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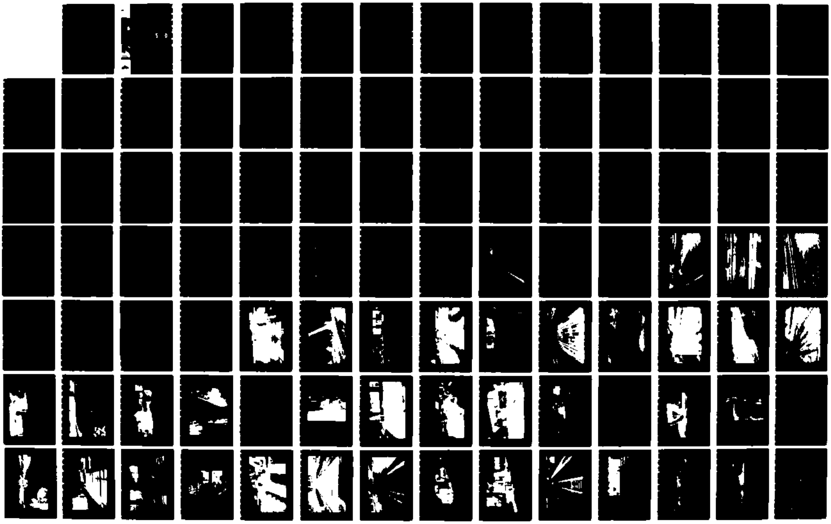

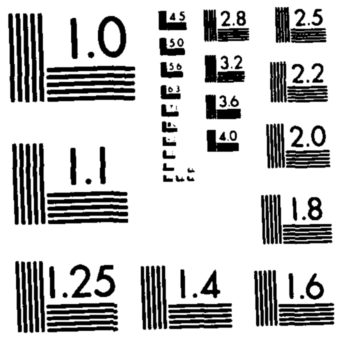

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STRUCTURAL ENHANCEMENT OF RAILROAD TRACK STRUCTURES USING ASPHALT UNDERLAYMENT

by

David M. Coleman

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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Water intrusion into low strength and/or swelling subgrade soils under railroad track results in the need for almost continuous maintenance as well as operational problems for railroad traffic. In recent years many techniques for stabilizing unstable track structures have been developed. One of these techniques is the use of hot-mix asphaltic concrete as a structural layer in the track structure. The use of a hot-mix asphalt structural layer in the track structure combined with the provision for adequate drainage of water away from the track has been shown to reduce or eliminate water intrusion into the subgrade. This helps to reduce maintenance requirements and improve operating conditions.

This report documents the design and construction of an asphalt underlayment in the railroad track at Red River Army Depot (RRAD), Texarkana, Texas. Also included is a brief

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Railroad track rehabilitation
Railroad trackbed stabilization

19. ABSTRACT (Continued).

review of the use of hot-mix asphaltic concrete in railroad track, a benefit-cost analysis, and a discussion of the factors that should be considered contemplating when considering track rehabilitation using the underlayment technique.

PREFACE

The study reported herein was conducted and this report prepared for the Office, Chief of Engineers (OCE) under the Facilities Technology Application Test (FTAT) program. The Technical Monitor at OCE was Mr. R. W. Williams.

The project was conducted at Red River Army Depot (RRAD) in Texarkana, Texas. Mr. J. N. Stewart, Facilities Engineering Division (FED), was the installation project engineer, and Mr. W. H. McFerrin, FED, was the inspector and contracting officer's representative. The project was conducted under the general supervision of Mr. C. R. Wilcox, RRAD Facility Engineer. Messrs. J. Hicks and S. McDonald, FED, also participated in the project design. Mr. J. C. Miller, Internal Rail Branch, Transportation Division, RRAD, assisted by providing a locomotive and crew for the preconstruction and postconstruction track deflection testing. Messrs. J. Isbell, B. Dodd, and G. Gibson, Mobile Equipment Maintenance Branch, Depot Equipment Division, RRAD, assisted by providing Waterways Experiment Station (WES) personnel with a location for equipment storage throughout the project.

Drs. J. Rose, Y. H. Huang, and V. P. Drnevich from the University of Kentucky assisted in the design of the demonstration section and provided many valuable recommendations on the design and construction procedures that were used.

Personnel of the Pavement Systems Division (PSD), Geotechnical Laboratory (GL), WES, actively participating in this project were MAJ R. A. Hass, FTAT Project Manager and Mr. D. M. Coleman, project engineer. Messrs. V. Magee, Jr. and J. E. Warwick, Motion Picture Photographers, Publications and Graphic Arts Division (P&GAD), WES, provided photographic coverage of the construction. This project was performed under the direct supervision of Messrs. R. W. Grau, Chief, Prototype Testing and Evaluation Unit, PSD; J. W. Hall, Jr., Chief, Engineering Investigations, Testing, and Validation Group, PSD; and H. H. Ulery, Jr., Chief, PSD; and Dr. W. F. Marcuson III, Chief, GL. Ms. Odell F. Allen, P&GAD, edited the report.

COL Dwayne G. Lee, CE, was Director of WES during the preparation and publication of this report. Dr. Robert W. Whalin was Techinical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic inches	16.38706	cubic centimetres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
gallons per square yard	4.5273	cubic decimetres per square metre
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (force) per yard	0.5932764	kilograms per metre
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic inch	27.6799	grams per cubic centimetre
square inches	6.4516	square centimetres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

STRUCTURAL ENHANCEMENT OF RAILROAD TRACK STRUCTURES USING ASPHALT UNDERLAYMENT

PART I: INTRODUCTION

Background

1. The conventional railroad track system is a structure constructed to (a) provide guidance for locomotive and rolling stock wheels, (b) support the loads resulting from these wheels, and (c) distribute the wheel/axle loads throughout the track structure in such a manner as not to overstress the subgrade material. The conventional railroad track structure is composed of rails, tie plates, ties, ballast, and subgrade. In some locations a subballast layer is used below the ballast. While each of the components of the track structure has the primary function of distributing the wheel loads to the subgrade, the subgrade performs several very important functions. These functions are to (a) support and distribute the applied loads of the locomotives and rolling stock, (b) facilitate drainage away from the track structure, and (c) provide a smooth platform on an established grade for the placement of the ballast, ties, and rails. If the subgrade will not support the loads produced by the passing trains, loss of surface, alignment, and gage will occur in addition to pumping, ballast fouling, and roadbed subsidence.

2. Water intrusion into low strength and/or swelling subgrade soils under railroad track results in the need for almost continuous maintenance as well as operational problems for railroad traffic. In recent years many techniques for stabilizing unstable track structures have been developed. One of these techniques is the use of hot-mix asphaltic concrete (AC) as a structural layer in the track structure.

3. The use of a hot-mix asphalt structural layer in the track structure combined with the provision for adequate drainage of water away from the track has been shown to reduce or eliminate water intrusion into the subgrade. This helps to reduce maintenance requirements and improve operating conditions.

Purpose

4. The purpose of this project was to demonstrate the use of an asphalt underlayment as a rehabilitation alternative on Army railroad track. Specific objectives were to (a) design an asphalt underlayment section suitable for use on Army railroads, (b) reconstruct a section of Army track using the asphalt underlayment technique, (c) monitor changes in the track strength and subgrade moisture content before and after reconstruction, and (d) fully document design and construction techniques to provide technology transfer.

Scope

5. This report documents the design and construction of an asphalt underlayment in the railroad track at Red River Army Depot (RRAD), Texarkana, Texas. Also included is a brief review of the use of hot-mix AC in railroad track, a benefit-cost analysis, and a discussion of the factors that should be utilized when considering track rehabilitation using the underlayment technique.

PART II: USE OF HOT-MIX ASPHALT IN RAILROAD TRACK

Types of Asphalt Structures

6. There are two different types of asphalt structures used in railroad track: the full-depth section and the underlayment section. A full-depth section is one in which 8 to 12 in.* of hot-mix asphalt is placed directly on the subgrade and the crossties are placed directly on the asphalt mat. Ballast is normally placed in the cribs between the ties and on the shoulders of the section to provide lateral stability. In an underlayment section 4 to 8 in. of asphalt acts as a subballast layer beneath a conventional ballasted track having 8 to 12 in. of ballast above the asphalt. Figure 1a presents a typical section of a conventional ballasted track that has a built-up ballast section caused by periodic addition of ballast. Figure 1b shows a new conventional ballast section having a granular subballast. Figures 2a and 2b present typical sections of a full-depth and an underlayment section, respectively.

Applications and Advantages of Using Asphalt Sections

7. The use of a hot-mix asphalt layer in a railroad track structure is most applicable to short sections of track having poor subgrade conditions or those tracks experiencing severe pumping problems. Asphalt sections can be used to increase the track strength and to improve track geometry in the vicinity of turnouts, rail crossings, highway crossings, and bridge approaches as well as areas exhibiting poor subgrade conditions.

8. Advantages of using a hot-mix layer in the track structure are:

a. A nearly impermeable layer over the subgrade is provided, thereby minimizing changes in the subgrade moisture content due to surface water.

b. Track support and load-carrying capacity are increased.

c. Subgrade intrusion into the ballast, commonly known as ballast fouling is prevented.

d. Better track geometry and operating efficiency are provided.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

e. Track maintenance is reduced.

f. The maintenance cycle is increased, resulting in long-term cost savings.

9. The major disadvantage of using an asphalt layer in the track structure is the track time lost during construction. However, the extra time required is negligible if the rehabilitation is to be an out-of-face renewal where the entire track is to be removed anyway, or in new track construction.

Previous Uses

10. The use of hot-mix asphalt as a structural layer in railroad track is not a new concept. Various test sections and other small installations have been built over the last 25 years. Rose, Lin, and Drnevich (1984) report that several foreign countries including Japan, Great Britain, West Germany, Sweden, and Italy have installed various types of asphalt trackbeds. The Asphalt News (1982) reports that the Italian railways have asphalt underlayments of approximately 120 miles of track, have had excellent performance from these sections, and are planning another 26-mile section of underlayment.

11. Various (Rose 1983, 1984; Rose, Lin, and Drnevich 1984) reports indicate that the major uses of asphalt in railroad track applications in the United States have been:

a. 1959-1964 - California. Several highway crossings and railroad crossings were rebuilt using hot-mix asphalt bases.

b. 1968 - Cleveland, Ohio, Cleveland Transit System. Two underlayment sections 1,000 ft long, 10 ft wide, and 4 and 5 in. thick, respectively, were placed directly on the subgrade. Conventional ballast and wood ties spaced on 30-in. centers were used along with 100-lb/yd rail. The traffic is frequent transit vehicles at speeds up to 60 mph.

c. 1969 - Northeastern New Mexico, Santa Fe Railway Company. Three 700-ft-long underlayment sections on a new line servicing a coal mining region. The asphalt mats were 2.5, 5, and 7.5 in. thick, 16 ft wide, and topped with 10 in. of ballast.

d. 1973 - San Jose, California, Southern Pacific Railroad. One-mile-long underlayment section 13 in. thick.

e. 1981 - Ravenna, Kentucky, Seaboard System (L&N) Railroad. Two 500-ft-long full-depth sections on mainline in the Ravenna Yard. The asphalt mats were 8 and 12 in. thick, respectively, and 12 ft wide. Two 500-ft-long control sections abut the full-depth section. One 117-ft-long underlayment section, 8 in. thick and 14 to 24 ft wide, was placed under a No. 10 mainline turnout. One 99-ft-long full-depth section 12 in. thick and 14 to 21 ft wide was placed under a No. 8 turnout on the south ladder track.

f. 1982 - Oklahoma City, Oklahoma, Santa Fe Railway Company, Flynn Yard. One 532-ft-long underlayment section was placed. Asphalt mat was 8 in. thick, 12 ft wide on a curve of the trim lead track.

g. 1982 - Oklahoma City, Oklahoma, Santa Fe Railway Company, Oklahoma City Auto Unloading Yard. Approximately 5-acre underlayment. Asphalt mat is 4 in. thick with asphalt pavement between the tracks.

h. 1982 - Lexington, Kentucky, Seaboard System (L&N) Railroad Forbes Road Crossing. One 90-ft-long underlayment section. Asphalt mat is 8 in. thick and 11 ft wide under a highway crossing on the Louisville to Lexington mainline.

i. 1982 - Harrison County, Kentucky, Seaboard System (L&N) Railroad Lair Road Crossing. One 150-ft-long underlayment section. Asphalt mat is 8 in thick and 12 ft wide on the Cincinnati to Knoxville northbound mainline. One 175-ft-long underlayment section. Asphalt mat is 8 in. thick and 12 ft wide on the Cincinnati to Knoxville southbound mainline.

j. 1983 - Conway, Kentucky, Seaboard System Railroad, Two 1,000-ft-long underlayment sections. Asphalt mats are 5 and 8 in. thick and 12 ft wide under mainline track from Atlanta to Cincinnati. Thirty to forty million gross tons (MGT) of traffic are carried yearly at speeds up to 60 mph. Two undercut control sections were installed adjacent to the asphalt sections. One 110-ft-long underlayment section. Asphalt mat is 6 in. thick and 12 ft wide. Section was constructed on the Cincinnati to Knoxville mainline at the Snider crossing.

k. 1983 - Lawrence County, Kentucky, Kentucky Power Company Baker Station (US 23) Crossing. One 104-ft-long full-depth section on a spur track leading from the Chessie System to the power station. Asphalt mat is 12 in. thick and 12 ft wide.

l. 1984 - North Andover, Massachusetts, Boston and Maine Railroad Sutton Street Crossing. One 130-ft-long underlayment section was placed. Asphalt mat is 6 in. thick and 11 ft wide, topped with 6 in. of ballast. This was constructed on the Boston to Haverhill westbound mainline.

m. 1984 - Deepwater, West Virginia, Chessie System Railroad Loup Creek Bridge Approaches. Two 200-ft-long underlayment sections were constructed on each end of a bridge on the Huntington to Hinton mainline. Asphalt mat is 12 ft wide and 8 in. thick for the first 100 ft and 4 in. thick for the second 100 ft. The ballast thickness is 8 and 12 in., respectively. One 80-ft-long underlayment section under a highway crossing abutting the west bridge approach underlayment. The asphalt mat is 4 in. thick and 12 ft wide with 12 in. of ballast.

n. 1984 - Cynthiana, Kentucky, Seaboard System Railroad. One 1,300-ft-long underlayment section. Asphalt mat is 6 in. thick and 16 ft wide. The section was constructed on the Cincinnati to Knoxville mainline and extends under three highway crossings.

Several additional installations of asphalt trackbeds were made in 1985; however, none have been documented at this time.

PART III: DESIGN OF DEMONSTRATION PROJECT

Site Selection and Characteristics

12. A section of track on RRAD near Texarkana, Tex., was chosen for this demonstration project. The US Department of Agriculture (USDA) (1980) indicates that much of the railroad roadbed (subgrade) at RRAD is a clay soil that is classified as either CL, CH, or CL-ML on the Unified Soil Classification System (USCS). This soil survey report indicated that these roadbed materials typically have Liquid Limits (LL) in the range of 30 to 70 and a Plasticity Index (PI) in the range of 10 to 45 with swelling potential from moderate to high.

13. Climatologically RRAD experiences long hot summers and fairly short cool winters. The yearly average daily temperature is 63.1°F. In summer the average daily maximum temperature is 92°F, and the average daily temperature is 80°F. In winter the average daily temperature is 45°F with an average daily minimum temperature of 34°F. The total annual rainfall is 44.3 in., of which 23 in. generally falls in April through September. Table 1, adapted from Soil Survey of Bowie County, Texas (USDA 1980) summarizes the weather conditions at RRAD.

14. The site chosen for this demonstration project was an area leading into the locomotive maintenance shop. Three tracks exit the shop converging to one track near the end of the project area. Figure 3 presents a plan view of the area, and Figure 4 gives an overall view of the project area. An initial inspection of the project area was made in July 1984. The rail was an 85 lb/yd ASCE* section rolled in 1941. The ties were generally 6 in. by 8 in. by 8 ft with some 6 in. by 8 in. by 8.5-ft ties. The overall tie condition was good with only a few failed ties observed. The average tie spacing was 22 in. center-to-center with each tie having 7-in. by 9-in. single shouldered tie plates. All three turnouts were No. 9 turnouts with the components of the switches and frogs in good condition. The gravel ballast generally fell within the American Railway Engineering Association (AREA) G-1 gradation, was 12 to 16 in. deep below the bottom of the ties, and was completely filled with fines. Figure 5 presents a composite gradation curve using the results of

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* American Society of Civil Engineers.

four samples taken at various locations during the initial site inspection. Samples of the subgrade soil were obtained through auger holes along the center track of the demonstration site. A large sample of subgrade material was excavated from near the edge of the track for compaction and laboratory California Bearing Ratio (CBR) testing. This material had a LL of 51 and a PI of 35 and was classified as a CH soil according to the USCS. The results of the laboratory compaction using the CE-55 compaction procedure and CBR tests are presented in Figure 6, and indicate a maximum dry unit weight, γ_{dmax}, of 113.4 pcf at an optimum water content of 15.3 percent. The design CBR is 2, as determined from the soaked condition. A swell pressure test was run on samples of the subgrade soil compacted to the maximum dry density at optimum moisture content and at 95 percent of the maximum dry density. These tests indicated swell uplift pressures of 2.28 tons per square foot (TSF) at the maximum dry density and 1.56 TSF at 95 percent of the maximum dry density.

15. Surface water drainage in the project area was poor. Small drainage ditches ran along both sides of the project area with culverts under the adjacent tracks (Figure 3). As shown in Figures 7 through 9, these ditches were partially filled with sediment as were the culverts. In several locations the surrounding natural ground was higher than the top of the ballast preventing drainage of the water away from the track. Employees of the locomotive maintenance shop adjacent to the project reported a continual water seepage into their service pits. This seepage was later found to be from water trapped between the ballast and subgrade adjacent to the building as well as excess water running through the track flangeways.

Section Design

Preliminary design

16. The underlayment section installed in this demonstration was designed with the assistance of the University of Kentucky (UK), Department of Civil Engineering. Information obtained during the site visit and from the laboratory testing of the subgrade was supplied to UK. The procedures used to determine the required thickness of asphalt underlayment and ballast are found in "Hot-Mix Asphalt For Railroad Trackbeds, Structural Analysis and Design" (Huang, Lin, and Deng 1984) and in "KENTRACK: A Computer Program for Hot-Mix Asphalt and Conventional Ballast Railway Trackbeds" (Huang et al. 1984). Six

computer runs were made using the KENTRACK computer model to determine the required section of 6 in. of ballast over 4 in. of AC. The design was based on 1,500 repetitions per year of two 30,000-lb wheel loads spaced 70 in. center-to-center. In the computer modeling the 2 CBR subgrade was assumed to be represented by a Young's Modulus (E) value of 3,000 psi. Young's Modulus values of 6,000,000 psi and 60,000 psi were assumed for the asphalt underlayment and the ballast layer, respectively.

17. Design recommendations provided to WES by UK were reviewed and the final design recommendations prepared and forwarded to RRAD for use in the development of the project plans and specifications. Appendix A presents the design recommendations provided to RRAD by WES.

Final design and project specifications

18. The final design and preparation of the project plans and specifications were performed by the Engineering and Services Section, Facilities Engineering Division, RRAD. Figure 10 presents a typical cross-sectional view of the underlayment section in the concrete road crossing adjacent to the locomotive maintenance shop (sta 0+95 to 1+20). The old grade crossing was to be removed and a new concrete grade crossing constructed over the asphalt underlayment. Figure 11 presents a typical cross section of the track between sta 1+20, the end of the concrete crossing, and sta 1+80, the end of the concrete structure on the north side of the project. The underlayment from the edge of the locomotive maintenance shop (sta 0+95) to sta 1+80 was sloped away from the building to prevent excess surface water from becoming trapped beneath the crossing and adjacent to the building. Beginning at sta 1+80 the underlayment is crowned at the center line of Track 3 with a 1.5 percent slope to both sides (Figure 12). Transition sections similar to that shown in Figure 13 were designed at the end of the underlayment to provide a smooth transition between the soft conventional track and the more rigid underlayment sections.

