	773	1,296
32519	11-Jan-89	137	0	151	0	910	1,447
32521	13-Jan-89	194	0	76	0	1,104	1,523
32525	17-Jan-89	0	0	250	0	1,104	1,773
32526	18-Jan-89	0	0	303	0	1,104	2,076
32527	19-Jan-89	1	0	1	0	1,105	2,077
32528	20-Jan-89	9	0	9	0	1,114	2,086
32531	23-Jan-89	10	0	9	0	1,124	2,095
32533	25-Jan-89	1	0	1	0	1,125	2,096
32548	09-Feb-89	1	0	1	0	1,126	2,097
32549	10-Feb-89	54	0	91	0	1,180	2,188
32552	13-Feb-89	234	0	208	0	1,414	2,396
32553	14-Feb-89	151	0	239	0	1,565	2,635

Table 8
Summary of Test Traffic

Pavement Type	High Pressure Lane, passes		Low Pressure Lane, passes	
	Loaded	Unloaded	Loaded	Unloaded
Asphalt	6,764	1,113	8,333	1,385
Aggregate	2,645	1,112	3,089	1,384

Table 9
Files in XSECT Directory

Name	Extension	Size, bytes
I10XS	.ASC	6,232
I11XS	.ASC	6,912
I12XS	.ASC	6,094
I13XS	.ASC	10,457
I14XS	.ASC	10,612
I15XS	.ASC	13,684
I1HPLXS	.ASC	2,934
I1LPLXS	.ASC	3,044
I2XS	.ASC	9,057
I3XS	.ASC	6,980
I4XS	.ASC	5,545
I5XS	.ASC	13,976
I6XS	.ASC	7,993
17XS	.ASC	7,251
I8XS	.ASC	6,763
I9XS	.ASC	6,764

Table 10
Example XSECT File of Item 8[1]

Item	Station	Date	LPL		HPL		16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	10.5	10.0	9.5
			Loaded	Unloaded	Loaded	Unloaded														
8	18+81	22-Oct-88	0	0	0	0	8.50	8.60	8.70	8.85	9.00	9.10	9.20	9.30	9.40	9.50	9.60	9.70	9.80	9.90
8	18+81	16-Feb-89	3000	0	1568	0	8.60	8.65	8.70	8.80	8.90	8.90	8.90	9.00	9.10	9.20	9.30	9.45	9.60	9.80
8	18+81	05-Jun-89	3000	0	1568	0	8.70	8.75	8.80	8.90	9.00	9.05	9.10	9.15	9.20	9.30	9.40	9.55	9.70	9.85
8	18+81	06-Jul-89	4492	0	3397	0	8.60	8.65	8.70	8.80	8.90	8.90	8.90	8.85	8.80	8.90	9.00	9.25	9.50	9.75
8	18+81	28-Nov-89	8333	1385	6764	1113	8.80	8.90	9.00	9.10	9.20	9.20	9.20	9.10	9.00	9.10	9.20	9.45	9.70	9.95
8	19+13	22-Oct-88	0	0	0	0	8.10	8.25	8.40	8.60	8.80	8.95	9.10	9.20	9.30	9.45	9.60	9.80	10.00	10.15
8	19+13	16-Feb-89	3000	0	1568	0	8.40	8.45	8.50	8.65	8.80	8.85	8.90	9.00	9.10	9.30	9.50	9.75	10.00	10.20
8	19+13	05-Jun-89	3000	0	1568	0	8.40	8.50	8.60	8.70	8.80	8.90	9.00	9.10	9.20	9.40	9.60	9.80	10.00	10.25
8	19+13	06-Jul-89	4492	0	3397	0	8.30	8.35	8.40	8.50	8.60	8.65	8.70	8.70	8.70	8.85	9.00	9.30	9.60	9.90
8	19+13	28-Nov-89	8333	1385	6764	1113	8.60	8.65	8.70	8.80	8.90	8.90	8.90	8.85	8.80	9.00	9.20	9.55	9.90	10.20
8	19+44	22-Oct-88	0	0	0	0	9.20	9.40	9.60	9.75	9.90	10.05	10.20	10.35	10.50	10.60	10.70	10.85	11.00	11.15
8	19+44	16-Feb-89	3000	0	1568	0	9.40	9.55	9.70	9.85	10.00	10.05	10.10	10.20	10.30	10.45	10.60	10.85	11.10	11.20
8	19+44	05-Jun-89	3000	0	1568	0	9.50	9.60	9.70	9.85	10.00	10.05	10.10	10.20	10.30	10.45	10.60	10.85	11.10	11.25
8	19+44	06-Jul-89	4492	0	3397	0	9.40	9.55	9.70	9.80	9.90	9.85	9.80	9.75	9.70	9.90	10.10	10.40	10.70	11.00
8	19+44	28-Nov-89	8333	1385	6764	1113	9.50	9.65	9.80	9.90	10.00	9.95	9.90	9.85	9.80	9.95	10.10	10.45	10.80	11.10

[1] See page 13 for explanation and units of each column.

Table 11
Files in PROF Directory

Name	Extension	Size, bytes
I10PROF	.ASC	4,960
I11PROF	.ASC	4,552
I12PROF	.ASC	4,559
I13PROF	.ASC	6,894
I14PROF	.ASC	7,314
I15PROF	.ASC	9,353
I2PROF	.ASC	5,651
I3PROF	.ASC	4,559
I4PROF	.ASC	5,050
I5PROF	.ASC	6,673
I7PROF	.ASC	10,040
I8PROF	.ASC	5,200
I9PROF	.ASC	5,848

Table 12
Example of PROF File of Item 8[1]

Item 8							
Wheel Path	1	1	1	3	3	3	3
Date	32438	32694	32840	32438	32555	32695	32840
Loaded	0	3397	6764	0	3000	4492	8333
Unloaded	0	0	1113	0	0	0	1385
0	16.44	14.64	14.76	12.72	11.76	10.32	10.44
1	16.44	14.64	14.76	12.72	11.64	10.32	10.44
2	16.44	14.64	14.76	12.6	11.64	10.2	10.44
3	16.44	14.52	14.82	12.6	11.64	10.2	10.38
4	16.44	14.64	14.88	12.6	11.64	10.08	10.32
5	16.44	14.64	14.88	12.48	11.52	10.2	10.32
6	16.44	14.76	14.88	12.48	11.52	10.08	10.32
7	16.44	14.76	14.88	12.48	11.52	10.08	10.26
8	16.44	14.76	14.88	12.48	11.52	10.08	10.2
9	16.44	14.76	14.88	12.36	11.4	9.96	10.2
10	16.44	14.76	14.88	12.36	11.52	9.96	10.2
11	16.44	14.88	14.88	12.36	11.52	10.08	10.2
12	16.44	14.88	14.88	12.36	11.52	10.08	10.2
13	16.56	14.88	14.88	12.36	11.52	10.08	10.2
14	16.56	14.88	14.88	12.36	11.52	9.96	10.2
15	16.56	14.88	14.94	12.36	11.52	10.08	10.2
16	16.56	15	15	12.36	11.52	10.08	10.2
17	16.56	15.12	15.06	12.24	11.52	10.08	10.2
18	16.56	15.12	15.12	12.24	11.52	10.08	10.2
19	16.56	15	15.12	12.24	11.52	10.08	10.2
20	16.56	15.12	15.12	12.24	11.52	10.08	10.2
21	16.56	15	15.12	12.36	11.52	10.08	10.2
22	16.56	15	15.12	12.36	11.64	10.2	10.2
23	16.44	15	15	12.36	11.64	10.2	10.26
24	16.44	15	14.88	12.36	11.76	10.2	10.32
25	16.44	15	14.94	12.36	11.76	10.2	10.38
26	16.44	15.12	15	12.36	11.76	10.2	10.44
27	16.44	15.12	15	12.48	11.76	10.32	10.38
28	16.44	15.12	15	12.48	11.76	10.2	10.32
29	16.44	15.12	15	12.36	11.88	10.32	10.32
30	16.44	15.12	15	12.36	11.88	10.32	10.32
31	16.44	15.12	15	12.48	11.76	10.32	10.38
32	16.44	15.12	15	12.48	11.88	10.32	10.44
33	16.44	15	14.94	12.36	12	10.44	10.44
34	16.32	15	14.88	12.48	12	10.44	10.44
35	16.32	15	14.94	12.48	12	10.44	10.44
36	16.32	15.12	15	12.48	12	10.44	10.44
37	16.32	15	14.94	12.48	12	10.44	10.44
38	16.32	15	14.88	12.48	12	10.44	10.44
39	16.32	15	14.88	12.48	12	10.56	10.44
40	16.32	14.88	14.88	12.48	12.12	10.56	10.44
41	16.32	15	14.88	12.48	12.12	10.56	10.44
42	16.32	14.88	14.88	12.48	12.12	10.56	10.44
43	16.2	14.88	14.88	12.6	12.12	10.68	10.5

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[1] See page 14 for explanation and units of each column.

Table 13
NDT Files

Filename	Test Locations
3NOV88.NDT	Items 12, 11, 10, 9, 8, 7, 6, 5, and 4 (wheel paths 1, 2, 3, and 4)
21NOV88.NDT	Items 12, 11, 10, 9, 8, 7, 6, 5, and 4 (wheel paths 1, 2, 3, and 4)
1DEC88.NDT	Items 12, 11, 10, 9, 8, 7, 6, 5, and 4 (wheel path 1), Item 12 (wheel path 2)
2DEC88.NDT	Items 11, 10, 9, 8, 7, 6, 5, and 4 (wheel path 2), Items 12, 11, 10, 9, and 8 (wheel path 5)
5DEC88.NDT	Items 7, 6, 5, and 4 (wheel path 5), Item 5 (wheel path 2), and Items 12, 11, 10, 9, 8, 6, 5, and 4 (wheel path 3, and 4)
8DEC88.NDT	Items 7, 6, 5, and 4 (wheel path 5), Item 5 (wheel path 2), and Items 12, 11, 10, 9, 8, 6, 5, and 4 (wheel path 3, and 4)
9DEC88.NDT	Items 6, and 5 (wheel path 3, and 4)
22DEC88.NDT	Item 4 (wheel path 1, and 2)
22FEB89.NDT	Items 12, 11, 10, 9, 8, 7, 6, 5, and 4 (wheel paths 3, and 4)
19JUN89.NDT	Items 9, 8, 6, and 5 (wheel paths 1, 2, 3, and 4), Item 10 (wheel paths 3, and 4), and Item 4 (wheel path 3, and 4)
23JUN89.NDT	Items 15, 14, 13, 3, 2, and 1 (wheel paths 1, 2, 3, and 4)
27JUN89.NDT	Items 15, 14, 13, 3, 2, and 1 (wheel paths 1, 2, 3, and 4)
10JUL89.NDT	Item 8 (wheel paths 1, 2, 3, and 4)
1SEP89.NDT	Items 15, 14, and 13 (wheel paths 1, 2, 3, and 4)
14SEP89.NDT	Items 15, 14, and 13 (wheel paths 1, 2, 3, and 4)
18SEP89.NDT	Items 12, 11, 10, 9, 8, and 7 (wheel paths 1, 2, 3, and 4), Item 6 (wheel path 1, 3, and 4), and Item 5 (wheel path 3, and 4)
3OCT89.NDT	Items 15, 14, and 13 (wheel path 5 on the center line)
30NOV89.NDT	Items 12, 11, 10, 9, 8, 7, and 6 (wheel paths 1, 2, 3, and 4)

Table 14
Example NDT File[1]

PAVEMENT FACILITY OR FEATURE ID: RoadNumrRoadway Name
7 DROPS PER LOCATION; DATE:890710; PLATE RADIUS: 5.9IN
7 DEFLECTION SENSORS

					Deflection, mils						
STATION	LANE	TEMP	TIME	LOAD	0.0	12.0	24.0	36.0	48.0	60.0	72.0
18.81	1	80	0807	13848	45.4	30.1	15.6	7.9	4.9	3.9	3.6
18.81	1	80	0807	14232	45.2	30.3	15.9	8.0	5.0	4.0	3.6
18.81	1	80	0807	14040	45.2	30.4	15.9	8.0	5.1	4.0	3.5
18.81	1	80	0807	8464	25.9	17.3	9.0	4.5	2.9	2.3	2.0
18.81	1	80	0807	8520	25.9	17.3	8.9	4.6	3.0	2.3	2.0
18.81	1	80	0807	5584	16.1	10.8	5.6	2.9	1.9	1.5	1.3
18.81	1	80	0807	5600	16.1	10.8	5.6	2.9	1.9	1.5	1.3
19.13	1	81	0808	13904	44.8	29.8	15.3	8.0	5.9	4.2	3.7
19.13	1	81	0808	14024	43.8	29.1	15.3	8.0	5.5	4.3	3.7
19.13	1	81	0808	14048	43.7	29.1	15.3	8.0	5.8	4.2	3.6
19.13	1	81	0808	8248	25.2	16.8	8.7	4.5	3.1	2.4	2.1
19.13	1	81	0808	8304	25.3	16.7	8.8	4.6	3.3	2.4	2.1
19.13	1	81	0808	5584	16.0	10.6	5.5	2.8	2.1	1.5	1.3
19.13	1	81	0808	5592	15.8	10.5	5.4	2.8	2.0	1.5	1.3
19.44	1	81	0809	13832	51.9	35.3	18.0	8.7	5.3	4.4	3.9
19.44	1	81	0809	13952	51.0	35.0	18.1	8.8	5.3	4.4	3.9
19.44	1	81	0809	14016	51.0	35.0	18.2	8.8	5.3	4.4	4.0
19.44	1	81	0809	8336	29.4	20.2	10.4	5.1	3.1	2.6	2.3
19.44	1	81	0809	8352	29.2	20.1	10.4	5.0	3.1	2.5	2.3
19.44	1	81	0809	5632	18.4	12.7	6.6	3.1	2.0	1.6	1.4
19.44	1	81	0809	5632	18.3	12.6	6.5	3.1	2.0	1.6	1.4
18.81	2	81	0811	13920	40.7	23.9	11.4	6.4	4.7	3.9	3.2
18.81	2	81	0811	13992	39.5	23.6	11.5	6.4	4.8	3.8	3.3
18.81	2	81	0811	14008	39.4	23.7	11.4	6.3	4.6	3.8	3.3
18.81	2	81	0811	8288	22.9	13.6	6.5	3.7	2.7	2.2	1.9
18.81	2	81	0811	8320	22.7	13.6	6.6	3.7	2.7	2.2	2.0
18.81	2	81	0811	5624	14.6	8.6	4.0	2.2	1.7	1.4	1.1
18.81	2	81	0811	5584	14.5	8.6	4.0	2.2	1.7	1.3	1.1
19.31	2	81	0812	13528	63.5	31.8	11.9	6.1	4.8	4.4	3.6
19.13	2	81	0812	13520	61.0	32.1	12.3	6.1	5.1	4.4	3.8
19.13	2	81	0812	13480	60.5	32.6	12.4	6.1	5.0	4.3	3.7
19.13	2	81	0812	8168	36.5	19.2	6.8	3.4	2.9	2.5	2.2
19.13	2	81	0812	8168	36.3	19.1	6.7	3.4	2.8	2.5	2.2
19.13	2	81	0812	5464	23.9	12.3	4.2	2.1	1.8	1.5	1.3
19.13	2	81	0812	5432	23.7	12.2	4.2	2.2	1.9	1.6	1.4
19.44	2	81	0814	13328	71.5	36.0	14.6	6.6	2.7	4.4	2.5
19.44	2	81	0814	13432	69.4	38.2	15.4	6.9	4.9	4.2	3.7
19.44	2	81	0814	13424	68.1	38.5	15.5	6.9	4.9	4.3	4.0
19.44	2	81	0814	8456	41.8	23.0	8.7	3.8	2.8	2.4	2.1
19.44	2	81	0814	8320	41.6	22.9	8.6	4.0	3.0	2.8	2.1
19.44	2	81	0814	5568	27.1	14.6	5.1	2.5	1.8	1.9	1.3
19.44	2	81	0814	5536	26.5	14.4	5.2	2.4	1.8	1.8	1.3
18.81	3	81	0815	13968	59.0	33.3	14.4	8.3	6.4	5.1	4.2
18.81	3	81	0815	14048	57.5	34.0	15.2	8.5	6.6	5.2	4.2
18.81	3	81	0815	14064	57.6	34.5	15.3	8.5	6.6	5.2	4.2
18.81	3	81	0815	8456	35.6	20.9	8.6	4.9	3.8	3.0	2.5

[1] See page 15 for explanation and units of each column.

Table 15
Example of File of the TEMP Directory

Date	Time	Pavement Temperature, °C, at Item and Depth Indicated						Ambient Temp (°C)	Humidity (%)	Solar Radiation (nanometer)	Barometric Pressure (mb)	Wind Speed (mph)	Precipitation in.
		10-1"	10-2"	10-3"	12-1"	12-3"	12-4"						
01-Jun-89	0	55.1	37.4	38.0	41.5	44.2	76.0	23.8	79.7	0.04	1009	0.4	0.00
01-Jun-89	100	53.0	36.2	36.8	40.1	42.6	72.4	22.9	80.9	-0.01	1009	0.4	0.00
01-Jun-89	200	51.2	35.2	35.8	38.9	41.3	69.3	22.3	81.6	-0.05	1009	0.4	0.00
01-Jun-89	300	49.7	34.2	34.9	37.9	40.2	66.7	21.9	82.0	-0.04	1009	0.4	0.00
01-Jun-89	400	48.3	33.4	34.1	37.0	39.2	64.3	21.5	82.4	-0.07	1008	0.4	0.00
01-Jun-89	500	47.1	32.6	33.3	36.2	38.4	62.2	21.3	82.8	-0.05	1008	0.4	0.00
01-Jun-89	600	46.2	32.0	32.6	35.5	37.6	60.3	20.9	83.0	0.32	1009	0.4	0.00
01-Jun-89	700	45.7	31.5	32.1	35.0	37.0	58.7	20.8	83.2	23.23	1009	0.4	0.00
01-Jun-89	800	47.9	31.8	32.1	36.6	37.9	58.3	23.0	82.4	170.20	1010	0.4	0.00
01-Jun-89	900	55.5	34.4	33.9	40.9	41.2	60.8	26.9	76.1	366.00	1011	0.6	0.00
01-Jun-89	1000	65.9	38.2	36.9	46.2	45.6	66.7	29.2	70.6	586.90	1012	1.0	0.00
01-Jun-89	1100		43.0	41.0	52.3	50.8		31.1	61.4	781.00	1012	1.0	0.00
01-Jun-89	1200		46.7	44.5	55.9	54.2		32.0	56.2	823.00	1012	0.9	0.00
01-Jun-89	1300		50.3	47.8	60.1	58.0		32.8	52.2	936.00	1012	1.2	0.00
01-Jun-89	1400		53.2	50.8	63.3	61.4		33.6	49.0	940.00	1011	1.3	0.00
01-Jun-89	1500		55.4	53.1	65.4	63.8		34.2	46.3	929.00	1010	1.3	0.00
01-Jun-89	1600		56.4	54.5	65.8	65.1		34.3	43.9	701.00	1010	1.2	0.00
01-Jun-89	1700		49.8	52.0	56.0	60.9		27.6	70.6	236.50	1009	0.9	0.27
01-Jun-89	1800	68.5	44.4	48.4	50.7	67.7		26.4	80.5	132.70	1008	0.4	0.00
01-Jun-89	1900	61.0	40.8	45.4	45.0	66.1		25.1	80.4	12.96	1008	0.7	0.07
01-Jun-89	2000	55.6	37.9	42.5	41.7	59.1		23.3	81.3	12.23	1009	0.5	0.00

Table 16
Example RAIN Directory

Date	Time	Daily Precipitation, in.
18-Oct-88	2300	0.00
19-Oct-88	2300	0.19
20-Oct-88	2300	0.57
21-Oct-88	2300	0.21
22-Oct-88	2300	0.05
23-Oct-88	2300	0.33
24-Oct-88	2300	0.01
25-Oct-88	2300	0.00
26-Oct-88	2300	1.11
27-Oct-88	2300	0.00
28-Oct-88	2300	0.00
29-Oct-88	2300	0.02
30-Oct-88	2300	0.00
31-Oct-88	2300	0.00
1-Nov-88	2300	0.24
2-Nov-88	2300	0.19
3-Nov-88	2300	0.00
4-Nov-88	2300	2.61
5-Nov-88	2300	0.01
6-Nov-88	2300	0.00
7-Nov-88	2300	0.13
8-Nov-88	2300	0.00
9-Nov-88	2300	0.00
10-Nov-88	2300	0.01
11-Nov-88	2300	0.00
12-Nov-88	2300	1.77
13-Nov-88	2300	0.02
14-Nov-88	2300	0.00
15-Nov-88	2300	0.00
16-Nov-88	2300	0.11
17-Nov-88	2300	0.00
18-Nov-88	2300	0.00
19-Nov-88	2300	0.25
20-Nov-88	2300	0.00
21-Nov-88	2300	0.00
22-Nov-88	2300	0.00
23-Nov-88	2300	0.00
24-Nov-88	2300	0.00
25-Nov-88	2300	0.00
26-Nov-88	2300	0.99
27-Nov-88	2300	0.07
28-Nov-88	2300	0.00
29-Nov-88	2300	0.01

Table 17
Summary of Rut Depth Measurements Taken in AC Failures

Test Section	Lane	Wheel Path	Number of Passes	Maximum[1] Rut Depth, in.	Remarks
4	H	2	158	2.3	Severe cracking.
4	H	2	323	7.0	Severe cracking.
6	H	1	1,104	8.3	Severe cracking.
5	H	1	1,414	4.9	Severe cracking.
6	L	3	2,076	4.0	Severe cracking.
5	L	4	2,076	7.5	Severe cracking.
5	H	1	2,210	6.0	Severe cracking.
10	H	1	2,210	9.0	Severe shoving and cracking.
4	L	3	3,324	3.3	Severe cracking.
4	L	4	3,845	3.8	Severe cracking.