19. Project specifications required that the subgrade compaction be at least 90 percent of the CE 55 maximum density as outlined in Military Standard 621-A Method 100 (Department of Defense 1964). Table 2 presents the aggregate gradation specified by the project specifications for use in the AC mix. The required density of the asphalt was specified as 96 percent of the maximum laboratory density. The specifications called for the ballast to be a crushed stone or crushed slag of size No. 4 that meets all of the applicable

AREA specifications for quality, soundness, and gradation. Table 3 presents the specified gradation ranges for the ballast. The specifications required the installation of new ties with nominal dimensions of 7 in. by 9 in. by 8.5 ft conforming to Federal Specification MM-T-371E (Headquarters, Department of Army 1975). Hardwood ties were specified for use in the turnouts. All spikes and other track materials (nuts, bolts, washers, etc.) were to be new with the spikes being the 5/8-in. by 6-in. size. The specified tie spacing was 22 ties per 39-ft rail length, which results in a 21-in. center-to-center spacing. The 85-lb/yd rail removed from the track was to be relaid with tie plates used on each tie. The tolerances specified for the finished track were:

Gage	4 ft - 8.5 in. ± 1/4 in.
Runoff at the end of a raise in 31 ft of rail (Runoff)	1 in. maximum
Deviation from a uniform profile on either rail at the midordinate of a 62-ft chord (Profile)	1/2 in. maximum
Deviation from zero cross-level (Cross-level)	1/2 in. maximum
Difference in cross-level between any two points less than 62 ft apart (Warp)	5/8 in. maximum

Preconstruction Testing

20. Prior to the construction of the underlayment section, a series of track deflection tests were performed at various locations on the tracks to be rehabilitated and on the adjacent tracks not included in the project. Auger borings were made at several locations in the test area, subgrade moisture content samples were obtained, and the subgrade moisture content was determined. Presentation and analysis of these data along with data taken after construction are found in Part V of this report.

PART IV: CONSTRUCTION OF DEMONSTRATION PROJECT

Track Removal

21. The three tracks in the project area were removed from sta 0+95 to 6+50. A total of 1,375 ft of track was removed along with three turnouts. The procedure for removing the track was to pull the spikes, unbolt the rail, pick up and stockpile the rail, and pick up the used spikes, bolts, joint bars, tie plates, and other track material for stockpiling. Figures 14 and 15 are typical photographs showing pulling spikes and picking up the rail. The next step was to pick up the crossties and stockpile them for removal from the project site. The ties were removed from the ballast by men with tie tongs and stacked so that they could be transported easily. Each stack was then moved out of the work area while awaiting removal.

22. Once all the track materials had been removed the contractor began removing the ballast. The ballast was removed using a bulldozer, endloader, and dump trucks. Figures 16 and 17 are typical of the ballast removal process. As the ballast was removed, a layer of water was found to be present between the ballast and subgrade. This water covered the entire area between sta 0+95 and 3+00 and was apparently surface water that had drained through the ballast only to become trapped on top of the subgrade. This trapping of the water was most likely due to the impermeable nature of the clay subgrade and the fact that the natural ground surrounding this area was higher than the roadbed. During the ballast removal numerous soft spots and pumping areas were observed. Figure 18 shows the soft subgrade conditions that existed after all of the ballast was removed.

23. The old concrete and timber crossing adjacent to Building 166 (Figure 19) were completely removed to allow the underlayment to abut the building thereby preventing any water from ponding against the building foundation.

Subgrade Preparation

24. Upon removal of the ballast material, a commercial testing laboratory obtained samples of the subgrade material for laboratory compaction testing. These samples were taken at sta 1+75 and 5+25. Table 4 presents the

complete results of the laboratory testing. Based on these tests, the CE-55 maximum dry density, γ_{dmax}, and optimum moisture content, ω_{opt}, used were 121.0 pcf and 11.2 percent, respectively.

25. The first step in preparing the subgrade was to set grade stakes to determine if the existing roadbed elevation was sufficiently close to the required subgrade elevation and identify areas where cuts would have to be made. While setting the grade stakes, it was discovered that the 1.5 percent slope away from Building 166 between sta 0+95 and 1+80 would result in severe drainage problems in the vicinity of sta 3+00. To correct this problem, the slope between sta 0+95 and 1+80 was changed from 1.5 percent to 0.20 percent. The 0.20 percent slope will provide adequate drainage away from the building without causing extensive subgrade excavation from sta 2+75 to the end of the project. The grade stakes were set and it was determined that very little excavation of the subgrade would be required.

26. In order to obtain the compaction required by the project specifications the contractor had to dry the existing subgrade material. The moisture content in the top 6 in. of the subgrade was estimated at approximately 26 percent immediately after the ballast was removed. To dry the soil, the contractor used a bulldozer to rip open the subgrade and work it back and forth. Figures 20 and 21 present typical views of this drying process. The entire project area was cut out and worked in this manner. The subgrade from sta 0+95 to 3+50 was cut out approximately 24 in. deep and the material worked with a dozer. After the material had dried, it was placed back in the hole in approximately 6-in. lifts and rolled with a sheeps-foot roller as shown in Figure 22. The subgrade from sta 3+50 to 6+25 was worked by cutting it with the dozer blade turned at an angle, then the soil was bladed back into place and the section rolled with a sheeps-foot roller. Due to the extremely wet initial condition of the soil and the frequent afternoon showers that occurred, seven working days where required to adequately dry and compact the subgrade. The moisture content and in-place density of the compacted subgrade were measured using a nuclear moisture-density gage and the direct transmission method of testing. The in-place dry density varied from 105.2 to 114.1 pcf throughout the section upon completion of the initial compaction with an average of 110.4 pcf. The in-place moisture content varied from 12.6 to 15.8 percent with an average moisture content of 14.5 percent. The average

dry density of 110.4 pcf equates to 91.2 percent of the maximum laboratory density.

27. Once the subgrade compaction was completed the contractor set the final grade stakes and began cutting the subgrade to the final shape and grade. Figure 23 shows the motor grader cutting and dressing the subgrade prior to the final rolling. Some of the ballast rock that had previously been pushed into the soft subgrade and subsequently mixed into the compacted subgrade can also be seen in Figure 23.

28. Final rolling was accomplished with a 25-ton pneumatic tired roller (Figure 24). The roller was only about half full of water ballast making the total weight approximately 25,000 lb. To facilitate the final rolling and eliminate the dust that had formed on the surface, the subgrade was sprinkled lightly with water. The entire section was then rolled until smooth. During this final rolling two severe pumping areas became evident. These areas were between sta 1+00 and 2+00, an area approximately 6 ft wide adjacent to the driveway on the south side of the project; and between sta 2+25 and 3+00, an area approximately 75 ft long by 25 ft wide along the center line and to the right of the center line. These areas were excavated approximately 12 in. deep and the material was stockpiled. Additional dry material obtained from the stockpile of the subgrade material previously removed to meet the grade requirements was placed in the excavated areas and compacted. Once again the subgrade was dressed to final grade using a motor grader. The subgrade was again rolled, and a hand tamper was used to compact the soil adjacent to Building 166, Building 168, and the concrete driveway south of sta 0+95 to 1+70. Upon completion of the final rolling, nuclear moisture content and density tests were again run on the compacted subgrade. These tests indicated an average moisture content of 12 percent and an average dry density of 111.2 pcf, which is 91.9 percent of the maximum dry density obtained in the laboratory. Figure 25 presents a typical view of the subgrade after the final rolling was completed.

Placement of Underlayment

Prime coat

29. The job specifications called for the application of a prime coat to the subgrade prior to the placement of the asphalt underlayment. Although

a prime coat is not a required item in the construction of the underlayment, it does serve to help seal the subgrade and prevent the surface from being disturbed by construction traffic during the laydown process. Prime coats should be used with caution because on impermeable clays adequate penetration of the liquid asphalt may not be obtained.

30. The section was primed with an MC-30 liquid asphalt. The prime was applied using a distributor truck having both a spray bar and a hand hose. The subgrade adjacent to the buildings and concrete driveway was primed using a hand hose as seen in Figure 26. The remainder of the section was primed using the spray bar on the distributor truck as shown in Figure 27. The prime was applied at an average rate of 0.25 gal/sq yd over the entire section. Figure 28 presents a typical view of the subgrade after the prime coat was applied. The prime penetrated into the subgrade fairly well with the exception of a few small areas where the clay prevented almost all penetration. Within 5 hr after the prime coat was completed almost all of the prime had penetrated the subgrade.

31. The section was primed on Friday morning with paving scheduled to begin the following Monday. Rain began that Friday night and continued through Monday. These heavy rains resulted in some water ponding on the subgrade adjacent to Building 166. This water was pumped out; however, the water had broken through the prime coat and had softened a large area of the subgrade. This soft area extended across the entire width of the project from sta 0+95 to 1+15, and investigation in several locations showed the subgrade to be wet approximately 3 in. deep. Investigations at several locations throughout the project indicated that the prime coat had effectively shed the water with little or no moisture reaching the subgrade. Level shots on the soft area indicated that some low spots did exist in the subgrade. Instead of trying to remove the wet material and dry it again or replace it with more soil to bring the subgrade up to grade, it was decided to remove all of the wet subgrade adjacent to Building 166 and replace it with hot-mix just prior to placing the underlayment. The soft area from sta 0+95 to 1+15 across the full width of the project was excavated an average of 4 in. deep, and the wet subgrade material was removed.

Hot-mix asphalt concrete used

32. The job mix formula given in the job specifications (Table 2) is a conventional dense graded highway intermediate course mix modified slightly to

contain more mineral aggregate fines (minus No. 200 material) and slightly more asphalt cement to produce a mix with lower air voids. The actual amount of AC required for this job was small, with the original estimate being 560 tons. Because of the small amount required and the difficulty and expense of reconfiguring a plant to produce the specified mix design, the decision was made to use a standard Texas Highway Department Type "D" fine graded surface course modified by increasing the asphalt content until the air voids were in the 1 to 3 percent range. Copies of recent laboratory tests performed on samples of the Type "D" surface course that the paving contractor was producing were obtained from a local testing laboratory. These laboratory results indicated an optimum asphalt content of 6.2 percent. An asphalt content of 6.5 to 6.6 percent resulted in approximately 2 percent air voids while 6.8 percent asphalt resulted in air voids of about 1.3 percent. The AC used for this underlayment was the standard Texas Type "D" Fine Graded Surface Course mix with an asphalt content of approximately 6.6 percent. Figure 29 presents the aggregate gradation ranges specified in the job specifications.

Asphalt laydown

33. Conventional asphalt paving equipment and procedures were used to place the asphalt underlayment. The first two dump truck loads of hot-mix brought onto the project were placed in the excavated area between sta 0+95 and 1+15. A total of 25.3 tons of mix was dumped in this area and spread with an end loader, shovels, and rakes as seen in Figures 30 and 31. A vibratory plate compactor and a steel wheeled vibratory roller were used to compact this mix. After the hole had been repaired, the placement of the underlayment was begun. A small laydown machine with a maximum laydown width of 12 ft was used to spread the asphalt. Compaction of the mix was accomplished with a Dynapac CC14 vibratory roller and a small 1-ton roller. The underlayment was placed in two lifts with each lift being approximately 2.25 in. thick uncompacted or approximately 2 in. thick compacted, for a total compacted thickness of 4 in. The first lift began at sta 0+95 and continued to sta 6+25 on Track No. 3. An additional pass was made north of sta 5+00 to place the underlayment under the entire turnout to Track No. 5. The first lift of the underlayment extended back to sta 5+00 on Track No. 5 to include the additional section and a 2-in.-thick transition section. The second lift extended from sta 0+95 to 6+00 on Track No. 3, and back to sta 5+15 on Track No. 5. Figures 32 and 33 present typical scenes of the laydown operation during the

placement of the first and second lifts, respectively. Figure 34 shows the asphalt being compacted with the vibratory roller, and Figure 35 presents an overall view of the paving operation during the placement of the second lift.

34. During the application of the second lift the loaded dump trucks began rutting a section of the underlayment approximately 20 ft right of the center line between sta 2+25 and 2+75. These ruts occurred in the same general vicinity as the severe pumping that occurred during the subgrade preparation. The maximum rutting occurred approximately 20 ft right of center line at sta 2+65 (Figure 36). The 1-ton roller was used to smooth the ruts and the second lift of asphalt placed over the rutted area. Only two passes of the large vibratory roller was made over this area where the rutting occurred to prevent the pavement from cracking. These passes plus rolling with the 1-ton roller were sufficient to seal the surface.

35. During the laydown operation samples of the AC were obtained from the plant by the independent commercial testing laboratory. Laboratory tests on these samples indicate that the AC had a maximum laboratory density of 144.9 pcf, a Marshall stability of 2,072 lb, and a flow value of 0.10 in. Cores were extracted from the underlayment at four locations along the project. The results of the laboratory density test are presented in Table 5. It can be seen from these data that the in-place asphalt density is relatively constant and ranges from 130.5 to 132.2 pcf with an average in-place density of 131.1 pcf. This average density is 90.5 percent of the maximum laboratory density. The holes remaining where the cores were removed were patched with cold-mix asphalt and compacted with a hand tamper. Figure 37 presents an overall view of the project upon completion of the asphalt laydown.

Track Replacement

36. The ballast rock used in this project was a crushed Arkansas sandstone. This ballast has the gradation shown in Figure 38 and a Los Angeles abrasion loss of 26.5 percent. The gradation is generally within the specifications for a No. 4 gradation, and the abrasion loss is less than the 40 percent maximum specified in the job specifications. The ballast was brought to the project site in dump trucks. The ballast was dumped and spread with a dozer to a depth of approximately 4 in. (Figure 39). Some compaction

of the ballast was obtained by walking it in with the dozer. This first layer of ballast served as a working platform for construction of the track.

37. After the ballast had been spread, the replacement of the track began. Bundles of new ties were unloaded over the project area, and men with tie tongs moved them into position (Figure 40). Once the ties were in the correct location, tie plates were placed in their proper location on the ties (Figure 41). The rail was then replaced as shown in Figure 42. Each rail had been numbered prior to removal, and the rails were returned to their original location in the track. The joint bars were cleaned and oiled prior to their installation in track (Figure 43). New bolts and washers were used in all joints along with the previously used joint bars. Any defective joint bars found during the installation were replaced prior to installation. The rails were gaged (Figure 44) and spiked every fourth tie to hold them in place until all the rail could be installed and the final spiking completed.

38. After the trackwork had been installed, the remaining ballast was hauled in by truck and stockpiled adjacent to the track. An endloader was used to place the ballast in the track and spread the ballast. Figure 45 shows the track after the addition of the ballast prior to the final raise, tamping, and surfacing.

39. A mechanized tamper was used to raise, surface, and align the track as shown in Figure 46. This type of equipment raises the track to the desired elevation including any required superelevation, aligns the track, and tamps the ballast under the tie. The amount of raise is set by the operator and is obtained as follows:

- a. The projection unit on the forward projector buggy is set to the desired height of raise.
- b. An infrared light is projected from the projector buggy toward the tamper. The receiving unit on the tamper is at the same elevation above the track as the projection unit creating a level beam of light.
- c. Rail clamps on the machine grip the ball of the rail and hydraulic jacks lift the track.
- d. As the track is raised, a shadowboard attached to the lifting unit rises. When the shadowboard breaks the infrared light beam, the jacking stops.

The raising, surfacing, aligning, and tamping process is a nearly continuous action (Figure 47). Only one pass of the tamper was required to surface and align the track on the project. A ballast regulator was used to sweep the track and form the ballast section. Figure 48 presents an overall view of the project upon completion of the surfacing.

40. After the final surfacing of the tracks in the project area, the grade crossing adjacent to Building 166 was rebuilt. This crossing was constructed as shown in Figure 10 to provide a smooth, long-lasting, crossing for access to Building 168. Figure 49 presents an overall view of the new concrete grade crossing.

Correction of Drainage Problems

41. During the construction of this demonstration project the ditches and culverts adjacent to the project were graded and opened to facilitate better drainage of the surface water away from the track. Figure 50 shows the contractor using a backhoe to open the ditch leading to the culvert under Track No. 1 at sta 4+70. This is the same area where water was ponding in Figure 7. Both a backhoe and a small dozer were used to open the ditches and culverts. Figures 51 through 54 show some of the major drainage improvements made in the project area.

Completed Construction

42. Figure 55 presents an overall view of the project area after completion of the entire project. Sta 6+00, the end of the 4-in. underlayment section, is in the extreme foreground of this figure. Figure 56 presents a plan view of the project area with the extent of the underlayment, new grade crossing, and new or reopened ditches indicated. Figure 57 presents an overall view of a typical turnout, and Figure 58 shows a detail of the frog and guard rails.

Postconstruction Testing

43. Upon completion of the construction of the underlayment and reconstruction of the track a series of track deflection tests were performed on the track. These deflection tests along with the preconstruction deflection test help to identify the increase in structural support received from the

underlayment. A top of rail profile was obtained on the top of both rails on all of the tracks in the project area. These data will be used to monitor the long term settlement of the track.

44. Data collected during the postconstruction testing along with data collected during the preconstruction testing and during construction will be discussed in Part V.

PART V: ANALYSIS OF FIELD TEST DATA

45. Prior to the construction of the demonstration section, auger borings were performed along the center line of Track Nos. 1 and 3, and moisture content samples were obtained. Track deflection tests were performed on the tracks to determine the preconstruction track modulus. Upon the completion of the construction the track deflection tests were repeated in the same locations as the preconstruction tests, and the top of rail profiles on both the north and south rail of each track were obtained. To assist in the future location of the project stationing, stamped metal plates approximately 2 in. by 2 in. were nailed into the ties at 50-ft intervals.

46. Table 6 presents the moisture content data for the section. As shown in the table, the data were obtained at various times during the planning and construction of the demonstration section. The October 1985 data for Track No. 3 presented in Table 6 are the final subgrade moisture contents prior to placing the underlayment, except for sta 7+00 which was not included in the underlayment.

47. Table 7 presents the results of track deflections obtained on the tracks of the demonstration section. These deflections were obtained by clamping a scale on the base of the rail (Figure 59) and then using a surveyor's level to measure the track deflection under the wheel of a 100-ton locomotive (Figure 60). The track deflections were used to calculate the track modulus value using the procedures outlined in "Synthesis of Railroad Design Methods, Track Response Models, and Evaluation Methods For Military Railroads" (Coleman 1985). The calculated track modulus values are presented in Table 8. Figure 61 presents plots of the measured track deflection for each of the tracks in the demonstration section, and Figure 62 presents plots of the calculated track modulus values. Track No. 1 was considered the control track for the deflection and moisture content measurements as no reconstruction took place there. The measured deflections along Track No. 1 were very similar for the preconstruction and postconstruction tests indicating little change in the track deflection with time. Similarly the track modulus plots in Figure 62 show little change for Track No. 1. The postconstruction track deflections along the tracks having the underlayment show a decrease in track deflection over the preconstruction deflection readings. The track

modulus plots indicate that this decrease in deflection has resulted in an average increase in track modulus of 48 percent. Because of the freshly tamped condition of the tracks in the demonstration section, the deflections measured during the postconstruction testing are higher than the deflections that are to be expected after a significant amount of traffic has been applied to the tracks to compact the ballast section. Because of this, the track modulus value will increase with time as traffic compacts the ballast and the track structure "tightens up." The data in Tables 7 and 8 and Figures 61 and 62 indicate that the underlayment did assist in increasing the overall stiffness of the track structure for Track Nos. 2, 3, and 4 within the project area.

48. Table 9 presents the finished elevations of the top of rail profile of each rail in the demonstration section. Table 10 presents elevations of the tie center line for selected locations. These data are presented in this report for reference and will be used in long-term evaluation of the performance of this demonstration section.