[1] Exceeded failure criteria because of 20-ft length requirement.

Table 18
Example of Rut Depth Measurements (File Rut) CTI Rut Measurement Item 8

		Passes			Rut Depth, in. at Station			Max Rut	
Date	Date	Loaded	Unloaded	WP	18.81	19.125	19.44	Depth in.	Station
32451	04-Nov-88	323	0	1	0	0	0		
32451	04-Nov-88	323	0	2	0	0	0		
32451	04-Nov-88	323	0	3	0	0	0		
32451	04-Nov-88	323	0	4	0	0	0		
32498	21-Dec-88	1077	0	3	0.25	0.125	0		
32498	21-Dec-88	1077	0	4	0.125	0.125	0		
32500	23-Dec-88	773	0	1	0.125	0	0		
32500	23-Dec-88	773	0	2	0.5	0.375	0.5		
32500	23-Dec-88	1296	0	3	0.375	0.125	0.25		
32500	23-Dec-88	1296	0	4	0.125	0.125	0		
32526	18-Jan-89	1104	0	1	0.125	0	0		
32526	18-Jan-89	1104	0	2	0.5	0.375	0.5		
32526	18-Jan-89	2076	0	3	0.375	0.125	0.25		
32526	18-Jan-89	2076	0	4	0.125	0.125	0		
32555	16-Feb-89	1565	0	1	0.13	0	0		
32555	16-Feb-89	1565	0	2	0.5	0.38	0.5		
32555	16-Feb-89	3000	0	3	0.5	0.13	0.5		
32555	16-Feb-89	3000	0	4	0.25	0.38	0.25		
32668	09-Jun-89	1712	0	1	0.13	0.25	0.25		
32668	09-Jun-89	1712	0	2	0.5	0.625	0.875		
32668	09-Jun-89	3128	0	3	0.625	0.25	0.625		
32668	09-Jun-89	3128	0	4	0.5	0.625	0.75		
32671	12-Jun-89	1946	0	1	0.13	0.38	0.25		
32671	12-Jun-89	1946	0	2	0.5	0.75	0.875		
32671	12-Jun-89	3324	0	3	0.625	0.25	0.625		
32671	12-Jun-89	3324	0	4	0.5	0.625	0.625		
32672	13-Jun-89	2210	0	1	0.5	0.375	0.875		
32672	13-Jun-89	2210	0	2	0.5	0.875	0.875		
32672	13-Jun-89	3566	0	3	0.5	0.375	0.75	1	19.28

Table 19
Example Summary PCI File

Item	Lane	Survey Date		Loaded Passes	Total Passes	PCI
9	H	SEP 26 88	32412 26-Sep-88	0	0	100
9	H	OCT 24 88	32440 24-Oct-88	2	2	100
9	H	DEC 29 88	32506 29-Dec-88	773	773	89
9	H	JUN 19 89	32678 19-Jun-89	2,210	2,210	23
9	H	NOV 29 89	32841 29-Nov-89	6,764	7,877	24
9	L	SEP 26 88	32412 26-Sep-88	0	0	100
9	L	OCT 24 88	32440 24-Oct-88	2	2	100
9	L	DEC 29 88	32506 29-Dec-88	1,296	1,296	77
9	L	FEB 22 89	32561 22-Feb-89	3,000	3,000	56
9	L	JUN 19 89	32678 19-Jun-89	3,566	3,566	39
9	L	NOV 29 89	32841 29-Nov-89	8,333	9,718	23
10	H	SEP 26 88	32412 26-Sep-88	0	0	100
10	H	OCT 24 88	32440 24-Oct-88	2	2	100
10	H	DEC 29 88	32506 29-Dec-88	773	773	97
10	H	JUN 19 89	32678 19-Jun-89	2,210	2,210	9
10	H	NOV 29 89	32841 29-Nov-89	6,764	7,877	53
10	L	SEP 26 88	32412 26-Sep-88	0	0	100
10	L	OCT 24 88	32440 24-Oct-88	2	2	100
10	L	DEC 29 88	32506 29-Dec-88	1,296	1,296	94
10	L	FEB 22 89	32561 22-Feb-89	3,000	3,000	65
10	L	JUN 19 89	32681 22-Jun-89	3,566	3,566	25
10	L	NOV 29 89	32841 29-Nov-89	8,333	9,718	22
11	H	SEP 26 88	32412 26-Sep-88	0	0	100
11	H	OCT 24 88	32440 24-Oct-88	2	2	100
11	H	DEC 29 88	32506 29-Dec-88	773	773	100
11	H	JUN 22 89	32681 22-Jun-89	2,679	2,679	40
11	H	NOV 29 89	32841 29-Nov-89	6,764	7,877	51
11	L	SEP 26 88	32412 26-Sep-88	0	0	100
11	L	OCT 24 88	32440 24-Oct-88	2	2	100
11	L	DEC 29 88	32506 29-Dec-88	1,296	1,296	93
11	L	FEB 22 89	32561 22-Feb-89	3,000	3,000	68
11	L	JUN 22 89	32681 22-Jun-89	4,045	4,045	48
11	L	NOV 29 89	32841 29-Nov-89	8,333	9,718	48
12	H	SEP 26 88	32412 26-Sep-88	0	0	100
12	H	OCT 24 88	32440 24-Oct-88	2	2	100
12	H	JUN 22 89	32681 22-Jun-89	2,679	2,679	38
12	H	NOV 29 89	32841 29-Nov-89	6,764	7,877	56
12	L	SEP 26 88	32412 26-Sep-88	0	0	100
12	L	OCT 24 88	32440 24-Oct-88	2	2	100
12	L	DEC 29 88	32506 29-Dec-88	1,296	1,296	90

Table 20
Example Inspection Report (CTI PCI)

```
____________________________________________________________________________
Branch Name     - ITEM 8        Section Length -  125.00 LF
Branch Number   - I8            Section Width  -   16.00 LF
Section Number  - H             Section Area   - 2000.00 SF
____________________________________________________________________________

----------------------------------------------------------------------------
Inspection Date: NOV/29/1989
Riding Quality:                      Safety:                   Drainage Cond.:
Shoulder Cond:                  Overall Cond:                          F.O.D.:
----------------------------------------------------------------------------
----------------------------------------------------------------------------

SAMPLE UNIT-1  (RANDOM)    SAMPLE SIZE-1600.00 SF

Distress-Type     Severity        Quantity        Density %     Deduct Value
15 Rutting        Low             300.00 (SF)      18.75            35.0
15 Rutting        Medium          165.00 (SF)      10.31            44.5
15 Rutting        High            135.00 (SF)       8.44            56.7

                               SAMPLE PCI -  18
----------------------------------------------------------------------------

PCI OF SECTION - 18                   RATING - V. POOR

Total Number of Sample Units - 1
Number of Random Sample Units Surveyed - 1
Number of Additional Sample Units Surveyed - 0
Recommend Every Sample Unit be Surveyed.
Standard Deviation of PCI Between Random Units Surveyed - .0%


            *** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***
                                (continued)

Distress-Type     Severity        Quantity        Density %     Deduct Value
15 Rutting        Low             375.00 (SF)      18.75            35.0
15 Rutting        Medium          206.25 (SF)      10.31            44.5
15 Rutting        High            168.75 (SF)       8.44            56.7


        *** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

Load Related Distresses -                    100.00 Percent Deduct Values.
Climate/Durability Related Distresses -         .00 Percent Deduct Values.
Other Related Distresses -                      .00 Percent Deduct Values.
```

Table 21
Summary of Multidepth Deflectometer Directory MDD1212

File	Location of MDD		Loading Device[2]
	Item	Lane[1]	
D10HFWD1	10	H	FWD
D10HFWD2	10	H	FWD
D10HFWD3	10	H	FWD
D10LFWD1	10	L	FWD
D10LFWD2	10	L	FWD
D10LFWD3	10	L	FWD
D12FWD1	12	H	FWD
D12FWD2	12	H	FWD
D12FWD3	12	H	FWD
D10LT1L	10	L	LPT
D10LT2L	10	L	LPT
D10LT3L	10	L	LPT
D10LT2H	10	L	HPT
D10LT3H	10	L	HPT
D10T0H	10	H	HPT
D10T1H	10	H	HPT
D10T2H	10	H	HPT
D10T3H	10	H	HPT
D10T1L	10	H	LPT
D10T2L	10	H	LPT
D10T3L	10	H	LPT
D12T1H	12	H	HPT
D12T2H	12	H	HPT
D12T3H	12	H	HPT
D12T1L	12	H	LPT
D12T2L	12	H	LPT

[1] Lane: H = high pressure, L = low pressure.

[2] Loading device: FWD = falling weight deflectometer, LPT = low-tire-pressure truck, HPT = high-tire-pressure truck.

Table 22
Summary of Multidepth Deflectometer Directory MDD1111

File Name	MDD Location		Loading Device[2]
	Item	Lane[1]	
WES10HP1	10	H	FWD
WES10HP4	10	H	FWD
WES12HP1	12	H	FWD
WES12HP2	12	H	FWD
WES12HP3	12	H	FWD
WES12HP4	12	H	FWD
WES10HT1	10	H	HPT
WES10HT2	10	H	HPT
WES10HT3	10	H	HPT
WES10HT4	10	H	HPT
WES10HT5	10	H	HPT
WES10HT6	10	H	HPT
WES10HT7	10	H	HPT
WES10LT1	10	L	LPT
WES10LT2	10	L	LPT
WES10LT3	10	L	LPT
WES12HPT	12	H	HPT
WES12HT2	12	H	HPT
WES12HT3	12	H	HPT
WES12HT4	12	H	HPT

[1] Lane: H = high pressure, L = low pressure.

[2] Loading device: FWD = falling weight deflectometer, HPT = high-tire-pressure truck, LPT = low-tire-pressure truck.

Table 23
Example Multidepth Deflectometer File

	Deflection, Mils		
Time, msec	LVDT$_1$	LVDT$_2$	LVDT$_3$
32.60394	9.925489	8.826842	4.029415
32.82313	10.03535	8.900085	4.066036
33.04231	10.18184	9.009948	4.139278
33.2615	10.25509	9.046569	4.175899
33.48069	10.40157	9.156439	4.249141
33.69988	10.43819	9.19306	4.285762
33.91907	10.58468	9.302923	4.322383
34.13826	10.6213	9.376165	4.359005
34.35745	10.73117	9.449408	4.359005
34.57663	10.80441	9.52265	4.395626
34.79582	10.87765	9.559271	4.432254
35.01501	10.91427	9.632521	4.468875
35.2342	10.95089	9.632521	4.468875
35.45338	10.98752	9.669142	4.468875
35.67257	10.98752	9.669142	4.468875
35.89176	11.02414	9.705763	4.505496
36.11095	10.98752	9.669142	4.468875
36.33014	10.98752	9.705763	4.505496
36.54933	10.91427	9.632521	4.505496
36.76852	10.91427	9.632521	4.505496
36.98771	10.84103	9.559271	4.468875
37.20689	10.80441	9.52265	4.468875
37.42608	10.69455	9.412787	4.432254
37.64527	10.6213	9.376165	4.432254
37.86446	10.51143	9.266302	4.359005

Table 24
Deflection Basins Associated with the MDD1212 and MDD1111 Directories

		Deflection, mils Distance from Center of Load Plate, in.						
File Name	**lb**	**0**	**12**	**24**	**36**	**48**	**60**	**72**
Directory MDD1212								
D10HFWD1	14,856	45.62	28.13	13.04	6.32	3.60	2.51	2.06
D10HFWD2	9,056	24.48	16.46	8.68	4.72	2.97	2.15	1.82
D10HFWD3	6,136	15.30	10.33	5.43	2.94	1.90	1.39	1.19
D10LFWD1	14,328	38.56	27.58	15.18	8.59	5.50	3.98	3.21
D10LFWD2	8,952	21.69	15.40	8.39	4.84	3.09	2.27	1.88
D10LFWD3	6,008	13.57	9.55	5.18	2.98	1.94	1.39	1.15
D12FWD1	14,808	45.62	28.13	13.04	6.32	3.60	2.51	2.06
D12FWD2	9,024	26.17	16.03	7.36	3.61	2.10	1.47	1.19
D12FWD3	6,056	16.48	9.98	4.57	2.27	1.31	0.88	0.71
Directory MDD1111								
WES10HP1	16,148	51.15	33.38	16.89	8.66	5.35	4.05	3.45
WES10HP4	7,000	19.61	12.74	6.34	3.27	2.38	1.62	1.25
WES12HP1	15,893	65.02	35.29	14.96	6.17	3.37	2.55	2.12
WES12HP2	14,848	60.00	32.79	14.00	5.80	3.22	2.39	1.97
WES12HP3	10,468	41.13	22.28	9.43	3.86	2.14	1.58	1.33
WES12HP4	6,995	25.78	13.75	5.73	2.39	1.35	1.01	0.84

Table 25
Summary of Rut Depth Measurements Taken in Aggregate Failures

Test Item	Lane	Wheel Path	Number of Passes Loaded/ (Unloaded)	Maximum Rut Depth (in.)	Degree of Washboarding	Remarks
1	H	2	58	4.0	None	Failed section overlaid with 12 in. of aggregate.
2	H	1	58	4.8	Low	Failed section overlaid with 12 in. of aggregate.
3	H	1	58	3.5	None	Failed section overlaid with 12 in. of aggregate.
1	L	3	66	5.0	None	Failed section overlaid with 12 in. of aggregate.
2	L	4	66	3.0	None	Failed section overlaid with 12 in. of aggregate.
3	L	3	66	4.5	None	Failed section overlaid with 12 in. of aggregate.
2	H	1	60 (112)	6.9	Moderate	Failed; section graded.
2	H	1	282 (259)	5.0	Severe	Failed; section graded.
2	H	1	282 (282)	4.5	Severe	Failed; section graded.
2	H	1	282 (342)	4.5	Moderate	Failed; section graded.
2	H	1	584 (556)	4.0	Severe	Section graded.
13	H	1	883 (672)	4.3	Low	86 passes in rain; rutting increased 3.1 in.; graded.
13	L	4	1,077 (838)	4.8	Low	98 passes in rain; rutting increased 3.3 in.; graded.
14	H	2	883 (672)	5.8	Low	86 passes in rain; rutting increased 4.0 in.; graded.
14	L	3	1,077 (838)	5.0	Low	98 passes in rain; rutting increased 3.2 in.; graded.
15	H	1	883 (672)	4.3	Low	86 passes in rain; rutting increased 1.5 in.; graded.
15	L	4	1,077 (838)	3.5	Low	98 passes in rain; rutting increased 1.2 in.; graded.
13	H	2	1,331 (1,112)	2.3	Low	Section graded prior to watering.
13	L	3	1,600 (1,384)	1.4	Low	Section graded prior to watering.
14	H	1	1,331 (1,112)	2.0	Low	Section graded prior to watering.
14	L	3	1,600 (1,384)	1.8	Low	Section graded prior to watering.
15	H	2	1,331 (1,112)	1.6	Low	Section graded prior to watering.
15	L	4	1,600 (1,384)	2.5	Low	Section graded prior to watering.
14	H	2	2,015 (1,112)	4.9	Severe	Failed; section graded.
15	H	2	2,103 (1,112)	4.0	Severe	Failed; section graded.
15	H	1	2,321 (1,112)	>4.0	Moderate	Failed.
15	H	1	2,544 (1,112)	4.9	Moderate	Failed.

Table 26
Summary of Induced Failure Results

	Water Added, in.		Passes Per Lane		
Date	**Irrigation**	**Rain**	**High-Tire Pressure**	**Low-Tire Pressure**	**Remarks including change in performance**
30 Oct	0.0	0.0	25	25	Bladed all items and applied 25 passes to compact loose material before watering
31 Oct	0.75	0.0	10	30	High severity pot holes in low pressure lanes of items 13 & 14
1 Nov	0.50	0.0	69	59	No change in severity of rutting
2 Nov	0.50	0.0	85	81	Photographs of all items, low to medium severity rutting all items
3 Nov	0.50	0.0	110	120	DCP & rut depth measurements, high severity rutting in HTPL[1] item 14
5 Nov	0.75	0.79	0	0	No traffic due to rain
6 Nov	0.00	2.04	98	113	No change in performance
7 Nov	0.0	0.48	119	131	High severity rutting all lanes and items except LTPL[2] section 15 which was had medium severity rutting. Medium severity pot holes and corrugations in HTPL of items 13, 14, & 15
8 Nov	0.0	0.0	15	15	HTPL item 14 failed
9 Nov	0.0	0.0	88	103	HTPL item 15 failed
12 Nov	0.0	0.20	0	0	Sunday no traffic
13 Nov	0.0	0.0	25	24	Graded HTPL in items 14 & 15 and part of LTPL item 15 after 25 passes low severity corrugation in HTPL item 15
14 Nov	0.0	0.21	95	109	High severity rutting in HTPL items 14 & 15
15 Nov	0.0	0.0	73	95	High severity pot holes in HTPL item 15
16 Nov	0.0	0.0	69	100	HTPL item 15, failed due to severe rutting
17 Nov	0.25	0.0	78	104	Simulated rain on item 13 only
20 Nov	0.0	0.0	102	121	High severity ruts throughout HTPL item 15, high severity pot hole in LTPL item 15
21 Nov	0.0	1.56	78	89	No change
22 Nov	0.0	0.0	22	25	No change, all test traffic stopped - end of test

[1] HTPL = High-tire-pressure lane.
[2] LTPL = Low-tire-pressure lane.