PART VI: BENEFIT-COST ANALYSIS

49. While the initial cost of construction or reconstructing a track with an asphalt underlayment is greater than that of a conventional ballast section, there are some advantages in decreased maintenance of the underlayment.

Cost

50. Table 11 summarizes the actual cost of this project. All costs have been normalized to indicate the cost for rehabilitation of 1,000 ft of single track. The roadbed is assumed to be 16 ft wide with a 14-ft-wide underlayment. As seen in Table 11, the total cost of this project was $78,430 per 1,000 track ft, or approximately $78.43 per track ft. Table 12 presents a comparison of the construction cost between rehabilitation using an asphalt underlayment and conventional out-of-face rehabilitation. As seen in this table, the conventional rehabilitation would cost approximately $67.23 per track foot compared to $78.43 per track foot for the underlayment, or $11.20 per track foot less than the underlayment.

Benefit

51. The frequency with which track maintenance is required varies from railroad to railroad (Army installation to Army installation) depending on the traffic volume, axle loads, speeds, existing gradients, ballast type and depth, subgrade strength, and environmental factors. Underlayment sections have been in place on commercial railroads for up to 15 years. While definite information on the cost of maintenance of these sections is not available, indications are that the underlayments can extend the surfacing cycle from 1 to 2 years to 5 to 7 years; decrease the need for ballast cleaning and/or replacement; and decrease the wear on rails, tieplates, and ties leading to a longer life for track materials. The underlayment sections have improved the quality of the track by reducing the number of geometric deviations. Operating interference due to maintenance crews is reduced in an underlayment section as is the number of slow orders required due to track condition and track maintenance activities.

52. At RRAD the railroad maintenance force currently averages surfacing the track annually with some locations requiring semiannual maintenance due to the nature of the subgrade conditions. A three-man crew is used for this routine maintenance activity at a cost of approximately $8,000 per track mile per year. With the traffic levels that exist at RRAD, it is expected that the underlayment section will require surfacing about every 8 years. For the tracks involved in this demonstration section, the normal maintenance cost would be approximately $1,500 per thousand track foot per year. Since no maintenance is anticipated for at least 8 years, a cost savings of at least $15,000 is expected for this section. Contrasting this with the additional $11,200 expense in constructing the underlayment yields a break even point of 7.5 years where the savings resulting from the underlayment exceeds the initial cost of the underlayment. Additional long-term benefits will be seen from better drainage of the track structure that will reduce tie decay, reduce track deterioration, and improve operating conditions.

PART VII: PROJECT CONSIDERATIONS

53. Based on the experience obtained during the design and construction of this demonstration project, there are several things that should be considered in the design and construction of future asphalt sections for use in Army railroad track. These can be grouped into the general categories of potential uses, section design, and section construction.

Potential Uses

54. Because of the increased cost of track rehabilitation using the underlayment technique the use of this method of track rehabilitation on military trackage may be limited. Possible uses of underlayments on military track include stretches of track, turnouts, road crossings, rail crossings, and bridge approaches where poor subgrade conditions result in the requirement for intensive track maintenance.

Section Design

55. Based on the research into the use of asphalt structures in railroad track conducted prior to the design of the underlayment in this demonstration project, the underlayment is the recommended type of asphalt track enhancement for military trackage. The full-depth section offers no advantage over the underlayment and in fact limits the workability of the track. The underlayment performs the functions of a structural layer in the track while allowing conventional maintenance procedures to be used.

56. General design curves have not been developed to aid in the design of an underlayment for use in railroad trackage. The design should be performed on a case-by-case basis using the procedures presented in "KENTRACK, A Finite Element Computer Program for the Analysis of Railroad Tracks - User's Manual" (Huang et al. 1986). The design will vary depending on subgrade strength and conditions, drainage characteristics, train traffic, and wheel loads. For most military applications a 4-in.-asphalt underlayment combined with 8 to 12 in. of crushed stone ballast will be an adequate track section.

57. Prior to the selection of an asphalt underlayment as the method of railroad rehabilitation to be used, a thorough benefit-cost comparison should

be conducted. This analysis should consider the initial cost of constructing the underlayment versus the cost of conventional rehabilitation techniques. Additionally, the long-term maintenance cost of both types of track should be considered.

Section Construction

58. One of the major disadvantages of using an underlayment as a track rehabilitation method is the loss of track time during construction. To speed the installation of the section, and reduce the track time lost during construction and the cost of the project, consideration should be given to unbolting the rail and sliding the entire track, rail, and ties still together, to the side of the construction area (Figure 63). As shown in Figure 64, the old ballast is then removed, the subgrade prepared, and the underlayment placed without completely disassembling the track. Upon completion of the underlayment placement the track is pulled back into line on the asphalt section, any changeout of ties made, the track reballasted, surfaced, and aligned.

59. During construction, adequate subgrade compaction should be obtained to ensure that the construction equipment, especially the laydown equipment and dump trucks, will not rut the subgrade. Additionally, the subgrade should be firm enough to allow adequate compaction of the asphalt to be obtained. If the asphalt begins cracking during the placement and compaction under the roller, the rolling should be limited to the minimum required to seal the surface of the mix in that location.

PART VIII: SUMMARY AND CONCLUSIONS

60. Railroad maintenance using an asphalt underlayment as a structural enhancement technique has been shown to decrease long-term track maintenance cost and to improve the railroad's operating efficiency. While not a "cure-all" for every railroad track maintenance problem that exists on Army installations, an asphalt underlayment is a feasible rehabilitation alternative for reducing maintenance and repair costs and increasing the life cycle of track located over very soft subgrades or subgrade soils having swelling tendencies.

61. If further information on this study is desired, the following may be contacted:

OCE Representative:
HQDA
DAEN-ZCF-B (Mr. Robert Williams)
Washington, DC 20314-1000
Phone: FTS - 272-0597
AUTOVON - 285-0597

WES Principal Investigator:
David M. Coleman
ATTN: WESGP-IP
PO Box 631
Vicksburg, MS 39180-0631
Phone: (601) 634-2223
FTS - 542-2223

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Table 1

Temperature and Precipitation

(Recorded in the period 1951-75 at Clarksville, Texas)

	Temperature			Precipitation	
Month	Average Daily Maximum °F	Average Daily Minimum °F	Average Daily °F	Average Rainfall in.	Average Snowfall in.
January	54.0	31.6	42.8	2.70	0.2
February	58.2	34.9	46.5	3.21	0.1
March	65.2	41.3	53.3	3.70	0.0
April	74.9	51.7	63.4	5.37	0.0
May	81.7	60.0	70.9	4.89	0.0
June	88.7	67.2	78.0	3.45	0.0
July	93.1	70.5	81.8	3.25	0.0
August	93.1	69.4	81.3	2.37	0.0
September	86.8	63.1	74.9	3.97	0.0
October	78.3	52.0	65.1	4.05	0.0
November	65.4	41.1	53.3	3.92	0.1
December	56.6	34.0	45.3	3.44	0.0
Yearly:				--	0.4
Average	74.7	51.4	63.1		

Table 2

Specified Aggregate Gradation For Use In Asphaltic Concrete

Sieve Size	Percent Passing
1 1/2 in.	100
1 in.	90 - 100
1/2 in.	56 - 90
No. 4	29 - 59
No. 8	19 - 45
No. 50	5 - 17
No. 200	1 - 7
Asphalt Content (% by weight)	3 - 9

Table 3

Specified Gradation Ranges For Ballast

Sieve Size	Percent Passing
2 in.	100
1 1/2 in.	90 - 100
1 in.	25 - 55
3/4 in.	0 - 15
1/2 in.	--
3/8 in.	0 - 5

Table 4

Laboratory CE-55 Compaction Test Results for Subgrade

Sample No.	Locations	γ_{dmax} pcf	ω_{opt} %	LL	PL	PI
1	1+75	121.4	10.8	34.9	16.4	18.5
2	5+25	120.5	11.5	39.8	17.1	22.7
Average		120.95	11.2	37.4	16.8	20.6

Table 5

Laboratory Test Results on Asphalt Cores

Core No.	Location	Thickness, in.	Unit Weight pcf	Percent Of Maximum Density*
1	Sta 1+50 5 ft left center line	3.50	130.6	90.1
2	Sta 3+00 7 ft right center line	4.65	130.5	90.1
3	Sta 5+00 5 ft left center line	4.55	132.2	91.2
4	Sta 6+15 3 ft right center line	1.65**	131.0	90.4
Average		4.23	131.1	90.5

* Maximum laboratory density = 144.9 pcf
** Transition section, design AC thickness = 2.0 in.

Table 6

Subgrade Moisture Content

	Mositure Content (%)														
	Track 1						Track 3						25ft N ℄	15ft S ℄	10ft S ℄
Date	1+50	2+50	4+00	5+00	6+15	7+00	1+50	2+50	4+00	5+00	6+15	7+00	2+00	4+00	6+00
July 1984	--	--	--	--	--	--	16.4	--	--	18.1	--	19.5	--	--	23.4
May 1985	--	20.2	25.6	19.9	20.8	17.6	26.2	21.3	17.6	28.0	22.1	24.4	16.9	22.3	23.0
October 1985*	--	--	--	--	--	--	11.9	15.0	11.6	13.2	11.1	20.3	16.2	20.1	17.9
January 1986	--	--	--	--	--	--	--	--	--	--	--	--	16.3	17.9	15.9

* Moisture content under Track 3 is subgrade moisture content before asphalt laydown, except for Sta 7+00 which is in-situ subgrade moisture content.

Table 7

Track Deflection Readings

Track No.	Date*	Track Deflection, in.						
		1+50	2+50	4+00	5+00	6+15	6+35	7+00
1	May 1985	-	0.13	0.37	0.29	0.29	0.45	0.17
	January 1986	0.24	0.28	0.34	0.26	0.31	0.50	0.20
2	May 1985	0.15	0.16	0.38	--	--	--	--
	January 1986	0.13	0.17	0.21	--	--	--	--
3	May 1985	0.09	0.14	0.12	0.16	0.21	0.21	0.53
	January 1986	0.11	0.12	0.11	0.12	0.14	0.14	0.33
4	May 1985	0.20	0.29	--	--	--	--	--
	January	0.14	0.14	--	--	--	--	--

* May 1985 tests were preconstruction; January 1986 tests were postconstruction.

Table 8

Track Modulus Values

Track No.	Date*	Track Modulus, psi						
		1+50	2+50	4+00	5+00	6+15	6+35	7+00
1	May 1985	-	2751	783	1035	1044	627	1996
	January 1986	1308	1088	864	1188	964	551	1633
2	May 1985	2337	2154	748	--	--	--	--
	January 1986	2806	1997	1538	--	--	--	--
3	May 1985	4551	2672	2951	2154	1538	1538	516
	January 1986	3487	3113	3487	3113	2552	2552	895
4	May 1985	1633	1044	--	--	--	--	--
	January 1986	2552	2552	--	--	--	--	--

* May 1985 tests were preconstruction; January 1986 tests were postconstruction.

Table 9

Top of Rail Elevations, Postconstruction, ft

Track 2			Track 3			Track 4			Track 5		
Station	South Rail	North Rail	Station	South Rail	North Rail	Station	South Rail	North Rail	Station	South Rail	North Rail
0+95	368.58	368.64	0+95	368.59	368.62	0+95	368.69	368.70	4+00	367.26	367.31
1+00	368.59	368.60	1+00	368.57	368.57	1+00	368.60	368.63	4+25	367.21	367.19
1+25	368.67	368.67	1+25	368.67	368.64	1+25	368.58	368.59	4+50	367.19	367.19
1+50	368.73	368.73	1+50	368.64	368.65	1+50	368.58	368.60	4+75	367.25	367.25
1+75	368.70	368.72	1+75	368.65	368.65	1+75	368.58	368.62	5+00	367.18	367.16
2+00	368.56	368.58	2+00	368.59	368.61	2+00	368.62	368.61	5+25	367.07	367.07
2+25	368.49	368.50	2+25	368.52	368.54	2+25	368.48	368.50	5+50	366.92	366.91
2+50	368.36	368.38	2+50	368.45	368.47	2+50	368.42	368.42	5+75	366.72	366.74
2+75	368.21	368.22	2+75	368.32	368.32	2+75	368.31	368.31			
3+00	368.14	368.16	3+00	368.25	368.20	3+00	368.17	368.12			
3+25	368.00	368.02	3+25	368.07	368.04	3+25	368.04	368.00			
3+50	367.80	367.82	3+50	367.93	367.94	3+50	367.93	367.93			
3+75	367.67	367.69	3+75	367.78	367.76	3+75	367.76	367.76			
4+00	367.60	367.64	4+00	367.66	367.69						
4+25	367.53	367.60	4+25	367.59	367.65						
4+50	367.52	367.58	4+50	367.54	367.60						
4+75	367.34	367.37	4+75	367.34	367.39						

(Continued)

Table 9 (Concluded)

Track 2			Track 3			Track 4			Track 5		
Station	South Rail	North Rail	Station	South Rail	North Rail	Station	South Rail	North Rail	Station	South Rail	North Rail
			5+00	367.21	367.19						
			5+25	367.07	367.07						
			5+50	366.93	366.91						
			5+75	366.72	366.73						
			6+00	366.57	366.60						
			6+05	366.55	366.58						
			6+10	366.52	366.56						
			6+15	366.51	366.54						
			6+20	366.49	366.52						
			6+25	366.46	366.50						
			6+30	366.44	366.46						
			6+35	366.42	366.41						
			6+40	366.39	366.36						
			6+45	366.39	366.32						
			6+50	366.38	366.31						
			6+60	366.37	366.32						
			6+70	366.34	366.32						
			6+80	366.30	366.25						
			6+90	366.26	366.19						
			7+00	366.22	366.16						
			7+25	366.00	365.90						
			7+50	365.84	365.81						
			7+75	365.76	365.69						

Table 10

Tie Center-line Elevations, Postconstruction, ft

Station	Track 2	Track 3	Track 4	Track 5
1+50	368.23	368.18	368.10	--
2+00	368.08	368.13	368.14	--
2+50	367.88	367.97	367.93	--
3+00	367.67	367.73	367.64	--
3+50	367.33	367.46	367.46	--
4+00	367.14	367.19	--	366.82
4+50	367.06	367.09	--	366.72
5+00	--	366.72	--	366.68
5+50	--	366.44	--	366.44
6+00	--	366.12	--	--
6+50	--	365.93	--	--
7+00	--	365.73	--	--
7+50	--	365.37	--	--

Table 11

Normalized Actual Construction Cost*

Red River Army Depot, 1985

Item	Cost per 1,000 Track Feet
Remove Old Track	$ 8,800
Subgrade Preparation	7,112
Bituminous Prime Coat	1,387
Hot-Mix Asphalt Underlayment	21,784
Ballast	10,000
Ties	12,126
Spikes, Bolts, Anchors, and Other Track Material	2,621
Replace Track	9,650
Line, Surface, and Dress	3,000
Clean Ditches	1,950
Total	78,430

* Cost is normalized to indicate cost for rehabilitation of 1,000 ft of single track. The roadbed is assumed to be 16 ft wide with the underlayment 14 ft wide.

Table 12

Comparison of Construction Cost

Underlayment Versus Conventional Out-of-Face Rehabilitation*

Item	Cost per 1000 Track Feet		
	Underlayment	Conventional	Difference**
Remove Old Track	8,800	8,800	-0-
Subgrade Preparation	7,112	7,112	-0-
Bituminous Prime Coat†	1,387	-0-	+ 1,387
Hot Mix Asphalt Underlayment†	21,784	-0-	+21,784
Ballast††	10,000	21,970	-11,970
Ties	12,126	12,126	-0-
Spikes, Bolts, Anchors, & OTM	2,621	2,621	-0-
Replace Track	9,650	9,650	-0-
Line, Surface, & Dress	3,000	3,000	-0-
Clean Ditches	1,950	1,950	-0-
Total	$78,430	67,229	+11,201

* Cost is normalized to indicate cost for rehabilitation of 1,000 ft of single track. The roadbed is assumed to be 16 ft wide.

** Difference = Cost underlayment; Cost conventional.

† Prime coat and underlayment assumed to be 14 ft wide.

†† Ballast thickness for underlayment = 8-in. below bottom of tie; ballast thickness for conventional rehabilitation = 18-in. below bottom of tie.

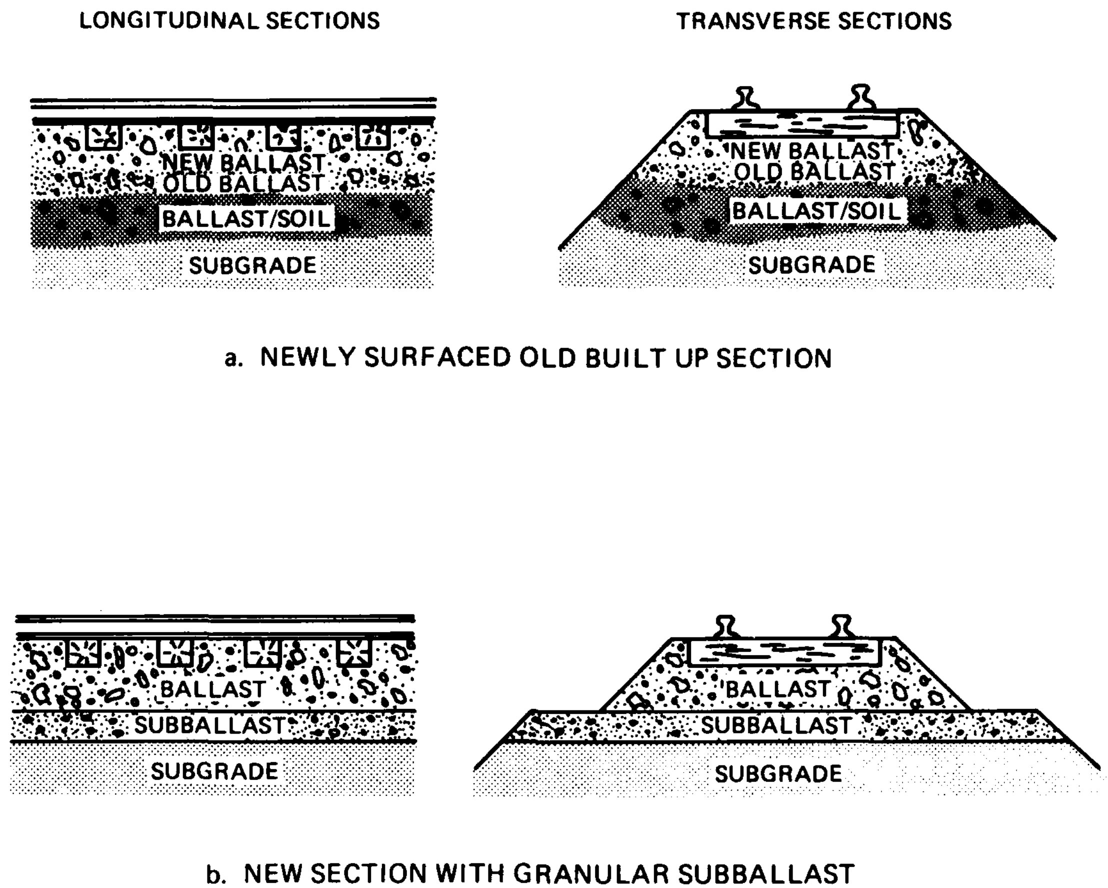


Figure 1. Typical conventional ballasted trackbed sections

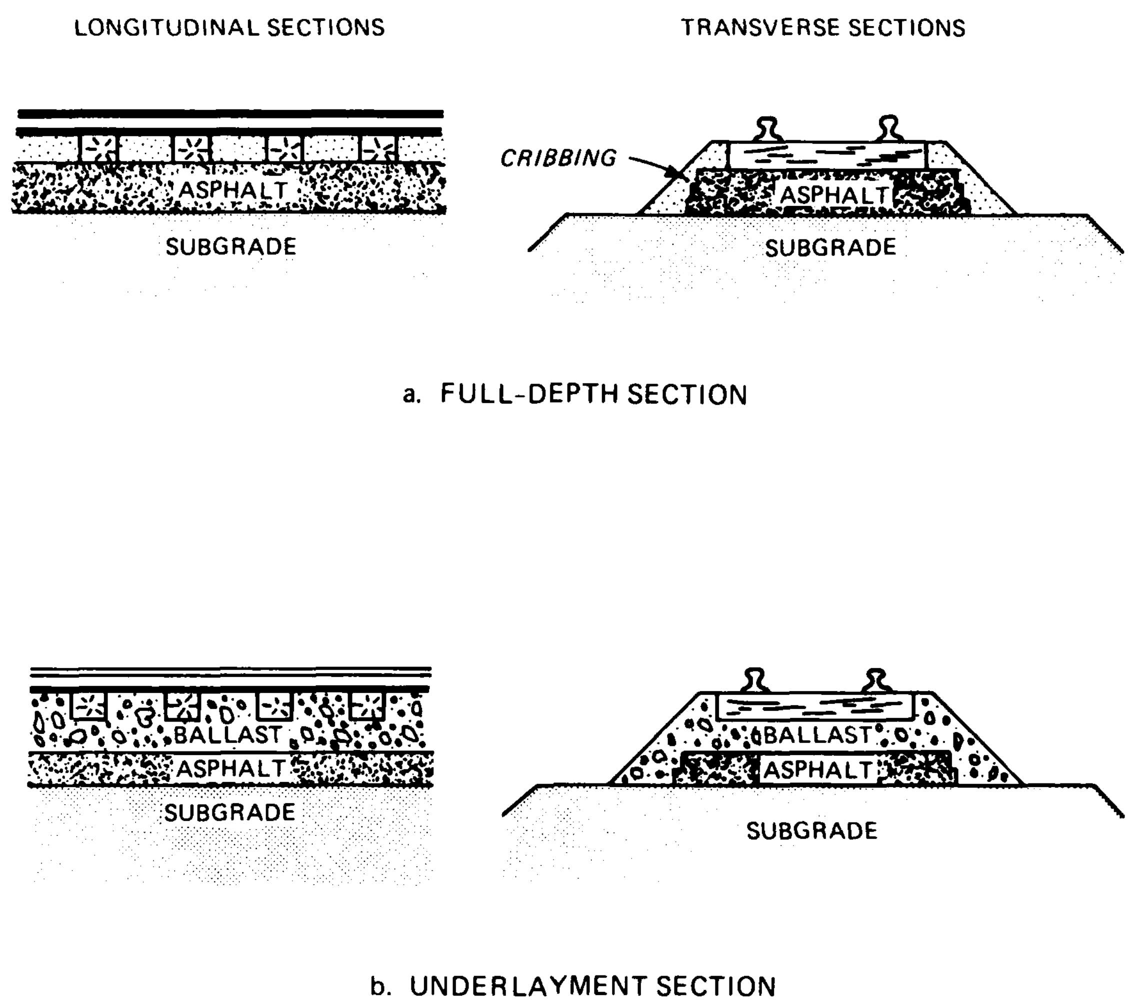


Figure 2. Typical hot-mix asphalt trackbed sections

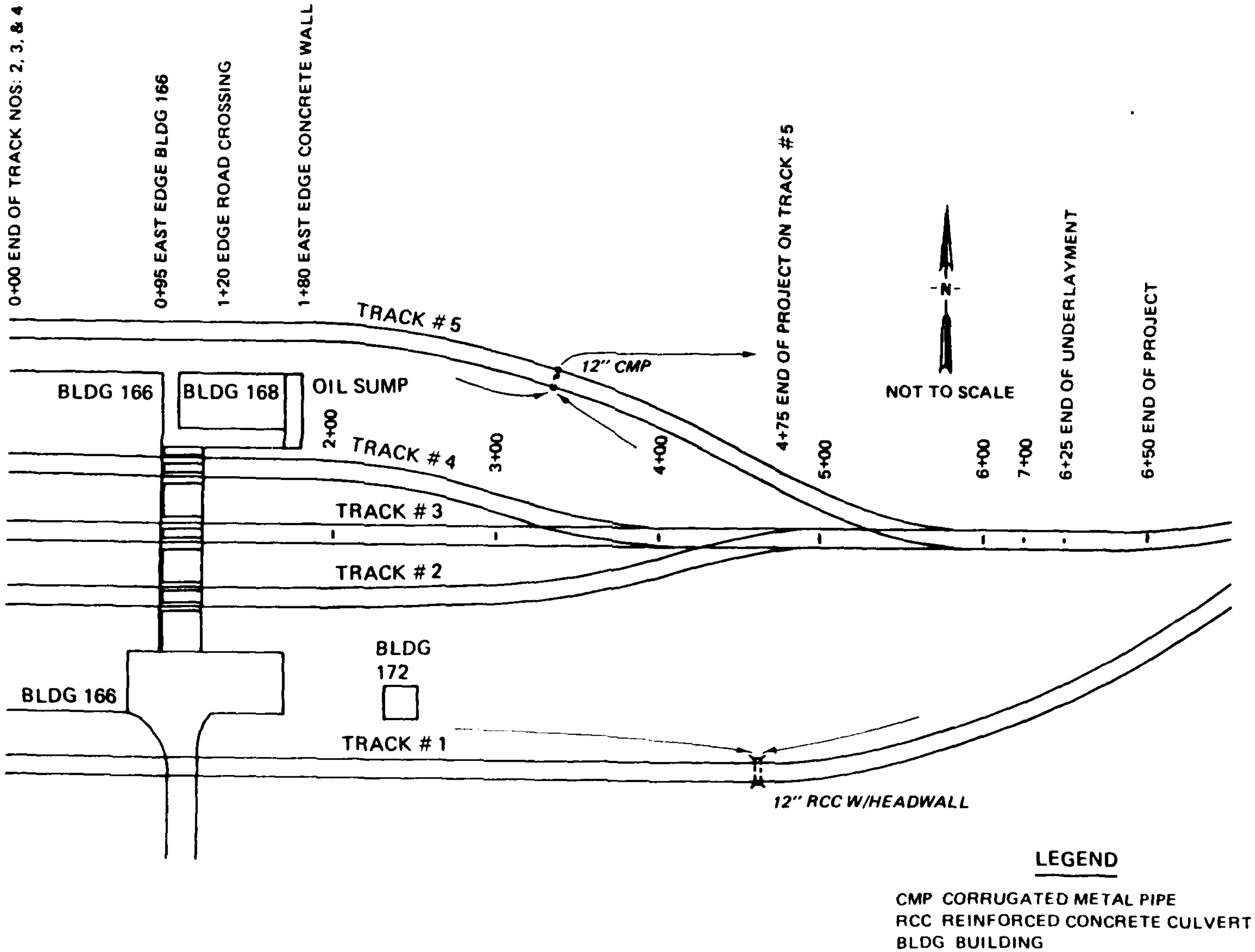


Figure 3. Demonstration site plan

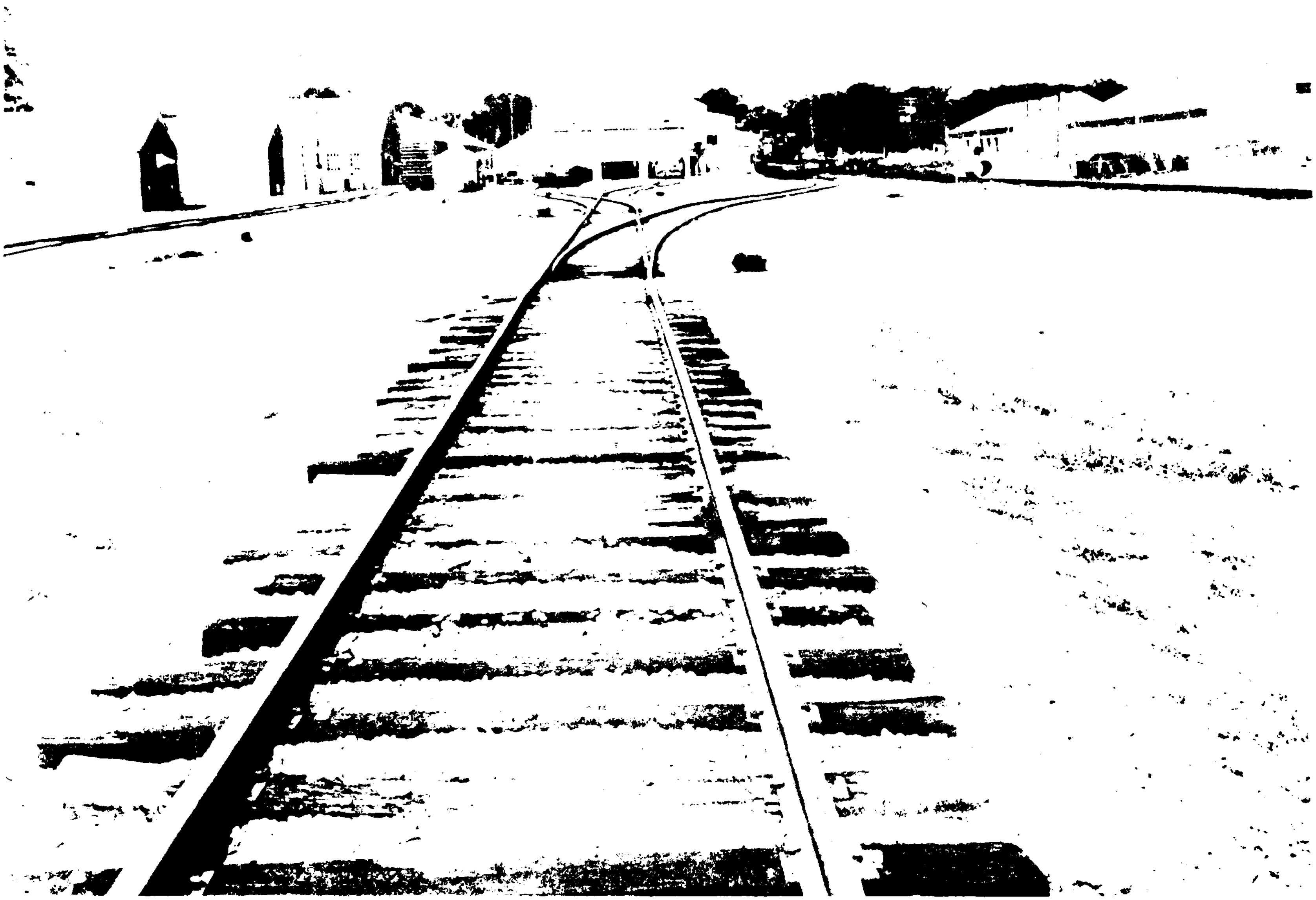


Figure 4. Project area overall view

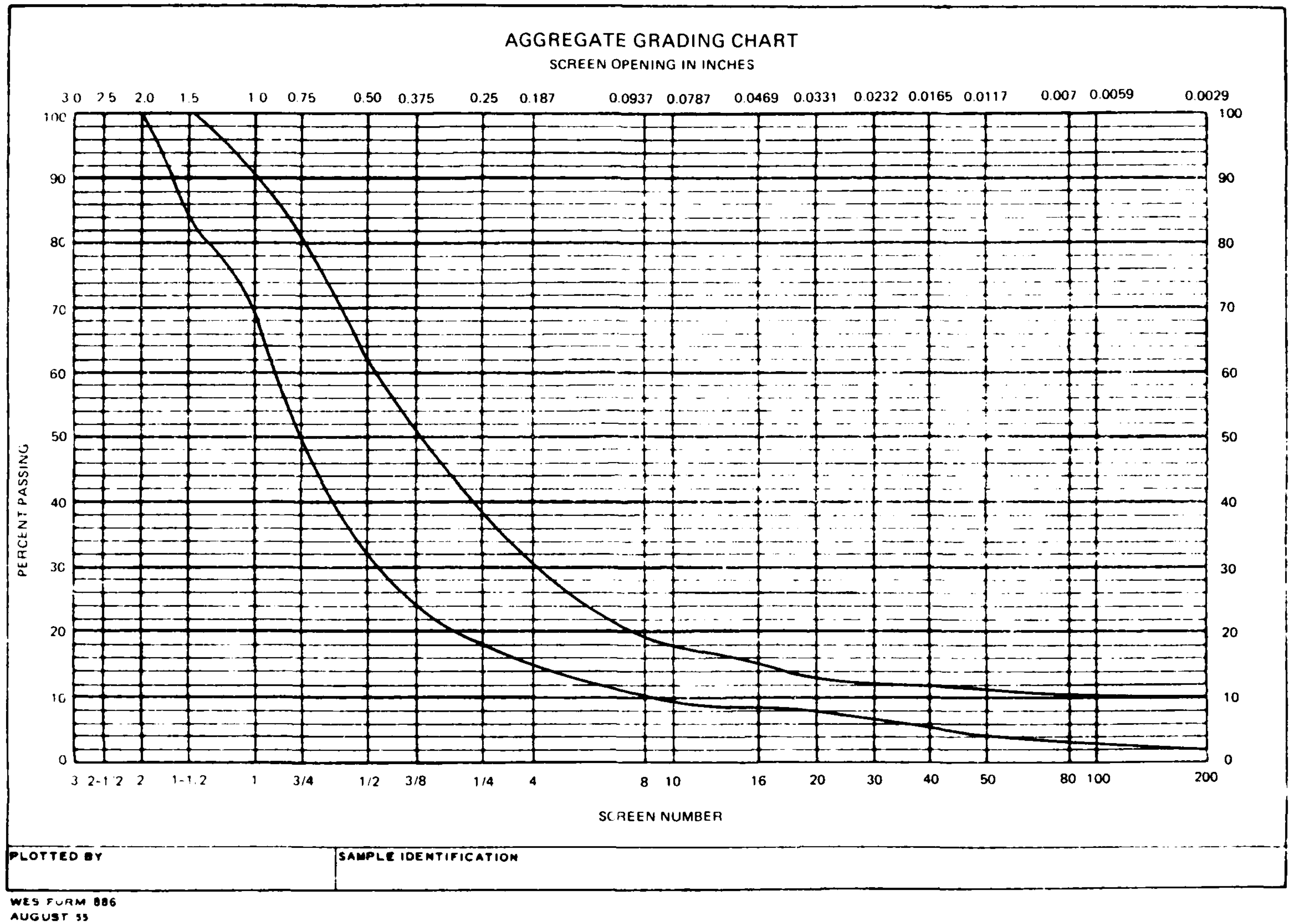


Figure 5. Gradation curves, old ballast

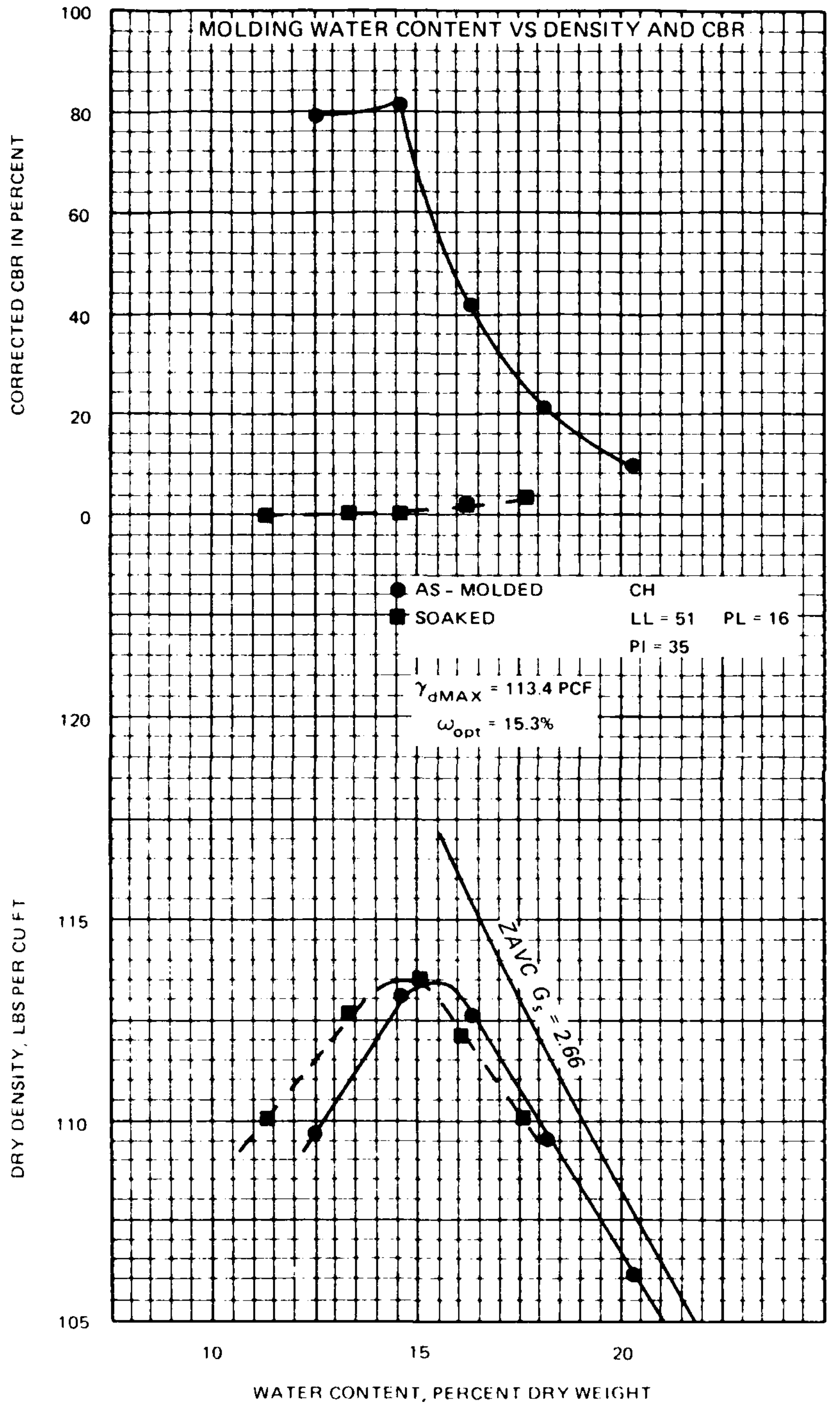


Figure 6. Moisture-density relationship of subgrade

Figure 7. Inadequate drainage, sta 5+00

Figure 8. Partially clogged 12-in.-diam culvert under Track 1, sta 4+70

Figure 9. Partially clogged 8-in.-diam culvert under Track 5, sta 3+30

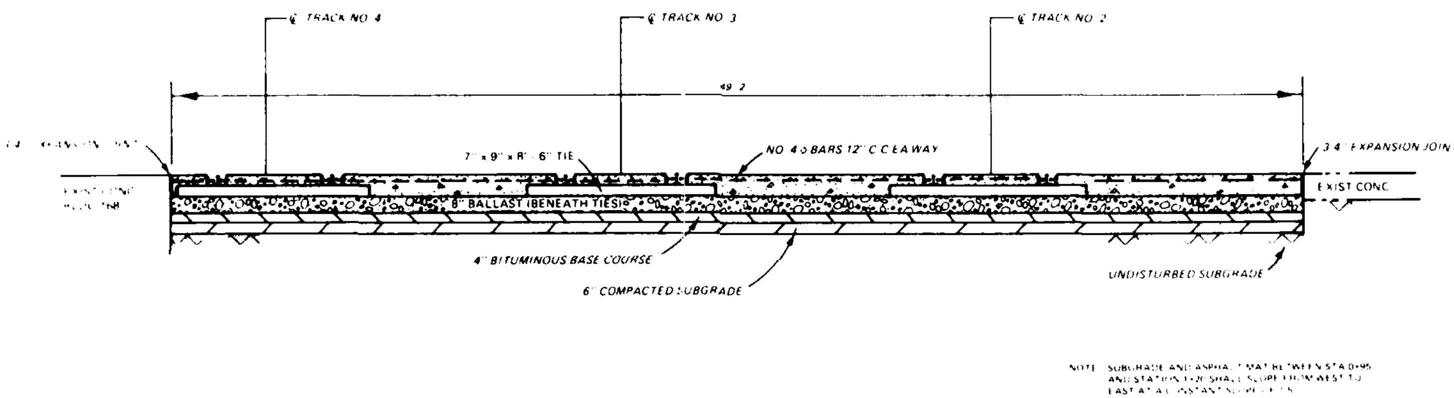


Figure 10. Typical cross section, sta 0+95 to 1+20

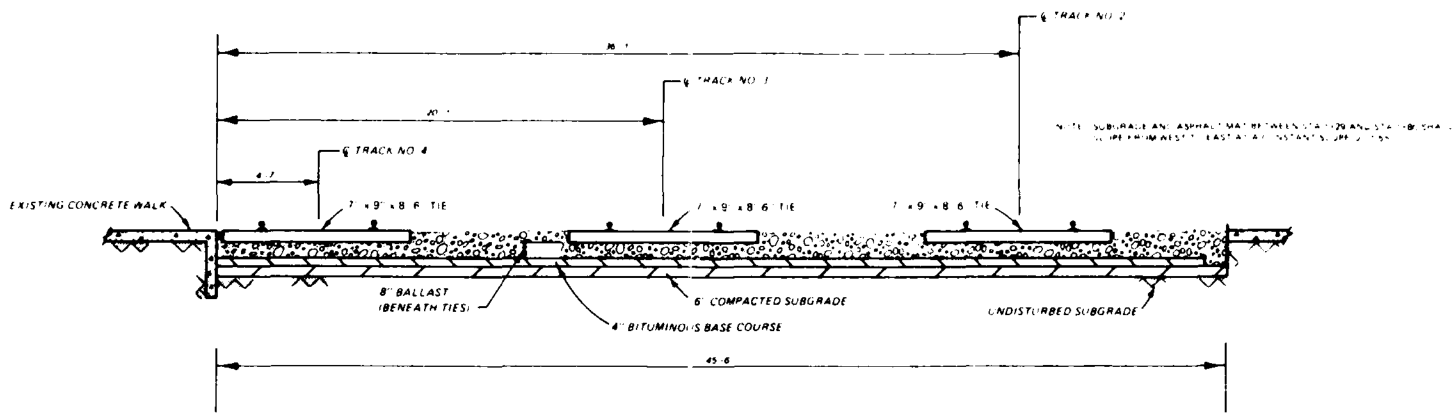
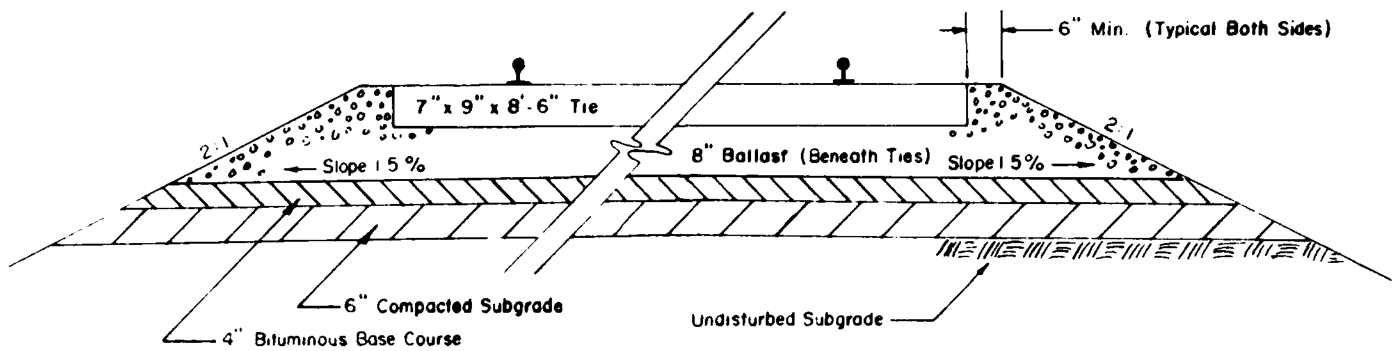


Figure 11. Typical cross section, sta 1+20 to 1+80



NOTE: Where More Than One Track Is Involved In The Cross Section Of The Track Structure Bituminous Base Course Shall Extend Continuously Under All Tracks At Indicated Slope A Minimum Of 6'-6" Outside The ℄ Of The Outside Track Each Way