Table 27
Example of Aggregate Surfaced Inspection Report

```
Agency Name:  US Department of Agriculture- Forest Service
Agency Number:                 Report Date:  NOV/01/1990

------------------------------------------------------------------------
Branch Name      - ITEM 1              Section Length -  248.00 LF
Branch Number    - I1                  Section Width  -   20.00 LF
Section Number   - H                   Section Area   - 4960.00 SF
------------------------------------------------------------------------

------------------------------------------------------------------------
Inspection Date: NOV/29/1989
Riding Quality:                Safety:                       Drainage Cond.:
Shoulder Cond:               Overall Cond:                          F.O.D.:
------------------------------------------------------------------------
------------------------------------------------------------------------

SAMPLE UNIT- 1  (RANDOM)    SAMPLE SIZE- 1700.00 SF

Distress-Type    Severity       Quantity        Density %     Deduct Value
83 Corrugation   Low            125.00 (SF)       7.35             5.3
86 Rutting       Low            300.00 (SF)      17.65            19.4
86 Rutting       Medium         300.00 (SF)      17.65            24.4
87 Loose AG      Low            200.00 (LF)      11.76            15.9

                              SAMPLE PCI -  64
------------------------------------------------------------------------

PCI OF SECTION - 64                  RATING - GOOD

Total Number of Sample Units - 1
Number of Random Sample Units Surveyed - 1
Number of Additional Sample Units Surveyed - 0
Recommend Every Sample Unit be Surveyed.
Standard Deviation of PCI Between Random Units Surveyed - .0%


          *** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***


Distress-Type    Severity       Quantity        Density %     Deduct Value
83 Corrugation   Low            364.71 (SF)       7.35             5.3
86 Corrugation   Low            875.29 (SF)      17.65            19.4
86 Rutting       Medium         875.29 (SF)      17.65            24.4
87 Loose AG      Low            583.53 (LF)      11.76            15.9
```

Table 28
DCP Directory

File	Extension	Size, bytes
Item 1	DCP	24,315
Item 10	DCP	8,763
Item 11	DCP	3,214
Item 12	DCP	3,317
Item 13	DCP	109,561
Item 14	DCP	122,765
Item 15	DCP	128,329
Item 2	DCP	25,045
Item 3	DCP	21,662
Item 4	DCP	23,003
Item 5	DCP	25,955
Item 6	DCP	16,148
Item 7	DCP	3,232
Item 8	DCP	2,878
Item 9	DCP	3,294

Table 29
Example DCP File

Item	Station (ft)	Wheel Path	Test Number	Date	Passes		Blows	Penetration (in.)	CBR %	Clegg (CIV)
					Load	Unload				
15	825	5	1	06-OCT-88	0	0	0	0.0	0	32
15	825	5	1	06-OCT-88	0	0	5	2.0	22	29
15	825	5	1	06-OCT-88	0	0	5	3.7	25	32
15	825	5	1	06-OCT-88	0	0	5	6.1	18	31
15	825	5	1	06-OCT-88	0	0	5	8.9	15	
15	825	5	1	06-OCT-88	0	0	5	11.4	17	
15	825	5	1	06-OCT-88	0	0	5	14.6	13	
15	825	5	1	06-OCT-88	0	0	5	16.5	22	
15	825	5	1	06-OCT-88	0	0	5	17.7	39	
15	825	5	1	06-OCT-88	0	0	5	19.3	28	
15	825	5	1	06-OCT-88	0	0	5	20.5	39	
15	825	5	1	06-OCT-88	0	0	5	21.7	39	
15	825	5	1	06-OCT-88	0	0	5	22.4	62	
15	825	5	1	06-OCT-88	0	0	5	23.2	62	
15	825	5	1	06-OCT-88	0	0	5	24.0	62	
15	825	5	1	06-OCT-88	0	0	5	24.6	85	
15	825	5	1	06-OCT-88	0	0	5	25.6	48	
15	825	5	1	06-OCT-88	0	0	5	26.6	48	
15	825	5	1	06-OCT-88	0	0	5	27.2	85	
15	825	5	1	06-OCT-88	0	0	5	28.0	62	
15	825	5	1	06-OCT-88	0	0	5	29.1	39	
15	825	5	1	06-OCT-88	0	0	5	30.7	28	
15	825	5	1	06-OCT-88	0	0	5	32.5	25	
15	825	5	1	06-OCT-88	0	0	5	34.3	25	
15	825	5	2	06-OCT-88	0	0	0	0.0	0	
15	825	5	2	06-OCT-88	0	0	5	2.6	17	
15	825	5	2	06-OCT-88	0	0	5	4.9	18	
15	825	5	2	06-OCT-88	0	0	5	7.9	14	
15	825	5	2	06-OCT-88	0	0	5	11.0	13	
15	825	5	2	06-OCT-88	0	0	5	14.0	14	

(Continued)

Table 29 (Concluded)

Item	Station (ft)	Wheel Path	Test Number	Date	Passes		Blows	Penetration (in.)	CBR %	Clegg (CIV)
					Load	Unload				
15	825	5	2	06-OCT-88	0	0	5	16.3	18	
15	825	5	2	06-OCT-88	0	0	5	17.3	48	
15	825	5	2	06-OCT-88	0	0	5	18.7	33	
15	825	5	2	06-OCT-88	0	0	5	20.1	33	
15	825	5	2	06-OCT-88	0	0	5	21.7	28	
15	825	5	2	06-OCT-88	0	0	5	22.6	48	
15	825	5	2	06-OCT-88	0	0	5	23.6	48	
15	825	5	2	06-OCT-88	0	0	5	24.8	39	
15	825	5	2	06-OCT-88	0	0	5	25.6	62	
15	825	5	2	06-OCT-88	0	0	5	26.4	62	
15	825	5	2	06-OCT-88	0	0	5	27.2	42	
15	825	5	2	06-OCT-88	0	0	5	28.3	39	
15	825	5	2	06-OCT-88	0	0	5	29.5	39	
15	825	5	2	06-OCT-88	0	0	5	30.9	33	
15	825	5	2	06-OCT-88	0	0	5	32.3	33	
15	825	5	2	06-OCT-88	0	0	5	34.3	22	
15	825	5	3	06-OCT-88	0	0	0	0.0	0	

Photo 1. Weather station

Photo 2. Compaction of the aggregate base material

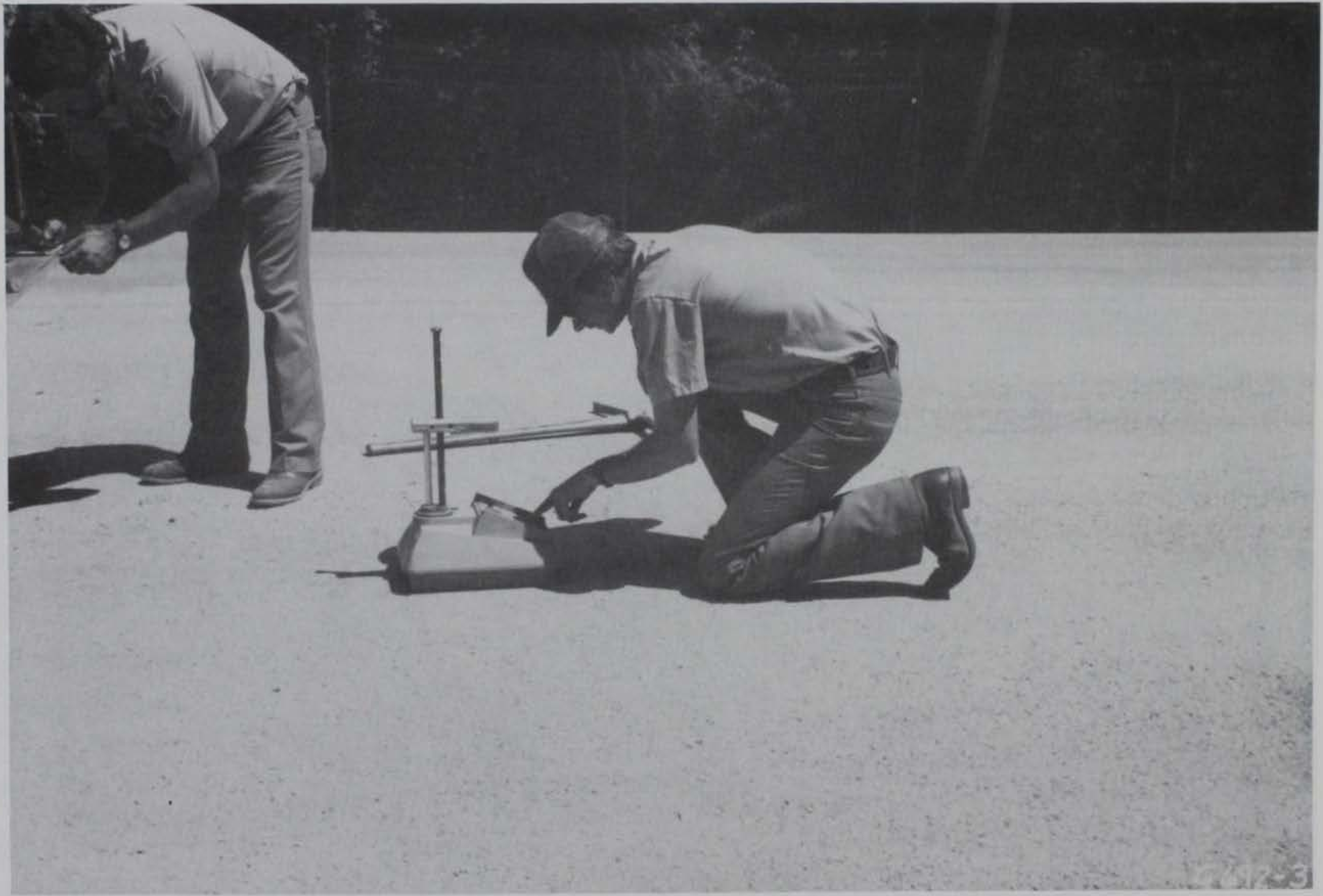

Photo 3. Density determination during base construction

Photo 4. Placement of the asphalt concrete

Photo 5. Breakdown rolling of the hot asphalt mix

Photo 6. Compaction of the asphalt mix with a rubber-tired roller

Photo 7. Test vehicles

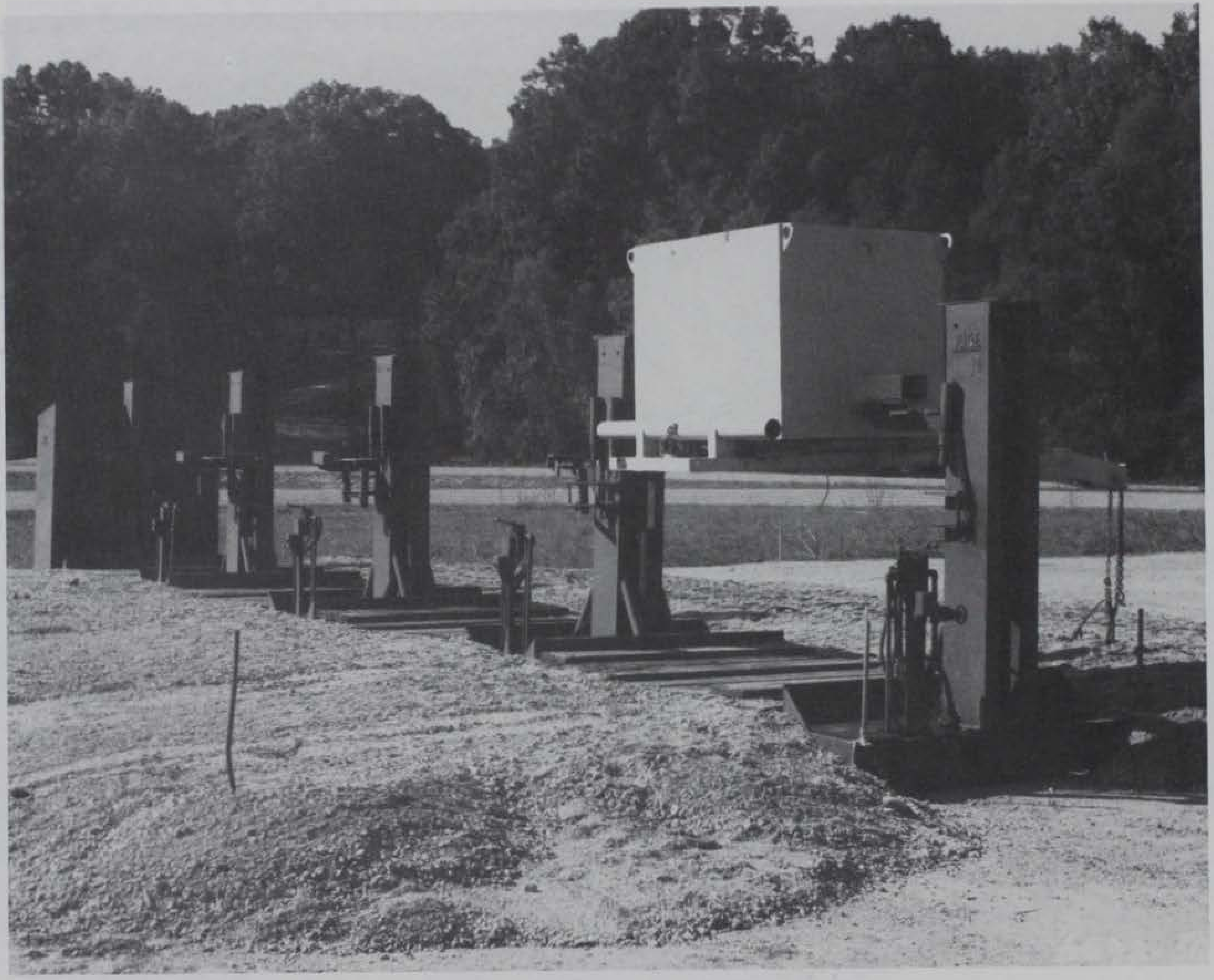

Photo 8. Hydraulic log bunk lifting device

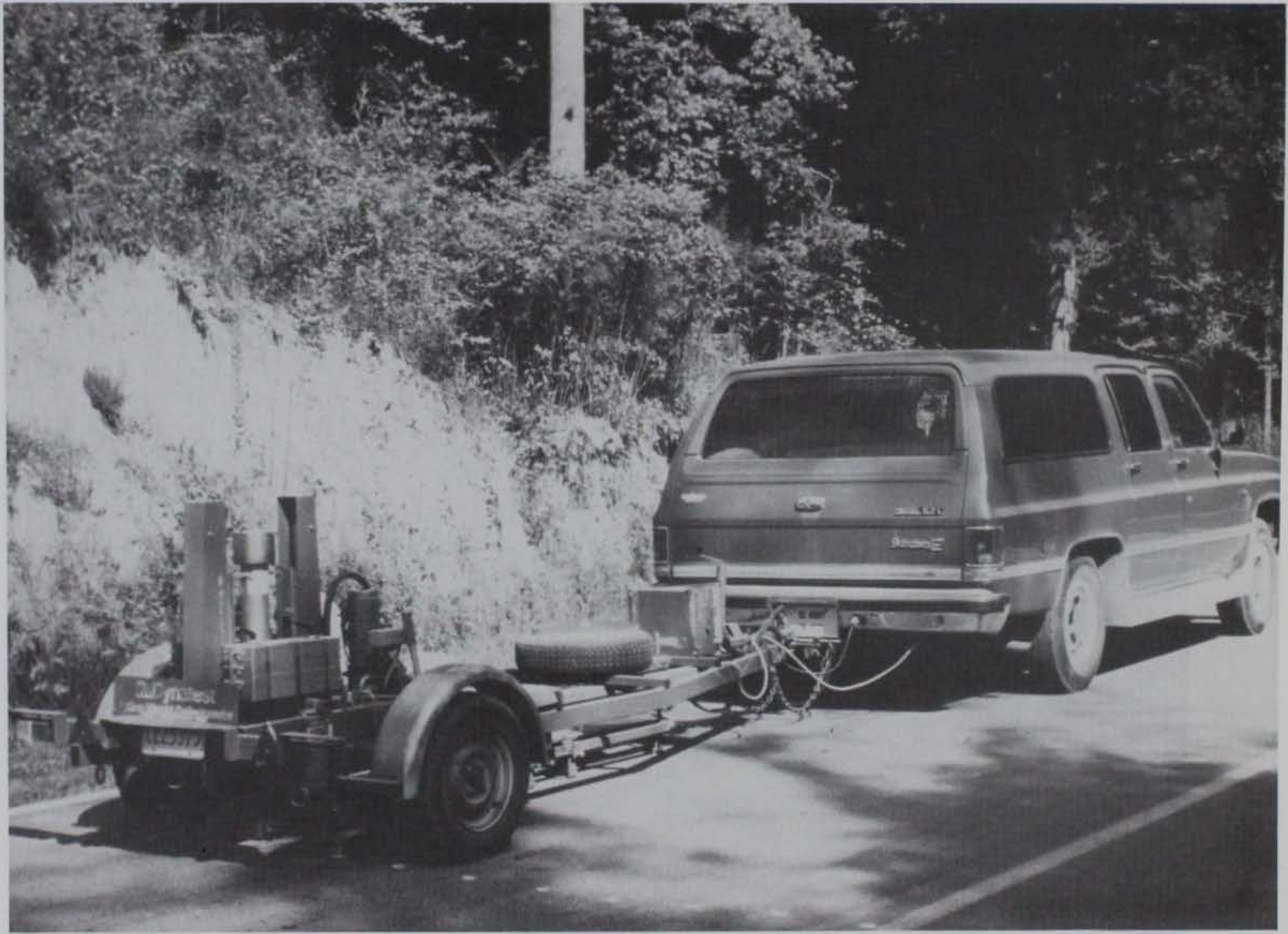

Photo 9. Falling weight deflectometer

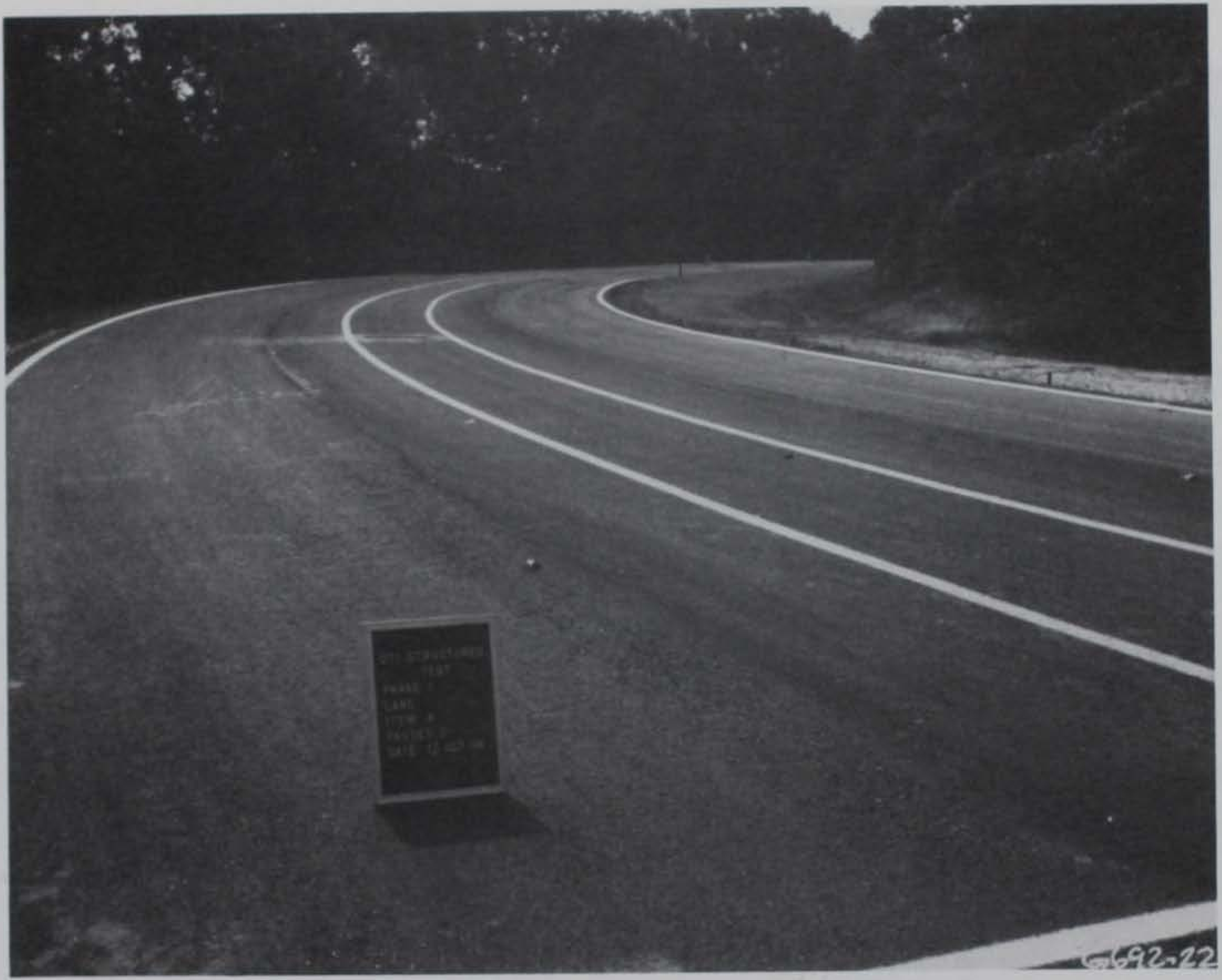

Photo 10. General view of Item 4 before traffic

Photo 11. General view of Item 5 before traffic

Photo 12. General view of Item 6 before traffic

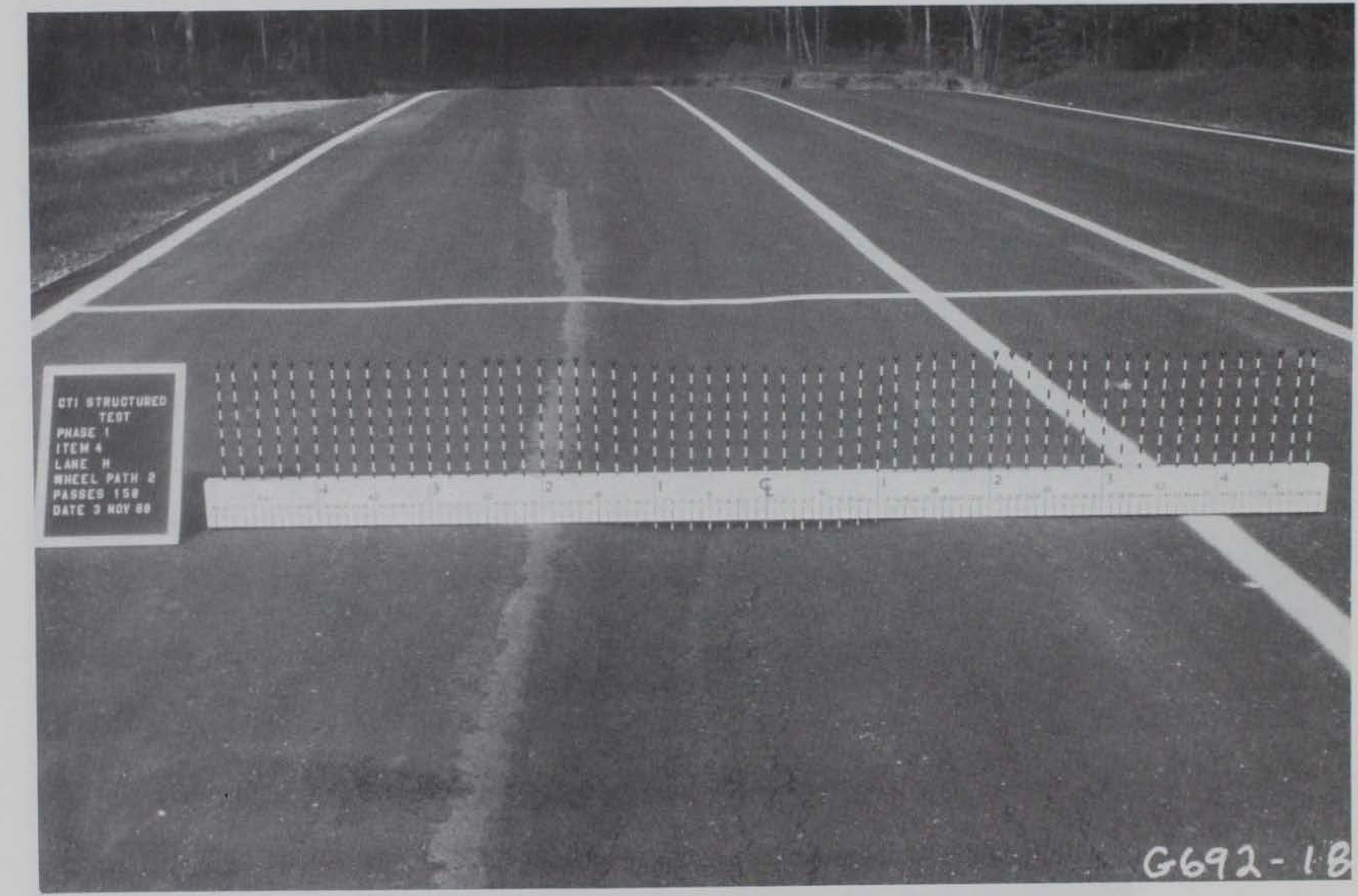

Photo 13. Item 4, wheel path 2, general view of initial failure, 158 passes

Photo 14. Item 4, wheel path 2, general view of second failure, 323 passes

Photo 15. Item 4, wheel path 2, test trench after 323 passes

Photo 16. Item 5, high-tire pressure lane, maximum 1-in. rutting after 323 passes

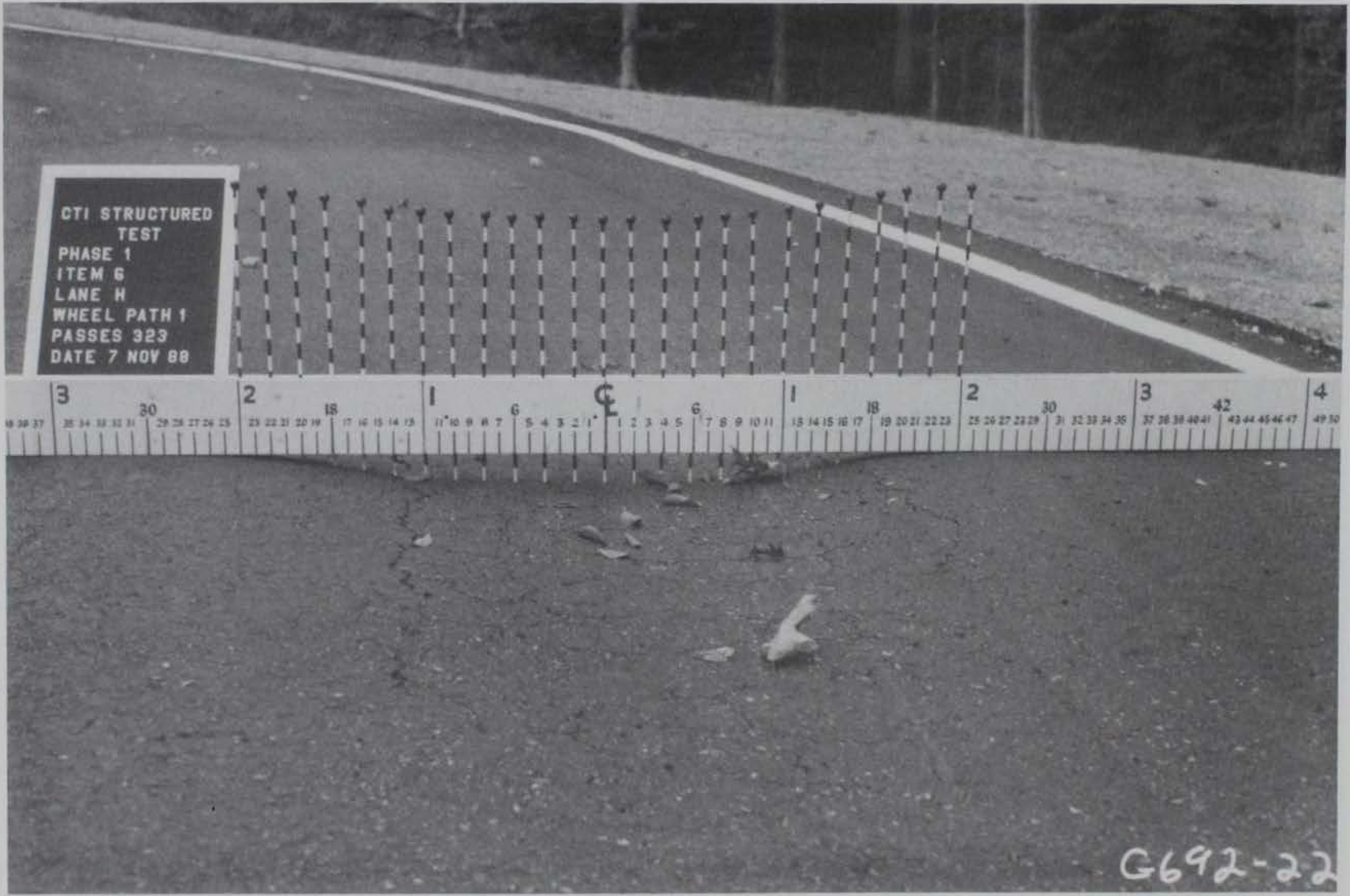

Photo 17. Item 6, high-tire pressure lane, 2.25-in. rutting in localized area after 323 passes

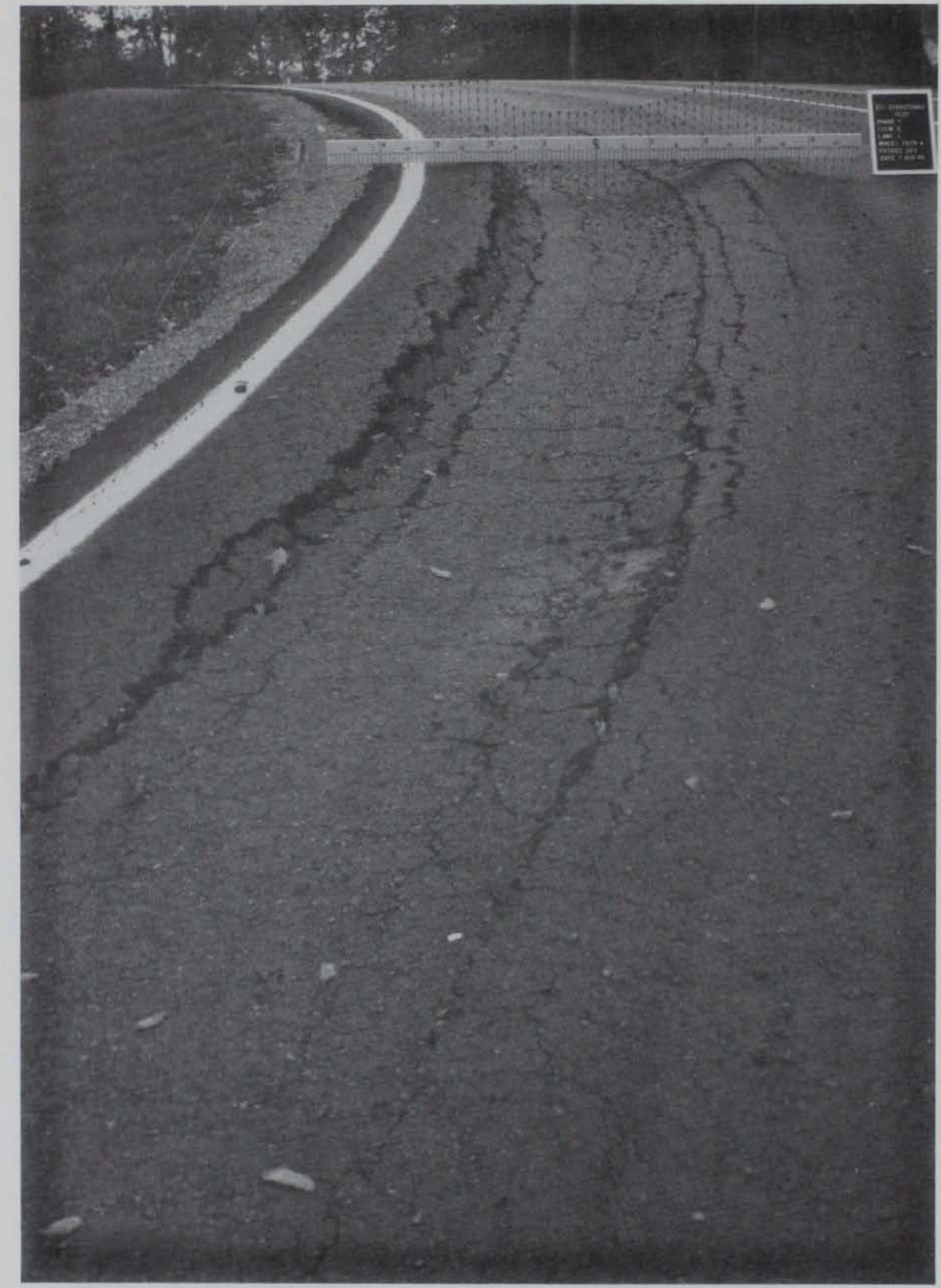

Photo 18. Item 5, wheel path, high-severity rutting and cracking in a localized area

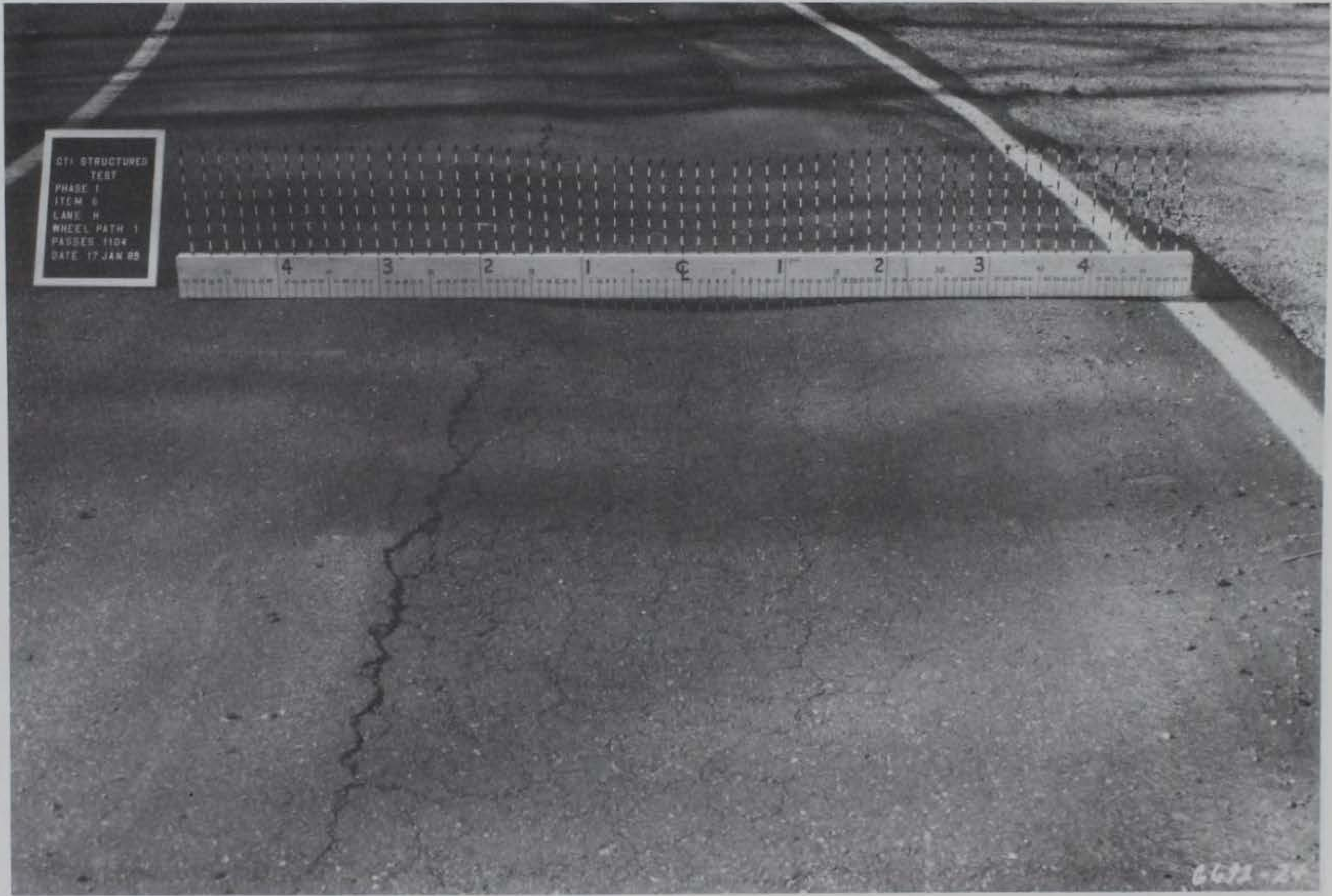

Photo 19. Item 6, high-tire pressure lane general view of failed area after 1,104 passes

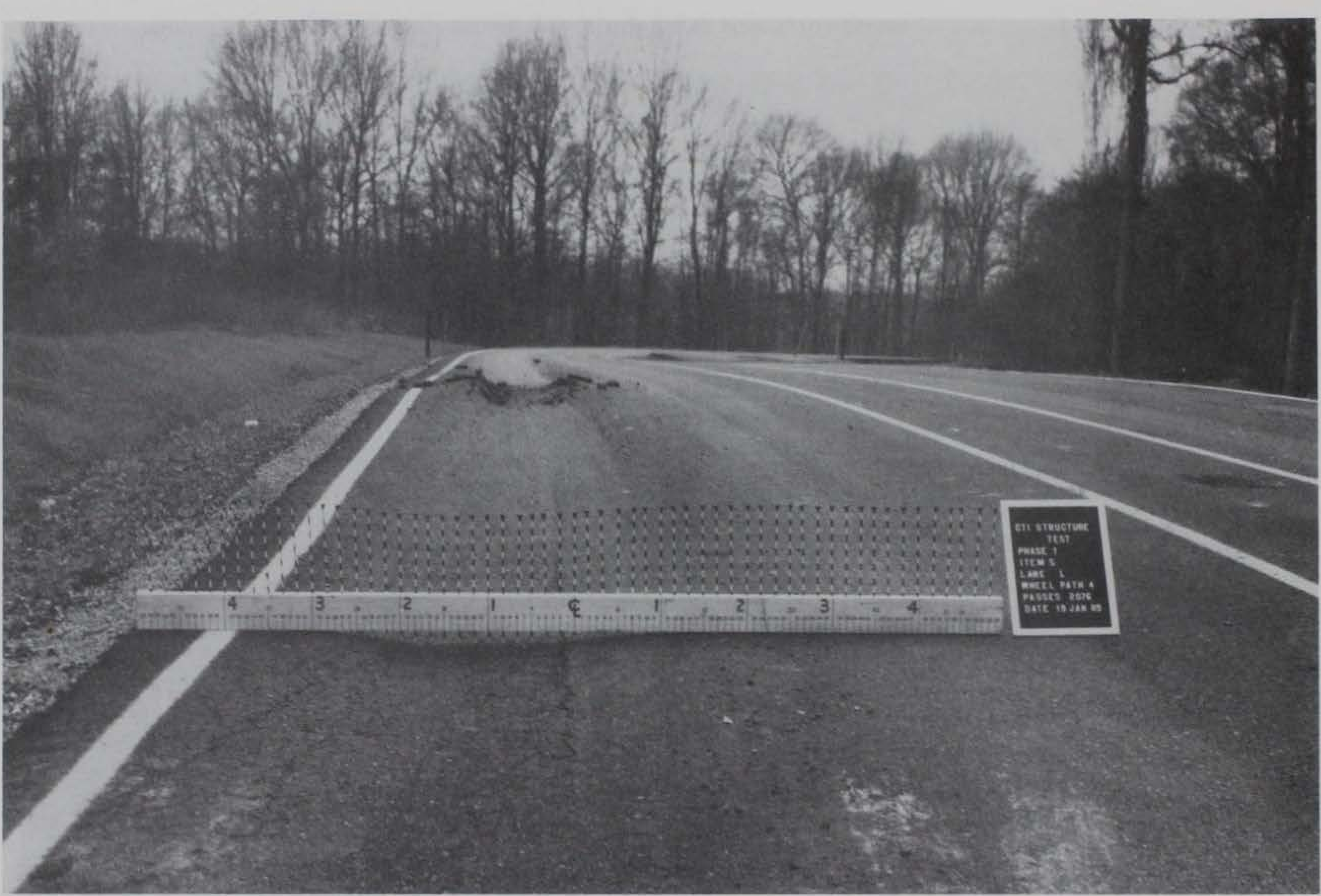

Photo 20. Item 5, wheel path 1, general view of failure after 2,210 passes

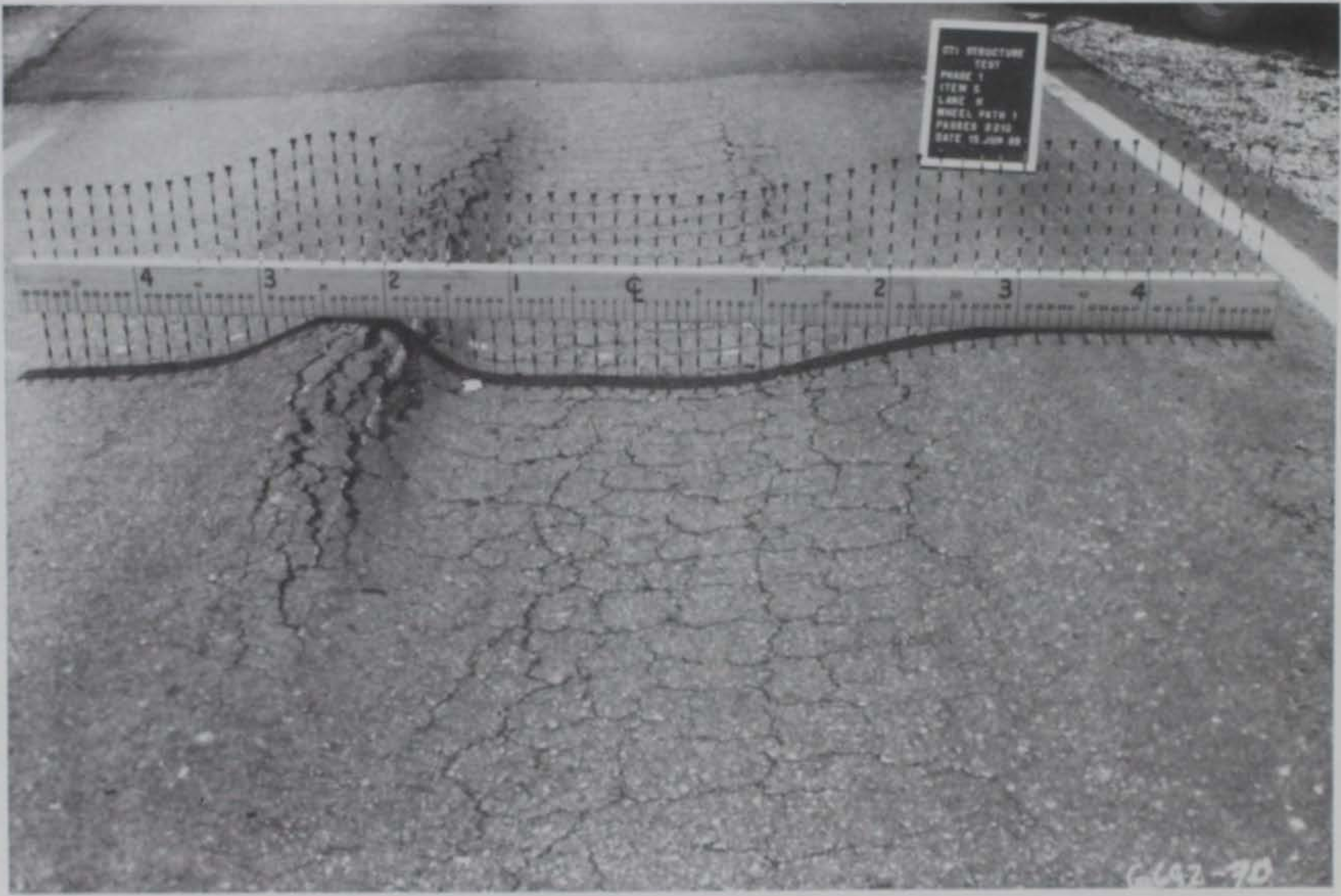

Photo 21. Item 5, wheel path 4, general view of failure after 2,076 passes

Photo 22. Item 6, wheel path 3, general failure after 2,076 passes

Photo 23. Item 4, low-tire pressure lane, general view of failure after 3,324 passes