NOT TO SCALE

Figure 12. Typical cross section, underlayment section, sta 5+50

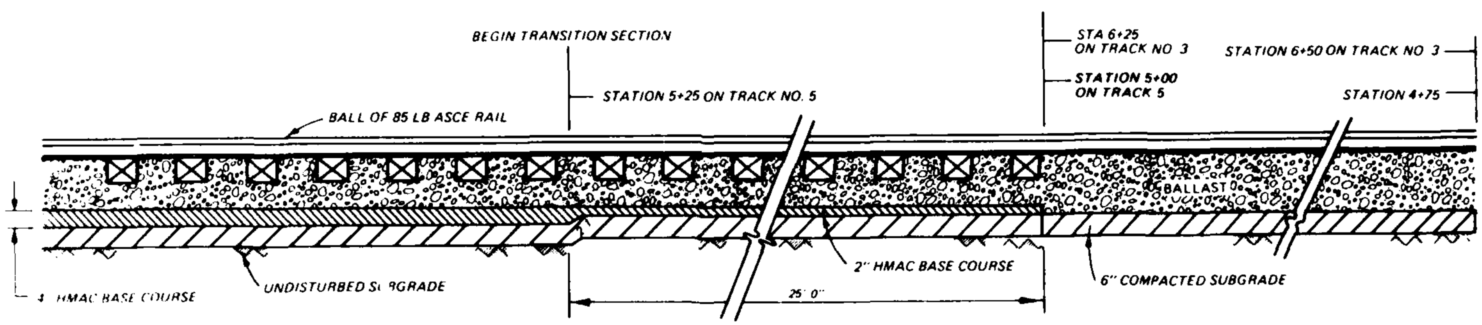


Figure 13. Transition section profile view

Figure 14. Pulling spikes

Figure 15. Picking up rail

Figure 16. Removing old ballast, sta 6+00

Figure 17. Removing old ballast, sta 2+00

Figure 18. Soft subgrade conditions existing after ballast removal

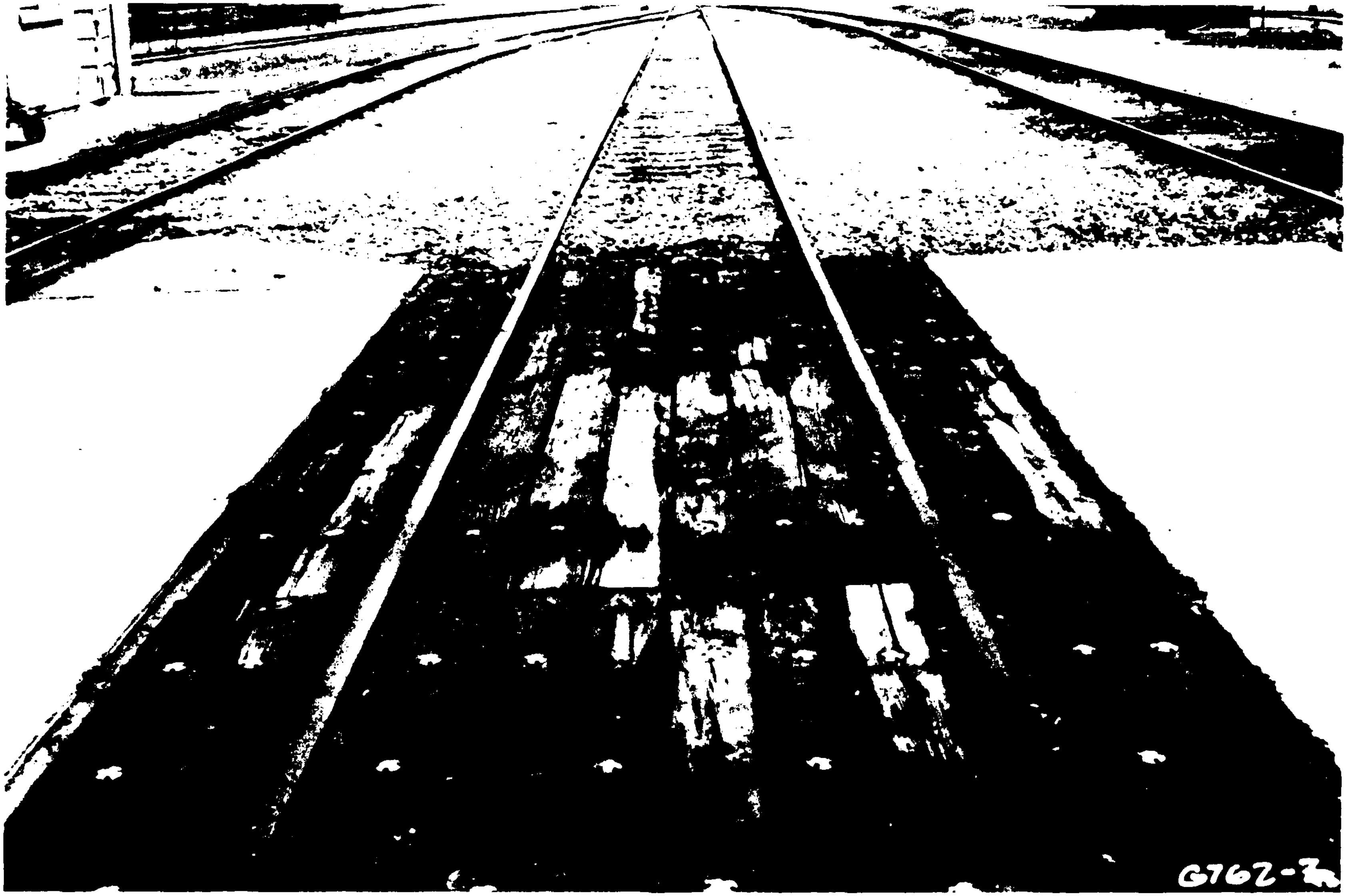


Figure 19. Old concrete and timber crossing adjacent to Bldg 166

Figure 20. Ripping subgrade to dry soil

Figure 21. Working subgrade to dry soil

Figure 22. Rolling subgrade with sheeps-foot roller

Figure 23. Cutting final grade with motor grader

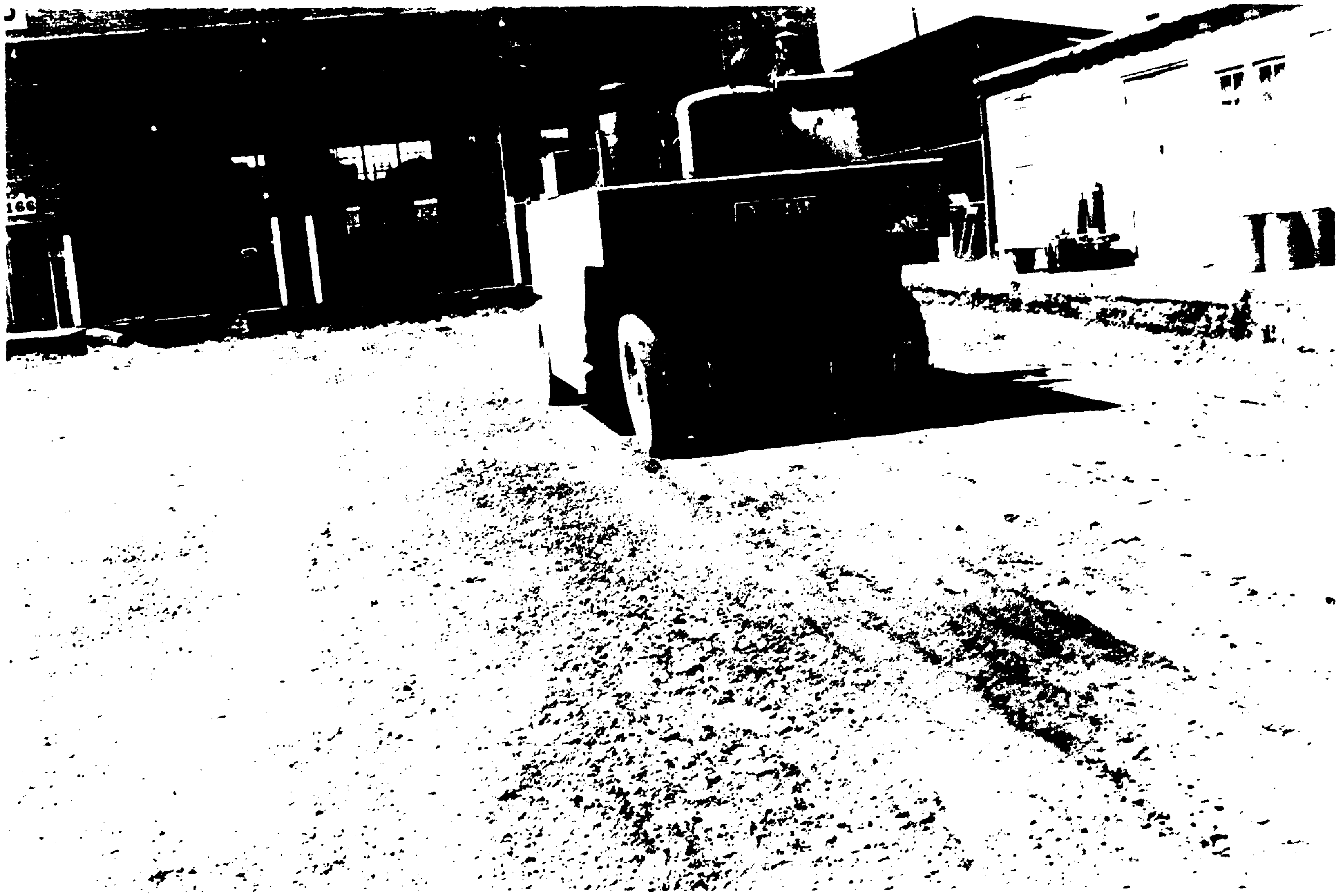


Figure 24. Final rolling of subgrade

Figure 25. Typical view of subgrade after final rolling

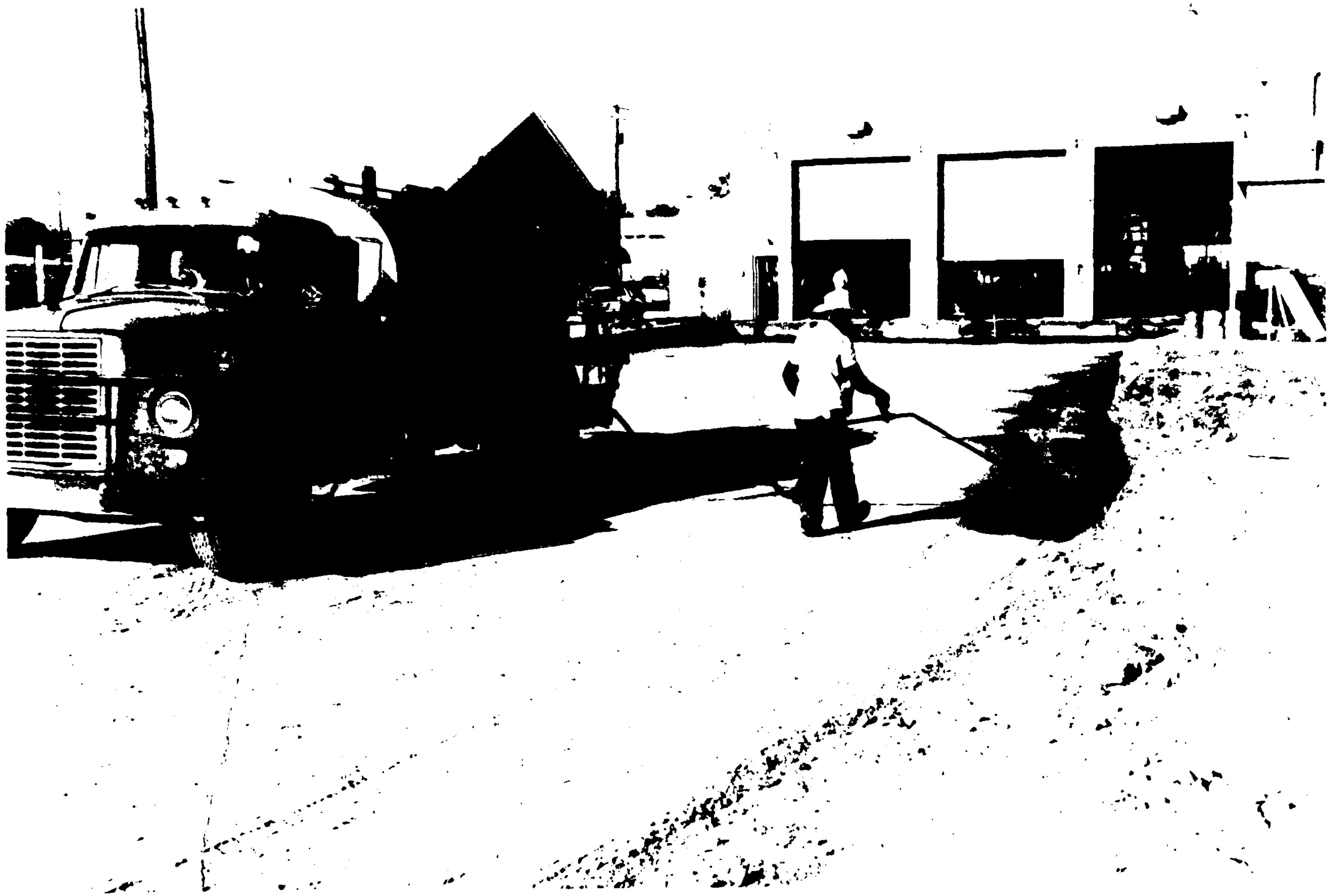


Figure 26. Application of prime coat using hand hose

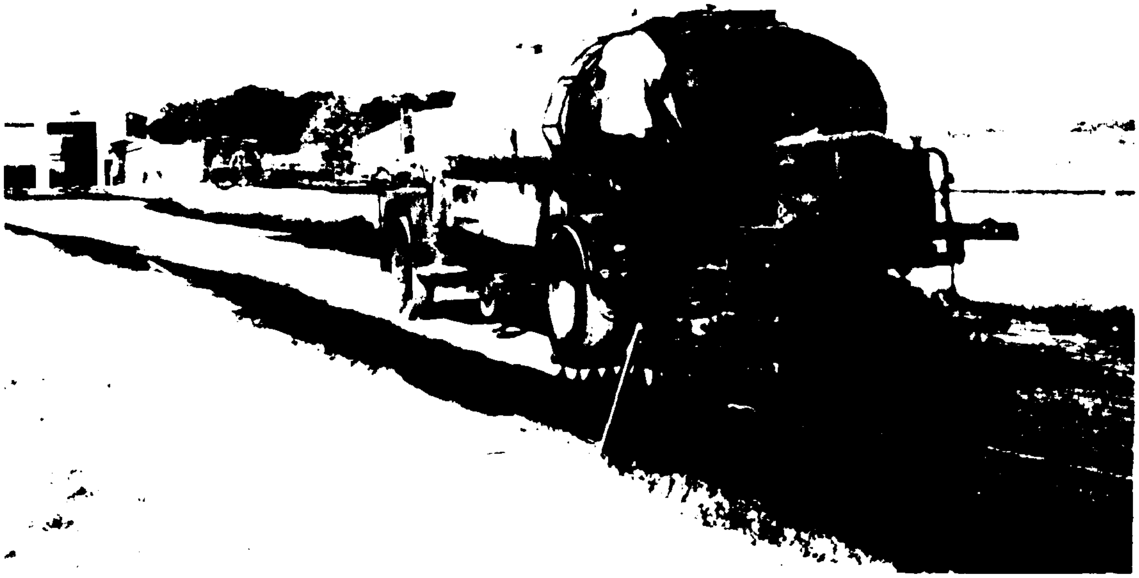


Figure 27. Application of prime using spray bar

Figure 28. Typical view of subgrade after priming

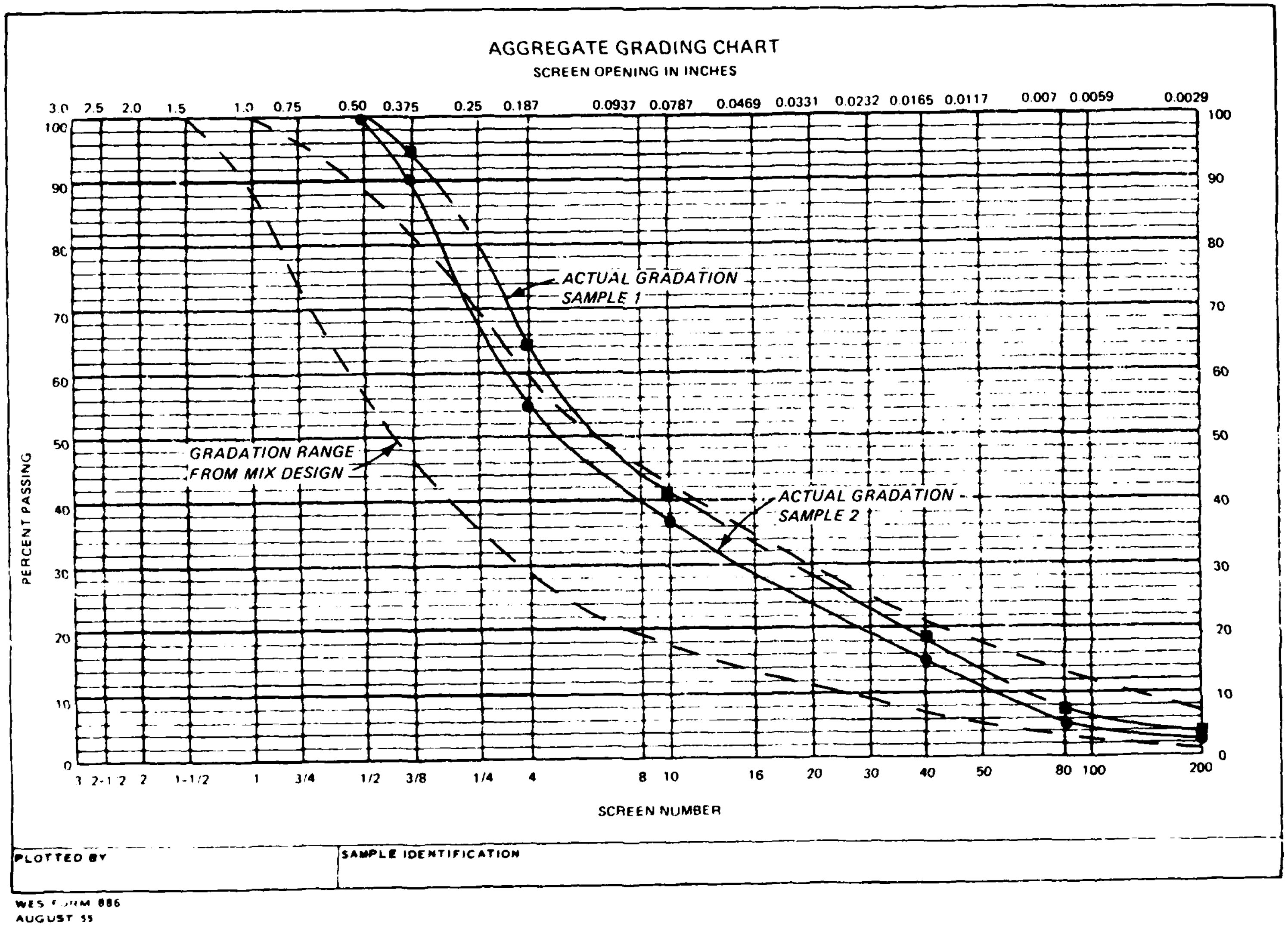


Figure 29. Aggregate gradation used in underlayment