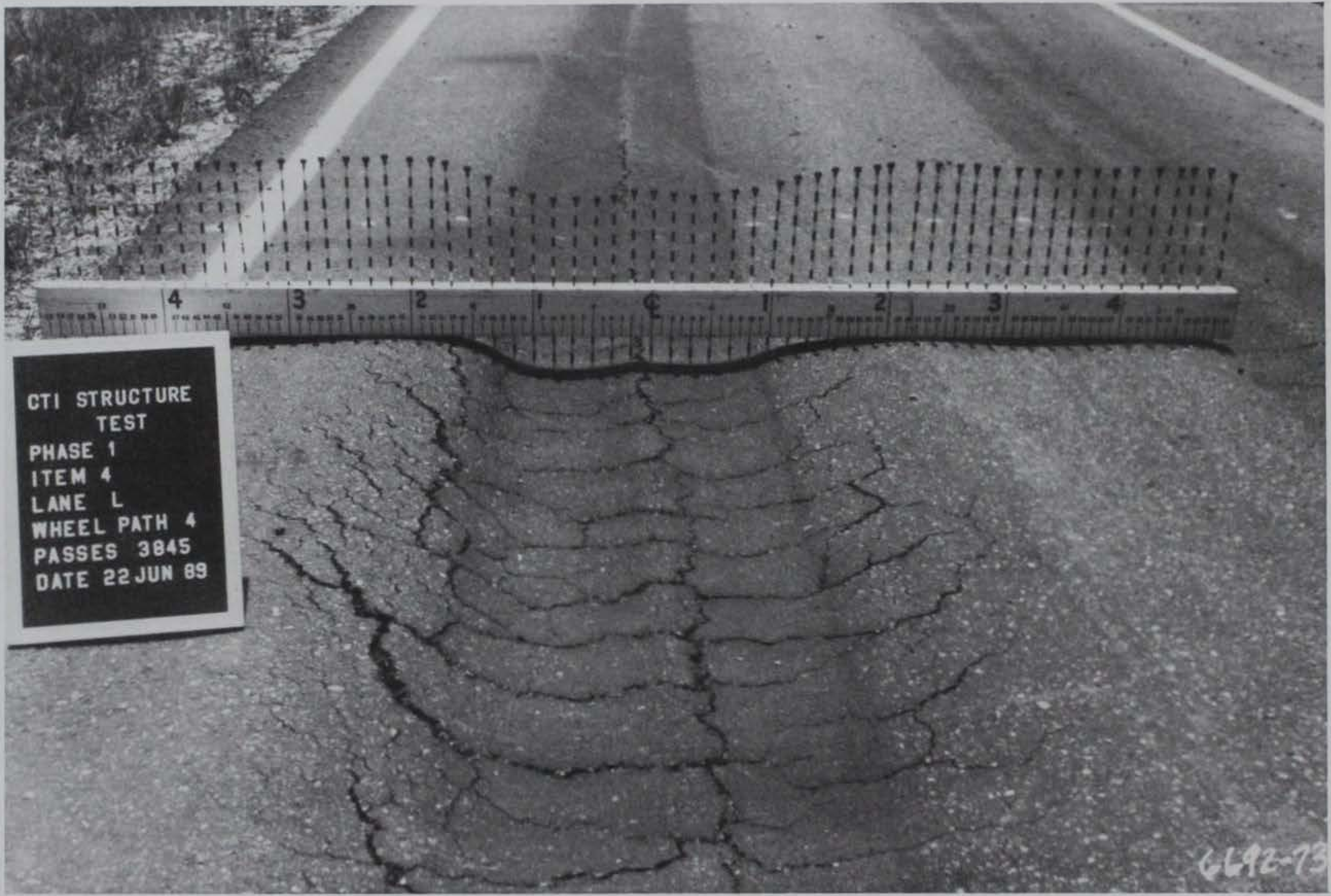

Photo 24. Item 4, wheel path 4, failure after 3,845 passes

Photo 25. Item 7, general view before traffic

Photo 26. Item 8, general view before traffic

Photo 27. Item 9, general view before traffic

Photo 28. Item 10, general view before traffic

Photo 29. Item 11, general view before traffic

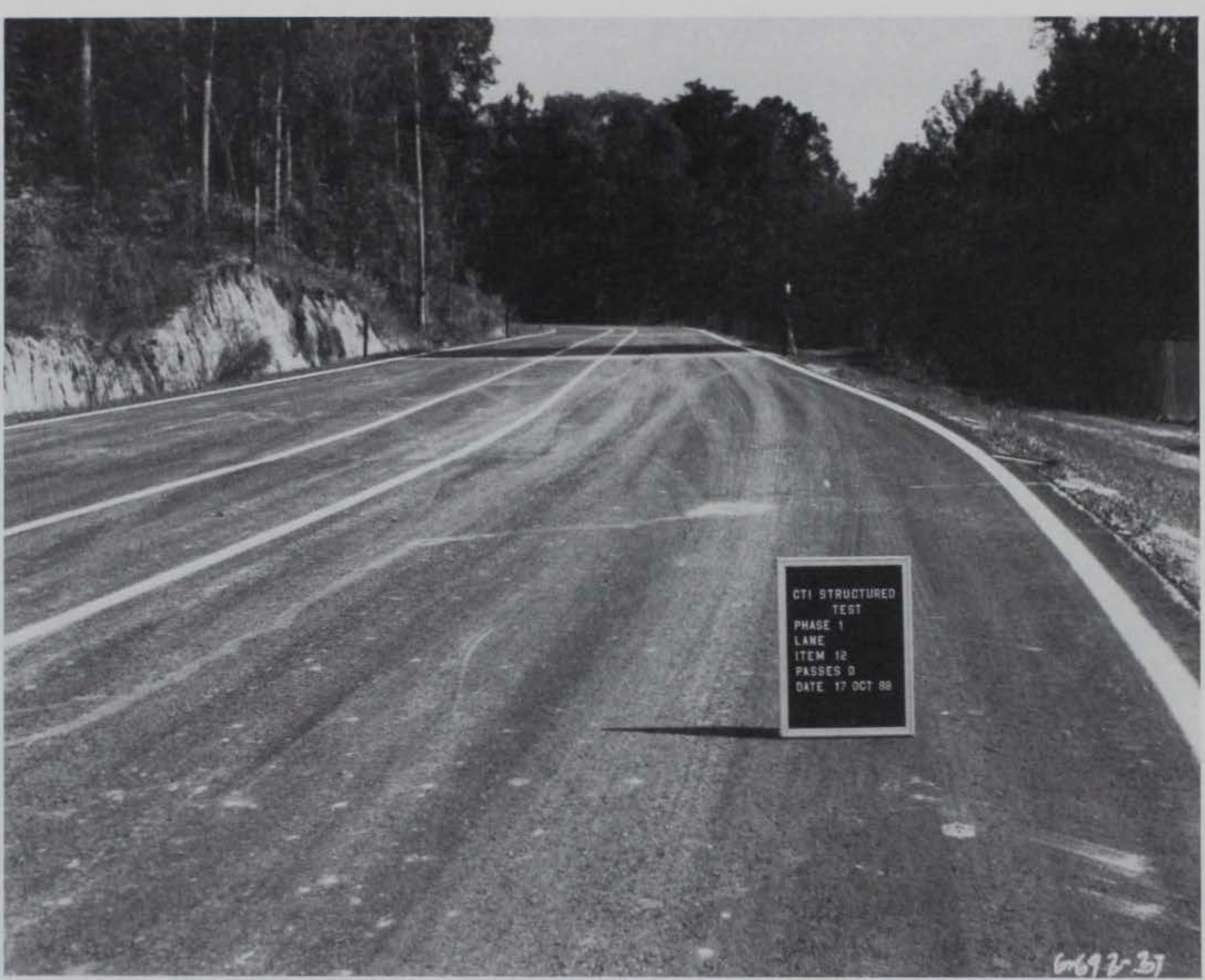

Photo 30. Item 12, general view before traffic

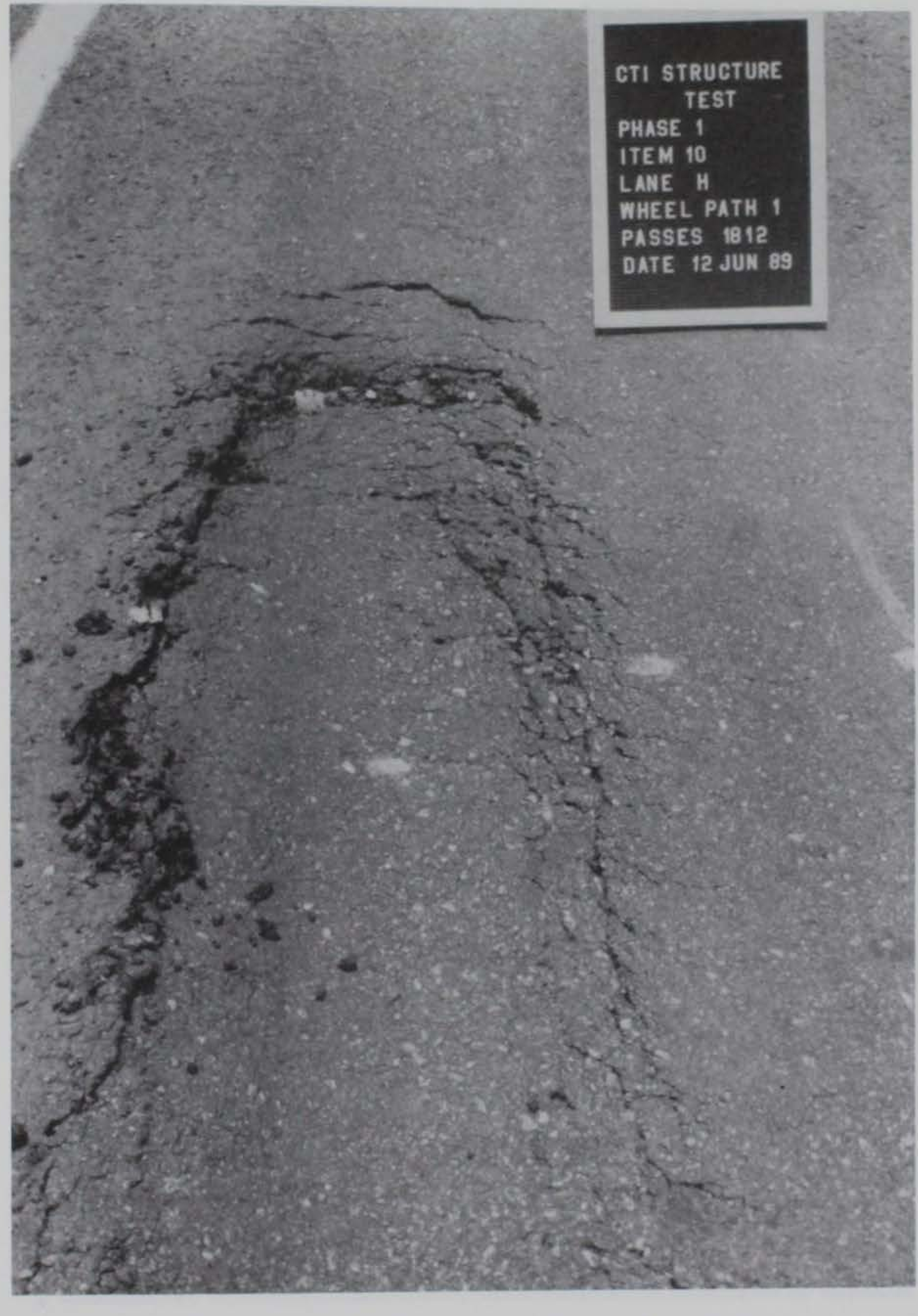

Photo 31. Item 10, wheel path 1, high-severity shoving after 1,812 passes

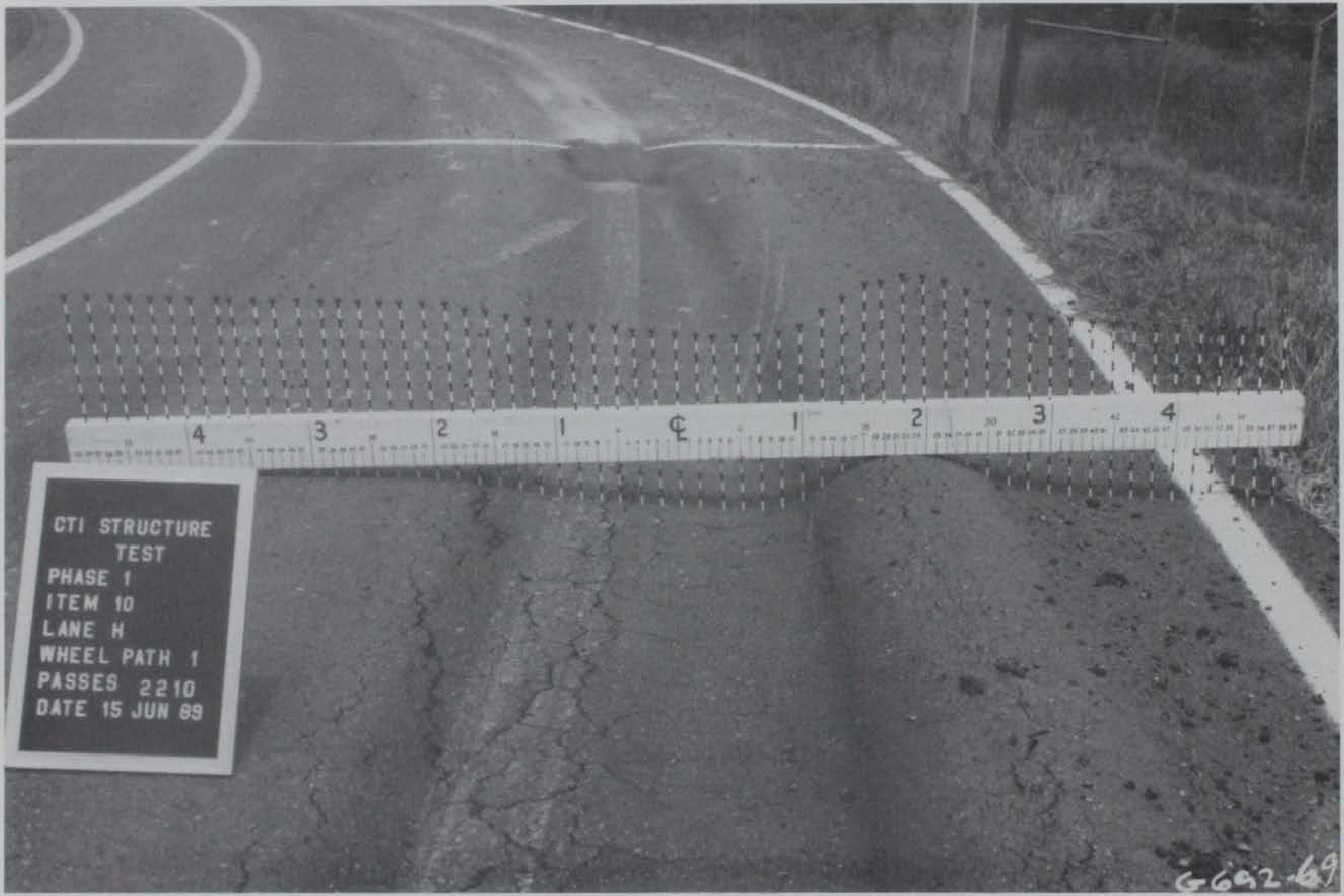

Photo 32. Item 10, wheel path 1, high-severity rutting and cracking, failure after 2,210 passes