Figure 30. Initial spreading of asphalt in excavated area between sta 0+95 and 1+15

Figure 31. Spreading asphalt by hand in excavated area between sta 0+95 and 1+15

Figure 32. Asphalt laydown, first lift

Figure 33. Asphalt laydown, second lift

Figure 34. Vibratory roller compacting first lift

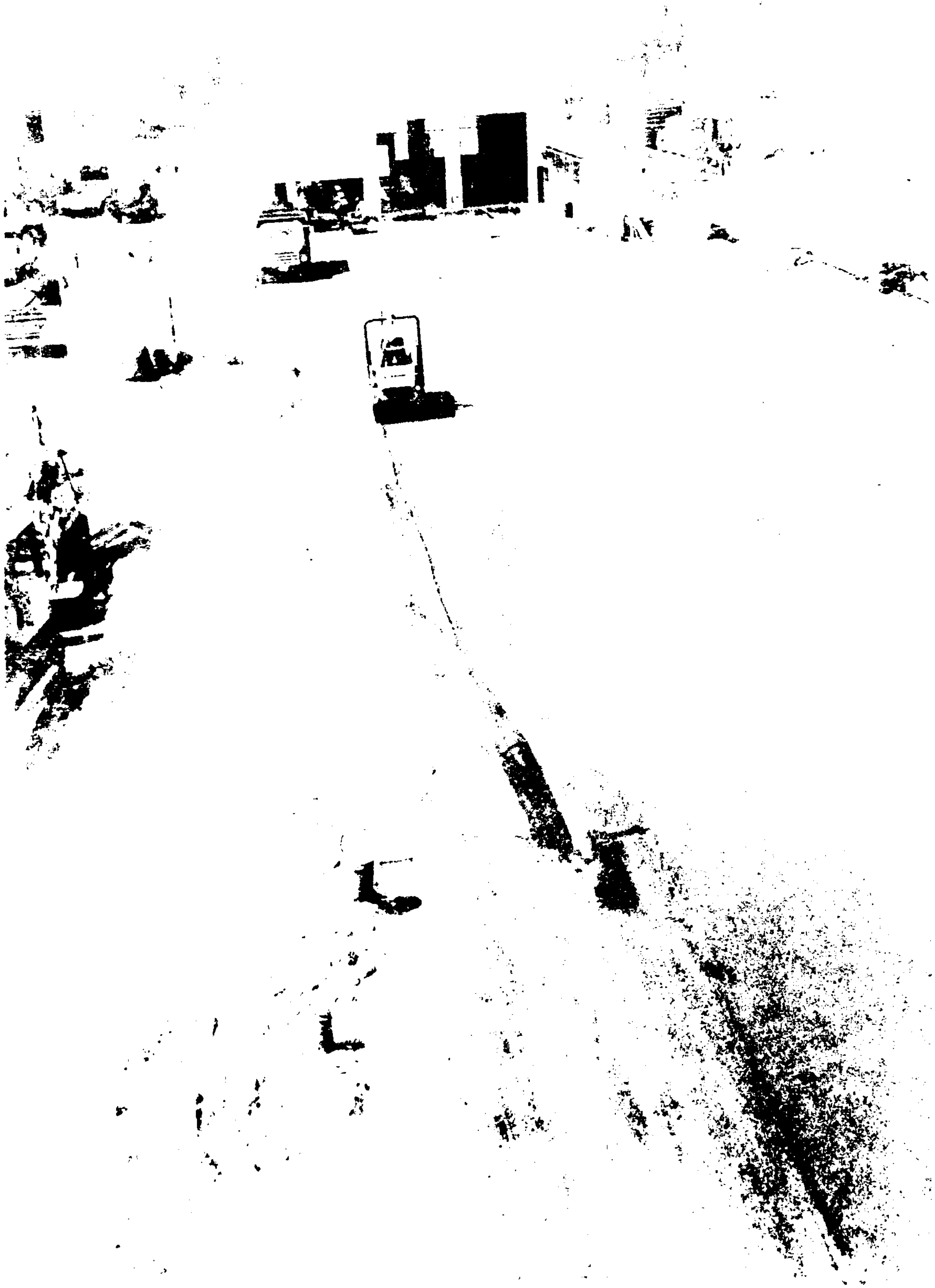


Figure [illegible]. Overall view of paving operation

Figure 36. Rutting of first lift due to soft subgrade 20 ft right, sta 2+65

Figure 37. Overall view after asphalt laydown

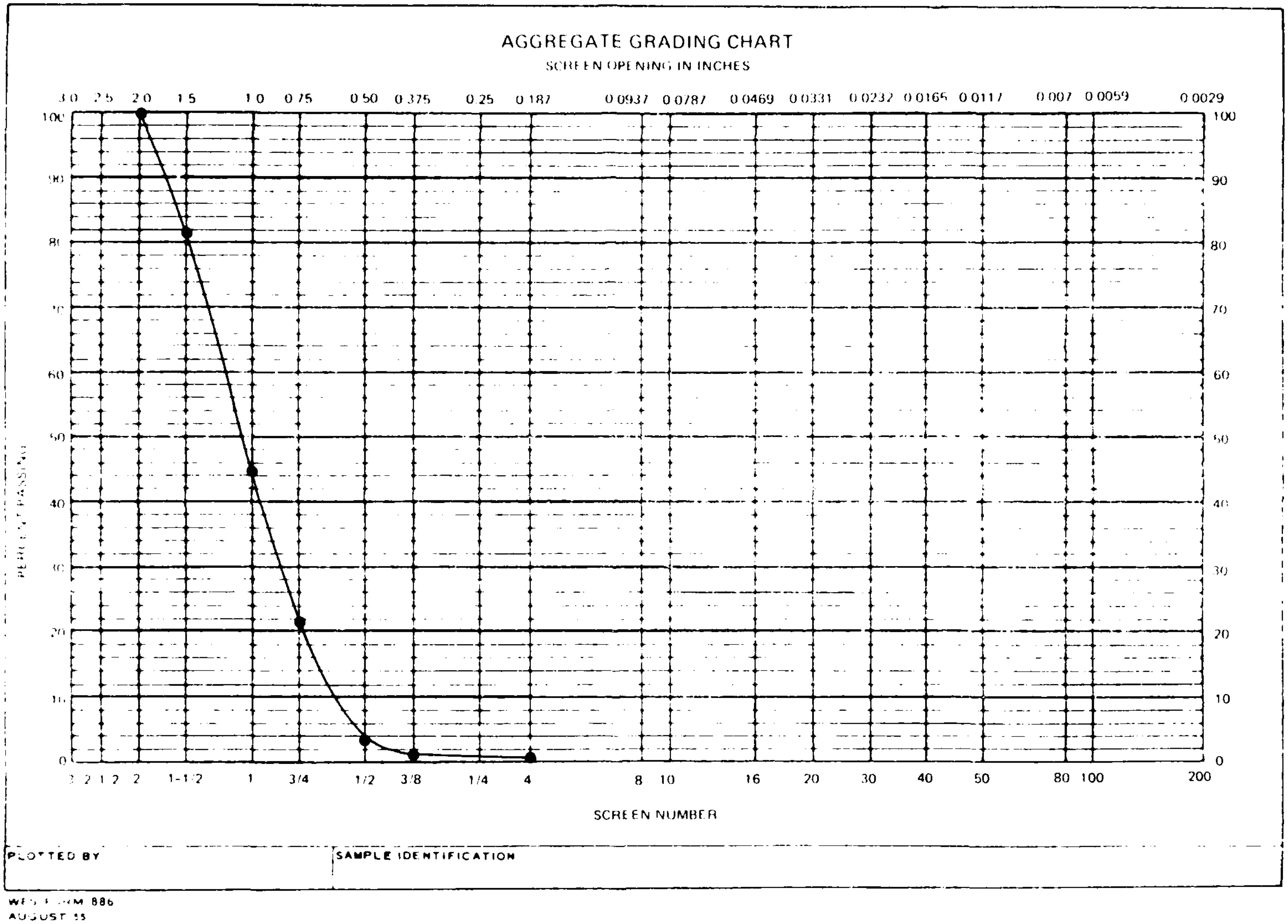


Figure 38. Ballast gradation

Figure 39. First layer of ballast placed over underlayment

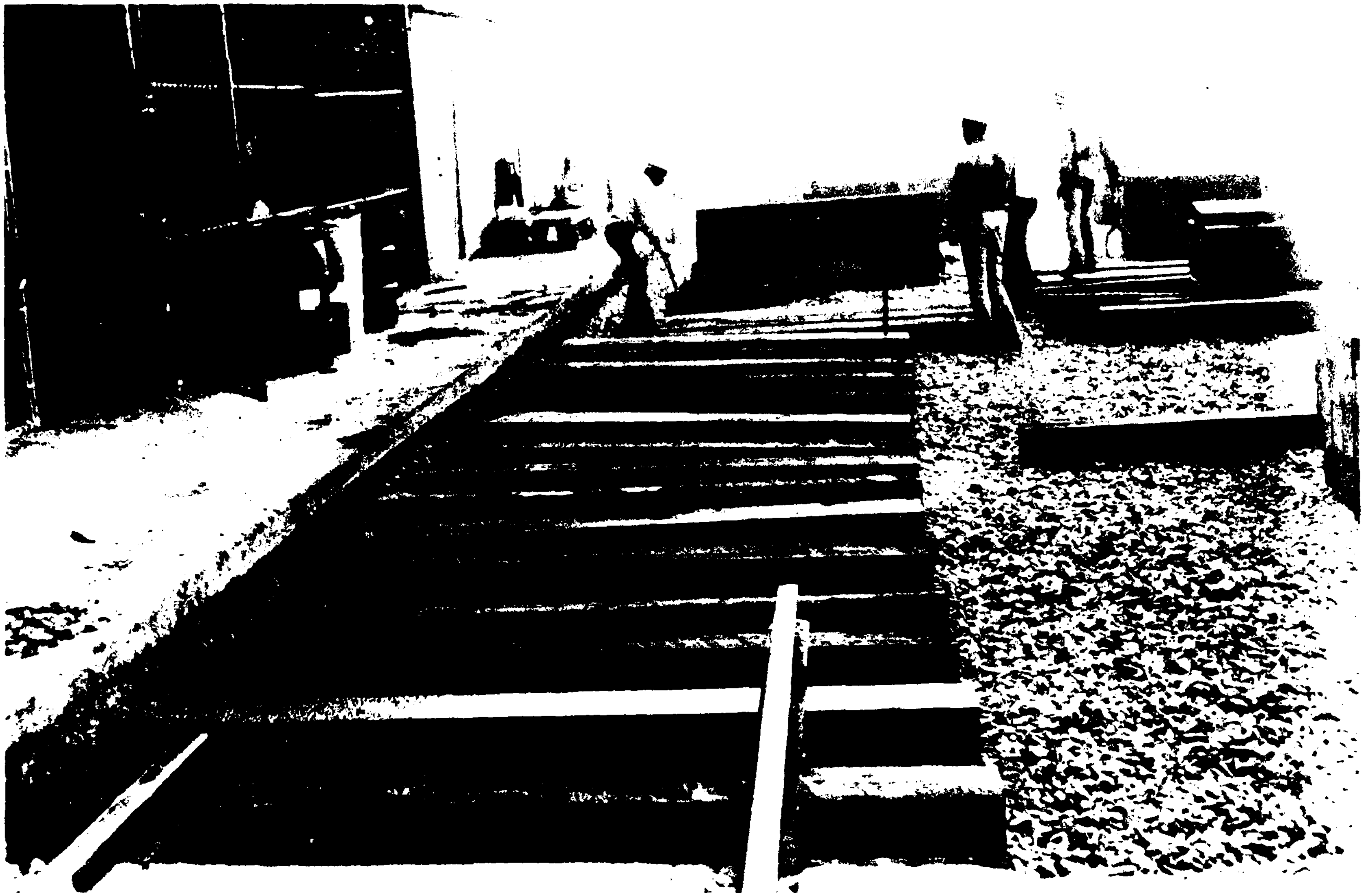


Figure 40. Placing ties

Figure 41. Placing tie plates on ties

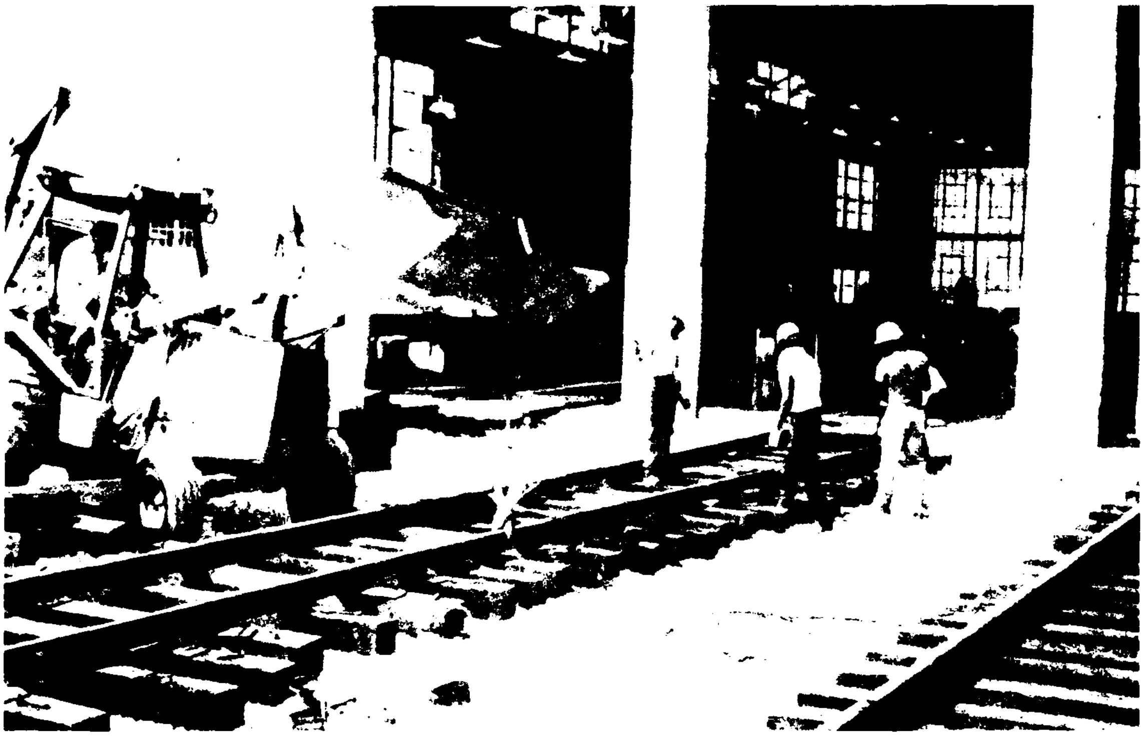


Figure 42. Replacing rail

Figure 43. Lubricating and replacing joint bars

Figure 44. Spiking track

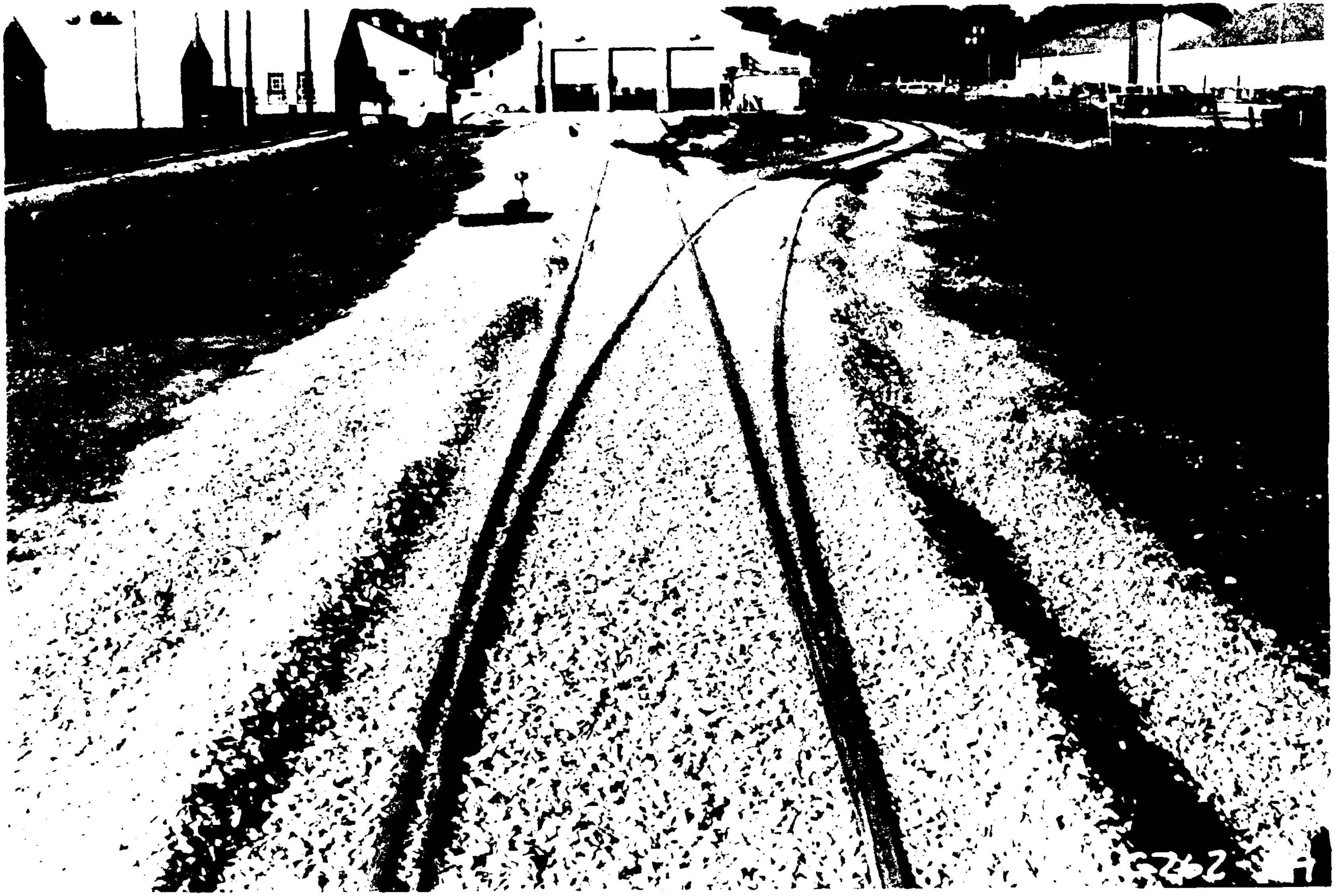


Figure 45. Track after ballasting prior to final raise and surface

Figure 46. Mechanized tamper performing the final raise, surfacing, lining, and tamping