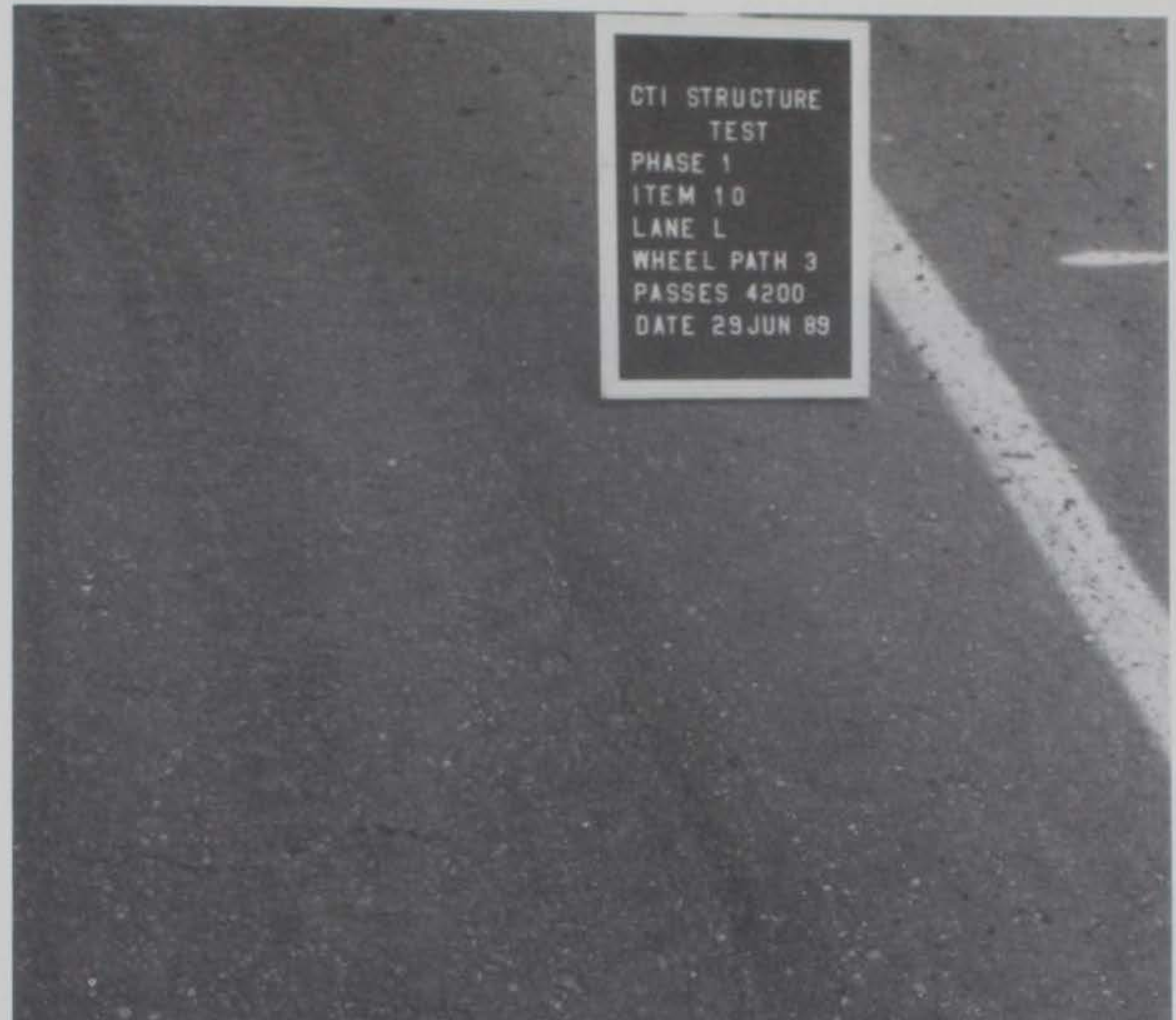

Photo 33. Item 10, wheel path 3, low-severity shoving after 4,200 passes

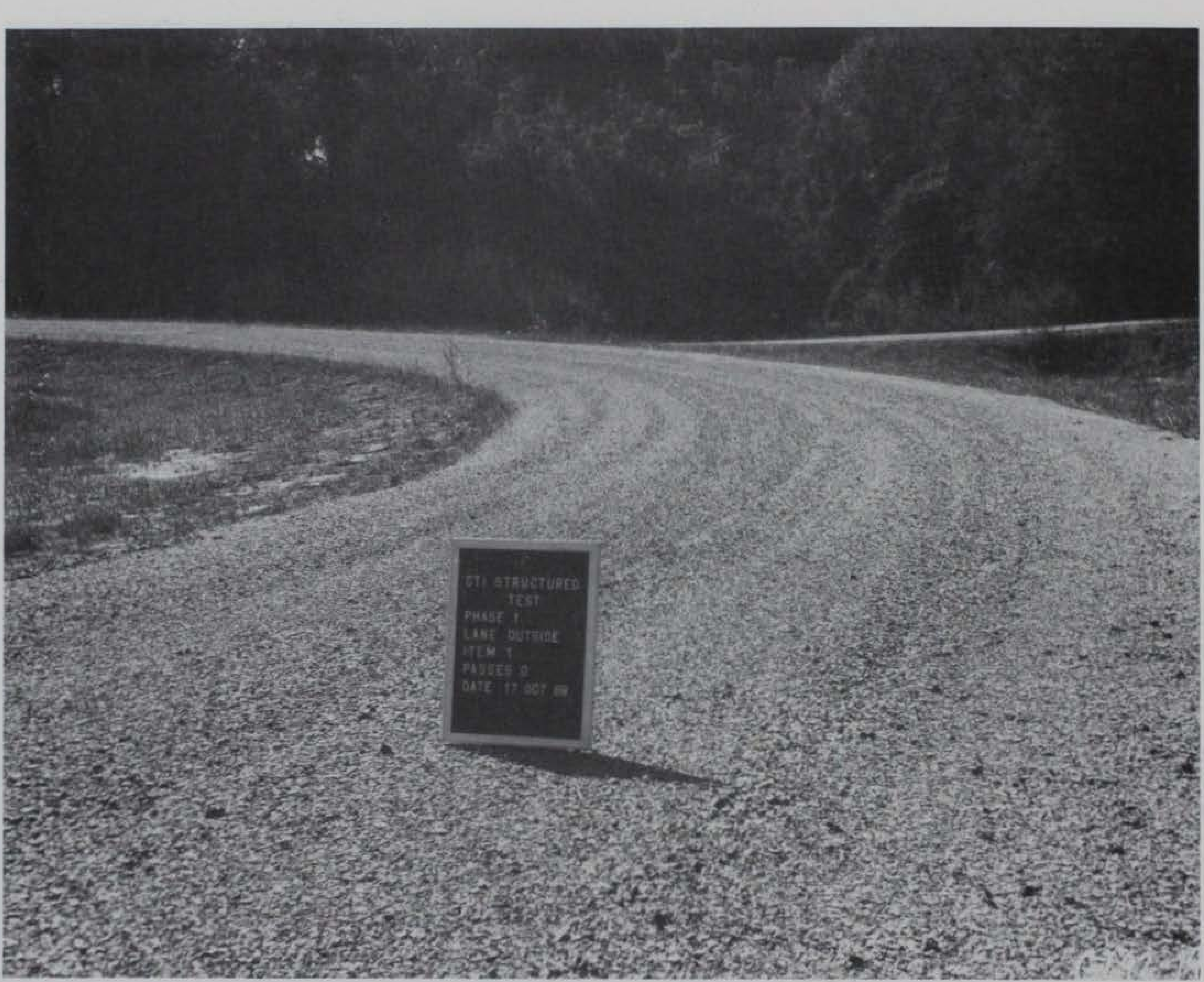

Photo 34. Item 1, high-pressure tire lane, general view before traffic

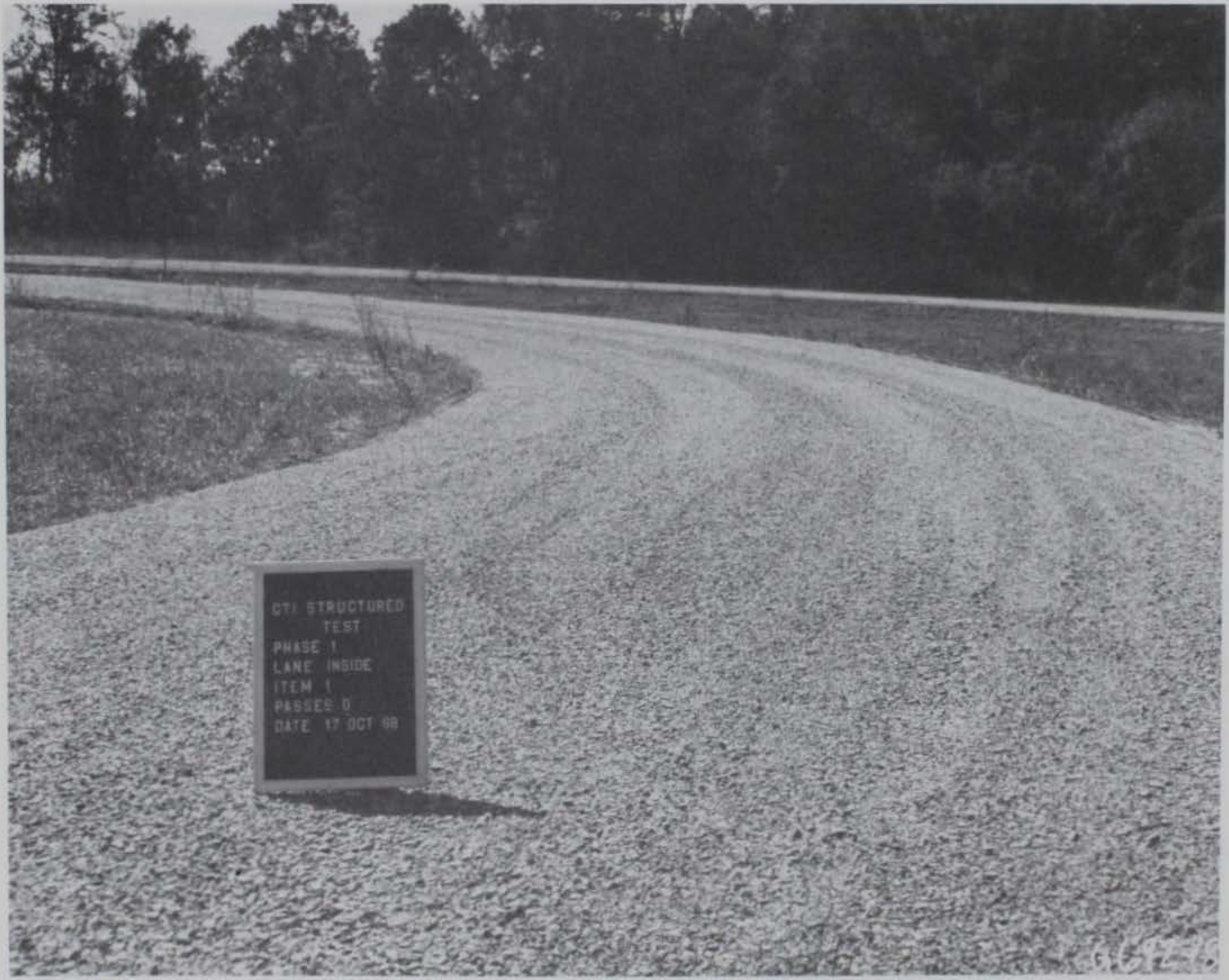

Photo 35. Item 1, low-pressure tire lane, general view before traffic

Photo 36. Item 2, general view before traffic

Photo 37. Item 3, general view before traffic

Photo 38. Item 13, general view before traffic

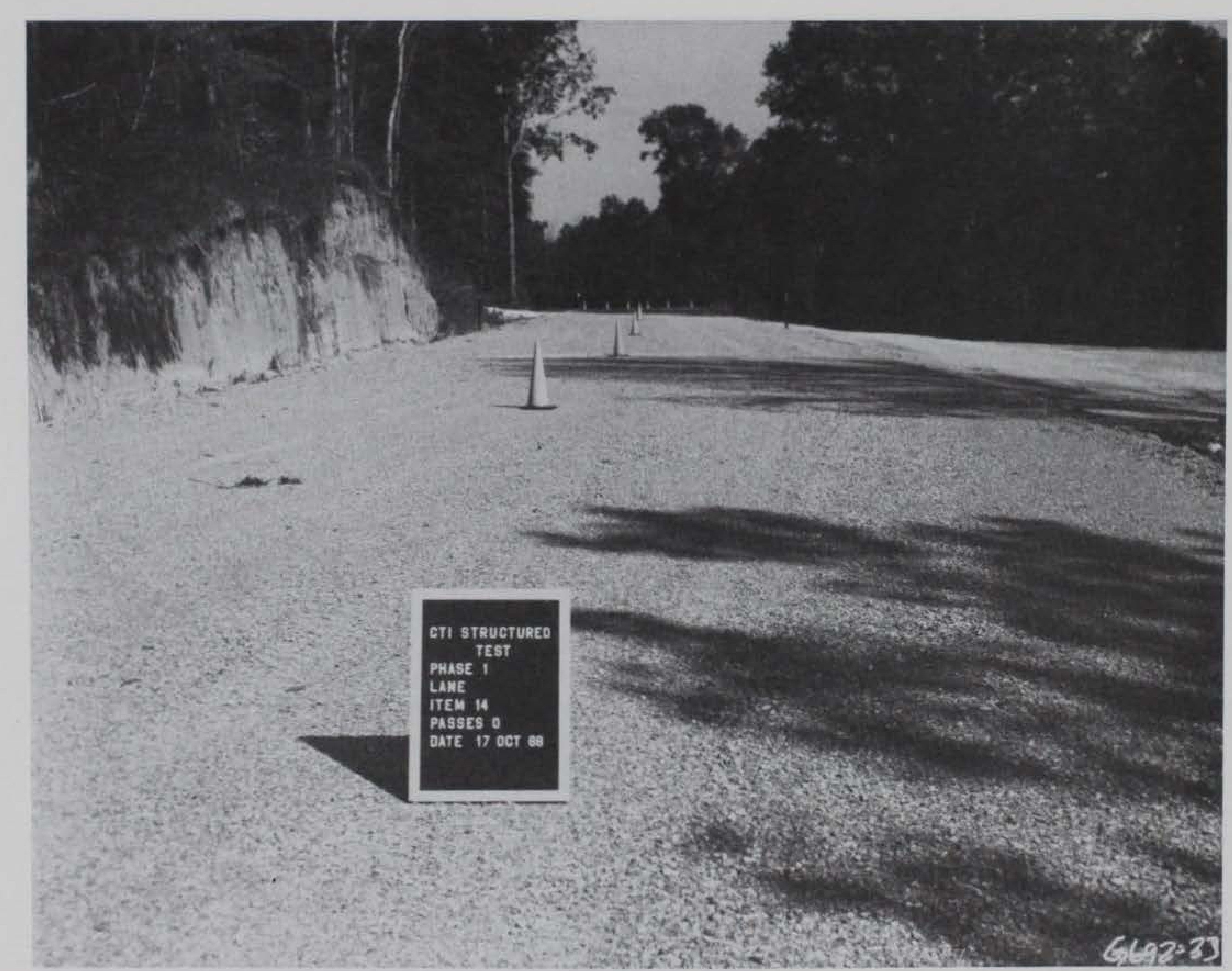

Photo 39. Item 14, general view before traffic

Photo 40. Item 15, general view before traffic

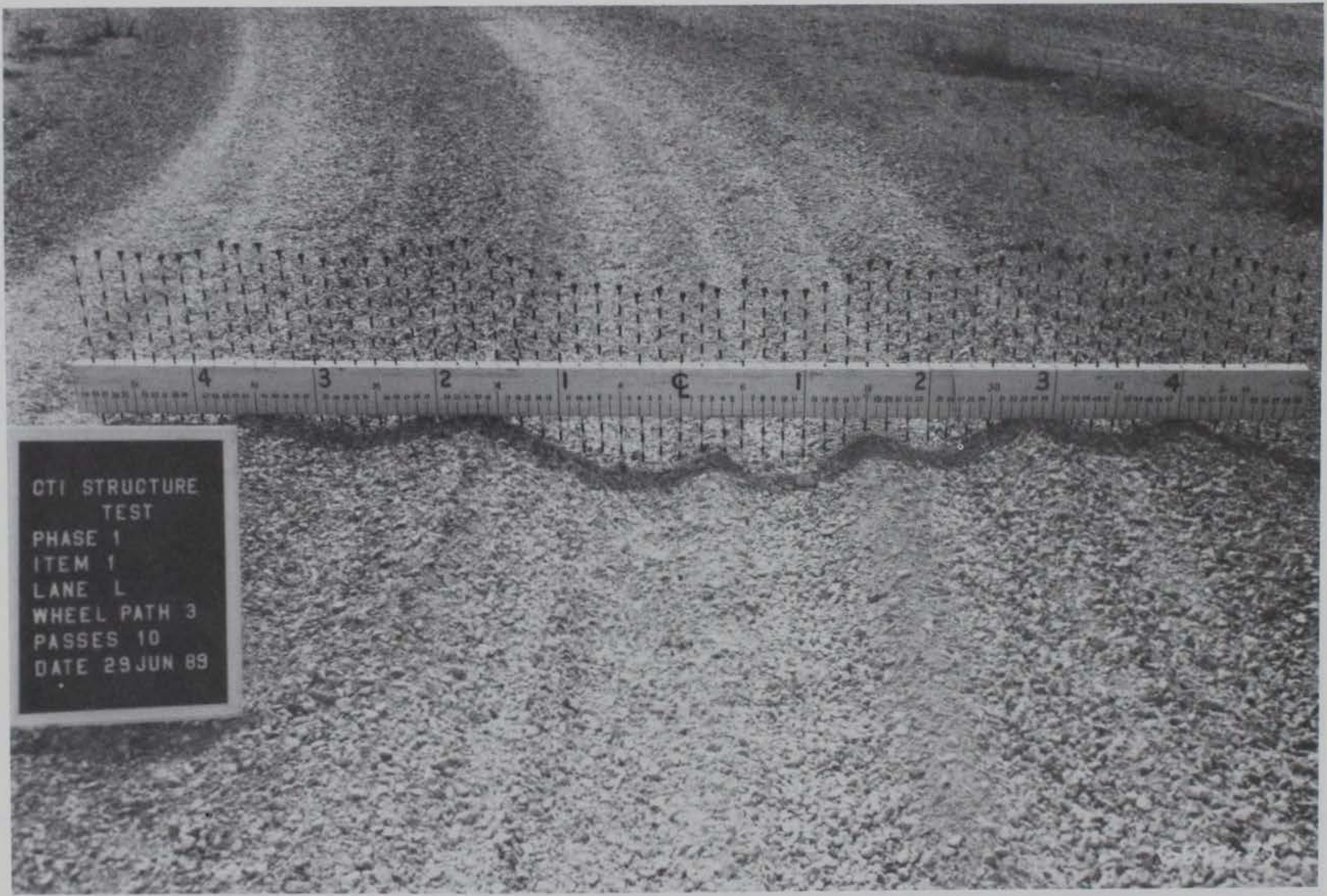

Photo 41. Item 1, low-pressure tire lane 5.5 in. rutting after 10 passes

Photo 42. Item 1, low-pressure tire lane, failure after 66 passes

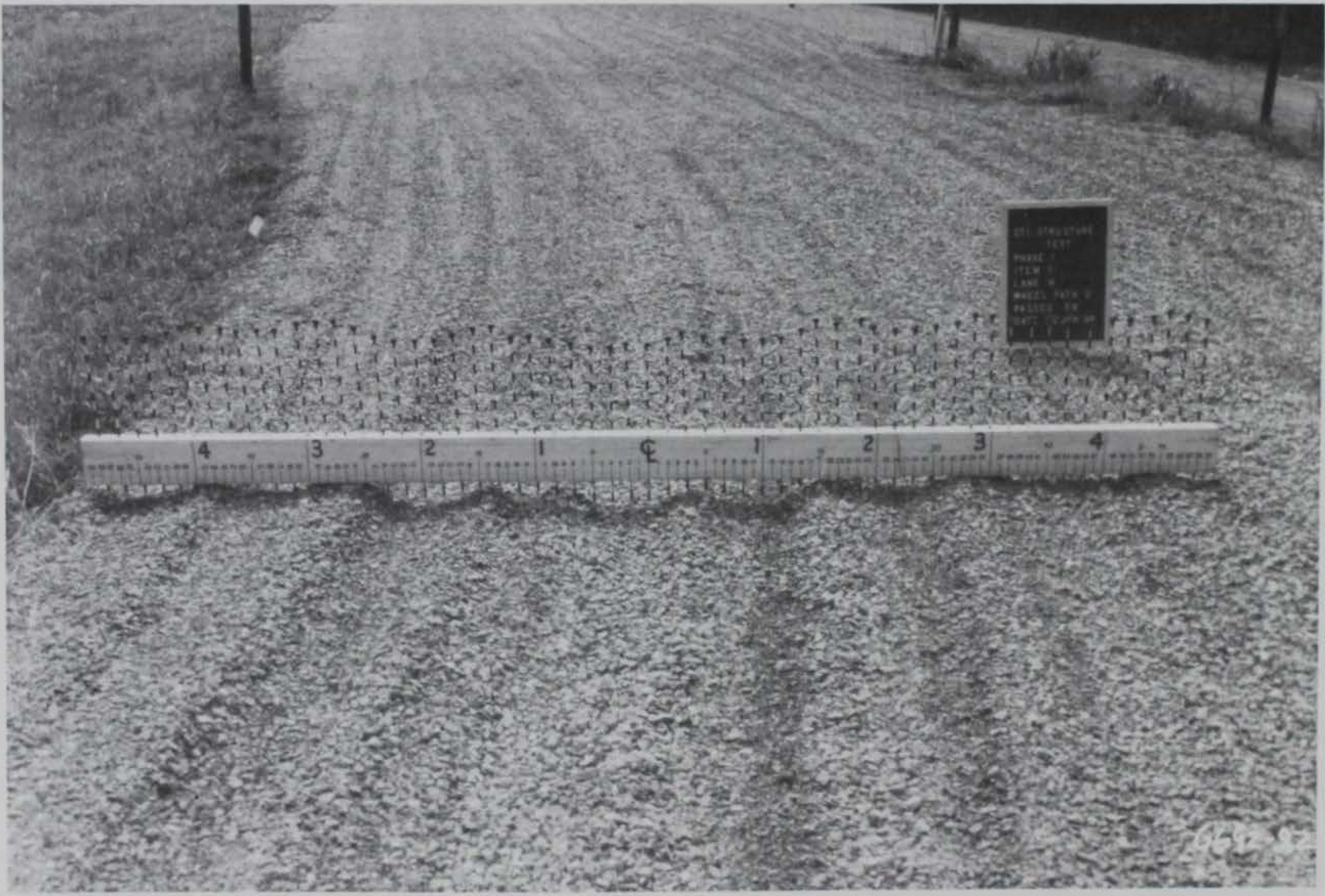

Photo 43. Item 1, high-pressure tire lane, failure after 58 passes

Photo 44. Item 2, high-pressure tire lane, failure after 58 passes

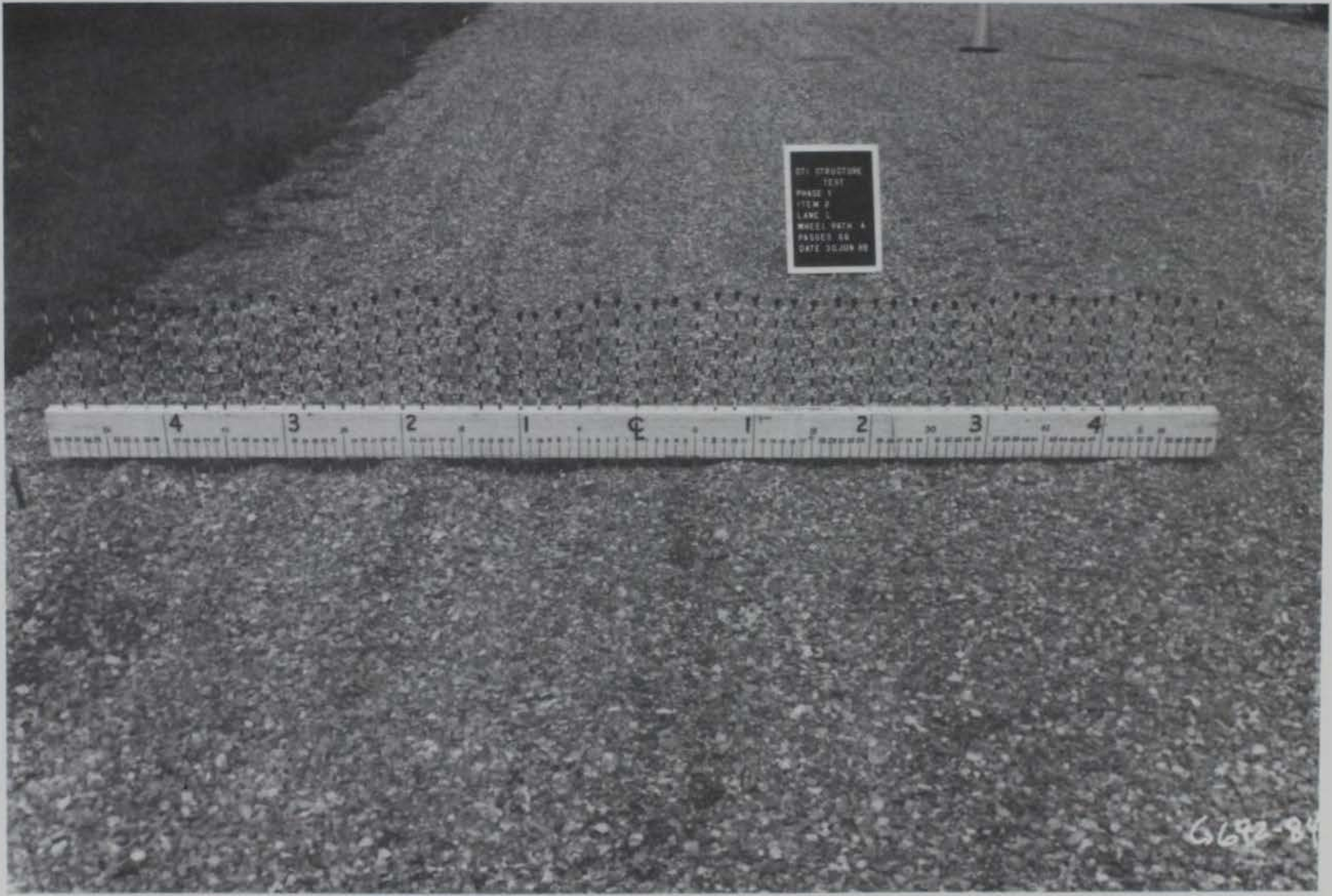

Photo 45. Item 2, low-pressure tire lane, failure after 66 passes

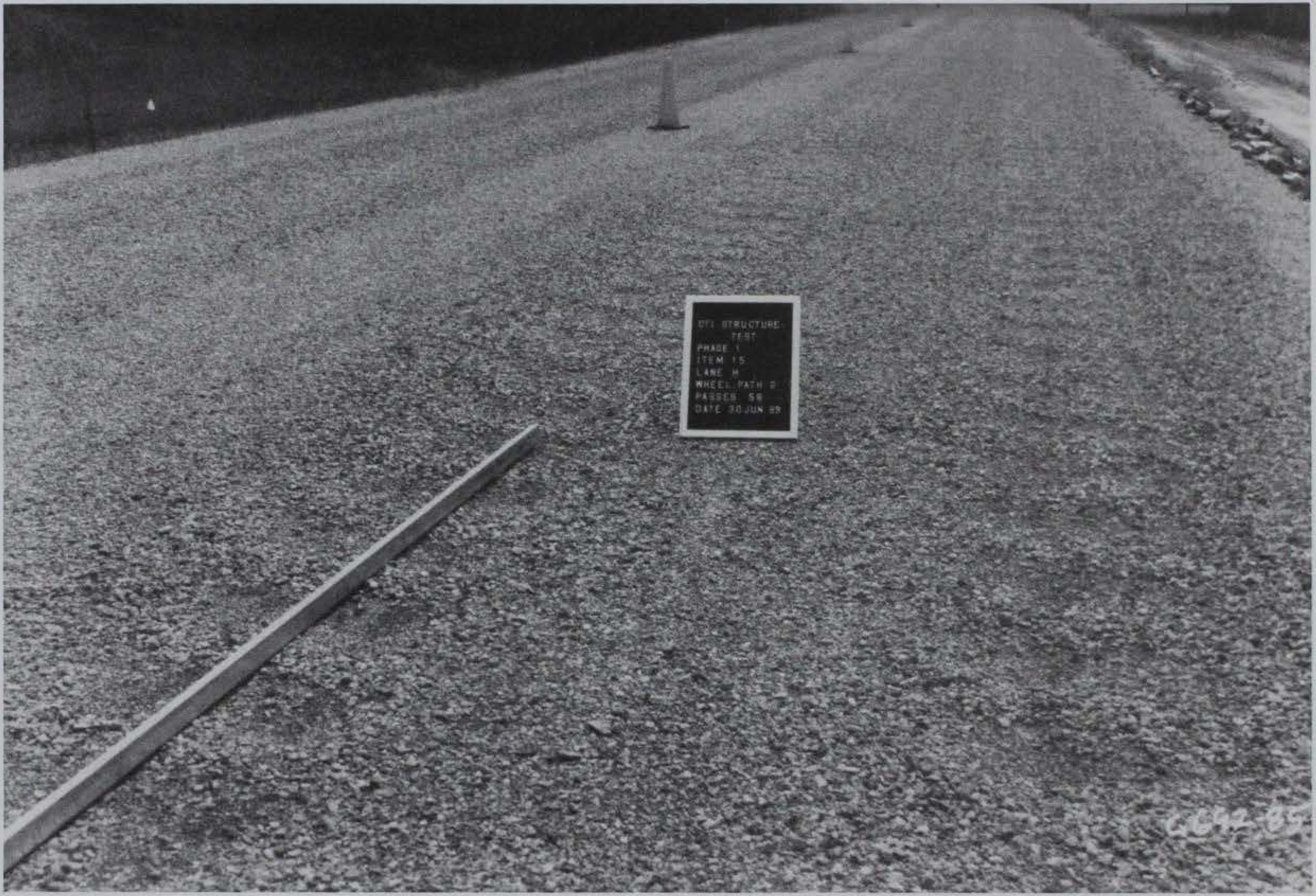

Photo 46. Item 15, high-pressure tire lane, low-severity washboarding after 58 passes

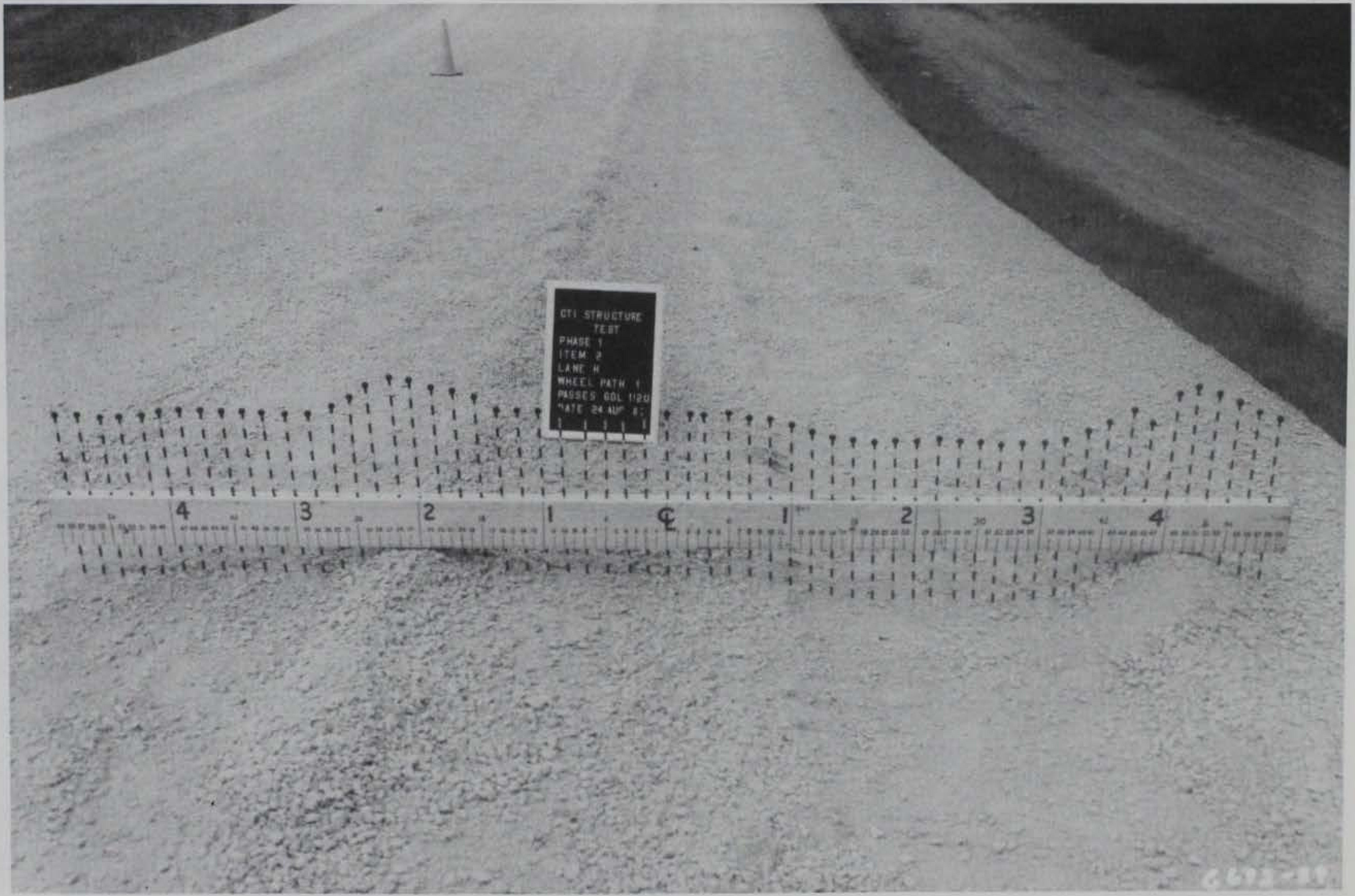