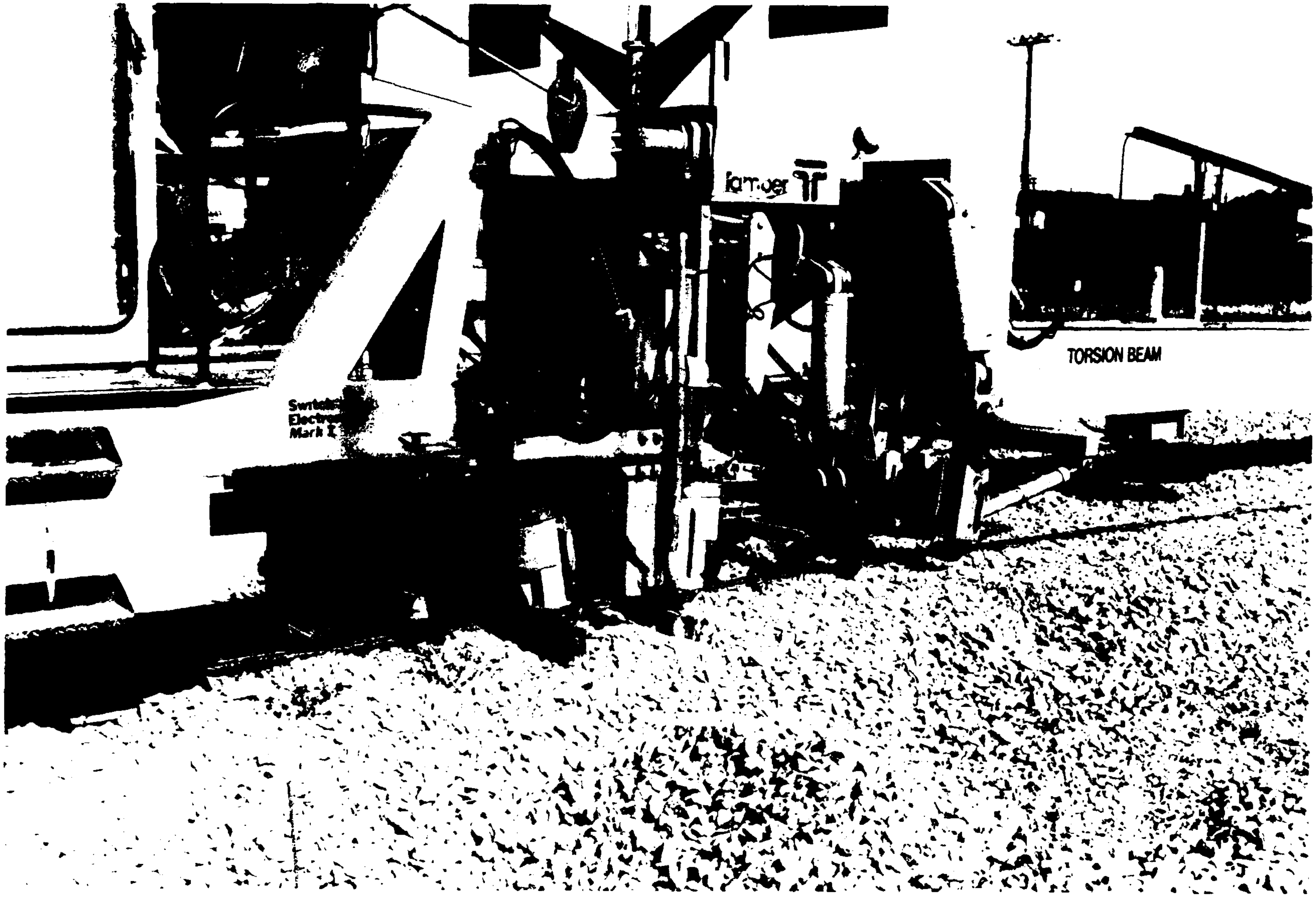


Figure 47. Close-up of tamper operation

Figure 48. Overall view of project after tamping

Figure 49. New concrete grade crossing

[illegible] with backhoe, vicinity of sta 5+00

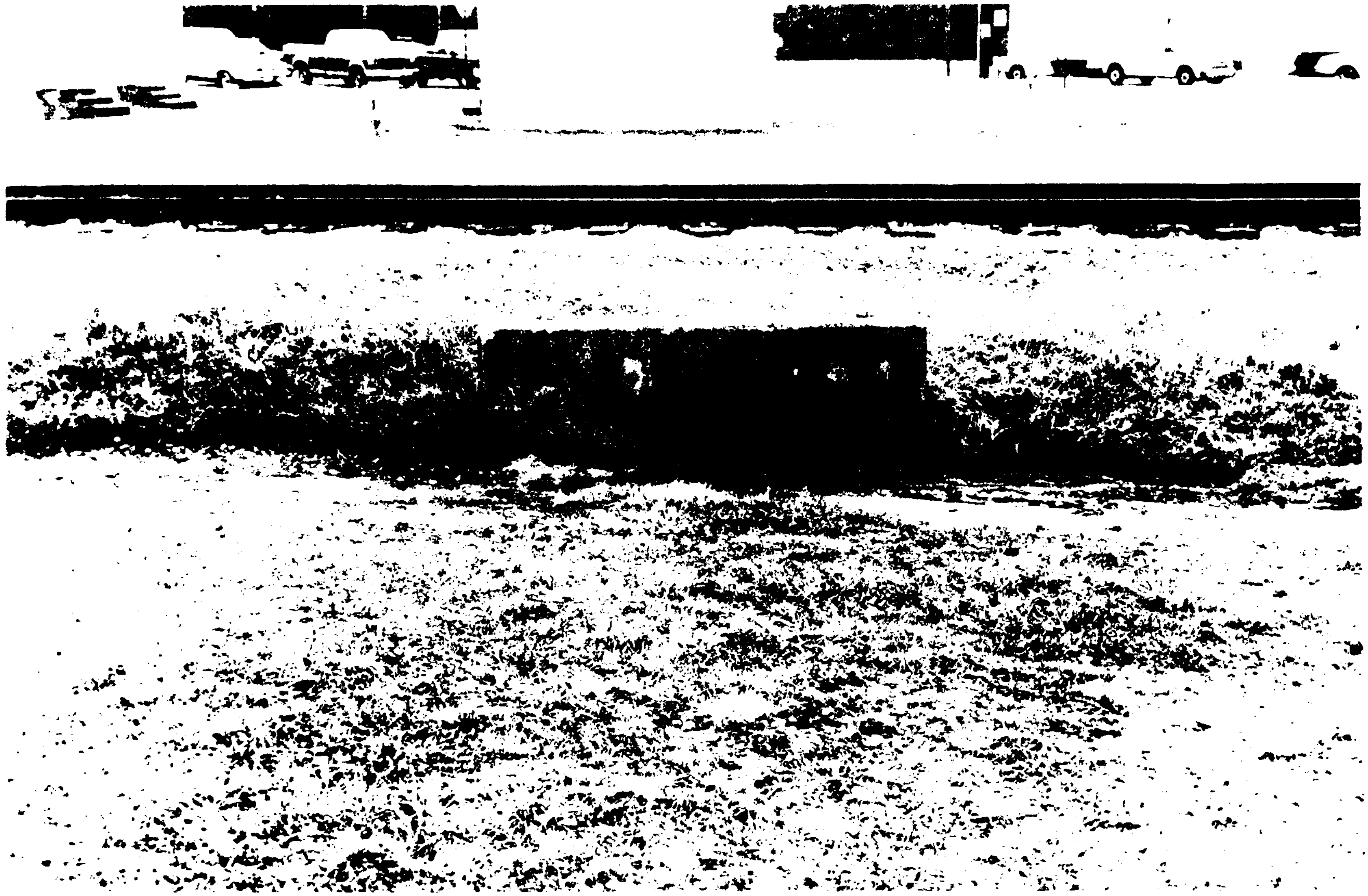


Figure 51. Open culvert under Track No. 1 at sta 4+70

Figure [illegible]. Open culvert under track No. 5 at sta 3+30

AD-A172 953 STRUCTURAL ENHANCEMENT OF RAILROAD TRACK STRUCTURES USING ASPHALT UNDERLAYMENT(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTE.. D M COLEMAN 2/2