Photo 47. Item 2, high-pressure tire lane, failure after 112 unloaded passes

Photo 48. Item 2, high-pressure tire lane, close-up of high-severity washboarding after 112 unloaded passes

Photo 49. Item 2, low-pressure tire lane, long intervals between corrugation

Photo 50. Item 1, high-pressure tire lane, low-severity rutting and washboarding at the end of traffic

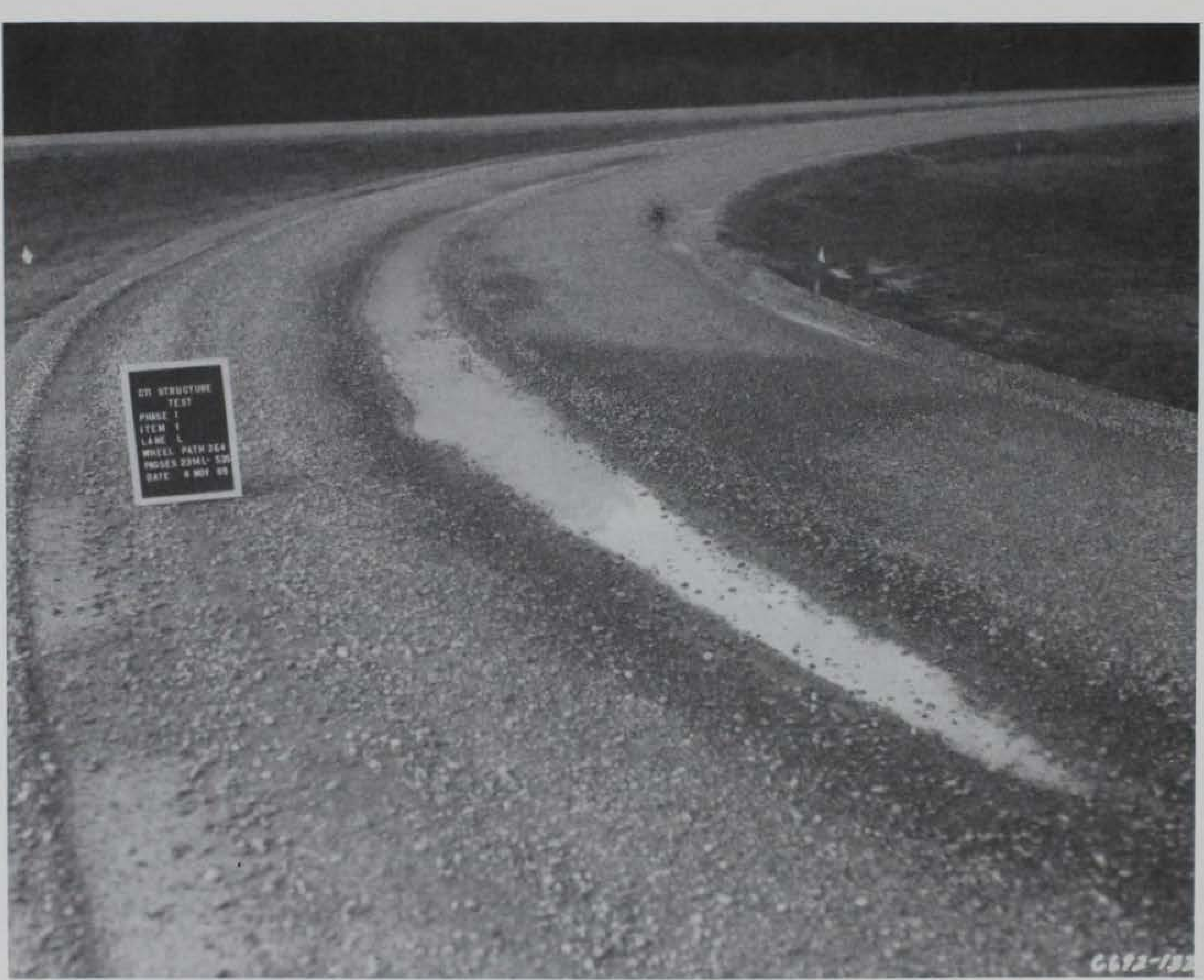

Photo 51. Item 1, low-pressure tire lane, low-severity rutting at the end of traffic

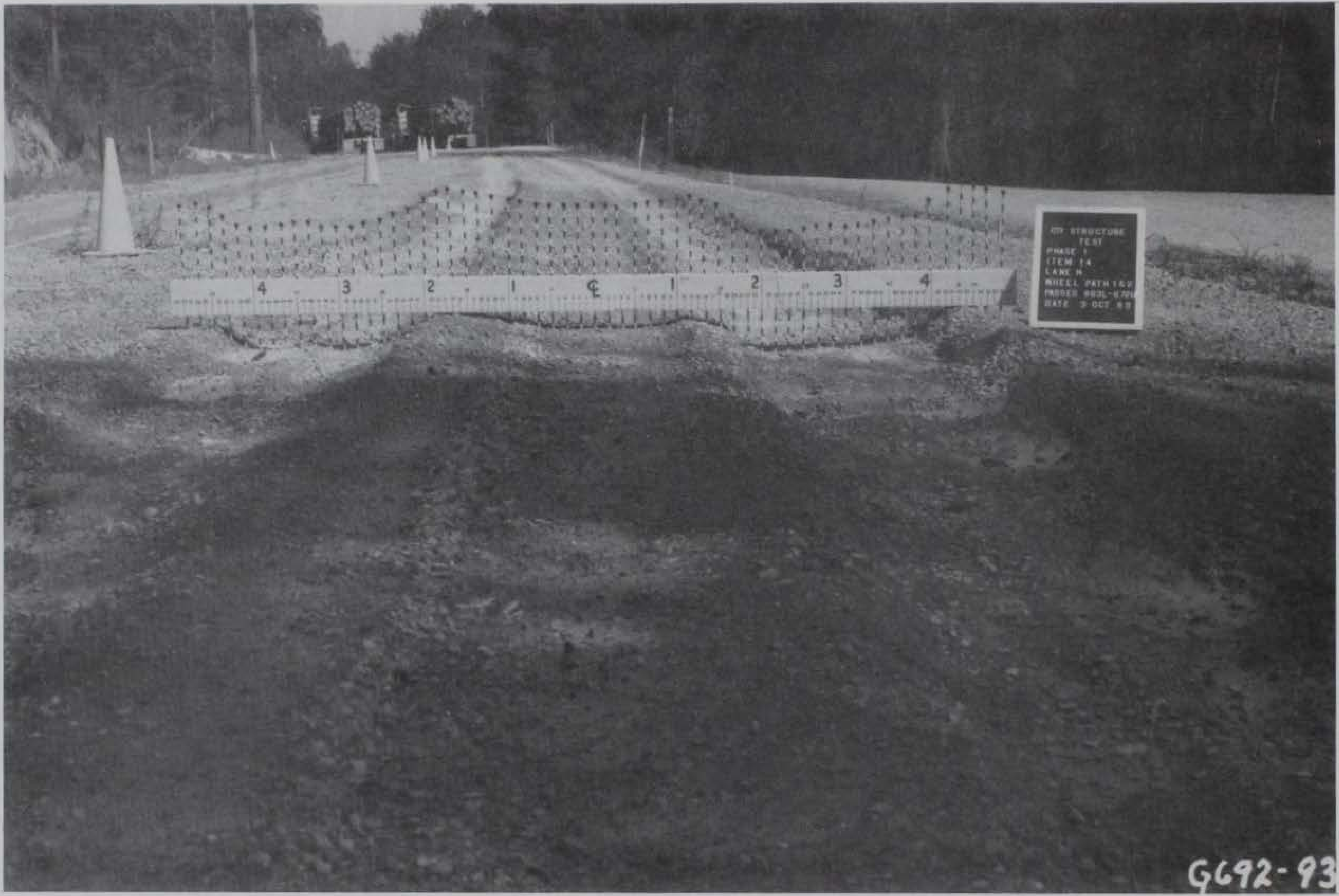

Photo 52. Item 4, high-pressure tire lane, high-severity rutting after 90 passes over a wet subgrade

Photo 53. Item 14, low-pressure tire lane, high-severity rutting after 90 passes over a wet subgrade

Photo 54. Grading both lanes of Items 13, 14, and 15

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Photo 58. Item 15, low-pressure tire lane, general view after 130 passes during the failure induced plan

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Photo 60. Item 14, high-pressure tire lane, general view after 139 passes during the induced failure plan

Photo 61. Item 15, high-pressure tire lane, general view after 139 passes during the induced failure plan