UNCLASSIFIED JUL 86 WES/MP/GL-86-21 F/G 13/3 NL

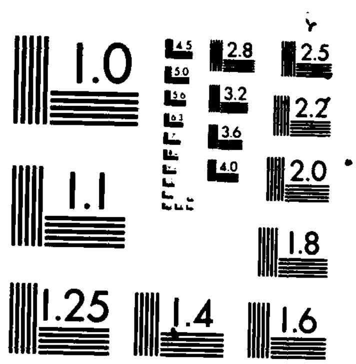

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

Figure 53. New ditches south of project adjacent to Track No. 1

Figue 54. New ditch between Tracks 4 and 5

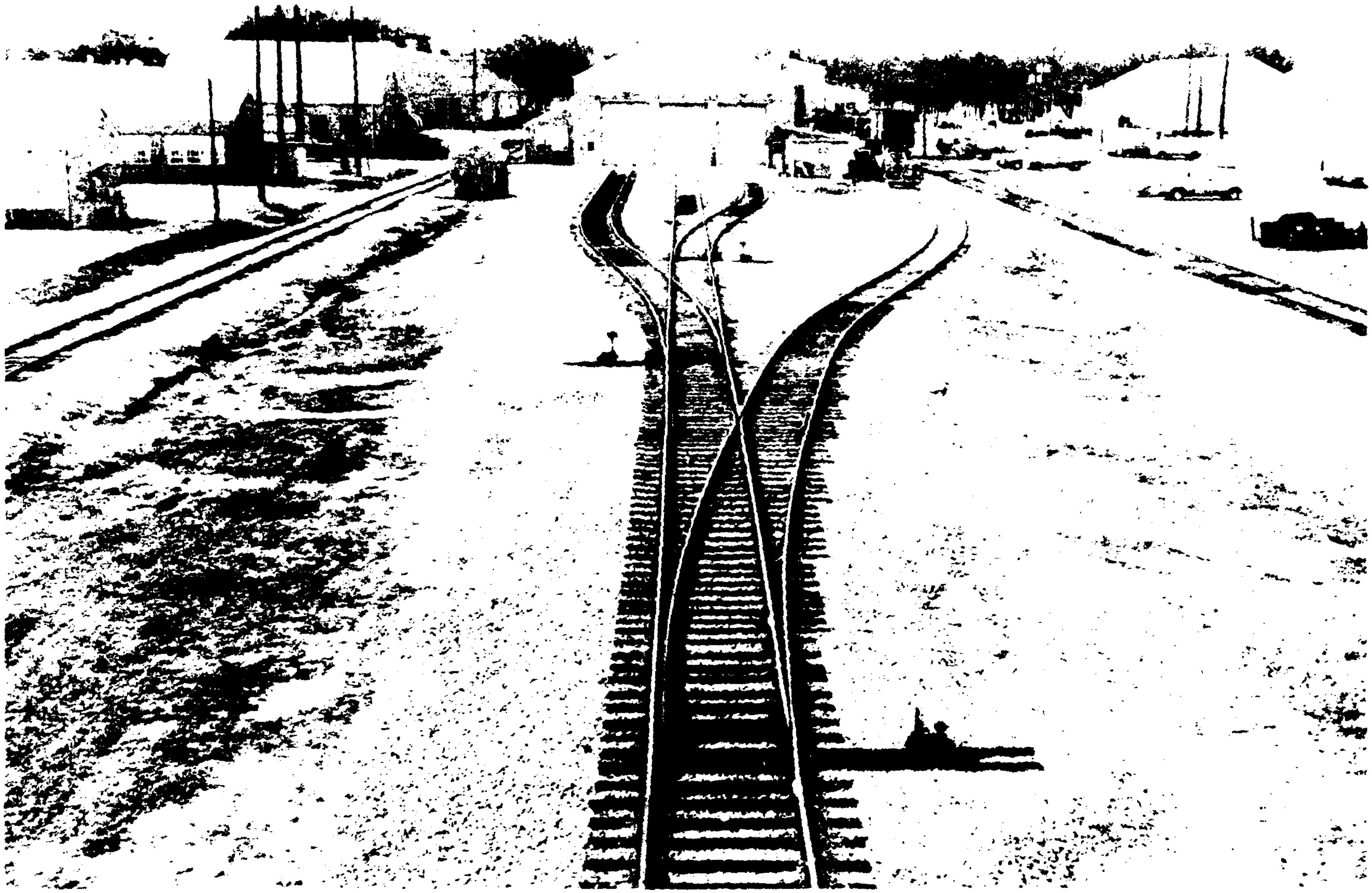


Figure 55. Overall view of completed project

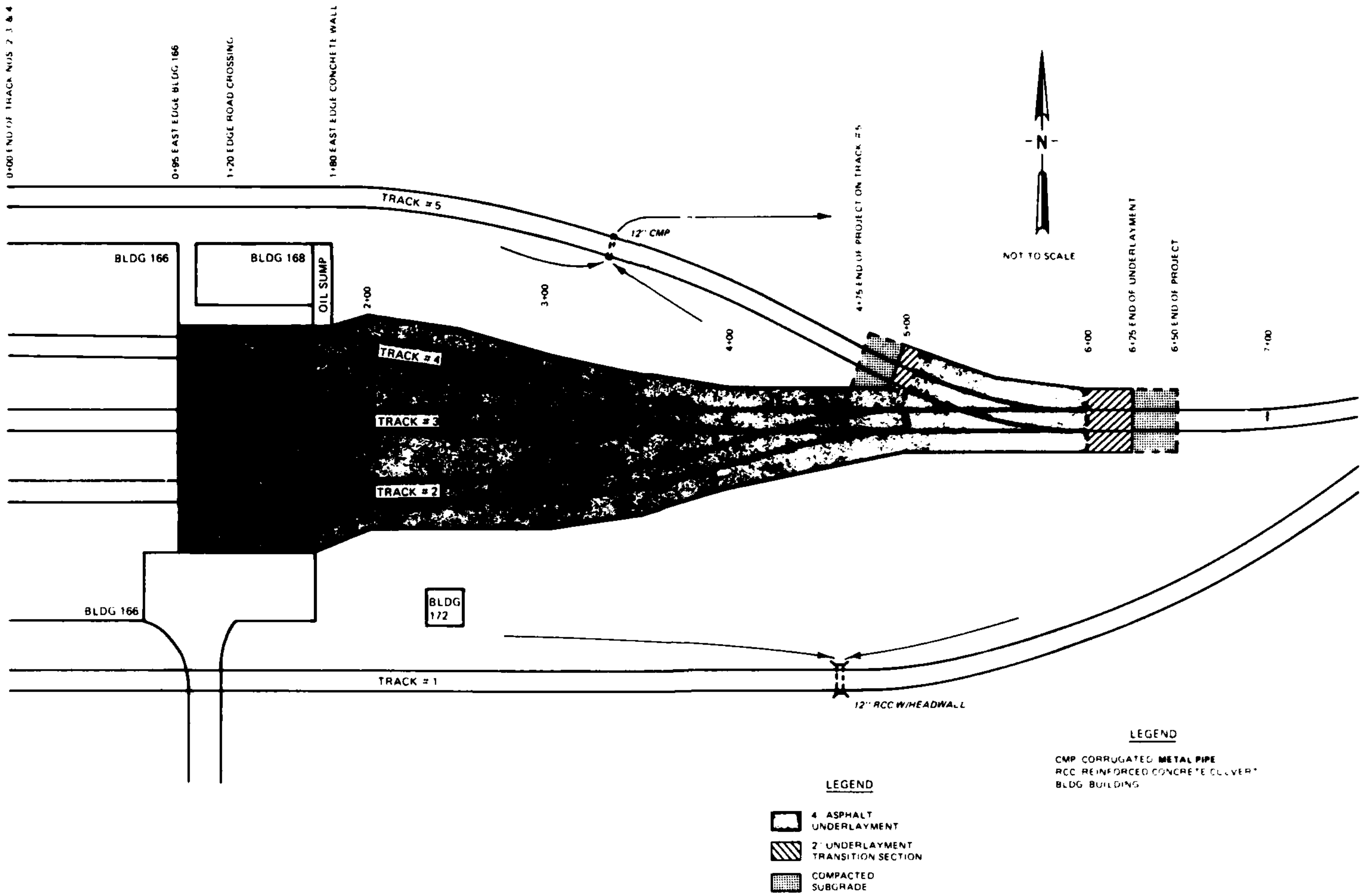


Figure 56. Plan view of project area showing completed project

Figure 57. Typical turnout

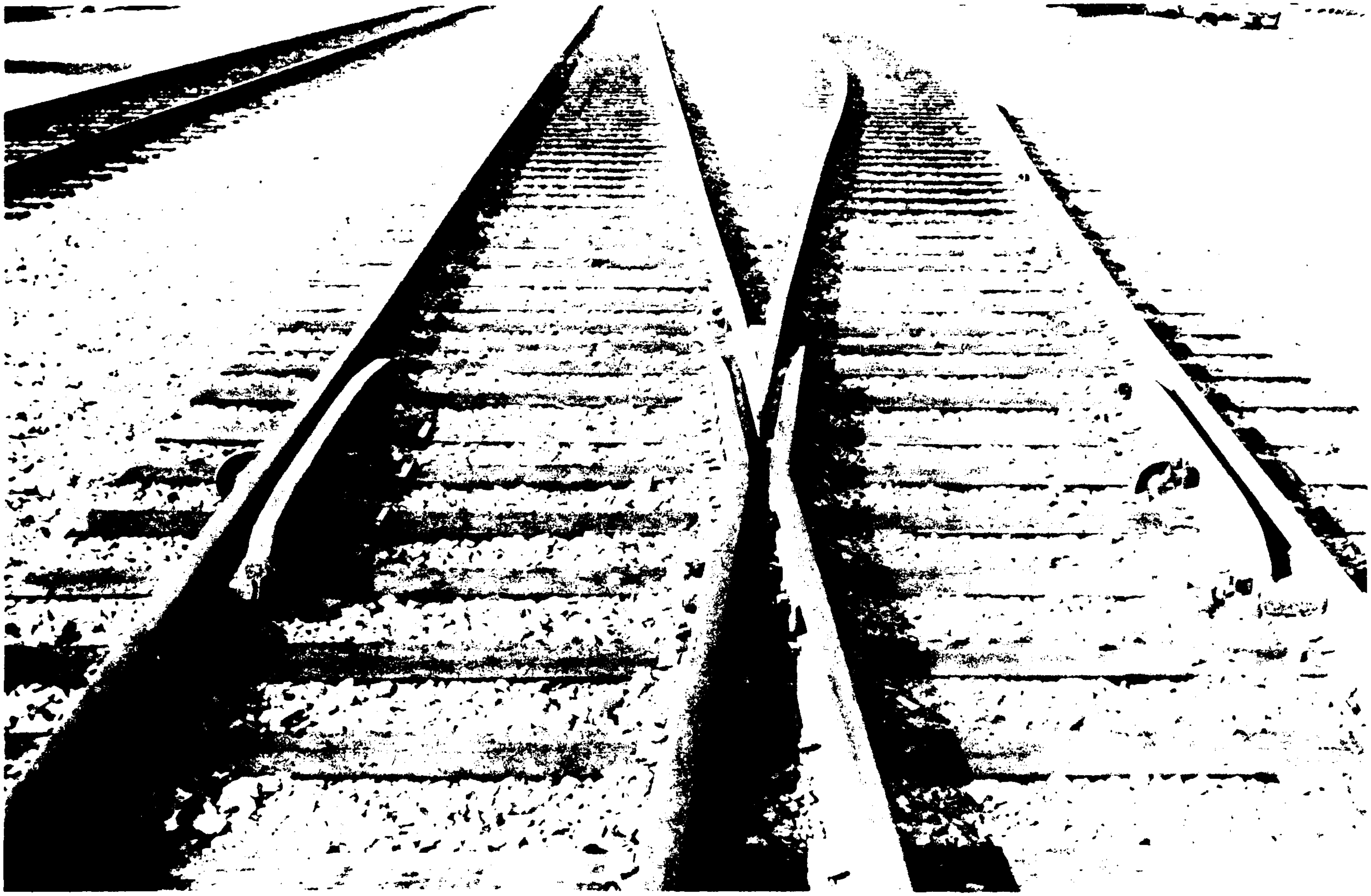


Figure 58. Detail of frog and guard rails

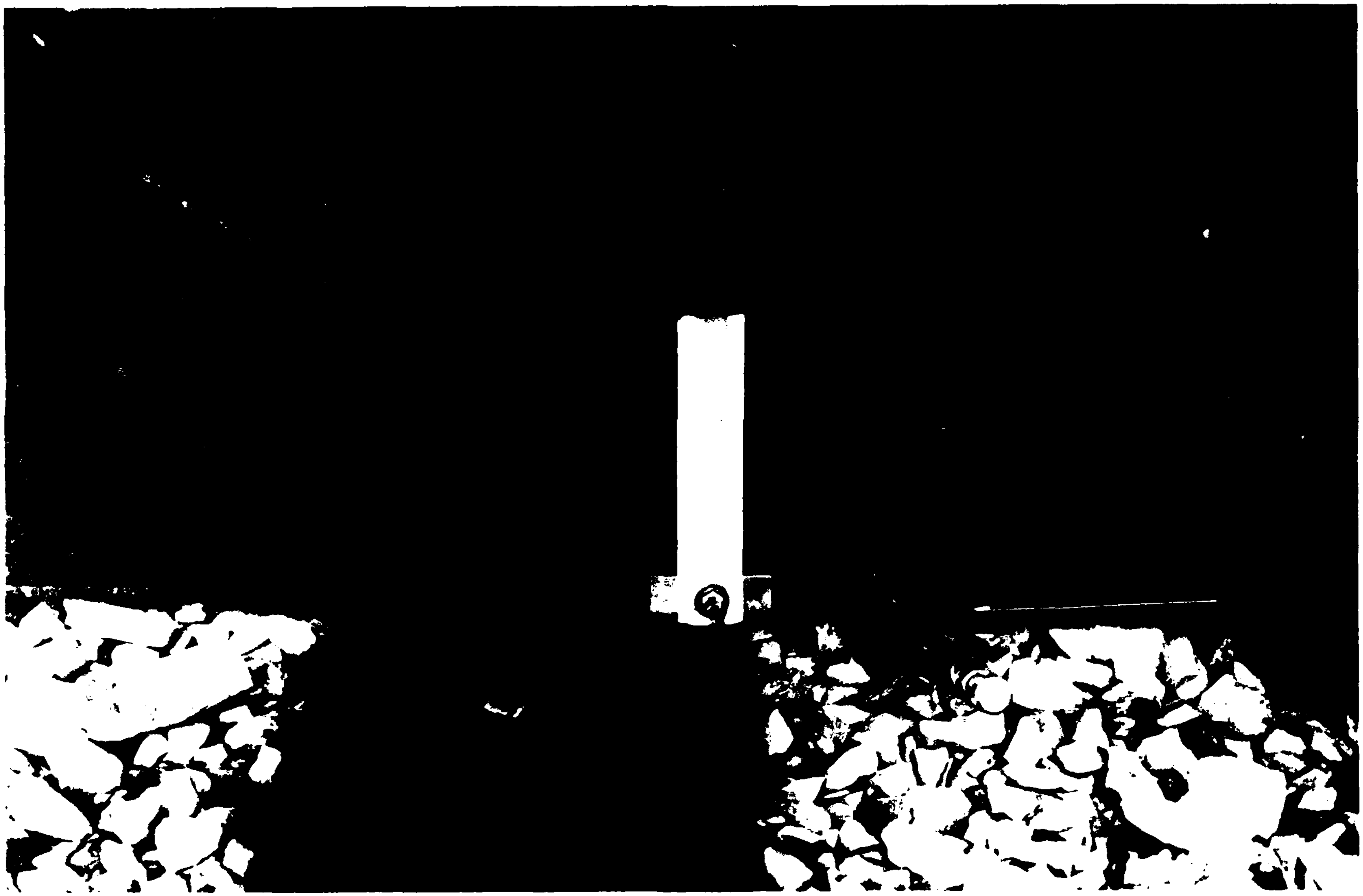


Figure 59. Scale for track deflection readings

Figure 60. Track deflection test setup

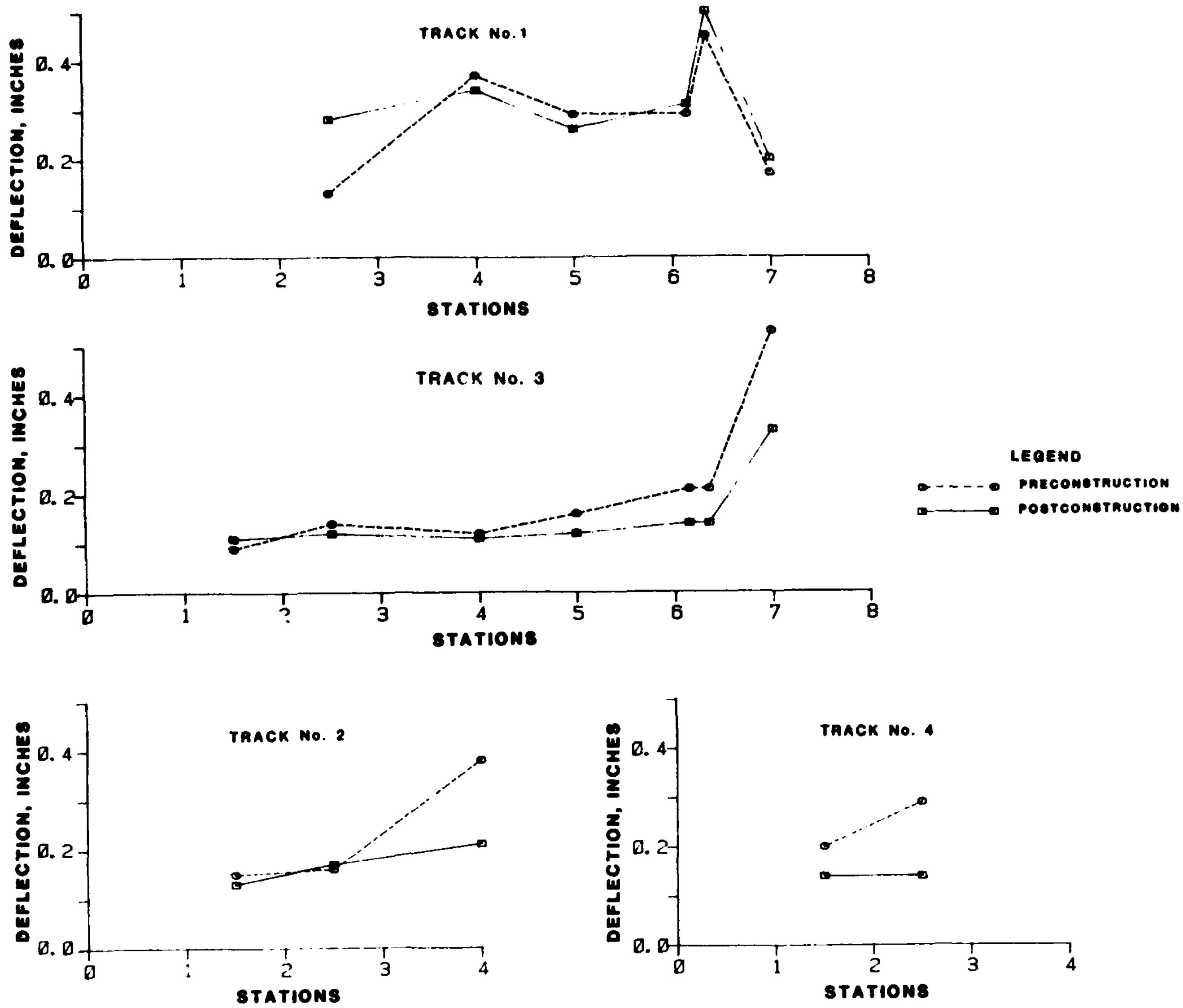


Figure 61. Measured track deflection

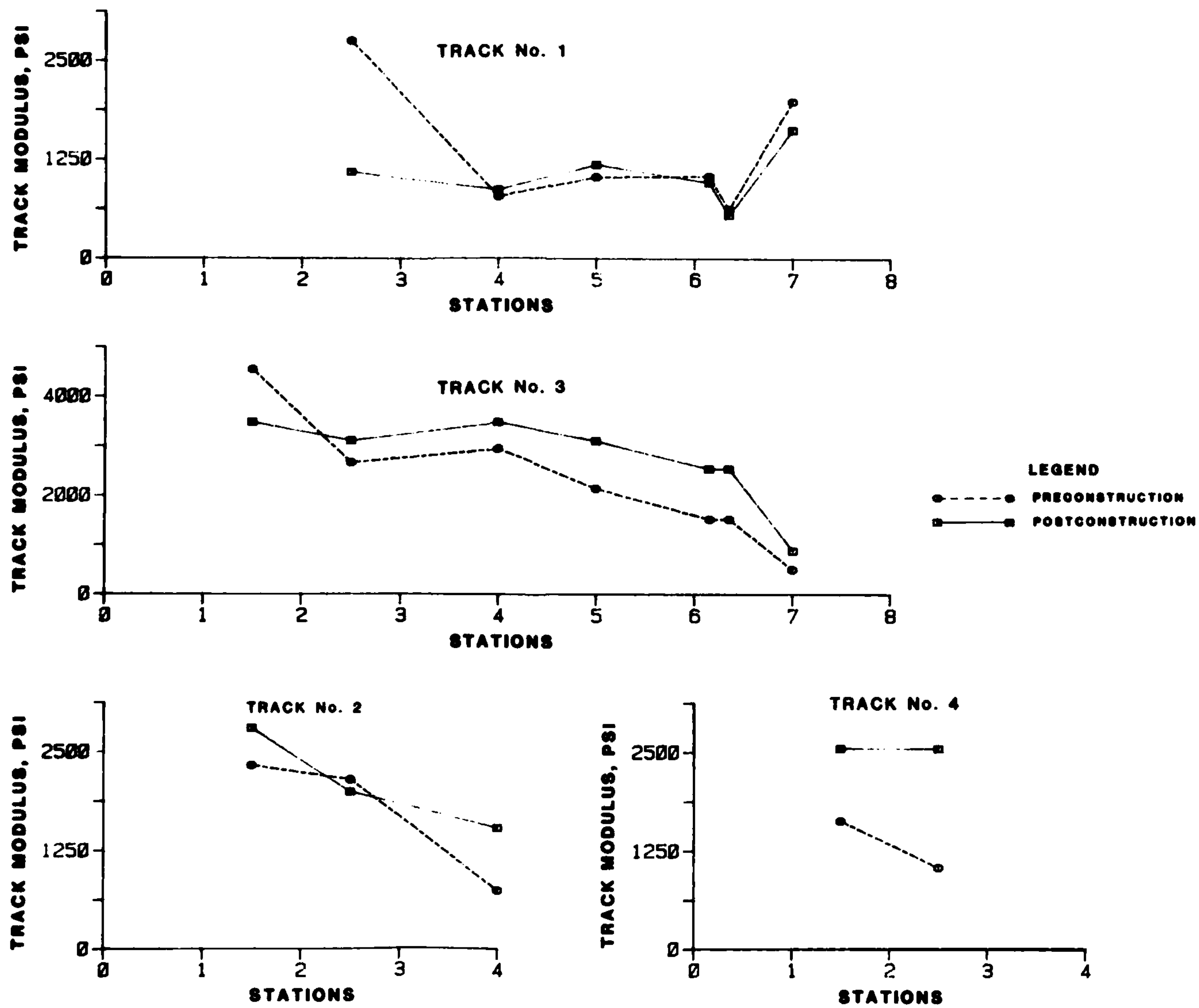


Figure 62. Calculated track modulus

Figure 63. Moving track to side for construction

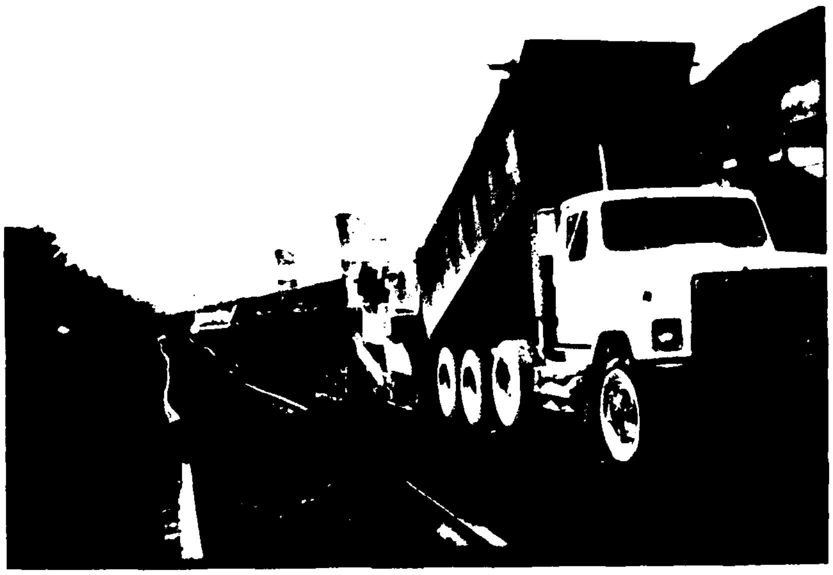


Figure 64. Underlayment construction with track pulled to side

APPENDIX A: DESIGN RECOMMENDATIONS FOR HOT-MIX ASPHALT UNDERLAYMENT AT RED RIVER ARMY DEPOT, TEXARKANA, TEXAS

26 October 1984

Subgrade

1. Laboratory tests indicate that the subgrade is a CH soil, liquid limit of 51, plastic limit of 16, and plasticity index of 35. At the CE-55 compaction effort, the maximum dry density, γd_{max}, is 113.4 pcf at an optimum moisture content of 15.3 percent.

- a. After the desired grade has been obtained, the subgrade should be compacted to at least 95 percent of the CE-55 compaction effort. Compaction should be accomplished at, or slightly wet of, optimum moisture content.
- b. The compacted subgrade should extend 1 ft beyond the proposed edge of the asphalt mat.
- c. A 25-ft-long transition section of compacted subgrade should be provided at the ends of the underlayment section. This will provide a gradual transition from soft subgrade to firm underlayment.
- d. Grading and Slopes:
  - (1) The compacted subgrade must be graded and sloped to provide positive drainage away from the track structure.
  - (2) Recommended crown and slopes are:

Sta 0+95 to 1+80:	No crown.
	Constant slope to east to provide positive drainage away from Buildings 166 and 168.
Sta 1+80 to 6+25:	Crowned.
	Approximately 1.5 percent slope from center line to edge.
Transition Sections:	Crowned.

Sta 4+75 to 5+00 on Track 5: Approximately 1.5 percent slope from sta 6+00 to 6+25 on Track 3, center line to edge.

Underlayment

Asphalt thickness

2. Constant 4 in. placed directly on compacted subgrade so that the asphalt surface will have the same slope as the compacted subgrade.

Dimensions

3. Asphalt should extend out 4 ft from the center of the outside rails or 6-1/2 ft from the center line of the outside tracks.

Turnout to Track E

4. Underlayment should extend up Track E to sta 4+75. The end of the asphalt mat should be perpendicular to the track.

Transitions

5. The first 10 ft of asphalt underlayment should provide a transition to the full asphalt depth. On Track 3 the asphalt mat will be the full 4-in. design depth at sta 6+00 thinning to 2 in. at sta 6+25. On Track 5 the transition will begin at sta 5+00 with the full 4-in. design thickness and end at sta 4+75 with 2 in. of asphalt. This will allow a gradual change from the soft subgrade to the firm compacted subgrade to the firmer underlayment section.

Mix design

6. The asphalt mix design should be based on ASTM 3515, Dense Graded Highway Base Mix. The recommended gradations are:

Sieve Size	Amount Finer, Weight %*
1 1/2 in.	100
1 in.	90 - 100
1/2 in.	56 - 80
No. 4	29 - 59
No. 8	19 - 45
No. 50	5 - 17

(Continued)

* ASTM D3515 for medium traffic conditions.

Sieve Size	Amount Finer, Weight %
No. 200	1 - 7**
Asphalt Cement, Weight % of Total Mixture	3 - 9**

** Selected to provide less than 3 percent air void contents in the compacted mix and a minimum (voids in mineral aggregate) VMA of 13 percent.

7. It is recommended that the percentage passing the No. 200 sieve be kept in the 5 to 7 percent range and that the asphalt content be approximately one half of a percent above optimum.

Ballast

8. The minimum ballast depth below the bottom of the tie will be 6 in. The thickness may be increased to achieve required track elevations.

Drainage

9. Adequate drainage of surface water away from the track structure is critical to the success of the underlayment.

10. All pipes, culverts, and other drainage structures should be opened to allow unobstructed runoff.

11. Ditches should be opened and sloped for positive drainage.

12. The natural ground should be sloped away from the track structure to provide adequate drainage away from the track.

13. A shallow ditch or swell ditch should be provided between Tracks 3 and 4 and sta 3+30 and 4+35.

END

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