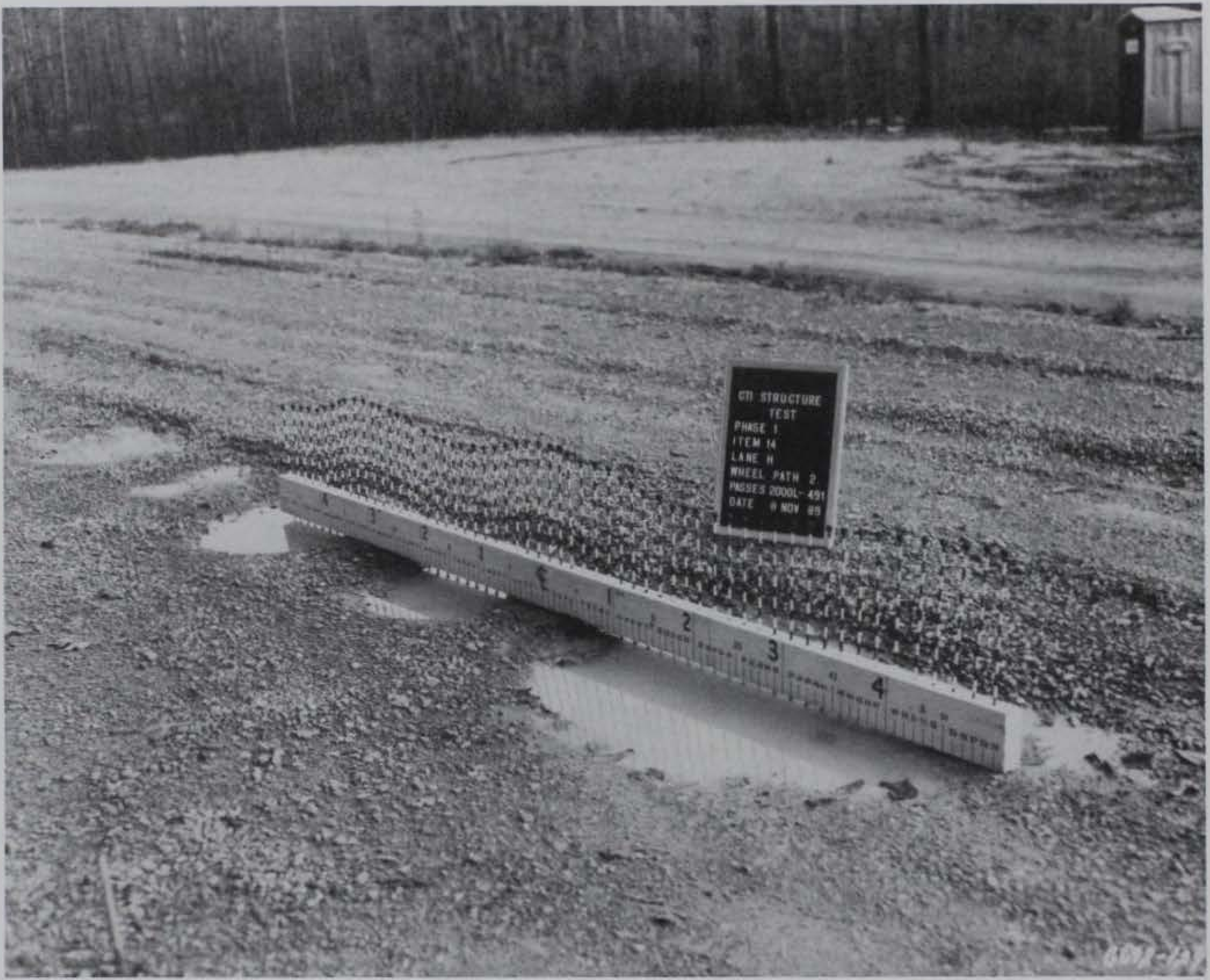

Photo 62. Item 14, high-pressure tire lane, high-severity washboarding after 491 passes during the induced failure plan

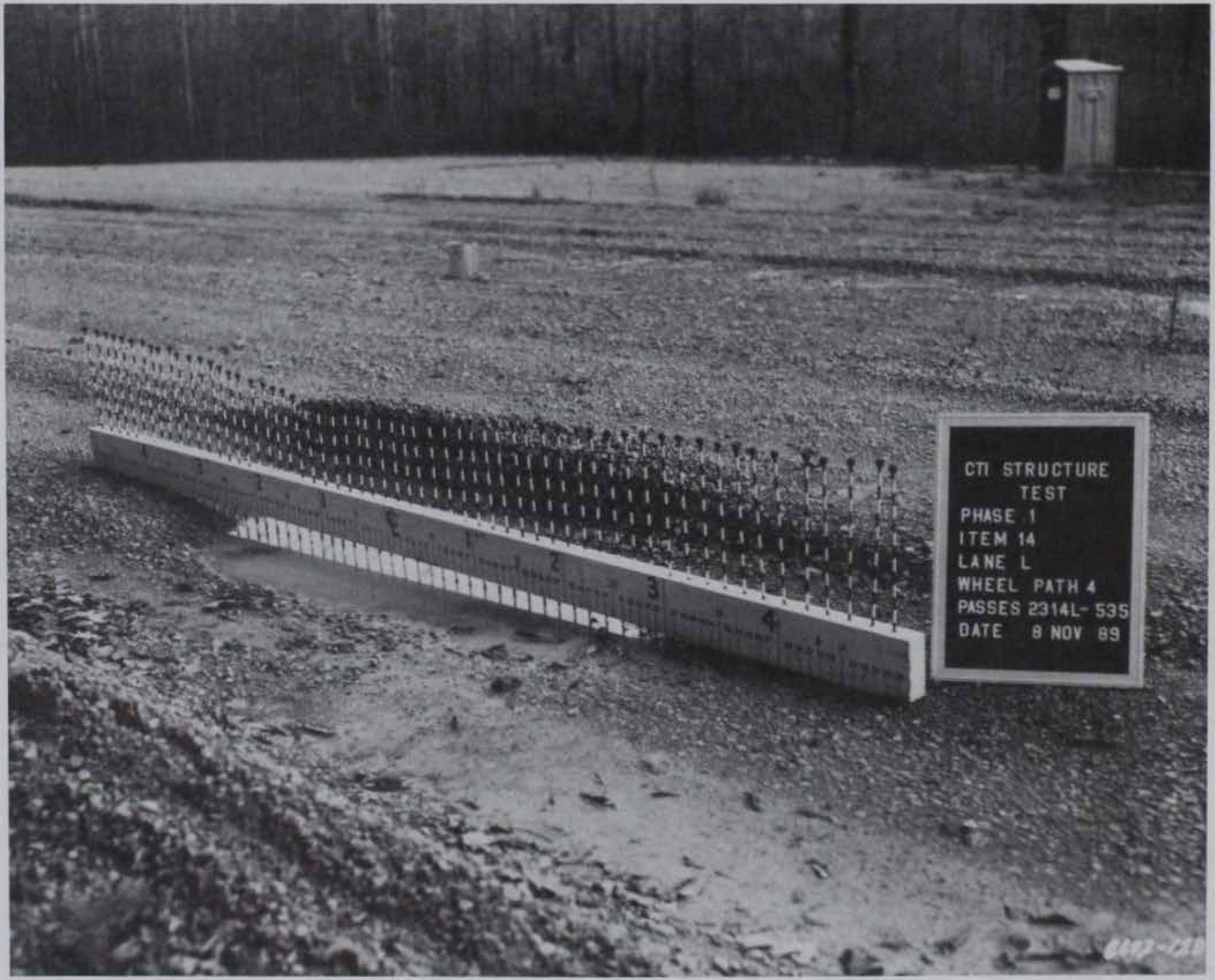

Photo 63. Item 14, low-pressure tire lane, high-severity pothole after 535 passes during the induced failure plan

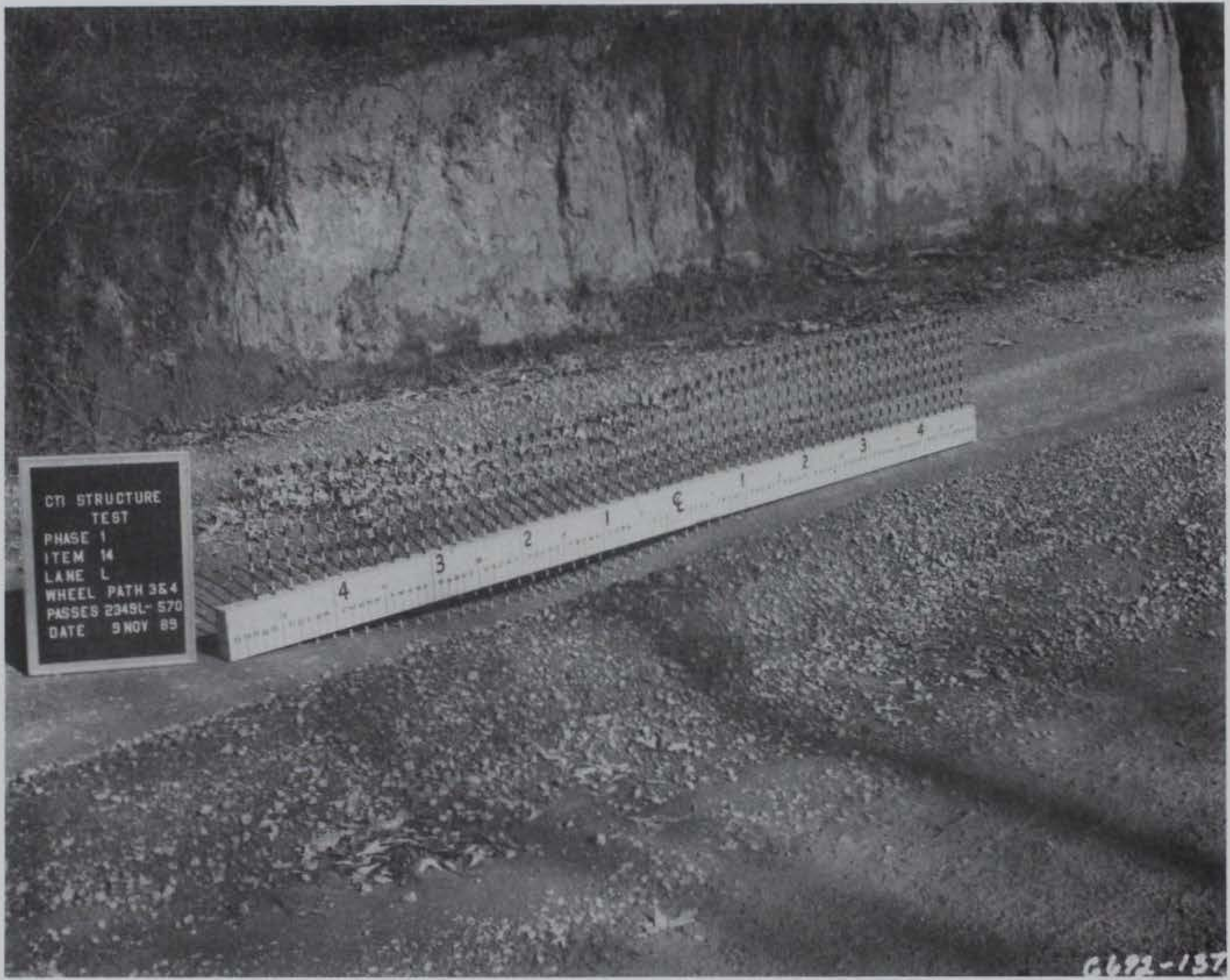

Photo 64. Item 14, low-pressure tire lane, low-severity depression after 570 passes during the induced failure plan

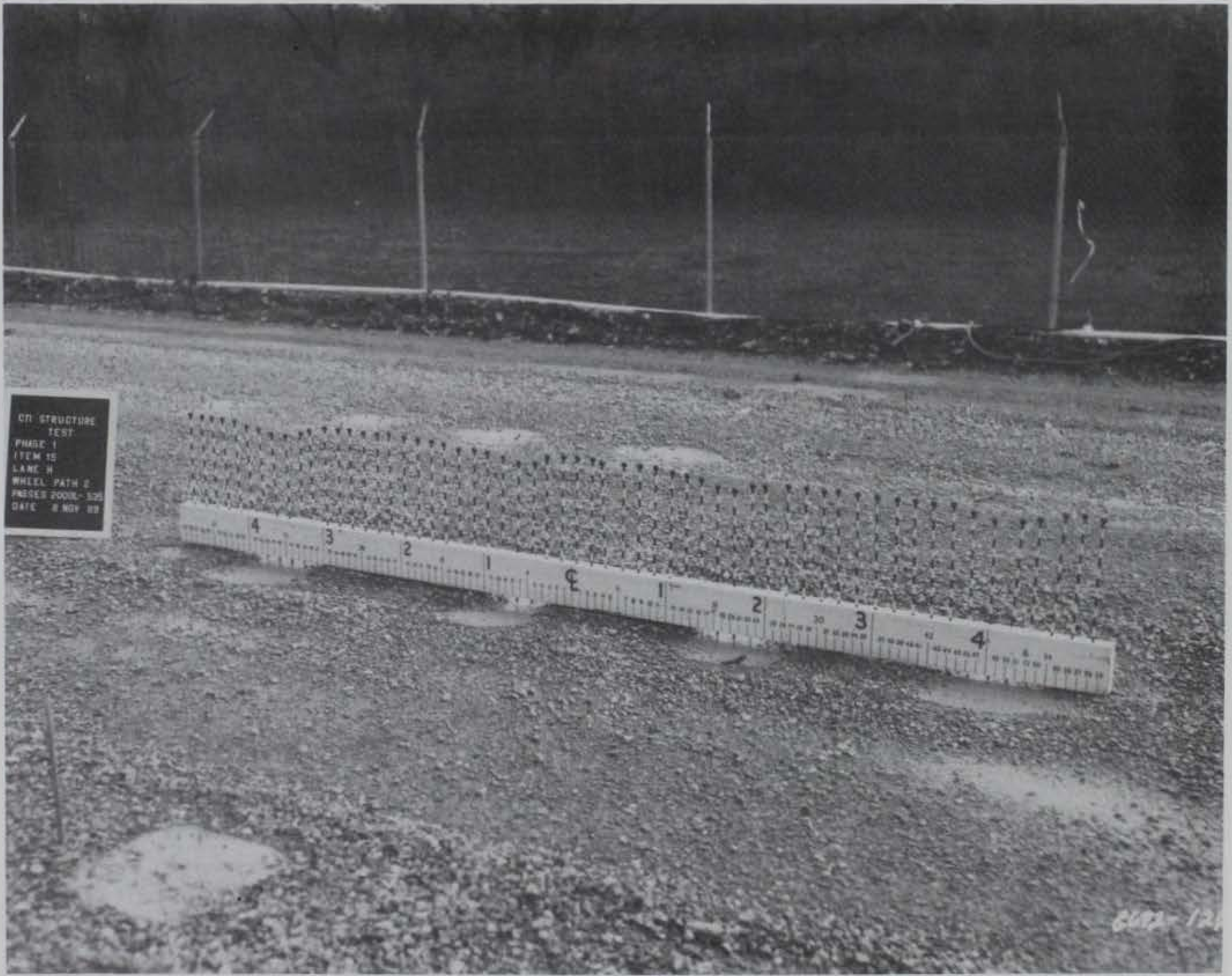

Photo 65. Item 15, high-pressure tire lane, typical high-severity washboarding after 535 passes during the induced failure plan

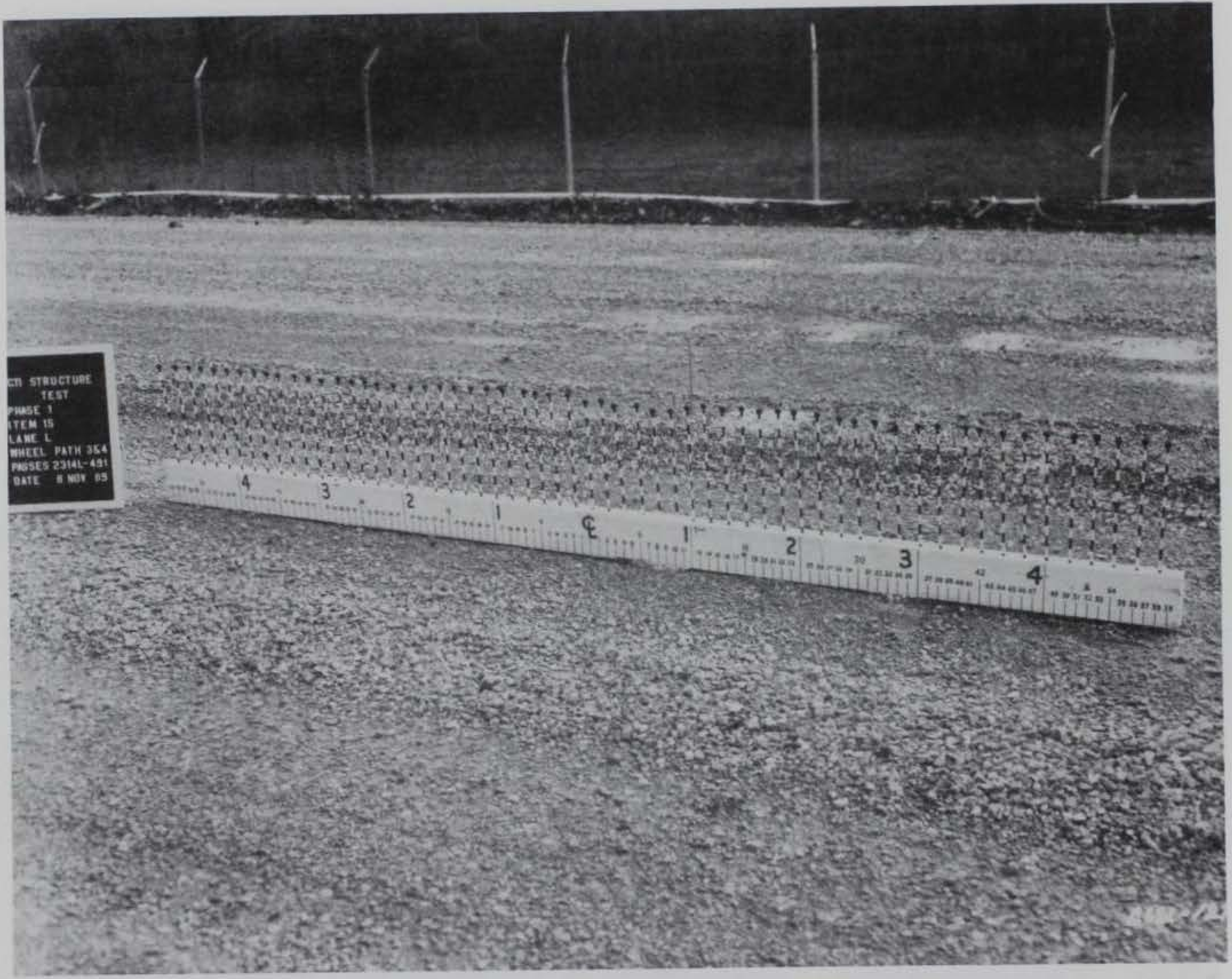

Photo 66. Item 14, low-pressure tire lane, typical low-severity washboarding after 491 passes during the induced failure plan

Photo 67. Item 15, high-pressure tire lane, severe rutting and loose aggregate after 913 passes of induced traffic for a total of 2364 loaded passes

Photo 68. Item 13, general view of the post-traffic test pit

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1993

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Effects of Variable Tire Pressure on Road Surfacings
Volume I: Design, Construction, Behavior under Traffic, and Test Results

5. FUNDING NUMBERS

6. AUTHOR(S)
Robert W. Grau

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
Geotechnical Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report GL-93-20

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Agriculture Forest Service
Technology and Development Center
444 East Bonita Avenue, San Dimas, CA 91773

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The objective of this study was to determine the effects of variable tire pressure on road surfacings. A specially designed test road was constructed and subjected to both loaded and unloaded 18-wheeled log trucks operating in two distinct traffic lanes. The traffic was applied with the trucks operating at low- and high-tire pressures. This report presents the background, design, construction procedure, and discussion of the performance of the various items during traffic.

The results show that (a) when failures occurred in both lanes of the same asphalt concrete item, the ratio of low-tire-pressure traffic to high-tire-pressure traffic ranged between 1.5 and 21, (b) considerable maintenance will be required on aggregate-surfaced grades receiving high-tire-pressure unloaded traffic because of severe washboarding, (c) the installation of central tire inflation systems that allow a driver to adjust a vehicle's tire pressure while in motion will be cost-effective for heavy trucks traveling on low volume, low speed roads.

14. SUBJECT TERMS
Aggregate
Asphalt concrete
Central tire inflation
Maintenance
Native material
Road surfacings
Traffic tests
Variable tire pressures

15. NUMBER OF PAGES
152

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102